Proceedings of the International Pandalid Shrimp Symposium

February 13-15, 1979
Kodiak, Alaska

Sea Grant Report 81-3
June 1981

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PROCEEDINGS OF THE INTERNATIONAL PANDALID SHRIMP SYMPOSIUM

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IN MEMORIAM
BIRGER RASMUSSEN

Dr. Birger Rasmussen died on December 10, 1978. He was 71 years old.

Birger Rasmussen studied marine biology at the College of Fisheries, University of Washington, from 1927 to 1931. He then returned to Norway and joined the Directorate of Fisheries in Bergen and started work on fisheries investigations in arctic waters. In 1938 he participated in an expedition to the Spitsbergen area where extensive material on the deep sea prawn, *Pandalus borealis*, was collected. Rasmussen analyzed the material and the results were published in 1942. This was the beginning of his research into the biology of the prawn. Several other publications dealing with the deep sea prawn in various fjords and coastal areas in Norway followed. In "On the Geographical Variations in Growth and Sexual Development of the Deep Sea Prawn (*Pandalus borealis*) Kr.", 1953, he compared material from different prawn populations distributed from southern Norway to the arctic waters of Spitsbergen and Jan Mayen. This study on the biology of the deep sea prawn and especially the variation in growth and sexual development was pioneer research. The results also have implications for management, which Rasmussen recognized in 1958, when he concluded that variation in growth and maturity will influence the productivity and renewal of the stocks and that therefore, the fishing intensity a stock can withstand may vary between prawn fields.

Birger Rasmussen's interests were very wide. He was particularly interested in arctic waters and their living resources. Shellfish, especially the deep sea prawn, continued to be one of his main interests throughout his life. He always took a practical approach to the various problems. In connection with the shrimp fishery, he was especially aware of the possibility of stabilizing or increasing the yield by mesh size regulations and of reducing the by-catch of young fish by making the shrimp trawl more selective.

He fulfilled an increasingly important task as advisor to the fisheries administration and other governmental bodies in Norway on a variety of problems ranging from the effect on the marine life of underwater explosions in connection with seismic investigations to the effect of trawling for seaweed on fish and shellfish. His interest in the shrimp investigations and fisheries did not suffer. He continued to take an active part in these throughout his career, and was always glad of opportunities to discuss the various aspects of shrimp biology and exploitation with his younger colleagues.

Øyvind Ulltang
1979

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INTRODUCTION AND KEYNOTE ADDRESS

WELCOME

Ronald O. Skoog
Commissioner
Alaska Department of Fish and Game
Juneau, Alaska

Fellow fisheries managers, scientists, processors and fishermen. I want to welcome you on the occasion of the convening of this truly international resource workshop. To those of you from outside Alaska and from other countries, special appreciation for your willingness to spend your valuable time to travel the long distance to share your knowledge with us. I have been forced by legislative commitments to remain in Juneau this week or I would have enjoyed being an active participant.

Alaska has a unique relationship to the sea and its resources. With 34,000 miles of shoreline and 547,000 square miles of continental shelf, Alaskans have a bountiful supply of fisheries resources at their doorstep. The relatively small residential population is largely coastal and dependent on commercial and subsistence fisheries to a major degree.

Fishing and related activities are the second largest source of employment in the state. In 1978 over 20,000 fishermen harvested over $800 million worth of fisheries products at a value to them of about $400 million.

This special dependence on renewable fisheries resources makes sound resource management a high priority to Alaskans. The Alaska Department of Fish and Game allocates the efforts of some 130 employees and over $9 million annually to commercial fisheries management and research. Permanent offices are maintained throughout the state and field activities carried out on most major bodies of fresh and salt water. Nevertheless the complexity of the resources managed coupled with the vast size of the state and our offshore areas results in many gaps in the knowledge required to manage these resources for the optimal public benefit.

You have convened to discuss one such problem area. Despite our serious efforts to maintain the Gulf of Alaska, shrimp stocks in the Kodiak Island/Alaska Peninsula area have declined drastically in abundance over the past few years. The reasons for this decline and its remedy are not clearly evident. We hope that by detailing our experiences and program for you and examining your areas of resource expertise, we can arrive at some new and innovative approaches to shrimp research and management. I wish you success in your deliberations over the next few days.

INTRODUCTION

Dayton L. Alverson
Director, Northwest and Alaska Fisheries Center
Seattle, Washington

Welcome to the International Pandalid Shrimp Workshop. This meeting is jointly sponsored by the North Pacific Fishery Management Council, the Alaska Department of Fish and Game, the University of Alaska Sea Grant Program and the National Marine Fisheries Service.

The objective of this workshop will be to review circumpolar pandalid shrimp research and management programs. Recent radical declines of pandalid shrimp in the Gulf of Alaska have prompted this meeting of pandalid specialists. We hope the participants can shed some light on the problems which have occurred worldwide in the attempt to study and optimize the harvest of pandalid shrimp.

The workshop will develop in a sequence of four major topics, beginning today with a worldwide review of catch histories and an overview of research and management. The latter portion of the afternoon and all of tomorrow will be devoted to in-depth discussion of research, including predator-prey relationships, stock assessment techniques, year-class abundance and environmental relationships. The third day will begin with industry panels dealing with the evolution of fishing gear and techniques and constraints of management on shrimp processing and the fishing industry. The remainder of the day will be devoted to the discussion of management strategies. This will include current management strategies and a discussion of their value and alternatives. Management implications of pandalid life history will also be considered. The workshop will conclude with the final panel on the need for management. The chairmen of the previous committees will sit on this panel and discuss the need for management and whether it can be successful with pandalid shrimp.

It is hoped that this workshop will be a mind expanding experience for all participants. In order to fully capitalize on the experience of our international colleagues, we must point out at this time that the focus of the workshop will be on the interactions of panel participants. The objective of this meeting is not to critique the Alaskan experience, but to review the international experience in pandalid shrimp research and management. This will enable everyone to learn from this experience.

We hope this meeting will establish a continuing forum for international pandalid workshops.

KEYNOTE ADDRESS

A REVIEW OF PANDALID SHRIMP FISHERIES IN THE NORTHERN HEMISPHERE

James W. Balsiger
Northwest and Alaska Fisheries Center
National Marine Fisheries Service
Seattle, Washington

INTRODUCTION

Pandalid shrimps from four genera and some dozen species support fisheries throughout the world, but most of major commercial importance are found in cool, temperate and subarctic waters (Fox 1972). Catches of shrimp of all species, on a world basis, are dominated by those of the family Penaeidae which inhabit the warm, temperate and tropical waters of the world and in recent years have accounted for 85 to 90 percent of the annual world shrimp catch (FAO 1976). However, pandalid shrimps assume great regional importance wherever they are fished in the northern hemisphere, including well documented fisheries along the west coast of North America from California to Alaska, the east coast of North America from Maine to the maritime provinces of Canada, the west coast of Greenland, and in the Norwegian Sea and North Sea. Pandalid fisheries are also found in the northwestern Pacific Ocean, where they are fished by Japan, the Soviet Union, and Korea (Fox 1972), but we have not been able to document their magnitude and historical development. In addition, there are significant pandalid fisheries in the southern hemisphere off Chile and India, but they will not be discussed here.

IMPORTANCE

The growing importance of shrimp in today's fisheries can be demonstrated in two ways: by the production trends of the shrimp fleets, as discussed in later sections, and by examining the role of shrimp in the marketplace.

The determination of demand for and consumption of pandalid shrimp is confounded by the existence of separate product forms and markets for pandalid versus penaeid shrimps. Hemming (1971) observed that two distinct markets exist for the two types of shrimp and that demands and prices in the two markets appear to move independently. Yet, very little information is available in the literature to allow an analysis of pandalid shrimp disposition once it has been processed.

Figure 1 shows that United States annual consumption of all kinds of shrimp has climbed steadily from .9 lbs per capita in 1950 to nearly 2.25 lbs in 1977. Over this same period of time, per capita consumption of all seafoods has remained remarkably stable with some products declining and consumption of others increasing. Increased consumption of any product must be associated with increased supplies. Since 1950, supplies of practically all shellfish species have risen sharply (Whitaker 1971). In the case of shrimp, increased U.S. consumption has been associated with increased imports of penaeid shrimp to the U.S. from South America and Asia. Pandalid shrimp enter the U.S. market primarily as cocktail or salad shrimp (Orth et al. 1978).

GENERAL PRODUCTION TRENDS

All-nation production of seafood has remained very stable from 1970 to 1975 (FAO 1976), with a total annual all-species catch of about 70 million mt (Figure 2). Figure 2 also shows that over the same period of time, the all-nation catch of all shrimp increased approximately 25 percent from nearly 1 million mt in 1970 to 1.25 million mt in 1975. Pandalid shrimp catches were approximately 90,000 mt in 1970 and increased 50 percent to about 135,000 mt in 1975.

Most of the increases in pandalid catches came from the northwest Atlantic, where catches increased from about 21,000 mt in 1970 to 47,000 mt in 1975, and the northeast Pacific, where catches rose from 41,000 mt to 61,000 mt over the same period of time. The increased catches in the northwest Atlantic were shared by several countries (Canada, Faeroe Islands, Norway, Spain and Russia), while the United States accounted for the increases in the northeast Pacific (FAO 1976).

BIOLOGICAL FEATURES

The knowledge of the biology of pandalid shrimp has progressed rapidly since 1930, stimulated by rapidly developing commercial fisheries over a broad geographic area.

Shrimps of the family Pandalidae have the following taxonomic identities:

- Phylum Arthropoda
  - Class Crustacea
    - Subclass Malacostraca
      - Order Decopoda
        - Suborder Natantia
          - Section Caridea
            - Family Pandalidae

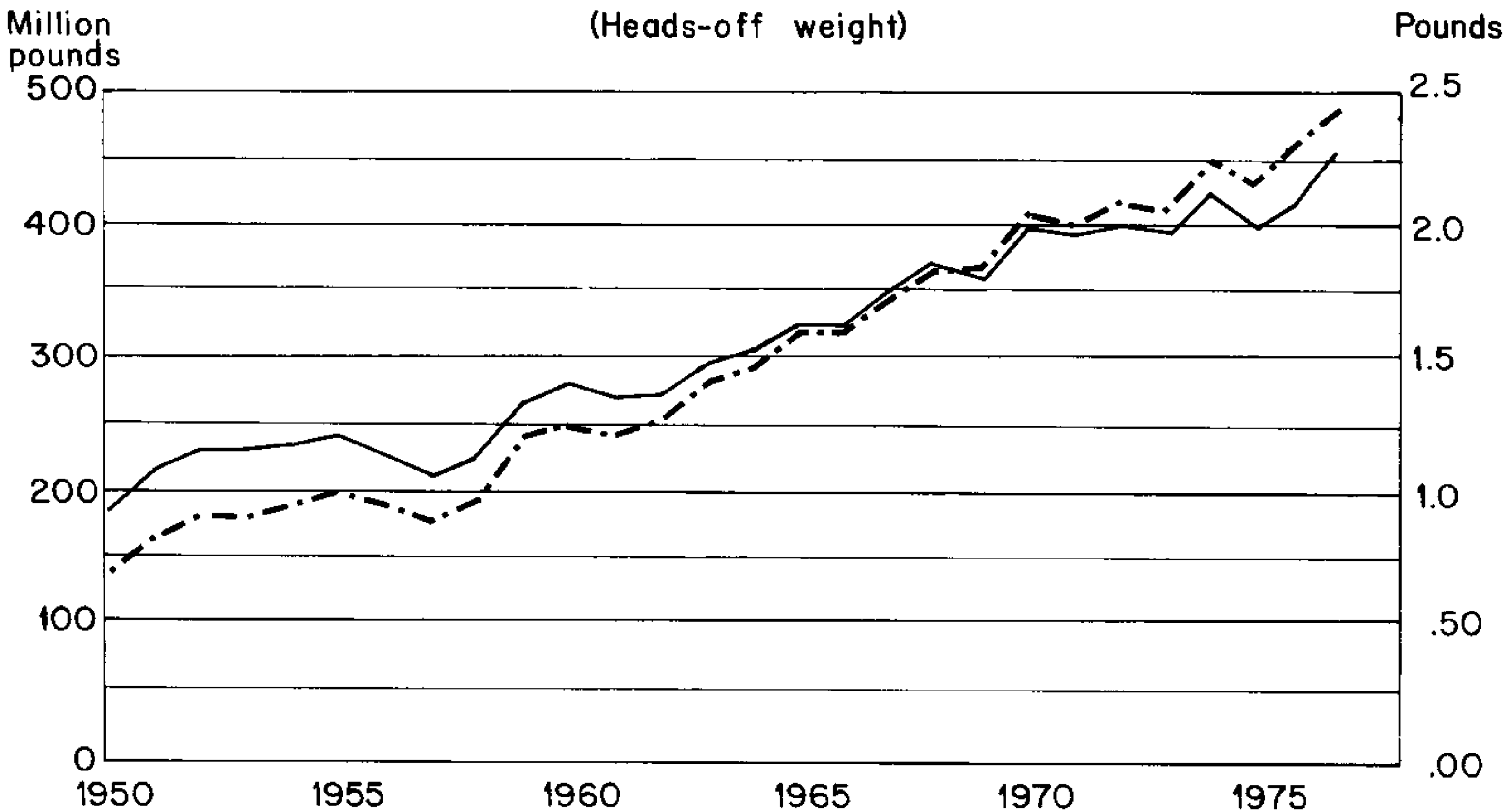

Figure 1. U.S. annual consumption of shrimp. (Whitaker 1971; U.S. Shellfish Market Review and Outlook)

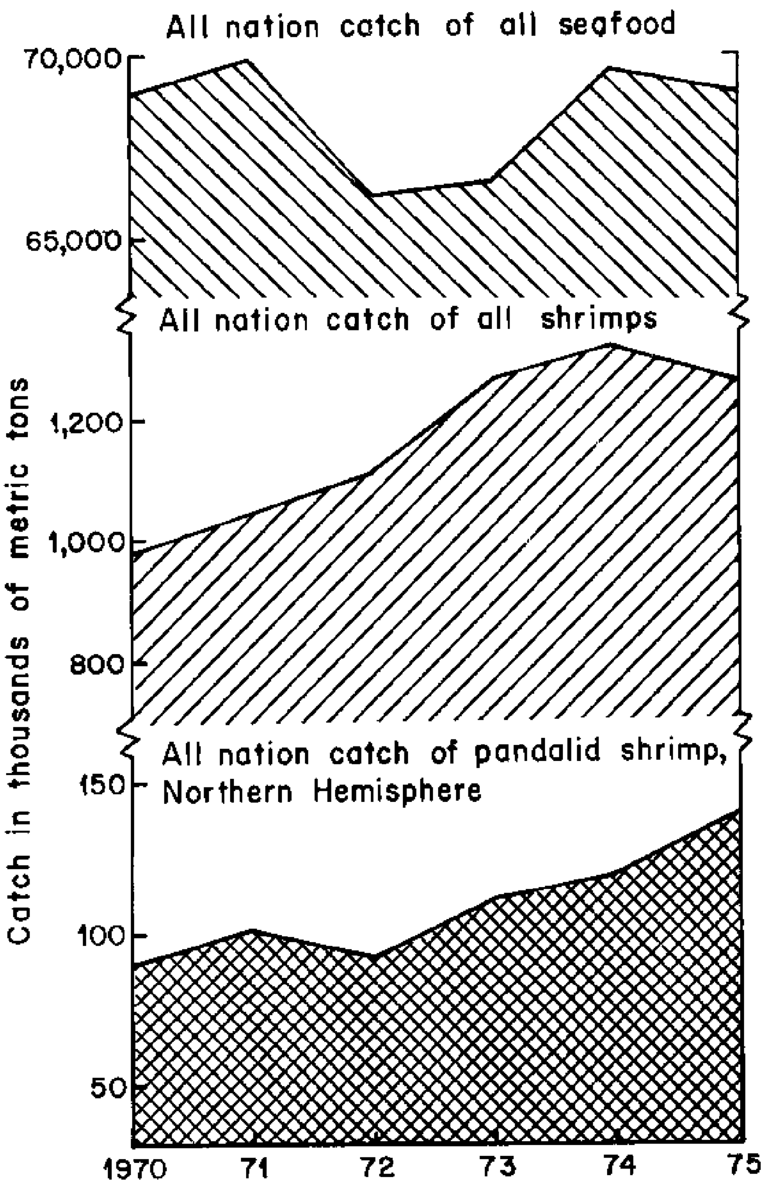

Figure 2. World production of seafood, shrimps and pandalid shrimp. (FAO 1976)

Fox (1972) provides the following table of commercially exploited pandalid shrimps.

SCIENTIFIC NAME	COMMON NAME
<u>Heterocarpus grimaldii</u> Milne-Edwards and Bouvier, 1900	none
<u>H. reedi</u> Bahamonde, 1955	nylon shrimp
<u>Pandalopsis dispar</u> Rathbun, 1902	sidestripe shrimp
<u>Pandalus borealis</u> Krøyer, 1938	Pink shrimp (U.S.A.), Deepwater prawn (Europe)
<u>P. danae</u> Stimpson, 1860	dock shrimp (U.S.A.), coonstripe shrimp (Canada)
<u>P. goniurus</u> Stimpson, 1860	humpy shrimp
<u>P. hypsinotus</u> Brandt, 1851	coonstripe shrimp (U.S.A.) humpback shrimp (Canada)
<u>P. jordani</u> Rathbun, 1902	ocean or smooth Pink shrimp
<u>P. montagui</u> Leach, 1814	Pink shrimp
<u>P. platyceros</u> Brandt, 1851	spot shrimp or prawn
<u>P. prensor</u> Stimpson, 1860	none
<u>Plesionika edwardsii</u> Brandt, 1851	none
<u>P. martia</u> Milne-Edwards, 1883	none

The following descriptions of general distribution of the pandalid species listed above are from Fox (1972), Ronholt (1963), Butler (1964), Wigley (1960), Berkeley (1930), Hancock and Henriquez (1968), NPFMC (1978), Mistakidis (1957).

<u>Heterocarpus grimaldii</u> is fished in the southeastern Atlantic Ocean from the coast of Portugal, the Azores, and along the north and west coasts of Africa as far south as Nigeria.

<u>Heterocarpus reedi</u> is found in the southeastern Pacific Ocean off the coast of Chile between 25° south and 39° south latitude and between 100 and 500 m in depth. Locations of highest abundance are between 29° south and 35° south latitude and at depths of 180 to 200 m. They are generally confined to a bottom of muddy sand, clay, or compacted clay.

<u>Pandalopsis dispar</u> is located from the Bering Sea near the Pribilof Islands to Oregon in depths from 37 to 642 m. The

areas of greatest abundance are near Kodiak Island and the Shumagin Islands in the Gulf of Alaska at depths from 110 to 218 m. They normally are found on muddy bottoms but are also taken on rocks.

Pandalus borealis is circumpolar in its distribution occurring in both the Atlantic and Pacific Oceans. Its depth range is from 20 to 1,450 m. Off the west coast of North America P. borealis is distributed from the Bering Sea to the Columbia River with greatest concentration in the central part of the Gulf of Alaska. In the Atlantic Ocean there are population centers in the Gulf of Maine, along the southwestern coast of Greenland, near Iceland, and in the North Sea and Norwegian Sea as far north as 82° north latitude. They generally occur over muddy bottom with few rocks.

Pandalus danae is distributed from Sitka, Alaska to southern California in depths from 18 to 185 m. They are most abundant off British Columbia in depths to 65 m, and are much less common both north and south. They usually live on a gravelly or sandy bottom.

Pandalus goniurus is found from the Arctic coast of Alaska southward to Puget Sound in depths from 5 to 180 m. This species also occurs in commercial concentrations in the western Pacific from the Gulf of Anadyr to the Koryan coast of the Bering Sea at depths to 85 m.

Pandalus hypsinotus occurs from the Bering Sea to the Strait of Juan de Fuca in depths from 5 to 180 m. They also occur near the Kurile Islands in the western Pacific and off the Kamchatka Peninsula. They are usually found on sandy or gravel bottoms but occasionally are found on mud or rocks.

Pandalus jordani is located off the western coast of North America from Unalaska, Alaska to southern California in depths from 37 to 450 m. The area of greatest abundance is from northern California to the Strait of Juan de Fuca, with highest concentrations off the coast of Oregon at depths generally greater than 100 m. They occur mostly on mud or muddy sand bottoms.

Pandalus montagui is found from the extreme northern coast of Norway to the English Channel over the entire North Sea and near Iceland and the Faeroe Islands. A subspecies P. montagui tridens Rathbun is found from central Alaska southward to British Columbia. Depths of occurrence are from 4 to 400 m with greatest abundance between 18 and 92 m.

Pandalus platyceros is found from Unalaska, Alaska to San Diego, California, but is more common toward the northern part of their range. They occur from 4 to 487 m with greater densities from 90 to 137 m. P. platyceros is also reported in commercial numbers off the Republic of Korea in the western Pacific Ocean. They are usually located on rocky bottoms, but are occasionally taken on muddy bottoms near rocks.

Pandalus prensor is found off Korea and Japan.

Plesionika edwardsii is generally a Mediterranean species taken off Morocco, Israel, Yugoslavia, Italy, France, and Spain.

Plesionika martia is taken near shore all around the Mediterranean Sea, along the western and southern coasts of Africa, near Japan, off Tasmania, and near the Hawaiian Islands.

LIFE HISTORY

REPRODUCTION

Berkeley (1930) was first to document the morphological changes that pandalid shrimps exhibit as they mature and change from male to female. These protandric hermaphrodites generally mature sexually as males. After spawning one or more times, they pass through a transitional phase and subsequently spawn as females. Transition usually occurs rapidly enough so that an individual who spawns one year as a male will spawn the next year as a female (Fox 1972).

In southern portions of the range early maturing females, in which the male phase is bypassed, are often observed (Butler 1971). Two categories of these are identified: primary, which mature directly as females without ever developing male characteristics (Allen 1959); and secondary, which as juveniles have male characteristics, but spawn for the first time as females (Haynes and Wigley 1969). Early maturing females have been observed in populations of P. jordani, P. borealis, P. danae, P. hypsinotus, and P. montagui.

Fecundity in pandalid shrimps ranges from a few hundred eggs to about 4,000 eggs and is proportional to the size of the female. Consequently, the larger species and the larger females of a given species are generally more fecund (Fox 1972, Mistakidis 1957; Haynes and Wigley 1969).

Female pandalid shrimp carry their fertilized eggs until they hatch; thus, mortality to the female precipitates mortality to her egg clutch.

Over their geographic range, pandalid shrimp have different seasons of spawning and hatching with water temperature being the apparent controlling factor (Rasmussen 1953).

This phenomenon is most noticeable and most studied for *P. borealis* because it has a far wider geographic distribution than any other pandalid species. However, there are reports of similar variations in reproductive periods at least for *P. jordani* (Dahlstrom 1970) and *P. montagui* (Mistakidis 1957).

For *P. borealis* in the northern extremities of its range, the incubation of the eggs is longer due to both an earlier spawning and a later hatching date (Rasmussen 1953; Allen 1959). Near Spitzbergen, spawning takes place from July to October and hatching occurs the following spring from late April until June. In the southern portion of its range, off Northumberland, egg deposition occurs from mid-October to early December with hatching between mid-March and mid-April. This means that in the southerly part of the range eggs are carried for four or five months, while in the northern regions the ovigerous period lasts for about nine months.

GROWTH

Pandalid shrimp eggs hatch into planktonic larvae which go through six stages in two or three months before attaining the juvenile form (Berkeley 1930). At this time they assume a semi-benthic nature similar to adult shrimp.

Because of the lack of suitable organs with which to determine age, estimates of growth rates have been made by examining length frequency data. Modal frequencies were generally assumed to represent the average pandalid cohort size by a number of investigators, including Berkeley (1930), Mistakidis (1957), Minet, Forest, and Perodou (1978), and others. Anderson (1978) was able to follow a particularly strong year-class of *P. borealis* through seven years of trawl survey data. Rasmussen (1969) pointed out a difficulty with the procedure when discussing growth of *P. borealis* in the Norwegian Sea:

> The general rule seems to be that the largest males of an age group undergo the transformation into females first. The growth of the transition animals in the following months is accelerated, while those animals which remain males have a restricted growth. As a natural consequence, a single age group of prawns may come to consist of two distinct size groups, one of small males and the other of large females....If not closely followed, they would normally have been misinterpreted as two different age groups.

Butler (1964) summarized the growth of nine species of pandalid shrimps. P. platyceros was the largest of these and attained a carapace length (CL) of 45 mm and a weight of 50 g. P. dispar and P. hypsinotus reached 30 mm CL and 20 g. P. borealis, P. danae, and P. jordani reached about 25 mm CL and about 10 g. All of these values pertain to British Columbia waters, but serve to show the approximate range of pandalid sizes. As with most animals, growth rates are generally slower in the colder limits of each species range. Figure 3 depicts the growth rates of several populations of P. borealis from various parts of its range (Rasmussen 1953; Allen 1959; Butler 1964; Haynes and Wigley 1969; Ivanov 1969).

Age at first maturity and transitional age also vary with species and geographic location. Individuals of a given species mature less rapidly as they inhabit waters in the colder portion of their range (Rasmussen 1969; Haynes and Wigley 1969; Ivanov 1969). P. danae and P. goniurus off British Columbia and P. montagui off England begin to mature in their first year of life. P. borealis and P. jordani off the Pacific coast of North America mature during the second year of life (Butler 1964; Dahlstrom 1970). P. borealis in the Bering Sea does not mature until its third year, and the same species near Spitzbergen does not mature until its fourth year (Fox 1972; Rasmussen 1969). Generally, most pandalid shrimp function one or two years as a male.

MORTALITY

Mortality is high for pandalid shrimps, but it has proven difficult to quantify. Gotshall (1969) provided some of the first estimates of mortality of pandalid shrimps by comparing numbers of P. jordani by age-class in trawl surveys in successive years off California. His estimates of annual mortality ranged from 48 to 70 percent (instantaneous rate z = .65 to 1.20).

Rinaldo (1976), using commercial CPUE and research survey data, calculated annual natural mortality for P. borealis in the Gulf of Maine to be about 22 percent (m = .25) and total mortality as high as 85 percent (z = 1.90).

Anderson (1978), using successive annual trawl surveys to calculate the relative abundance of a year-class from one year to the next, estimated total annual mortality for P. borealis near Kodiak at about 48 percent (z = .65) for cohort age 3 to 4 and for age 5 to 6.

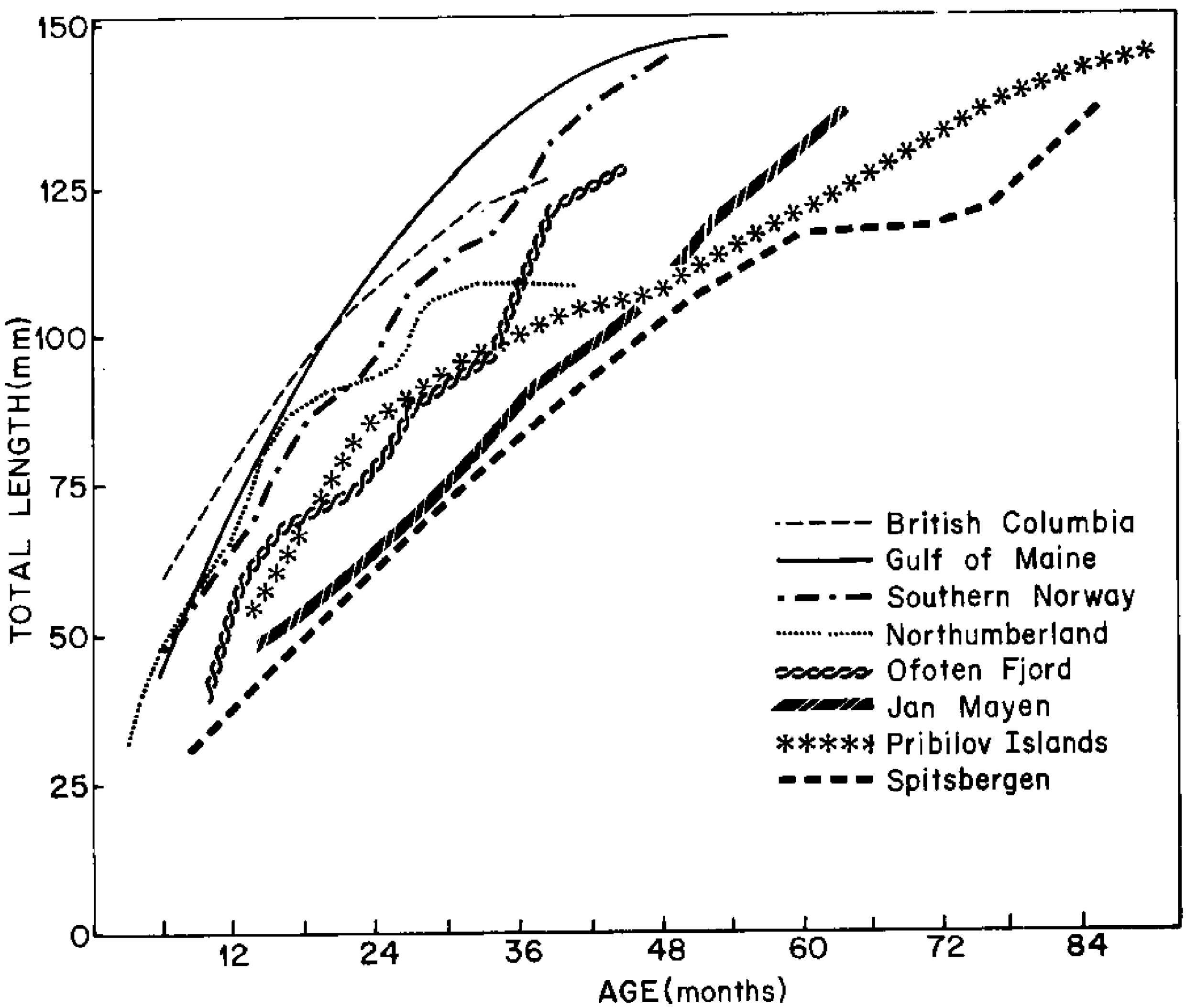

Figure 3. Growth curves of several populations of P. borealis. (Haynes and Wigley 1969; Ivanov 1969; Butler 1971)

ICES (1971) reported using the "catch curve" method to estimate annual natural mortality for P. borealis off southwest Iceland at 40 percent (m = .50) and suggested that natural mortality was probably higher in the North Sea. Most P. jordani off California and P. montagui off England survive only four years (Simpson, Howell, and Warren 1970). P. borealis in the Gulf of Maine survive about five years (Haynes and Wigley 1969), off Kodiak Island about seven years (Fox 1972), and off Spitzbergen about eight years (Rasmussen 1969).

Most large fish, including many commercially exploited species, are predators of pandalid shrimp.

FOOD

Pandalid shrimp are primarily benthic feeders that will eat a wide variety of organisms, including polychaetes, echinoderms, protozoa, copepods, euphausids (Butler 1964; Fox 1972; Mistakidis 1957; Dahlstrom 1970).

MIGRATION

Pandalid shrimp migrate from deep to shallow water and vertically in the water column. Dahlstrom (1970) reported that P. jordani moves offshore during winter to spawn. Mistakidis (1957) indicated quite extensive offshore migration of P. montagui during winter to spawn. In the Gulf of Maine, P. borealis females are reported to move inshore as their eggs develop in the late fall and early winter (Haynes and Wigley 1969).

Clark and Anthony (1977) reported that two distinct fisheries for P. borealis have developed in the Gulf of Maine in response to the migratory cycle: an inshore winter fishery harvesting primarily adult ovigerous females, and an offshore summer fishery targeting on immature and mature males and transitional shrimp.

Some pandalid shrimp are also characterized by diel vertical migration. Barr and McBride (1967) demonstrated that P. borealis move off the bottom in the evening, occupy the whole water column for much of the night, concentrate in the upper layers for about three hours after midnight and return to the bottom in early morning. Pearcy (1970) observed similar movements for P. jordani off the Oregon coast.

SHRIMP FISHERIES

An examination of Alaska Shellfish Commercial Fishing Regulations (ADF&G 1977) shows that within the Kodiak district there are 16 sections for which there are distinct sets of management regulations. This is perhaps an indication of the detail to which individual stocks of shrimp must be identified to assure appropriate management. This review, while recognizing the necessity of management on a stock basis, will group the pandalid shrimp fisheries in the following categories (see Figure 4):

California-Washington
British Columbia
Alaska (except Bering Sea)
Bering Sea
New England
Canadian east Coast
Greenland
Iceland
Barents Sea
Spitzbergen and Bear Island
Norwegian Sea
North Sea and Skagerrak

Table 1 shows the recent catch history for each area.

WASHINGTON-CALIFORNIA

Jones (1971) summarized the shrimp fishery off Washington-California. Although shrimp fishing occurred in inside waters such as San Francisco Bay and Puget Sound since the late 1800s, the first significant commercial fishery for ocean-caught shrimp began in 1952 in Californian waters, 1956 off Washington, and 1957 off Oregon. The target species over the entire area is P. jordani which constitutes over 99 percent of the catch (Robinson 1974). Trace amounts of P. platyceros, P. danae, and Pandolopsis dispar are taken occasionally in the northern part of the range. Shrimp fishing grounds occur all along the coast of the area, typically between 100 and 300 m deep. Presently the fishery is producing well off all states, with the fishing grounds off Oregon producing about 60 to 65 percent of the total harvest.

The California shrimp fishery was managed on a quota system by the California Fish and Game Commission until 1976, when the quotas were removed. The fishery is controlled by a season (April through October) which can be terminated if size composition of the catch or CPUE drops significantly during the season.

Shrimp fishing in Oregon is managed by Oregon Department of Fish and Wildlife only by a season restriction which permits the fishery to operate only during the non-ovigerous period from April to October.

The Washington Department of Fisheries permits shrimp fishing off the Washington coast without a closed season. There

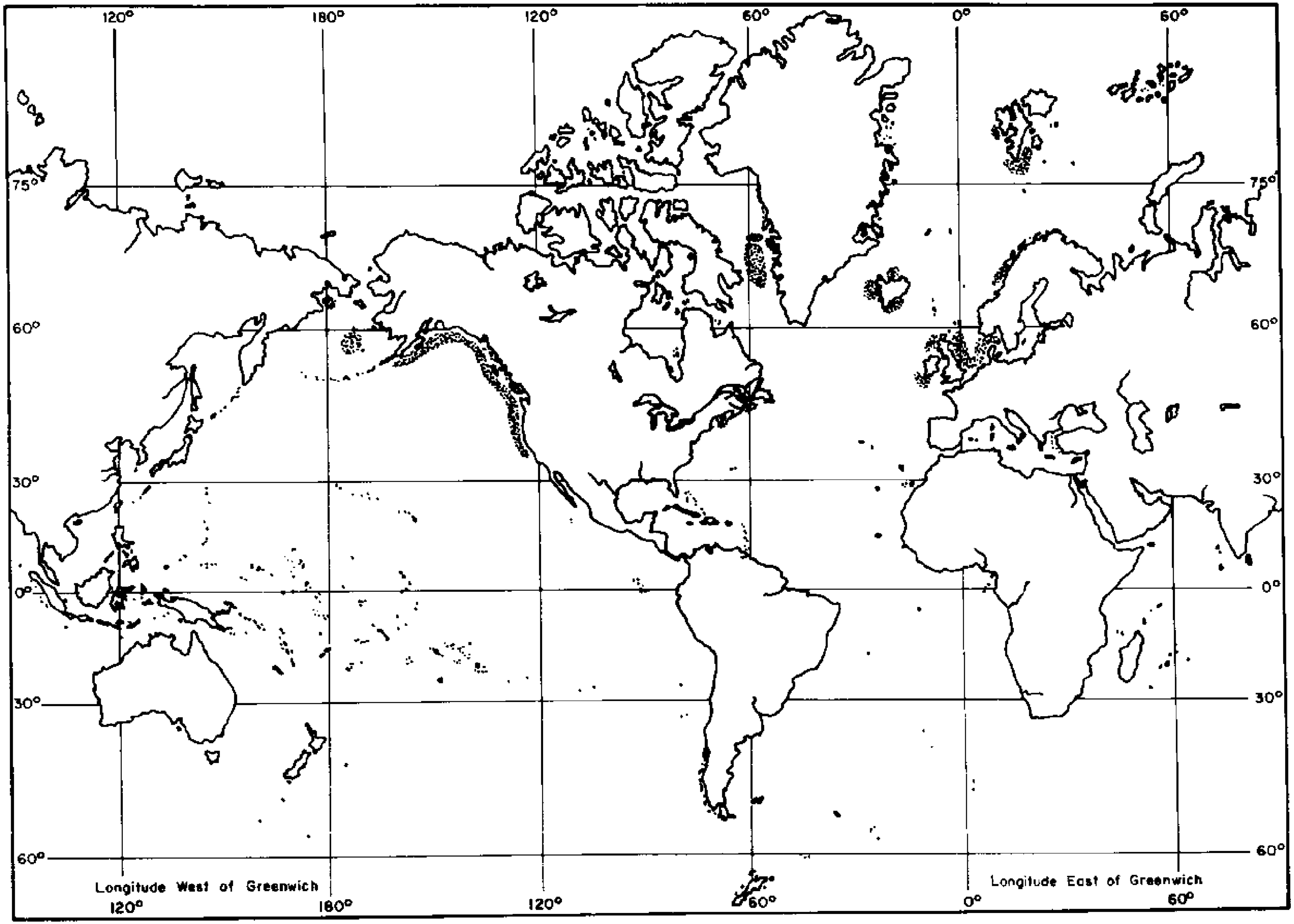

Figure 4. Major world pandalid fishing grounds.

Table 1. Pandalid shrimp catches by area in metric tons, heads on

Year	Wash.-Calif.[1]	British Columbia[2]	Alaska[1]	Bering Sea[3]	New England[1]	Canada East Coast[2]
1961	2,240	550	7,250	14,120	30	-
1962	2,700	755	6,685	18,390	175	-
1963	2,780	810	6,860	29,540	255	-
1964	3,070	475	3,505	20,880	420	-
1965	1,485	795	7,630	9,765	950	-
1966	2,835	765	12,790	2,935	1,765	-
1967	5,735	770	18,960	3,300	3,170	570
1968	6,500	710	19,085	12,735	6,610	1,015
1969	6,620	960	21,680	9,505	12,820	1,141
1970	8,485	700	33,725	6,155	10,645	2,020
1971	5,915	335	42,670	2,855	11,130	1,780
1972	10,930	360	39,330	220	11,095	1,385
1973	14,140	785	51,805	155	9,405	2,170
1974	14,340	1,200	48,756	105	7,945	3,520
1975	17,680	785	44,900	3,555	6,135	4,710
1976	17,235	3,505	58,520	2,205	1,665	5,015
1977	34,010	2,765	53,030	615	365	-

[1]From Fisheries of the United States, U.S. Department of Commerce.
[2]From Annual Statistical Review of Canadian Fisheries, Vol. 9, Fisheries and Canada.
[3]From NPFMC Bering Sea Shrimp FMP, Draft ms., and refer only to Japanese harvests.

Table 1 (con't.)

Year	Greenland[4]	Iceland[4]	Barents Sea[4]	Spitzbergen/ Bear Isl.[4]	Norwegian Sea[4]	North Sea and Skagerrak[4]
1961	2,545	1,375	835	-	2,910	13,930
1962	3,365	-	500	-	3,500	16,590
1963	3,340	-	335	-	3,315	17,900
1964	3,770	675	360	-	3,325	15,590
1965	5,050	900	665	-	4,075	14,635
1966	5,380	1,790	985	-	3,925	9,050
1967	5,650	1,510	1,185	-	4,365	8,650
1968	5,605	2,450	940	-	3,570	9,925
1969	6,740	3,275	1,500	-	3,090	9,020
1970	8,560	4,510	2,115	290	3,105	9,100
1971	9,440	6,325	2,280	315	2,550	10,440
1972	9,530	5,290	2,985	1,070	2,720	8,775
1973	12,640	7,285	1,645	2,460	2,815	6,570
1974	22,010	6,515	1,345	3,120	4,530	5,250
1975	37,890	4,940	60	5,160	2,980	6,730
1976	49,675	6,450				
1977						

[4]From Bulletin Statistique des Peches Maritimes, ICES.

are seasonal restrictions placed on fisheries in Puget Sound.

The fishery has been conducted until recent years by trawl vessels from 50 to 80 ft in length. These are gradually being replaced by modern steel vessels capable of fishing double gear; i.e., two trawl nets are towed simultaneously, usually with one pair of trawl doors in common.

BRITISH COLUMBIA

Butler (1968) reports that a shrimp fishery existed near Victoria in 1890, and commercial trawling took place in English Bay and other areas near Vancouver as early as 1917. The shrimp fishery began to expand in the late 1940s on stocks of P. borealis near Vancouver. In the 1950s, commercial exploitation expanded to include new grounds off the coasts of Vancouver Island where P. jordani was the dominant species. During this same period of time, a fishery on P. borealis and Pandalopsis dispar was developing in northern British Columbia near Prince Rupert. Today the shrimp fishery remains a relatively minor fishing operation involving six species which are, in order of decreasing importance, P. jordani, P. borealis, P. platyceros, Pandalopsis dispar, P. hypsinotus, and P. danae.

There are no closed seasons for shrimp fishing in British Columbia except in Burrard Inlet from December through March, and in Vancouver Harbor and English Bay where no fishing is permitted at any time (PMFC 1977).

Prior to 1974, all trawl caught shrimp in this area were harvested by single rigged vessels. In 1974 some double rigged otter trawlers fished off British Columbia, and in 1975 double rigged beam trawlers joined the fleet. There is a small catch in some areas by a trap fishery confined mostly to the larger species.

ALASKA

NPFMC (1976) summarized the shrimp fisheries in the Gulf of Alaska. This fishery began exploiting P. borealis as early as 1915 in southeastern Alaska near Petersburg and gradually expanded to annual harvest of about 500 to 1,500 mt from 1945 to 1955. Growth has been rapid since 1958 and present day fisheries occur all along the Gulf of Alaska coast, mostly well within 12 miles of the coastline. The fisheries around Kodiak provided about 85 percent of the total Alaskan catch in the early 1970s, but have dropped to about 35 percent of the total catch in recent years as the shrimp fishery has begun to exploit new stocks along the Alaska Peninsula.

P. borealis is about 85 percent of the commercial catch of the area with some areas dominated by P. goniurus and Pandalopsis dispar. Other pandalids, P. hypsinotus, P. danae, P. montagui tridens, P. jordani, and P. platyceros occur in catches to a minor extent.

The stocks of shrimp in Alaskan waters are generally considered fully exploited but healthy, with the exception of some stocks around Kodiak Island which are considered over-exploited. (Note: Many stocks in western Alaska waters have continued to decline since 1978.)

The Alaskan shrimp fishery is managed by closed season for biological protection of stocks during critical time periods and guideline harvest levels (quotas) determined by stock assessment programs. There is a provision allowing emergency closures if in-season monitoring of catch shows drastically declining CPUEs or other biological indicators.

The Alaskan shrimp fleet comprises double rigged otter trawlers of from 120 to 220 ft, single rigged otter trawlers of 70 to 130 ft, and beam trawlers generally less than 40 ft. In addition, there is a small pot fishery for the larger pandalid species.

Bering Sea

NPFMC (1978) summarized the shrimp fishery in the Bering Sea. A Japanese mothership fishery with about 25 catcher boats began harvesting P. borealis and P. goniurus near the Pribilof Islands in 1960. The fishery in this area peaked rapidly at nearly 30,000 mt in 1963, then declined dramatically and has been inconsequential since 1967. During the late 1960s and early 1970s, the fishery exploited shrimp stocks in the Gulf of Anadyr and in the northcentral Bering Sea. P. goniurus provides the major share of the catch from the Gulf of Anadyr and along the Koryan coast of the Bering Sea.

Indications are that shrimp stocks in the eastern Bering Sea remain in a depressed state, despite the lack of a directed shrimp fishery since 1967. Little is known about stocks of pandalids in the western Bering Sea.

The shrimp fisheries in the eastern Bering Sea had not been managed until 1977, when prohibitions were placed on retention of shrimp by any nation other than the United States within United States jurisdictional waters in the Bering Sea.

NEW ENGLAND

Wigley (1973) and the Northern Shrimp Scientific Committee (1978) summarized the New England shrimp fishery in the

Gulf of Maine which exploits P. borealis and P. montagui (5 to 20 percent). Modest amounts of shrimp were landed incidentally with catches of other groundfishes since the early 1900s, but it was not until 1938 that the commercial fishery for shrimp began. From 1940 to 1945, shrimp landings increased from 4 to 264 mt. Then catches declined rapidly and only a few metric tons were landed annually for several years. The fishery stopped totally from 1954 to 1957.

Beginning in the early 1960s, the fishery gradually expanded until from 1969 to 1962 annual catches of between 10,000 and 12,000 mt were maintained, despite a decreased catch per tow from 30,345 to 3,587 (numbers of shrimp) over the same time period. Landings in 1977 were only 365 mt. The assessment is that stocks are severely depressed and will not recover substantially for at least a few years.

Harvest has traditionally been with otter trawls, although there is great diversity among the vessels. Wigley (1973) suggested that the diversity owes to the fact that most vessels in the shrimp fishery were originally used in other fisheries, including boats formerly directed at lobsters and draggers once employed in groundfish fisheries.

Management of the fishery has been conducted by the State-Federal Northeast Marine Fisheries Board composed of members from state and federal agencies. The management regime began in 1975 with a closed season intended to constrain the total harvest. A minimum mesh size intended to protect small shrimp was implemented along with a closed season and catch quotas for 1976 and 1977.

CANADA EAST COAST

Couture (1971) and Frechette (1971) presented information on the early fisheries for shrimp off the east coast of Canada. Commercial groundfish trawlers have encountered and landed incidental catches of shrimp since the early 1900s in Nova Scotia and more recently in New Brunswick and Quebec. A small directed effort for shrimp began in 1965, but the total harvest did not reach 500 mt annually until 1967. These first commercial efforts were directed at P. borealis and P. montagui and conducted in the St. Lawrence estuary. The annual harvests have increased gradually and about 5,000 mt were landed in 1976.

GREENLAND

Carlsson and Smidt (1978) have summarized the P. borealis shrimp fishery at Greenland. The fishery began in 1935 in nearshore waters and continued at moderately low levels until 1955 when it first surpassed a 500 mt harvest. The inshore stocks of shrimp were exploited with increasing effort until 1970, when offshore shrimp fishing was started in Davis Strait. The annual landings rose from about 6.75 mt in 1969 (mostly nearshore) tc nearly 50,000 mt in 1976.

The offshore fishery is regulated by ICNAF; the first limit on this fishery was imposed as a quota of 36,000 mt on the 1977 fishery (ICES 1977). Carlsson and Smidt report that the Greenland fishery size is self regulated by a price differential between large and small shrimp.

The fishing fleet is composed of trawl vessels.

ICELAND

The Icelandic shrimp fishery has been recently summarized by Hallgrimsson (1977). This fishery has exploited P. borealis commercially since 1936; however, the first significant catches were made in 1964 (Table 1). The fishery began in inshore bays on the northwest coast of Iceland, and has gradually expanded as new stocks of shrimp have been discovered. The fishery appears to be very healthy.

The shrimp fishery, beginning in October and continuing until April or May, is fished by small boats of from 10 to 45 tons. They fish with trawl gear.

The Iceland Marine Research Institute established total allowable catches for each fishing area based, generally, on historical CPUE trends of the fishery. The catch is monitored during the season so that emergency closures of the fishery can be made, if necessary.

Regulations for licensed shrimp boats specify minimum size of shrimp in terms of maximum number per kilogram, and a weekly quota intended to achieve shrimp landings in relation to processing capacity in each geographic locality.

BARENTS SEA/SPITZBERGEN/BEAR ISLAND/NORWEGIAN SEA

ICES (1963 to 1978) data show that the shrimp fisheries in this area have been conducted by Norwegian trawl vessels. Table 1, which shows the annual landings in each of these ICES areas since 1961, demonstrates a relatively low level fishery in the Barents Sea which peaked at nearly 3,000 mt in 1972 and since has declined rapidly to only 60 mt in 1975; a fishery in the Norwegian Sea which has fluctuated between 2,500 and 4,500 mt from 1961 to 1975; and a relatively new fishery near Spitzbergen and Bear Island which has increased steadly from 290 mt in 1970 to 5,160 mt in 1975.

The fishery is for P. borealis.

NORTH SEA AND SKAGERRAK

The North Sea and Skagerrak combined annual landings of P. borealis peaked at nearly 18,000 mt in 1963 and have declined gradually since then to less than 7,000 mt in 1975 (ICES 1963-1978). The fishery is multinational in scope, conducted by trawlers from Norway, Sweden, Denmark, Scotland, and England.

The Working Group on Assessment of Pandalus borealis Stock (ICES 1977) suggested that in the absence of reliable population parameters, increasing mesh sizes in the commercial gear would increase the age at which shrimp are recruited to the fishery, and would be an effective means of assuring continued recruitment to the stocks.

POPULATION ASSESSMENT

BIOMASS ESTIMATES

Trawl surveys designed to locate commercial abundances of pandalid shrimps have been conducted on the west coast of North America at least since 1950 (Alverson, McNeely and Johnson 1960). The subsequent step of expanding the trawl survey catches into biomass estimates of the stocks involved is more recent, but now occurs routinely (Ronholt 1974; Horsted 1978). The procedure is to stratify the survey grounds according to habitat, calculate the shrimp catch per unit area covered by the trawl, and finally apply the catch rate to the stratum size determining a population biomass for the area. Kanneworff (1978) describes a similar technique based on bottom photography rather than trawl samples.

Rinaldo (1976) used virtual population techniques to gain insight into the population structure and magnitude of Gulf of Maine shrimp stocks. His analysis confirmed a pattern of increasing fishing mortality and increasing exploitation rates on successive year-classes entering the fishery.

An alternate approach to determining stock biomasses has evolved with the development of sophisticated ecosystem simulation models, such as those by Laevastu (1978). These models consider the ecosystem to be balanced and determine the mean standing crops of various species which are required to keep the system stable.

YIELD ASSESSMENTS

Abramson and Tomlinson (1972) used two types of yield models to analyze catch data from a P. jordani stock off California. They found the "stock production" model to be superior to the "dynamic pool" model and were able to estimate the maximum sustainable yield for the fishery. The relevance of the surplus production model, in view of the recent radical increases in populations of P. jordani in Oregon and northern California, is not clear. The greatly increased abundance in this area suggests that population sizes may be more closely related to environmental features than to density dependent characteristics of the spawning biomass. Abramson and Tomlinson pointed out that they could not find a satisfactory spawner-recruit model. Consequently, conclusions were made only on a yield per recruit basis.

Rinaldo (1976) applied a dynamic pool model to the P. borealis fishery in the Gulf of Maine. He noted that the character of the fishery had changed greatly from 1966 to 1974, going from conditions which produced optimum yield in weight per recruit to a much lower figure. This resulted from an ever-increasing fishing mortality and a continuing decline at the age of entry to the fishery.

The ICES (1977) Working Group on Pandalus has also applied a dynamic pool yield model to stocks of P. borealis off Skagerrak and Iceland. It found that the maximum yield is sensitive to the level of natural mortality which they were unable to determine precisely. For many stocks of pandalids, natural mortality is thought to be quite high. ICES (1977) found that yield per recruit curves were generally flat-topped, suggesting that increasing fishing effort above fairly low levels of fishing mortality produce only small additional catches.

In general, ICES found that some stocks were being fished with high fishing mortalities and at a low recruitment age. Their suggestion was to increase mesh size substantially in the North Sea and Skaggerak study areas to reduce possibilities of recruitment failure.

MANAGEMENT STRATEGIES

Pandalid shrimp populations are characterized by several features which cause unique management problems. Foremost of these attributes is the shrimps' existence as a protandric hermaphrodite, spending its early life as a male and later stages as a female. This unusual life history has been known since 1930 (Berkeley 1930); however, traditional approaches to the development of management regimes are based on populations whose sexes are separate and in most cases are present in a 1:1 ratio. An exception is an analysis by Fox (1973) who developed a simulation model to analyze hermaphroditic populations.

Horsted (1978) clearly exposes the difficulty by showing that the Greenland shrimp fishery exploits mainly transitional animals and females. This emphasizes the importance of understanding the stock-recruitment relationship and exploitation rate since the females in this area are exposed to at least one full year of fishing before they produce any larvae.

Rasmussen (1969) has found great differences in the rate of maturation and transition from male to female among shrimp stocks along the coast of Norway. He reported that pandalid shrimp in southern regions spawned as early as 2 1/2 years of age, while those in Spitzbergen waters (lat. 78°N) did not mature as females until 5 years old. A further variation in sexual development has been reported for pandalid stocks in the southern part of their range, where early maturing females which effectively bypass the male phase enhance the reproductive capacity of the stock (Butler 1964; Haynes and Wigley 1969).

Pandalid shrimp, like other crustaceans, grow in exterior dimensions only when they molt. The molting process results in a loss of all except soft tissue parts of the animal and thereby precludes the possibility of age determination by examining annual accumulations on hard body parts. This inability to determine age results in difficulty in determining growth rates and consequently, in estimating cohort size. While this problem is not unique to pandalid shrimp, other heavily exploited crustaceans have either been effectively tagged or exhibit less variations in growth patterns so that modal frequencies of size classes can be more easily analyzed.

A major difficulty encountered by pandalid shrimp managers is the tendency of a stock to produce for a number of years at very high levels and then precipitously decline. Notable examples are the Pribilof Islands fishery, the Washington and Oregon coast fishery, and the Gulf of Maine fishery. Some of these fisheries have remained at unproductive low levels after their decline, e.g., the Pribilof Island fishery in the Bering Sea produced 65 million lbs in 1963, dropped to 4 million in 1971 and has produced no significant harvests since. Other areas seem to rise and fall in a cyclic manner. For example, the fishery off the Washington coast landed 5.5 million lbs in 1958, dropped to 23,000 lbs in 1965, rose to 1.5 million lbs in 1969, dropped to 680,000 lbs in 1971, and rose again to approximately 11.5 million lbs in 1977 (see Figure 5).

Declines of this nature have been attributed to rapidly built up fisheries operating on the entrance of one or more extraordinarily large year-classes to the fishable population (Fox 1972). Although this may well reflect the increased production in certain years and in certain areas, the stock

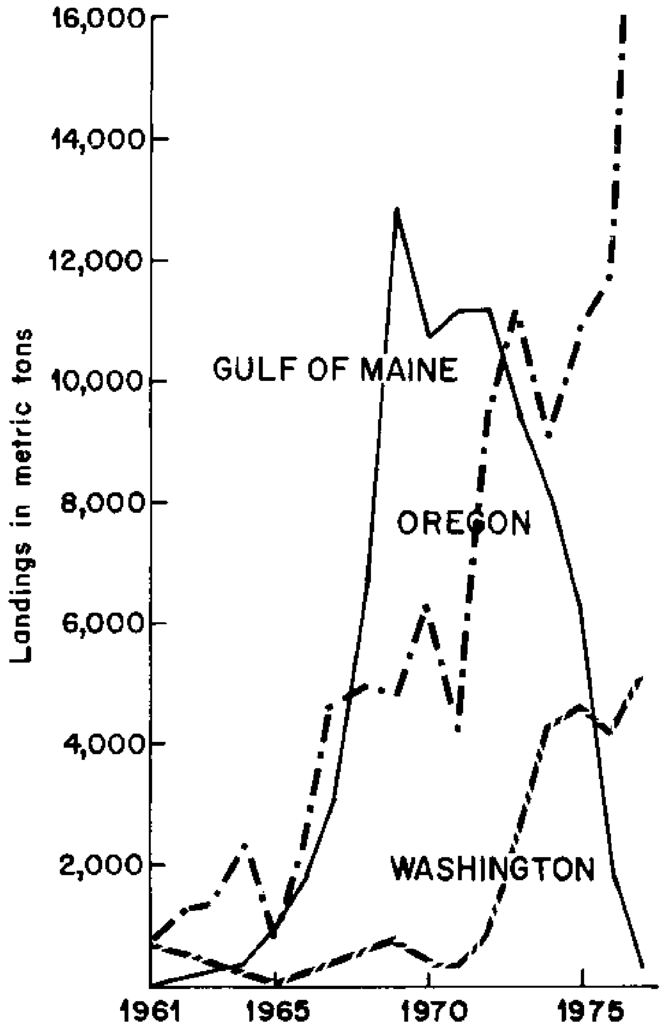

Figure 5. Pandalid shrimp landings from the Gulf of Maine, Oregon and Washington, showing year to year variation in harvest.

size undoubtedly responds to nonfishery environmental factors. Little has been accomplished in understanding the reaction of the pandalid populations to exploitation.

Shrimp fishermen often encounter significant amounts of incidentally caught fish in their shrimp nets (Jurkovich 1971). The catch of unwanted fish in shrimp trawls has been considered a problem. Additional labor is required to sort the catch and some quality is lost as shrimp are crushed while lifted aboard or during sorting. These incidental catches, when composed of foodfish, need also to be considered as losses to the exploitable foodfish population. Attention is being directed at this problem, evident from recent discussions by ICES (1977), MacIsaac and Diodati (1978), and others.

A final aspect of shrimp populations, which causes problems for managers, is the difficulty encountered in estimating population biomasses. The high oceanographic input which characterizes some shrimp areas (Anderson 1978), coupled with the natural migratory habits discussed earlier, results in shrimp stocks which shift their locations periodically. This leads to great variability in abundance forecasts and to uncertainty in the application of management models.

Management of pandalid fisheries has generally involved the establishment of seasonal closures to protect female shrimp during the ovigerous period, the establishment of minimum size to protect small shrimp, and the establishment of quotas to guard against overexploitation. Several examples of the application of these management measures are given in the section summarizing the area fisheries.

Problems arise in the shrimp fisheries not because of lack of available management strategies to protect the stocks, but rather because basic population parameters are not precisely known or because of a lack of timeliness in implementation of conservation measures.

An ICES (1977) working group suggested that in order to improve management, improved population estimates were needed in the following areas, by priority: determination of natural mortality, age determination and growth rates, stock identification and the origin of recruitment with regard to larval distribution, and the selection properties of the trawl gear.

Several recent attempts have been made to incorporate population parameters into management models which would integrate the available information (Fox 1973; Abramson and Tomlinson 1972; Rinaldo 1976; ICES 1977). These are important advances in pandalid management, but cannot account for the fact that recruitment processes are not well understood. Until these processes are more thoroughly defined, frequent resource assessment programs and in-season monitoring of commercial catches of shrimp may be required to determine population trends, their impacts on fisheries, and the potential impact the fisheries may have on the changing nature of the pandalid population.

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FEBRUARY 13, 1979

HISTORY OF
PANDALID SHRIMP FISHERIES
MANAGEMENT AND RESEARCH
AND
PANEL DISCUSSION

HISTORY OF RESEARCH AND MANAGEMENT IN GREENLAND WATERS

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SUMMARY

Pandalus borealis is the only crustacean target species for the Greenland fishery, known there for a couple of centuries. Various expeditions in the late 19th century and in the beginning of this century contributed greatly to the knowledge of distribution and biology of fish, marine invertebrates and hydrography in Greenland waters.

The TJALFE expedition, 1908 and 1909, directed by Adolph Jensen, initiated commercial fisheries in Greenland, primarily on Greenland halibut. From 1920, cod were included and to some extent Arctic halibut. This first shrimp fishery started in 1935 as a substitute for a collapsed halibut fishery.

Paul M. Hansen carried out annual surveys (mainly sampling and tagging of cod) from 1925. In 1946, the Greenland Fisheries Investigations were officially established under his directorship with a research cutter, *Adolf Jensen*, at its disposal.

Mapping of inshore shrimp grounds and continuous studies of shrimp biology have taken place since 1946. Inshore shrimp fishing was initiated in many places in the 1950s. By far the best region was Disko Bay. Inshore annual catch level has been up to 10,000 tons.

In Disko Bay, some restrictions on catches have been necessary in periods when fleet fishing capacity has exceeded that of fishing plants. Investigations of offshore grounds started in 1963. Vast grounds were found in 1964 and later years. Fishing on these grounds started with Faroese vessels in 1969, followed soon by other nations. Offshore catches by foreign vessels were about 40,000 tons by 1976. A quota regulations of offshore fishing was established through ICNAF in 1977.

Shrimp assessment is presently based mainly on annual stock size estimates by trawl surveys, bottom photography and commercial catch effort data. Lack of knowledge concerning occurrence of pre-recruits and the mechanisms of recruitment is hampering long term assessment.

Discard of shrimp is a problem in the statistical reporting and in control of quota. By-catches, especially of small redfish, are another problem associated with extensive shrimp fishing.

THE DANISH *PANDALUS* FISHERY

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SUMMARY

The Danish fishery for *Pandalus borealis* began in 1931 and was based on the Kattegat and Skagerrak stocks (ICES Subarea IIIa). Later it expanded into the North Sea. In 1960, fishing was pursued in Fladen Ground (ICES Subarea IVa), and at present the largest quantities are landed there (Figure 1). The annual landings are shown in Table 1.

After World War II, the fishery increased steadily from 288 tons in 1946 to a peak of 5,434 tons in 1969. A sudden fall in the Fladen Ground fishery in 1973 seems to reflect a decrease in stock abundance, since catch per unit effort dropped from more than 100 kg/hour to less than 50 kg/hour (Figure 2).

The boats used in the Danish fishery are typical cutters ranging from about 20 to 150 GRT. Small meshed otter trawls of various desings are used, but exclusively side trawls are used. By inter-Scandinavian law, a minimum of mesh size of 34 mm internal stretched mesh has been in force for Denmark, Norway and Sweden since 1953.

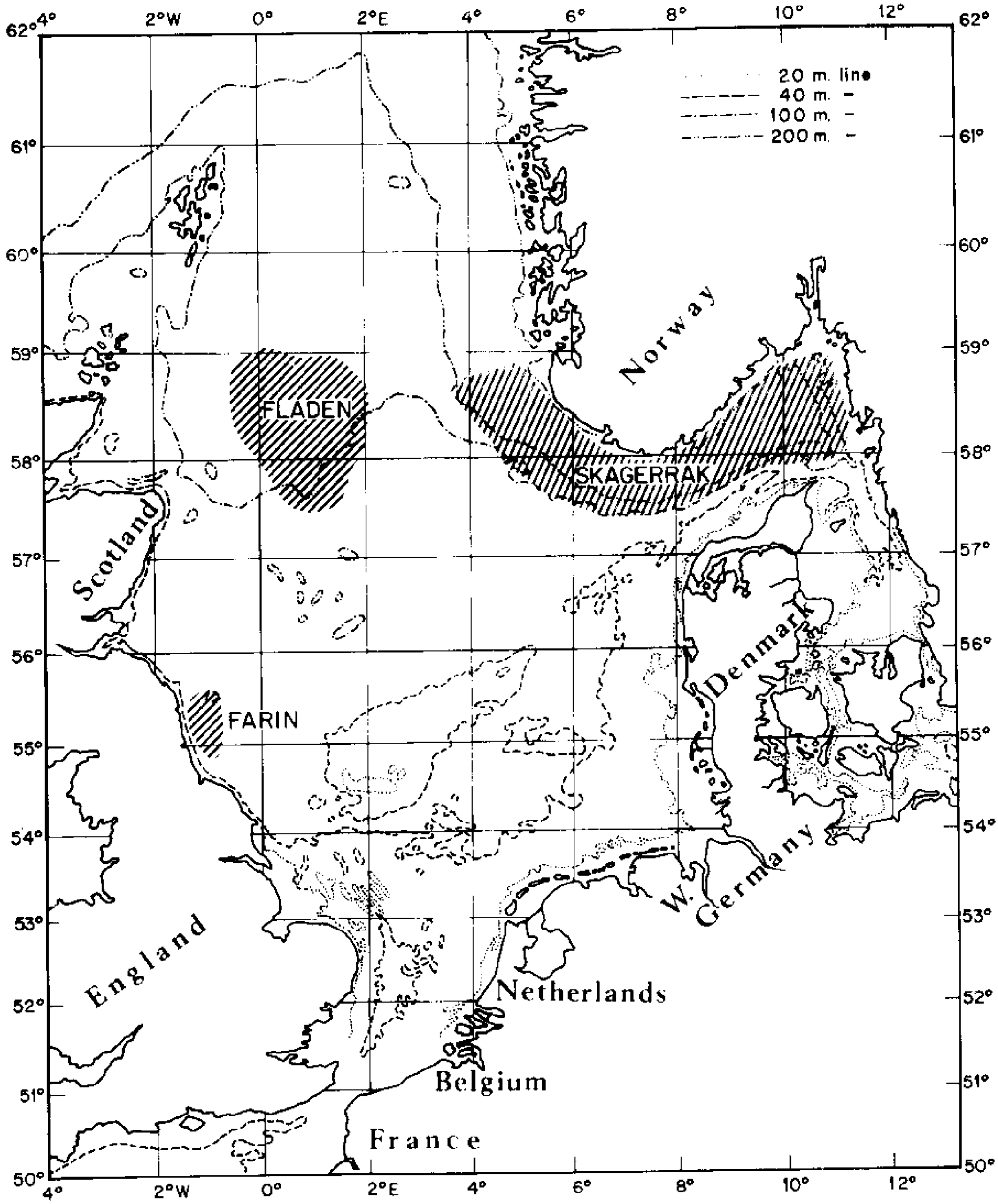

Figure 1. Fladen and Skagerrak fishing grounds for Pandalus borealis.

Table 1. Annual Danish catches in different areas (metric tons)

Year	Skagerrak-Kattegat Subarea IIIa	North Sea Subarea IVa-b	Total
1931	a. 30		ca. 30
1940	219		219
1950	457		457
1960	2,364	216	2,580
1970	757	3,460	4,217
1971	834	3,572	4,432[1]
1972	773	2,448	3,221
1973	716	196	912
1974	475	337	812
1975	743	1,392	2,135
1976	865	1,861	2,726
1977	763	782	1,545

Source: ICES Bull. Stat.

[1]Incl. 26 tons from the Barents Sea.

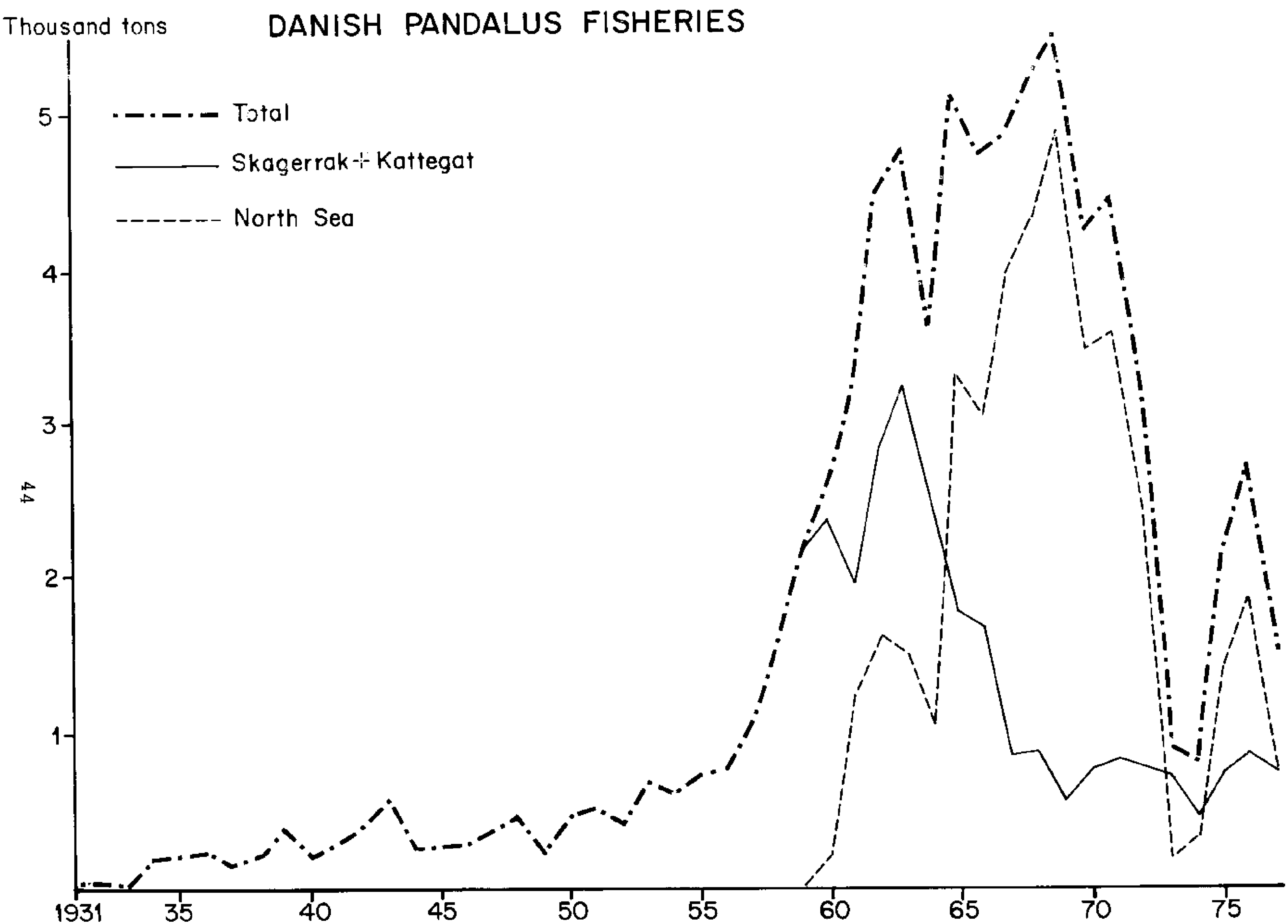

Figure 2. Danish *Pandalus* fisheries catch figures 1931 to 1976.

SHRIMP MANAGEMENT IN BRITISH COLUMBIA

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(Ed.'s note: This presentation was transcribed from tape for inclusion in this proceeding.)

British Columbia has had a commercial shrimp fishery since the early 1890s. Basically, the fishery in those days was the small local fishery that supplied local markets. The fishery has been directed at various times through various types of effort on six species of pandalid shrimp: P. jordani, P. platyceros, P. borealis, P. hypsinotus, P. danae and P. dispar.

The P. jordani fishery is at present our largest fishery, situated on the western coast of Vancouver Island. It's a relatively new fishery, which began in 1973. It was actually discovered through work done by Terry Butler in our industrial development arm. It's located primarily on the Nootka and Tofino grounds.

The rankings since 1973 have varied quite a bit, mainly due to increased effort. Unregulated fisheries were carried out from 1973 to 1976. From the landing figures, 1976 was a boom year. We had large American and Canadian fleets fishing on the Tofino grounds. The industry was keen after that on expanding the effort in what seemed like a bonanza fishery. At that time, the only monitoring of the fishery was through sporatic sampling of commercial catches and a series of swept trawls designed after similar surveys by Oregon.

Information on commercial samples from the 1976 fishery showed it was the product of two very strong year-classes, the 1973 and 1974. Our initial estimates for the 1975 fishery was that it was only about 28 percent of the two previous year-classes. So in 1977, we imposed two regulations on the fishery. The first was a license regulation. It was designed to prevent further vessel investment in a fishery that we thought was uncertain. There was no way to prevent overcapitalizaton by industry in the fishery. Since that time, several of our companies have gone bankrupt. A precautionary TAC was set on the initial bay survey in 1977. After that TAC was taken, we were going to close and resurvey the area. In addition to these surveys, we also hired a port sampler to collect information from a volunteer log book system we set up, and to collect and process samples from the commercial catch.

The major problem with using regulation that requires a quota system is you have to be able to monitor the fishery on a real-time basis to determine when the TAC is taken. This proved to be a problem because we didn't hire the port sampler until late in the fishing year and the only monitoring system we had was through a rather slow sales slip system. So, the TAC was exceeded that year, at least in the Tofino area. Subsequent surveys of the area didn't allow any further extension of the TAC at that time.

Since 1978, the regulations have been maintained. We still have a license limitation and we still have precautionary TAC's and resurvey in September.

In order to monitor the TAC this year, we set up a real-time computer data center at the biological station and with cooperation from our operations people we are now able to take our raw landing data in and get a figure. We correct it later, as sales slip data comes in. It seems to be working quite well. We can retrieve information at any time on any vessel.

The log book information received in 1977 and 1978 has been virtually 100 percent. As we get more data from our log books, we are hoping to use it in conjunction with our stock assessment techniques. With a relatively new fishery we feel the best program is to continue our stock assessment and set TAC's for them. We date our shrimp year from May to May, so this one isn't quite over yet. The decrease seen on the Tofino grounds in 1978 is basically due to a shift over to the more lucrative grounds at Nootka. Shrimp densities haven't been all that great on Tofino ground, at times and places you can find heavy concentrations but you really have to look for them.

It is hoped that our assessment techniques can be defined to correct some of the more pretentious assumptions we had to make. Our port sampling program will be continued, corrected, and refined. Through accuracy, as more and more reliable information is available, we hope to use it in a variety of stock models.

British Columbia's other shrimp fisheries are presently unregulated. The larger shrimps, what we call prawns, *P. platyceros* and *P. dispar* are in high demand. We are at present consolidating information available on these shrimps. We're having a problem with our sales slip system right now with landings of prawns. A lot of them are landed sort of off the cuff and nobody has ever bothered to count them, because if you don't report them you don't have to pay income tax on them.

Our initial target in management now is determining what regulations are enforceable. In the prawn fishery there are so many stocks we would probably never be able to manage on a TAC. We are looking at the work done in Washington state with regard to mesh size and savings-type gear. Then we want to find models that will give us an idea of the effect of these regulations. What information do we need for the models? Is it collectable? If so, how do we go about collecting it accurately, given a small amount of funding and manpower? These are all questions to consider. As a fishery manager of sorts, I now often recommend that a precautionary TAC be established until more information is available.

REVIEW OF SHRIMP FISHERIES, RESEARCH AND MANAGEMENT IN EASTERN CANADA

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SUMMARY

Fisheries for shrimp in eastern Canada are directed at Pandalus borealis. The distribution of the species is related to the occurence of relatively warm (3° to 5°C) water over a bottom substrate which usually consists of mud. Fishable concentrations occur in several discrete areas (Figure 1).

BAY OF FUNDY

A small fishery developed on the northwestern side of the Bay of Fundy in 1967. Following one or two years when landings of about 500 mt were achieved, catch rates dropped and the fishery died out. Exploratory systematic fishing was carried out, but research and management were not attempted.

NOVA SCOTIA SHELF

An extensive exploratory fishing program in the mid-60s revealed that fishable concentrations of shrimp existed in some of the deep holes that occur in the Nova Scotia shelf. Minor fisheries developed on some of these stocks, but efforts were generally short lived as catch rates rapidly dropped off. Fishing on a larger and more promising stock at the northern part of the shelf developed in 1977. In 1978 a biomass survey revealed a minimum fishable biomass of about 12,000 mt. Research was initiated in this area in 1978. To date, no management measures have been imposed.

GULF OF ST. LAWRENCE - SEVEN ISLANDS AREA

See separate report by J. Frechette.

GULF OF ST. LAWRENCE - NORTH OF ANTICOSTI AREA

See separate report by J. Frechette.

GULF OF ST. LAWRENCE - FEQUIMAR CHANNEL AREA

A fishery at a depth of 120 to 160 fm and prosecuted by small vessels (45 to 65 ft) most of which were converted from long liners or gill netters started in 1970. The fishery developed quite rapidly. Apart from a minor setback in 1972, it has expanded with the number of vessels participating in the fishery, rising to a maximum of 39 vessels in 1976. Since

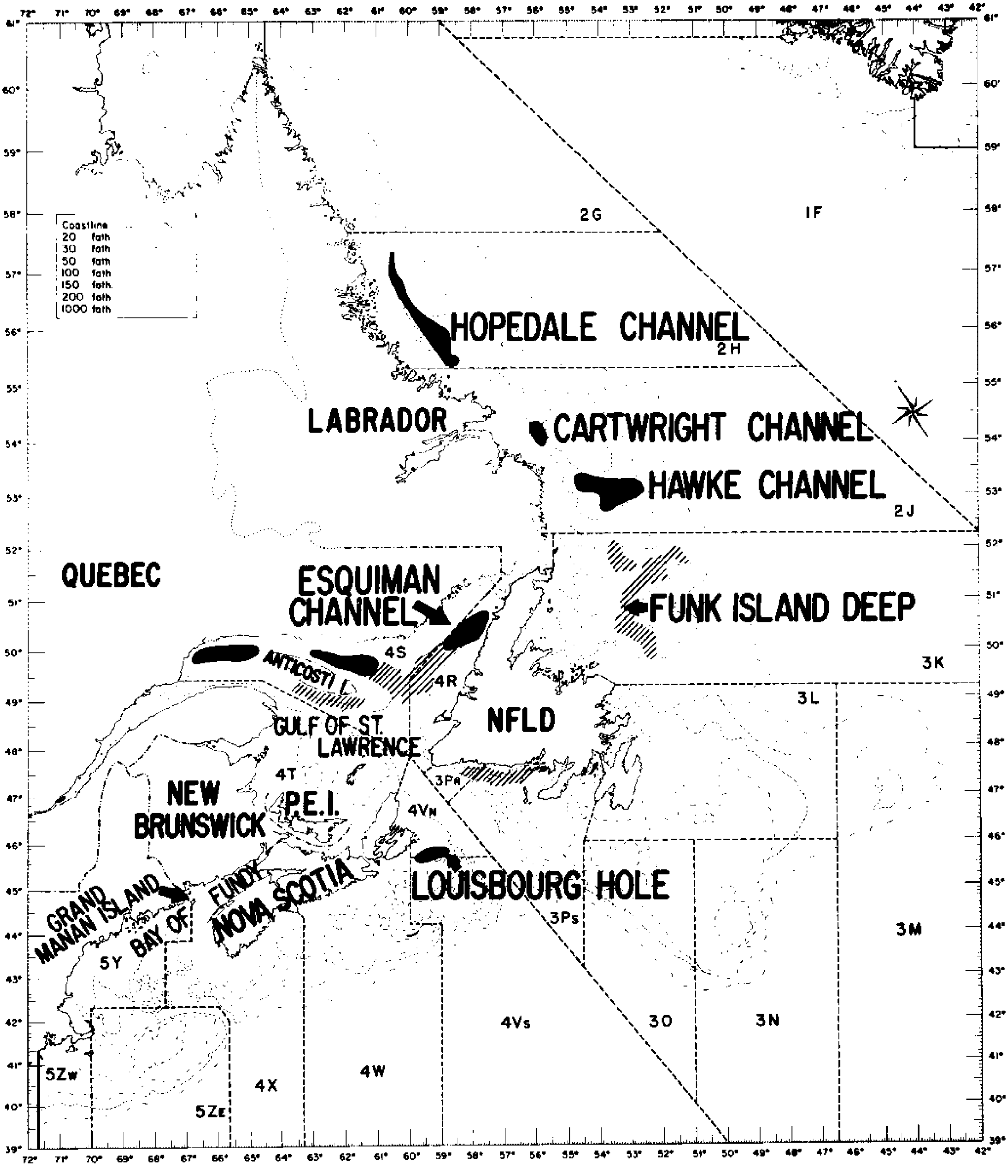

Figure 1. Fishable concentrations of Pandalus borealis in eastern Canada.

1972, the shrimp biomass in the area has shown an upward trend, indicated by the greatly increased catch rates (Figure 2) obtained in recent years (100 percent increase) and minimum fishable biomass estimates which have also shown an increase (158 percent) between 1972 and 1976.

A small research program was instituted at the onset of the fishery in 1970. Since then the fishery has been monitored and sampled on a monthly basis. The only management strategy in place is that of limited entry, instituted in 1976 at the request of the fishermen. This limited the number of vessels in the fishery to 40, a figure based on the present number of participants rather than the number required to take the TAC. A recent economic study has shown that in spite of the greatly increased abundance of shrimps in the area in recent years, and the outward prosperous appearance of the fishery, economically it is only marginal. It continues only because many of the vessels are not repaying the loans they obtained to purchase the new vessels. Ice coverage in the area restricts the fishery severely from about January to the beginning of May in most years.

LABRADOR

Three areas have been identified on the Labrador shelf where a fishery potential for shrimp exists. These areas are offshore, relatively remote from present processing facilities and to date have only satisfactorily been fished by large (150 to 170 ft) freezer trawlers. A license limitation of 11 such vessels was applied in 1978. Ice coverage prevents fishing in the area during most years from January to May to June.

Hawke Channel

No fishery has developed in this area to date, though commercial concentrations are known to exist there. A precautionary quota of 800 mt was established for this area in 1978.

Cartwright Channel

Following exploratory fishing in 1976, a fishery developed in this area in 1977 when a catch of about 1,200 mt was taken from an area of about 100^2 nautical miles. Following a crude assessment (biomass survey and De Lusy type) a quota of 800 tons was instituted in 1978. Catch rates in this fishery have varied between about 1,500 to 500 kg/hour with the higher rates occurring during the early months of the fishery each year.

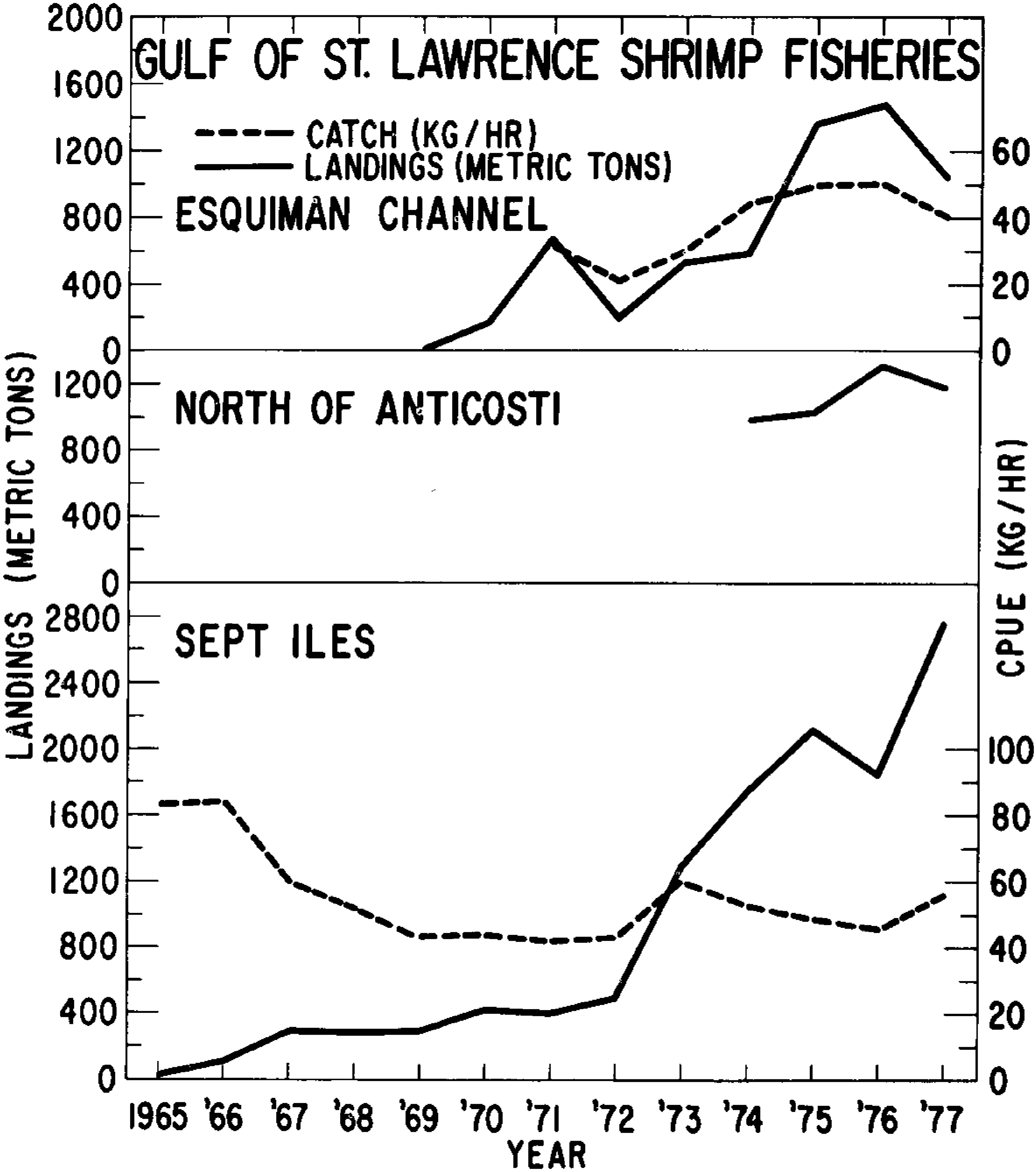

Figure 2. Catch rates for Pandalus borealis, Gulf of St. Lawrence, 1965 to 1977.

Hopedale Channel

Development of a fishery research and management strategy in this area has closely paralleled that of the Cartwright Channel area. The area is considerably larger and the quota established in 1978 at 4,500 mt. This quota was not reached in 1978.

Northern Labrador To Dairs Strait

Although conditions appear reasonably favorable for the occurrence of shrimp concentrations at several localities, exploratory fishing to date has not revealed stocks of real commercial significance in the area.

SHRIMP FISHERY OF PANDALUS BOREALIS IN QUEBEC

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INTRODUCTION

Since 1965, trawlers from Quebec have exploited shrimp populations of the Gulf of St. Lawrence. First exploitation was based mainly on exploration surveys in 1965 and 1966 (Couture 1966).

Compared to known large offshore fisheries, such as the Greenland fishery or Alaskan offshore fishery, Quebec's fishery in the Gulf is relatively small and should be qualified by the expression "inshore fishery". About 35 boats now fish for shrimps. These boats measure from 18.3 to 26.5 m and practically all are wooden side trawlers. The trawls used are Yankee trawl no. 36 or no. 41, the same type that was used in the Maine fishery, with mesh sizes from 38 to 44.5 mm. The semi-balloon trawl is now increasingly used by some fishermen.

The main fishing area is near the Quebec north coast in the northwest part of the Gulf of St. Lawrence between the estuary of the St. Lawrence and Anticosti Island. The catch is processed by three small shrimp plants which are relatively near the shrimp grounds (about 6 to 8 hours of running time). Few boats operating from the north coast (Mingan) fished in the Anticosti Channel, another important area for shrimps in the Gulf, where they fish together with New Brunswick fishermen.

RESEARCH ON SHRIMP IN QUEBEC, HISTORY

Usually, research programs on species are in proportion to the expansion of the fishery. That was the case in Quebec. Exploration and sampling works (Couture 1971) were the basis of commercial exploration for P. borealis in Quebec As the fishery grew, exploration was done in other areas of the Gulf including Esquiman Channel in 1972 and Anticosti Channel in 1973 (Fréchette et al. 1973; Fréchette and Dubois 1974), looking for places to extend commercial fishing grounds.

With the sharp augmentation of fishing effort from 1972 to 1973 and after, research needs shifted from our exploration objective to management needs. In 1972, a catch sampling program started with the collaboration of both industry and fishermen. At regular intervals samples of 300 to 400 shrimp were collected in landing sites, our main objective being to relate monthly and annual catches to visible year-classes and sexes.

At the same time, we refined our method of collecting catch and fishing effort data, introducing a log book system on a set-by-set basis. This system was introduced first in 1975 and is still in force. The first objective of this program is to return information to fishermen in a cumulative and comprehensive form, but also to collect accurate fishing data to use in research and management.

From 1974 to 1977, a program of year to year surveys was conducted. Spring and fall surveys were made yearly with the first objective to produce biomass estimates. Results first enabled us to annually produce advice on the management of the exploitation and second, to accumulate useful data for estimation of population parameters such as mortality and recruitment to the fishery and growth.

Among the results obtained from analysis of commercial samples and stock estimation surveys is a study of growth and a study on selectivity of the commercial trawl.

Intensive work was done to estimate year-class abundance and mortality rates, using biomass estimates from year to year and size distribution, on which age classes were separated using normal curves fitting NORMSEP. Mortality rates were finally calculated: mean total mortality as estimated to 1.0 with a range from 0.6 to 1.4 from fully recruited age-classes; mean natural mortality was estimated to be around 0.7.

MANAGEMENT

Up to now management of the Seft Isles fishery, in the north-west part of the Gulf of St. Lawrence has consisted only of license limitation, our first objective being to produce a step by step increase of fishing effort.

As a result, for the last three years we observed a stablilization in abundance of the stock as indicated by biomass estimates results and by very low variability of the mean commercial catch rate from 1975 to 1977. Mean biomass for these years was estimated to be about 8,500 mt. Under the assumption that this stock is in an equilibrium state and by relating actual catch rate at the beginning of the fishery to the corresponding biomass, we estimated the virgin biomass to be around 14,000 mt.

Using our estimation of natural mortality of 0.7, that is the best estimation we have for the area, the MSY for that area is around 5,000 mt.

Compared to Seft Isles area, Anticosti Channel stock are not fished very intensively. Four to five boats of Quebec and about ten to fifteen boats of New Brunswick fished in that area for an average landing of 1,000 mt from 1973 to 1977. Two stratified random surveys were made in 1976 by a federal biological station of St. John in Newfoundland and in 1977 by the Department of Marine Fisheries of the Quebec government. Using combined data for the two surveys the mean biomass estimate is about 14,000 mt. Assuming negligible mortality, the MSY estimate using a natural mortality of 0.7 is 5,000 mt. So the best advice we can offer for the area is to increase fishing effort.

SHRIMP MANAGEMENT IN THE GULF OF MAINE

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(Ed.'s note: This presentation was transcribed from tape for inclusion in this proceeding.)

No really serious attempt at planned environmental and biological research on Pandalus borealis, in terms of resource management, was undertaken in the Gulf of Maine until 1966, when Spencer Appolonio was employed by the Maine Department of Marine Resource under Public Law 88-309 to begin a modestly funded program. Aside from exploratory fishing and gear development, previous efforts were by-products of directed research on other species. These by-product results included information on seasonal locations of shrimp populations in relation to: sediments types, water depths, organic contents of bottom sediments, abundance cycles, migration, size and age distribution, growth, possible overfishing, the impact of directed fishing for other species, and possible oceanographic changes.

The Gulf of Maine is the southern limit of the northern shrimp in the northwest Atlantic. My interest was largely concentrated on sea temperature influences as an extension of my work with American lobster, sea scallops, and hard and soft clams with abundance fluctuations in relation to sea surface temperatures as measured at Boothbay Harbor.

From my current work, it appears that all the species I looked at are influenced strongly either in abundance or availability by sea temperatures.

In their final report, April 1969, Appolonio and Dunton concluded that fluctuations in shrimp abundance resulted primarily from abiotic physical factors in the environment which suggested "the temperature measurements can be used to predict the vital parameters of shrimp in the Gulf of Maine." Other findings included:

1. The relative abundance of shrimp offshore in summer varied inversely with bottom temperatures.

2. The age of female maturity is inversely related to temperature.

3. The time of egg production in third year shrimp is related to temperature. The lower the temperature, the earlier the egg production.

4. Larger numbers of non-viable eggs appear when temperatures exceed 6°C. Migration to avoid warm water by ovigerous shrimp appears to be a characteristic of the species.

Following the hiatus of fishing years 1953-54 and 1956-57, there was a slight improvement in landings but both fishermen and processors were discouraged by the past behavior of the resource.

The fishery, as far as any continuous effort is concerned began in 1937-38. There was a rapid increase until the mid-1940s and then there was a decrease. There was a four year period in which no shrimp were landed at all. This was a period where the mean annual temperature was 10°C or higher. This is the highest on record. The fact is that during this first peaking in the mid-40s, the maximum number of vessels fishing was 31. These are small, otter trawlers working out of nearby ports, converted lobster boats which are even smaller--most at around 30 to 40 feet long.

Following the hiatus, there was a gradual increase that reached a peak of approximately 24 million pounds in 1969. During these peak years, there were nearly 300 vessels fishing. One of the things we have to keep in mind is that catch per unit effort is not too precise an indicator of what is going on. I throw in these vessel numbers to show the interest the industry has in fishing for shrimp.

1962 and 1963 I served as a consultant to several coastal county resource studies on evaluating the apparent relationship between sea temperature and catch. I wrote in my final report, if the current reversal of the 1939-53 sea temperature upward trend continues, temperatures favorable to shrimp should last until the late 1960s. The peak year was 1969.

The industry has been plagued in the past by the lack of a diversified market. Since almost any product could be canned profitably during World War II, shrimp in excess of the limited local fresh market were generally canned.

With increased abundance of landing through the 1960s, two trends began. One was an established export market, the other a year-round demand. Since the summer-fall fishery depended largely on mature males with approximately one-fourth the volume of mature females used in the inshore fishery, the potential yield of the resource was appreciably reduced by man's fishing practices.

Processors, on the other hand, insisted that they had to have a continuous and dependable supply of raw material if they were to operate successfully. It was during this period that varying segments of the industry urged that management regulation be established. As in other fisheries, there were various segments trying to exert influence on management decisions. The two general courses taken were to establish a mesh size limit as a gear saving device, aimed primarily at shrimp more than three years of age, and a closed season, justified by the assumption that the more shrimp that were present and the more egg hatch successes there were, the faster the fishery would improve.

The former was promulgated in November of 1974. The fishery was also closed from April 15, 1976 to January 1, 1977 when it was opened for four and a half months, with a landing quota of 3.5 million pounds. A closure remained in force until February 1, 1979 when a two month open season was declared with a mesh regulation still in effect.

REVIEW OF THE OREGON PINK SHRIMP FISHERY, MANAGEMENT STRATEGY AND RESEARCH ACTIVITIES

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Oregon Department of Fish and Wildlife
Newport, Oregon

THE OREGON FISHERY

The Pink shrimp (Pandalus jordani) is the target species of Oregon's commercial shrimp fishery. This species, also called ocean shrimp, ranges from Unalaska to San Diego, California at depths from 20 to 250 fm (37 to 457 m). Commercial concentrations occur from Vancouver Island to the area off Morro Bay on the south central California coast. The center of distribution of the Pink shrimp population is off the Oregon coast.

Pink shrimp attain a maximum age of five years in the northern range of commercial distribution and three years at the southern portion of the range. They become vulnerable to trawl gear when they attain 12 to 13 mm carapace length (measured from the base of the eyestalk to the posterior edge of the mid-dorsal line). This normally occurs in Oregon when the shrimp are 11 to 13 months old. Maximum carapace length is about 26 mm.

The commercial shrimp fishery off Oregon ranges from 2 to 25 miles (4 to 46 km) offshore and at depths ranging from 40 to 140 fathoms (73 to 256 m). Pink shrimp are found on continental shelf areas that typically have a green mud or green mud and sand substrate.

There are four areas along the the Oregon coast where shrimp stocks occur, separated by physical boundaries and/or differences in age composition (Figure 1).

The Oregon fishery began in 1957, but was hampered by a regulation allowing only beam trawls and by a relatively high poundage tax. Industry claimed the beam trawl was inefficient and unsafe. In the fall of 1957, experimental work was conducted by the Oregon Fish Commission (now Oregon Department of Fish & Wildlife) comparing catches of a beam trawl and a Gulf of Mexico style semi-balloon shrimp trawl. Of concern was the extent of incidental groundfish catches. The results showed that the semi-balloon trawl caught more shrimp and more incidental groundfish than the beam trawl, but the quantity of fish caught would not be harmful to the stocks. The regulation requiring beam trawls was rescinded in late 1957, and the poundage tax was reduced to help the new shrimp fishery develop. In 1958, interest and participation in the fishery increased spurred by the regulation

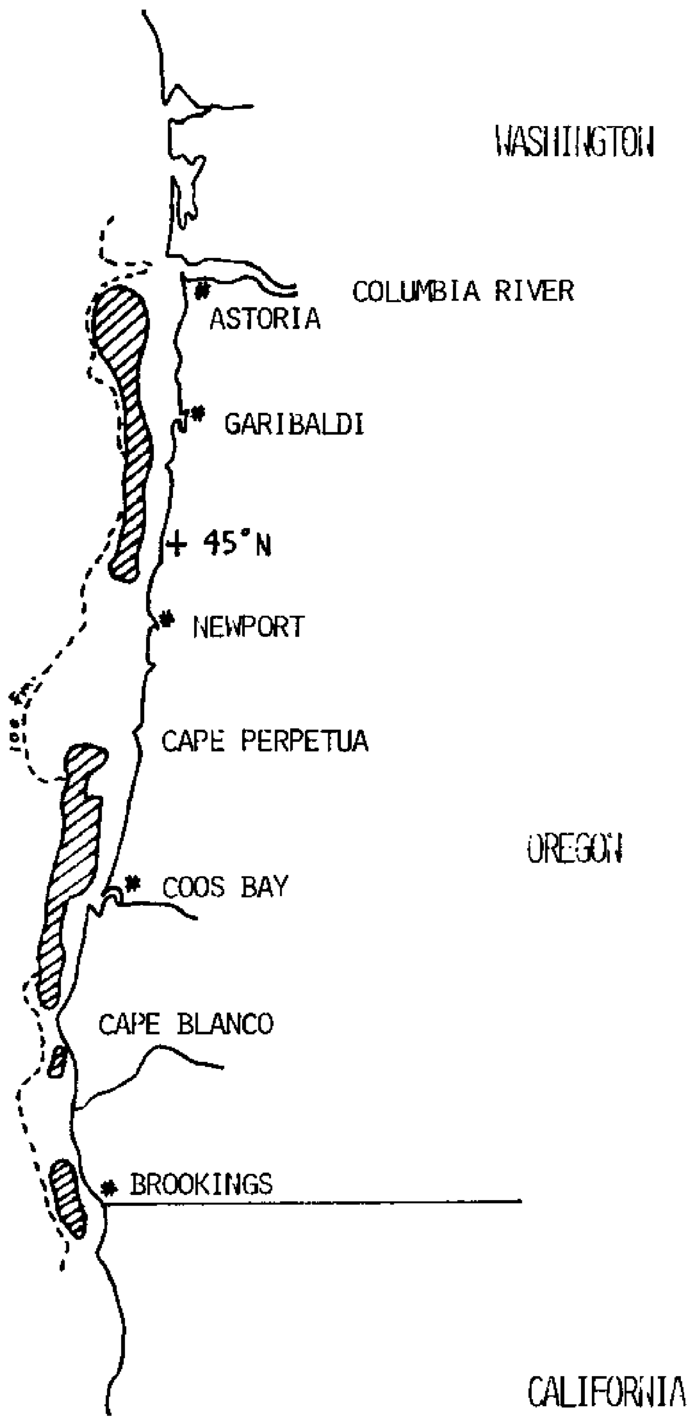

Figure 1. Principal shrimp producing areas along the Oregon coast.

contributed to the increased landings. An unusually large class of shrimp was available all along the coast, coupled with a strong market demand. Most vessels were able to make unlimited deliveries. In that year, a high proportion of the shrimp fleet had begun using large high opening box trawls. Vertical openings on these nets ranged from 12 to 18 ft (3.6 to 5.5 m) and headropes and footropes of equal lengths ranged from 80 to 100 ft (146 to 183 m). These larger nets increased fishing efficiency, especially during periods when reduced light transmission to the bottom caused shrimp to move up off the substrate. Increased use of sophisticated electronic gear enabled the shrimpers to expand some of their fishing grounds, allowing tows closer to reef areas.

The successful 1977 fishery caused a fleet expansion in 1978. Many fishermen, through low cost federal loans, were able to buy additional new boats. Most of these were the Gulf style double riggers of fiberglass or steel construction in the 80 ft (24 m) length range. With the increased fishing power and effort, Oregon landings increased again in 1978 to a record 57.0 million lbs (25,862 mt).

DEVELOPMENT OF MANAGEMENT STRATEGY

The status of Oregon shrimp stocks is monitored through annual surveys, commercial fishing catch and effort and market samples. Thus far, the fishery apparently has not seriously impacted stocks. Consequently, the regulations under which the shrimp fishery operates are quite liberal.

When the fishery began in 1957, there was no season closure. However, by 1964 concerns were expressed by industry over the lack of protection of gravid female shrimp, especially in light of the then rapidly increasing shrimp landings. After reviewing the situation, the Oregon Fish Commission passed a regulation establishing a shrimp season from March 1 to October 31. The winter closure period coincided approximately with the egg bearing period of female shrimp. The closure was enacted at the request of industry, and the commission's technical staff neither opposed nor supported the issue. However, the fishery in October and March was still harvesting gravid females. By the first of October, ovigerous females began occurring in the catch and by the end of the month, 20 to 40 percent were gravid. When the season opened in March about 75 to 80 percent were still gravid, but by the end of the month nearly all the eggs had hatched. After the establishment of a season in 1964, fishing and landings continued to increase and by 1972 had reached a new high of 20.6 million lbs (9,347 mt). Because of this upward trend in landings and a concern for the changes. However, during the first ten years (1957 to 1966) annual landings remained at a relatively low level, averaging 2.5 million lbs (1,134 mt)/year (Figure 2). The vessels that participated in the fishery were of the western seiner type. Combination boats ranging from 50 to 70 ft (15 to 21 m) in length also participated in the groundfish and/or Dungeness crab fisheries. The standard net was the Gulf of Mexico style semi-balloon trawl with a 57 ft (17 m) headrope and 4 ft (1.2 m) vertical opening.

In the mid-1960s, processing capacity increased and the number of ports where shrimp could be landed increased from three to seven. All known shrimp grounds became easily accessible. Also, foreign fleets began fishing off the coast and substantially reduced the Pacific ocean perch population. The paucity of perch resulted in a shift of effort from the groundfish fishery to the shrimp fishery. As a result, during the five year period between 1967 and 1971, Oregon shrimp landings increased, averaging 11 million lbs (4,990 mt)/year. Good market conditions prevailed during most of the period, allowing continued expansion of the industry with the introduction of new boats and processors. The late 1960s marked the introduction of the pre-stream blanch peeling machines. This came at an opportune time because stricter Food and Drug Administration sanitation standards and higher labor costs were becoming problems for processors who still employed hand peelers. The new machines produced shrimp meat of improved appearance that allowed it to be competitive in the fresh frozen market.

In 1969, the first double rigged shrimp vessel participated in the fishery. The increased efficiency of the double rigged shrimper was quickly recognized by the industry. Since then there has been a continued increase in numbers of double riggers participating in the fishery. The fishermen either converted their vessels or purchased used double rig vessels from the Gulf of Mexico.

From 1972 to 1976 Oregon landings reached a new, higher plateau that averaged 22.9 million lbs/year (10,390 mt). The increased landings during this period were brought about by a combination of factors similar to that which occurred in the mid 1960s. Fishing effort increased as a result of a declining Dungeness crab fishery, causing an influx of vessels. Good market conditions and strong year-classes also played important roles in the increased landings.

In 1977, Oregon shrimp landings, at 48 million lbs (22,042 mt) were double the previous five year average (1972 to 1976) of 23 million lbs (10,435 mt). Several factors

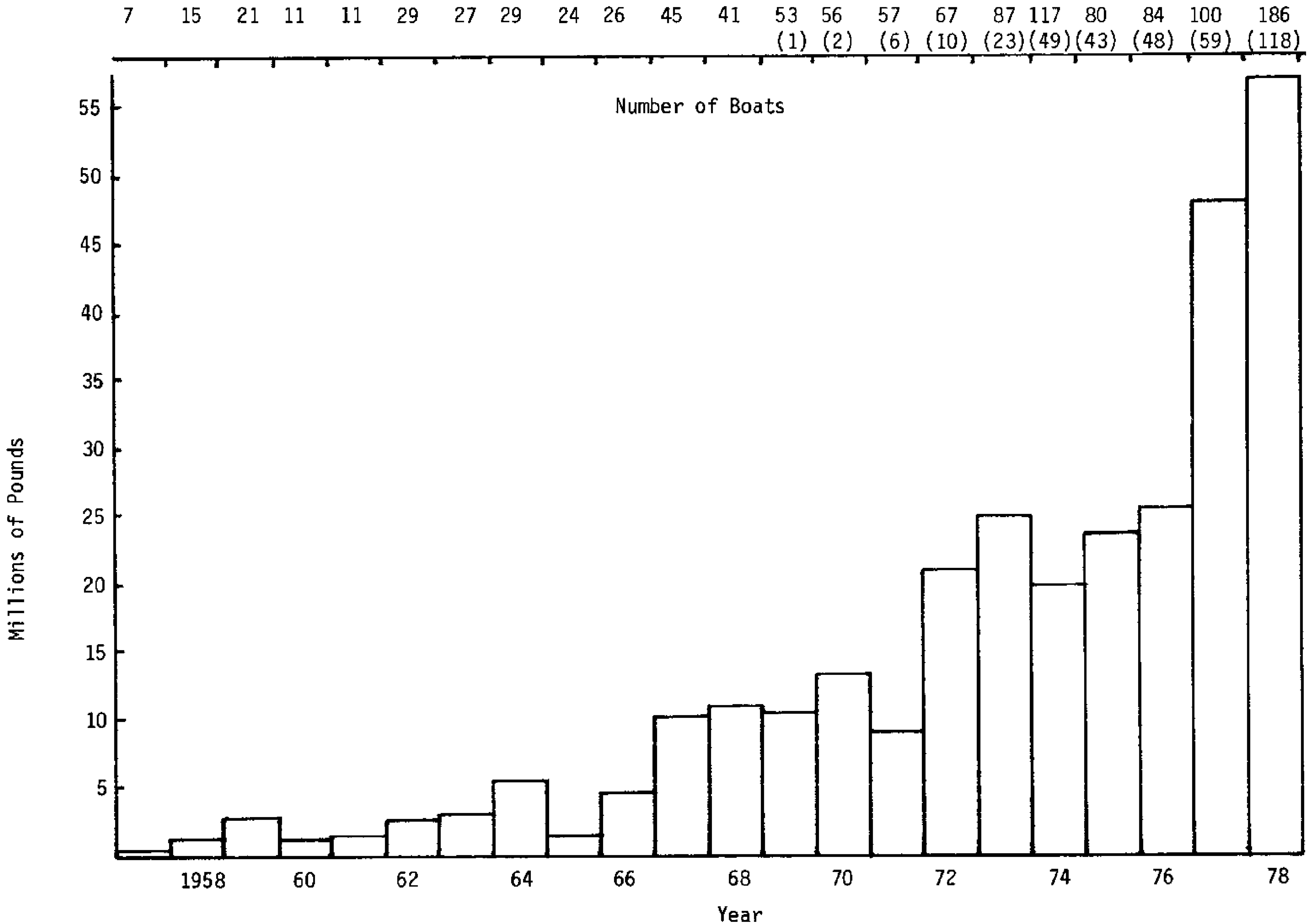

Figure 2. Annual Oregon shrimp landings and number of shrimp boats, number of double rigged boats in parenthesis and included in total.

resource, the staff asked the commission to consider extending the winter closure period as a way to protect gravid females. Industry supported the proposal. The commission responded in 1972 by establishing a season closure from October 16 to March 31. Since then, there have been no adjustments in season length.

A minimum mesh size regulation restricting nets with stretch mesh measuring less than 1 1/4 in. (32 mm) was eliminated in 1969. This action was the result of an effort encouraging use of the separator trawl, developed by the Bureau of Commercial Fisheries (now National Marine Fisheries Service). This net, designed to separate fish from shrimp and thereby eliminate sorting, used a 1 in. (25 mm) mesh in the body and codend. The staff felt there was no biological justification for retaining a minimum mesh size regulation. Even though widespread use of the separator trawl never occurred, no attempt has been made to re-establish a minimum mesh size regulation. Shrimp fishermen typically use nets that average 1 1/2 in. (38 mm) stretch measure between the knots. Processors discourage landings of small shrimp because they are an undesirable market product.

RESEARCH ACTIVITIES

Investigation of the Pink shrimp resource off Oregon was directed at first towards stock distribution and abundance studies. After the extent of the stocks were known through information gathered from survey cruises and the commercial fishery, shrimp research focused on life history and behavior studies during the late 1960s. Since the early 1970s, Oregon has conducted annual surveys of the major shrimp areas to obtain an index of shrimp biomass.

The first research efforts off Oregon were a series of exploratory surveys, conducted in 1951 and 1952, designed to determine the extent and abundance of Pink shrimp off Oregon. These surveys revealed several areas of potential commercial concentrations of shrimp between the Columbia River and the Rogue River off southern Oregon. In 1957 and 1958, exploratory cruises were resumed, conducted by the Oregon Fish Commission and the Bureau of Commercial Fisheries. These surveys were more intensive than the earlier surveys and covered the northern Oregon area only. In 1960, further exploratory work was conducted along the south central Oregon coast. These surveys aided the developing fishing as new areas with commercial quantities of shrimp were found.

In 1966 and 1967, another series of shrimp cruises began. One of the objectives was to survey the entire coast of Oregon and close any gaps of knowlege in known shrimp distribution, especially between the Coquille River and the California-Oregon borders. The cruises were also designed to obtain an estimate of biomass. These surveys were conducted in the spring and fall.

Comparisons of biomass estimates between areas and time periods suggested north-south and east-west drifts in abundance. No conclusions were reached for the causes in shifts of distribution. The biomass of the Oregon shrimp resource in 1967 was estimated at 111 million lbs (50,362 mt).

Following completion of coastwide shrimp surveys in 1967, emphasis shifted to studies on life history and behavior. A project was initiated to study the vertical distribution of shrimp off Tillamook Head using a baited trap, a mid-water trawl and a semi-balloon trawl. It was determined that shrimp moved off the bottom at night and dispersed throughout the water column. The extent of their vertical distribution varied, apparently influenced by time of year, water temperature and sex and/or age composition.

In 1969, a one year study was conducted off Tillamook Head to determine the benthic movements of shrimp, the distribution of age 0 shrimp and to investigate the effects of light intensity on the vertical distribution of shrimp during the daytime. Conclusions from the study indicated that shrimp were not dispersed in a random pattern within the study area during the year. They were at times grouped by sex or age in certain areas. Further, they moved out of the study area in an apparent offshore migration in the fall and returned to the study area from the south in the spring. It was concluded that the juvenile pink shrimp (age 0) do not occupy a nursery area and mingle with the adult population soon after they end their larval phase and settle to the bottom. Finally, it was determined that shrimp do respond to a decreased amount of light caused by murky water and/or heavy cloud cover and move at least as high as 12 ft (22 m) off the bottom during the day.

A shrimp tag feasibility study was conducted in 1971 involving observations of shrimp held in containers aboard a fishing vessel and under varying conditions in laboratory aquaria. It proved difficult to obtain and maintain live shrimp captured in a trawl net since they suffered stress-related mortalities caused by the handling. Salinity and temperature changes also were stress factors that affected survival. Because of these results, plans for a tag and recovery program were abandoned. It was also evident that enormous numbers would have to be marked.

Annual surveys of the shrimp grounds from the Columbia River to Coos Bay have been conducted since 1971 to obtain biomass estimates of the resource and to provide an index of stock status.

We chartered commercial shrimp vessels and supplied the trawl nets for the surveys. The nets were of semi-balloon design with 41 ft (75 m) headropes and 52 ft (95 m) footropes and were constructed with 1 1/8 in. (23 mm) mesh in the body and intermediate, 1 1/2 in. (38 mm) mesh in the cod end with a 1/2 in. (13 mm) liner. Survey area boundaries were established as the limit of known shrimp as determined from commercial and research fishing activity. Stations within the survey areas were at the intersections of four mile grid lines. Initially, surveys were conducted in the fall but were switched to a spring period to obtain preseason biomass estimates.

Six surveys were conducted in northern Oregon: four in the fall and two in the spring (Figure 3). During the first four years, total biomass estimates in the fall held steady averaging 14 million lbs (6,352 mt). With only two estimates made in the spring of 1976 and 1977, it is difficult to assess stock status. Unfortunately, no survey was conducted in 1978. It is not known if the 1977 fishery impacted stocks, resulting in decreased landings in 1978. Market samples indicated a possibility of two consecutive weak year-classes in that area, which would certainly impact landings since the fishery depends on three year classes.

Coos Bay fall surveys also indicated a relatively stable biomass averaging 12 million lbs (5,444 mt) per year (Figure 4). In 1974, we had the opportunity to compare pre- and post-season estimates. Considering the removal of biomass by the fishery and the variability the two estimates appeared reasonable.

In 1977, the biomass estimate was extremely low, but the pattern of the fishery that year indicated shrimp were distributed beyond the northern and southern survey boundaries. In 1978, we extended the survey boundaries based on the area covered by the fishery the year before. The biomass estimate we obtained was higher but so was the variability. Again, the commercial landings from the area exceeded the midpoint estimates. It is possible that shrimp were again beyond the study area during the survey and immigrated during the season. Survey techniques and procedures need re-evaluation before they can be used as a tool to manage the fishery.

Midpoint Biomass Estimate (lbs)

Year	Spring	CL at 95% C.I.	Fall	CL at 95% C.I.	Commercial landings
1971	-		12,877,000	±46%	6,054,000
1972	-		13,027,000	±46%	9,311,000
1973	-		15,272,000	±30%	8,947,000
1974	-		13,981,000	±39%	6,071,000
1975	No Survey				8,500,000
1976	21,808,000	±48%	-		12,353,000
1977	17,148,000	±45%	-		13,638,000
1978	No Survey				3,611,000

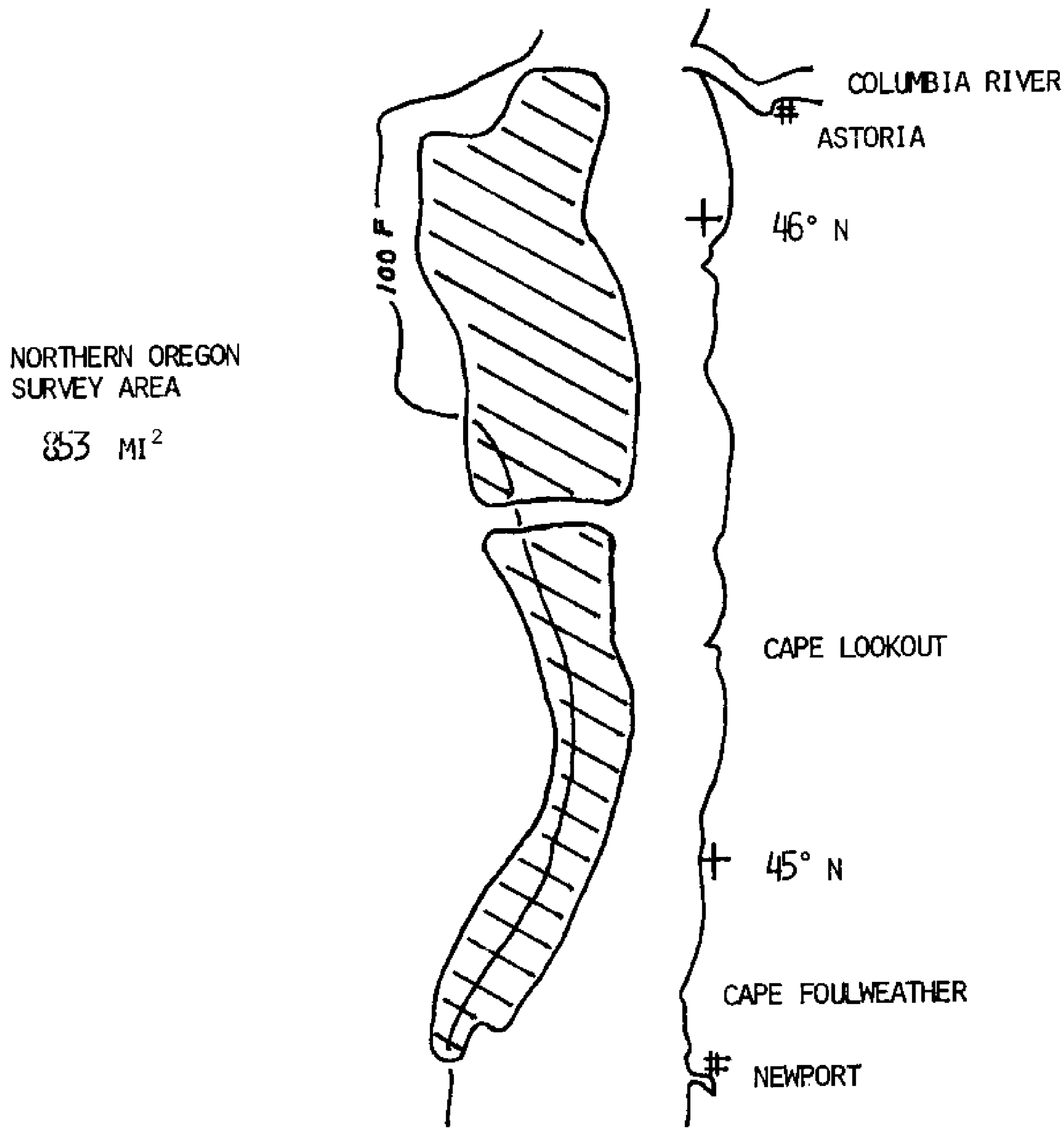

Figure 3. Northern Oregon survey boundary, midpoint biomass estimate and commercial landing totals, 1971 to 1978.

Midpoint Biomass Estimate (lb)

Year	Spring	CL at 95% C.I.	Fall	CL at 95% C.I.	Commercial landings
1971			9,029,000	±45%	≈1,460,000
1972			13,184,000	±50%	≈6,660,000
1973			13,426,000	±28%	≈9,680,000
1974	18,467,000	±58%	11,813,000	±43%	≈4,592,000
1975	16,789,000	±54%			9,502,000
1976	14,157,000	±35%			6,752,000
1977	2,273,000	±42%			17,209,000
1978	18,124,000	±80%			21,026,000

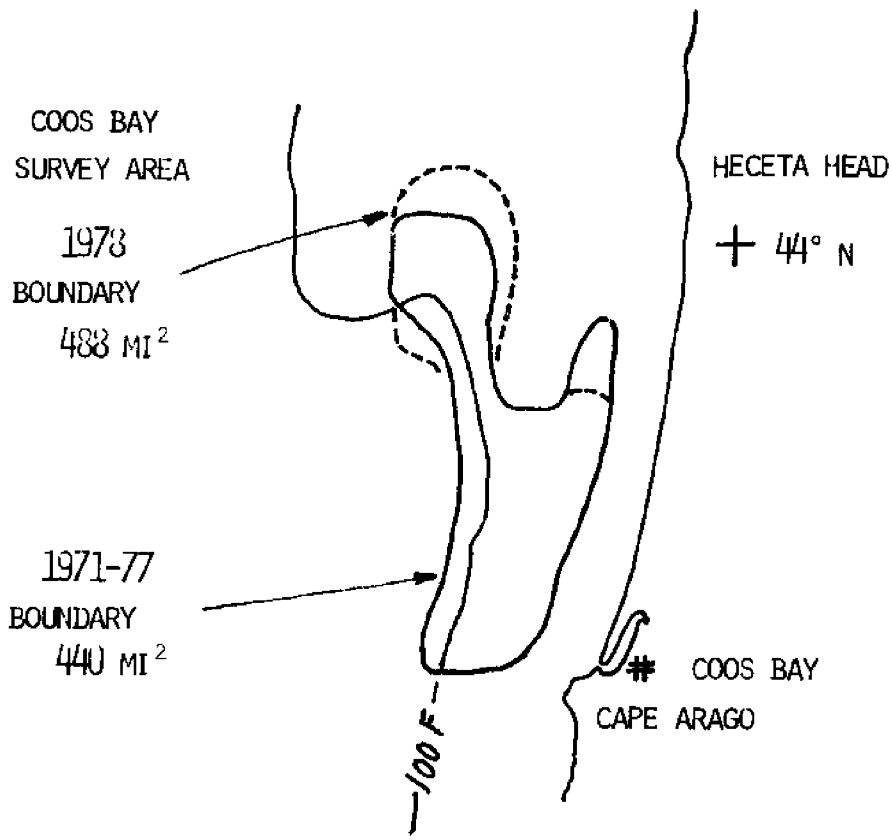

Figure 4. Coos Bay boundaries for survey, midpoint biomass estimate and commercial landing totals, 1971 to 1978.

HISTORY OF PINK SHRIMP MANAGEMENT AND RESEARCH IN WASHINGTON STATE

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ABSTRACT

Washington's fishery for Pandalus jordani began in 1957. Following 1958 landings of nearly 3,000 mt the fish declined to low levels until a resurgence in 1973. Since 1974, landings have averaged over 4,500 mt tons. Low catches from 1959 to 1972 were primarily due to lack of fishing effort. A highly mobile fleet of predominantly double rig vessels, combined with good market conditions has greatly expanded the fishery. Initially implemented regulations have been modified to the point where Washington now has: (1) a year-round fishing season; (2) a 1 1/2 in. minimum mesh size; (3) a 2 in. maximum mesh size; (4) 10 fm maximum between otter doors and net wings; (5) no limit on landings of incidentally caught bottomfish; (6) prohibition of double layer cod ends and (7) a mandatory logbook.

Research in Washington has been limited to sampling commercially landed shrimp for factors such as growth, count per pound and relative year-class strength.

Washington is working in concert with Oregon and California to develop a coastwide pink shrimp management plan since adoption of the Fisheries Conservation and Management Act of 1976.

INTRODUCTION

The Pink shrimp fishery in waters off the coast of Washington state began in 1957. During the previous two years, a cooperative survey conducted by the Washington Department of Fisheries and the branch of Commercial Fisheries, U.S. Fish and Wildlife Service, demonstrated that Pandalus jordani were available in commercial quantities at various locations and depths off Washington. A small scale fishery was attempted in late 1956, but was not successful until a shrimp peeling machine was installed at the cannery in Westport.

The fishery got off to a shaky start in 1957, because the initial participant fished a converted salmon troller towing a small Gulf of Mexico style shrimp trawl and catches were limited. As other fishermen geared up with larger trawler vessels and larger nets, the shrimp fishery began in earnest. Landings in this first year were slightly over 1,000 mt but were depressed by economic factors. The entire fishery was conducted in one very small area off Grays Harbor.

Initial management measures were enacted by the Washington Department of Fisheries in anticipation of this developing fishery. These were: (1) implementation of a closed season from November 1 to March 15 in order to protect egg bearing females, (2) 1 1/2 in. (38 mm) minimum mesh size to allow escapement of one-year-old shrimp, (3) 2 in. (51 mm) maximum mesh size to prevent targeting on small bottomfish (4) a requirement that otter doors be attached directly to the wings of the net to prevent use of long dandy lines that herd bottomfish into the net and (5) prohibition of landings of incidentally caught bottomfish. These regulations were drawn up on a tentative basis without benefit of experience or knowledge of exactly what characteristics this fishery would assume. As a result, early regulations were subject to frequent change.

The seasonal closure was dropped almost immediately in order to encourage development of the fishery. In fact, the early part of 1958 saw considerable fishing effort. In that year there was major expansion throughout the industry and development of new fishing grounds off Destruction Island, Washington and Tillamook, Oregon. Landings in 1958 totaled nearly 3,000 mt. Late in 1958 and again in 1960 there was consideration given to reinstatement of a closed season from November 1 to March 15. Opposition from some segments of the industry and the inability to coordinate a closure with the state of Oregon resulted in no action being taken. Because the shrimp grounds (depths of 90 to 180 m) are more than three miles off the coast, the state government did not have authority to prevent boats from other states fishing off the Washington coast. Thus it was rationalized that Washington based boats should not be prevented from fishing when vessels from out of state could do so.

In early 1959, gear design restrictions were eased to allow shrimpers to separate the otter doors from the wings of the net by a distance of one-half the total vessel length. This action was to make the nets more effective and make handling of the nets easier.

In 1957, all restrictions on landings of incidental bottomfish catches were removed, but less than one year later, a 500 lb (227 kg) per trip limit was imposed. Only six months later the limit was raised to 3,000 lbs (1,361 kg) and in 1975 the limit was again dropped. Arguments on this issue persist presently. Probably more regulatory effort has been related to limiting incidental catches of bottomfish than to shrimp.

The initial development of Washington's shrimp fishery came at an unfortunate time. Following the very successful fishery of 1958, much of our state's industry, both vessels and processing equipment, responded to the lure of an even more promising fishery developing in Alaska. In addition, the bottomfish market was particularly good at that time. In 1959, despite continued good shrimp fishing, landings and effort dropped to less than one-half that of the previous year. Further, for the next 13 years, through 1972, the shrimp industry was at a very low level, averaging only 452 mt (slightly under 1 million lbs) per year. In nine of those 13 years, the catch per unit of effort was good and only lack of effort kept landings at low levels. In addition, there was no exploration of new grounds during this period; fishermen tended to fish a few well known areas. Only in 1965 was there a total failure of the fishery, reflecting recruitment failures of both the 1962 and 1963 year-classes. There were few management changes during this period.

In 1971, Washington moved to prohibit landings of shrimp caught off the Oregon coast during that state's closed season. Also in 1971, some gear restrictions were rescinded to facilitiate introduction of a sorter trawl designed by National Marine Fisheries Service. The minimum mesh size restriction was lifted and fishermen were allowed 10 fm (18 m) between the otter doors and the net as opposed to one-half the boat length. (The sorter trawl was not accepted by the industry because while it did deliver cleaner catches, it did not catch shrimp in volumes desired by fishermen and it was difficult to repair). The 1 1/2 in. minimum mesh size was finally reinstated in 1977. In 1972, Washington established a mandatory logbook system in order to more uniformly collect catch and effort data. This information was previously collected by interviews. This logbook is similar in format to those used in other west coast states.

Double rigged shrimp trawlers entered our fishery in force in 1973. Also, for the first time, a substantial part of the fleet was composed of fishermen whose primary fishery was shrimping, rather than bottomfish trawling. Activity has continued to increase up to the present time with a steady building of fishing and processing capacity. Several shrimp fishermen, chiefly those who had moved into the fleet from the Gulf of Mexico, explored considerable new ground in 1974 and discovered approximately 100 mi^2 (259 km^2) of previously unused fishable area off the Washington coast. More sophisticated depth sounding gear and expanding fleets made this move both possible and necessary.

The only changes in Washington's management scheme during the past five years have been the aforementioned reinstatement of a minimum mesh size and the prohibition of double layer cod ends. These measures were adopted through concern over wastage in canneries of one-year-old shrimp retained by small mesh nets and/or cod end liners. These regulations did not impact the existing fishery appreciably. They were adopted to forestall possible undesirable developments, such as targeting on young shrimp for pet food or aquarium food markets.

Other management techniques have been considered but not been adopted by our state. This is due in part to skepticism over effectiveness of existing techniques, combined with the assumption that the entire matter would eventually be worked out with our neighboring states as a function of implementation of the Fisheries Conservation and Management Act. Washington has never implemented the closed season, first advocated in 1958, which would close fishing during the egg-bearing period. Landings in Washington during the months of November through March have averaged about 7 percent of total landings overall (6.5 percent during the last six years). Winter weather precludes any substantial activity, especially by the double rig vessels, and most processors have been less interested in shrimp during the winter period when they are occupied with either crab or oysters.

Implementation of a quota system has never been seriously considered in Washington. It was felt that stock assessment techniques were not reliable enough and too costly, and in most years shrimp were underfished. Developments of recent years have caused concern but again we have chosen to pursue this matter through the FCMA.

Research in Washington has a limited scope. Sampling of commercially landed shrimp provides information on factors such as growth, count per pound and relative year-class strength. More extensive research has been precluded by low budgets, which are the result of low key management methods and the fact that through most of the fishery's history it has been relatively minor and underexploited.

HISTORY OF RESEARCH AND MANAGEMENT OF ALASKAN SHRIMP

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Alaska's domestic shrimp fisheries occur in coastal waters of the Gulf of Alaska, generally well within three miles of the coastline. Domestic shrimp fleets are currently exploiting all major shrimp stocks with the exception of those in the Bering Sea. A formerly large population of shrimp in the Pribilof Island region of the Bering Sea has been exploited only by foreign fleets. Distinct fisheries occur in the Alaska Peninsula, Kodiak Island, Cook Inlet, Prince William Sound, and southeastern Alaska areas.

Eight pandalid shrimp species representing two genera occur in commercial catches, but only five are of commercial significance. Numerous species from the families Crangonidae and Hippolytidae are taken incidentally but none are considered of commercial value. Pink shrimp, *Pandalus borealis* Krøyer, are estimated to be at least 85 percent of all trawl caught shrimp from the Gulf of Alaska, Aleutian Islands and eastern Bering Sea. Other pandalid species, *Pandalus hypsinotus* Brandt (coonstripe), *P. goniurus* Stimpson (humpy), and *Pandalopsis dispar* Rathbun (sidestripe) are most often taken incidental to the fishery for *P. borealis*. The latter two species are at times dominant in trawl catches from specific areas and occasionally support small fisheries. Other pandalids, *Pandalus danae* Stimpson (dock), *P. montagui tridens* Rathbun, *P. jordani* Rathbun (ocean pink), and *P. platyceros* Brandt (spot), occur in catches to a minor extent. The former two species are least common of the pandalids taken commercially and *P. danae* is rarely taken in Kodiak and more westerly regions. *Pandalus platyceros* and/or *P. hypsinotus* have at times supported small pot fisheries in the central and eastern Gulf regions.

The shrimp fishery in Alaska began in southeastern Alaska near Petersburg in 1915. The fishery principally harvested pink shrimp which were cooked, hand peeled, and frozen for special markets. The fishery gradually expanded and annual harvests of 1.2 to 3.0 million lbs (544 to 1361 mt) occurred from 1945 to the mid-1950s. In 1957, the mechanical peeling machine was introduced in Wrangell, Alaska. And in 1958, a fishery developed using the mechanical peeling process in Lower Cook Inlet and Kodiak where large stocks of shrimp had been located. The fishery grew rapidly from 7.9 million lbs (3500 mt) in 1958 to 15.1 million lbs (6900 mt) in 1963.

Growth slowed when shore plants and the fishing fleet were badly damaged by the 1964 earthquake but then grew rapidly to 128.8 million lbs (58,400 mt) in 1976. Many historical production areas in western Alaska began showing signs of stress and by 1978, catches declined to 73.2 million lbs (33,200 mt). If stock declines continue, the 1979 Alaska catch will be approximately 30 million lbs (13,600 mt).

Three types of vessels participate in the Alaska shrimp fishery: vessels that fish two otter trawls simultaneously, vessels that fish a single otter trawl, and vessels that fish with beam trawls. Most modern double rigged otter trawl vessels are constructed of steel and manufactured in states bordering the Gulf of Mexico. These vessels range from 80 to 100 ft (24.2 to 30.3 m) in keel length and are capable of carrying 200,000 to 300,000 lbs (90 to 136 mt) of shrimp in their hold. The average sized vessel in the fleet is 86 ft (26.1 m) in length and powered by a 565 horsepower diesel engine. Most of these vessels have duplicate electronic systems which include radar, loran, radios and various types of recording fathometers. Many vessels are also equipped with side scanning sonar.

Single rigged vessels have steel or wooden hulls and vary from 50 to 70 ft (15.2 to 21.2 m) in length, with a few up to 110 ft (33.3 m) in length. The average single rigged vessel can carry 75,000 to 150,000 lbs (34 to 68 mt) of shrimp in the hold. The modern electronic equipment is similar to that of the double rigged vessels. The beam trawl vessels are generally small, 25 to 40 ft (8 to 12 m) of the salmon seiner type. Many of the new beam trawlers are constructed of fiberglass. These vessels generally make frequent deliveries of less than 20,000 lbs (9 mt) per trip. Modern electronic equipment is also present on the beam trawlers.

Simultaneous with the evolution from small, single rigged to large, double rigged otter trawl vessels, has been an evolution of gear. Prior to 1970, the fleet almost exclusively used west coast manufactured shrimp trawls ranging from 60 to 100 ft (18.2 to 30.3 m) footrope length. Double rigged vessels in 1971 and 1972 used Gulf of Mexico manufactured trawls which were quickly adopted by the single rigged vessels, since they were more efficient. Many fishermen now use custom designed trawls. Single rigged vessels use trawls with groundlines from 70 to 125 ft (21.2 to 37.9 m) in length, while double rigged vessels use 60 to 100 ft (18.2 to 30.2 m) trawls. Accompanying this evolution in gear type have been changes in accessory gear, especially by single rigged vessels. These changes include conversion from wooden otter boards to steel doors and the use of wing tip extensions. Also, each fisherman has his own method of "tuning" his trawl for peak efficiency. Most double rigged and large single rigged vessels have modified their vessels with a stern ramp to facilitate handling of gear.

National Marine Fisheries Service (NMFS), the Alaska Department of Fish and Game (ADF&G), the Soviets and Japanese have all conducted shrimp research off Alaska. NMFS (formerly the Bureau of Commercial Fisheries) commenced exploratory fishing operations off Alaska in about 1940. These cruises provided valuable exploratory information to the shrimp fishing industry, but they lacked the systematic coverage needed to adequately estimate shrimp abundance for management purposes. In 1971, NMFS and ADF&G began an intensive survey program in Cook Inlet and Kodiak Island. These surveys were subsequently expanded to the Alaska Peninsula, Unalaska Island and the Bering Sea. An average of 166 vessel days per year provide the data base to closely monitor the performance of individual stocks. Severe declines in major shrimp stocks have been noted since 1974. For example, along the Alaska Peninsula, which has 1,065 nautical mi^2 of shrimp ground, the population estimates from 1972 through 1974 averaged 300 million lbs. In 1975, the stock estimates declined to 104 million lbs. By 1978, these stocks are estimated to be only 23 million lbs.

ADF&G has conducted a voluntary shrimp trawl logbook program since 1967. This program has provided high quality catch per unit of effort (CPUE) information for approximately 50 to 70 percent of the commercial harvest. Concern that increased fleet efficiency was masking a serious decline in shrimp stocks stimulated an effort to standardized CPUE. Two mathematical models were developed to deal with in-season and between-season variation. These models were incorporated in a highly flexible comprehensive data base management system called SYSTEM LBOOK. Standardized CPUE data from the fleet substantiates the large scale changes in the shrimp stocks which have been observed in the stock assessment program.

The management plan for the domestic shrimp fishery is described in Alaska commercial fishing shellfish regulations. It is a complex set of regulations describing geographical management districts and fishing sections, registration, inspection and validation requirements for Alaska's landing law, commercial fisheries entry permits, exclusive fishing areas and gear restrictions, methods of harvest, subsistence, biological and economic fishing season, catch reporting requirements, and harvest ranges for each exploited fishing stock.

This management regime has evolved through broad public participation in shrimp study groups, local Fish and Game advisory committees and the Alaska Board of Fisheries. Traditionally, a previously unfished or little used fishery has been encouraged with no restrictive regulations. Once a data base has been established for a definable stock, the state's regulatory plan is imposed by the Alaska Board of Fisheries. This management plan is presented for public scrutiny, modification and appeal.

The concept of a biological season has been extensively used since 1972. Biological seasons have been applied primarily to stocks which appear to be fully exploited. This season defines that period of the year during which harvesting can be the most damaging. With pandalid shrimp stocks, the two months during which the majority of egg hatching (larval release) occurs has been identified as the most sensitive. Females at this time are generally more concentrated and segregated from other stock segments and, therefore, more vulnerable to harvesting. Biological seasons have generally not inhibited the development of shrimp fisheries as stocks have usually been exploited prior to the egg hatching period. In most instances, both harvest limitations (quotas) and biological seasons have been applied during the second year of substantial exploitation of the stock. Harvest levels have been assigned assuming that each geographical area contains separate manageable units of adult shrimp. These harvest levels, which are actually ranges, are based on historical fisheries performance, catch effort from the fleet and stock assessment survey results. During the 1978-79 fishing season, a further classification of a "depressed fishery" was described. The Alaska Board of Fisheries designated a depressed shrimp fishery as a historically productive stock which has demonstrated a significant reduction of harvestable shrimp. With this designation, a fishery would be limited to that time of year in which mating and reproduction were not occurring. It would also be subject to reduced harvest levels. Short of a total closure, this strategy would afford the depressed stock an opportunity to recover.

THE HISTORY OF RESEARCH AND MANAGEMENT OF THE ICELANDIC SHRIMP FISHERIES

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ABSTRACT

A short history is given of the Pandalus fisheries in Icelandic waters as well as the main changes in gear. Collection of samples and catch reports was initiated in 1959. The methods of management used since then are related, both concerning models used for quota decisions, practical rules (limitations) suggested by the fishermen themselves and other rules introduced by the Ministry of Fisheries in collaboration with the Marine Research Institute.

HISTORY OF THE FISHERIES

Commercial fishing for *Pandalus borealis* started in 1936. At the beginning, fishing was only carried out in two areas, Arnarfjördur and Ísafjardardjúp, each now considered to have a separate population. Gradually new grounds were discovered and by now seven fiord or bay populations are known (Skúladóttir, Jonsson, and Hallgrímson 1978). Seven offshore fishing areas fishing areas have also been discovered, each possibly having a distinct population.

Before 1967 small trawls without bobbins (60 ft headline) were used, but in 1967, larger trawls (75 to 90 ft headline) were taken into use (Skúladóttir 1970). The fishing efficiency of these larger trawls was twice that of the smaller trawls, so fishing became profitable in areas which were not usually fished before. Thus, the fishing grounds expanded a great deal (Skúladóttir 1968). Since 1970, a footrope with bobbins has generally been used causing further expansion of the fishing grounds (Table 1). Mesh size has increased. Originally 25 mm, it increased to 32 mm, 36 mm and 38 mm in 1962, 1974 and 1978 respectively.

Research started in 1959 (Sigurdsson and Hallgrímsson 1965) and from 1960 onwards Arnarfjördur and Ísafjardardjúp have been sampled regularly. The fishery was subject to licensing from the start, but catch reports to be filled out (at first daily and later by every haul) were introduced in 1960. Since then continuous information on catch per trawling hour exists.

Table 1. Shrimp catch (mt) in Icelandic waters 1964-78

Location	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Breioafjördur						59	204	143	338	662	913	344	200	100	
Arnarfjördur	157	204	282	187	499	602	692	588	507	632	579	408	406	550	302
Ísafjardardjúp	447	683	1259	893	1579	1758	2460	2915	2110	2501	2442	1699	2677	2563	1644
Húnaflói	44	32	262	342	391	841	714	796	978	2437	2029	1400	2016	2120	1959
Oxarfjördur												535	711	899	1064
Berufjördur								76	46	57	54	63	70	47	68
Tálknafjördur														48	
Eldey							315	1725	1368	877	237				215
Offshore west															363
Offshore north							4				74	571	315	939	1365
Other areas						21	42	5					54		10
Total	648	919	1803	1422	2469	3281	4431	6248	5347	7166	6328	5020	6449	7266	6990

METHODS AND MODELS USED FOR DECIDING QUOTAS

In 1968 the "maximum sustainable yield" (MSY) was calculated by the method of Gulland (1961) to be about 200 tons per year for Arnarfjördur and about 700 tons for Ísafjardardjup (Skúladóttir 1974). Since these calculations did not hold after the introduction of the large trawl in 1967-68, there were no quotas and little effort limitations from 1968 to 1974, when quotas were introduced again in several areas, using the method of Gulland. The MSY appeared to have tripled in Arnarfjördur and Ísafjardardjup after the uptake of larger trawls. About 8 percent of the increase in MSY has been estimated to be due to the increase in mesh size.

Aging of the shrimps has been attempted since 1968 by the deviation method (see Skúladóttir in these proceedings on the deviation method) a modification of the method of Sund (1930).

In 1976, the cohort length (Jones 1974, 1976) and cohort age methods (Pope 1972) were tried on the population of Arnarfjördur. The cohort length method uses the von Bertalanffy growth equation as a model for growth. It was noted that minor differences in values of the growth constant K and the maximum length L_∞ of the von Bertalanffy growth curve gave vastly different values of MSY in subsequent yield calculations (Skúladóttir 1979). The values used at first were K = 0.1616, L_∞ = 31 mm and the terminal instantaneous rate of fishing mortality F = 0.80 for the oldest age-classes. This gave a MSY of 720 tons. The values were then changed to K = 0.1545, L_∞ = 31.5 mm and the terminal F = 0.85 mm. This gave a MSY of 575 tons for the same population with all other inputs being the same. The instantaneous natural mortality was 0.2 in both instances. The cohort length method being so very sensitive to input values, led to the reconsideration of the simpler approximating methods of the linear model of Gulland (1961) and the exponential model of Fox (1970), especially since the very high MSY value of 720 tons was about 25 percent higher than found to be most likely by the simpler models. Moreover, only once has the total catch of Arnarfjördur reached 700 tons, i.e. 692 tons in 1970 after which a noticeable drop was observed in catch per unit effort.

MANAGEMENT

Hallgrímsson (1977) described the management of the Icelandic shrimp fisheries. Before the shrimp season in autumn, the Marine Research Institute estimates the total allowable catch for the various fishing areas with the consent of the Ministry of Fisheries. Fishermen and factory owners are then informed and asked to send in applications for fishing licenses. In January when considerable data on the present season has been gathered, the estimates are reassessed and the quotas changed accordingly. The revised quotas are then valid for the remainder of the season.

The licenses issued by the Ministry of Fisheries define the fishing areas for which the licenses are valid and include also the following general stipulations:

1. If the Ministry considers further fishing unadvisable, due to the condition of the stock or other reasons, the license is void immediately on receipt of a declaration to that effect from the Ministry.

2. The maximum number of shrimp per kilogram is 340.

3. The license is given on condition that the catch be processed by a licensed shrimp factory.

4. Catch reports are to be sent to the Fisheries Association every forthnight. These are to be filled out daily for every haul.

5. While shrimp fishing under this license, no other fishing gear is to be carried onboard.

6. The licensee must allow employees of the Marine Research Institute or the Ministry of Fisheries to take part in fishing trips on demand unless this causes appreciable inconvenience.

7. The minimum mesh size is to be 36 mm when wet.

8. Contraventions of the provisions of the license or any misuse as construed by the Ministry may result in the license being suspended temporarily or revoked at the Ministry's discretion.

9. The license is to be kept onboard the licensed vessel.

The provisions of the licenses vary in some respect, according to special stipulations valid only for certain fiord areas. These special stipulations are mostly based on an agreement between the fishermen and the shrimp factory owners in the area established before the season starts, and initiated by the Ministry of Fisheries or the Marine Research Institute. These stipulations include for example, provisions on quotas, limitations on daily fishing hours and days of the week. Usually fishing is carried out five days a week. As to the quotas, the maximum allowable weekly shrimp catch is for example 5 tons per each licensed boat in Ísafjardardjúp. Only 1,500 kg of that is to be caught daily the first three days of the week. In other areas there is one factory in every village. There it is common that the manager of the factory decides a daily maximum quota for every boat. Thus, shrimp landings do not exceed the processing capacity in each locality.

In addition, a check is made regularly on the by-catch by research vessels or fishing inspectors. If the number of juvenile cod, haddock, herring and/or Norway lobster exceeds a certain amount, based on value per recruit of these species against the value of the shrimp catch, the area is closed till the by-catch has decreased again.

As a result of the increasing shrimp fishery and the discovery of new shrimp fishing grounds, a tendency to establish new shrimp processing plants arose. Therefore, the Ministry of Fisheries was of the opinion that an over investment in shrimp processing plants was eminent and decided that the initiation of any new processing plant should be under government control. Thus a new act was passed in 1975 which entitles the Ministry to coordinate the shrimp fishery and the factory capacity or to share catches among the existing factories in relation to their individual capacity. This act also entitles the Ministry to divide the local shrimp catch quotas among the boats taking part in the fishery. The establishment of new factories, as well as an increase in capacity of the existing ones, is also subject to the Ministry's consent.

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THE NORWEGIAN SHRIMP FISHERIES
HISTORY OF RESEARCH AND MANAGEMENT

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ABSTRACT

The Norwegian fishery for the deep sea prawn Pandalus borealis started in coastal waters in southern Norway in 1897. Around 1930 an offshore fishery developed in Skagerrak. After the war, 1940 to 1945, the shrimp fishery expanded further, especially in northern Norway, where the fishery gradually changed to a predominantly offshore one. During the 1970s exploitation of newly detected offshore grounds at Spitsbergen and in the Barents Sea has increased Norwegian shrimp catches from about 7,000 tons in 1970 to 21,000 tons in 1978, excluding catches from west Greenland (Figure 1).

Rasmussen (1953) studied the life history of the deep sea prawn by comparing material from different populations distributed from southern Norway to the Arctic waters of Spitsbergen and Jan Mayen. His results seemed to prove that decreasing temperatures in the sea cause slower growth and retarded maturation.

Since 1969, a main part of shrimp research conducted by the Institute of Marine Research in Bergen has been directed toward determining the distribution of shrimp in the Barents Sea and Spitsbergen area. Swept area estimates of stock size indicate that by 1977, total catches from these areas had reached the maximum sustainable yield level. These estimates are preliminary, and will probably be improved by properly designed stratified random trawl surveys.

Closing of selected fjords for shrimp trawling was, until recently, the only restriction imposed on the shrimp fishery. In 1974, mesh size regulations were introduced, not allowing mesh size in cod end below 30 mm and 35 mm (stretched) south and north of 65°N, respectively. Participation in the fishery of trawlers larger than 50 GRT has since 1973 been regulated through a licensing system.

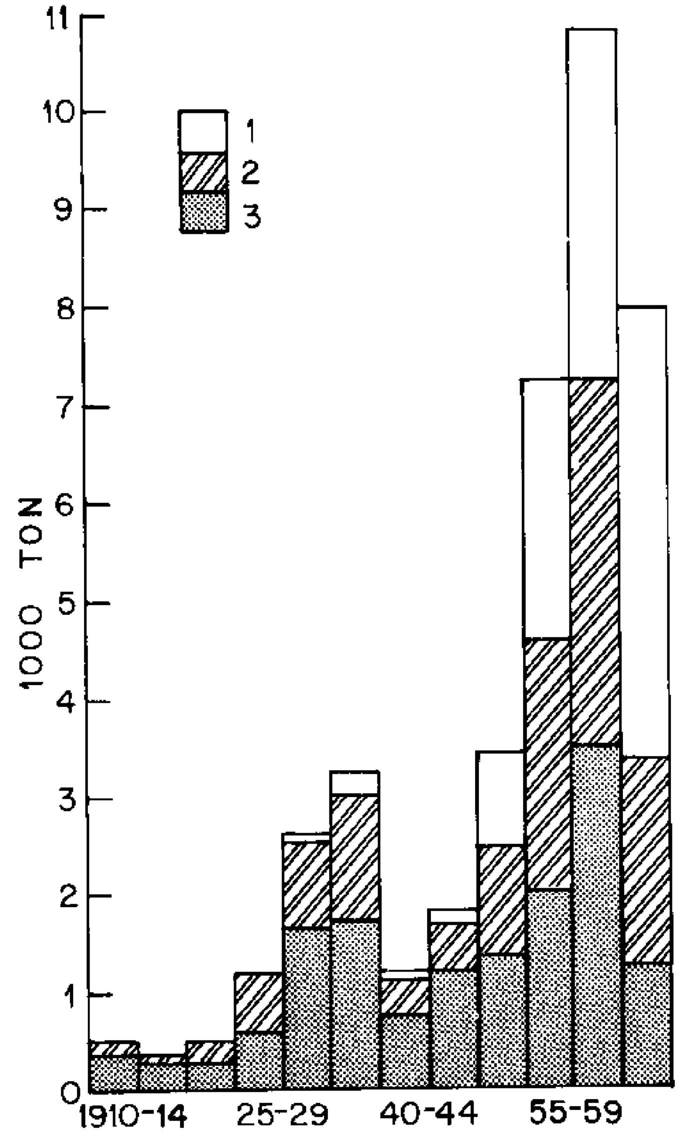

Figure 1. Mean annual Norwegian shrimp catches by five year periods from 1910 to 1969.
1) northern Norway 2) western Norway and Trøndelag 3) Skagerrak.

PANDALID SHRIMP FISHERIES OF JAPAN

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ABSTRACT

Japanese consumption of shrimps and prawns recently exceeded 190,000 mt a year. Roughly one-third of the total consumption was supported by Japanese domestic production, of which pandalid shrimps constituted 15 to 20 percent. Commercial use of deep water pandalids began in the early 1950s off the Japan Sea coast of Hokkaido and expanded rapidly within a decade throughout most of the shrimp's range.

Important species are *Pandalus borealis*, *P. hypsinotus*, *P. goniurus*, *P. kessleri*, *P. nipponensis*, *Pandalopsis ochotensis*, *P. japonica* and *Plesionika izumie*. With the exception of the last, they occur in the cold sector of Japanese waters from estuaries down to a continental slope of 500 m or more of water, showing an apparent zonation of habitat owing to the depth preference exhibited by each species. Biological information so far reported in Japan is viewed with respect to biometry, reproduction, growth, sexual phases and larval development.

Pandalid shrimps are fished by various trawls and shrimp pots. Inshore and offshore type trawls were the main shrimping gears during the 1950s, while shrimp pots became popular in the early 1960s. All accessible grounds in Japanese waters are almost fully exploited and decreasing abundance has been reported in many of the exploited stocks. Shrimp farming was attempted in recent years to restore decreasing stocks.

Japanese northern shrimp fisheries in international waters began in 1961 in the Bering Sea. Activity was extended to the Gulf of Alaska in 1963 and to the west coast of Kamchatka in 1970. Its development and fate will be briefly reviewed.

INTRODUCTION

Japanese people consumed 190,040 mt of shrimps and prawns in 1976, almost 15 percent of total world production. On a per capita basis, it is about 1.7 kg or 3.2 lbs per year. Domestic production supported roughly one-third of the total consumption (Table 1). The rest was imported from abroad from 70 nations at a total expense of ¥223.1 billion, a little more than $1 billion in U.S. currency. The potential Japanese demand for shrimps and prawns has been estimated at 310,000 mt per year.

During the last decade, an average of 78 percent of the total Japanese domestic production of shrimps and prawns was captured within Japanese territory, the bulk of which was southern penaeid species. The fraction of pandalid shrimps may be estimated at 15 to 20 percent.

Distribution of pandalid shrimps in Japanese waters is strongly influenced by the system of ocean currents in the northern west Pacific area (Figure 1). Except for Plesionika, they comprise major shrimp stocks in the cold sector of Japanese waters. They support a number of fisheries on Hokkaido and along the Japan Sea coast of Honshyu. In the southern regions of Honshyu however, coastal waters are for the most part dominated by penaeid species. The occurrence of pandalids is scarce and patchy in deep water.

Fishing gear commonly used to capture pandalid shrimps includes various trawls and shrimp pots. In estuaries and relatively shallow nearshore waters, shallow water species are fished by sailing trawls or inshore type otter trawls, varying locally. Deepwater pandalids are fished by offshore and inshore type trawls throughout most of their range, though they are usually a small fraction of the total annual catch of these fisheries. Beam trawl and shrimp pot fisheries, on the other hand, are largely supported by pandalid shrimps in Hokkaido and along the Japan Sea coast of Honshyu at several localities where pandalid population is concentrated within accessible range of local boats.

HISTORY

Pandalid shrimp fisheries have a long history in estuaries and relatively shallow water in several localities of Hokkaido. Historical evidence is not available concerning the beginning of shrimping activity. Kambara (1938) reported that in Funka Bay, southern Hokkaido, P. hypsinotus has been trawled since 1913 by non-motorized small boats. In 1938, 85 such boats operated in about 60 m of water from October to March, landing almost 165 mt of shrimp a year. In Notsuke Bay of eastern Hokkaido, Kinoshita (1937) reported that pandalid shrimps had been fished for years by about 60 sailing trawlers in 2 m or less of water from June to October, landing from 230 to 260 mt of shrimp per year.

Commercial use of deepwater species began in the early 1950s in the Japan Sea region of Hokkaido. Pioneer attempts to catch the species were made several times after 1910, but

Table 1. Japanese consumption of shrimps, prawns, and lobsters (mt)

	Domestic production						
			Marine fisheries				
Year	Culture	Fresh water fisheries	Domestic area	International area	Subtotal	Import	Total consumption
1968	269	2,322	49,625	13,438	70,294	35,204	105,498
1969	309	2,845	45,434	14,051	62,639	48,886	111,525
1970	295	3,277	43,560	12,077	59,209	57,146	108,538
1971	400	4,982	42,028	9,123	56,533	78,874	135,407
1972	571	5,272	49,680	8,596	64,119	88,120	152,239
1973	742	6,441	49,219	13,043	69,443	177,474	186,912
1974	963	5,739	52,034	26,880	85,616	103,311	188,927
1975	1,000	6,840	50,945	18,392	77,177	113,672	190,849
1976	1,060	5,301	46,390	11,291	64,042	125,998	190,040

Source: Fisheries Agency 1978b, Statistics and Survey Division 1978

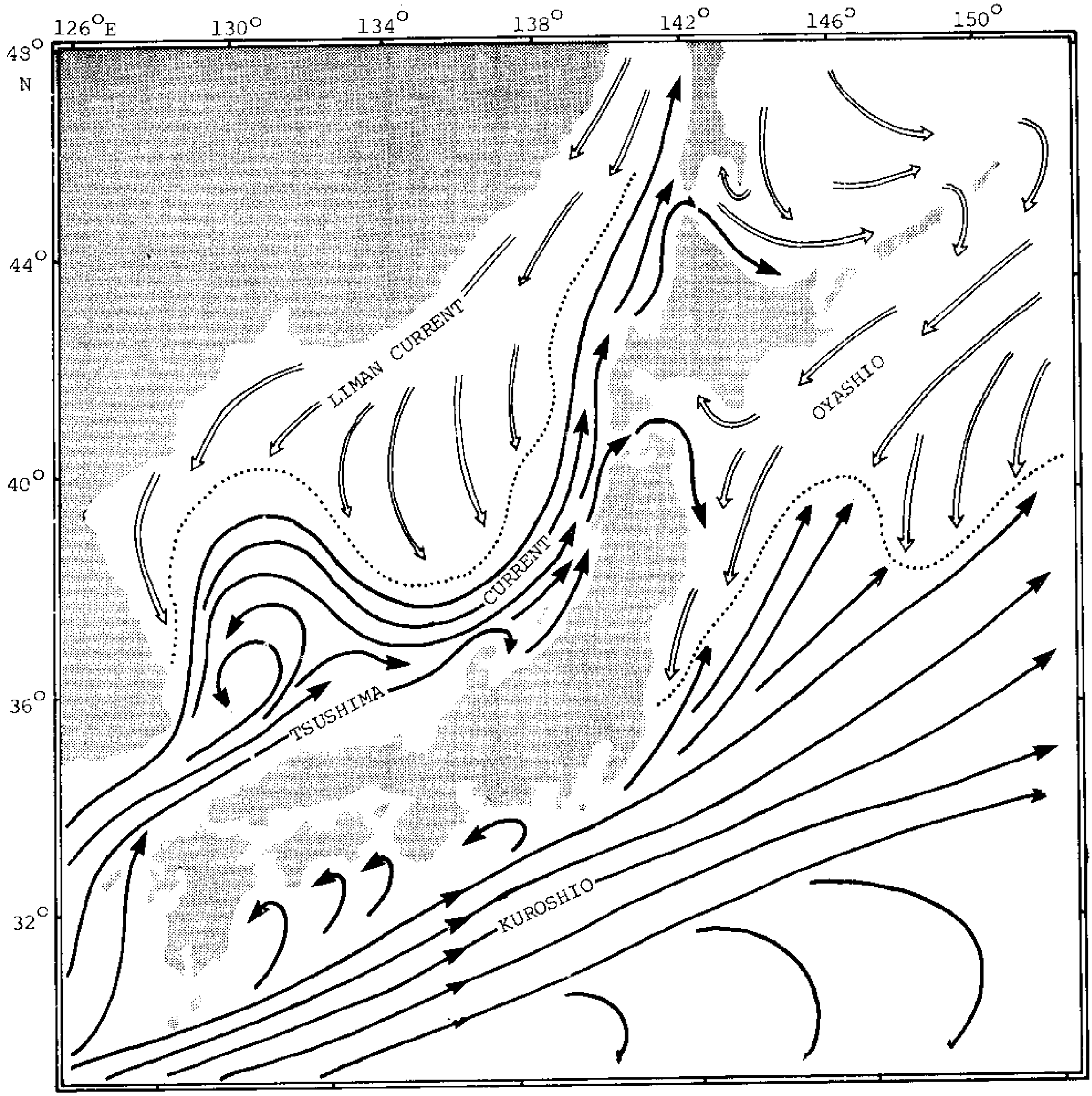

Figure 1. Ocean current systems around the Japanese Islands and adjacent areas. (Modified from Suda 1943)

it was not until 1951 that any substantial quantity was landed. Extensive and systematic trawling surveys carried out by the Hokkaido Prefectural Fishery Experiment Station from 1949 to 1953 were successful, locating several promising grounds along the edge of the continental shelf. In 1951, a large quantity of deepwater shrimps were captured incidentally by a commercial inshore trawler targeting Alaska pollock, operating further offshore than usual. This accidental discovery of a dependable supply of offshore shrimp has led to a prompt expansion of trawling activities in both inshore and offshore sectors of deepwater grounds off the Japan Sea coast of Hokkaido and elsewhere. Discoveries of many other payable grounds followed. Deepwater shrimps developed in a few years into one of the most valuable fisheries in Hokkaido with landings of several hundred metric tons a year.

In the meantime, the beam trawl net was developed by the Hokkaido Perfectural Fisheries Experiment Station, (Machida and Kosugi 1952, Ohgaki et al. 1954), to capture deepwater species in inshore areas of their range. Shrimp pots were also developed by the same station during the late 1950s, and expanded promptly to the other regions of Hokkaido and Honshyu. Almost every accessible ground for deepwater pandalids was exploited within a decade after discovery.

P. hypsinotus, living in relatively shallow water, was the main species exploited during the early stages. Unfortunately, it was not sufficiently abundant to support expanded shrimping activities. As early as 1964, fishermen had to change their main target to P. borealis living in deeper water offshore. At present, pandalid shrimp fisheries in Japan are supported by this species.

During the last decade, pandalid shrimp catches in Japanese waters ranged from 7,000 to 9,000 mt (Table 2). The declining trend in catch per unit of effort became apparent in recent years throughout most of the shrimping grounds. Protection and management of these valuable shrimp stocks based on sound scientific knowledge are highly needed. Restrictions and regulations carried into effect so far are not adequate for effective conservation of available shrimp stocks. Recently, artificial production of shrimp fry for release and environmental improvement of shallow water habitats have started on an experimental scale at several places on Hokkaido and Honshyu. So far, there is no reported change in the overall declining trend of pandalid stocks in Japanese waters.

Japanese shrimp fisheries in international grounds began in 1961 in the Bering Sea with a factory ship, Eijinmaru, accompanied by a fleet of trawlers (Yoshizaki 1967). Shrimping activity expanded in the following years, and annual catch reached a maximum of 31,612 mt in 1963. As early as 1965,

Table 2. Japanese domestic catch of pandalid shrimps by region. Data from various sources (metric tons)

Year	Okhotsk Sea	Japan Sea		Pacific Ocean			Total
					Honshyu		
		Hokkaido	Honshyu	Hokkaido	Pandalus	Plesionika	
1963	150	1,427	-	504	-	-	2,081
1964	85	2,019	-	501	-	-	2,605
1965	3,141	1,574	-	484	-	-	5,199
1966	4,940	1,820	-	454	-	-	7,214
1967	2,594	1,512	-	560	-	1,300*	5,966
1968	3,929	1,561	-	566	-	1,800*	7,856
1969	5,474	1,706	1,705	585	-	-	9,470
1970	3,541	1,653	1,531	728	-	1,700*	9,153
1971	1,858	2,017	1,482	986	-	-	6,343
1972	1,487	2,797	1,750	798	-	-	6,832
1973	1,375	3,374	1,674	851	47	-	7,371
1974	551	4,294	2,462	809	159	...	8,275
1975	1,436	4,226	2,600	798	84	...	9,144
1976	890	4,299	2,783	694	70	...	8,736

* Approximation
\- Data not available
... No fishing activity

however, it became evident that shrimp stocks could not support the expanded fishery with the apparent decrease in shrimp size and catch per unit of effort.

Shrimping grounds in the Gulf of Alaska were explored in 1960 and subsequent years. Shrimping in this area developed into a considerable fishery in 1963 with a 657 mt catch of deep water pandalids. The northern shrimp in these waters made a substantial contribution to the Japanese fishery until 1971 (Figure 2).

Pandalid stocks along the west coast of Kamchatka Peninsula were exploited extensively by the Japanese land-based stern trawlers from 1970 until 1976. Variation of stock size during the exploited period was studied by Kitano and Yorita (1978), and their results will be reviewed here in some detail.

Daily catch and effort data was obtained from logs reported by the commercial trawlers. More detailed data was also obtained from certain sample boats with respect to the amount of effort targeted at shrimps and to the exact place of fishing grounds. Biological data was obtained from shrimp samples taken once a year in July from the center of abundance.

The fishing season extended from May to December, with a peak in July when shrimp were believed to gather for mating along the edge of the continental shelf. The main fishing grounds ranged from 52° to 54°north latitude and from 200 to 300 m in depth. Temperatures ranged from 0.1° to 2.1°C. and salinity from 33.0 to 33.5 ppm.

The annual shrimp catch reached a maximum of 5,000 mt in 1973 and then declined to 2,500 mt in 1975. Percentage of _Pandalus borealis_ among the total catch, on the other hand, showed a continuous decrease throughout the study period, from 96 percent in 1970 to 81 percent in 1975.

Abundance of available stocks was estimated from catch per unit of effort and from age composition of commercial catches. It was somewhere between 10,000 and 15,000 mt in 1970, when this stock was first subjected to commercial capture. Abundance decreased steadily during exploitation until it reached about 5,000 mt in 1974 and later years.

The observed decrease in available stock size was attributed mainly to fishing activities. The result of age composition analyses showed that the larger females had been most severely depleted by fishing (Figure 3). The amount of annual catch, on the other hand, was estimated as almost equivalent to recruitment of respective years (Figure 4). The decrease in stock size has been attributed to the depletion of breeding females and of subsequent recruitment, rather than to the decrease in survival rate among the population due to fishing in excess of the level of recruitment.

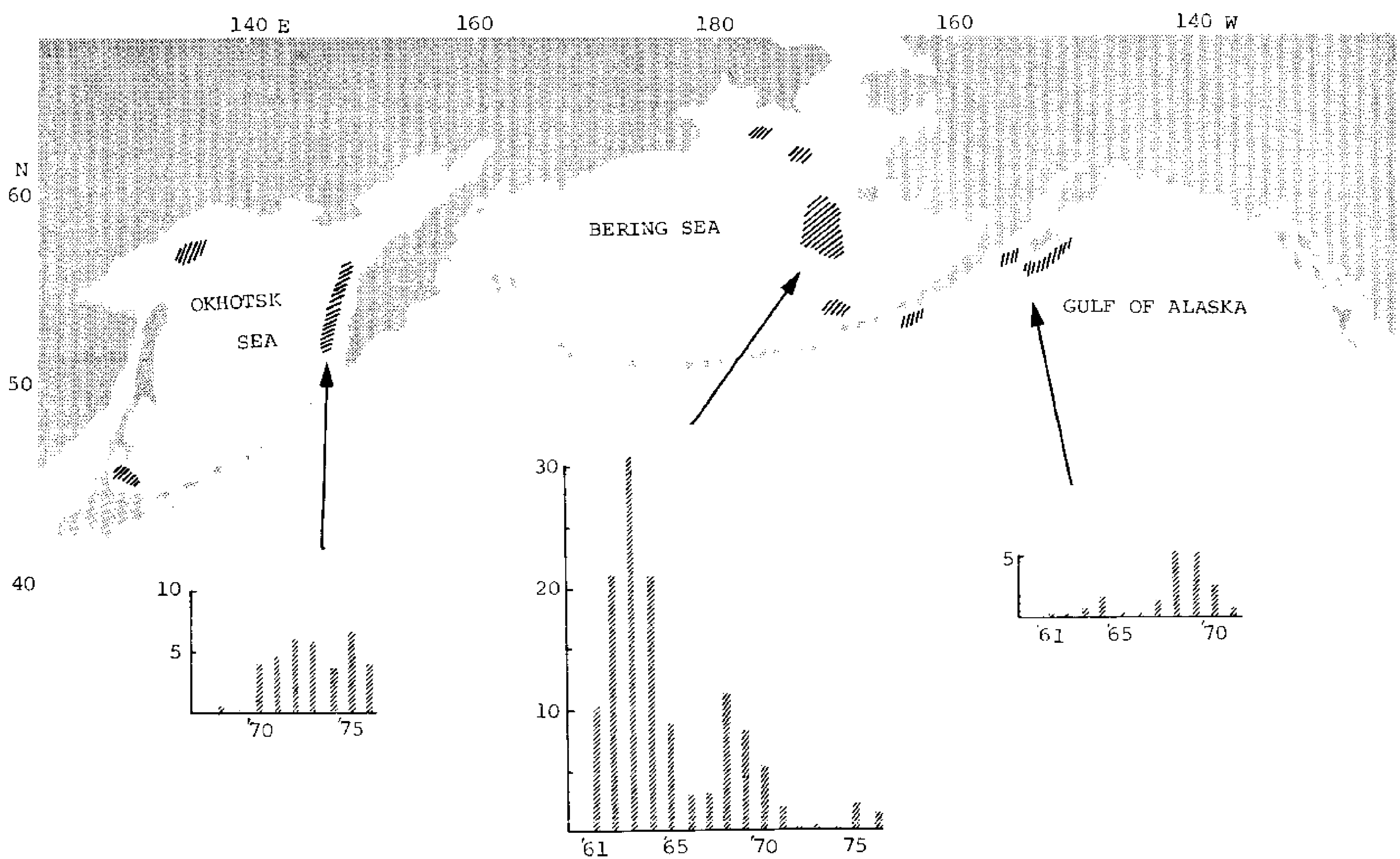

Figure 2. Distribution of fishing grounds for the northern pandalid shrimps and and trends in annual catch (1,000 mt) by the Japanese fisheries.

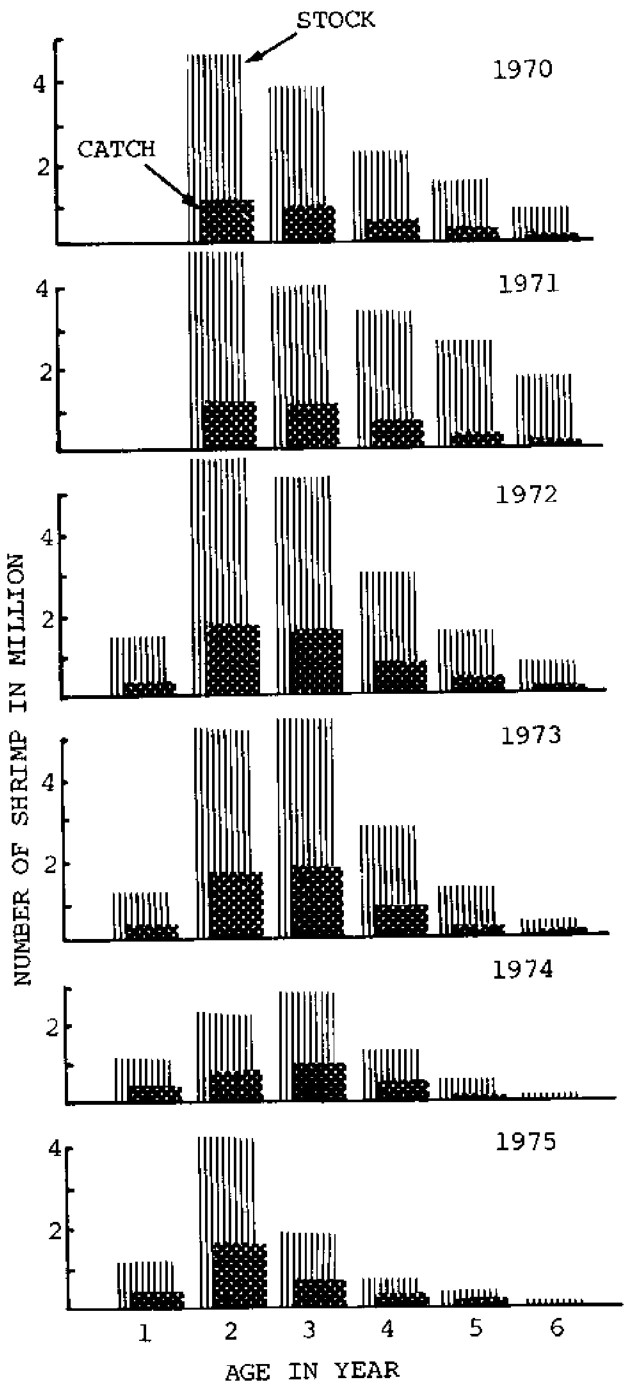

Figure 3. Abundance and catch of P. borealis stock on the west Kanchatka Peninsula ground. (Kitano and Yorita 1978)

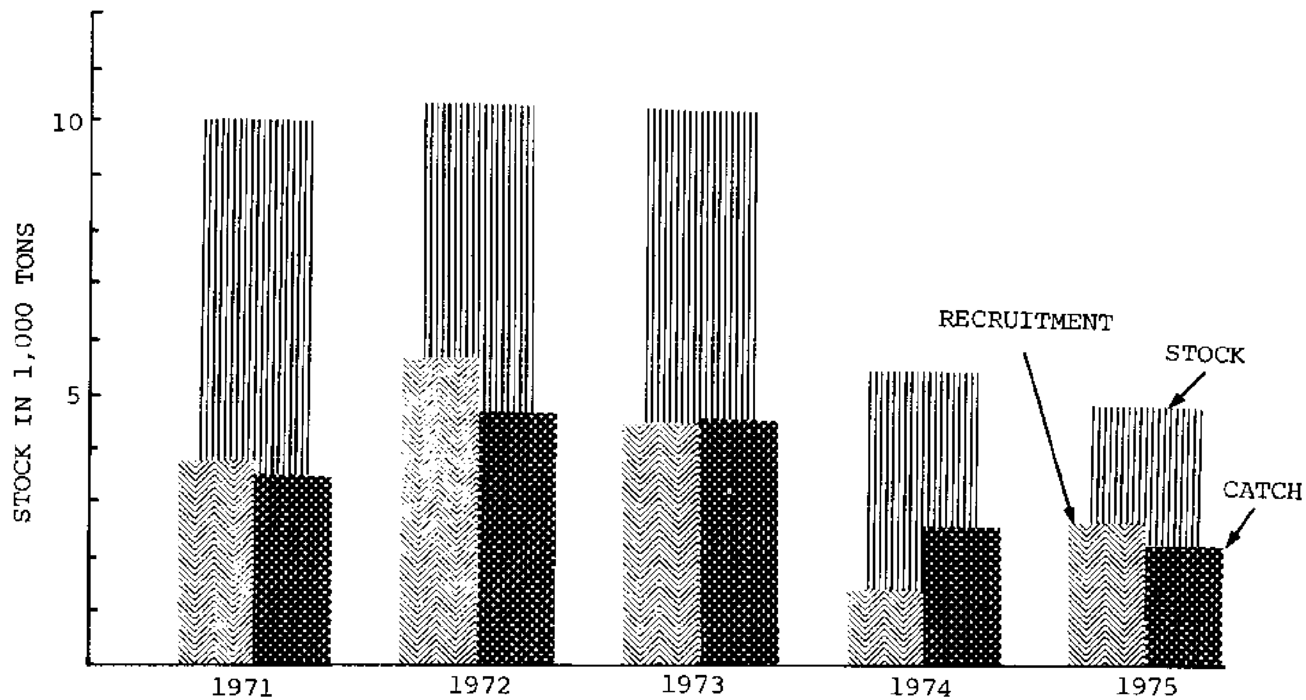

Figure 4. Abundance, recruitment and catch of *P. borealis* stock on the west Kamchatka Peninsula ground. (Kitano and Yorita 1978)

The allowable biological catch from this stock was estimated at a level of about 3,500 mt/year with a total of 18,000 hours of trawling effort.

SPECIES OCCURRING IN THE COMMERCIAL CATCH

Although pandalid shrimps belonging to seven genera are reported by Yokoya (1934) in Japanese waters, commercial fisheries are supported by members of three genera: *Pandalus*, *Pandalopsis* and *Plesionika*. The first two live in cold water, while the last lives in warm water.

The commercial species in Japan are *Pandalus borealis* Krøyer, *P. hypsinotus* Brandt, *P. goniurus* Stimpson, *P. kessleri* Czerniavski, *Pandalopsis ochotensis* Kobjakava, *Pandalus nipponensis* Yokoya, *Pandalopsis japonica* Balss and *Plesionika izumi* Omori, in the probable order of importance. The first three species are common to other waters of the world, while the rest of the species are endemic to Japanese and adjacent waters. Other species are too rare or too small to warrant capture in payable quantity.

Japanese waters may be divided into three main regions with respect to the distribution of commercial pandalids: the Japan Sea region, the Okhotsk Sea and northern Pacific Ocean region and the southern Pacific Ocean region. Each region may be characterized by the presence of its own particular species in any commercial quantity (Figure 5).

Japan Sea region:	*Pandalopsis japonica*
Okhotsk Sea and northern Pacific Ocean region:	*Pandalus kessleri* in shallow water and *Pandalopsis ochotensis* in deep water
Southern Pacific Ocean region:	*Plesionika izumie* in coastal water and *Pandalus nipponensis* in deep water.

P. borealis and *P. hypsinotus* are common to the first two regions while *P. goniurus* is confined to the southwestern corner of the Okhotsk Sea between Hokkaido and Sakhalin. Coastal water pandalids are absent from the Japan Sea region.

The Japanese genera and species of Pandalidae may be identified by the following working keys made up with slight modifications after Yokoya (1934) and Urita (1941a).

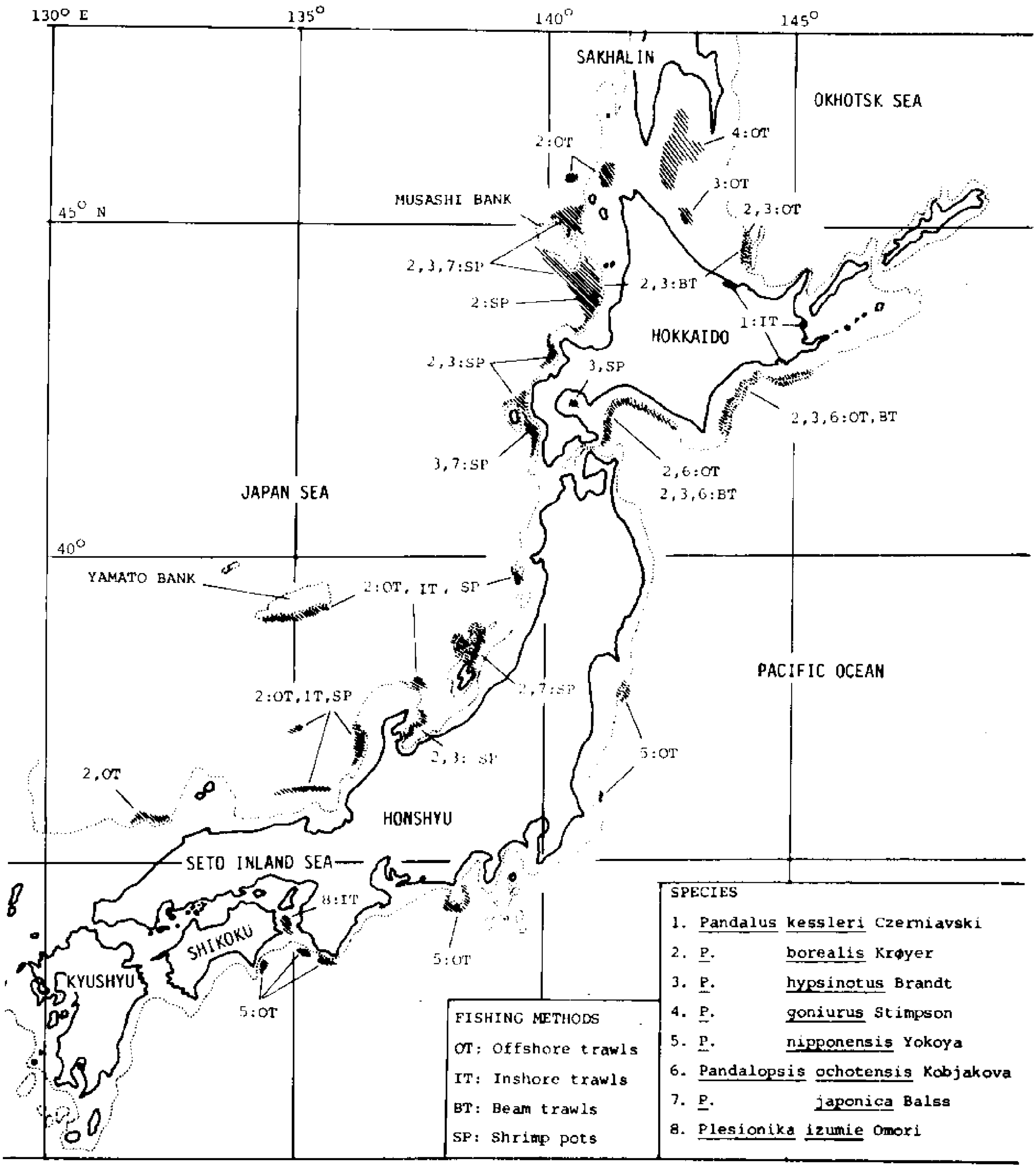

Figure 5. Distribution of major fishing grounds for pandalid shrimps in Japanese waters. Dotted line indicates 200 m isobar. (Ito 1976; Yorita personal communication; Ishikawa 1977)

Working key to the Japanese genera of Pandalidae

1 Carpus of leg 2 subdivided into 3 or more articulations..2

Carpus of leg 2 subdivided into 2 articulations, carapace lacks supra-orbital spine..............................Chlorotocus

2(1) Carapace smooth except dorso-median ridge...............3

Carapace with longitudinal ridges in addition to dorso-median one, exoskeleton ridge..Heterocarpus

3(2) Cornea of eye larger than stalk..........................4

Cornea of eye more slender than stalk............Dorodotes

4(3) Maxilliped 3 with exopod..................................5

Maxilliped 3 without exopod..............................6

5(4) Epipod present on legs 1-4.....................Plesionika

Epipod absent on all legs....................Parapandalus

6(4) Ischium of leg 1 expands along its inner edge into lamella, merus of maxilliped 3 produced into lamella along its inner edge and fringed with setae....................................Pandalopsis

Ischium of leg 1 does not expand along its inner edge, mersus of maxilliped 3 does not produce into lamella...Pandalus

Working key to the Japanese species of genus Pandalus

1 Dorsal margin of abdominal somite 3 compressed laterally producing behind into a pointed process at just in front of hind margin..................P. borealis

Abdominal somite 3 round and smooth......................2

2(1) Dorsal rostral teeth do not extend beyond middle of carapace..............................3

Dorsal rostral teeth extend behind beyond middle of carapace and more than 17 in total number.....................P. hypsinotus

3(2) Mid-rib of rostrum greatly developed and broad..4

Mid-rib of rostrum not developed..............*P. nipponensis*

4(3) Rostrum exceeds tip of scaphocerite..............*P. prensor* (=*P. meridionalis*)

Rostrum equals or slightly exceeds tip of scaphocerite..............................*P. kessleri*

Working key to the Japanese species of genus *Pandalopsis*

1 Rostrum armed dorsally throughout its length......................................*P. japonica*

Rostrum unarmed dorsally along its anterior half..2

2(1) Dorsal rostral teeth arise at far in front of middle of carapace and end far behind middle of rostrum..............*P. mitsukurii*

Dorsal rostral teeth arise at about middle of carapace and extend forward to about middle of rostrum....................................3

3(2) Rostrum only slightly exceeds tip of scaphocerite, proximal ventral rostral tooth greater than that in front of it........*P. lamelligera*

Rostrum exceeds tip of scaphocerite by one-third of its length, procimal ventral rostral tooth smaller than that in front of it...........................*P. ochotensis* (=*P. coccinata*)

FISHING GROUNDS

Pandalid shrimps are commercially captured in Japanese waters from the estuaries of 2 m or less of water to offshore continental slope of 500 m or more (Figure 6).

P. kessleri is a shallow water species and confined to estuaries and lagoons of less than 10 m of water where the vegetation of eel-grass, *Zostera marina*, flourishes. *P. goniurus* and *P. izumie* prefer relatively shallow oceanic waters less than 80 m deep and within 10 miles of shore. The rest of the commercial species lives further offshore in deeper waters.

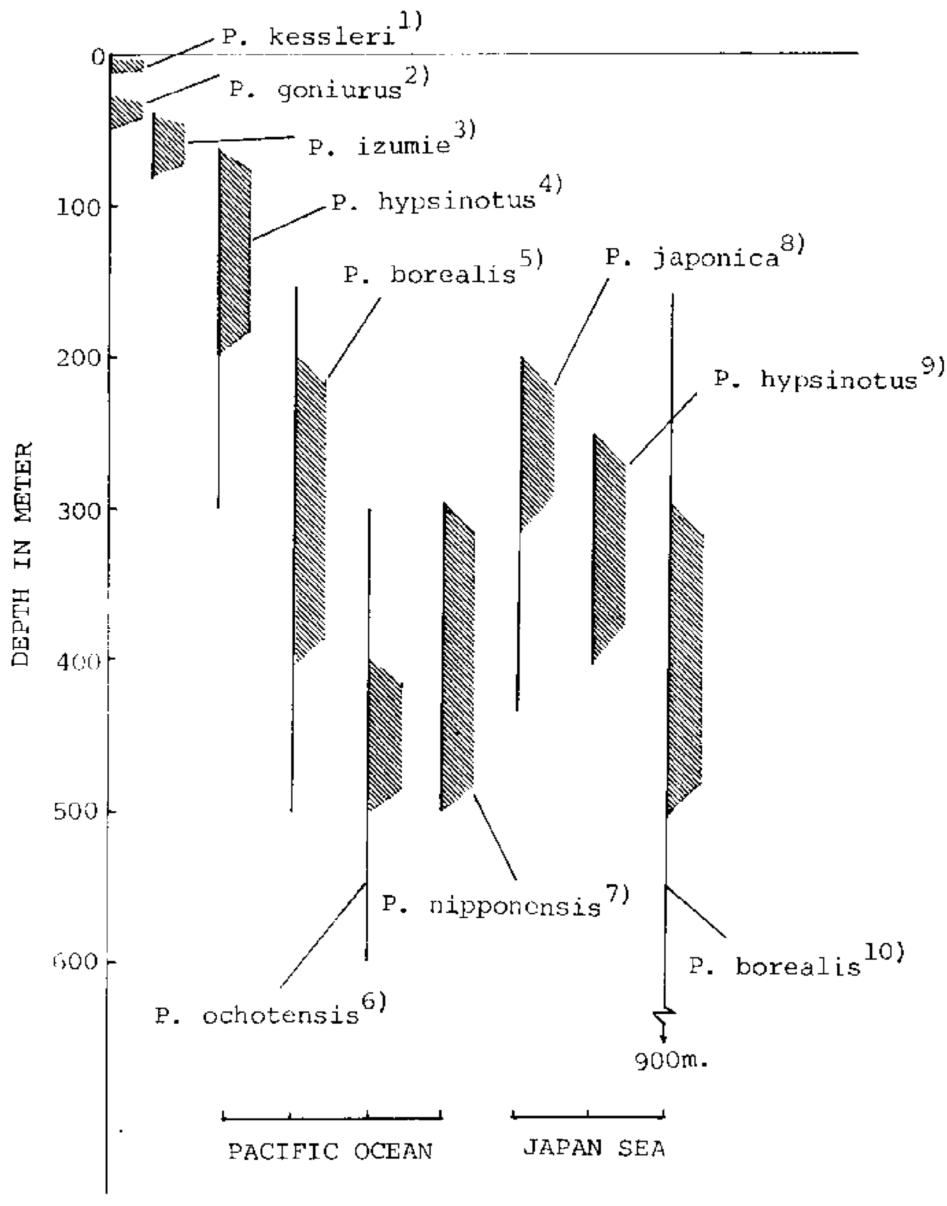

Figure 6. Zonation of pandalid shrimps in Japanese waters. Hatching indicates main fihsing areas. (1)Kubo and Morishita 1954, Kashiwagi 1973; 2)Urita 1941; 3)Omori 1971, Tohriyama and Asami 1973; 4)Kambara 1938, Sakurai et al. 1966; 5)Sakurai et al. 1966; 6)Sakurai et al. 1966; 7)Tamura 1950; 8)Ito 1978; 9)Kojima 1967; 10)Ito 1976, Yamada and Naiki 1976)

Each species living in deep water is restricted to different depth ranges. The main habitat seldom overlaps between sympatric species. Two or more species may be found at a similar depth, however they are for the most part separated geographically and seldom caught together in any significant quantity (Yoshiwara et al. 1970).

Bottoms of deepwater shrimping grounds are reported in many cases to be a mixture of sand and mud. P. borealis is said to prefer more mud than does P. hypsinotus. However, available data are inadequate to analyze bottom preference of particular species in any detail. Much data is available on the temperature and salinity range where each species is found in commercial concentration.

Average temperatures in shallow water habitats where P. kessleri is commercially fished are reported in Hokkaido (Aoto 1952) to vary from -1.2°C in February to 19.9°C in August, and at southern limits of its range (Kashiwagi 1973) from 5.8°C in February to 25.8°C in August. This species can tolerate the widest range of temperature among the Japanese pandalids. In P. goniurus grounds of Okhotsk Sea, bottom water temperature may reach as high as 9.7° or 10.3°C during the summer, while salinity remains almost constant around 34 ppm. In Funka Bay, Hokkaido, were P. hypsinotus is fished, bottom water temperatures at 100 m depth may reach 9.2°C during summer and salinity varies from 33.0 to 33.7 ppm. P. nipponensis lives in water of 7.4° to 9.1°C in temperature and 34.3 to 34.4 ppm in salinity.

Other species of the Japanese northern pandalids so far reported prefer much lower temperatures within a narrow range. Thus, the bottom water temperatures of shrimping grounds range from 0.7° to 2.3° C off the Japan Sea coast of Hokkaido (Yorita 1969), from 1.5° to 3.2°C off the Pacific coast of Hokkaido (Fisheries Agency 1978a), and from 0.4° to 0.8°C off the Japan Sea coast of Honshyu (Ito 1976). Salinity remains almost constant in the Japan Sea grounds throughout the year at about 34.0 or 34.1 ppm, while it ranges from 33.5 to 34.0 ppm off the Pacific coast of Hokkaido (Fisheries Agency 1978a.)

The Okhotsk Sea region is unique, having a large expanse of continental shelf between Hokkaido and Sakhalin and commercial pandalid stocks in relatively shallow oceanic waters. The coastal lagoons are inhabited by the shallow water pandalids which support small local fisheries.

The Japan Sea region is characterized by many shrimping grounds along the edge of the continental shelf and on isolated offshore banks (Figure 5). Every accessible ground is almost fully exploited by offshore trawlers throughout much of the region: by beam trawlers off Hokkaido, by inshore trawlers off northern Honshyu and by shrimp pots off various localities of both Hokkaido and Honshyu. P. borealis is the main species supporting recent shrimping activities in this region, constituting more than 90 percent of the total catch. The use of shrimp pots with large vessels, instead of beam and inshore trawls with small vessels, became more and more common for shrimping as the center of fishing grounds shifted to deeper waters of 500 m or more.

In the Pacific Ocean region, pandalid shrimps are captured by various fisheries from estuaries and deep waters of 500 m or more. Every accessible ground is fully exploited. The species composition in Hokkaido, on the average of five years from 1971 to 1975, was roughly 10 percent P. kessleri, 10 percent P. hypsinotus, 38 percent P. borealis, and 42 percent P. ochotensis (Abe, personal communication).

The Pacific Ocean region off Honshyu is the least productive area for pandalid shrimp. Apart from P. izumie, only small amounts of P. nipponensis are captured on scattered intermittent grounds by offshore trawlers which normally fish various groundfishes and squid. P. izumie once supported a substantial fishery of inshore otter trawls at the eastern entrance of the Seto Inland Sea. At present, however, fishing activity has virtually ceased because of low demand.

FISHING METHODS, VESSELS AND GEARS

OFFSHORE TRAWLS

There are two types of offshore trawls in Japan. The one vessel type and the two vessel type. The one vessel trawls are common to all regions, while the two vessel trawls are confined to southern regions of Honshyu. Pandalid shrimps are mainly fished by one vessel trawls because they are suited for trawling in deep water, to 600 m, on the continental slope where the deepwater pandalids live in greatest concentration.

In 1976, a total of 728 one vessel trawlers operated throughout Japan. Vessels of common usage vary from 15 to 125 mt in gross weight. The prevailing vessel size varies locally, and it is generally larger in Hokkaido than in Honshyu. The vessels are powered with diesel engines. Horsepower value per metric ton of vessel weight ranged from 3.1 to 4.0 until the late 1950s, while it increased to about 5.6 in recent years. The general trend is to use larger vessels with higher powered engines.

Structure of trawl nets varies in detail, depending on locality and main target. Figure 7 shows a general layout and method of drag of offshore trawl net in the one vessel operation by a 125 mt vessel. Otter boards are not allowed, except in certain defined areas for exploratory purposes. The net is hauled in from the side in old vessels. Recent method is to use a stern trawl system, becoming more common since it saves manpower. Offshore trawlers usually catch various groundfishes and squid in offshore sectors beyond the abstention line. Pandalid shrimp are a small fraction, less than 2 percent of the total annual catch.

INSHORE TRAWLS

Inshore trawls are the most popular fishing gears used throughout Japan. In 1976, 29,000 vessels made 2.4 million trawling trips. They caught various groundfishes and shellfish but no reliable data are available on the effort devoted to shrimping.

The trawl net in common usage varies enormously in detail with locality and main target of capture. Otter boards are restricted except in certain defined areas. A beam of bamboo or of plastic is generally used for shrimping to keep the mouth of the net open while it is dragged. Structure and dragging method of a typical beam trawl is illustrated in Figure 8. A towing rope is extended to about three times the depth of water. It is hauled by a drum in old vessels, or with a reel in new vessels. The net is dragged at 1 to 2 knots and emptied from four to six times a day every two or three hours. A one day trip is usual.

Vessels used for inshore trawls are limited in gross weight to less than 15 mt. Most vessels used for shrimping in deep waters are approaching the maximum limit. Horsepower values of diesel engine per metric ton of vessel weight were quite comparable to those in offshore trawlers until the end of the 1950s, and have increased to about 6.3 in recent years.

Sailing trawls are used in estuaries where there is rich seaweed vegetation (Figure 9). Wind power is used to drag the net.

SHRIMP POTS

Shrimp pots are relatively new to Japanese waters. They became popular and use expanded rapidly after the discovery of promising grounds during exploratory surveys carried out by the Hokkaido Fisheries Experiment Station from 1955 to 1959. General structure of shrimp pot and the method of operation are illustrated in Figure 10. According to Kudo (1970) the pots usually stayed overnight. A fisherman uses 500 pots or more at a time and changes fishing ground every

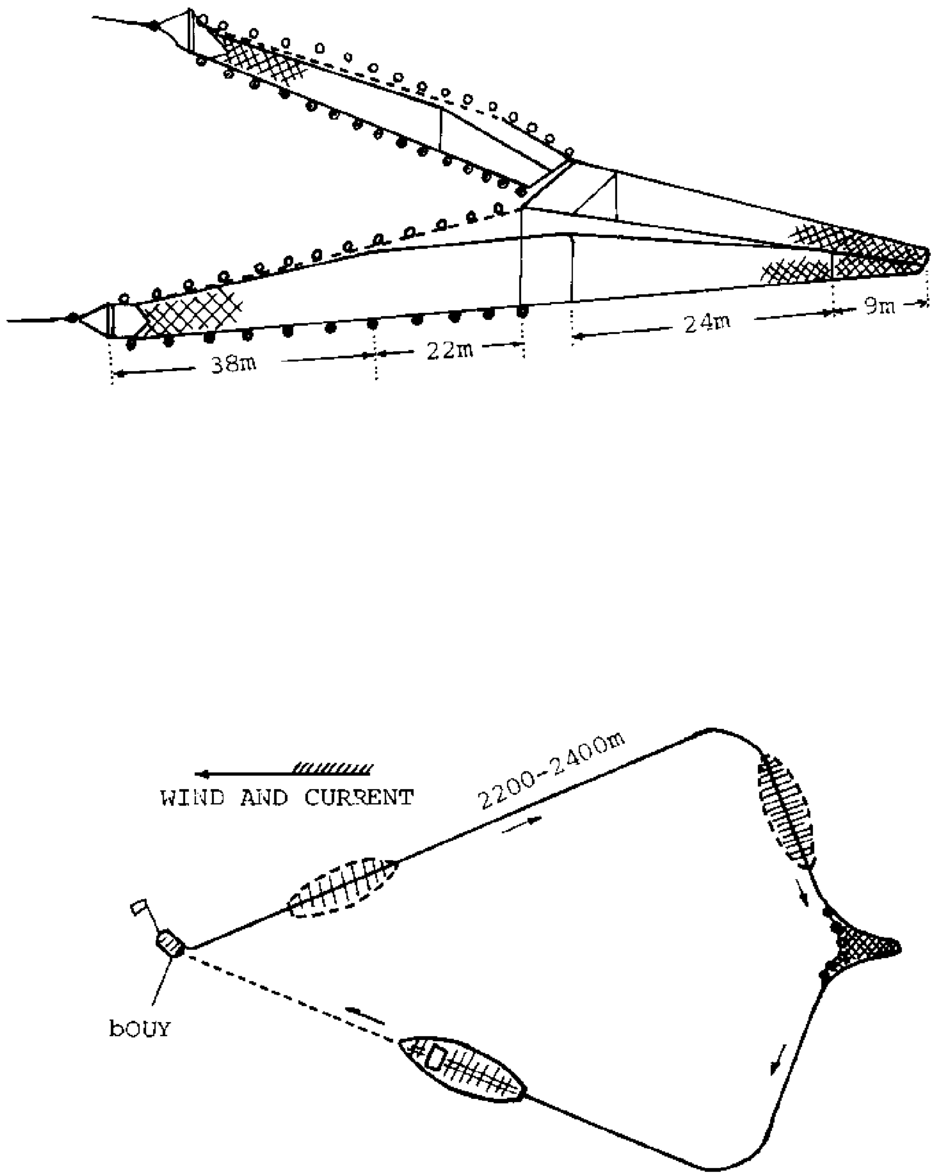

Figure 7. Typical offshore trawl net and trawling method by a 125 ton vessel. (Kaneda 1977)

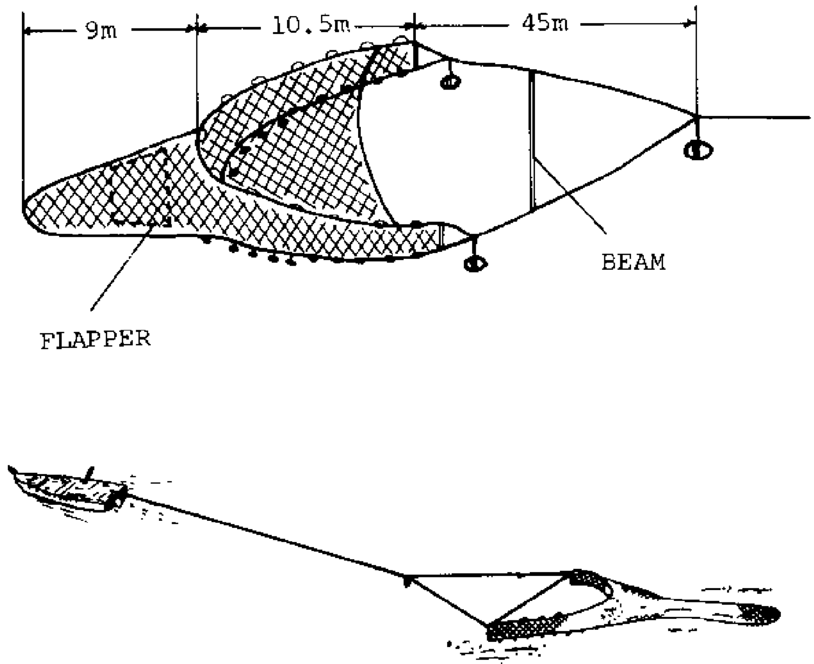

Figure 8. A typical beam trawl net (Kaneda 1977) and trawling method (Miyazaki 1960) for shrimping.

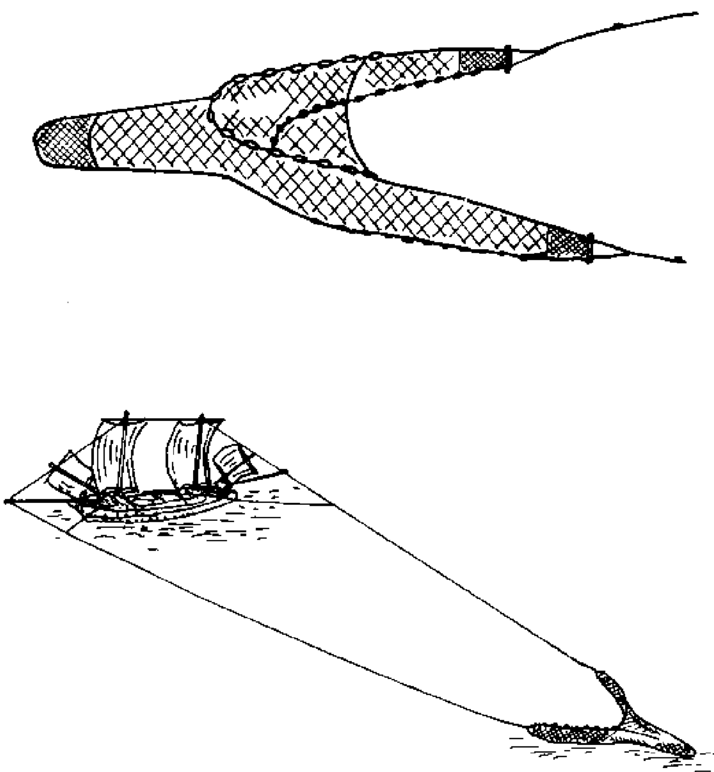

Figure 9. A typical trawl net (Kaneda 1977) and sail trawling method (Miyazaki 1960).

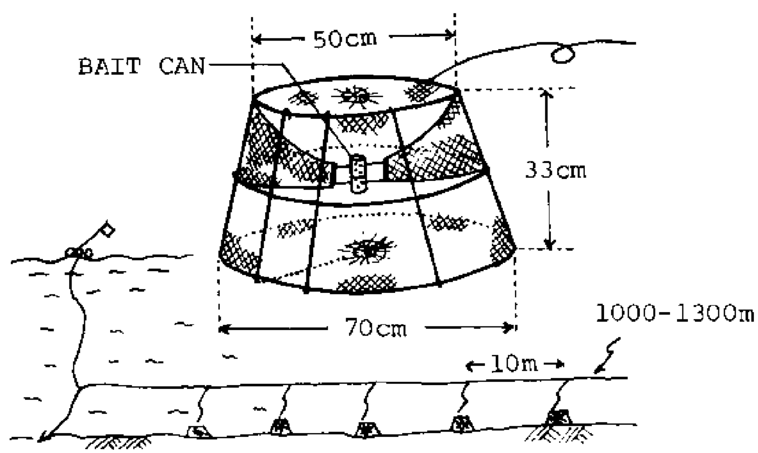

Figure 10. Shrimp pot and its fishing method in Hokkaido. (Kudo 1970)

three or four days, depending on the amount of catch. Round fishes and canned chopped fish meat are used as bait. Vessels used for this purpose in Hokkaido range from 10 to 50 mt or more in gross weight and are powered with diesel engines ranging from 50 to 200 horsepower. They are usually operated by four or five crews.

SEASONAL VARIATION

Estuarine species are fished from June to November in Notsuke Bay, eastern Hokkaido. Fishing is closed during the breeding season. Deepwater species are fished during the winter from December to March when the shrimp are concentrated along the edge of the continental shelf. The shrimp are believed to gather at this time of year for mating. They are more or less scattered during the rest of the year. On isolated offshore banks, however, deepwater shrimp are fished during summer when the sea is relatively calm.

CATCH STATISTICS

In Japan the total shrimp catch, when northern and southern shrimp are combined, is only about 4 percent of the total annual catch of about 2 million mt by the whole coastal marine fisheries. Official catch statistics published by the Statistics and Survey Division, Ministry of Agriculture, Forestry and Fisheries combined all shrimp, except kurma shrimp, *Penaeus japonicus* and ise-ebi, *Panulirus japonicus*, which are highly esteemed among the Japanese people and specified in the Statistics Bulletin. Catch statistics for the pandalid shrimp (Table 2) are made up from various sources and represent about 85 percent of the total landings.

TREND IN ABUNDANCE

Marked decrease in abundance is reported among *P. hypsinotus* populations off the Japan Sea coast of Hokkaido. In 1952, when the shrimping activity began in this region, the commercial catch was largely supported by *P. hypsinotus*, which was almost 75 percent of the total landings (Machida and Kosugi 1952). In recent years, the bulk of the shrimp catch (more than 90 percent) was composed of *P. borealis* (Yorita 1975). The trend in catch per unit of effort for *P. hypsinotus* by beam trawlers was presented by Kojima (1967) for the early stage of trawling activity (Figure 11d). Apparently, the *P. hypsinotus* population was not large enough to support the expanded fishery. Recent increase in total annual catch seems to be largely because shrimping grounds have expanded to deeper water and use of *P. borealis* stocks has increased. A similar situation occurs in the southern Japan Sea area off Honshyu.

So far as the commercial catch is concerned, the Okhotsk Sea region was the most productive for pandalid shrimp and a maximum of 5,474 mt were landed in 1969 (Table 2) by offshore trawlers, mostly from a restricted ground between Hokkaido and Sakhalin (Figure 5). Good catches from this ground were supported by P. goniurus stocks and maintained only until 1971 (Figure 11a). Shrimp abundance has decreased markedly since then, without restoration, probably owing to overfishing by the rapidly expanded trawling activities.

A gradual decrease in catch per unit of effort for the combined species was also noted in the shrimping grounds off the Pacific coast of Hokkaido (Figure 11b). Although total annual catch has been maintained at a relatively constant level, it is attributed mainly to the improvements of fishing intensity and expansion of fishing grounds (Abe, Sakamoto and Koike 1977).

MANAGEMENT AND REGULATIONS

All commercial fishing activities in Japan are regulated and restricted to conserve available stocks and avoid trouble with other fisheries operating nearby. Limitation of the number and size of vessels and the extent of fishing grounds are common. Closed seasons for certain periods of the year, mostly during breeding season, are also set up in many cases.

The trawl fisheries are subjected to the most severe restrictions including the use of otter boards, since they can seriously damage exploited stocks and cause trouble with other fisheries operating in the coastal areas. With regard to the inshore beam trawlers in Hokkaido, the type and size of gear and main species to be fished are also limited. Shrimp pot fishery is limited in the maximum number of pots available at a time and in other ordinary regulations.

In spite of these efforts, however, many of the Japanese fisheries have been unsuccessful in proper management of their available stocks. This failure seems to be primarily because regulation of fishing activities in Japan has been undertaken as arbitration between fisheries rather than as conservation of a particular stock. The quota system has seldom been adopted by fishery management, except in certain coastal fisheries for shellfish.

With the advent of the 200-mile fishery conservation zone, however, a nationwide survey system was established in 1977 to assess the available stocks of important fishery resources, including pandalid shrimp, in Japanese waters. The maximum allowable catch will be evaluated every year from a biological point of view. The concept of stock conservation will also be included in future Japanese fishery management plans.

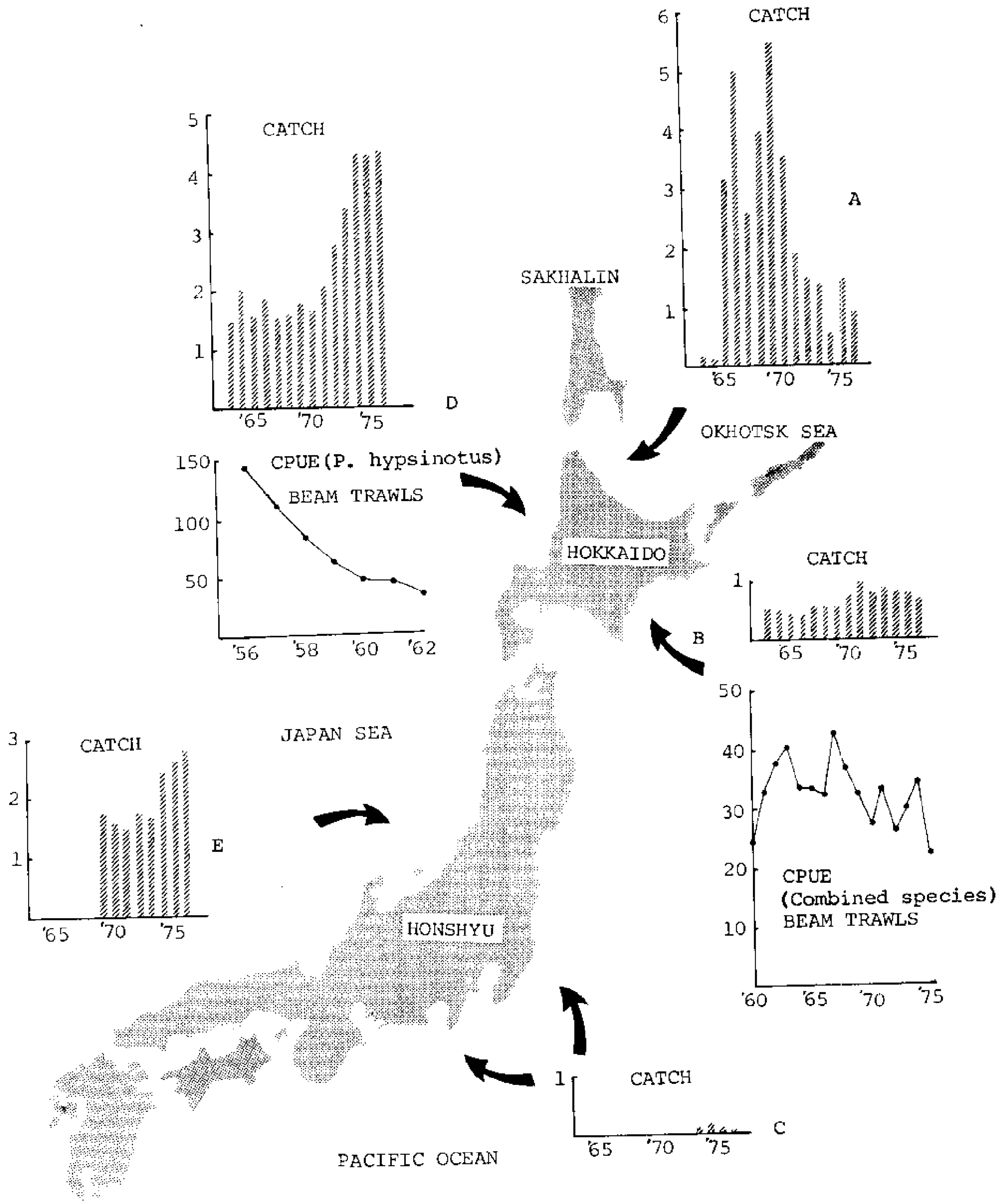

Figure 11. Regional trends in annual catch (1000 mt) and CPUE (kg per boat per day) for pandalid shrimps.

Another activity in Japan, aiming at the rebuilding and conservation of fishery stocks, is called "farming fishery" or "saibai gyogyo" in Japanese. It involves artificial mass production and release of fry and improvement and control of habitat.

We have a long history of "saibai gyogyo" in several freshwater fisheries, including domestic salmon, and in certain coastal shell fisheries. Farming activities have been expanded in the last decade to other marine fish and shellfish, including kuruma shrimp and red sea bream. The target species will increase rapidly and technical advances are expected in years to come.

Among pandalid shrimps, Pandalus kessleri, P. hypsinotus and P. borealis are being studied for possible habitat improvements and mass production of fry. The studies are still experimental. Several thousand fry have been reared each year since 1972 for behavior and environmental adaptation studies of larvae and juveniles.

BIOLOGICAL INVESTIGATIONS

PANDALUS KESSLER CZERNIAVSKI

Biometry

Biometric data were reported by several authors. According to Kashiwagi (1974a) the relationship between body length (L, mm) and carapace length (l, mm) may be expressed by the following formula:

$$l = 0.317 L - 1.0.$$

Body weight (W, g) may be expressed as a function of body length as follows:

$$W = 0.547 \times 10^{-5} . L^{3.2067}$$

Distribution

P. kessleri is endemic to northern Japan and adjacent waters. They are confined to shallow estuaries, less than 10 m of water in coastal bays and lagoons. Association with vegetation of eel-grass, Zostera marina, is well known. It occurs in commercial quantity in certain bays of eastern Hokkaido, such as Notsuke Bay, Furen Lake and Saroma Lake, extending southward intermittently as far as Yamada Bay, Iwate Prefecture at about 39° 30' N along the Pacific coast of Honshyu.

Reproduction

The ovigerous period extended for about nine months from September to June in Hokkaido, where the average water temperature was 6.5°C during egg carriage (Kubo 1951; Aoto 1952). It extended for six months or less from October to March at the southern extremity of the range, where the average water temperature was 12.6°C during egg carriage (Kashiwagi 1974b).

During the breeding season, virtually all females carried eggs in all localities studied. Some of the females may produce two broods of eggs consecutively during a lifetime, at one and two years of age. The external eggs are comparatively large, measuring across the long axis 2.3 mm when spawned and 2.6 mm in later stages. The egg counts for females from 80 to 110 mm in body length were from 140 to 320.

Growth and sexual phases

The newly hatched larvae measured an average of 8.1 mm in body length (Kurata 1955). Kashiwagi (1974a), in an ecological study of the shrimp in Yamada Bay, northern Honshyu, was able to trace the growth and sexual phase from hatching until egg carriage (Figure 12). The juveniles of 10 to 15 mm in body length appearing in his June samples, had grown at an average rate of 8 mm per month and to 50 to 60 mm by October. Quite a similar growth was observed among 0 age individuals cultured in net cages (Kashiwagi 1973; Kashiwagi and Ohkawa 1973; Kasiwagi et al. 1973). They matured and functioned as male in October, then began to change sex from December. Growth almost ceased during winter and they were centered around 65 or 70 mm in March. They were then 12 months old, and for the most part in the transitional phase.

Growth was resumed from April at an average rate of 3 mm per month. The yearlings were centered around 90 mm by October, when few males remained and and most individuals, then 19 months old, were in the female phase, and laying their first brood of eggs. They may produce another brood of eggs the following year at 2 1/2 years of age, centering around 100 or 105 mm in body length.

Some of the yearlings remained in the male phase during the breeding season, October, and functioned as male again. They were smaller than transitionals, or females, of the same age and changed into transitional phase at the end of the second year. They produced the first brood of eggs in October at age two. The age-length relationships and sexual phases of P. kessleri in Yamada Bay are summarized in Figure 13.

For the P. kessleri populations in Hokkaido, on the other hand, a different life history was reported by Kubo (1951) and Aoto (1952). Their age-length curves and sexual phases are illustrated in Figure 13b. Few shrimps mature in the

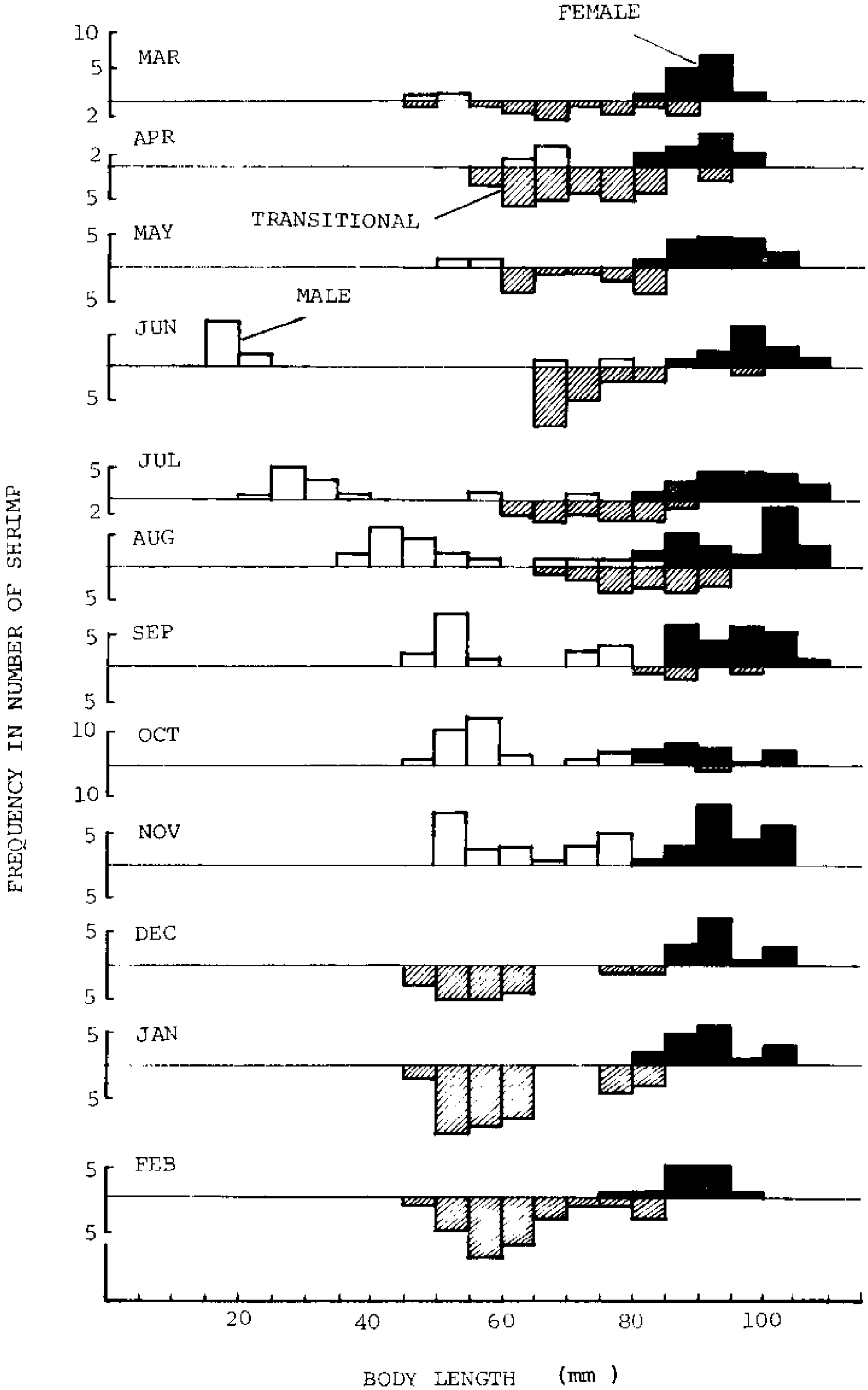

Figure 12. Pandalus kessleri length frequency distributions in Yamada Bay, northern Honshyu. Females were ovigerous from October to March. (Kashiwagi 1974b)

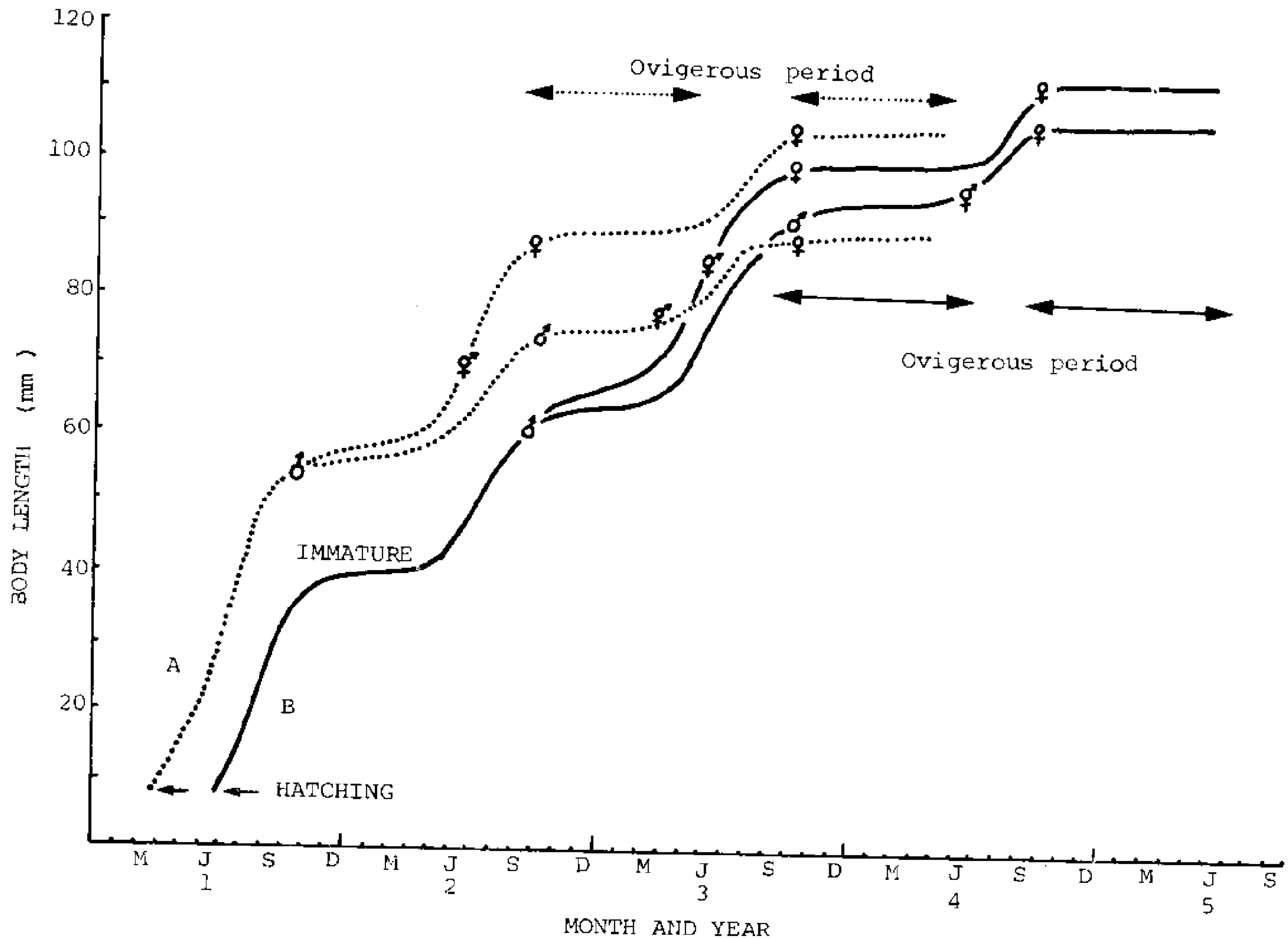

Figure 13. *Pandalus kessleri* age-length curves and sexual phases for the populations in Honshyu (A: Kashiwagi 1974b) and in Hokkaido (B: Kubo 1951, Aoto 1952).

first year, attaining a maximum body length of about 50 mm. The yearlings were sexually active and functioned as males in September. Most of them underwent sex change and produced the first brood of eggs by September of the following year. Some of them might produce another brood of eggs a year later at three years of age, attaining a maximum of about 120 mm in body length. A few males were observed among 2-year-old individuals. They changed sex at the end of the third year and produced eggs. Thus, the life history of the northern population differs from that of the southern population in sexual inactivity among 0 age individuals, the longer life span and the larger maximum size. No primary or secondary females were recognized in Hokkaido or in Yamada Bay, northern Honshyu.

Larval development

Larval stages were described by Kurata (1955) based on the materials hatched from eggs and reared beyond metamorphosis in the laboratory. The newly hatched larva was very much advanced in structure, with stout body and five pairs of functional legs (Figure 14). Exopods on three pairs of maxillipeds were setose during the first four stages, but seemed hardly effective for swimming. They usually clung to seaweeds or on the wall of rearing jars, seldom active unless frightened. The larva passed four molts within a month after hatching, then were essentially adult in all respects but size and secondary sex characteristics.

Omi and Mizushima (1972) reared the larvae at six different constant temperatures between 6° and 21°C. They found that the optimum range of temperature for rapid growth shifted from 12°C in stage one, to about 20°C in stage nine. These temperatures were strikingly similar to those observed in their natural habitat (Table 3), suggesting a probable adaptation of this species to ambient temperatures.

When the larvae were reared at different chlorinities, they showed a definite optimum range from 14 to 16 percent, within which they required a minimum number of days to reach metamorphosis (Figure 15). At chlorinities other than this range, the larvae required more time to pass through successive stages. On the other hand, adult shrimp preferred higher chlorinities than 15 ppm (Figure 16).

Food and feeding

Daily consumption of *Artemia nauplii* among stage two or three larvae, counted by Omi and Mizushima (1972), ranged from 25 to 35 at 6°C, from 65 to 70 at 12°C and was about 110 at 18°C.

Kubo (1951) observed that the stomach contents of wild adult specimens were for the most part small crustaceans and

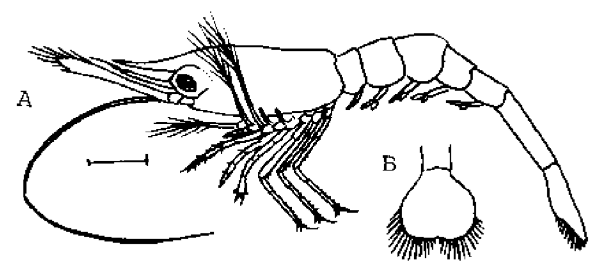

Figure 14. *Pandalus kessleri* newly hatched larva. A:lateral, B:telson. Scale denotes 1 mm. (Kurata 1955)

Table 3. Pandalus kessleri: Optimum termperatures from rearing experiments compared with ambient temperatures of natural habitat

Month	Larval and postlarval instar	Duration (in days)	Optimum temperature range in rearing exps. (°C)	Observed average temperatures in natural habitats (°C)
May	1	4-5	10-16	10.5
	2	4-5	14-18	15.6
	3	4	18-19	15.6
June	4	5-6	18-20	16.7
	5	6-7	16-18	-
	6	7	16-18	17.3
	7	6-7	17-19	17.3
	8	7	18-21	16.5
	9	5	19-22	18.1
	10	-	-	18.1

Source: Omi and Yamashita 1973.
- data not available

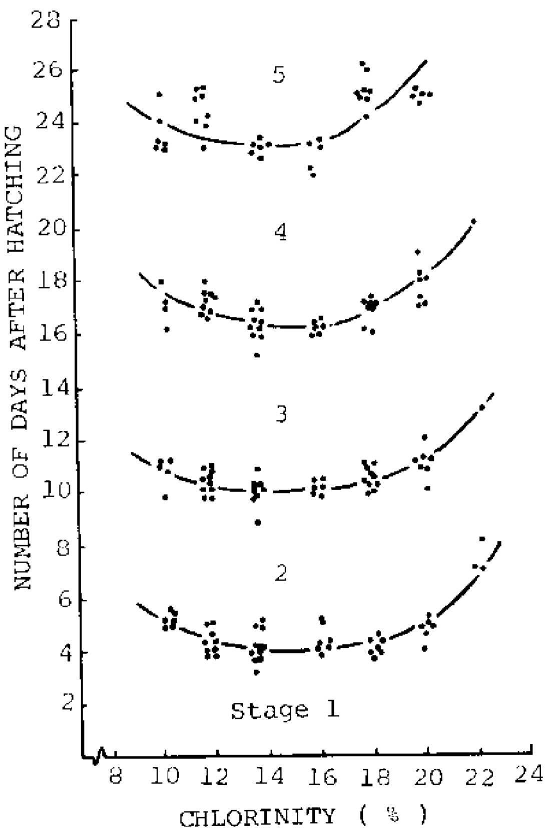

Figure 15. Pandalus kessleri variation in number of days required to reach successive stages after hatching at different salinities. (Mizushima et al. 1978)

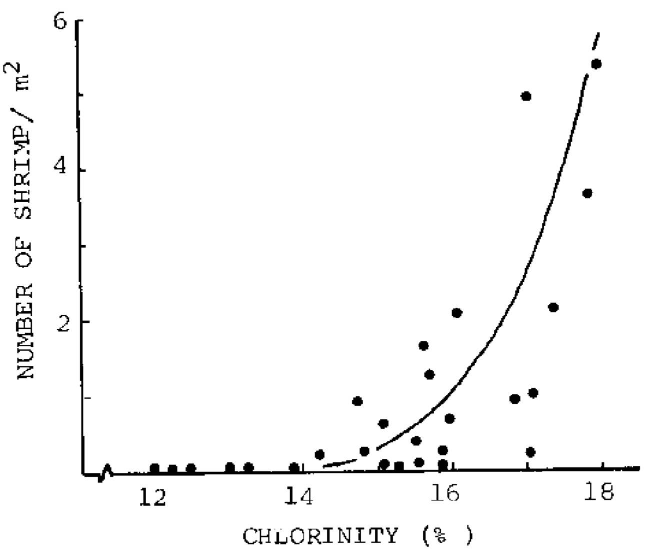

Figure 16. Pandalus kessleri variation of existing adult shrimp density with ambient salinity in Notsuke Bay, eastern Hokkaido. (Mizushima et al. 1978)

annelids. Diatoms and fragments of eel-grass and other seaweeds, detritus and sand grains were also common. Crustaceans such as small shrimp, mysids and amphipods were the major food items during growing season from July to September. Percentages of shrimp with empty stomachs were lower during spring and summer (14 to 33 percent) than during the winter (67 to 88 percent).

Culture

Exploratory attempts have been made by Kasiwagi and his coworkers since 1972 to examine the possibility of commercial culture of this species at Yamada Bay, northern Honshyu, where the maximum possible growth was expected to be similar to the southern limit of the species range.

The larvae hatched in April were reared in shore tanks and, after reaching juvenile stages, transferred in early June to floating net cages in the sea with bunches of plastic filaments inside (Kashiwagi et al. 1973, 1974). Chopped sardine and mackerel were fed to them daily. By the end of October, the shrimp were about 60 mm in body length and weighed 3.2 g. A year later, 16 months after hatching, they reached 85 mm in body length and laid viable eggs in the culture cages (Kashiwagi 1973).

PANDALUS HYPSINOTUS BRANDT

Biometry

Carapace length may be converted into body length by a factor of 3.10, and into total length by a factor of 4.23 (Igarashi 1951).

Distribution

P. hypsinotus occurs in the northern Pacific Ocean. It is common to both American and Asian waters. In Japan and adjacent waters, it occurs in association with P. borealis throughout most of the range of the latter except in southern part of Honshyu, though its habitats are relatively shallower than P. borealis.

Off the Pacific coast of Hokkaido, P. hypsinotus lives in 150 to 300 m of water, with main fishing grounds between 150 and 200 m (Sakurai et al. 1966). In Funka Bay, southern Hokkaido, it was fished from muddy bottoms within a coastal bay of 60 to 65 m of water (Kambara 1938). In the Japan Sea region, the main fishing grounds for this shrimp range from 250 to 400 m off Hokkaido (Kojima 1967; Yorita 1975), from 250 to 300 m off northern Honshyu and about 400 m off central Honshyu in Toyama Bay (Urita 1934). P. hypsinotus is seldom caught in any commercial quantity in the southern Japan Sea and along the entire Pacific coast of Honshyu. The depth range is definitely deeper in the Japan Sea than in the Pacific Ocean (Figure 6).

Reproduction

Period of egg carriage was studied for the Japan Sea population off Hokkaido by Kurata (1957a) by measuring the length of abdomen of the developing embryos throughout the year (Figure 17). It was concluded from this data that hatching would take place once a year, for the most part during April, and laying of the new brood eggs during the period from May to June. Thus, the duration of ovigerous period was 10 to 11 months. Very few non-ovigerous females were represented in the samples taken during the period from September to March. On the other hand, no females were found to have developing ovaries while carrying external eggs. After hatching of eggs, they were fairly well represented in the commercial catches until June, but virtually disappeared thereafter without any sign of gonadal maturation, suggesting a heavy mortality during summer. Most of the females, then, seemed to produce only one brood of eggs. The ovigerous population seemed to be newly recruited every year from the last stage males which underwent sex change during winter and early spring before egg laying.

Quite a different breeding pattern was observed for P. hypsinotus population in deep water off the Pacific coast of Hokkaido where Sakurai et al. (1958) found a large number of non-ovigerous females throughout the year. These were an average of 60 percent of the total females, and were estimated to be about 30 percent or more of the spawning population in the following season. They also found some of the females had mature ovaries while still carrying external eggs. The ovigerous period extended for about ten months, from June or July to February or March, with a considerable variation from year to year.

A much shorter ovigerous period was reported for the coastal population of P. hypsinotus in Funka Bay, southern Hokkaido, where Igarashi (1951) observed it extended for only six months, from September to February. Presence of a considerable number of ovigerous females with fully mature ovaries let him infer the possibility of spawning twice a year. The evidence, however, was not conclusive.

The egg counts for females from 30 to 50 mm in carapace length were 1,000 to 9,000 (Kurata 1957a). The egg was slightly elliptical and measured across the long axis 1.5 mm when spawned and 1.8 mm just before hatching (Sakurai et al. 1958).

Growth and sexual phases

The juveniles ranging in carapace length from 4.5 to 8.5 mm were captured in early June and August with bundles of cedar twigs submerged at 34 to 51 m off the Japan Sea coast of Hokkaido (Yorita 1969). They were then about four months old.

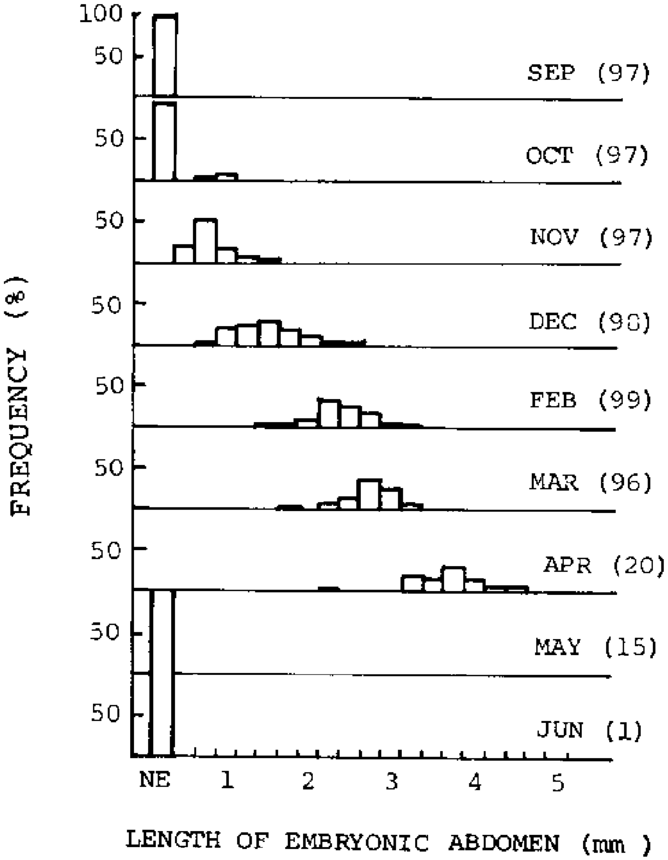

Figure 17. Pandalus hypsinotus development of embryos expressed by monthly shift in abdominal length compositions. Percentages of ovigerous among total females given in parenthesis. NE: no eye pigmentation. (Kurata 1957a)

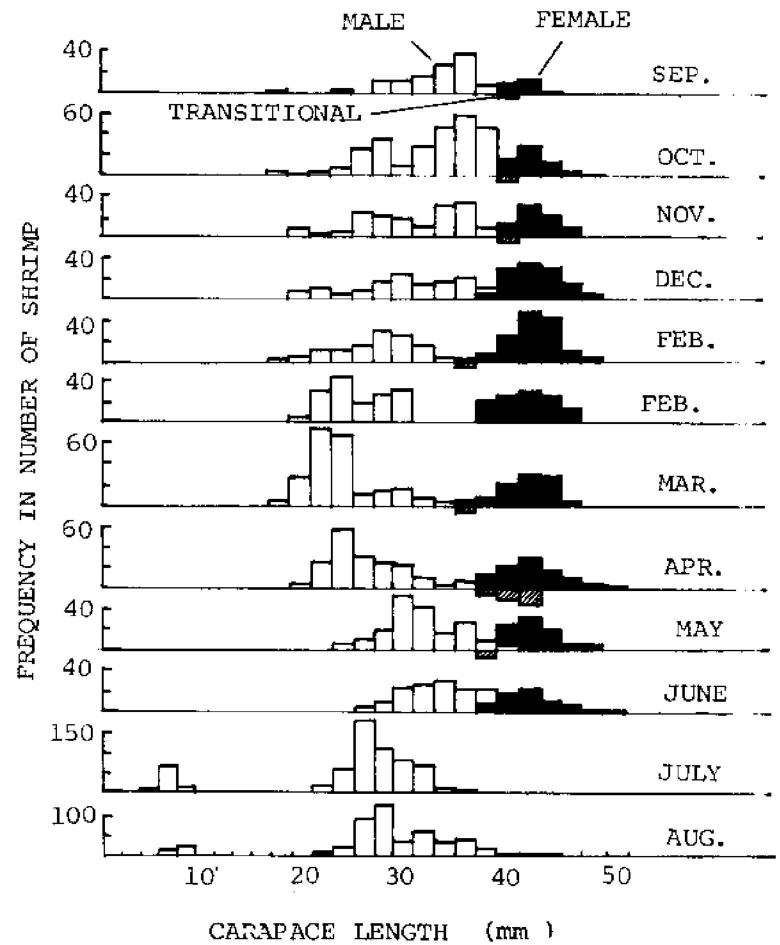

Figure 18. Pandalus hypsinotus length-frequency distributions of samples trawled off the Japan Sea coast of Hokkaido, from September 1955 to August 1956. (Juvenile data from Yorita 1969)

Samples taken from commercial catches operating off the Japan Sea coast of Hokkaido are graphed in Figure 18. The 0 age individuals first appeared in substantial quantity in February when they were about ten months old and centered between 22 and 24 mm in carapace length. They could be traced until December of the third year, centered at 36 mm and at about 2 3/4 years of age. Then they began to change sex and disappear from the commercial catch. They appeared again from April or May as transitional individuals or newly ovigerous females. The ovigerous females, then 3 years old, are apparently composed almost exclusively of a single age group. Age-length curves and sexual phases are summarized in Figure 19. Hermaphroditism seemed to be complete and no primary or secondary females were found.

Kurata (1957a) analyzed the sexual activity of males by measuring the percentage length of appendix masculina to that of endopod of second pleopod (AMP). The maximum AMP value reached 58 percent but usually centered at 48 or 50 percent during the breeding season from May to August, and between 44 to 46 percent during the rest of the year (Figure 20). The males seemed to become sexually active during breeding season at ages 1 and 2. The average AMP values were definitely greater in age 2 males than in age 1 males. Age 2 males still kept relatively high AMP values until December, however, their gonads were already filled with young oocytes and no traces of spermatocytes were detected.

The soft shell females were found only in May and June after hatching their external eggs. In males, molting occurred throughout the year except during mating season from May to August.

The sexual phases were more complicated among P. hypsinotus populations off the Pacific coast of Hokkaido, where Igarashi (1951) and Sakurai et al. (1958) found 1 1/2 year old transitional individuals, 2-year-old females, and 3-year-old males (Figure 21). The bulk of the breeding females were made up of 3-year-old individuals as among the Japan Sea populations.

Food and feeding

Kurata (1957a), from the observations of the stomach contents of specimens taken from commercial trawl catches, found that amphipods and other small crustaceans were the main food items in spring and summer, while annelids made up a bulk of stomach contents in autumn and winter. Small bivalves, gastropods and ophiuroids were common throughout the year in small quantities. Scales and bones of fish were found from time to time. Mud and sand were also common. No vegetable

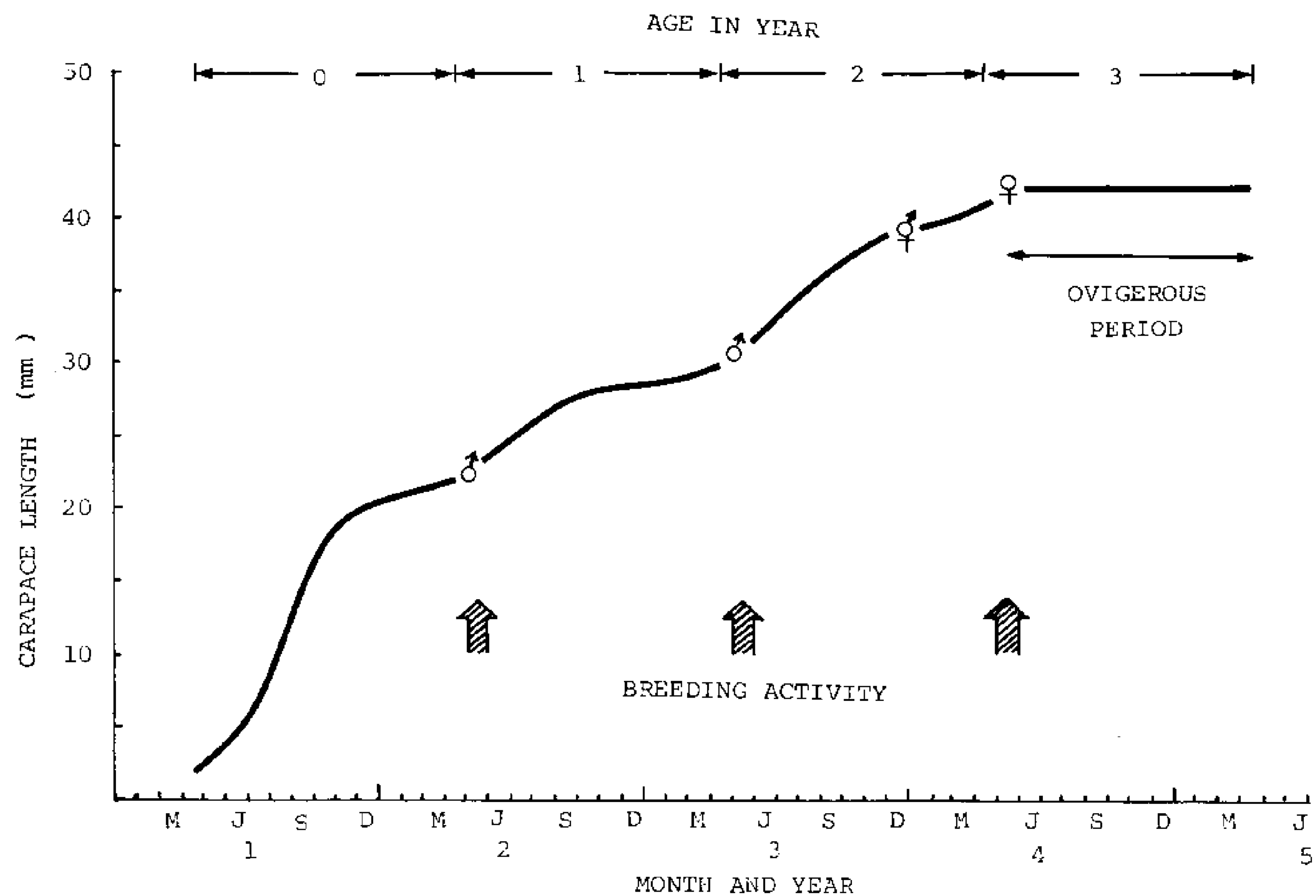

Figure 19. *Pandalus hypsinotus* age-length curve and sexual phases for the population off the Japan Sea coast of Hokkaido. (Kurata 1957a)

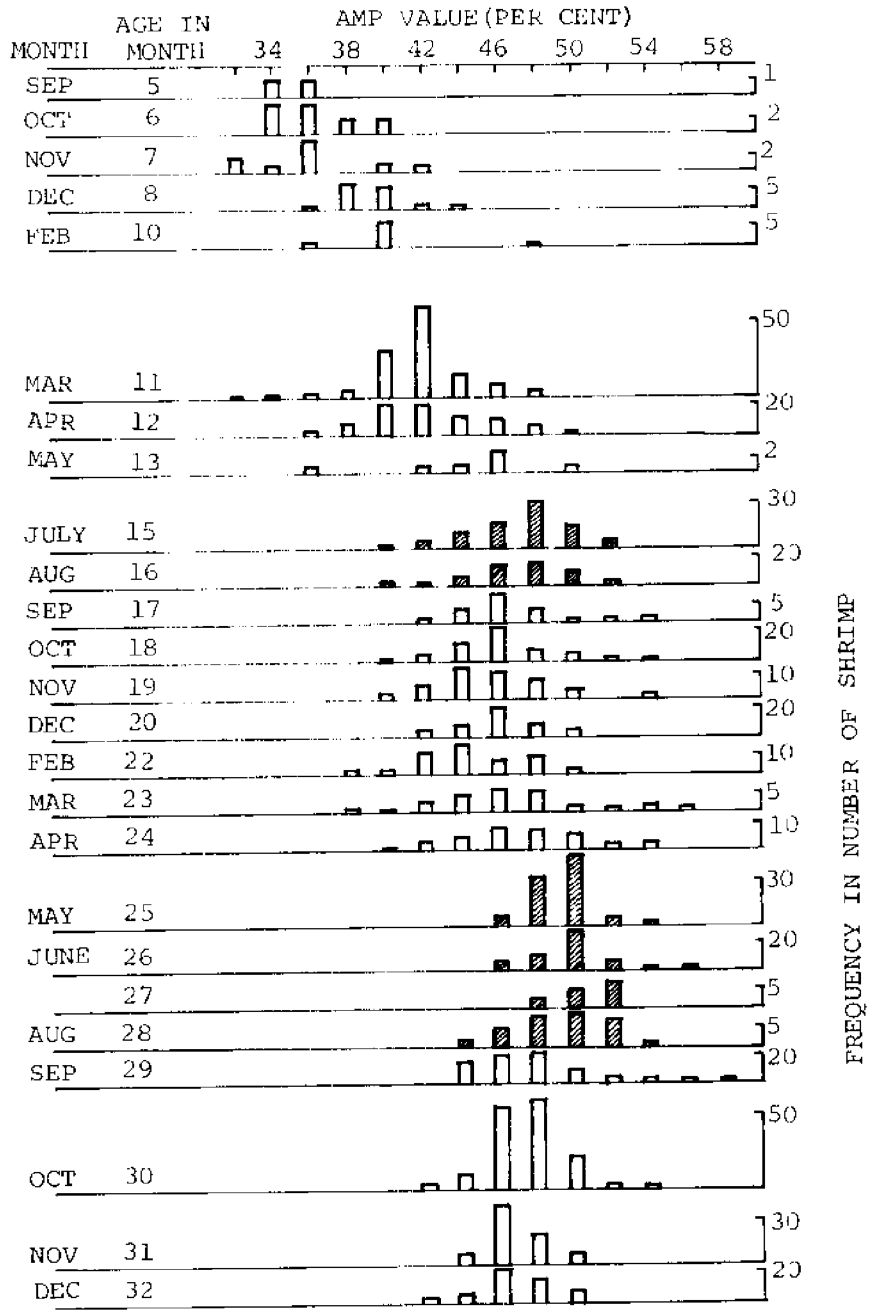

Figure 20. Pandalus hypsinotus variation of AMP values among males with age and season of the year. Note higher average values during breeding season from May to August. (Kurata 1957a)

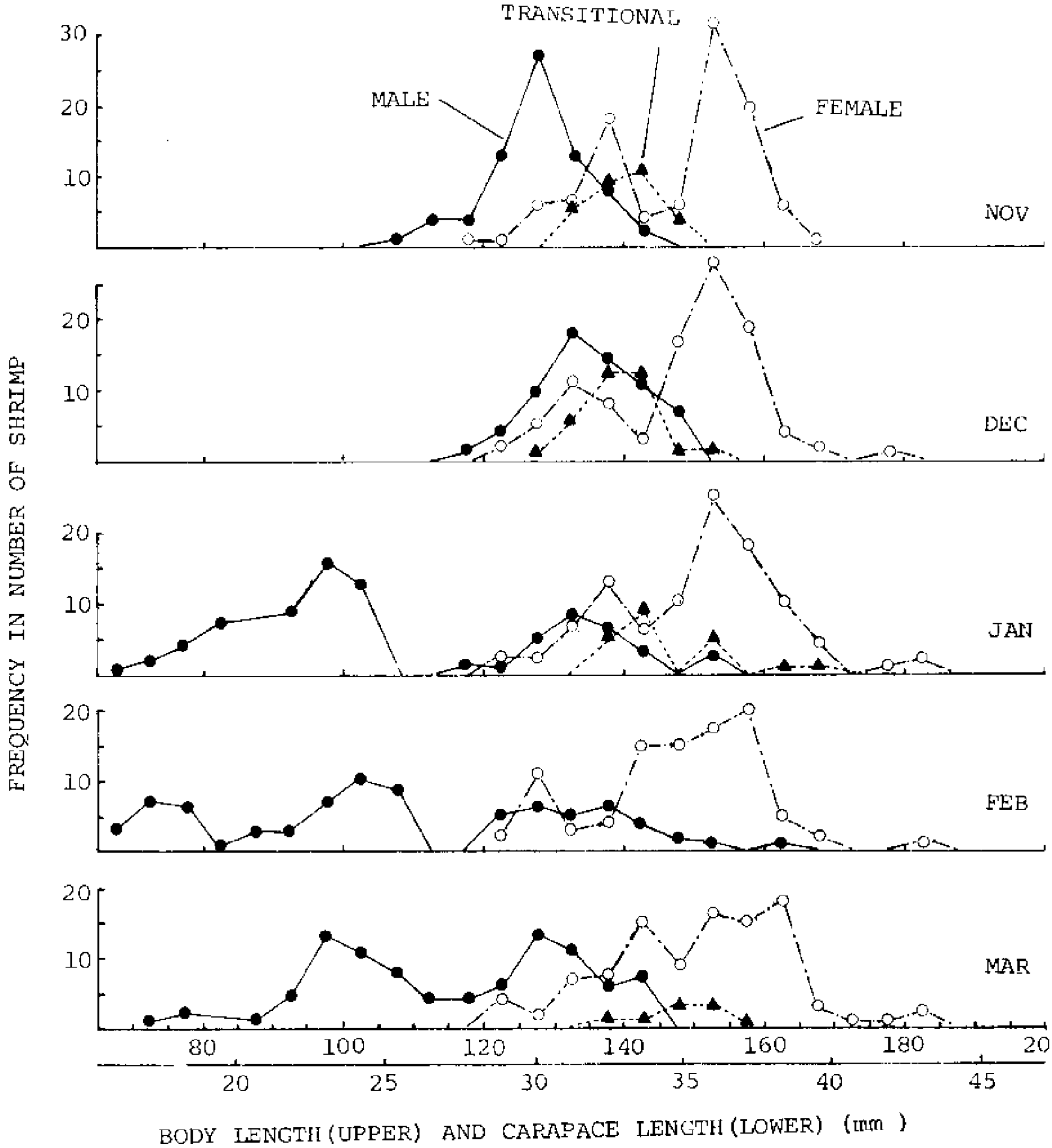

Figure 21. *Pandalus hypsinotus* length-frequency distributions of samples taken from Funka Bay, southern Hokkaido from November 1948 to March 1949. (Igarishi 1951)

materials were recognized. An average of 50 percent males and 75 percent females had empty stomachs at any time of the year.

Larval development

Larvae are planktonic and pass five or six stages before metamorphosis. Larval characteristics were described by Kurata (1964). The newly hatched larva is about 5.5 mm in total length and slightly smaller than P. borealis. The first post-larva measured 11.5 mm in total length. The larva may be distinguished from that of P. borealis by the absence of exopod on leg three (Figure 22).

Omi and Yamashita (1975) reared the larvae from eggs in the laboratory at several different constant temperatures from 7° to 21°C. The larval development was completed markedly earlier at higher temperatures than at lower temperatures (Figure 23). The minimum duration from hatching until metamorphosis was 21 days at 18°C, while an average of 53 days were required at 7°C. The rate of molt acceleration per unit increase of temperature was much more exaggerated at lower than at higher ranges. The optimum range of temperature for rearing was from 9° to 12°C with respect to the survival rate and the number of molts to reach post-larva. The larva changed into post-larva after passing five molts at lower temperatures of 9°C or less, while an additional sixth stage was observed when they were reared at 15°C and higher temperatures.

Planktonic larvae were obtained by Kurata (1964) and Abe (1968) by oblique tows of plankton nets in the coastal waters off the Japan Sea coast and off the Pacific coast of Hokkaido. Stage one larvae were found in offshore waters near the habitats of adults. Later stage larvae, however, were found in the coastal waters close to shore. The maximum concentration was observed two to four miles from shore in about 20 m of water (Figure 24), where water temperatures ranged from 51° to 11.0°C and salinity from 27.50 to 31.18 ppm. Their distribution tended to be more concentrated and closer to shore than that of P. borealis (Figure 33). Yorita (1969) found a juvenile population of this species in relatively shallow water ranging from 32 m to 51 m in depth, three to seven miles from shore off the Japan Sea coast of Hokkaido, where the water temperatures ranged from 6.3° to 11.8°C and salinity from 29.70 to 34.00 ppm.

Fry production

Experimental studies for the mass production of juveniles for the farming purposes have been carried out since 1972 at the Hokkaido Fisheries Farming Center by Omi and Yamashita (1973-1978). About five to 12,000 juveniles were reared from eggs each year. The larvae were fed Artemia nauplii

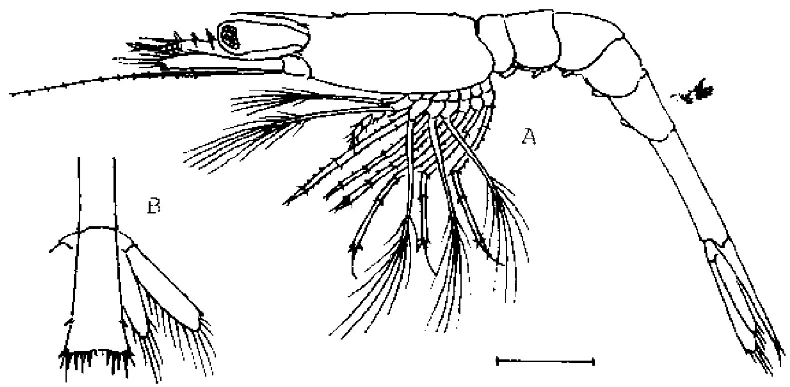

Figure 22. _Pandalus hypsinotus_ stage 3 larva. A: lateral, B: telson,dorsal. Scale denotes 1 mm. (Kurata 1964)

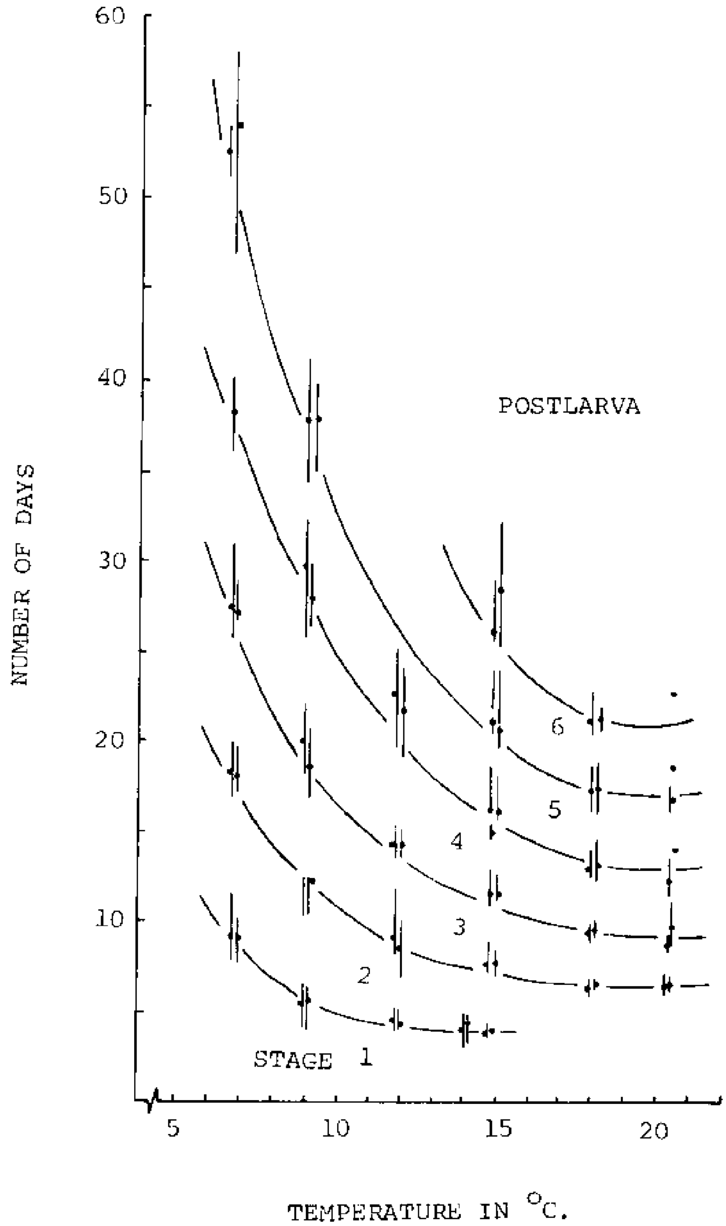

Figure 23. Pandalus hypsinotus variation in number of days required by larvae to reach successive stages after hatching at different constant temperatures. An extra stage 6 is passed at 15° and higher temperatures. (Omi and Yamashita 1975)

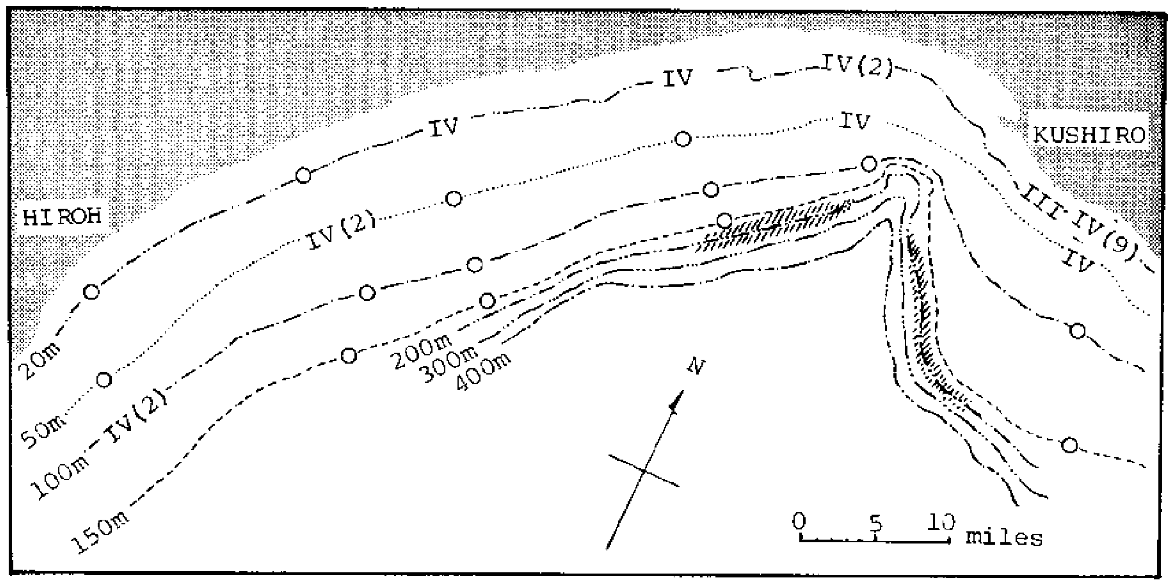

Figure 24. Pandalus hypsinotus distribution of planktonic larvae off the Pacific Ocean coast of eastern Hokkaido. Circles: sampling stations where no P. hypsinotus were found, Roman numerals: developmental stage of larvae captured, Parens: where two or more larvae were captured. (Abe 1968)

and rotifers. Stage one larva consumed 31 to 38 *nauplii* per individual per day. Feeding was more active at night than during daytime (Figure 25). At optimum temperatures from 9° to 12°C, the first post-larva was reached within 30 or 40 days after hatching. Juveniles were cultured in shore tanks by feeding chopped clam meat. They attained an average of 60 mm in body length and 3.5 g in weight 12 months after hatching, and 90 mm in body length and 12 g in weight within 24 months. Those hatched in January, 1973 had matured in August, 1975 and laid viable eggs in September when kept together with 1 and 1/2-year-old males hatched in January 1974. Thus, the life history of *P. hypsinotus* was completed in captivity.

PANDALUS BOREALIS KRØYER

Biometry

According to Ito (1976) the relationship between body length (L, mm) and carapace length (l, mm) may be expressed by the following formulae:

Males and transitionals: $L = 5.7910 + 3.8476\,l$
Females: $L = 17.0932 + 3.4543\,l$.

Body weight (W, g) may be expressed as a function of carapace length (l, mm) as follows:

Males and transitionals: $\log W = -3.3176 + 3.0942 \log l$
Females less external eggs: $\log \bar{W} = 2.4628 + 2.5028 \log l$.

Distribution

P. borealis is common to circumpolar waters. In Japan, it occurs in commercial abundance around Hokkaido, along the Japan Sea coast of Honshyu and on isolated offshore banks. The center of abundance is usually from 200 to 300 m of water off the Pacific coast of Hokkaido, though it shifts to 300 to 400 m during summer months. Sakurai et al. (1966), observed the most productive grounds ranging from 300 to 500 m. The main fishing grounds are distinctly deeper in the Japan Sea region than in the Pacific Ocean region (Figure 6). It is reported by Yamada and Naiki (1976) that the egg bearing females moved during autumn toward relatively shallow waters within the above range, while the rest of the population remained in deeper water more than 400 m. Concentration of *P. borealis* populations on the offshore banks was also observed within a similar depth range (Hamauzu 1972).

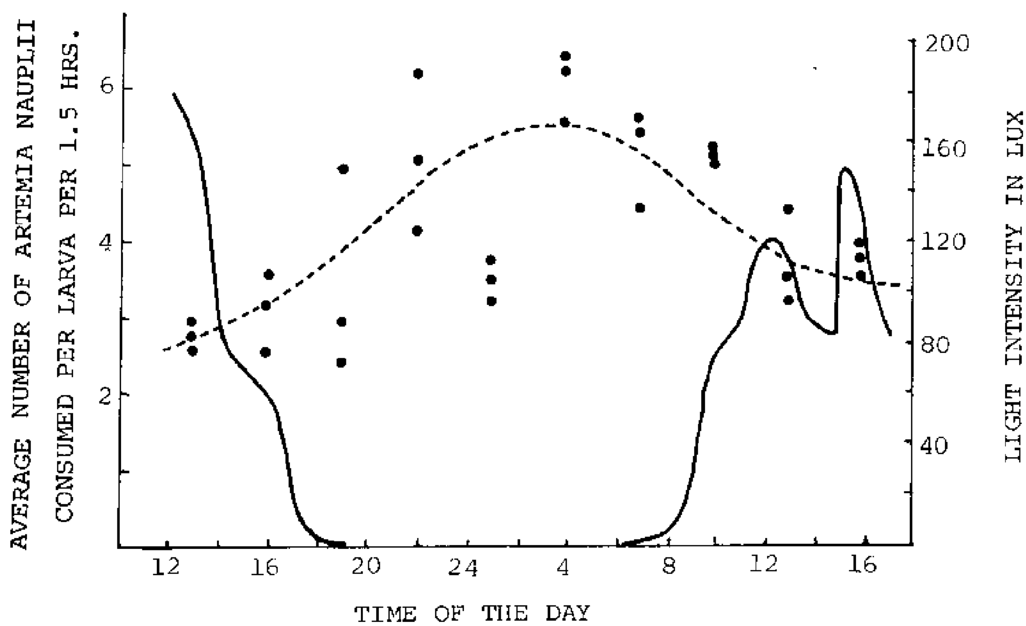

Figure 25. *Pandalus hypsinotus* daily variation in feeding activity in stage 1 larvae (circles, dotted line) associated with change in light intensity (solid line). (Omi and Yamashita 1973)

Reproduction

The length of ovigerous period was studied for several populations in different localities. Off the Japan Sea coast of Hokkaido, Kurata (1957b), by the analysis of embroyonic development, estimated it extended nine to ten months from May or June to February or March (Figure 26). For the populations off the Japan Sea coast of Honshyu, Ito (1976) claimed an ovigerous period of ten to 12 months extending from March or April to January or March. On the other hand, among populations off the Pacific coast of Hokkaido, Abe (1967) and Hayashi (1967) reported that spawning occurred in early July and hatching in February or March with an ovigerous period of only eight or nine months. The observed local variation in the timing and duration of ovigerous period is probably related to the ambient temperatures these shrimp populations are exposed to.

Among the Japan Sea populations, complete absence of ovigerous females with developing ovaries was reported by Kurata (1957b), Ito (1976) and Yamada and Naiki (1976). They observed a considerable number of non-ovigerous females with developing ovaries during breeding season. These were as much as 40 percent of total females. It was concluded, therefore, that a female would produce two or more broods of eggs in every other year. Yamada and Naiki (1976), based on the analysis of secondary sex characters, claimed that some of the females would produce as many as three broods during their lifetime.

Among the Pacific populations, on the other hand, Sakurai et al. (1958) observed as much as 63 percent of total ovigerous females having developing ovaries in March, strongly suggesting spawning in consecutive years. The non-ovigerous females comprised only 10 percent or less among the total females during the breeding season. It is worthwhile to mention here that the duration of egg carriage is considerably shorter among the population in this region than those of the Japan Sea.

The egg counts were reported to vary from 500 to 3,000 (Kurata 1957b), from 1,700 to 2,600 (Sakurai et al. 1958) and from 1,000 to 7,000 (Yamada and Naiki 1976). Generally, more eggs are carried by larger females than by smaller ones, though there is a considerable variation between individuals of the same size (Figure 27). Loss of eggs during development was claimed by Ito (1976), who found the average egg counts decreasing with development of embryos (Table 4). The egg is elliptical and measures across the long axis about 1.2 mm when spawned and 2.1 mm just before hatching.

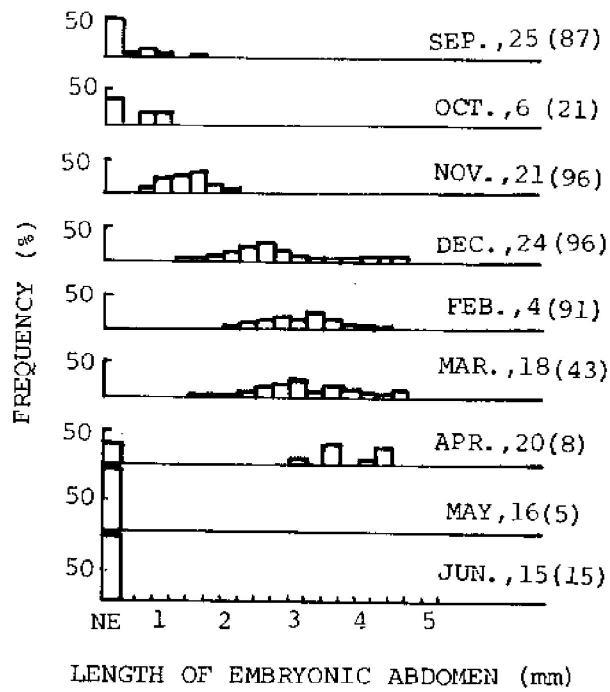

Figure 26. *Pandalus borealis* development of embryos expressed by monthly shift in abdominal length compositions. Percentages of ovigerous among females in parenthesis. NE: no eye pigmentation. (Kurata 1957a)

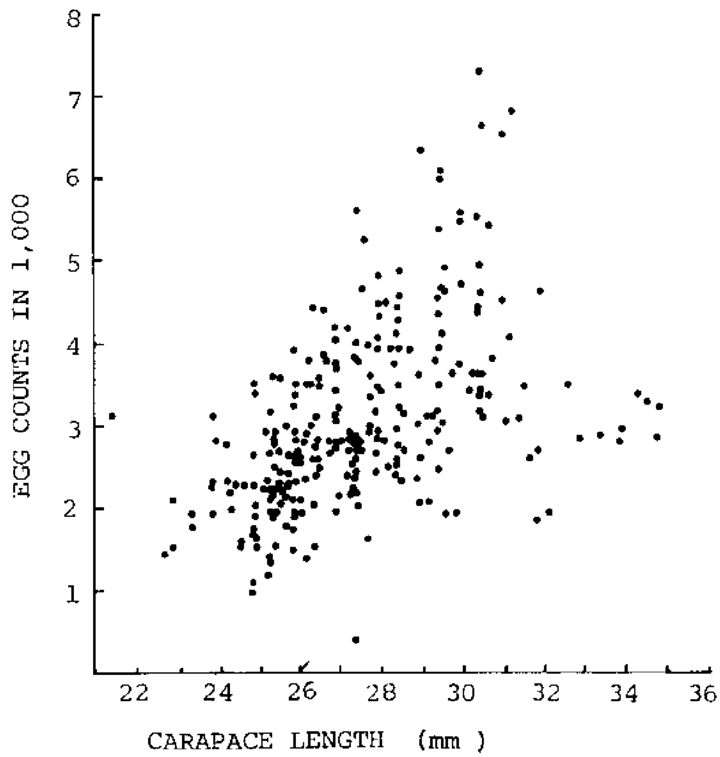

Figure 27. Pandalus borealis external egg counts plotted against carapace length. (Yamada and Naiki 1976)

Table 4. *Pandalus borealis*: seasonal variation in average egg counts

Month	Average egg counts	Approx. no. of months after egg laying
April - June	2,549	2 - 4
July - September	2,090	5 - 6
October - December	2,084	7 - 9
January - March	1,865	10 - 12

Source: Ito 1976.

Growth and sexual phases

The growth and sexual phases of *P. borealis* were studied by Ito (1976) and Yamada and Naiki (1976) off the Japan Sea coast of Honshyu. The results of their study are summarized in Figure 28. It was claimed that shrimp attain 15, 20, and 25 mm in carapace length at two, three and four years of age, respectively. Commercial catches usually ranged from 15 to 37 mm in carapace length and the 0 and 1-year-old individuals were rarely represented in their samples (Figure 29). The shrimp seemed to mature as male when 2 years old, since the minimum mature male was 16 mm in carapace length. They spent another year as male and then changed sex during the summer of the fourth year (Figure 30). The transitional individuals were always represented by a single size group centered around 25 mm, while two or three size groups were recognized among the females. Yamada and Naiki (1976) claimed, based on the analysis of secondary sex characters, that the Japan Sea population of *P. borealis* would live as long as nine years.

A much faster growth but a shorter life span was reported by Sakurai et al. (1966) and Abe (1967) for the Pacific population off Hokkaido, where the shrimp was estimated to attain 17.5 mm in carapace length within one year after hatching and to function as male. However, available data were not sufficient to draw a final conclusion.

Presence of primary and secondary females were seldom recognized among *P. borealis* populations in the Japanese waters. Ito (1976) found in his May samples three individuals of 20 to 22 mm in carapace length showing female characteristics. One of them carried external eggs. These individuals might represent primary or secondary females. The occurrence of these individuals, however, is apparently very scarce throughout Japanese waters.

Food and feeding

Stomach contents of *P. borealis* trawled off the Japan Sea coast of Hokkaido were composed of fragments of small crustaceans, bivalves, ophiuroids and annelids in the order of frequency of occurrence. Scales of fishes were also found in some specimens. Mud and sand were quite common, but no vegetable materials were found (Kurata 1957b).

Larval development

Larvae of *P. borealis* are planktonic, about 6 mm in total length at hatching (Figure 31). Seven stages were recognized by Kurata (1964) among the larvae obtained from plankton. Stage seven was considered to be the last larval stage based on the characters of the next stage larva seen through the integument of the specimens about to molt. Omi and

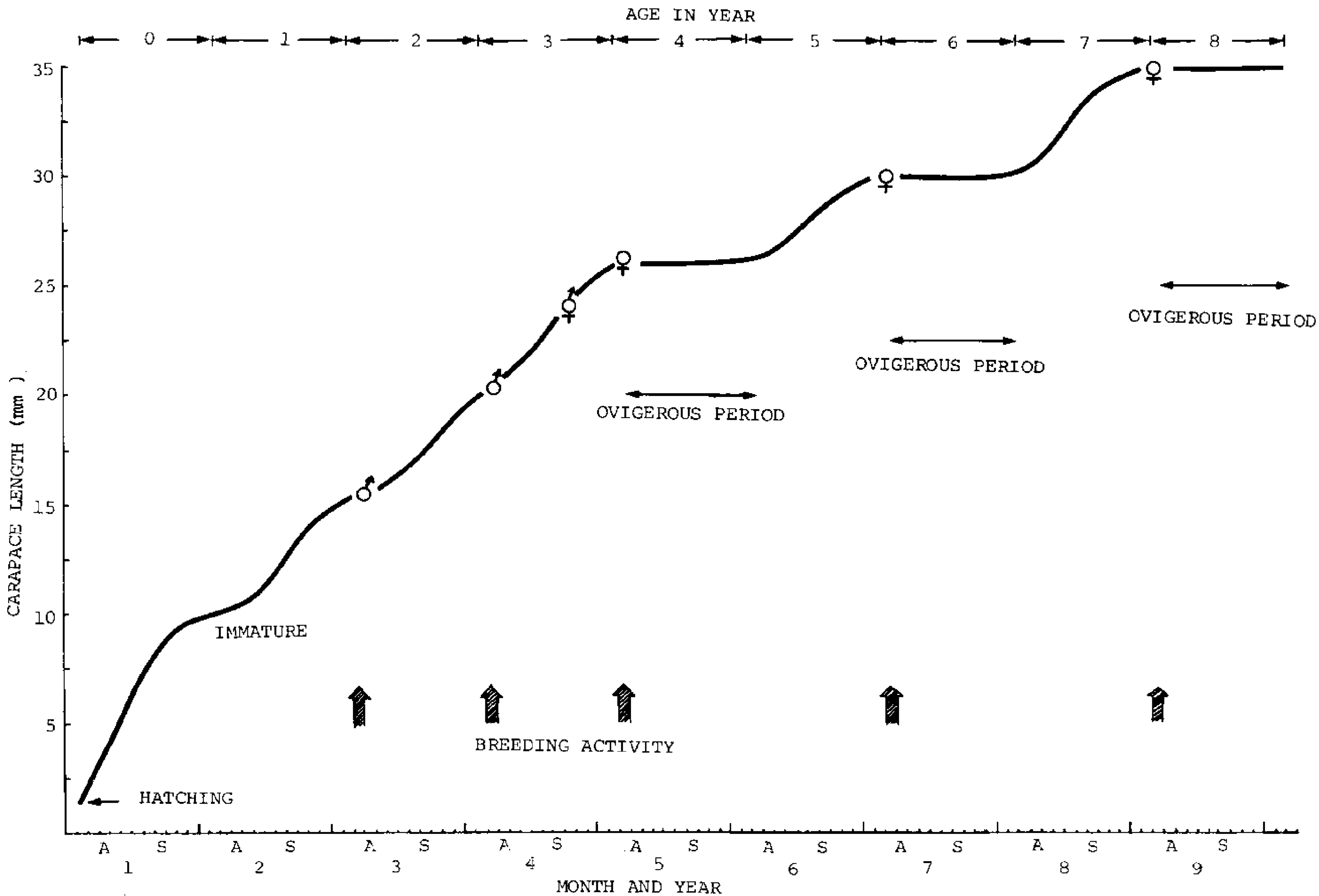

Figure 28. Pandalus borealis age-length curve and sexual phases for the population off the Japan Sea coast of Honshyu. (modified after Yamada and Naiki 1976)

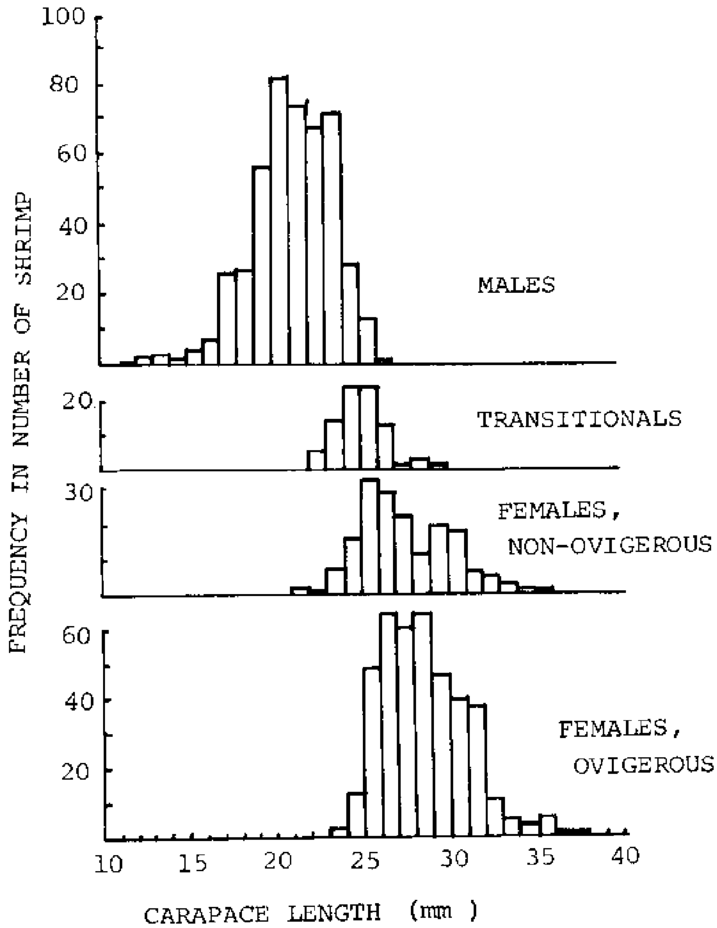

Figure 29. Pandalus borealis combined length-frequency distributions of samples trawled off the Japan Sea coast of Honshyu from October to December, 1973 and 1974. (Yamada and Naiki 1976)

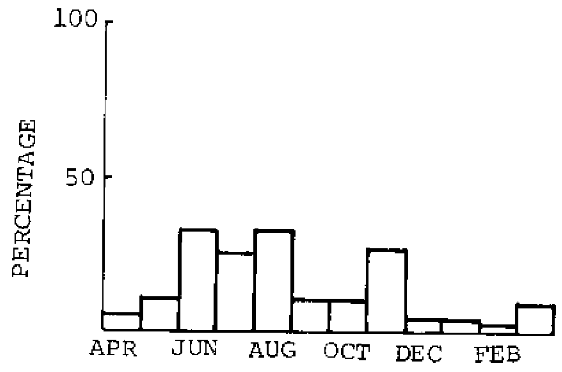

Figure 30. Pandalus borealis percentage ocurrence of transitional individuals among combined samples of males and transitionals taken off the Japan Sea coast of Honshyu.

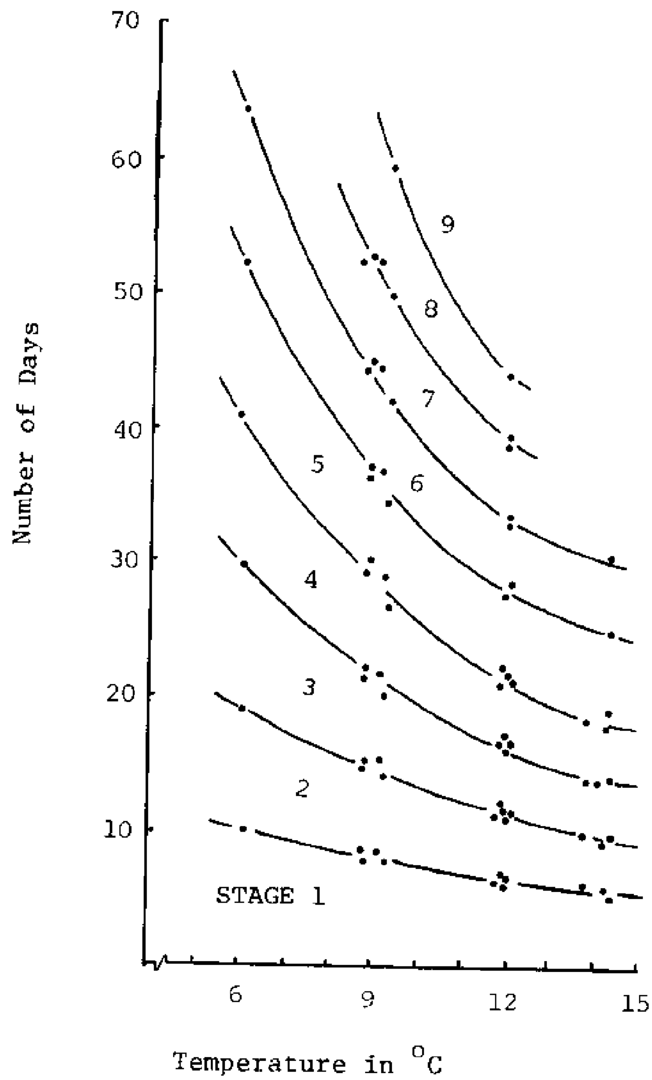

Figure 31. Pandalus borealis variation in the number of days required by the larvae to reach successive stages after hatching at different constant temperatures. (Omi and Yamashita 1978)

Yamashita (1977), on the other hand, found as many as nine larval stages when they reared the larvae from eggs in the laboratory. Duration of larval life varied greatly with temperature. Thus, the larva attained stage seven in 33 days at 12°C, while 63 or 64 days were required to reach the same stage at 6.1°C (Figure 32).

The distribution of planktonic larvae were studied by Kurata (1964) and Abe (1968). The larvae occurred widely in the coastal and offshore waters off the Japan Sea and the Pacific Ocean coast of Hokkaido (Figure 33). The greatest concentration was observed at 40 or 50 m of water and from 5 to 13 miles off shore, where water temperatures ranged from 4.7° to 12.2°C and salinity from 26.7 to 32.3 ppm. They seemed to adopt benthic existence mainly in the areas from 50 to 100 m of water, much shallower than habitats of adults.

Fry production

The mass production of fry by rearing them from eggs in the hatchery was attempted recently with a hope of improving local shrimp yield by releasing them in appropriate nursery areas. Pioneer experiments were undertaken by Kato (1974, 1975) at the Niigata Fisheries Farming Center and by Omi and Yamashita (1976, 1978) at the Hokkaido Fisheries Farming Center. The experiments were carried on in small scales.

PANDALOPSIS OCHOTENSIS KOBJAKOVA

Biometry

The carapace length may be converted into body length by a factor of 3.82, and into total length by a factor of 5.33 (Urita 1941a).

Distribution

P. ochotensis, once known as *P. occinata* Urita in Japan, occurs in commercial quantity off the Pacific coast of Hokkaido. It is also reported from the Okhotsk Sea in small quantity. It is endemic to these waters and is fished from deep waters of 300 to 600 m. The greatest concentration is usually found between 400 and 500 m (Sakurai et al. 1966).

Reproduction

Ovigerous period was estimated by Abe (1965) to extend for about 22 months. The evidence was obtained by tracing the development of embryos attached to the pleopods of females (Figure 34). Mature females about to molt for breeding and the soft shell females with newly laid eggs were found from April to August with a peak occurrence in June. Hatching was observed for the most part from March to May.

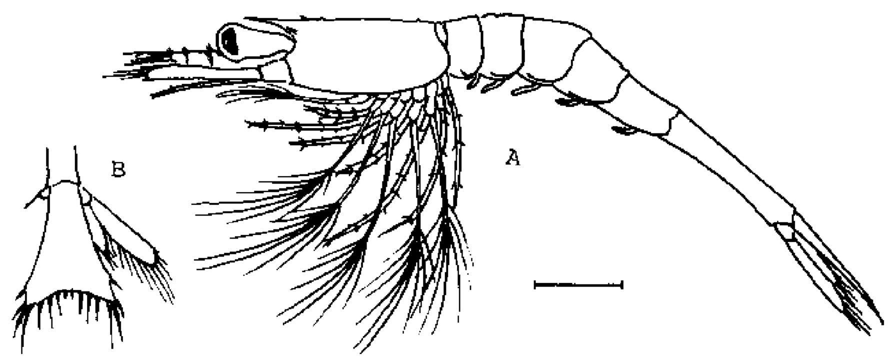

Figure 32. Pandalus borealis stage 3 larva. A:lateral, B: telson, dorsal. Scale denotes 1 mm. (Kurata 1964)

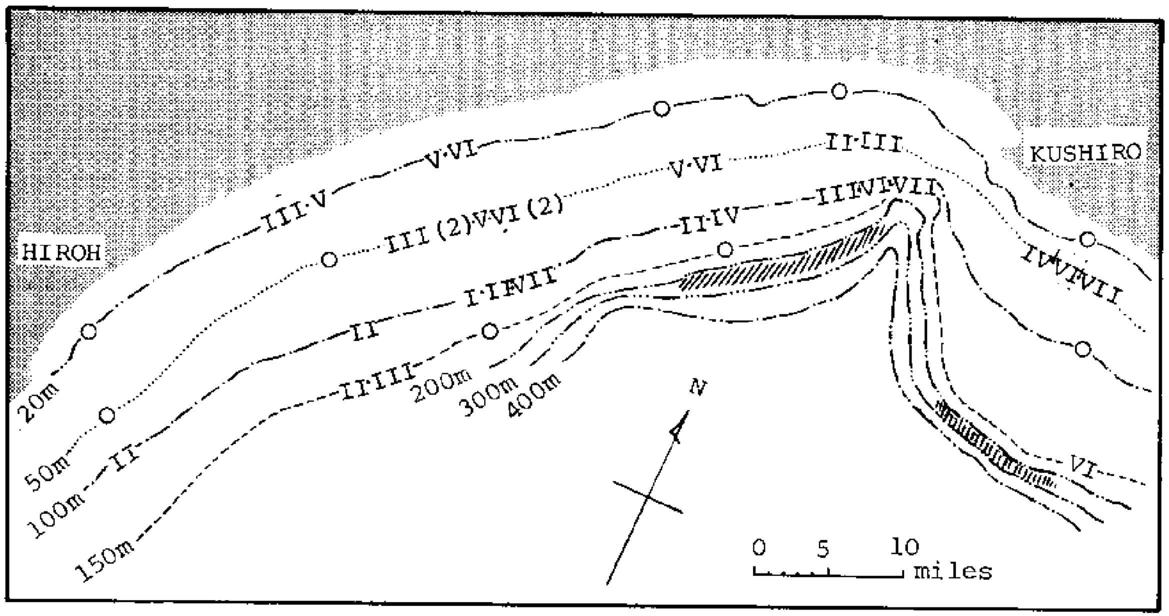

Figure 33. *Pandalus borealis* distribution of planktonic larvae off the Pacific Ocean coast of Hokkaido as in Figure 20. (Abe 1968)

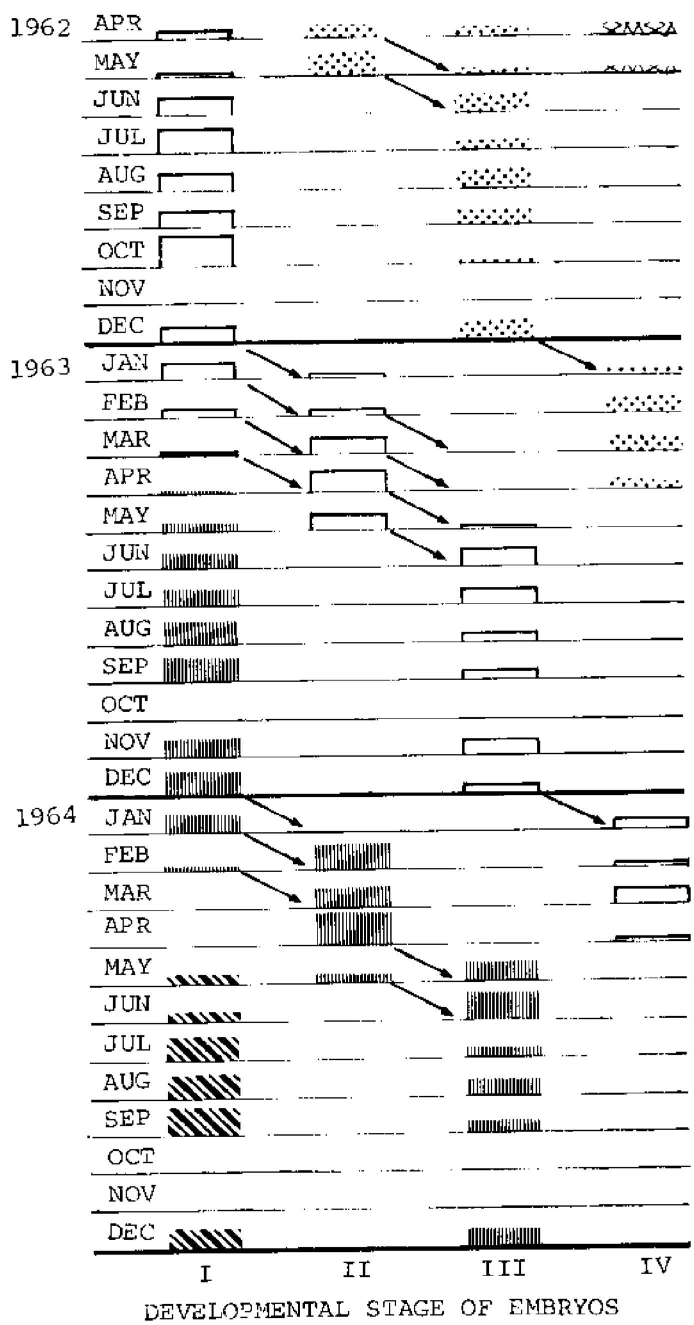

Figure 34. Pandalus ochotensis embryonic development showing duration of ovigerous period. Stage 1: no eye pigmentation, Stage 2: eye pigmentation, abdomen does not reach cornea of eye, Stage 3: abdomen reaches but does not exceed cornea, Stage 4: abdoment extends beyond cornea. (data from Abe 1965)

New recruitment of breeding females was about 70 percent of the total ovigerous females, with a little annual variation. The rest of the ovigerous population was supposed to be the survivors of breeding females during the previous season.

The eggs are very large in size and measure across the long axis about 3.7 mm when spawned and 4.9 mm just before hatching. The egg counts range from 160 to 250 with an average of 200 for females from 35 to 42 mm in carapace length (Sakurai et al. 1958).

Growth and sexual phases

A slow growth was estimated by Sakurai et al. (1966) for this species in the Pacific Ocean off Hokkaido by regular samplings from commercial catches. During breeding season in June, male specimens were usually made of four size groups (Figure 35). These were considered to represent different age groups because of their consistent occurrence. Thus, the shrimp was estimated to attain about 17 mm, 20 or 22 mm, 26 or 28 mm, and 30 or 32 mm in carapace length at ages 1, 2, 3 and 4 respectively. After functioning as a male during the breeding season in the fifth year, the shrimp changes sex and produces the first brood of eggs when 5 years old attaining from 35 to 37 mm in carapace length. An ovigerous period is believed to extend for about two years. Some of the shrimp may live as long as nine years, producing another brood of eggs. The growth and sexual phases of this shrimp are summarized in Figure 36.

Larval development

The newly hatched larva was described by Kurata (1964). It is 15.5 mm in total length, 6.2 mm in carapace length, and essentially adult in all respects but eye stalks, antennules and telson in which larval characteristics are retained (Figure 37). The five pairs of legs look sufficiently stout and rigid for locomotion and clinging. There are no setose exopods for swimming. They seem, upon hatching, to adopt benthic existence without planktonic life.

PANDALOPSIS _JAPONICA_ BALSS

Biometry

The relationship between body weight (W, g) and carapace length ($\underline{l}$, mm) may be expressed by the formula:

$$W = 0.001524\ \underline{l}^{2.8559}$$

and between body length (L, mm) and carapace length by the formula:

$$L = 3.5318\ \underline{l} + 15.3656 \text{ (Ito 1978)}$$

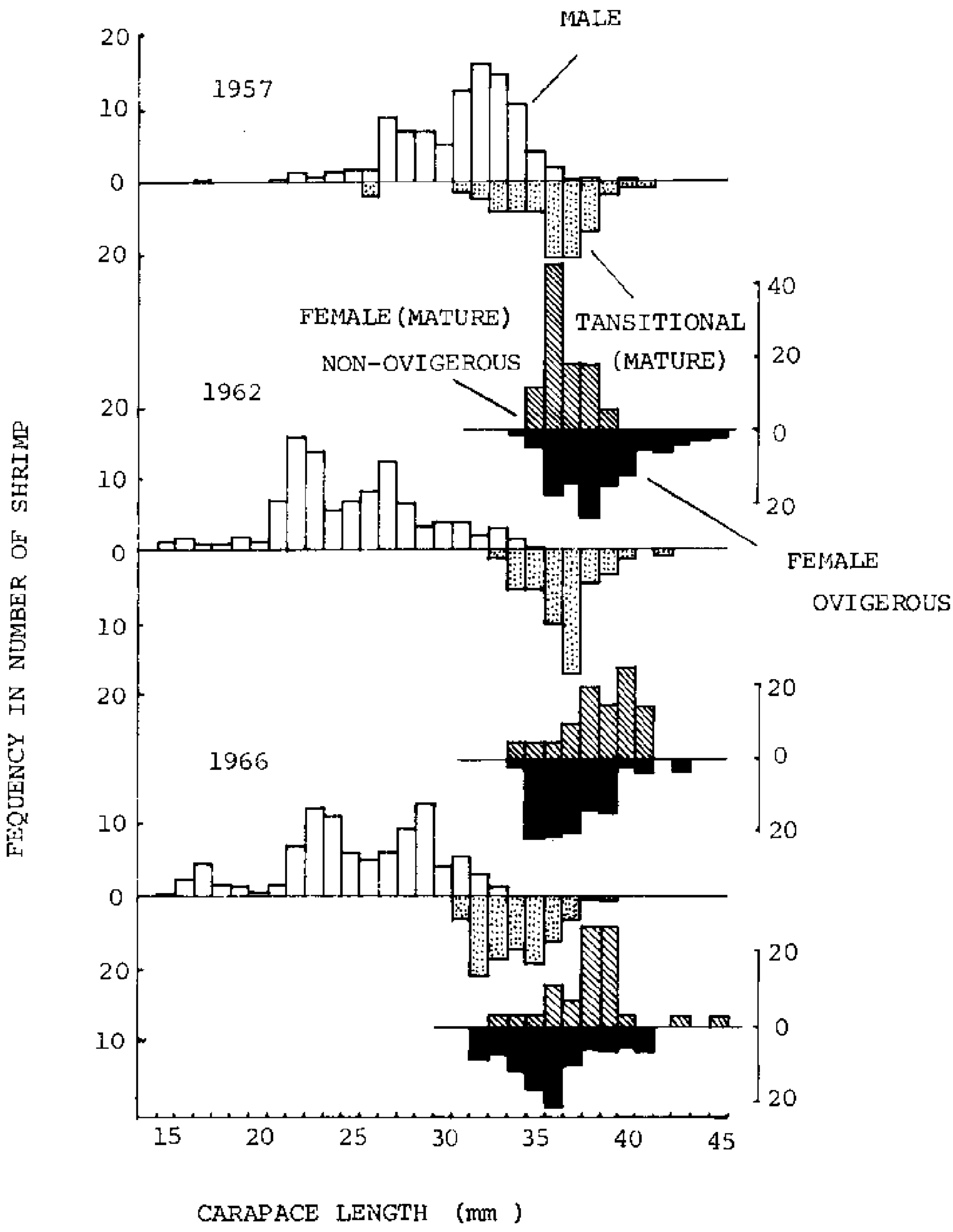

Figure 35. Pandalus ochotensis length-frequency distributions of samples taken off the Pacific Ocean coast of Hokkaido during breeding season in June of each year. (data from Sakurai et al. 1966)

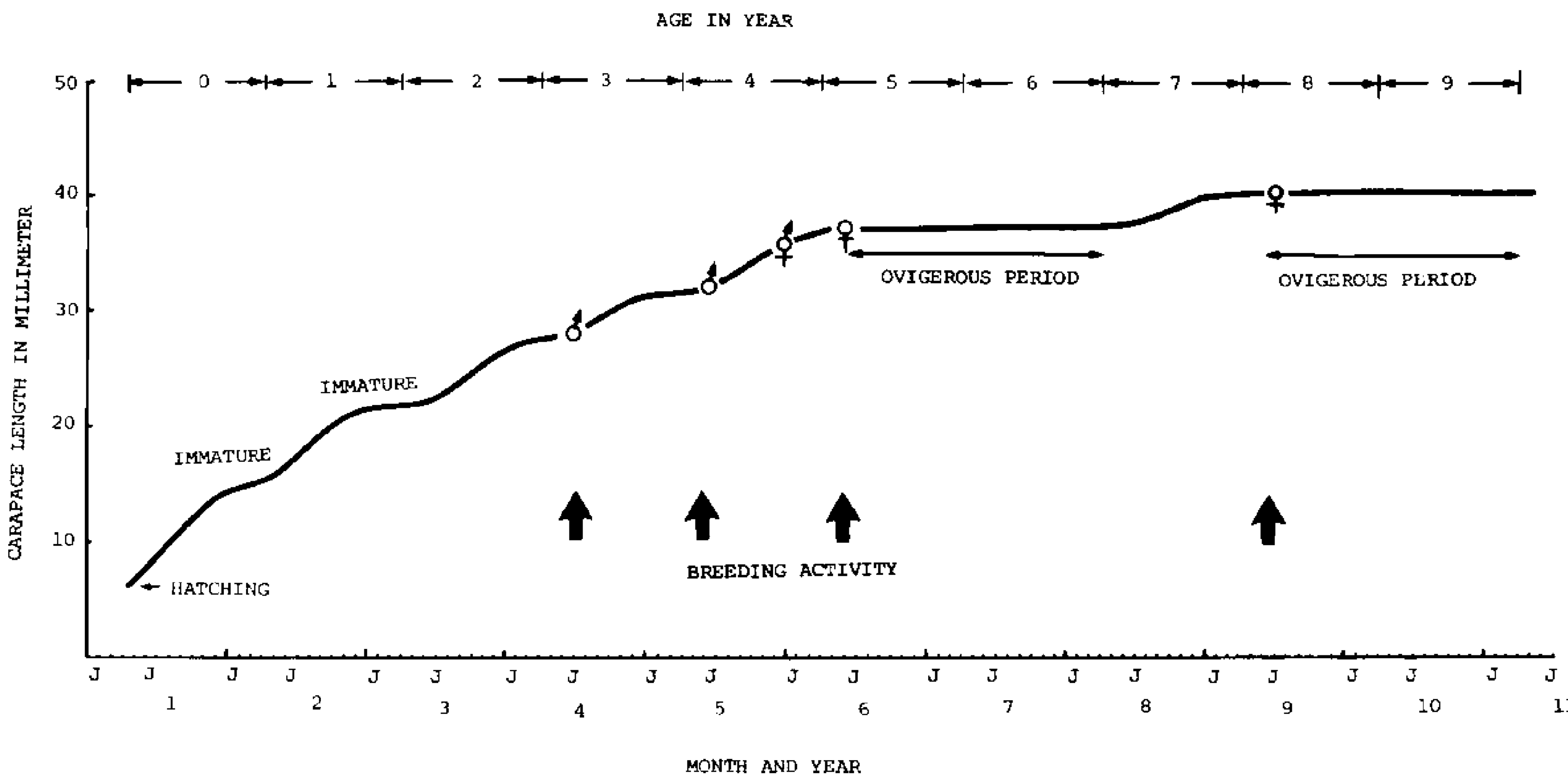

Figure 36. *Pandalus ochotensis* age-length and sexual phases for the population off the Pacific Ocean coast of Hokkaido. (data from Sakurai et al. 1966)

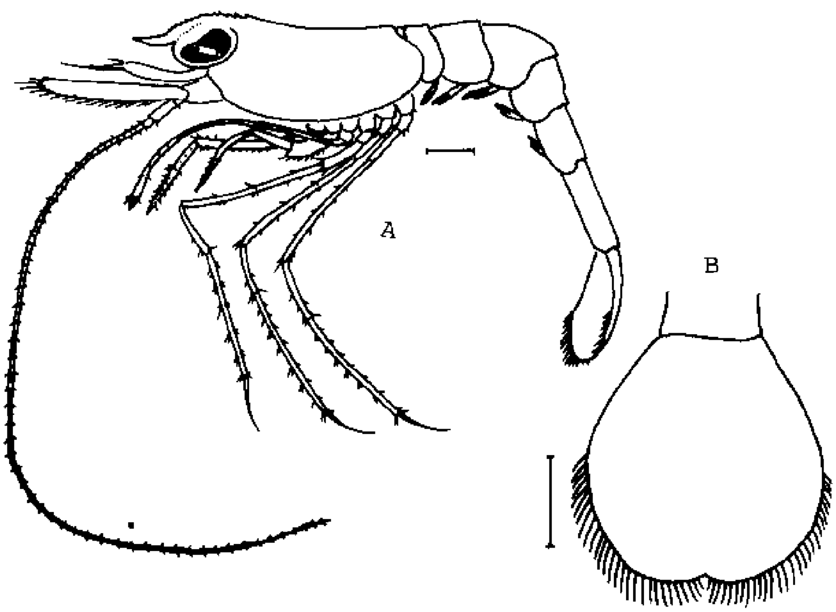

Figure 37. Pandalus ochotensis newly hatched larva. A: lateral
B: telson, dorsal. Scale denotes 1 mm. (Kurata 1964)

Distribution

This species is endemic to the Japan Sea. It occurs at many discrete and restricted grounds along the edge of the continental shelf in 200 to 300 m of water (Ito 1978).

Reproduction

Life history studies are limited to those by Ito (1978), who made monthly samplings of this species from May, 1969, to September, 1970, at Niigata on the Japan Sea coast of middle Honshyu.

Spawning was estimated to take place from November to April, and the ovigerous period to extend for almost 12 months. The ovigerous females were inactive in gonadal maturation at any time of the year. The external eggs measured 2.33 mm long and 1.83 mm across. Egg counts for females of 28 to 35 mm in carapace length ranged from 280 to 820, with an average of 490.

Growth and Sexual phases

Age and growth were studied by analyzing size frequency distributions. The yearlings appeared in the commercial catch in January and August as the smallest size group, centered around 17 mm in carapace length. The bulk of the commercial catch was comprised of 2-and 3-year old males, centered around 22 to 23 mm and 25 to 28 mm respectively in carapace length. Sex reversal was assumed to take place toward the end of the third year. They would live another year as female to produce a brood of eggs, centered around 30 to 33 mm in carapace length.

Larval development

Larvae are unknown. The relatively large size of external eggs, however, strongly suggests newly hatched larvae are very much advanced in development.

PANDALUS NIPPONENSIS YOKOYA

This is endemic to the Japanese waters and occurs off the Pacific coast of several intermittent localities of Honshyu in 300 to 500 m of water. Apart from a taxonomic study by Yokoya (1933), biological studies are limited to those by Tamura (1950) in Aichi Prefecture, central Honshyu, and by Ishikawa (1977) in Sendai Bay, northern Honshyu. According to Tamura (1950), ovigerous period extends for 11 or 12 months from between February and May to February or April. Ovarian egg counts ranged from 720 to 1,140 for females from 38 to 40 mm in carapace length. External egg measured about 2.7 mm across the long axis when spawned. The shrimp was estimated to attain 14 or 16 mm, and 24 or 30 mm in carapace length by the end of 1-and 2-years-of-age respectively.

Ovigerous females ranged from 36 to 42 mm in carapace length and were supposed mostly to be 3 years old.

In Sendai Bay, P. nipponensis is fished during winter and early spring from between 100 m and 400 m of water, while Tachypenaeus curvirostris (Penaeidae) is the bulk of commercial catches during the remainder of the year.

PANDALUS GONIURUS STIMPSON

This species occurs only in the Okhotsk Sea within the Japanese waters. Urita (1941b) reported on biology of this species from Sakhlin. It was fished in large quantity in relatively shallow waters between 30 and 50 m deep. Bottoms are a mixture of sand and mud with a small amount of gravel. Commercial catches were mostly males from 60 to 98 mm and females from 85 to 142 mm in total length. External eggs measured 0.8 or 0.9 mm across the long axis. The egg counts ranged from 1,098 to 2,581 for females from 95 to 130 mm in total length.

PLESIONIKA IZUMIE OMORI

This is a small pandalid attaining a maximum of 48 mm in total length and recently established as a new species by Omori (1971), who also reported some of the biological information. It occurs in large quantity in relatively shallow oceanic waters ranging from 30 to 80 m in depth, where water temperatures vary from 13° to 22°C, while salinity remains above 34.00 ppm throughout the year. Sexes are distinct and no hermaphroditisms are evident. Males and females can be distinguished when the shrimp attains 3.5 mm in carapace length, by the secondary sex characteristics appearing on the first two pairs of pleopods. External eggs measured 0.48 mm across the long axis. Egg counts ranged from 184 to 1,086 for females between 5.2 and 8.2 mm in carapace length. Tohriyama and Asami (1973) reported the egg counts ranging from 812 to 1,620 for females between 10 and 11 mm in carapace length. The spawning and hatching of this species were supposed by Omori (1971) to occur throughout the year with a peak season during late spring and summer producing a sequence of broods. The shrimp may live as long as 1 1/2 years.

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(J = in Japanese; J with ES = in Japanese with English summary; E = in English).

MULTISPECIES RELATIONSHIPS (PREDATOR/PREY) PANEL

Chairman

Svend Horsted (Greenland Fisheries Investigation, Denmark)

Panel Members:

John Geibel (California Department of Fish and Game)
Fred Gaffney (Alaska Department of Fish and Game)
Paul Anderson (NMFS, Kodiak)
Norm Abramson (NMFS, Tiburon Laboratory)

Other Speakers:

Mark Gaffney
Unnur Skuladottir (Hafrannsoknastofnunin, Iceland)
Bob Allen

INTRODUCTION

The panel discussed generally the predator/prey relationship in the marine environment as it applies to pandalid shrimp. Although none of the panel members were involved in food web research at the time, all related personal experiences with reagard to man's role as a predator, problems with rebuilding stocks after their place has been filled in the food chain, and the lack of literature on shrimp feeding habits. In general, panel members called for more research and cautioned against simplistic answers or those based too much on theoretical data.

Panel chairman Sven Horsted opened the discussion by introducing the panel. He commented particularly that the current one species assessment techniques are not the best and urged development of a multispecies assessment technique. Horsted also stated that fish/shrimp food chain relationships are more complex than previously thought and that the possibility of competition for food between the two groups should be considered.

Anderson: I think it's really interesting that your comments dealt with the whole ecosystem because in the Alaskan area and Bering Sea, where I've conducted research, I've noticed a great deal of discussion and concern going around about the relationship of pollock and shrimp. This is important not only as a predator/prey, but also a competition relationship. When we were in the Bering Sea last year and opened some pollock stomachs, we found very few adult shrimp. They seemed to be feeding on macronekton and other small organisms in the water column. This leads me to believe these young zero and one plus pollock age groups are in fact competing with shrimp for food supply. These animals co-occur, and so I think your discussion on the whole ecosystem really hits home in this particular instance. In my own experience, I have observed a situation that indicates there might be a competition factor.

Geibel: Back in the late 60s, Don Gotshall was using hake stomach contents to estimate the zero age shrimp with incoming year-class. It gave a pretty good indicator of the year-class. The last several years with the big year-classes we've had in California, there has been no hake stomach index because we can't find hake to look at. We have another biologist who has been correlating both crab and shrimp landings with silver salmon landings and has found an inverse relationship there. So it's hard to tell whether it's an environmental factor or due to direct predation. Recent data seems to indicate hatcheries for Columbia River salmon are replacing the natural stock. It also appears that these hatchery raised fish have a different method of feeding than the natural fish. They tend to stay in feeding schools. It appears that when they get in an area that has a lot of feed, they'll stay there until they've eaten it all, then move on. It's not that simple. Obviously it's also controlled by water temperatures. There may be a direct relation, but in this case, with silver salmon, especially between Columbia River salmon and our shrimp year-classes in California. In the last two years, our salmon landings have been very low. In fact, historically low, despite the fact that they're releasing higher numbers.

Abramson — I'm going back to what Paul Anderson said, I think competition is really an important factor. When a fishery depletes one of its species, like shrimp, you'd think that something might occupy its place. In fact, that might be one of the dangers of overfishing, that the species might not come back by itself, its place would be taken by another species, and then it wouldn't have a place to return to. It's difficult to get a handle on what might take its place. I'm not sure we can get that with ordinary fishing vessels. One investigator who studies animal behavior in fish communities by diving, makes many observations of things like this occurring and sequential changes, community composition which we wouldn't be able to detect by ordinary means. As we get out of shallow and into deeper water to make these observations, we're going to have to develop other methods... underwater photography or something else.

Gaffney — What really concerns me is that, with the short time I have been involved with shrimp research, I have not discovered in the literature any vast amount of direct research and observation that deals with shrimp eating habits or what they might eat. That is one area where we need more basic research. We haven't really indicated the complex food web and the position shrimp occupy in the chain. I thing there's alot of disagreement and perhaps misunderstanding in this area. In the past several years it has become quite evident that the incidental fish species are becoming more prevalent in catches. We do stock assessment work in which we keep track of various species by taxonomic groups and so on. A preliminary analysis, and this is by no means definitive, indicates that some of the predator species like halibut, flatfish, cod and pollock showed no signs of declining in areas where shrimp population had decreased. Now, naturally you're going to have increased predation if in fact these fishes are preying on the declining shrimp stock. It appears that after a year, in the second year, these predator species begin to leave, as though there were little food left for them. This is strictly preliminary and off-the-cuff. Also, very limited data indicates that juvenile pollock to be increasing, particularly at Kodiak Island. Some other fishes have shown no clear trend, some are up, some are down. Herring is quite interesting. We have sporatic results. It just shows from a cursory look that we need to spend more time looking at different taxonomic groups and their relation to declines in shrimp stocks.

Horsted — I have been watching the difference between the areas. You see an enormous catch-rate in the Alaska area, compared to other areas we have talked about. At the same time, I think I've seen cleaner catches there than in other parts of the world where by-catch is a real problem. I don't know whether that's proven, perhaps we can investigate that in the forthcoming days. It could be due simply to the fact that there are less predators in that than in other regions. I know for instance in our own waters off Greenland, the halibut is a frequent by-catch in the shrimp hauls. It feeds heavily on shrimp. We used to have a wharf off which you could fish for sustainable yield, we called it at that time, of 300,000 metric tons a year. One could estimate that would be a standard of close to one million metric tons of cod, which in wintertime fed heavily on shrimp. It's not there anymore to that extent and it is a question whether the good shrimp catches are related to that. At present we are trying to maximize shrimp harvests and when it comes to rebuilding cod stocks, should we do it in terms of shrimp fishing. It's not a difficult matter at present, because distribution is no longer the same. But if the cod is going to be rebuilt, we need environmental facts with which to put it back in its former distribution. This would involve overlapping in those areas. I realize we have been talking about predators on shrimp without talking about shrimp eating other species. Comments from the floor?

Skuladottir — From aquarium observations we have noted female hatching and the larvae liberated into the aquarium. I didn't think of it at the time, but the shrimps were rather hungry and they ate the larvae. In just a month, they all disappeared. I've also noticed when we were keeping shrimps, a lot of shrimps, feeding crawfish for two or three days in the same aquarium, when I came down to look at them once a day, I found out that the crawfish were lying on the bottom and they were still alive but it seems like shrimp were eating themselves into them so they'll just eat anything, I think.

Horsted: Thank you very much. Dr. Alverson would you like to say something?

Alverson: I think the whole ecosystem approach in the concept of predator to predator relationship, the interaction between species, is one that is really the new horizon in fisheries biology and marine science. I caution against making rather simplistic conclusions; in a way, you can trap yourself very quickly. We frequently talk about ecosystem stability in homeostasis which an ecosystem having a capacity to be dynamic in a sense of moving back toward some sort of equilibrium. That's not to imply that ecosystems themselves are not highly dynamic, and I think we get confused sometimes between the terms. With or without, fit man's intervention into the system, the ecosystems are highly dynamic and they're going through change continually. They are moving toward some equilibrium but they're overrunning, overshooting and coming back. The results of those are a lot of varieties of changes and cyclic patterns in abundance in the system. If you will begin to attack this in a very complex sense you can start from the bottom and go up and say through photosynthesis there is a certain amount of material put into the system. And often we have that partition among the various animals and phytoplankton in the system and then how does it channel itself and move it on up into the higher trophic forms. A very complex thing, you'll think. Finally, ask the question of the interactions and how man's involvement in this anyway alters that particular system. You can turn that around like some investigators are doing at the present time and come from the top down and say that the marine mammals and the large predators require so much material to stay in business. And having some understanding of the abundance of these particular animals, you can make some sort of model that reflects what is going on in the system. Ultimately, as far as shrimp, you're going to have to decide the role they play in a complex of other animals in the system and what's your intervention done to the shrimp. But your going to really have to relate that to what's your intervention against every other thing in the system you're involved in. Well, it's a very, very complex arena but one that I think needs to be better understood so that we do understand where we're going in the long run. So, I encourage further investigation but only caution the error of drawing quick conclusion that may be the consequence of a very normal situation within the ecosystem. Dr. Horsted, maybe you'd like to make a few concluding remarks and then I think we're going to have to adjourn.

Horsted Well, I really don't think I need to make a summary of what we have said. I think you actually did it Bob, by pointing out the complexity and the inevitable danger by going into the data and being misleading ourselves. I'm quite sure that is going to happen because we are often trying to see what was a stable situation and see if it doesn't exist in nature, and we never accomplish it. There will be many, I don't know the right word for it, but there will be many dangers along the way, where we are moving now. The thought occurred to me that the better observation you have, the better off you are, and you'll need a lot of observations in studies like this. You need observation at any life stage, what they're eating, who their predators are and so on. But it requires properly developed new knowlege. But the knowlege is to be right out in the field by contingent studies there.

FEBRUARY 14, 1979

RESEARCH PRESENTATIONS
AND
PANEL DISCUSSIONS

REVIEW AND DISCUSSION OF CURRENT STOCK ASSESSMENT TECHNIQUES USED IN THE MANAGEMENT OF GREENLAND SHRIMP RESOURCES

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SUMMARY

Inshore Greenland shrimp fisheries catch and effort data have been collected almost exclusively from the landings of catches, while in the offshore fishery logbook systems are used by state owned Greeland trawlers and vessels of several other nations.

Management of the inshore Greenland shrimp fishery depends more on limited landing and processing facilities than on stock management. In recent years, it has been the policy in Greenland not to increase inshore fisheries, as shrimp resources here are delivering close to maximum sustainable yield.

The first assessment of the offshore shrimp resources in 1975 was based on the areas of the known offshore shrimp fishing grounds and the mean annual yield per area in Disko Bay. Quota regulations were introduced in 1977, based on biomass estimates by catch per swept area data from commercial fisheries and from a stratified trawl survey in 1976.

Stratified trawl survey data produce more reliable estimates of fishable biomass than catch and effort data from the commercial fishery, which tends to concentrate on local high densities of shrimp. The influence of diurnal vertical migration of shrimp on catch per hour data may be compensated for by correction curves calculated from diurnal variations in catches of the commercial fishery.

Measurement of density of shrimp by bottom photography has been used since 1975 and is now used in the annual adjustment of the quota regulation of the offshore shrimp fishery.

WEST GREENLAND BIOMASS ASSESSMENT

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(Ed.'s note: This presentation was transcribed from tape for inclusion in this proceeding.)

I don't think I have too much to add to the presentation on how things are done in Norway. What I would like to do is shortly outline how we in the west Norway area calculate allowable catch from the mean and biomass estimates.

For those who are interested, I have outlined this for ICNAF and it was published in their selected papers.

I will not go into the details, I will just briefly outline the method. It is a very simple adaptation of the constant recruitment model. It started when the ICNAF shrimp working group tried to go from the biomass estimates to the calculation of a total allowable catch. With a fishery mesh size of 40 millimeters, stretched or large, we thought that even an uncontrolled fishery would not be harmful to the yield per recruit. Most of the shrimp in the catches would be 4 years old or older. At these ages, the shrimp probably suffer a high natural mortality anyway, especially after the females have produced their first larvae.

The important questions for management purposes are how much the reproduction potential is reduced by fishing and how much this potential can be reduced without causing a substantial decrease in recruitment.

Now, assuming that there is a knife-edged recruitment to the fishery at a certain age, and that we know the difference between this age and the age of first spawning, it is very easy to calculate how a certain fishing mortality will reduce the spawning stock compared with the unexploited stock if we know the natural mortality after first spawning, and the fishing mortality.

This difference in age between recruitment to the fishery and the age at spawning is quite important for how much fishing will reduce the natural spawning. I also, in the paper, give a table illustrating how much the spawning stock will be reduced for various levels of fishing mortality, assuming various values for natural mortality and this difference in age.

Now, in the ICNAF working group, we have really not much data to give us any indication of how much the spawning stock could be reduced without decreasing recruitment. We rather arbitrarily decided that spawning stock should not be reduced by more than 50 percent, compared to the unexploited equilibrium. Now add in the biomass estimates. Taking these as an estimate of the mean annual fishable biomass, the fishing mortality is simply given as a ratio of catch to the biomass estimate.

At the meeting in 1976, we estimated the total fishable biomass to be 100,000 tons. From this method of calculating how much the spawning stock is reduced at various levels of fishing mortality, we found that a fishing mortality of .4 would reduce the spawning stock by 50 percent. Assuming that the natural mortality was 1.5 after first spawning and that there was a difference in age in recruitment and first spawning of 1.5 years.

So we applied this fishing mortality of .4 to calculate a total allowable catch. So from a total biomass of 100,000 tons we got a quota of 40,000 tons. That was the first TAC for 1977.

Of course, one has to adjust these calculations if the stock is not in equilibrium. If the fishing mortality is increased, then our biomass estimate may not correspond to the equilibrium biomass for the new, higher fishing mortality. Unfortunately, we did not make that very clear in our report to ICNAF. At the last meeting of the shrimp working group we saw our biomass estimates had decreased by about 30 percent. When I went into this with my model and tried to calculate how much one would expect it to decrease if fishing mortality was increased from say .1 to .4, that also was about 30 percent. So far, there's nothing in the development in west Greenland which indicates something is wrong in our assumptions. Of course, that also doesn't prove our assumptions are correct.

The problem with the model is that it is very simple. One has to assume constant recruitment. But without having any estimates of recruitment, there's not much you can do but assume a constant recruitment.

SYSTEM LBOOK: A FISHERIES LOGBOOK INFORMATION MANAGEMENT SYSTEM[1]

SuzAnne M. Miller[2]

and

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ABSTRACT

The purpose of this report is to document the design and use of the fisheries logbook information management system, SYSTEM LBOOK. This computer system evolved out of the management need for timely analysis of standardized catch per unit effort (CPUE) data collected from the Gulf of Alaska commercial shrimp fishery (Gaffney 1977). SYSTEM LBOOK is a user oriented data base management system composed of subroutines which edits raw logbook information, updates the time series data base, retrieves user specified records, standardizes CPUE between fishing areas for a single fishing season or between fishing seasons, and reports this information in a variety of formats. The system was designed to be highly flexible but simple enough to be used by fisheries managers with little knowledge of computer programming.

INTRODUCTION

Although SYSTEM LBOOK was written specifically for the Alaska domestic commercial shrimp fishery, it can be readily adapted for use in other fisheries. The majority of the Alaska shrimp harvest is taken from many individual bays and fjords along the coast. This affords the opportunity to

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[1]This project was partially funded by the Commercial Fisheries Research and Development Act of 1964 (P.L. 88-309 as amended) project number 5-42-R. The text of this paper is taken from Informational Leaflet No. 1978. Alaska Department of Fish and Game. Feb. 1979. Supporting material may be found in that publication.

[2]Present address: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska 99503.

manage these individual shrimp concentrations as discrete stock segments. These segments are identified as Geographical Catch Areas which are in turn composed of one or more Statistical Reporting Areas. The shrimp fishing year in Alaska begins the spring of one year and runs to the spring of the next year. Compilation of data on this basis is more meaningful biologically as stock trends are compared from the termination of one egg hatch period through the duration of the next.

Effort data, along with catch reports, are generally the first information collected by a fisheries management agency. Implicit in the interpretation of effort data is the assumption that the catchability coefficient must remain constant among time area strata and the measure of effort must be proportional to the instantaneous fishing mortality coefficient (Beaverton and Holt 1957). The assumption of a constant catchability is likely invalid for a complex and varied fishery such as the Gulf of Alaska domestic shrimp fishery (Gaffney 1977). Hence, the need to standardize fishing effort in order to make critical management decisions of the commercial exploitation of fish stocks.

Standardization of fisheries effort has been discussed by other investigators (Abramson and Tomlinson 1972; Fox and McCrary 1976; Gulland 1956; Robson 1966; Rothschild 1977). Previous work has hinged on the selection of a standard gear or vessel operating in a standard area. This assumes that stock distribution and abundance does not change in the time and area stratum. Also, the standard vessel's fishing performance does not change. Computerized standardization routines are available (Berude and Abramson 1972; Stark 1971), but they do not offer the necessary flexibility in analysis or reporting, nor do they provide for continuous data base management. To fill these needs, SYSTEM LBOOK was written.

SYSTEM LBOOK is a comprehensive data base management system which offers a unique approach to effort standardization. Relatively large data sets over numerous time-area stratas can easily be standardized. This system is unique in the flexibility it affords the user, because there is no prescribed standardization method. This technique does not select a standard for comparison but rather assumes that the deviation in the mean reflects the deviation in the stock. Because of this greater flexibility, the user assumes more responsibility.

Copies of the program on punched cards or magnetic tapes can be obtained from the Alaska Pandalid Shrimp Research Project, Commercial Fisheries Division, Alaska Department of Fish and Game, Box 686, Kodiak, Alaska 99615.

SYSTEM DESIGN

Fisheries logbook information has many uses. Resource managers may be primarily interested in using the catch and effort statistics as an index to stock status. This requires timely reporting of up to date information. They also may be investigating the relationship between CPUE and vessel characteristics which require accessibility to logbook information over many years and areas. However, an individual skipper may be interested in comparing his vessel's performance in a number of different areas. His needs require that the information specific to his vessel be separated and analyzed independently.

In view of the varying demands for fisheries logbook information, the goal of a logbook information management system is flexibility and timeliness. This is reflected in the criteria used for the design of SYSTEM LBOOK:

1. Information Completeness
   All information on the original logbooks as filled out by the vessel skippers must be readily accessible.

2. Information Correctness
   Original logbook data must be edited for errors in coding.

3. Flexibility Reporting of Information
   Each user must have the flexibility to tailor logbook information reports to his specific needs.

4. Timely Reporting of Information
   There must be no delay between the time new information is added to the system and the time new reports are generated.

5. Meaningful Reporting of Information
   The information must be reported in such a manner as to facilitate interpretation.

6. System Simplicity
   Minimal training should be required for system use.

INFORMATION FLOW

The task of processing fisheries logbook information was broken into five basic steps: editing of raw logbook records, condensing logbook information into meaningful categories, retrieving both current and historical logbook information, report generating, and information analysis. Since logbook information is received on an almost continual basis throughout the fishing season, simultaneous processing of individual steps is necessary.

Editing New Logbook Information

The editing step consists of two functions:

1. Error checking
   New logbook information is checked for validity of data. This requires the development of edit specifications. New data can be compared to the specifications, and errors noted. The edit specifications must be able to handle extra-normal data, but which is valid.

2. Addition of Information
   Information which is static or calculated on the basis of other information need not be entered on the new logbooks. Vessel characteristics, for example, rarely change throughout the duration of a fishing season. CPUE is desired for each logbook entry, but this is a calculated value. This type of information is automatically added to the new logbook records.

Condensing Logbook Information

While it is important that the original logbook information be retained, the most common use of the information is on a summary basis. To prevent continued recalculation of summary statistics and to condense large data sets into smaller, more manageable sets, meaningful categories of data must be formed. Information on different gear types, however, is often required. Similarly, stocks identified to specific geographic catch areas are more meaningful than the smaller statistical reporting areas. This led to the formation of summary categories based on gear type, geographic catch area, and date.

Retrieving Logbook Information

As new information is added to existing data sets, the ability to extract portions of the data for reporting or analysis becomes more important. To insure complete flexibility, the criteria for data selection should include all possible combinations of data groups. Geographic catch area, statistical area, season, month, day, gear type, and vessel are designated as retrieval criteria.

Reporting Logbook Information

The most commonly used logbook information includes effort, catch, and CPUE. This information may be required on the basis of a number of different factors: by vessel, by area, by season, by date, or by a combination of breakdown factors: geographic catch area, statistical area, season, month, day, gear type, or vessel. The number of tows, the total catch, the mean CPUE, and the standard deviation of the CPUE is presented for each breakdown category (unique combination of breakdown factors). Breakdown factors are properly labeled to identify each category.

Information Analysis

While logbook information may be used to investigate many different aspects of a fishery, one of the most important uses involves comparisons of the CPUE between different seasons, areas, vessels, gear types, or other factors. These types of comparisons can be misleading if the unit of effort is subject to change. Two analyses of variance models are included in the logbook information system to adjust for variation introduced in CPUE as a result of changes in the unit of effort. These two models are the results of an in depth analysis of the sources of variation in CPUE (Miller 1977). Model I, the Within Season Model, is based on an individual vessel performance at a given time in a given geographical catch area. A substantial amount of data from a number of different vessels of each gear type is necessary for the model. This enables the model to correct for bias in the data. Model II, the Between Seasons Model, is based on the performance of the different gear types through time for a given geographical catch area. Model II can be employed with a small amount of data, and from Model II the standardized CPUE on an in-season basis can be predicted:

1. Anova Model I

   The first model is a two factor nested or hierarchic analysis of variance. It assumes that the second factor is nested or grouped under the different levels of the first factor. For example, the individual vessels of a particular gear type can be considered as being nested within that gear type. Development of Model I is based on individual vessels within a gear type within a time-area strata. The CPUE of a vessel operating in a specified time-area strata is assumed to consist of four quantities: the mean CPUE for the strata; the effect of the type of gear; the effect of the individual vessel; and a random error. Catch-effort frequency distributions for each time-area strata were calculated and found to be log normally distributed.

Model I assumes the following relationship:

$$Y_{ijk} = \mu + \alpha_i + \beta_{j(i)} + E_{ijk}$$

where:

Y_{ijk} = $\log_e$ CPUE of the kth tow of the jth level of the second factor within the ith level of the first factor.

α_i = effect of the ith level of the first (major) factor.

$\beta_{j(i)}$ = effect of the jth level of the second (nested) factor within the ith level of the first factor.

E_{ijk} = error

The coefficients of α and β are estimated under the following restrictions:

$$\Sigma\alpha = 0 \text{ and } \Sigma\beta_{(i)} = 0 \text{ for each i.}$$

Using these coefficients, the standardized CPUE is defined as:

$$\text{Stand CPUE}_{ij} = e^{\hat{\theta}(1 + .5\sigma^2_{\hat{\theta}})}$$

where:

$$\hat{\theta} = \hat{\mu} + \hat{\alpha}_i + \beta_{j(i)}$$

The estimates of the coefficients and the standardized CPUE are presented for each level of the two factors. An analysis of variance (ANOVA) table is an option which can be requested by the user.

2. Anova Model II

The second model is a two way factorial analysis of variance without interaction. It assumes that the variation in CPUE is due to two factors of equal rank. For example, the performance of gear types across various seasons. Development of Model II was similar to that of Model I. Model II breaks down the CPUE for a given catch area into four quantities: the average CPUE for the area over the seasons considered without regard to gear type; the effect or deviation from the average of each gear type; the effect of deviation from the average of each season; and a random error term with an expected value of zero.

Model II assumes the following relationship:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + E_{ijk}$$

where:

Y_{ijk} = $\log_e$ CPUE of the kth tow of the ij combination of factors one and two.

α_i = effect of the ith level of the first factor.

β_j = effect of the jth level of the second factor.

E_{ijk} = error

The coefficients of α and β are estimated under the following restrictions:

$$\Sigma\alpha = 0 \text{ and } \Sigma\beta = 0$$

Using these coefficients, the standardized CPUE is defined as:

$$\text{Stand CPUE}_{ij} = e^{\hat{\theta}}(1 + .5\alpha^2_{\hat{\theta}})$$

where:

$$\hat{\theta} = \hat{\mu} + \hat{\alpha}_i + \beta_j$$

The estimates of the coefficients and the standardized CPUE are presented for each level of the two factors. An optional ANOVA table can be requested by the user.

3. Model I vs Model II

Model I is intended to be used for specific detail during a given time period, i.e. a single fishing season. Model II is used to give a more generalized comparison between fishing seasons. Comparison of the results of Model I and Model II using the same data indicates a high degree of correlation (Miller 1977). The use of Model I for vessels within gear type across time did however, indicate interaction between area (i.e. stock abundance and distribution) and a gear type's relative ability to exploit the stock.

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THE EXPERIENCE OF THE CATCH PER EFFORT VERSUS AVERAGE EFFORT, THE METHODS OF GULLAND AND FOX, IN <u>PANDALUS BOREALIS</u> FISHERIES AT ICELAND

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ABSTRACT

Here catch per effort and average effort of every two years are fitted by least squares to two simple models, namely a linear model (Gulland 1961) and an exponential model (Fox 1970). The exponential model appears to give more reasonable results than the linear model at times when effort varies a great deal. For little variation in effort however, the linear model seems to give more realistic results than the exponential one. The catch data of the <u>Pandalus borealis</u> fisheries of two fiords at Iceland are used for the analysis.

INTRODUCTION

The method of Gulland (1961) has been used for assessing the maximum sustainable yield (MSY) of the populations of <u>Pandalus</u> of Arnarfjördur and Ísafjardardjúp for quite a number of years (Skúladóttir 1974 and 1979). The method is based on a least squares fit to a straight line between catch per effort on one hand and average effort on the other, where average effort should correspond to the mean time during which the animals are subject to fishing. The populations of the two areas (Figure 1) have been found to be separate (Skúladóttir, Jónsson, and Hallgrímsson 1978). Gulland (1961) and Garrod (1968) suggest that a curvilinear regression would describe the relationship between catch per effort and average effort better than a straight line. Fox (1970) uses an exponential curve fit for the catch per effort and effort. Both these methods were tried on the <u>Pandalus</u> population of Arnarfjördur with moving averages of effort of 2, 3, 4 and 5 years respectively, always using eight sets of yearly catch per effort against average effort (Skúladóttir 1979). In both the linear and the exponential models the average effort of every two years gave the best fit. The average effort of every two years has also been found to be better for Ísafjardardjúp when comparing to that of every three years. In this paper the models are fitted to data spanning over a different number of years to see whether there is a change in applicability between the two methods. The period before the uptake of a large, more efficient trawl is also included with an approximate change of catch per trawling hour into that of catch per unit effort.

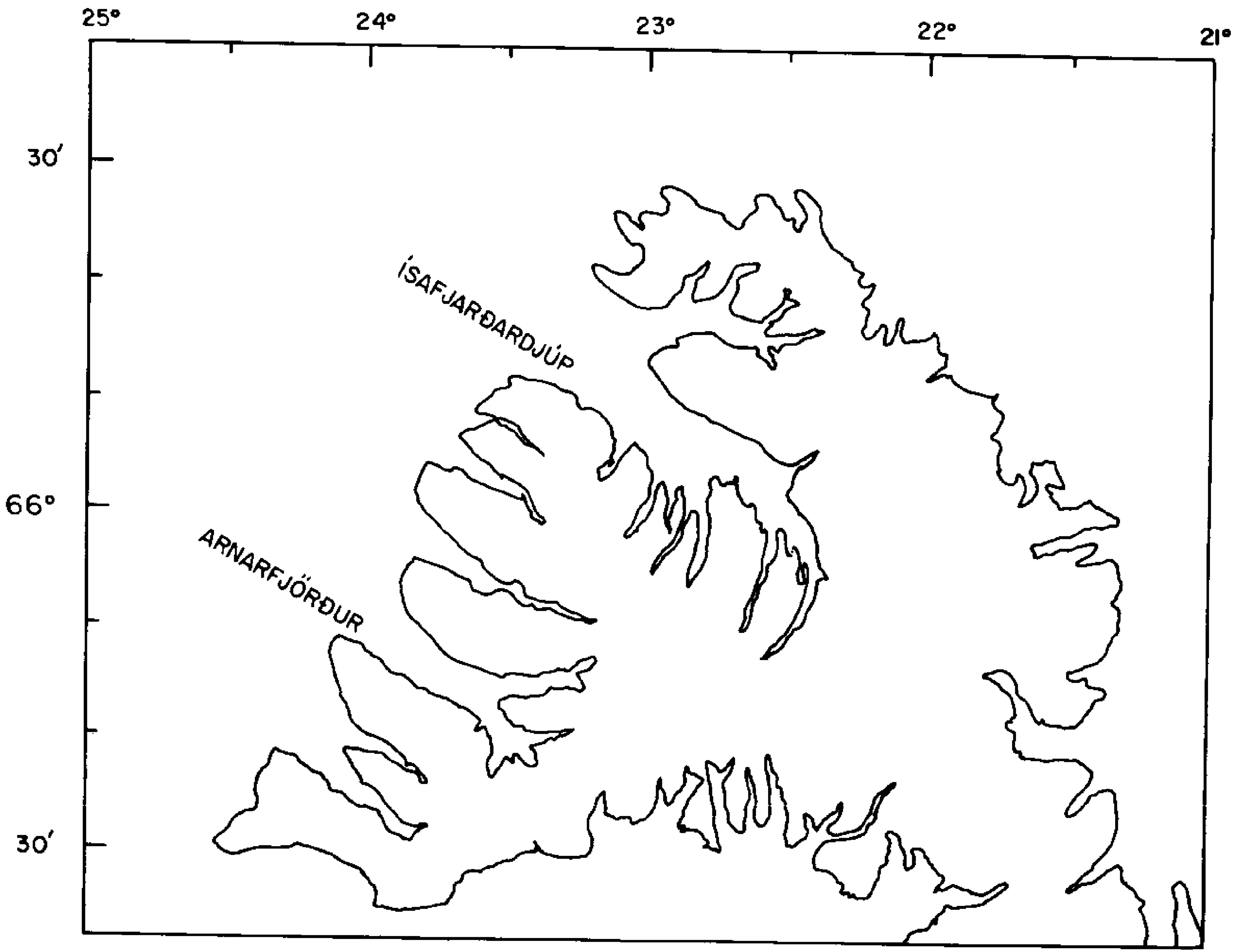

Figure 1. The location of Isafjardardjúp and Arnarfjördur fiords. There is no shrimp fishery in the fiords between these two.

Definition of Symbols Used

LIN	the linear model
EXP	the exponential model
MSY	the maximum sustainable yield as calculated in the linear and exponential models where change of mesh is ignored
Y	the catch per year (winter)
U	the catch per unit effort of one year or winter
f	the effort in trawling hours of one year (winter) or the effort of every two years (winters) divided by 2
r	the correlation coefficient
exp	the exponential function

The Models Used

The basic data are on one hand the information on catch per haul, length of haul, area and subarea, handed in by every skipper on a logbook form, and on the other hand catch statistics on landings every month by area. The fiord fisheries are driven solely by the fiserhmen living in a distinct area, thus if reports have not been turned in 100 percent, the total catch is still known from the landings.

The linear model consists of a linear curve fit on one hand where:

$$U = af + b \qquad (1)$$

The MSY is calculated by multiplying both sides of the equation by effort f. Thus as

$$U = Y/f \qquad (2)$$

the linear regression becomes a parabola

$$Y = af^2 + bf \qquad (3)$$

MSY is when

$$Y' = 2af + b$$

$$0 = 2af + b$$

f at MSY is $f = -b/2a$ (4)

The exponential model consists of an exponential curve fit on one hand where

$$U = \exp (bf) \qquad (5)$$

This becomes

$$Y = af \exp (bf) \qquad (6)$$

MSY is when $Y' = 0$

$$0 = a \exp (bf) + baf \exp (bf)$$

f at MSY is thus

$$f = -1/b \qquad (7)$$

RESULTS AND DISCUSSION

The data of Tables 1 and 2 are fitted to these two models for different periods for two areas, namely Ísafjardardjúp and Arnarfjördur (Figure 1). Effort is always a moving average of every two years. In both areas the catch per unit effort is kg per hour from the year 1968 or winter 1967/68 onwards. During 1966 and 1967 a larger more efficient trawl was taken up. This was later found to be about twice as efficient on an even bottom as the trawl used before (Skúladóttir 1970). This was considered to cause an expansion of the fishing grounds as indicated by the increase in mean depth of fishing for Pandalus after the winter 1966-67 (Skúladóttir 1968). Before 1967 the fishery was only profitable where the shrimp was very dense or on the steep slopes of the fiords. The MSY seems to have increased vastly after this or from 200 tons in Arnarfjördur and from 720 tons in Ísafjardardjúp (Skúladóttir 1974) when calculated for the data up until 1966. It is difficult to calculate catch per unit effort accurately if catch per effort of the years before 1968 are to be used in the calculations of MSY, because the large trawl may not be twice as efficient as the little trawl when used on the steep slopes. The data of 1968 to 1978 are therefore considered more reliable than data before 1968, at least for judging the present situation. Looking at the results for both areas the most reliable results are underlined in Tables 3 to 6. In the case of Ísafjardardjúp the period 1970 to 1978 is considered slightly more appropriate judging by a better fit (Figure 3).

Looking at the results for Arnarfjördur, the data of the period 1968 to 1978 are fitted to both the models and shown in Figure 2. The linear model seems to give an overestimate

Table. 1. Basic data from the fisheries at Arnarfjördur and Ísafjardardjúp

Year	Arnarfjördur Effort trawling (hours)	Arnarfjördur Catch (tons)	Arnarfjördur Catch (kg/ trawling hour)	Ísafjardardjúp Effort trawling (hours)	Ísafjardardjúp Catch (tons)	Ísafjardardjúp Catch (kg/ trawling hour)
1956	1,246	104.0	83.5			
1957	1,703	150.0	88.1			
1958	1,713	185.0	108.0			
1959	2,638	248.0	94.0			
1960	2,814	242.0	86.0			
1961	1,287	121.0	94.0			
1962	1,591	166.4	104.5	5,063	376.2	74.3
1963	1,356	202.6	149.3	7,103	506.7	71.3
1964	1,454	156.9	107.9	3,989	447.2	112.1
1965	2,019	204.0	101.0	4,088	683.4	167.1
1966	3,006	281.7	93.7	11,362	1,259.1	110.9
1967	2,117	186.6	88.1	8,950	893.2	99.8
1968	4,180	499.2	119.4	11,030	1,578.7	143.1
1969	4,717	602.1	127.6	11,857	1,758.1	145.8
1970	7,818	692.4	88.5	14,701	2,459.8	167.3
1971	10,502	588.4	56.0	25,110	2,915.3	166.1
1972	8,759	506.9	57.8	24,893	2,110.0	83.3
1973	8,816	632.5	71.6	25,513	2,501.4	98.0
1974	8,945	579.0	64.7	22,764	2,441.7	107.3
1975	6,872	408.4	59.4	14,693	1,699.3	115.6
1976	5,834	406.1	69.6	18,172	2,676.8	147.3
1977	4,043	550.3	136.1	15,933	2,563.0	160.9
1978	2,987	302.4	101.2	8,248	1,664.3	198.5

Table 2. The basic data from the fisheries by winter

Winter	Arnarfjördur Trawling effort (hours)	Catch (tons)	Catch (kg/trawling hour)	Isafjardardjúp Trawling effort (hours)	Catch (tons)	Catch (kg/trawling hour)
1966-67	2,627	236.8	90.1	10,925	1,074.8	98.4
1967-68	2,443	336.5	137.7	8,124	1,237.7	152.3
1968-69	4,472	614.1	137.3	12,850	1,809.6	140.8
1969-70	6,978	690.8	99.0	12,055	2,142.8	177.8
1970-71	10,197	638.5	62.6	23,852	3,070.9	128.7
1971-72	9,351	455.4	48.7	25,476	2,173.9	85.3
1972-73	9,058	602.9	66.5	21,536	1,926.4	89.6
1973-74	8,281	610.7	73.6	26,789	2,510.4	93.7
1974-75	9,416	527.0	56.0	19,467	2,334.3	120.0
1975-76	4,565	308.9	67.5	15,183	2,264.0	149.1
1976-77	4,506	520.7	115.6	16,681	2,527.6	151.5
1977-78	4,813	520.0	108.0	14,423	2,677.8	185.7

Table 3. The results of different periods in Arnarfjördur using the linear and exponental models : effort at maximum sustainable yield (f at MSY), maximum sustainable yield (MSY), catch per unit effort at MSY (U at MSY) and correlation factor (r) for each period

Period (years)	Linear model f at MSY	MSY (tons)	U at MSY	r	Exponential model f at MSY	MSY (tons)	U at MSY	r
1957-78	5,664	658	116.2	0.893	5,917	576	97.3	0.950
1963-68	2,493	437	175.0	0.843	2,681	422	157.5	0.881
1963-69	3,342	502	150.0	0.811	4,049	498	123.1	0.853
1963-70	4,137	568	137.3	0.842	4,762	540	113.4	0.912
1963-71	5,159	651	126.2	0.861	5,319	571	107.3	0.953
1963-72	5,609	689	122.8	0.879	5,682	591	103.9	0.963
1963-73	5,760	703	122.0	0.889	5,952	605	101.6	0.963
1963-74	5,821	708	121.7	0.899	5,952	608	102.1	0.967
1963-75	5,731	699	121.9	0.906	5,814	596	102.5	0.966
1963-76	5,620	682	121.4	0.900	5,747	583	101.4	0.958
1963-77	5,620	682	121.4	0.900	5,882	582	98.9	0.968
1963-78	5,636	661	117.3	0.872	5,882	576	97.9	0.938
1968-70	7,526	609	80.9	0.809	9,709	636	65.5	0.826
1968-78	7,325	579	79.1	0.859	8,065	555	68.8	0.885
1971-75	19,925	792	39.8	0.200	30,303	917	30.2	0.211
1971-76	15,527	672	43.3	0.510	22,222	756	34.0	0.515

Table 4. The results for different periods in Arnarfjordur using pooled winter data instead of years (Table 2)

Period (winters)	f at MSY	MSY (tons)	U at MSY	r	f at MSY	MSY (tons)	U at MSY	r
1967-68/ 1969-70	6,752	591	87.6	0.962	9,090	630	69.3	0.962
1967-68/ 1977-78	6,869	585	85.2	0.971	7,143	551	77.2	0.964
1970-71/ 1975-76	10,116	550	54.4	0.564	10,753	546	50.8	0.581

Table 5. Results for Isafjardardjúp for different periods of years using the data presented in Table 1

Period (years)	Linear model f at MSY	MSY (tons)	U at MSY	r	Exponential model f at MSY	MSY (tons)	U at MSY	r
1963-68	9,775	1,634	334.3	0.607	14,085	1,741	123.6	0.559
1963-69	10,060	1,661	330.2	0.669	13,699	1,723	125.8	0.664
1963-70	12,028	1,838	152.8	0.637	17,857	2,021	112.6	0.608
1963-71	15,000	2,096	139.7	0.682	20,833	2,200	105.6	0.772
1963-72	16,681	2,245	134.6	0.754	20,408	2,166	106.1	0.841
1963-73	17,891	2,352	131.5	0.778	21,739	2,262	104.1	0.862
1963-74	18,540	2,414	130.2	0.791	22,727	2,332	102.6	0.869
1963-75	18,319	2,387	130.3	0.798	22,727	2,315	101.9	0.874
1963-76	18,377	2,393	130.2	0.799	22,727	2,336	102.8	0.871
1963-77	18,583	2,425	130.5	0.794	23,256	2,383	102.5	0.860
1963-78	18,586	2,446	131.6	0.795	23,256	2,399	103.2	0.856
1968-71	29,159	2,740	94.0	0.660	41,667	2,993	71.8	0.704
1968-78	21,951	2,475	112.7	0.822	25,000	2,437	97.5	0.851
1970-78	18,649	2,537	136.0	0.944	18,182	2,450	134.7	0.950
1972-75	25,939	2,381	91.8	0.765	29,412	2,396	81.5	0.735

Table 6. Results for different periods in Isafjardardjúp using pooled winter data instead of years (Table 2)

Period	f at MSY	MSY (tons)	U at MSY	r	f at MSY	MSY (tons)	U at MSY	r
1967-68/ 1970-71	36,986	3,334	90.2	0.437	55,555	3,893	70.1	0.479
1967-68/ 1977-78	22,480	2,485	110.6	0.797	25,000	2,426	97.1	0.818
1969-70/ 1977-78	18,091	2,562	141.6	0.943	16,393	2,493	152.1	0.942
1971-72/ 1974-75	14,693	3,799	258.6	0.769	5,814	12,594	2,166.1	0.776

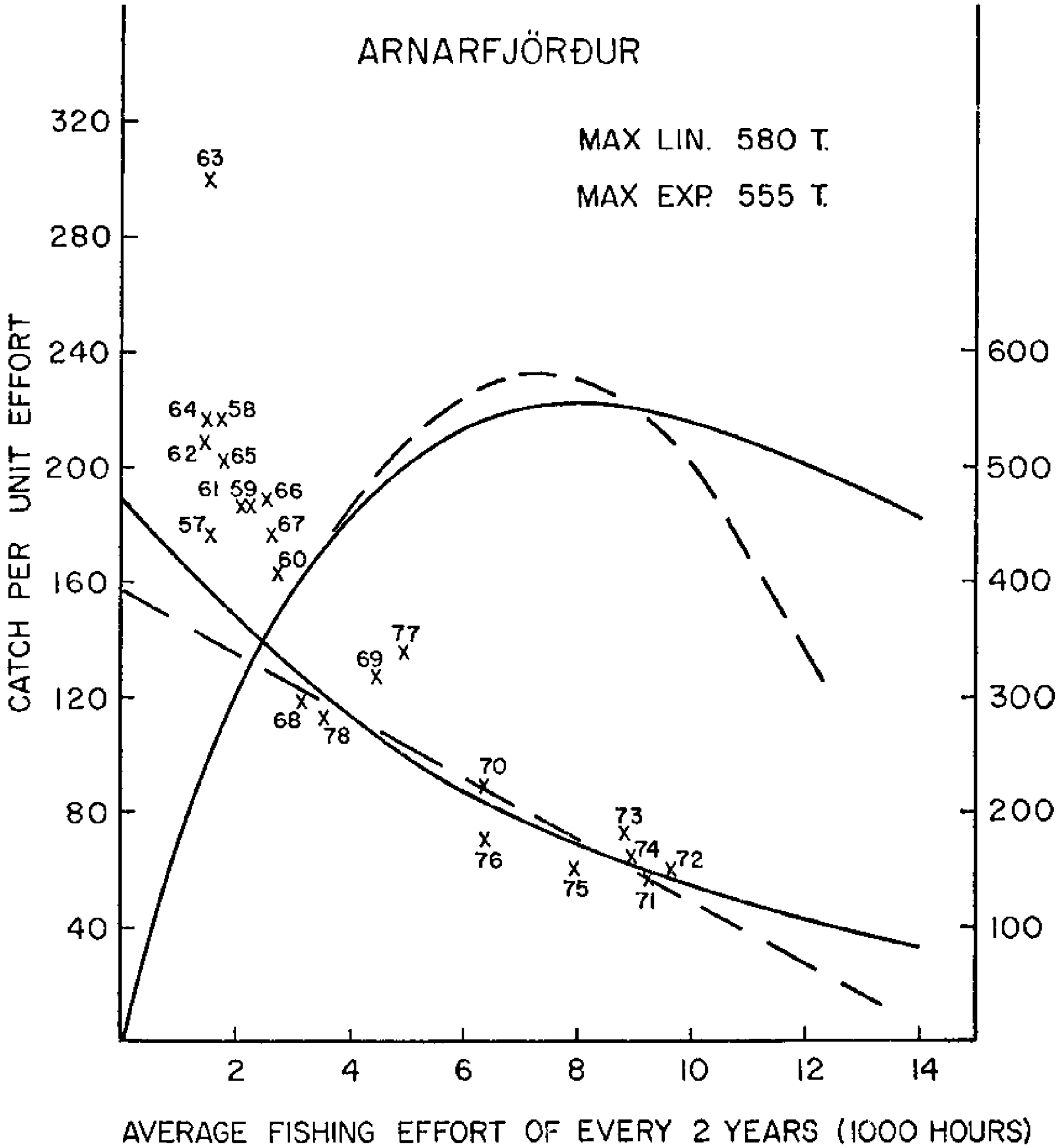

Figure 2. The relationship between biannual average effort and the average catch per effort in the second year. Solid curve is the fitted exponential curve for 1968-1978 as fitted to the broken line curve. The parabola and associated solid line indicate calculated sustainable yield using biannual sustained effort.

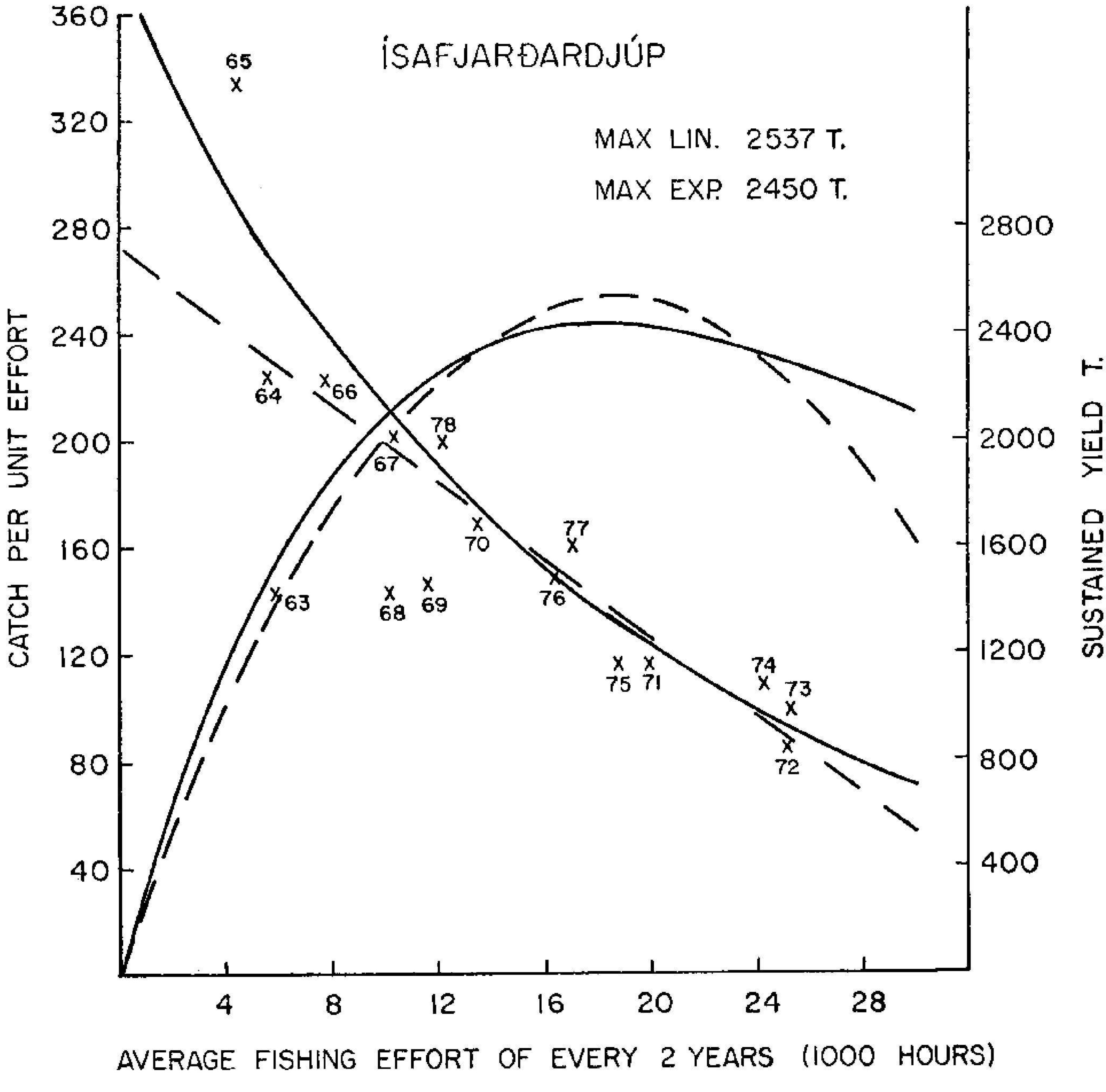

Figure 3. The relationship of biannual average effort and the average catch per effort in the second year for Isafjardardjúp. Key same as that in Figure 2.

of MSY in most cases when the data before 1968 are included (Table 3). A value of MSY above 600 tons is considered rather doubtful as shown by the severe drop of catch per effort during the winter 1971-1972 after catch had been above this for three winters (Table 2) or the catch per effort in the years 1971-1975 (Table 1 and Figure 2). The exponential model on the other hand shows more sensible MSYs for the period 1957 to 1978 and most of the periods starting with 1963 (Table 3). However when fitting for very short periods, like the years 1968 to 1970, 1971 to 1975 and 1971 to 1976 (Table 3), the linear model seems to be more realistic than the exponential model which gives absurd values of MSY. Looking at MSYs as calculated for various winter periods, again the longest period 1967-1968 to 1977-1978 (Table 4) gives very similar results to that of 1968 to 1978. But here the MSYs for the short periods 1967-1968 to 1969-1970 and 1970-1971 to 1975-1976 are not as far fetched when fitted to the exponential model as those for the before mentioned short periods of yearly data. The effort seems to vary considerably, but this is not as easy to manage anyway as is the total catch.

In Ísafjardardjúp the same development took place as in Arnarfjördur. Here both the linear and the exponential models seem to agree to a great extent on MSYs for periods starting with 1963. The MSY is seen to increase as more years are included. Some of this increase is caused by increase in mesh size. Mesh was about 25 mm open mesh till 1962 when it was changed to about 32 mm. In 1973, mesh size had become 36 mm. As in Arnarfjördur, the exponential model can give absurd results for MSY when using short periods like the period 1968 to 1971 when MSY is 2,993 tons (Table 5). Only once in the fishing history of Ísafjardardjúp was there as much as 2,900 tons caught over the year or in 1971 (Table 1). This caused a drop of catch per trawling hour to 80 to 98 kg/hr in 1972 and 1973 (Figure 3 and Table 1). The short periods of winter data give very absurd values for MSY for the periods 1967-1968 to 1970-1971 and 1971-1972 to 1974-1975 (Table 6), particularly the exponential mode.

From the examples given here it can be concluded that the linear model is more reliable when using short periods with little variation in effort, whereas the exponential model seems more reliable when data are available over a large range of effort, judging by the correlation coefficients (Tables 3 and 5). Also it can change the value of MSY drastically if changed from yearly data to winterly data, when periods are very short.

Neither model takes into account any changes in interspecies relationships, nor enlargement of fishing grounds, nor any changes in year-class strength, nor changes in mesh size.

However, a change in inclination and/or elevation of the line can be detected as a new trend for a series of years. The advantage of the methods is that all the data used are well documented as more than 80 percent of boats turn in accurate reports on the effort.

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HYDROACOUSTIC ASSESSMENT OF PANDALID SHRIMP

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ABSTRACT

Pandalid shrimps represent good acoustic targets. A mean TS of about -50 dB is given for mature prawns. Improved acoustic fish finding instruments, combined with expanders that magnify the depth stratum immediately adjacent to the bottom, are increasingly used by the shrimp fleet. Very recent developments in processing acoustic signals allow quantification of narrow strata following the bottom contour line. This permits estimation of the biomass contained in these same water layers. Thus, the feasibility of assessing shrimp acoustically is becoming a reality.

Some constraints exist such as the need for placing a signature on the acoustic signals by fishing with conventional gear for species composition. Furthermore, assessment could be difficult during winter time when diel activity of the shrimp might be reduced. At depths beyond 100 m sounders operating on low frequencies such as 38 kHz are more suitable although the bottom definition is reduced. Hydroacoustic assessment techniques are rapidly developing in contrast to conventional net sampling techniques, which have remained rather static and retained their inherent biases. It, therefore, appears a promising venture to adapt hydroacoustics for use in shrimp management.

INTRODUCTION

During the last three decades, hydroacoustics methods for exploration, research, and management of aquatic resources have undergone explosive development. Wartime development of ASCIC (Sonar) for finding and tracking submarines in the north Atlantic, was quickly turned into peaceful use in exploratory fishing programs. The decline of many exploited fish stocks in the sixties prompted a need for quantification of received acoustic signals in order to assess stocks.

Research led first to analog and then to digital integration techniques. A further development was the incorporation of acoustic monitoring surveys as part of a regular and established management system (Mathisen 1975).

The success in assessment of pelagic stocks, notably herring and cod, was followed by application to demersal or semi-demersal fish. Other more specialized adaptations have been made for assessing anadromous stocks of salmon, either on their seaward migration or on their return as adults. One of the latest involves survey of krill in the south seas of the Antarctic. Krill, although euphausid, possess much the same acoustical properties as pandalid shrimp. They form dense schools which acoustically represent strong targets. Even single krill represent targets which are detectable 100 to 200 m deep.

Many nations, like the USSR, Poland, Japan, and West Germany (FDR), are actively pursuing harvest. Technological processing problems are currently restraining expansion; but with a conservatively estimated potential yield of 50 million mt, a latent pressure rests on this resource. One task of the multi-nation "BIOMASS" program is to assess the abundance of krill and acoustic assessment is one of the employed methods. A group of international experts is trying to solve some of the problems related to assessment. Some of their findings can be applied directly to pandalid shrimps.

THEORETICAL BASIS

The problems, but also the possibilities, of acoustic assessment of pandalid shrimp can only be fully appreciated after a brief survey of the theoretical foundation of hydroacoustics.

In a sounder, the electric energy is converted by the transducer into sound waves for a fraction of a millisecond. But even if the shrimps are within detectable range, they may be difficult to see on the echogram unless the area of interest is expanded. The nature of the returning signals can be analyzed on its oscilloscope tracing. Targets like a pelagic herring school offer no problems while demersal ones either are within the distance $C \cdot \tau$ from the bottom, or are at least part of the school.

However, it is possible to magnify the layers 3 m above the bottom to examine these in detail (Figure 1). All this is satisfactory for the fisherman who can position his fishing gear accordingly. But in the context of management application, the real question is if these signals can be quantified.

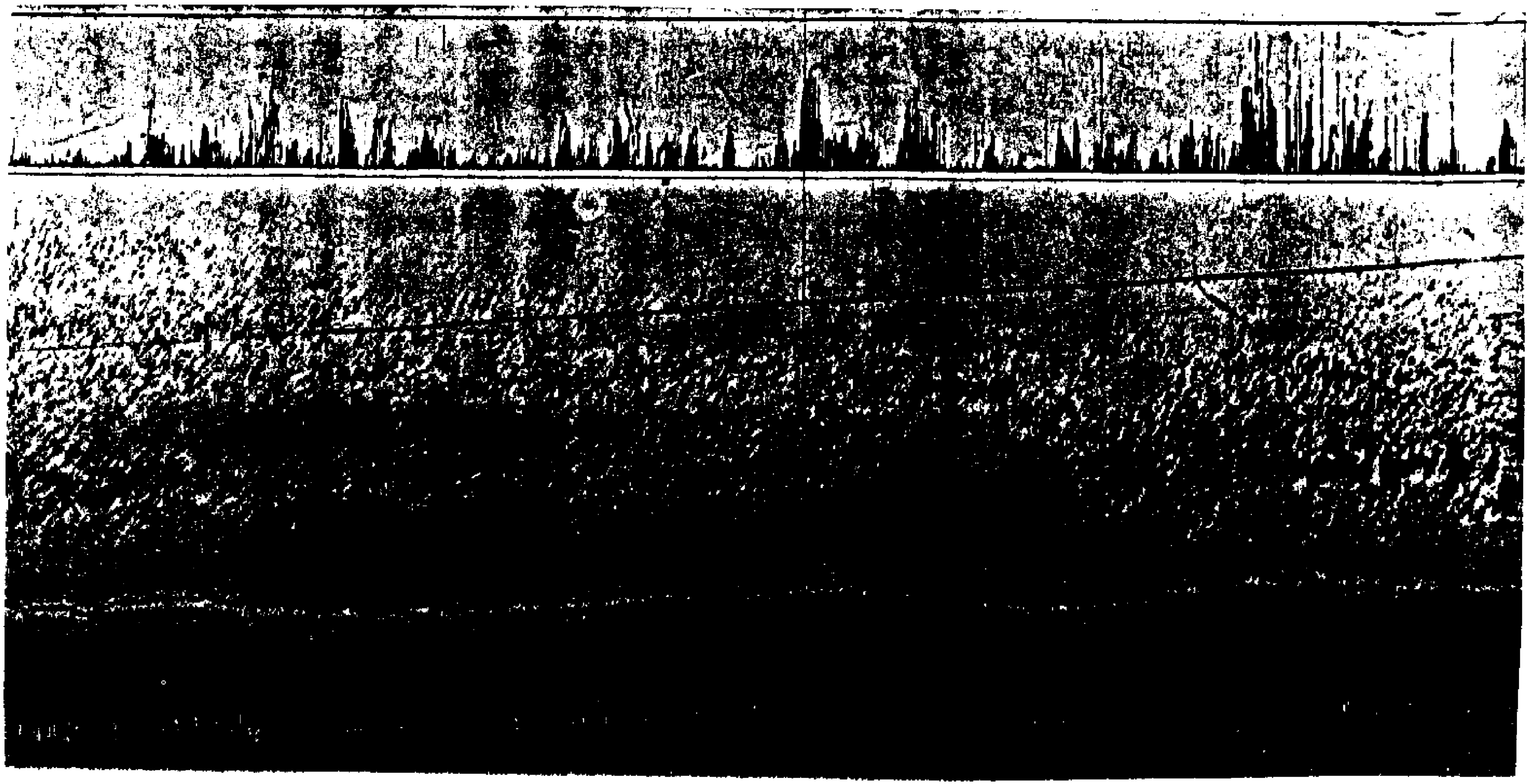

Figure 1. Bottom. Echogram made with SIMRAD EQ 3^{8} kHz on shrimp grounds in September at east Greenland (M/S _Pedro_).

Digital integration technique offers here the best possibilities, since the water column can be partitioned into strata and the signals originating within one single stratum can be digitized and integrated by themselves. On some integrating units, a total of 50 strata can be specified. But if one attempts to integrate one or two strata next to the bottom, complications arise if the bottom suddenly comes up and there is no bottom tracking routine, either automatic or manual. Then bottom signals will be integrated in the lowest stratum and lead to erroneous, inflated results.

The most advanced integrators can stop integration at a depth ranging from .1 to 20 m prior to the bottom echo. Power or energy emitted and the frequency of the sound waves, the duration of the pulse wave, and the efficiency of this conversion then become fixed physical parameters of the system.

There are now two types of losses: a geometric spreading loss proportional to the inverse of the second power of the distance to the subject, and an absorption in the water which is directly proportional to the distance, but which increases with the frequency of the sound waves.

When an object is encountered, part of the energy is reflected and returned to the transducer of the sounder which now acts as a receiver. The amount of energy is a function of the target expressed by the so called target strength. In reality, target strength is dependent on the difference in density between the object and the sound transmitting media, or sea water in this case. Reflection from solid bedrock is, therefore good, while mud bottom or sedimented layers give much weaker reflection. Likewise, the density interface (water-air) is great, so fish with a swim bladder give a much better signal than those with a less developed or non-existent swim bladder.

Unfortunately, krill, pandalid shrimp, and most other planktonic forms do not possess swim bladders. However, the chitin in the shell, the fat and the body meat do provide sufficient contrast to render them acceptable acoustic targets.

The signals, which finally reach back to the transducer where a conversion from wave energy to electic energy takes place, are so small that amplification of one million or more is needed in order to obtain a readable signal on the oscilliscope. However, just as signals can be amplified, so will the noise signals be amplified. Noise can be reduced by shortening the band width, but a minimum band width is necessary here as well as in a tuned radio circuit. In the end, we are forced to optimize various parameters against each other.

SYSTEM OPTIMIZATION

The criteria for selecting the primary systems parameters of frequency, pulse length, transmitted power, and source-recovery beam pattern can be judged by writing the echo level, EL, as equal to the reverberation level, RL, when other terms are removed:

$$RL = EL - DT - NL - CAV$$

where DT = the detection threshold

CAV = an arbitrary cavitation function.

The boundary conditions for these major system parameters are given in Table 1. For a selected target level, one seeks to minimize the noise level, to maximize isonified volume, and to minimize detection threshold. Neither of the functional relationships are monotonic increasing or decreasing relationships, so compromises must be made.

By examining the variance of the reverberation level, it can be demonstrated that the variance of the scattering cross section is the most important parameter. Hence, the estimation of this parameter becomes one of the first tasks in the proposed program for acoustic estimation of krill in southern oceans.

STRUCTURE OF A PANDALID SHRIMP ASSESSMENT PROGRAM

There is one set of suggestions for fishermen and another one for management biologists. In exploration for new grounds, studies of bottom echoes will define areas potentially suitable for pandalid shrimps, which prefer soft bottom but within rather wide depth ranges. The returned echoes from such bottoms will be stratified, as in Figure 2. The actual depicting of shrimps on the echogram is a little more complicated. As is well known, these shrimps live close to the bottom and will lift in the afternoon or evening.

For any acoustic system, there is imposed a resolution limit which can be computed from $C \cdot \tau$. Here C is velocity of transmission in water and τ pulse the duration or time the transducer is emitting soundwaves, so $C \cdot \tau$ becomes the length of the train of oscillations and half of this distance represents the boundary conditions below which no separation of targets is possible.

Table 1. Boundary conditions established by major system parameters

Variable	Lower boundary	Upper boundary
SL, τ	minimum detectable signal and decrease in total volume, insonified	cavitation (SL, τ, θ), increase in detection threshold
θ	minimum detectable signal and decrease in total volume, insonified	cavitation, increased noise level
f, Sv	Size of target $0.1 \leq ka \leq 1.0$ $k = 2\pi/\lambda$ a = radius of unit sphere	attenuation of sound, increased noise (thermal)
r	minimum resolvable distance from the receiver	maximum range determined by f

Source: MacCauley 1978.

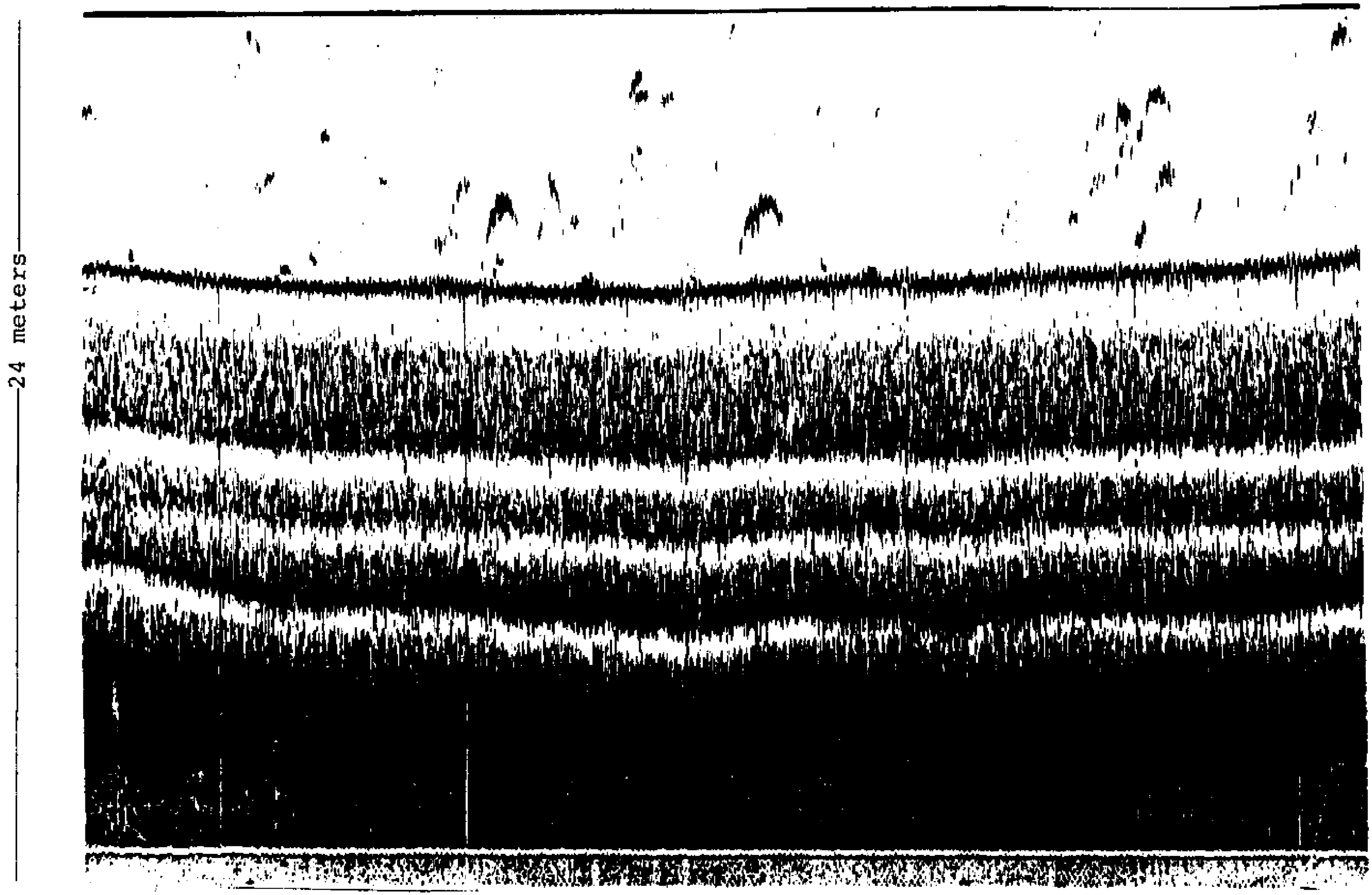

Figure 2. Expanded view of bottom signals returned from grounds suitable for pandalid shrimp (Oslo Fiord outside Norway, true bottom depth 200 m, vertical distance of expanded echogram 24 m).

While the thickness of the integrated stratum can be as narrow as 1 m, the integrated value from the specified stop or lowest depth to the bottom is always isolated and presented separately. The real problem with shrimp is the lack of sharp definition of the bottom echo due to the sedimented mud layers. For management use of this technique, there must be sufficient separation of the shrimp, or the majority of them, and the bottom echo. This has not yet been fully explored, but can easily be done during a preliminary fishing trip.

If the answer to the question posed above is affirmative, it may be followed by measurements of target strength. All other factors in the integration equation are either known or system parameters, which can be determined in the laboratory or are specified by the manufacturers.

One way to determine target strength or its equivalent, the scattering cross-section, is to decompose the shrimp into fluid spheres for which the compressibility and densities of the fluid media and target are known or can be determined. There are other, more advanced theoretical models which might be considered. Or an estimation can be done experimentally in a tank. Finally, one very practical way is to integrate and then simultaneously fish the same group by a suitable trawl. Corresponding values should then represent the coordinates of a data set, the loci of which form a straight line. If the trawl is 100 percent effective, then there is a true estimate of the scattering cross-section available. If not, which is the case with most trawling equipment, the estimate of the scattering cross-section will be biased. Whether the integrated value can be interpreted as an absolute biomass estimate or a relative one, is then contingent upon the size of this bias.

CONCLUDING REMARKS

Nets and trawls have been in use for more than a century as commercial fishing gear or scientific sampling gear. They are relatively stable, both in construction and performance. Their selectivity and bias are always present and very difficult to measure.

Hydroacoustic assessment technique, on the other hand, is young, two to three decades at the most, and subject to an exponential development today, both in regard to hardware and estimations procedures. The greatest promise lies here. Investment in equipment and time to explore the possibilities is small, relative to the potential benefits of measuring the abundance of pandalid shrimp.

There are restrictions imposed by present day technology. For example, if one is looking at shrimp at a depth of 300 m or more, it becomes difficult to use a hull mounted transducer. Lately there have appeared a series of towed-submerged bodies which house the transducer or transducers, since one can have both upward looking and downward looking units.

Even a simple mapping of relative densities from expanded echograms may provide the necessary input to stage one of a two-stage survey design, where only areas with indicated concentrations of shrimp should be surveyed in detail by calibrated sounding gear and simultaneous exploratory fishing. The necessary exploratory work falls well within the domain of the activities of the Alaska Sea Grant Program and thus qualifies for funding.

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AN ASSESSMENT OF THE GULF OF MAINE NORTHERN SHRIMP RESOURCE

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ABSTRACT

The current status of the northern shrimp resource in the western Gulf of Maine is reviewed. Historically, this fishery has been conducted primarily by Maine vessels during wintertime in inshore waters, where the catch has consisted primarily of mature (age 4+) females. In the late 1960s and early 1970s, an offshore fishery developed in which shrimp of all age groups were harvested. Landings rose rapidly during the early 1960s to a peak of 12,800 tons in 1969, averaged 11,000 tons from 1970 to 1972, and then declined precipitously to 387 tons in 1977. Commercial abundance indices suggest a period of increasing abundance from 1964 to 1969, followed by a decline. Maine and Northeast Fisheries Center (NEFC) research vessel survey data agree in suggesting a 90 percent decline in abundance from 1968 to 1977, similar to trends observed in stock size estimates calculated by applying exploitation rates obtained from Maine survey data to commercial land ings data. Abundance appears to have stabilized at a very low level during 1977-1978.

INTRODUCTION

The northern shrimp Pandalus borealis is widely distributed in the northern hemisphere, and in the north Atlantic occurs in commercially important concentrations from the Barents Sea westward to Baffin Island and southward as far as the Gulf of Maine. In the latter area, the species has been taken as by-catch since the turn of the century, although a directed fishery was not initiated until the late 1930s (Scattergood 1952). Since that time, commercial landings have fluctuated, increasing to peak levels in the mid-1940s and then declining to zero during the years 1954 to 1957 before again increasing to an all time high of 12,800 tons in 1969. Since 1972, landings have declined precipitously, and the resource has come under increasingly intensive management. It is generally agreed that temperature conditions have played an important role in determining historical trends in abundance (Apollonio and Dunton 1969; Dow 1964, 1966, personal communication), although the role of temperature during the present decade appears difficult to quantify in view of recent increases in fishing effort (Anthony and Clark, in press).

Beginning in 1974, the Gulf of Maine northern shrimp resource has been assessed annually by the Northern Shrimp Scientific Committee, which consists of biologists from Maine, New Hampshire, Massachusetts, and the National Marine Fisheries Service (NMFS). (The current assessment is basically the work of the senior author and other committee members, although both authors were responsible for the original assessment.) The Scientific Committee is responsible for preparing annual assessments and for transmitting them to the northern shrimp sub-board of the state-federal Northeast Marine Fisheries Board. Sub-board membership includes the commissioners of the marine fisheries agencies of Maine, New Hampshire, Massachusetts, and the director of the northeast region of NMFS. This group is responsible for management based upon results of assessments and other research by the Scientific Committee. In recent years, management has become increasingly restrictive, culminating in complete closure of the fishery during 1978.

Management of the Gulf of Maine northern shrimp resource has been unique in that participating member states have designated the Atlantic States Marine Fisheries Commission (ASMFC) as the joint regulatory agency under amendment one of the ASMFC charter. Under this arrangement, all regulatory measures are enacted and enforced in the name of the commission; however, actual law enforcement remains the responsibility of the individual states (Northern Shrimp Scientific Committee MS 1978).

NOTES ON BIOLOGY AND DISTRIBUTION

Northern shrimp in the Gulf of Maine migrate rather extensively, a circumstance which has significantly influenced the character of the fishery. Each year ovigerous (egg-bearing) females move into coastal waters in late autumn and early winter, where peak hatching occurs in late February and early March. After a planktonic phase lasting approximately two months, young shrimp settle to the bottom in inshore areas where they remain for over a year (Apollonio and Dunton 1969). With approaching maturation, young shrimp gradually move into deeper offshore areas, where they mate as males in the summer of their third year, and after a series of transitional phases, as females in the summer of their fourth year (Apollonio and Dunton 1969). In late autumn, adult females (now ovigerous) again move onshore to complete the cycle.

Annual inshore-offshore movements may be repeated for two or three consecutive years, although current evidence suggest that natural mortality increases significantly after first hatching (Haynes and Wigley 1969).

In response to this annual cycle, two fisheries have developed: an inshore winter fishery on adult females and an offshore fishery (primarily in warmer months) in which shrimp of all age groups have been harvested. The former (involving for the most part smaller Maine vessels) has been of primary historical importance; the latter fishery has been exploited primarily by Massachusetts vessels since the late 1960s. Figure 1 indicates the seasonal distribution of fishing effort in the Gulf of Maine northern shrimp fishery in recent years.

Bottom trawl survey data (discussed further below) indicates that the bulk of the population is concentrated in the western Gulf of Maine (Figure 2). This has been attributed both to temperature relationships (Apollonio and Dunton 1969) and substrate conditions (Haynes and Wigley 1969). There is no evidence to suggest significant movement into or out of the Gulf of Maine in recent years, and abundance in adjacent areas appears to be low. There is also no evidence that separate stocks should be recognized within the western Gulf of Maine as population structure, trends in abundance and other attributes appear reasonably consistent. Accordingly, the Gulf of Maine resource has been considered as a unit for purposes of this assessment.

COMMERCIAL FISHERY

Since the beginning of the fishery, commercial landings have fluctuated widely (Figure 3). A directed fishery was instituted in 1938, and landings subsequently increased to 264 tons in 1945 before declining to zero during the period from 1954 to 1957. In the following decade, landings increased rapidly to a peak of 12,800 tons in 1969, averaged approximately 11,000 tons from 1970 to 1972, and subsequently declined precipitously to 387 tons in 1977. The fishery was closed in 1978. Historically, the bulk of the catch has been taken in the Maine winter fishery; however Massachusetts vessels began to land appreciable quantities in 1969. Since that year, Massachusetts has accounted for an increasing proportion of the landings (over 40 percent of the 1973 to 1977 total), while Maine's share has declined. In 1977,

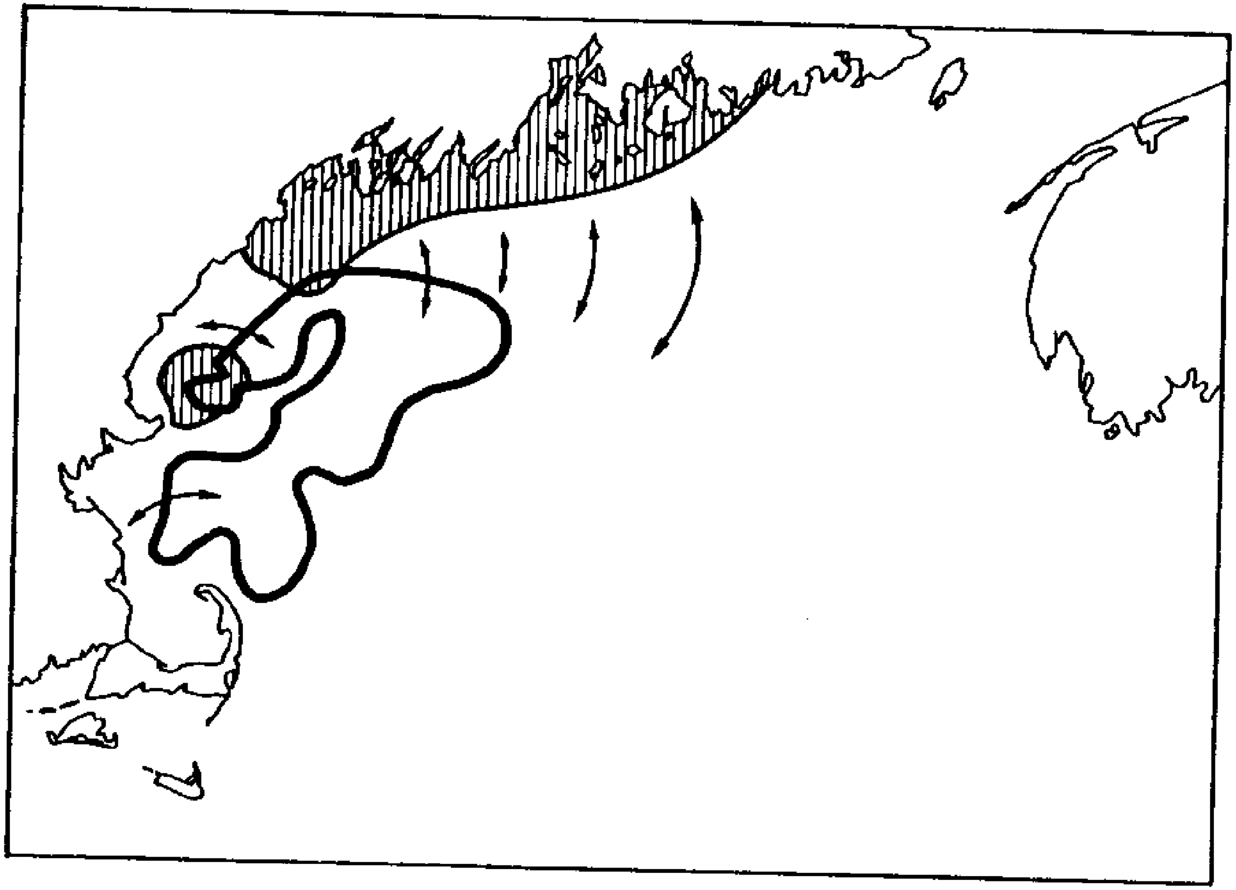

Figure 1. Western Gulf of Maine, indicating seasonal distribution of fishing effort for northern shrimp. Cross-hatching indicates winter fishing, solid line encompasses offshore areas of primary interest.

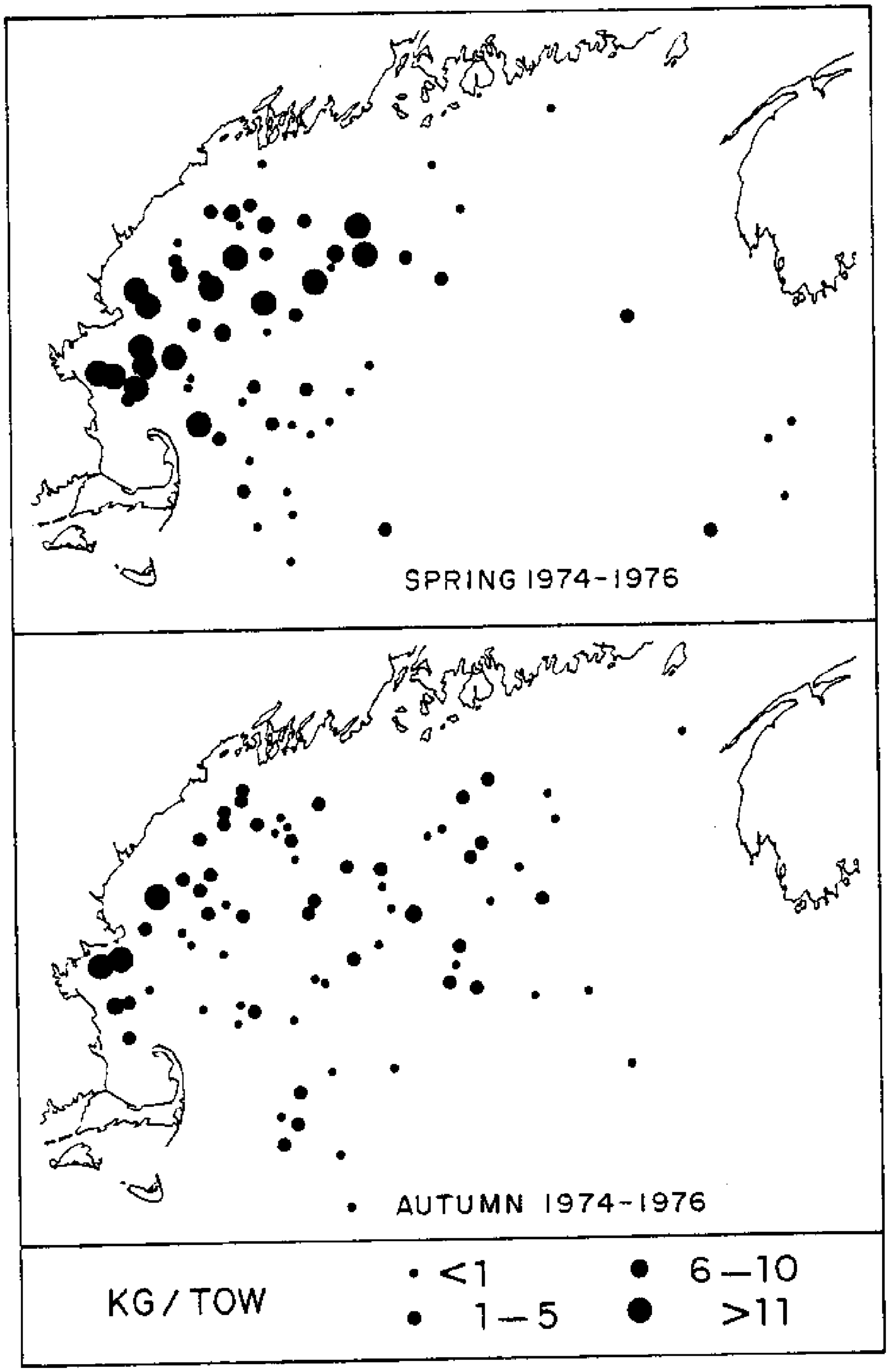

Figure 2. Distribution of northern shrimp in the Gulf of Maine area as evidenced by NEFC spring and autumn bottom trawl surveys, 1974 to 1976.

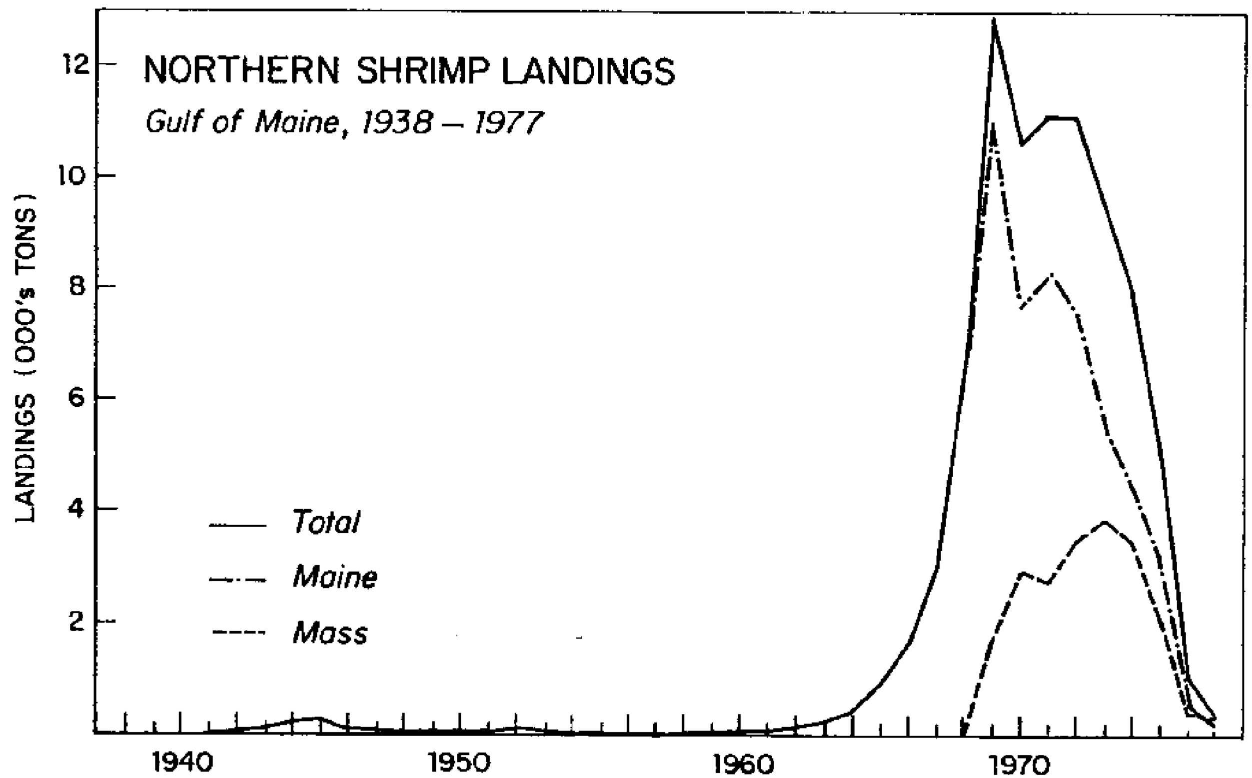

Figure 3. Northern shrimp landings in the Gulf of Maine by state, 1938 to 1977.

Massachusetts landings exceeded those of Maine (61 percent of the total). The recent offshore fishery (exploited primarily by Massachusetts vessels) was of some importance in supporting annual landings during the peak years of the early 1970s.

Percentage age composition of the Gulf of Maine northern shrimp catch (numbers) by quarter for 1973 to 1977 is given in Figure 4. (Sample data are not available for the second and fourth quarters of 1975. Remaining omissions reflect seasonal closures). Considerable seasonal variation is evident. Winter (first quarter) catches are documented by females (primarily age 4), which account for over 70 percent of the winter catch in numbers in all cases. In the remaining quarters, however, immature and mature male shrimp have been taken in much larger quantities, e.g., in 1974 over 60 percent of the summer catch consisted of age 1 shrimp (Figure 4). High winter catches of females reflect migration into coastal areas, while remaining data reflect age structure of the population in offshore situations.

CURRENT ASSESSMENT

Trends in abundance in recent years have been examined using both commercial and research vessel survey data. In the former case, an index has been developed from catch-effort data obtained by NMFS port agents during dockside interviews. Trip data for which 50 percent or more of the catch consisted of shrimp were used so as to reflect "directed" effort. This distinction was necessary because during summer and autumn, shrimp have been taken as by-catch in operations directed toward whiting (*Merluccius bilinearis*).

Effort data were standardized by vessel class using data for the 34 to 50 gt vessel class as standard (the most stable in terms of numbers involved). Standardization involved regressing catch per day fished of each tonnage class against catch per day fished of the standard. Resulting coefficients were then used to adjust effort data by vessel class, which were then combined on an annual basis and divided into annual landings data to obtain the index (Figure 5).

Calculated index values fluctuate somewhat but generally increase from 1964 to 1969, followed by a pronounced decline (Figure 5). The increasing trend from 1964 to 1969 appears reasonable in that environmental conditions appear to have been favorable for recruitment and observations from a number of sources suggest that population size was rapidly increasing during that period. Declines observed since 1969 are not as pronounced as evidenced from survey data. This may reflect changes in vessel efficiency, data base limitations, direction of fishing effort towards known concentra-

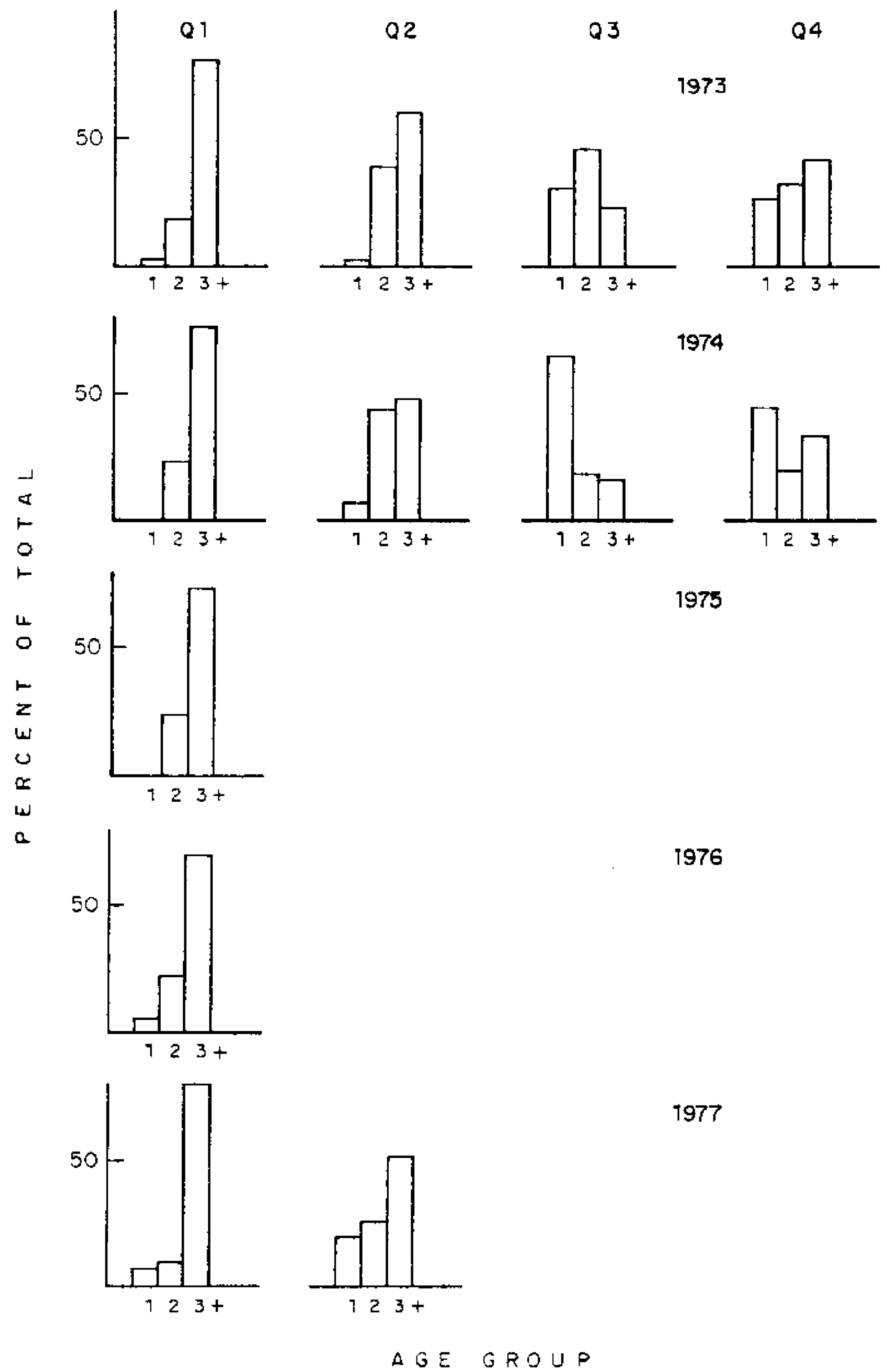

Figure 4. Percentage age composition of the Gulf of Maine northern shrimp catch by quarter, 1973 to 1977.

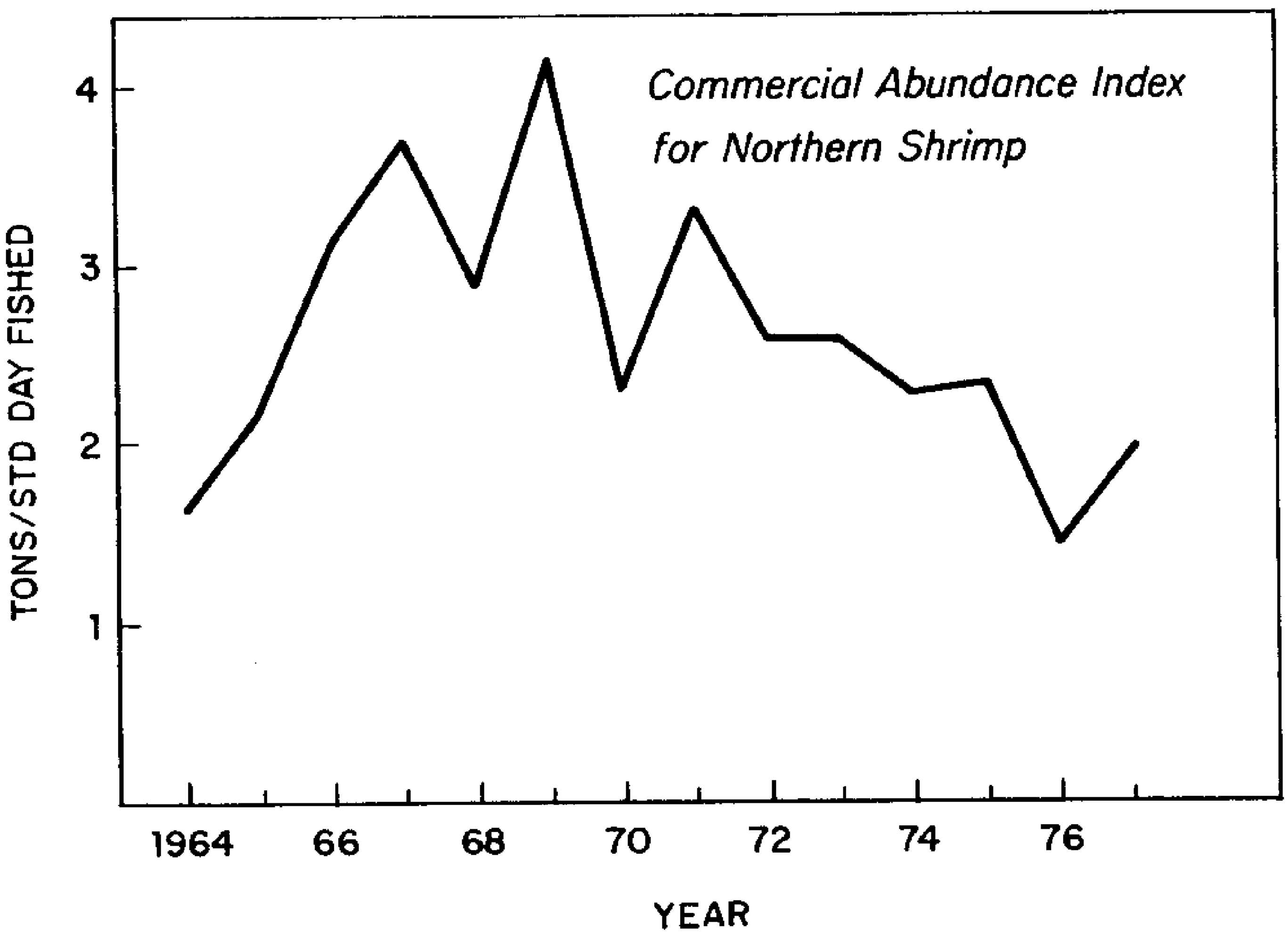

Figure 5. Commercial abundance index for Gulf of Maine northern shrimp, calculated from NMFS catch-effort data, 1964 to 1977.

tion areas, or other factors. However, Rinaldo (1976) reported an 80 percent decline in catch rates for selected Maine study vessels from 1969 to 1974, when these vessels stopped fishing.

Research vessel surveys have been conducted by the State of Maine in summer since 1967, and by the NMFS Northeast Fisheries Center (NEFC) beginning in autumn 1963, and spring 1968. In the Maine summer survey, tows are made at standard locations in known concentration areas (Figure 6) using a shrimp research trawl. Resulting data have been useful in evaluating trends in abundance, age composition, mortality, and recruitment. The NEFC surveys are based on a stratified random design and the Gulf of Maine has been divided into strata (Figure 7) primarily on the basis of depth. Stations are allocated to strata roughly in proportion to the area of each stratum and are assigned to specific locations within strata at random. Standard groundfish trawls have been used in these surveys, however, 1.25 cm liners are used in the cod ends.

Relative abundance indices for all of these surveys (catch per tow, kg) declined more or less continually from 1969 to 1977 (Figure 8). The Maine summer survey index declined from 56.9 kg in 1968 to 1.6 kg in 1977 (a decline of 97 percent) but then increased to 3.2 kg in 1978. However, the 1978 index value was still lower than values observed prior to 1977. The NEFC spring and autumn survey indices likewise declined by over 90 percent between 1968 and 1977. A slight increase occurred for the autumn survey index in 1977-78, but again values remained low compared to former years (Figure 8). In summary, available survey data agree in indicating that stock abundance has declined by over 90 percent since the late 1960s and remains at a very depressed level. Another aspect worth mentioning involves an apparent shift in species composition. For example, the percentage by weight of P. borealis in NEFC spring survey catches declined from approximately 100 percent in 1975 to 40 percent in 1978, while for autumn, survey data values declined from 86 percent in 1975 to 22 percent in 1977. The bulk of the catch of other species has consisted primarily of smaller Pandalids (e.g., Dichelopandalus leptoceras) which are currently of little or no commercial value.

Stock sizes have been approximated from annual catch data and mortality and exploitation rates generated from Maine survey catch at age data. Annual estimates of instantaneous total mortality (Z) (weighted by numbers caught in each age group) were calculated from Maine survey catch at age data. Estimates of instantaneous fishing mortality (F) were then obtained by subtracting an estimated instantaneous natural mortality (M) value of 0.25 (Rinaldo 1976). Corresponding rates of exploitation (u) and survival (S) were then calculated using these values (Ricker 1975) and applied to total

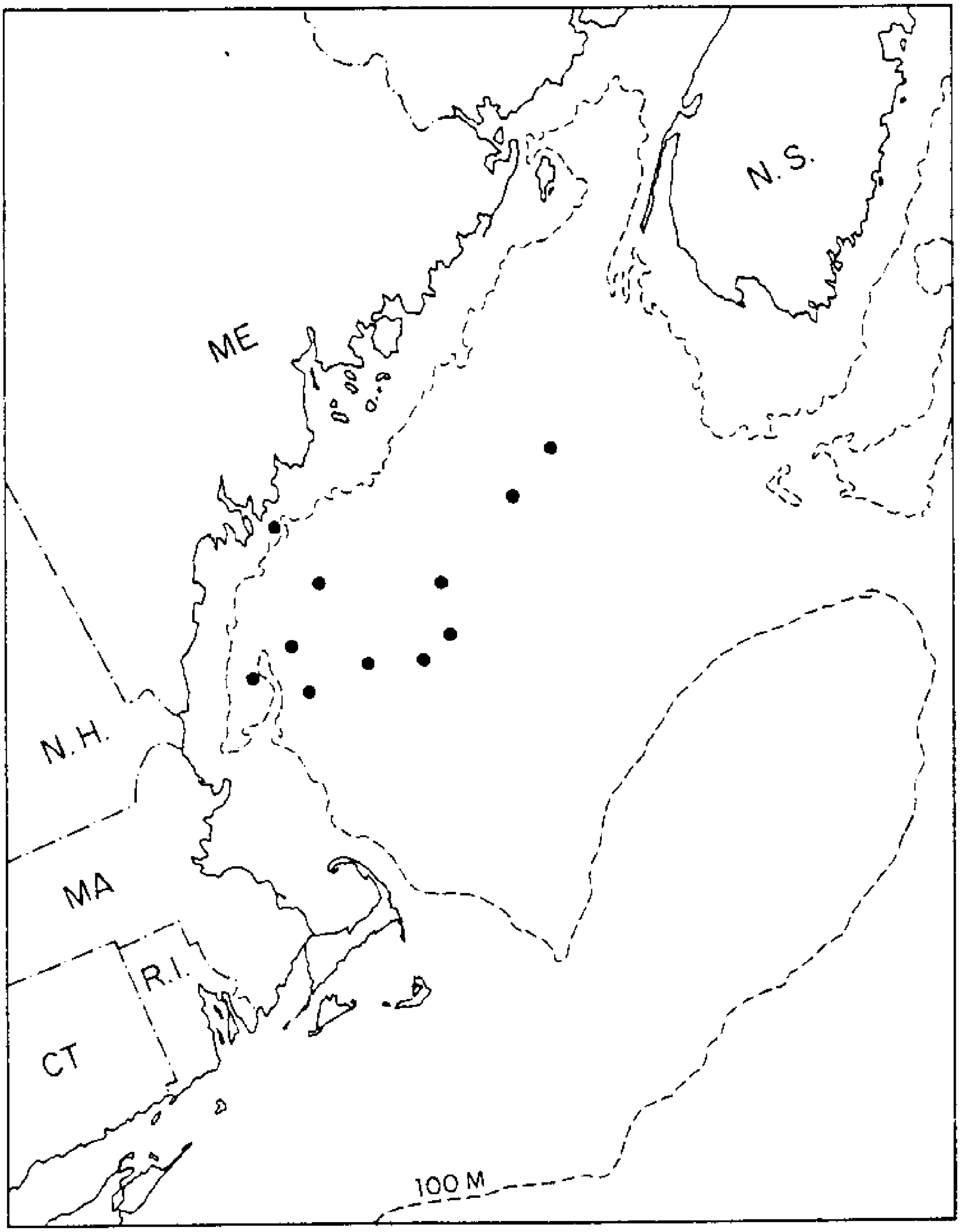

Figure 6. Locations of stations sampled during Maine state August research cruises.

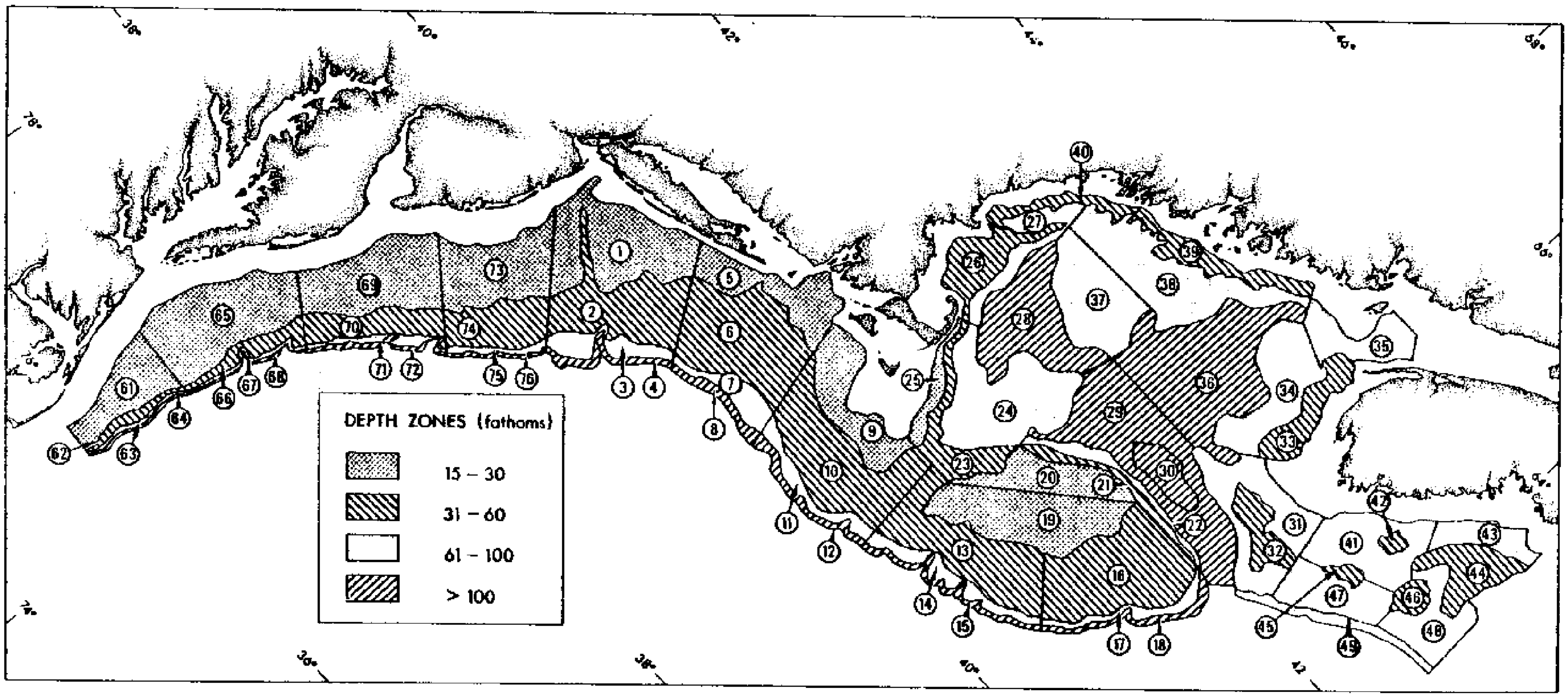

Figure 7. Northwest Atlantic area from the Scotian shelf to Cape Hatteras, showing locations of sampling strata used in NEFC surveys.

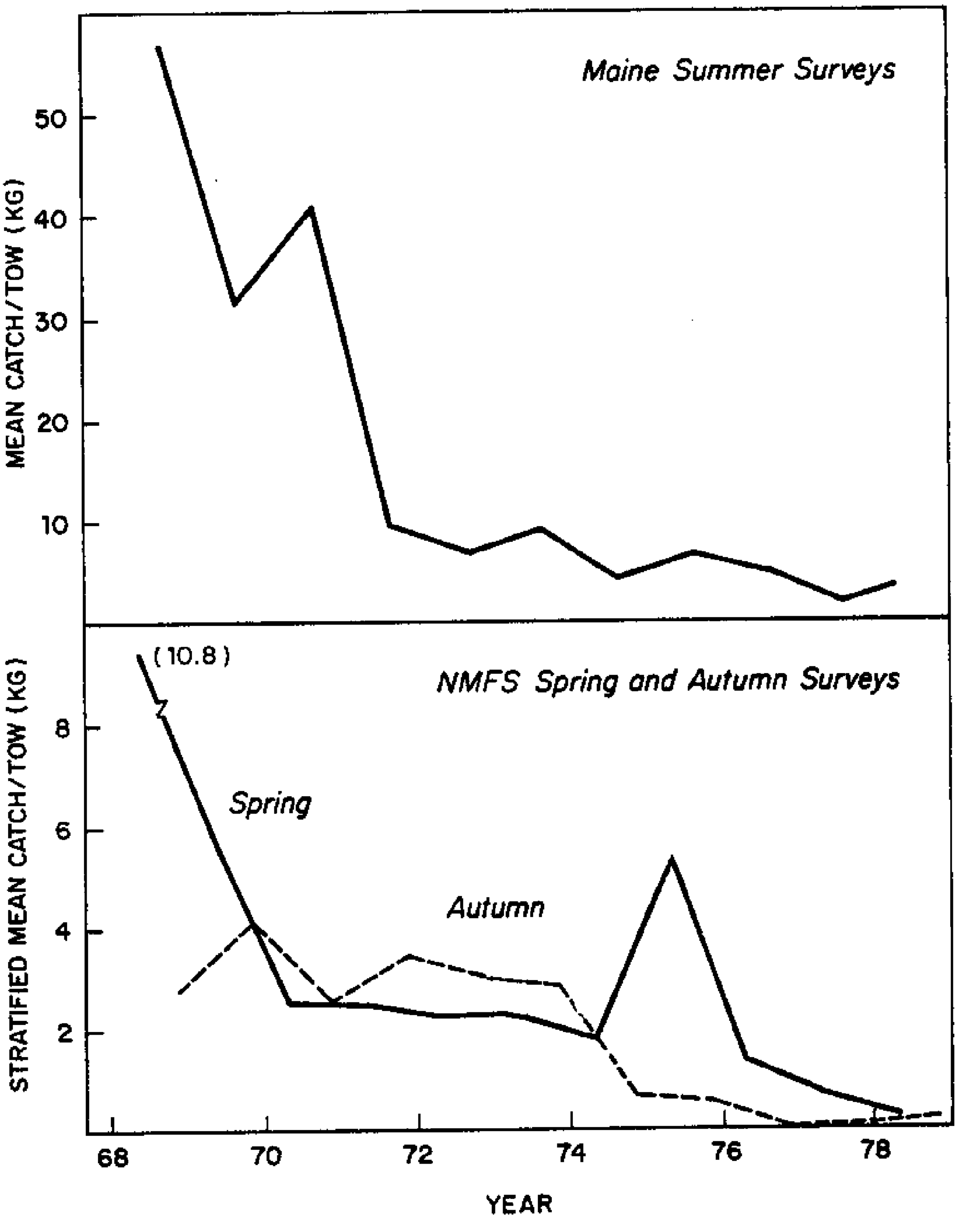

Figure 8. Indices of relative abundance calculated for Maine summer and NEFC spring and autumn bottom trawl surveys 1968 to 1978.

catch in weight to provide stock size and recruitment estimates. Stock size estimates were obtained by dividing catch by exploitation rate; recruitment estimates were obtained by subtracting survival estimates in year i from stock size estimates in year i + 1. Results are given in Table 1.

Calculated values of F and u fluctuate considerably, but in general increase substantially after 1970, apparently reflecting increased fishing pressure in offshore areas. Values for 1978 were the lowest in the series and appear to reflect closure of the fishery during that year. However, there was some potential for fishing mortality due to illegal fishing activity (documented by industry reports) and by-catch in the whiting fishery during summer and autumn. Earlier analyses (Northern Shrimp Scientific Committee MS 1977) suggest a potential by-catch in weight exceeding 10 percent of the total biomass present. Accordingly, some fishing mortality would be expected in 1978, although M may also have increased in recent years. Stock size and recruitment estimates declined by over 95 percent during 1969 to 1977, in reasonable agreement with survey trends.

A comparison of stock size estimates with corresponding NEFC autumn survey index values appears in Figure 9. Agreement is reasonably good (r = 0.93), suggesting that the analysis presented in Table 1 provide a reasonable approximation of recent trends in abundance and recruitment.

Table 1. Catch, stock size, recruitment estimates, and related parameters used in assessment of the Gulf of Maine northern shrimp stock. Estimates of instantaneous fishing mortality (F) were calculated from analysis of Maine survey catch at age data assuming M = 0.25

Year	Instantaneous fishing mortality (F)	Exploitation rate (u)	Survival rate (S)	Catch (000's tons)	Stock Size (000's tons)	Recruitment (000's tons)
1968	0.71	0.456	0.383	6.6	14	*
1969	0.75	0.474	0.368	12.8	27	22
1970	0.69	0.447	0.391	10.6	23	13
1971	1.95	0.788	0.111	11.1	14	5
1972	1.72	0.752	0.139	11.1	15	13
1973	0.87	0.524	0.326	9.4	18	16
1974	1.80	0.765	0.129	7.9	10	4
1975	1.41	0.688	0.190	5.3	8	7
1976	0.98	0.564	0.292	1.0	2	1
1977	1.98	0.792	0.108	0.4	1	1
1978	0.54	0.373	0.454	-	*	*

- No reported landings due to fishery closure.

* Not calculated. Landing data not available.

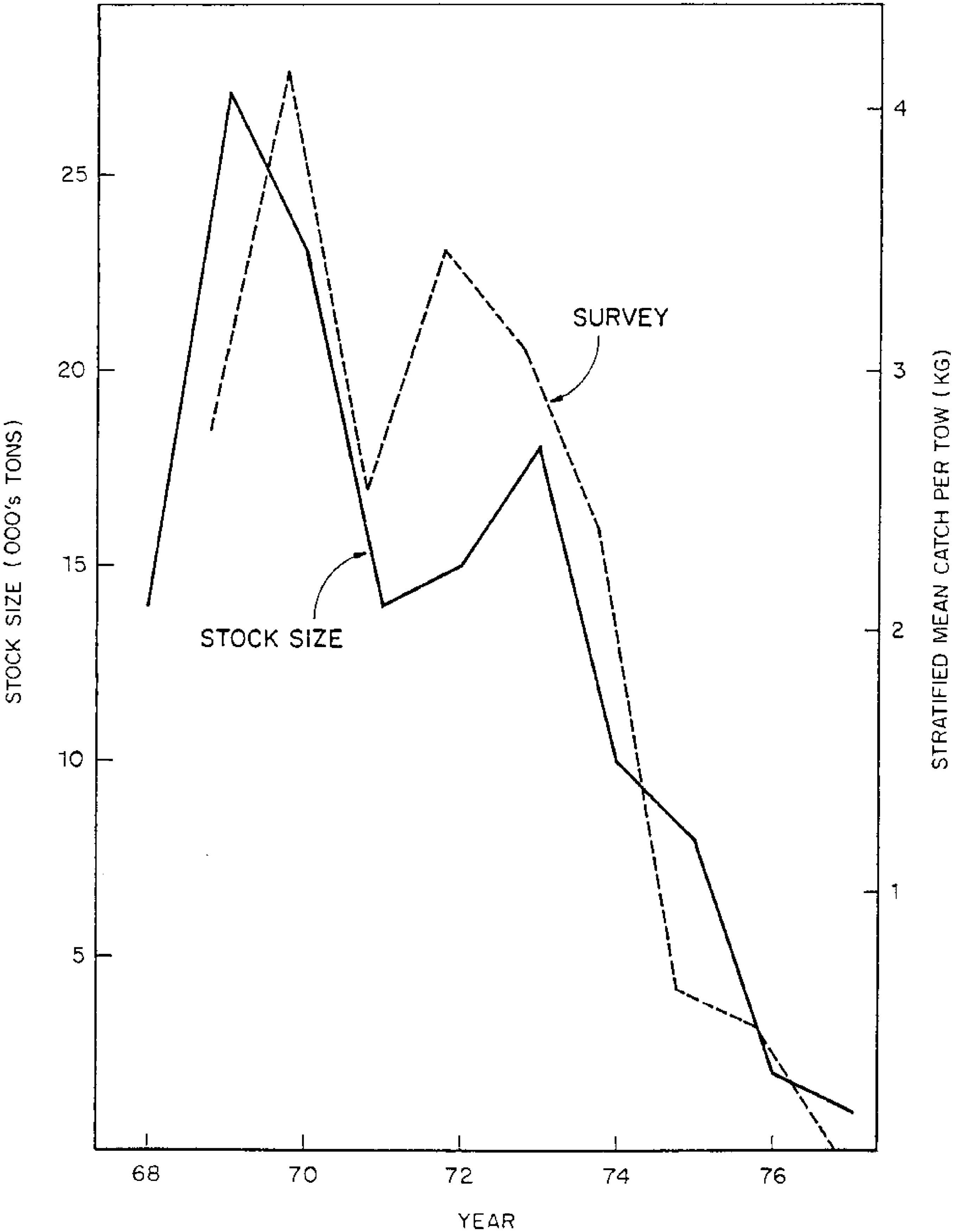

Figure 9. Stock size estimates calculated from commerical catch data and exploitation rates generated from Maine survey data compared to NEFC research vessel abundance indices, 1968 to 1977.

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HUMPY SHRIMP (*PANDALUS GONIURUS*) IN THE WESTERN BERING SEA: STOCK ASSESSMENT BASED ON TRAWL SURVEYS AND UNDERWATER PHOTOGRAPHY

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ABSTRACT

The density of *Pandalus goniurus* population in the Anastasiya Bay Area estimated from bottom photography in July and August 1972 proved to be about 4.5 times higher than that calculated using catch data. Hence, the catchability coefficient was determined as .22. The total biomass in the Gulf of Anadyr off Cape Navarine and in the Anastasiya Bay area based on trawl survey, was estimated at (160) (10^3) mt. (That is about (725) (10^3) mt if the catchability coefficient is taken into consideration). Temporal population dynamics of shrimps and their orientation on the bottom is discussed.

INTRODUCTION

The humpy shrimp, *Pandalus goniurus* Stimpson, is the most abundant species on the Asian shelf of the Bering Sea. A stock assessment made by the Pacific All-Union Research Institutes for Marine Fisheries and Oceanography (TINRO and VNIRO) has shown that this shrimp fishery is very promising. The stock was assessed mainly from trawl surveys and obviously underestimated, since the catchability coefficient was taken as 1. Consequently, it is highly desirable to diversify assessment methods to gain a proper insight into shrimp stocks.

With this aim, a photographic technique was used to assess shrimp concentrations in 1972 and 1975. Unfortunately, we failed to carry out the complete program. Observations were made only in one area of shrimp concentrations in 1972, and negatives obtained in 1975 were of poor quality. Owing to the delay in our survey, a decision was made to publish the preliminary results which seemed to be of some interest. The aim of the work was to estimate shrimp density and biomass from trawl survey and bottom photography, to derive the trawl catchability coefficient and to carry out behavioral studies based on bottom photographs. The results are regarded as tentative and demand further investigation.

MATERIAL AND METHODS

Studies were conducted aboard the R/V *Pelamida* (Captain, A.S. Kolokol'tsev) in 1972 and 1975 during the TINRO and VNIRO joint expeditions.

TRAWL SURVEYS

Data on distribution and abundance of shrimps was obtained using a 27.1 m otter trawl with a trawl haul of 30 minutes at a speed of 3 knots. The cod end was fitted with a fine mesh (10 mm from knot to knot). Vertical and horizontal openings were about 3.5 to 5 m and 16 to 17 m, respectively. A measurement of 17 m was assumed for calculation of the swept area. Trawlings were made on a 24 hour basis in 1972, and from 5 a.m. to 9 p.m. Petropavlosk time in 1975, when *P. goniurus* is confined to the bottom (Barsukov and Ivanov 1979).

The present paper deals with the following three main areas of shrimp concentrations in the Bering Sea: off Anastasiya Bay, off Cape Navarin and in the Anadyr' Gulf. Small concentrations of shrimp in areas off Nataliya and Dezhnev Bays and off Karaginskij Island are not discussed here. Positions of hauls in the investigated areas are as given in Figures 1 2, 3 and 4. Additional data on the results of the 1972 surveys are considered by Ivanov (1974). To study shrimp migrations, an attempt was made to repeat the survey in each area at monthly intervals.

UNDERWATER PHOTOGRAPHY

To make underwater photography observations, the PFA-6 camera with automatic shutter release was used. A box with the camera and flash were lowered to the bottom. Photographs were taken when a weight suspended from the apparatus touched the bottom. Sequential photos were taken by raising the unit about 5 m and lowering it again until weight actuated the next photos. Photos were taken at two minute intervals allowing the boat to drift away from the location of the previous photo. This avoided disturbing the bottom fauna.

Photographs were taken after trawling at the test stations was finished. However, because of delays related to treatment of trawl samples, the photography often started after the vessel had left the area of the trawl. A photo station lasted about 35 minutes. In areas of shrimp concentration, eight successful stations were made from July 8 to August 12, 1972 (Figure 1). Eighty photographs were taken at these stations, with the number of clear pictures varying from three to 19.

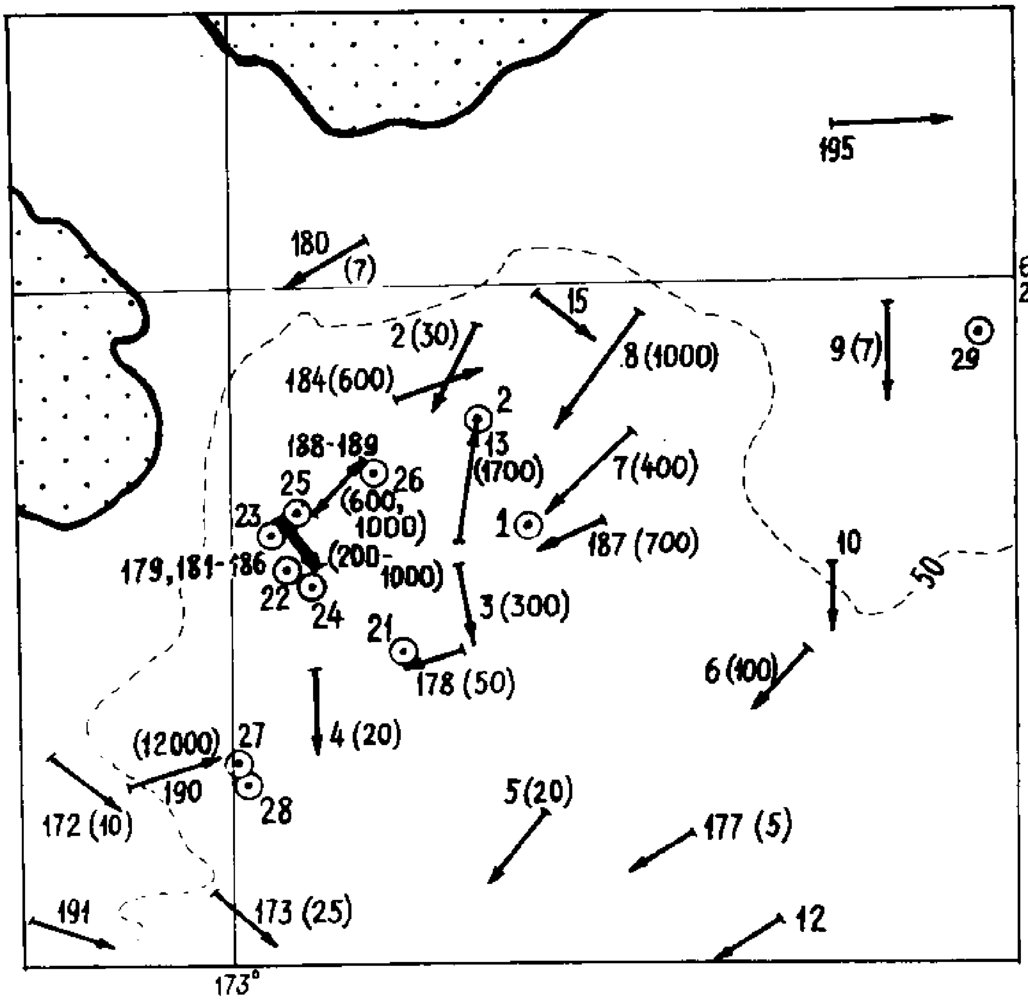


Figure 1. Pandalus goniurus off Anastasiya Bay, 1972. The vectors indicate trawl positions and are labeled by haul number. Parenthesis indicate the catch amount in kg. If these numbers do not appear, individual shrimp were counted. Circled dots: bottom photography stations. Dotted line: 50 m isobath.

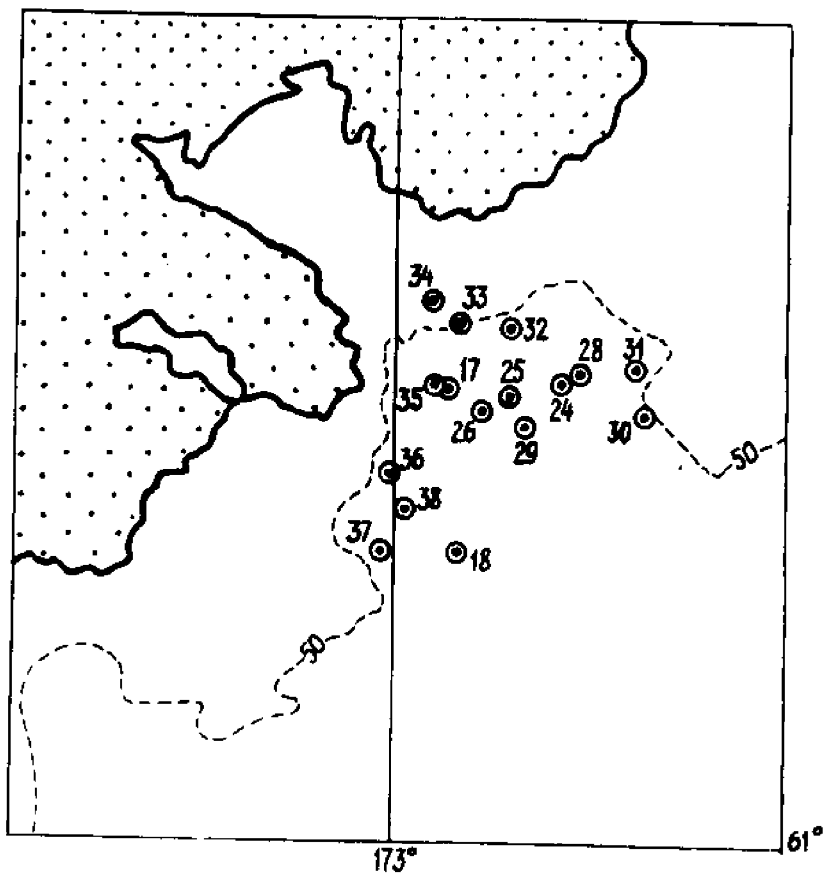


Figure 2. *Pandalus goniurus* off Anastasiya Bay in 1975, the location and number of bottom photography stations and the 50 m isobath.

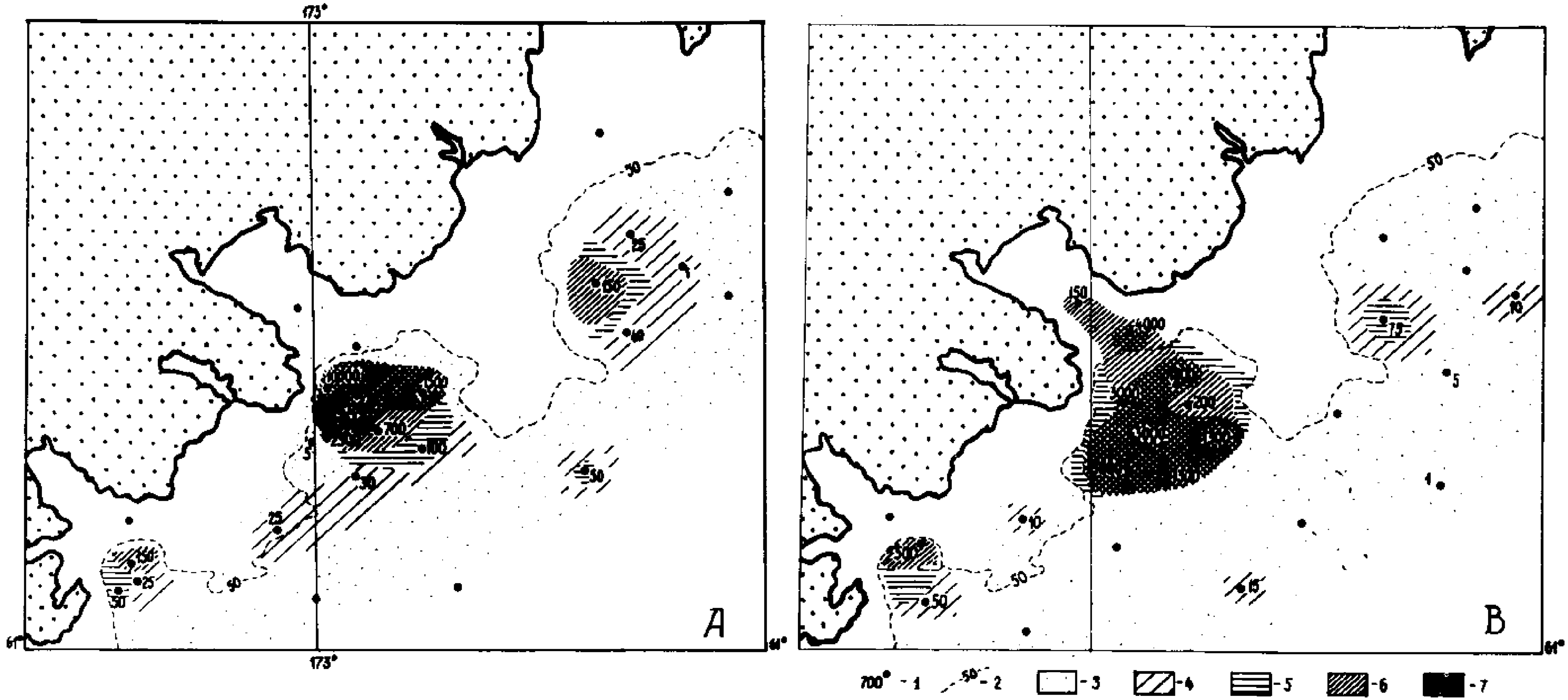


Figure 3. Catches and distribution of *Pandalus goniurus* off Anastasiya Bay in 1975. Map A: July 7-15, Map B: July 15-19. Numbers on map are the catch amount in kg. Dotted line: 50 m isobath. In the key: 3: less than 10 kg/30 minutes trawled, 4: 10 to 50 kg/30 minutes trawled, 5: 50 to 100 kg/30 minutes trawled, 6: 100 to 1000 kg/30 minutes trawled, and 7: more than 1000 kg/30 minutes trawled.

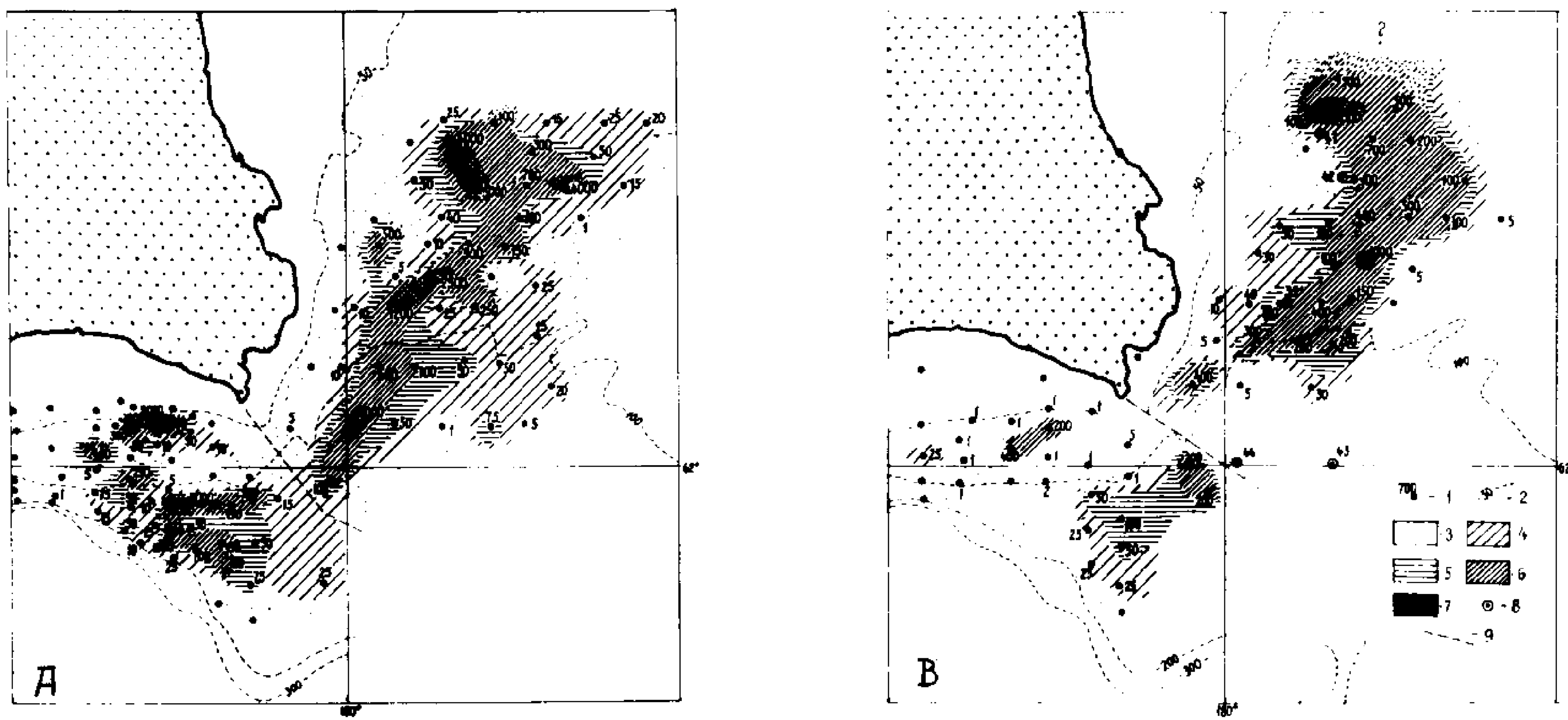


Figure 4. Catches and distribution of Pandalus goniurus in the Anadyr-Navarin area in 1975. Map A: June 22-July 8, Map B: July 20-30. Circled dots 8: bottom photography stations. Dotted lines 2: isobaths in meters. Legend: same as Figure 3. Dotted line 9: arbitrary line between the Navarin and Anadyr Gulf areas.

In 1975, the PINRO automatic underwater camera (Triton), adapted for an otter trawl survey, was used. However, photographs were not clear when the box was attached to the headrope. Soon after the start of the operation, during rolling seas, the camera hit the otter board and was heavily damaged. After the camera was repaired at the Port of Providenie, it was lowered using a rope. Photographs were taken at a 45^{o} angle. Photo stations lasted about 20 minutes. Their positions are given in Figure 2.

We have not succeeded in receiving clear bottom photographs, mainly because of water turbidity caused by phytoplankton bloom. Usually only shrimp eyes reflecting the electronic flash could be recognized on the negatives as pairs of black dots (Figure 5).

Shrimp eyes seem to be visible in different ways, depending on the position of shrimp in relation to the light, and are probably invisible when the shrimps' backs are to the light. As a consequence, the 1975 data on shrimp densities are highly underestimated and cannot be widely used.

DENSITY ESTIMATE

Population density figures were based on catch data on bottom photographs independently. In the first case, it was estimated from the number of shrimps caught divided by the area swept. It was assumed that at the vessel speed of 3 knots and the horizontal opening of 17 m, an area of 47,251 m^2 was swept every 30 minutes. The weight of the catch was estimated visually with possible errors of 10 to 20 percent. Shrimp numbers were determined by weight of catch (W_i) divided by the average shrimp weight in the catch sample ($\bar{w}_i$). The catchability coefficient was taken as one. The average population density was determined to be the arithmetic mean of densities from individual hauls.

For estimating shrimp density from bottom photographs, the following parameters were determined:

1. the number of shrimp in a picture
2. the area photographed in a single picture
3. the total area photographed at a station
4. the total number of shrimp photographed at a station
5. the mean density of shrimp at a station
6. the mean density of shrimp in the entire area investigated.

When counting shrimp in the picture, fully visible specimens or those which are a bit beyond frame, were taken into account. If only part of the shrimp was photographed, it was taken as a .5 specimen. (In Figure 6A for example, 25 specimen can be recognized, but they were counted as 23.)

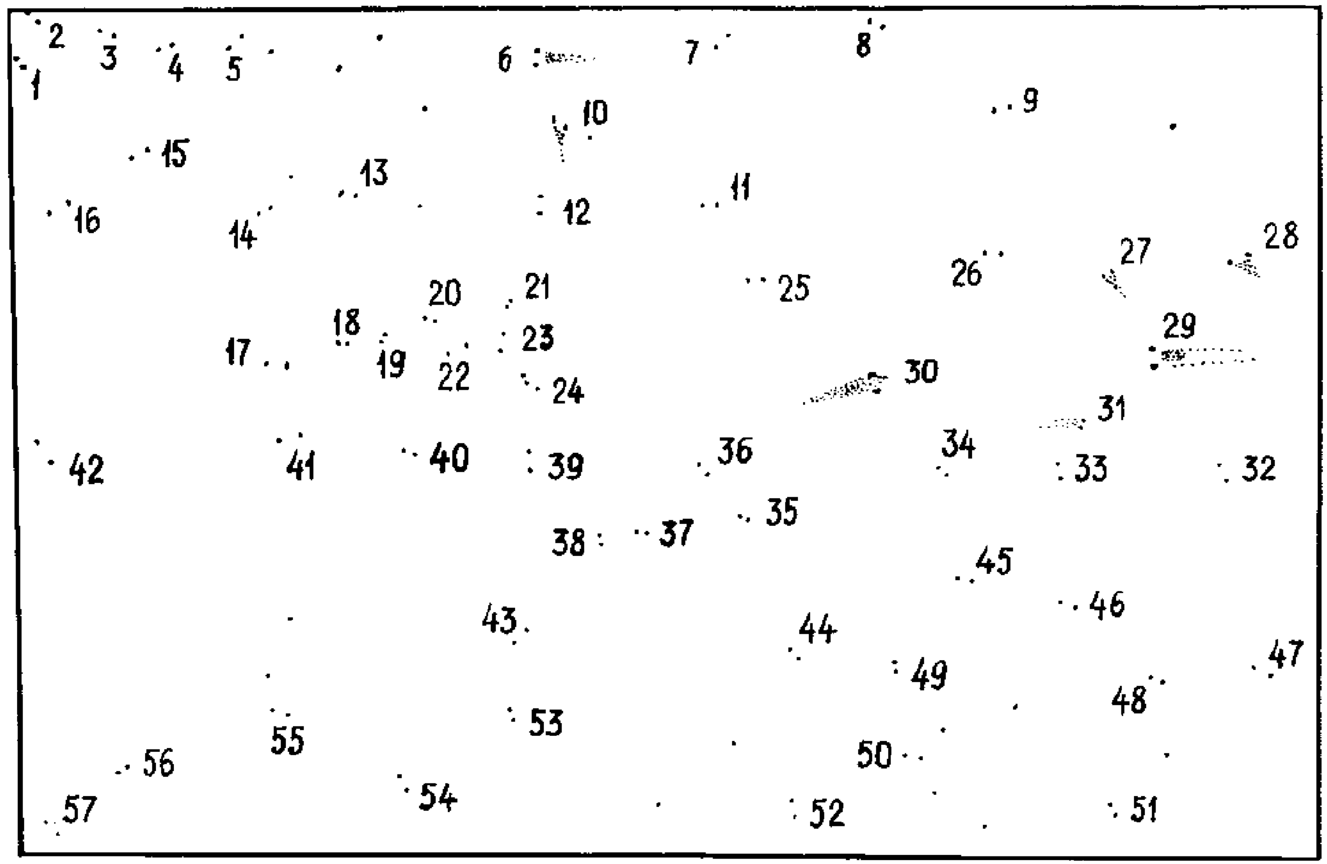


Figure 5. A schematic representation of a photographic negative taken off Anastasiya Bay during bottom photography experiments in 1975 at Station 36, July 19, 52 m to 54 m depth. Only shrimp eyes were visible.

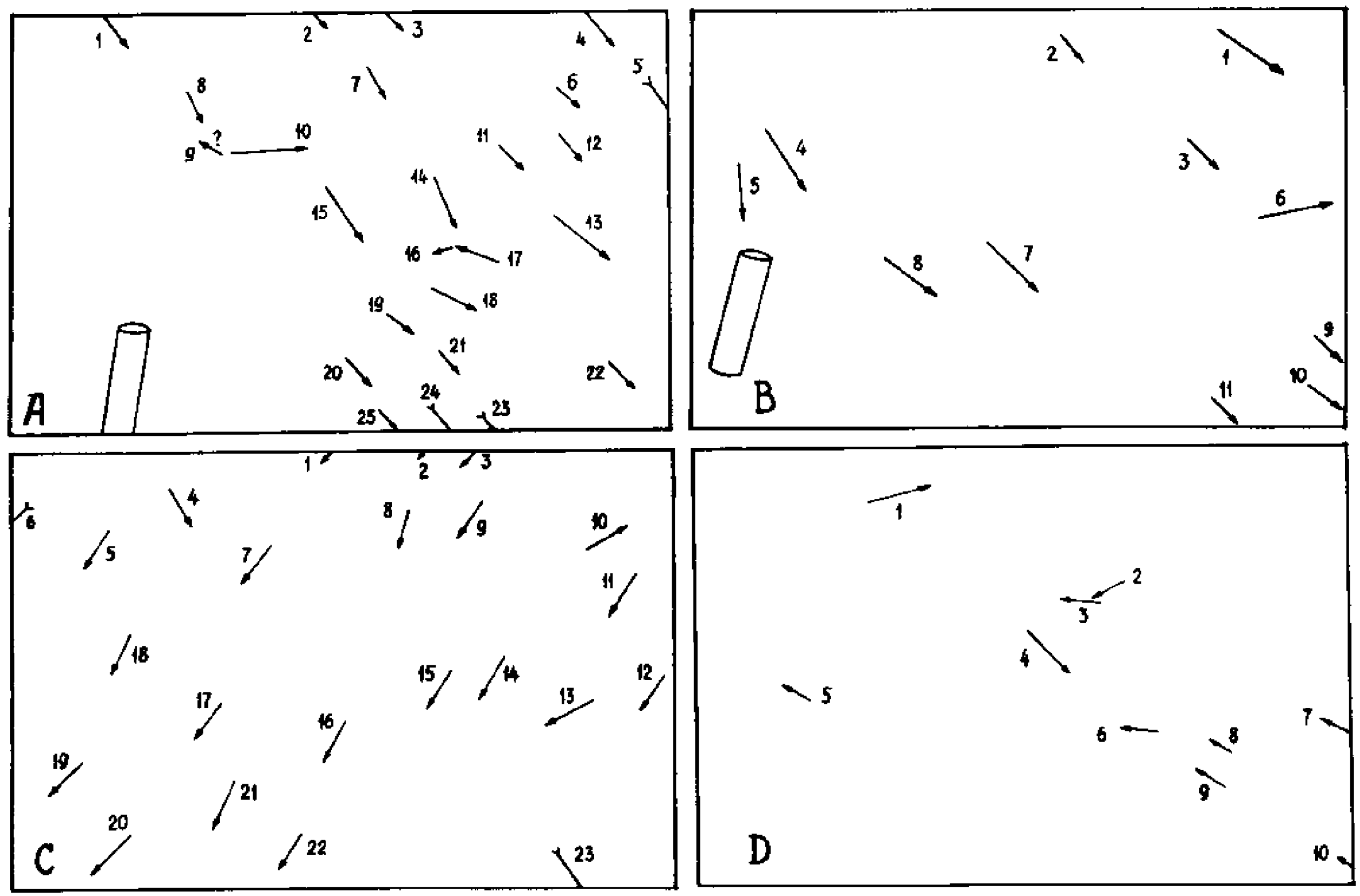


Figure 6. A schematic representation of photos of *Pandalus goniurus* demonstrating nearly uniform orientation. Figure 6a is a schematic of Figure 7a. Note the effect of the weight.

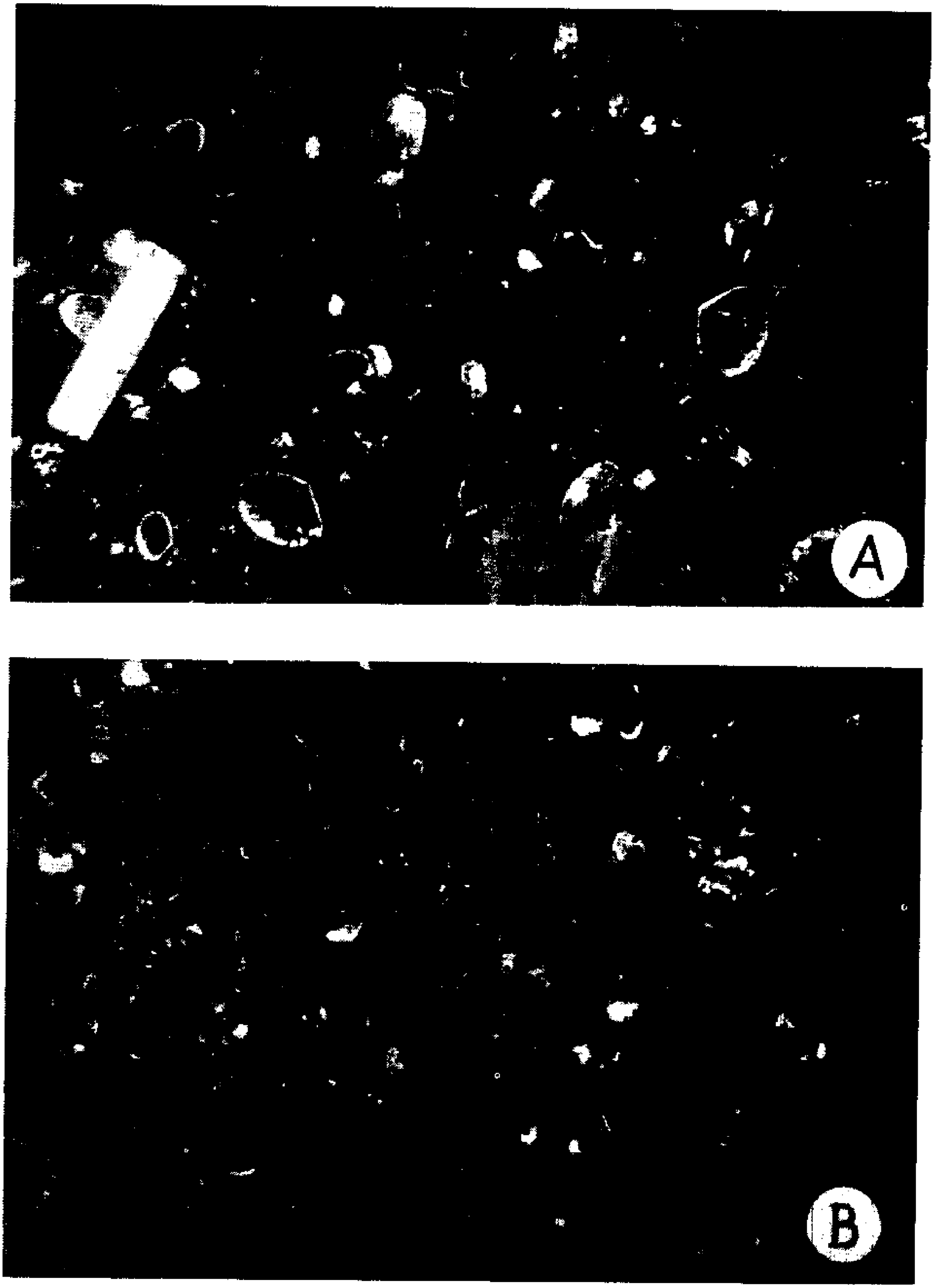
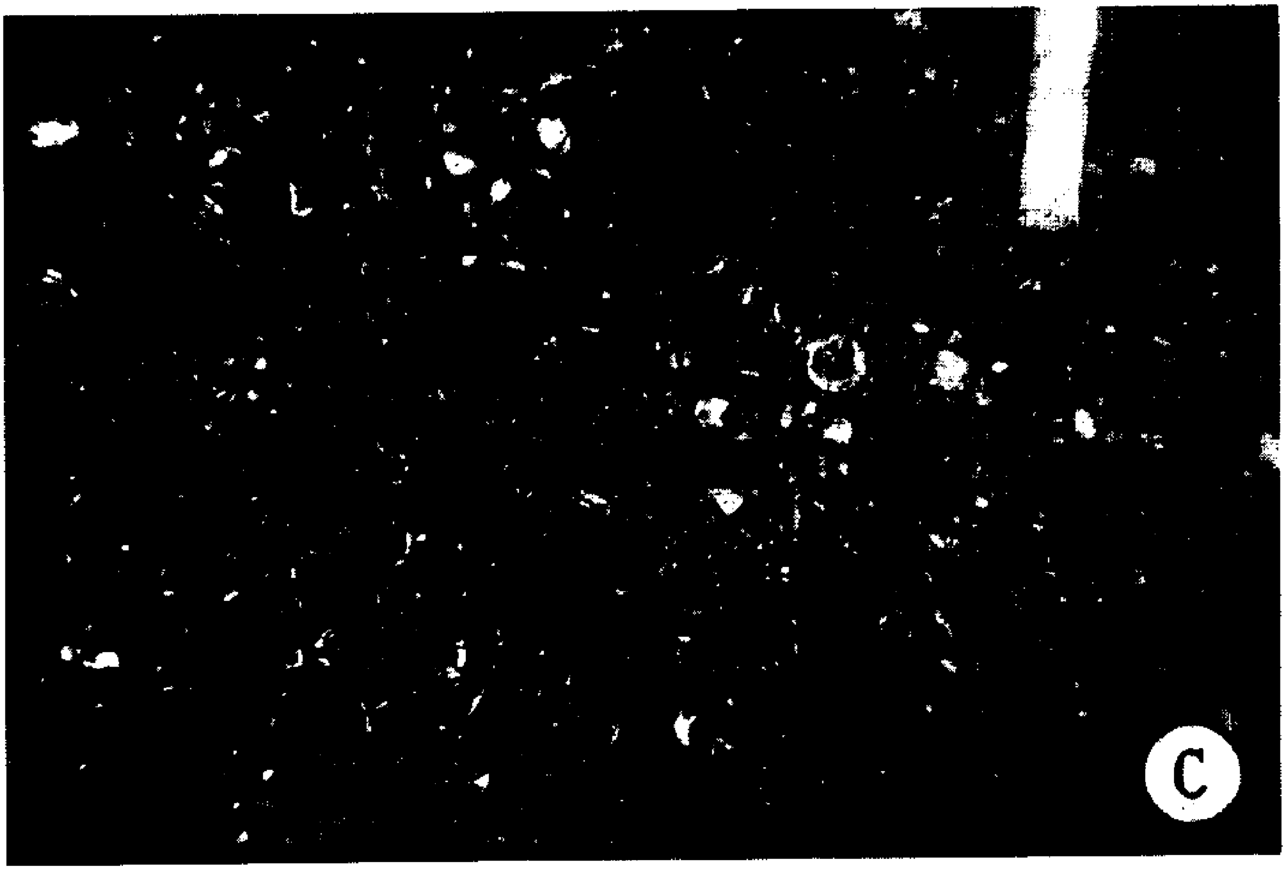
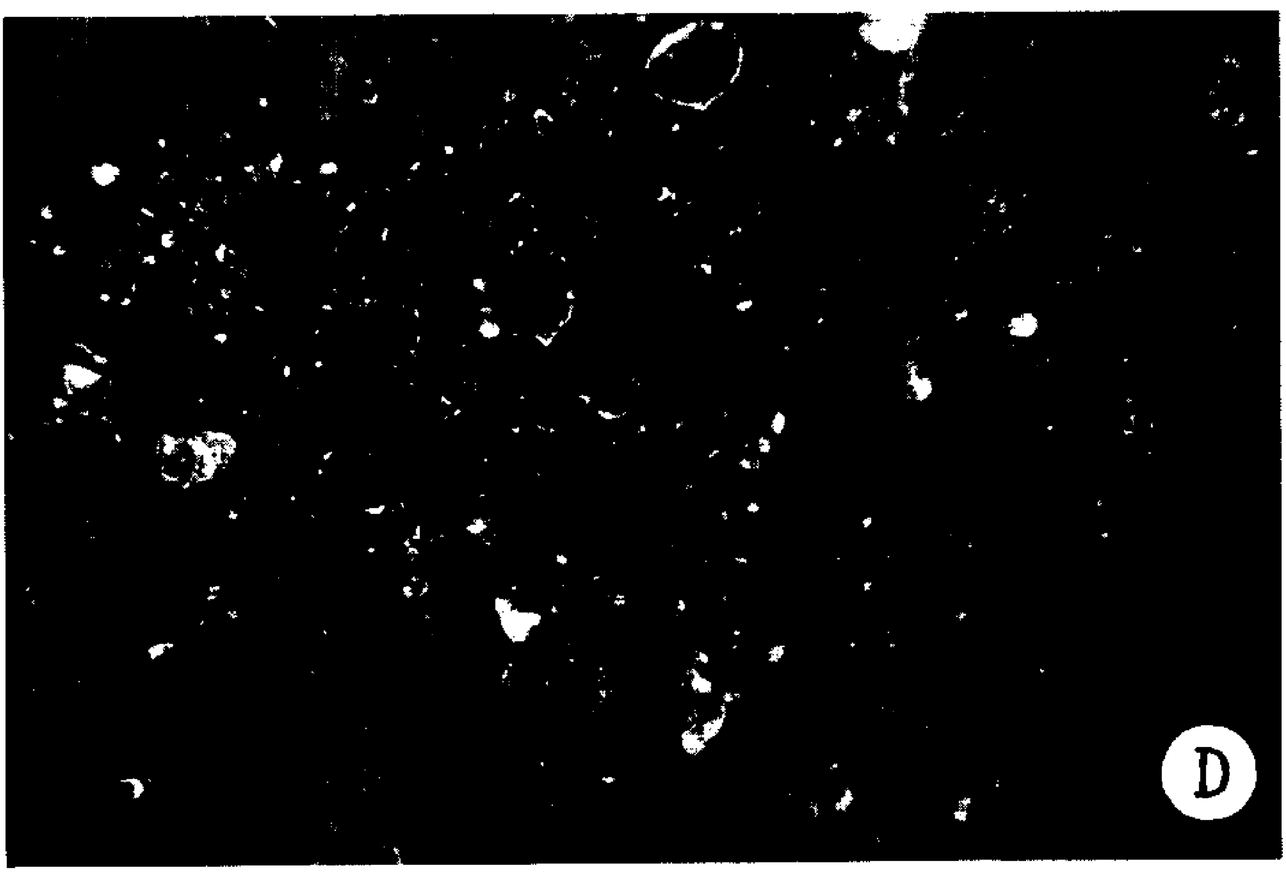


Figure 7. Bottom photographs of Pandalus goniurus taken at Station 23 in Anastasiya Bay, August 11, 1972, at a 78 to 84 m depth. Photos A and B clearly show shrimp oriented against the current, indicated by the bryozoan bush. Note the effect of the weight in photos A and C. (Photos by O.P. Pavlov).


C


D

The picture area photographed downward was determined from the formula:

$$S = \frac{(a)\ (b)\ (H^2)}{(F^2)\ (k^2)}$$

where:

S = area photographed

a and b = long and short sides of the picture (mm), respectively

H = distance from the camera to the bottom

F = focal length (50 mm in 1972, 40 mm in 1975)

k = refractive index (1.34)

At an angle of 45^0 (the angle most used in 1975) and a 1.2 m distance from the camera to the bottom, the photographed area is expected to be 1.56 m^2 and to look like an isosceles trapezium with the height H. Because of poor quality photographs, we consider shrimps to be visible in the nearest part of the trapezium with the height $\frac{H}{2}$ and the area of about .41 m^2.

In the 1972 pictures (Figure 7), a cylindrical weight 12.5 cm long and 3.1 cm in diameter was often visible. In this case, the area photographed was determined by the size of the weight in the picture which was used as a scale. The area photographed varied considerably within one station (e.g. from .29 to .38 m^2 at Station 22).

When dropped on the bottom, the weight could apparently scare the shrimps, thus decreasing their density. Judging by the photographs, the minimum distance between the weight and the shrimps was about 3 cm. The minimum distance of avoidance was assumed to be equal to the weight area plus the adjacent area of the band 3 cm wide, or near .02 m^2. This value was subtracted from the photographed area when the weight was visible in the picture.

BIOMASS ESTIMATES

Biomass (B) of shrimp from the catch data in the areas of shrimp concentrations was estimated from the formula:

$$B = \frac{(S)\ (W)}{(k)\ (a)}$$

where:

S = area of shrimp concentrations

W = average catch per 30 minutes trawled

k = catchability coefficient (assumed to be one)

a = area swept during one tow (.04725 km^2).

In 1972, data of two trawl surveys in Anastasiya Bay were combined, since no noticeable changes in the abundance of shrimps were recorded and the concentration area was almost the same (about 30 nautical mi^2) during both surveys, despite different positions of shrimp concentrations (Ivanov 1974).

The 1975 biomass, based on catch data, was estimated by the isoline method (Aksyutina 1968) for two separate trawl surveys.

Biomass based on underwater photography was calculated by multiplying mean density ($\bar{D}$) by mean shrimp weight ($\bar{w}$). The mean shrimp weight ($\bar{w}$) in the entire area was determined from the formula:

$$\bar{w} = \frac{\Sigma(\bar{w}_i)\ (N_i)}{\Sigma N_i}$$

where:

$\bar{w}_i$ and N_i = mean weight and number of specimen, respectively, in hauls 1, 2, 3, 4...i. $\bar{w}_i$ is based on length-frequency distribution data interpreted in terms of weight using the following equations (after V. M. Strel'nikova, unpublished):

$$W = (.00062)\ (l^{2.97}) \qquad W = (8.7478)\ (10^{-6})\ (L^{3.03786})$$

and

$$L = (4.97 \odot l) + 4.74$$

when preliminary original data used is based on 100 specimen

where:

l = carapace length (mm)

L = body length (mm)

W = weight (g)

Shrimp biomass in Anastasiya Bay in 1972 was estimated also by multiplying the mean weight of shrimps by the mean density (D_t) calculated from the catch data:

$$D_t = \frac{\Sigma W_i/\bar{w}_i}{(s)\ (n)}$$

where:

W_i = catch in one haul

$\bar{w}_i$ = mean weight of shrimp in the catch

s = area swept by one trawling

n = number of hauls (15 hauls were made in the area surveyed in 1972).

ESTIMATES OF CATCHABILITY COEFFICIENT

The catchability coefficient was determined by two methods. First, the mean density of shrimp determined from trawl survey data was divided by that determined from the bottom photography. In 1972, only results of trawlings made in the photographed area were taken into account. A second method was dividing the maximum density from catch data by the maximum mean density at bottom photography stations. (The maximum density of shrimp was recorded at Station 1 in 1972 and at Station 36 in 1975.) Thus, calculation of the catchability coefficient was based on the assumption that all shrimps in the swept area were on the ground. The shrimp occurring in the water column below the trawl headrope were not taken into account.

ORIENTATION OF SHRIMP ON THE BOTTOM

Bottom photographs were not orientated by the compass or in relation to each other since the rotation angle of the suspended camera was changeable. However, an attempt was made to develop a method of quantitative characterization of shrimp orientation.

Shrimp in all pictures were represented as vectors (Figure 6). All the shrimp whose orientation could be determined were taken into account, irrespective of whether or not they are fully visible in the picture. Deviations of vectors (shrimp) from a certain vector were measured by a protractor (from the larger side of the picture, 0°). Therefore, the deviations (a_i) can range from 0° to 180°. The "mean orientation angle" in each picture was determined by:

$$\bar{a} = \frac{\Sigma a_i}{n}$$

where:

n = number of shrimp in the picture, should be ≥ 2.

Deviations of shrimps (a_i') from $\bar{a}$ were measured in each picture. From the transformed data, a standard deviation (σ_i) from the mean orientation angle was estimated in each picture. Using σ_i, a standard deviation at the station (σ_s) was determined with the number of photographs 1, 2, 3...i

$$\sigma_s = \sqrt{\frac{\Sigma\sigma^2{}_i(n_i-1)}{n-i}}$$

where:

n_i = the number of vectors (shrimps) in pictures 1, 2, 3,...i

n = total number of vectors at Stations 1, 2, 3...i

i = total number of pictures at the Station.

The same method was used to determine the standard deviation of shrimp from the mean orientation angle in the entire area ($\bar{\sigma}$). For individual pictures, stations and the entire area of Anastasiya Bay, sectors were determined in which 95 percent of the vectors (shrimp) were recorded (orientation angles at the .95 confidence level). These confidence sectors equalling σ_i (n σ_s, $\bar{\sigma}$) X 1.96 X 2 were used as quantitative characteristics of shrimp orientation.

RESULTS

TRAWL SURVEYS

Shrimp Biomass

1972. Commercial concentrations were recorded in the Anastasiya Bay area (Ivanov 1974). The data of two surveys (July 7-9 and August 10-13) indicated an average catch of 743 kg/30 minutes trawled (the 0.95 confidence interval was from 528 to 958 kg/30 minutes trawled). Based on catch data and on area of concentration (about 103 km^2), shrimp biomass was estimated as (1.6) (10^3)ton (the confidence interval was (1.15 to 2.1) (10^3) ton. Based on the mean shrimp density (6.02 specimen/m^2 in the area with catches above 100 kg/30 minutes trawled), and on their average weight of 2.77 g, the stock is estimated to be (1.72) (10^3 ton), or very close to the previous assessment.

1975. Contrary to 1972, dense commercial concentrations were recorded in 1975 in both Anastasiya Bay and the Anadyr-Navarin areas (Figures 3 and 4). Tables 1a and 1b summarize

Table 1a. *Pandalus goniurus* in the Bering Sea: result of 1975 trawl surveys

Area Catch (kg/30 mins)	Anastasiya Bay June 7-11	Anastasiya Bay July 20-26	Cape Navarin June 22-July 1	Cape Navarin July 20-26	Anadyr Gulf July 2-8	Anadyr Gulf July 26-30	Total Area [a]Survey one	Total Area [b]Survey two
Area (km^2)								
10-49	110	-	2,540	686	6,280	2,539	8,930	3,225
50-99	30	-	1,030	1,200	2,179	1,544	3,239	2,744
100-999	20	90	1,132	480	3,844	5,834	4,996	6,404
1,000-4,999	50	180	247	-	594	230	891	410
≥5000	45	5	93	-	195	-	333	5
Total	255	275	5,042	2,366	13,092	10,147	18,394	12,788
Average catch (kg/30 mins)								
10-49	27.5	-	16.1	25	20.4	27.5	19.25	27
50-99	100	-	56.25	50	50	50	52.4	50
100-999	700	175	294.4	220	291	314	293.4	305
1,000-4,999	2,000	2,400	1,667	-	3,625	1,167	2,991	1,708.3
≥5,000	11,000	5,000	12,000	-	8,500	-	9,815.3	5,000
Mean weighed	2,412	1,719	388	77.2	394.6	221.4	420.7	148.8
Confidence limits (0.95)	2,016-2,807	1,147-2,291	269-507	57.7-96.7	277-512	167-276	-	-

[a] June 7 -July 8
[b] July 16-30

Table 1b. *Pandalus goniurus* in the Bering Sea: biomass results of 1975 trawl surveys (thousand tons)

Area Catch (kg/30 mins)	Anastasiya Bay		Cape Navarin		Anadyr Gulf		Total Area	
	June 7-11	July 16-19	June 22- July 1	July 20-26	July 2-8	July 26-30	[a]Survey one	[b]Survey two
10-49	0.06	-	0.9	0.4	2.7	1.5	3.66	1.9
50-99	0.06	-	1.2	1.3	2.3	1.6	3.56	2.9
100-999	0.3	0.3	7.0	2.2	23.7	38.7	31.0	41.2
1,000-4,999	2.1	9.1	8.7	-	45.6	5.7	56.4	14.8
≥5,000	10.5	0.5	23.5	-	35.1	-	69.1	.5
Mean weighed	~13.0	~10.0	~41.6	3.9	109.4	47.5	163.7	61.3
Confidence limits (.95)	10.9-15.2	6.7-13.3	28.8-54.2	2.9-4.8	76.8-141.9	35.9-59.2	-	-
[a]Average weight (g)	2.73	2.68	3.32	3.39	3.19	3.24	3.19	3.16
Average density (no/m^2)	41.4	23.8	9.1	1.87	8.8	2.95	9.33	3.2
Maximum density	86.1	41.7	93.6	2.5	92.2	9.6	93.6	41.7

[a]mesh size in cod end is 10 mm
- indicates no data available

the data of two trawl surveys in the three areas. They show that the bulk of shrimp were usually concentrated in comparatively small areas with high catches (more than 1 ton/30 minutes trawled). In all three fishing areas, average catches and biomass were lower during the second than the first survey. The maximum decrease in catches was observed in the Navarin area. (Figure 4, Table 1).

The highest shrimp concentrations were recorded in the Anadyr Gulf, while the lowest in Anastasiya Bay, with Navarin taking an intermediate position. However, shrimp concentration in Anastasiya Bay has not decreased as sharply within the two trawl surveys (Table 1) as it has in other areas. Significant changes in the distribution of shrimps in the Anadyr and Navarin areas, which occurred in the period between the trawl surveys (less than a month), are indicative of high mobility of shrimps in this area. Figure 4 shows that areas of commercial concentrations off the Navarin Cape and the Anadyr Gulf are close to each other and shrimps seem to migrate from one area to the other. Shrimps from Anadyr Gulf and Navarin evidently form a single commercial stock which can be assessed on the basis of surveys of both areas.

A comparison drawn between shrimp biomass in Anastasiya Bay in July-August 1972 and June-July 1975 indicates higher values for 1975, about eight times that of 1972.

Mean Weight and Population Density of Shrimps

1972. The mean weight of shrimps in the Anastasiya Bay area varied in individual catches between 1.25 and 4.07 g with 2.77 g for the entire area.

Based on catch data and the average weight of shrimp in this catch, shrimp density in the swept area ranged between .43 and 14.11 specimen/m^2. The average density, on the basis of 15 hauls in the concentration area where photographs were taken, was 6.02 specimen/m^2 (σ = 3.3428).

1975. The mean weight of shrimps in catches varied from 1.68 to 3.81 g in Anastasiya Bay, from .82 to 4.18 g in the Navarin area and from 2.27 to 3.62 in the Anadyr Gulf.

Mean weights are given in Table 1.

As a whole, the density of the shrimp was far higher in 1975 than in 1972 (14 times higher in Anastasiya Bay). Of special note is a decrease in density during the second survey of the Navarin and Anadyr areas.

Interestingly, outside areas of shrimp concentration, clear bottom photographs were obtained in which holothurians, Tanner crab and ophiuroids can be easily recognized. However, in the areas of shrimp concentrations, a high water turbidity prevented clear photographs. It remains to be seen whether this "fatal regularity" is accidental or if it is a general coincidence of shrimp concentration and phytoplankton bloom areas.

Biomass and Catchability Coefficient

1972. Based on the average shrimp density (26.8 specimen/m^2) estimated from bottom photography data in Anastasiya Bay on the average weight of 2.77 g, the average biomass was 74.24 g/m^2, giving a total biomass in the commercial area of 74.24 x 103 $km^2 \approx$ 7.6 x 10^3 ton. A comparison drawn between average shrimp density from bottom photography (26.8 specimen/m^2) and catch data (6.02 specimen/m^2) indicated the following catchability coefficent: 6.02:26.8 = .2245 or about 22.4 percent.

The catchability coefficient estimate, based on maximum densities from trawl surveys (14.11 specimen/m^2 in haul 190, the biomass is 25.40 g/m^2) and from bottom photography (64.73 specimen/m^2 at Station 1) will be 14.11:64.73 = 0.21798 $\approx$ 21.8 percent.

Obviously, similar results will be obtained by dividing the average biomass from catch data (1.6 g/m^2) by the average biomass based on bottom photography (7.6 g/m^2), i.e. .2105$\approx$ 21 percent (the .95 confidence interval is from 15.1 to 27.6 percent). Thus, the catchability coefficent based on the 1972 data and estimated by different methods proved to be very close.

1975. Similar estimates from 1975 provide the following data: 23.8:27.71 = .8589 $\approx$ 85.9 percent (according to the average density in Anastasiya Bay in July) and 86.09 (haul 42, the catch is 12 t):146.3 (Station 36, a single photograph, Figure 5) = 58.84 $\approx$ 58.8 percent based on the maximum values.

Only five comparatively successful camera stations were made in Anadyr Gulf in late July, out of which Station 43 was made outside the shrimp distribution area (Table 2). Only Station 39 was made after the haul (haul 240, the catch was 700 kg).

The catchability coefficient estimated from average and maximum shrimp densities at Station 39 (6.02 and 14.6 specimen/m^2) will be .842 and .347, respectively. Other bottom photography stations were situated outside the swept area and such comparison could not be made.

Table 2. *Pandalus goniurus* in the Bering Sea: results of 1975 bottom photography in Anastasiya Bay and Anadyr Gulf

Station	Date	Time	Average density (no/m^2)	Maximum density (no/m^2)	Pictures with detectable shrimp
			Anastasiya Bay		
17	7/16	1945-2005	40.73	68.3	11
18	7/16	2200-2218	41.22	70.7	20
24	7/19	0546-0605	22.32	51.2	13
25	7/19	0650-0707	18.29	24.4	4
26	7/19	0725-0752	14.39	36.6	14
27	7/19	0943 1000	4.88	9.8	3
28	7/19	1038-1055	25.61	34.1	4
29	7/19	1200-1220	4.88	34.1	1
30	7/19	134 -1400	24.39	24.39	1
32	7/19	1525-1553	34.39	43.9	8
33	7/19	1617-1635	7.32	39.0	9
34	7/19	1708-1725	12.20	31.7	4
36	7/19	1935-1952	146.3	146.3	1
37	7/19	2055-2105	13.41	24.4	22
38	7/19	2155-2215	5.29	7.3	-
Mean			27.71 ($\pm$33.840)	41.13 ($\pm$33.886)	15 stations

Table 2 (con't.)

Station	Date	Time	Average density (no/m^2)	Maximum density (no/m^2)	Pictures with detectable shrimp
			Anadyr Gulf		
39	7/28	0810-0825	6.02	14.6	18
41	7/30	2030-2045	0.63	2.4	23
42	7/30	2240-2305	4.24	17.1	30
43	7/31	1245-1300	0	0	15
44	7/31	1710-1730	3.71	9.8	24
Mean	-	-	3.65	10.975	4 stations
			(±2.243)	(±6.470)	

The average shrimp density in a large commercial area like the Gulf of Anadyr cannot be estimated on the basis of four stations. Therefore, there was no point in determining the catchability coefficient here based on comparison between average and maximum mean density of shrimps from catch data and photography. Despite the fact that shrimp density from the 1975 bottom photography data was underestimated, the concentration was sometimes more than 140 specimen/m^2 (Station 36).

BEHAVIOR OF SHRIMPS

General Remarks

Shrimps were always seen on the ground in the photographs. Swimming shrimps and their shadows are recognized in only a few pictures (Figure 5). In the photos taken at night, shrimp density on the bottom remained very high in spite of the fact that some of them undoubtedly came to the upper layers.

Due to difficulties in measuring shrimps photographed and to inadequate number of stations, diurnal changes in the size-composition of shrimps on the bottom have not been analyzed.

In some photographs, shrimps were recorded near the weight or near a small cloud rising from the weight dropped on the bottom. This indicates that P. goniurus cannot always detect the danger or do not always respond immediately to sharp changes in their environment. Observations made in the vessel aquarium show that P. goniurus usually sit on or move slowly along the bottom, sometimes swimming above the ground. Small-sized specimen seem more apt to swim, but a quantitative estimate of swimming activity of shrimps in relation to their size has not been made. Food (fish meat) introduced into the aquarium stimulated the activity of hungry shrimp, which probably found the food using chemotaxis. When sitting on the bottom, shrimp move their antennae back and forth slowly as if feeling the water around and above them. Shrimp seem to detect any approaching object visually, then stretch quickly one or two antennae in its direction. If the object touches the antennae and continues to approach, they jump backward.

Shrimp seem to remain near the weight only if it falls between the antennae without touching them (Figure 6B).

Orientation

Shrimp photographed in 1972 are obviously oriented in most of the pictures. Some photographs show that they are headed against the current: A small bryozoan bush seems to be leaned by an off-bottom current in the direction opposite to general shrimp headings (Figure 5).

Table 3 contains data on confidence orientation sectors (.95). In all cases, except Station 26, they were below 180°, i.e. shrimps were obviously orientated. A weak negative correlation (r = -.5035) was recorded between shrimp density and confidence orientation sector. For the whole shrimp population from Anastasiya Bay, the confidence orientation sector was about 133°, i.e. 95 percent of the shrimp headings (vectors) were in this sector. Deviation frequency distribution is presented in Figure 8.

DISCUSSION

TRAWL SURVEYS

The 1975 trawl surveys indicate that the bulk of shrimp are often concentrated in a small area. During the first survey of Anadyr and Navarin, three-fourths of the total stock were recorded in an area only 6 to 7 percent of the total area. *P. goniurus* catches were of ≥ 10 kg/30 minutes trawled. Such a pattern of distribution was most clearly expressed in the Navarin and Anadyr areas, where the main stock was concentrated.

The second peculiarity in *P. goniurus* distribution lies in an obvious decrease in catches (density) and biomass during the second trawl survey in July.

P. goniurus was not fished in the areas investigated during the 1975 surveys, no large concentration of fish species appeared to feed on shrimps. Alaska pollock, the most abundant commercial Bering Sea species, feed on euphausiids. The abundance of cod and halibut, which do eat shrimp, is not high. *P. goniurus* is a long-lived species with a multi-age structure of the population. Thus, a decrease of its stocks in the second trawl survey cannot be explained by a mass mortality of old specimen, commercial harvesting or grazing by predators. In view of this, it can be attributed to the fact that concentrations of *P. goniurus* became dispersed and less catchable with trawls, or to the fact that the area of concentration of the bulk of population was not discovered. Thus, the hypothesis that detecting all areas with high catch and conducting surveys during the time shrimp form concentrations are of primary importance for proper stock assessment of *P. goniurus*.

To assess the validity of these suppositions and the representativeness of the 1975 data, a comparison should be drawn between the results of trawl surveys made in different years.

Table 3. *Pandalus goniurus* in the Bering Sea: bottom photography results, Anastasiya Bay

Station	Date (1972)	Time	Density specimen/m²	Density standard deviation	Clear photos	Shrimps photographed	[a]Orientation sector
1	7/8	2105-2150	64.73	8.2944	4	72.5	114.5°
2	7/10	2015-2100	44.64	15.0448	7	87.5	93.8°
21	8/11	0415-0500	23.50	15.5712	15	67	174.0°
22	8/11	1330-1410	7.25	4.5072	13	28.5	129.0°
23	8/11	0005-0055	47.98	18.2480	19	249	156.3°
24	8/11	0400-0440	9.45	5.2789	12	29.5	123.7°
25	8/11	0840-0925	10.00	11.1418	3	21	177.9°
26	8/11	1150-1235	6.82	6.8182	7	6	240.0°
Total	7/8-8/11	0000-2400	26.80	22.6181	80	561	~133.0°

[a]0.95 confidence limit

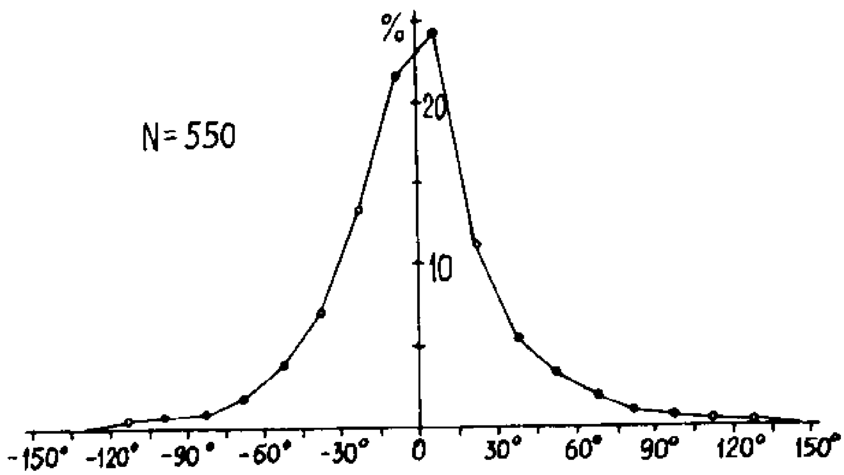


Figure 8. Summarized data on *Pandalus goniurus* orientation off Anastasiya Bay in 1972 (deviations from mean values).

In July and August 1972, commercial concentrations were found only in Anastasiya Bay (Ivanov 1974), while in October 1973 they were not recorded anywhere, including this area. However, the Navarin region was not properly surveyed in either year. In June and July 1974, the day and night trawls resulted in the following biomass estimates (x 10^3t):

Area	June	July
Anastasiya Bay	20	10
Navarin	12.5	29-35
Anadyr	30	evidence indicates a biomass decrease, but no detailed data available

The data shows that P. goniurus form concentrations in spring and early summer, while in July the dispersion of concentrations begins.

In October they are unlikely to be found. Shrimp biomass can apparently vary in different years depending on a year-class abundance, grazing by fishes and other factors, but considerable differences in the results of trawl surveys in 1972 through 1975 seem to be connected primarily with accuracy of investigations and to the shrimp concentration phase (dense or dispersed).

The most representative, from this point of view, is the 1975 trawl data. Investigations were carried out mostly during the day and all areas were surveyed where shrimp concentrations had been recorded before (particularly in 1974). Nevertheless, the 1975 estimates can be considered as a minimum for the following reasons:

1. Catchability coefficient was assumed to be one.

2. Not all the patches with high shrimp concentrations were necessarily detected.

3. Though trawlings were made mostly during the day, sometime they were conducted early in the morning and in the evenings when some P. goniurus were confined to the water column above the headrope. Because of this, trawl catches could provide underestimated data on shrimp density.

4. The season of our observations does not seem to be optimal. Trawl surveys made earlier in the year could probably provide better results.

Hauls were distributed rather evenly throughout the area investigated with no intensive trawlings in the regions of high catches to avoid overestimation which may occur when stock assessment is made based on catch data from commercial vessels operating mainly in the areas of dense shrimp concentrations (Hoydal 1978; Horsted 1978; Ulltang and Øynes 1978).

BOTTOM PHOTOGRAPHY

Because different areas were trawled and photographed, the 1972 investigations were not designed for comparison between actual trawl catches and shrimp density at respective photo stations. As a result, averaged data were used. Since camera surveys were made during a 24 hour period, night station data can be considered underestimated. Although shrimps were sometimes 3 to 10 cm away from the weight, the effect of the weight on shrimp density is more than assumed. Because of that, shrimp density in photographs where the weight can be recognized was higher than the estimated one. Thus, shrimp densities estimated in 1972 prove to be lower than the actual ones. Despite this, the results obtained indicate that *P. goniurus* stock estimates based on photographs are more efficient than those from catch data.

In 1975 data can be used, but with caution. Because of poor quality photographs, the maximum shrimp density at stations seems to be closer to actual average values than the average density data based on camera surveys. The area photographed was determined by applying a rather arbitrary assumption. Though shrimp density estimated from trawl survey data in Anastasiya Bay in 1975 was four times higher as that of 1972, the average density based on photographs is almost the same in both years. This indicates a considerable underestimation of shrimp density using 1975 photographs.

Catchability Coefficient

A catchability coefficient (about .22) estimated on the basis of the 1972 surveys is undoubtedly more realistic than that from 1975 surveys. However, taking into account that shrimp density based on 1972 camera survey is underestimated, the catchability coefficient may in fact be below .22.

The assumption seems to be more valid recalling that both shrimp confined to the ground and those swimming are trawled 4 to 5 m off the bottom layer up to the headrope and which are not photographed. The higher the number of shrimps in the water column outside the area photographed, the more the catchability coefficient is overestimated.

The obtained value of "q" equaling .22 is somewhat higher than the catchability coefficient of .15 to .24 used during and investigation of the *Pandalus borealis* fishery in the Barents Sea (Berenboim and Popkov 1980).

The fact that both shrimp catches and estimated biomass show a decrease during the second half of the summer and the autumn suggests that catchability coefficient decreases when shrimp concentrations become dispersed. That may be one of the reasons for the biomass dynamics observed. Seasonal changes in the "q" value are recorded in the Barents Sea. If "q" is directly proportional to shrimp density (catches), both seasonal and annual variations in the catchability can be expected (in this case, "q" should be higher in 1975 than in 1972). Nevertheless, actual "q" values can hardly be as high as .584 and .859, as shown by density data from 1975 photographs.

Behavior of Shrimps

Bottom photographs of *P. goniurus* have for the first time indicated that *P. goniurus*, similar to other pandalids occurring in the open sea (*P. borealis*, *P. jordani*, *Dichelopandalus bonnieri*), do not burrow into the ground. While many of the crangonids and shallow water penaeids do not, this characteristic feature simplified pandalid stock assessment by bottom photography and underwater observations. However, because shrimp ascend to the water column at night, the validity of night station photography data decreased.

Shrimp orientation is obvious, judging from many photographs. Similar behavior patterns were recorded in *P. borealis* (Blacker 1971; Bryazgin, Serebrove and Tarasova 1975; Serebrov and Bryazgin 1974) and *P. jordani* (Pearcy 1972). We have no data available on the directions of currents, but according to the Pearcy (1972) and Blacker (1971) observations, pandalids are oriented on the bottom facing against the current. The same conclusion was drawn by Soviet scientists in the Barents Sea. Since northeastern currents prevail off the Koryak coast, shrimps are likely to be headed in this direction in Anastasiya Bay. However, this supposition should be verified because the direction and intensity of the currents can vary by seasons and disturbed by an uneven bottom.

To characterize shrimp orientation, a method was applied similar to a windrose plotting (Blacker 1971; Serebrov and Bryazgin 1974).

This method is demonstrative enough, but does not permit quantative comparative analysis of orientation data. Our method of characterization, using the ".95 confidence sector of orientation" allows quantitative comparison of shrimp orientation, depending on their density, the time of day, season, current density, area, etc.

The knowledge of shrimp orientation direction can be of practical importance since the ability of shrimps to escape trawls by jumping away probably depends on the angle at which the trawl approaches. It is conceivable that knowledge of shrimp orientation will prove advantageous for trap fishermen if catch efficiency depends on the position of trap entrances in relation to current direction.

GENERAL DISCUSSION

Bottom photography is widely used for shrimp stock assessment in north Atlantic (Berenboim et al. 1976; Klimenkov, Berenboim and Lysy 1978; Kanneworff 1978). Soviet scientists frequently use data directly observed from hydrostat (Bryazgin et al. 1975). Our observations, despite their inadequate number and some failures show that bottom photography is a promising way to determine absolute density or shrimp biomass and a catchability coefficient.

Trawl survey and bottom photography data indicate a very high density of P. goniurus concentrations in commercial areas. Shrimp density based on trawl survey data was as high as 86.1 specimen/m^2 with catch of 12 ton/30 minutes trawled in the Anastasiya Bay area, 93.6 specimen/m^2 with the catch of 18 ton/30 minutes trawled in the Navarin area and 92.2 specimen/m^2 with the catch of 13.5 ton/30 minutes trawled in the Gulf of Anadyr.

Average catch density and catch values are also fairly high. Based on the 1972 bottom photographs, shrimp density in the Anastasiya Bay area in July-August, i.e. when P. goniurus concentration tends to decrease, was 26.8 specimen/m^2 or 4.5 times as high as the density estimated from trawl catches in this period. The maximum density in 1975 was 146 specimen/m^2. The maximum density of Pandalus jordani recorded by Pearcy (1972) off Cape Foulweather, Oregon was 17 individuals/m^2.

If the catchability coefficient at dense shrimp concentrations is .22, the density in the areas of maximum catches was as high as 425 specimen/m^2 in 1975. Such population densities have not been recorded either in other pandalids or in all other commercial bottom shrimp species. This is illustrated by P. borealis density of below .71 specimen/m^2 on the open sea banks off west Greenland and not more than 6.68 specimen/m^2 in Disko Bay based on bottom photographs (Kanneworff 1978). Based on photographs and hydrostat (wire suspended submersible manned apparatus) observations, P. borealis density in the areas of commercial concentrations in the Barents Sea was as low as .670 specimen/m^2 and 1.11 specimen/m^2 at the average within local groups (Bryazgin et al. 1975). The maximum density of P. borealis was 3 to 4 specimen/m^2 in the Barents Sea (Berenboim and Popkov 1980) i.e. about 100 times as low as expected maximum density and 25 times as low as actual P. goniurus density based on trawl surveys. The density of commercial concentrations of other commercial species proved to be far lower than of P. goniurus. Crangon crangon rarely reaches 1 specimen/m^2 in commercial areas. The fishery is conducted at the density of 1 specimen/20m^2. The density of tropical penaeid species on commercial banks amount to approximately 1 specimen/160 to 300m^2 (Boddeke, Kijaema and Siemelink 1977).

The TINRO and VNIRO studies have revealed large stocks of P. goniurus in the Bering Sea. Catch data which should be considered minimal, indicated a P. goniurus biomass of more than 160 x 10^3ton in Anastasiya Bay, Navarin and Anadyr areas, higher than off west Greenland where estimated biomass of P. borealis is below (120) (10^3ton) (Ulltang and Øynes 1978; Horsted 1978; Hoydal 1978; Carlsson and Smidt 1978; Carlsson, Horsted and Kanneworff 1978).

If the catchability coefficient is assumed to be .22 (as it was estimated in Anastasiya Bay in July-August 1972) estimated P. goniurus biomass can be about (725) (10^3ton). Thus, the western part of the Bering Sea may become one of the major commercial areas of shrimping.

CONCLUSIONS

As a result of the trawl surveys, large stocks of Pandalus goniurus were revealed in Anastasiya Bay, Cape Navarin, and in the Gulf of Anadyr. Based on trawl surveys and at the assumed catchability coefficient of 1, the total stock is estimated to be more than 160 x 10^3ton.

The highest shrimp density was recorded in spring and during the first half of the summer, while in late July the concentrations disperse.

The density of P. goniurus reaches 100 specimen/m^2 (and probably more than 400 specimen/m^2) in areas of maximum catches. The average density amount to dozens of specimen/m^2.

Shrimps proved to be oriented on the bottom. A method is suggested allowing for quantitative characterization of shrimp orientation. About 95 percent of shrimps show deviations from the mean orientation angle by not more than 66.5°. (Orientation angles are recorded in the 133° sector.)

Bottom photography was an efficient method of P. goniurus stock assessment. Shrimp density indicated by photographs (26.8 specimen/m^2 on the average) in Anastasiya Bay appeared to be almost 4.5 times higher than that obtained from catch data. Proceeding from this, the catchability coefficient was estimated at about .22. If the catchability coefficient show no increase or varies insignificantly at high concentrations, the total shrimp biomass is not less than 725 x 10^3ton in the western Bering Sea.

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CURRENT STOCK ASSESSMENT PANEL

Chairman:

Norm Abramson (NMFS, Tiburon Laboratory)

Panel Members:

Svend Horsted (Greenland Fisheries Investigations, Denmark)
Øyvind Ulltang (Institute of Marine Research, Norway)
Fred Gaffney (Alaska Department of Fish and Game)
SuzAnne Miller (U.S. Fish and Wildlife Service, Anchorage)
Ole A. Mathisen (University of Washington)
Unnur Skúladóttir (Hafrannsoknastofnunin, Iceland)
Steve Clark (NMFS, Woods Hole, MA)
Walter Dahlstrom (California Department of Fish and Game)
James Boutillier (Pacific Biological Station, Canada)

Other Speakers:

Dayton L. Alverson (NMFS, Seattle)
Dan Carlsson (Greenland Fisheries Investigations, Denmark)
E.J. Sandman (Department of Fisheries and Oceans, Canada)
Patrick Holmes (Alaska Department of Fish and Game)
Cptn. Ron Kutchick (f/v Captain, Kodiak)
Marilyn J. Kemerer (Alaska Department of Fish and Game)

Alverson — I wonder if the panel might address the question that's associated with the different estimates of natural mortality that we've heard over the last two days. If memory serves me correctly there was an estimate, I think from Steve, that they were using about .25, I heard another one from Jacques yesterday of about .7 for mass mortality on borealis in a similar area. I heard one estimate for the larger females of about 1.5. I've seen estimates for this area up here that suggests something in between those, something like .35. I guess my comment and question is (1) it makes a very large difference in ultimately developing a management strategy what this figure really is and what the life strategy of this animal is. If it's really .25, and that's a reasonable estimate for borealis, and it has a life span of somewhere around 7 and 8 then it must have a very truncated sort of climax spawn activity much like the salmon does. If that's the case, and you plot that against your growth curves, the strategies we're using now, I don't see any of them as being realistic in terms of a harvest strategy. I could assume you'd want to postpone harvest until the latest date possible if that was true. If the higher natural mortality rates are correct and they're sort of age specific throughout 2's, 3's, 4's and 5's, you'd want to use an entirely different strategy. I guess it seems to me very important to the shrimping industries of the northern hemisphere that problems of natural mortality be worked out both from the standpoint of stock assessment and from the standpoint of management. I'd like to hear some comments on this.

Abramson — Does anybody have any response?

Ulltang — Yes. I have only a short comment on the assessments we have made. In west Greenland, we have a natural mortality 1.5 for the large females. Now we have in this assessment, looked on the reduction of this spawning stock which certain fishing mortalities will generate. It doesn't matter very much whether the natural mortality of the larger females are 1 or 1.5 or even .75, it doesn't make a very big difference in age or recruitment to the fishery. An age for spawning is 1 1/2 years, then a fish mortality of .4 reduces spawning stock by 50 percent if mortality in large females is 1.5. This would reduce the spawning stock to 46 percent below the regularity and if it is 1, it would reduce it to 42 percent. So in that model and the way we had calculated the total catch, it doesn't make a very big difference. But of course, I agree that is a very critical parameter and as soon as one starts to use more advanced methods, this parameter will be of very high importance. One last comment, in this situation we really have had no data, I think, to get to the estimates of actual mortalities and I do not really trust the value, as an exact value, but we have reason to believe that the actual mortality of the large females of the first spawning is right.

Skuladottir — I was going to say that if the age estimation is not right, then you'll get the really high estimates for natural mortality. I would think actually this really high natural mortality, when you get an agreement, is due to this, do you think the animals are younger than they are really?

Abramson — That's a good point that aging is very tenuous when one must use length frequencies. Of course, in our assessment of natural mortality, which we have always neglected in fisheries, I guess, because they can't order us to do surveys before there is a fishery in the virgin stock although the natural mortality might change under exploitation. But in any case, we always get in a spot where the fishery is exploited and then we have to try and separate the two, which is very difficult.

Carlsson — I think I can add very little to this except that we do know the age, composition, of the other groups in the length-frequency distribution and we of course are working on that. If we had to go under this survey consideration doing this assessment, I think its quite true, there's a possibility of a stop in growth of the older females so that we have these merging length-frequency distributions.

Ulltang — If there is a stop in growth of the larger females then and the natural mortality is rather low, then you should get accumulated rather large group of shrimp in one size group. Really, I think, what one has to look for is how many females are there compared to the number of the younger stages. It depends on the way you do the analysis I suspect, but for matters you do not need at all the age of various females. If they are 5, 6, or 7 years, take the group together and compare with the advanced younger group to get an idea of how big the natural mortality is on this stock.

Abramson — Are there any more questions of the panel?

Alverson — I think Dr. Ulltang was right in his estimate that it doesn't make a great deal of difference in the final recruitment - talking about the consequences of the natural mortality figures in relation to the remaining stock - It makes a great deal of difference if the yield changes.

Abramson — Thank you, Dr. Alverson.

Horsted — Just a small comment to the discourse which just took place. It's, of course, nice to hear somebody take the viewpoint which I, myself had at the time. If they accumulate, and I think that they might do so, and the only reason that I could go along with that high natural mortality was indeed not that step-wise decrease in the older group of females as he sees them on length-frequency diagram because I don't think that can be broken down, as Carlsson said, into age groups. Growth takes place along the varied period of more than eight months in Greenland waters, there wouldn't be time in between for transformation unless there would be a year without maturation before the next year. That's as Dr. Ulltang said you have compared, and you could compare, but I think I'll come back to that in one of the other comments. The truth, for instance, that group was identified as transitional and the transitional states do only happen once in the life span of the shrimp. But that group for several years had a tendency to have relative abundance in the frequency diagrams in several of our catches, which is close to, not up to, but could be an accumulated group of several age groups of females. I took that as an indication that the mortality in the latter group could be identified. The model is simple and that makes it, of course, all easy. We don't exaggerate, at that situation, need to care much about the actual mortality found in the younger age groups. I agree with Dr. Alverson that it's an extremely important question and I'm glad for this discussion. Thank you.

Abramson There was someone else?

Sandeman I think what I want to ask is really a question rather than a comment although I guess I want to comment as well. Dr. Mathisen, I'd like to address this to you, if I may, and I think that this is really about one of the points that always comes up when you talk about hydroacoustic methods of a survey. Well, we have a whole set of biases that we get from trawl surveys. We've been discussing some of those today. We have another whole set of biases that we get from acoustic surveys. Both of these methods I'm giving you are relative abundance. How do you bring the two together, that is the crucial question. I don't think anyone has really answered that. Even with some of the classic Atlantic fisheries like herring, which do apparently integrate very well, the question really comes down to a specific one. I think that you brought that up when you mentioned the critical value of target strength, the fact that if you change the aspect ratio of fish very slightly, or of shrimp, presumably it's the same thing, you can change the value of your integration quite dramatically. And the fact that if you do have even a 3db error in your target strength, that you are going to half or double you populations estimates. And I think that's one of the things that's always worried me about the acoustic question.

The other thing I'd like to sort of ask the panel in general about and this is the use of at least one of the speakers has made of the general production models. I find this very difficult to see in shrimp fisheries because of the tremendous changes in biomass that seem to take place in any case. I think of my own case that I described yesterday, where we had under the conditions of an increasing fishery, an increase in biomass at the same time. That's sort of the extreme condition where you do your plot of catch for effort against effort, and you actually get a rising curve instead of a falling. I can see that brought into play in a milder way with your variation so that I think it would be very difficult to apply that type of method. The other point with regard to general production models, and that specific type of plot that you use there, concerns when you start to apply regulation to a fishery, particularly to a fishery which does show a decline in catch for effort throughout the season. I think that's very clear in the west Greenland fisheries throughout every year that we have it that there is a very marked catch per effort for the season which may not, or is likely not just due to fishery alone but due to a variation of availability, etc. What you're then getting, immediately biasing in your catch per efforts by not incorporating catches at the end of the season after you've closed it off because of a quota being reached or something like that. I don't know if I've made myself clear, it might be something worth discussing.

Abramson — Thank you, Dr. Sandeman.

Skuladottir — We use catch per effort for the whole winter. We don't take the estimates in the spring. Did I understand you might think this more appropriate? I have a feeling that the shrimp seasons are usually of the same length and we try to keep the quota very even so I think if you're taking this estimation early, you'll get a better picture really. Whereas, if you take survey at the end of the season you'll have to cover the area. We decide our quotas just before the season starts and have a routine survey just before the beginning of the season. When we decide the quota then, and we use the last year's fishing data and that survey. Then after half of the season, we revise our positions and we calculate again. So we do this twice a year.

Abramson — Thank you.

Mathisen — Yes, let me try to answer Dr. Sandeman's first question in three ways. First if you have two methods and you both agree in relative estimates at least you can establish the consistency by some teams' fishing. Now, if you are able to determine an absolute value, 1, and I think acoustically you can do this for each certain selected corporations, then you have a means to make an absolute comparison. Let me just add that in the actual survey, I don't think there is a question "either/or". Most clearly, as I see the problem, this is a two-stage sample problem. Of course, in your first stage you tend toward light coverage. I don't think a single survey is ever going to give a wide enough coverage to serve as your first stage input. So then you may resort to retro-grams and then come back to trawls to get the second stage samples.

Abramson — Are there anymore comments for the panel?

Holmes — Yes. Pat Holmes, ADF&G, Kodiak. My question, quite interesting listening to the discussions on sampling technique and finding that many of your assumptions are the same as ours, particularly the point on focusing on fall surveys of data of greatest consistency. The question that I have that is often raised to me when I'm on the docks is something that I haven't seen substantiated with our work in Alaska, it's a question on distribution of stocks. And generally we see much of what has been covered in several presentations on the general inshore-offshore relationship, between fairly well defined bay stocks and, offshore stocks. My question is, I wonder have any of you been able to track, with your survey programs, large scale migrations or changes in stock distribution where you might have a stock that would move several hundred kilometers, or something other than a seasonal distribution change. It's a question that's often put to me "well the resource has not declined, simply the shrimp have moved elsewhere". Have any of you been able to document or seen something of this nature? Thank you.

Clark — Yes, I don't know how helpful this is, Pat, because I haven't really seen what you're talking about, it's just that I found it amusing that we get the same type of input from many people on the Gulf of Maine. It doesn't decline, it simply moves to another area. This testimony has been submitted many times at meetings by a great many people. Now we have looked very hard at our survey data and we've seen year after year-spring, what summer data we have and autumn- and we have seen essentially the same distribution that I referred to in my talk this morning, mainly that they are more or less concentrated in the western Gulf of Maine and this partly reflects from the works of Haynes and Wigley earlier, the work of Appolonio and other people who have studied temperature/substrata conditions. It's more or less, I guess, an example of how the given law operates. That's my own observation.

Abramson — Thank you. Jim?

Boutillier — I guess we've noticed some distribution changes in jordani. Just this May we did a survey on the Tofino grounds, we actually did three surveys, we did one with our crew ship Reed and a simultaneous survey with four commercial vessels, all using standardized gear. After that, we resurveyed the ground. In total, we probably put in a - well, we put in 136 trawls within a 200 square mile limit. They were all basically on the same grid pattern and with the same constraints. When fishing was good they moved in or out, trying to follow the stocks of shrimp on the grounds. I'm sorry about not having the information here, but from my head, the first two surveys found the shrimp concentrated in an area 36 to 76 square miles and on the third survey the shrimp were concentrated in an area of about 200 square miles. So they moved out. We were getting catch rates at first of over 3,000 pounds per half hour tow and then it spread out, the catch rate declined as such. The estimates indicated very, very high catches. Now we may have caught shrimp in only four or five tows of the maybe 50 tows that we put in in the high concentration areas, so your variability is quite large in comparison. We also did a survey in 1977. We surveyed in May, and set a TAC. At that time the shrimp was again spread across the whole grounds. We closed it when TAC was taken. The industry said, "look our catch rates are as high or higher now then ever before." So again we used the multi-vessel survey, using four volunteer vessels, each equipped with standardized trawl, each having an excellent technician onboard to monitor the catches and we found catches in one particular area. About half the grounds, in that area were as high or higher than before, but when we extrapolated over to a biomass estimate and include growth and recruitment of 1 year olds, we didn't find anything very surprising in our estimate. I have yet to be surprised by a biomass estimate in catch rates. Although, as I said, we do use two assumptions and I'd like to correct these and get the best estimations possible for catchability and for the net measurement size with a mensuration system. So I'd like to combine our biomass area methods with perhaps photography and see if I can learn a little more about that.

Abramson — Thank you. Let's take this one last question before we go to an inter-panel discussion.

Carlsson — Just a short comment on this question about changes in distribution. In Greenland, you see every year in commercial fisheries a change in catch rates with a peak in May and June months and then falling catch rates. And at the same time a movement of the fishery from the southern part of the area, this area showed on the slide, a moving north throughout the season. Of course, ice conditions may influence the fishery position in the beginning of the year. We think this is a general tendency, we think it's a movement of the stock in the Norway region.

Abramson — Thank you, Dr. Carlsson.

Kutchick — I have a question on your biomass estimates. You say when you take a trawl over an area, you catch every shrimp that the trawl comes in contact with in that square area. You literally wipe that clean of shrimp, that's what your saying in your estimates here. How do you take into consideration if you've ever observed a shrimp fleet working an area 15 to 20 or 30 draggers when back and forth over the same area day after day filling up with shrimp? If your theory was true, that you catch every shrimp that your net went over, you'd have a blank space and after x number of tows over that area and you wouldn't be able to catch a shrimp. How do you account for that?

Abramson — I really didn't mean to get into this, but one answer is in the fisheries. One of the assumptions is that the shrimp instantaneously redisperse and there's an even distribution. Of course, we know this doesn't happen, but those are the assumptions. Now would the panel like to discuss the things they talked about plus what you've all talked about and then we could get into the audience questions? I guess we might as well keep this going until the lunch period. O.K., Fred.

Gaffney — In each one of these models, we're assuming of course that we have a good sample, in other words the sample that's collected, the one we are analyzing and have determined growth, mortality, recruitment, etc. We assume we have a representative sample from the stock. We've done a little work in Alaska on it. There are problems. I'd like to hear some dialogue from some of the other areas about assumptions on whether your samples are good samples, how large a sample you need in order to determine some of these parameters and if you have a commercial catch sampling operation, a dockside sampling, what type of samples do you get out of those. Are they good samples, are they questionable?

Boutillier — Yeah, I guess we've been concerned about the same thing in our sampling techniques. One of the things, I don't have any results on, but we're working on now, isn't even on our own survey techniques, is trying to statistically weigh our samples, according to a catch. Right now we're taking 100 samples from every tow that there is shrimp in. What we're trying to do now is find a weighing factor for each tow and then extrapolate that over the whole catch and then try to get a percentage composition by weighing our sample. In commercial catches its a little more difficult. We do take 100 to 200 samples from the commercial catch but the only way we may be able to weigh that is if we have the actual landing figures. It's something we're working on right now. I don't have any answers whether it's all that different than non-weighed samples.

Abramson — Do you take your samples from within tows at random, such samples of the catch when do you just take them?

Boutillier — Yeah, we just randomly, we just take the tow sample. As it's coming out of catch we have somebody there that collects the sample and then while we are processing the catch, he's in measuring samples.

Abramson — In California when they did the vessel surveys, they used to have boxes which were put right in the hold to certain samples. In the boxes were numbered compartments from which two compartments were selected at random. I'm sure that's a random sub-sample. Yes? Ole?

Mathisen — I'd like to answer, Fred by asking a question. You had a different base-independent and semi-independent stocks. Theoretically, you need a sampling of each stock. How do you get one of those parameters close enough so we can get a bottom sample?

Gaffney — There are differential growth rates which further substantiate the idea that they can be managed as a separate stock. The problem that I was alluding to, comes in a commercial sampling scheme in which say 10 million pounds was taken out of a particular area, certainly you can take only a certain number of samples, let's say 20 to 50 samples and each sample may have 3 to 400 individuals. These samples, of course, could be weighed and composited and etc. The problem comes in deciding what is a representative catch from the commercial fleet. We've done some studies in which we've actually composited samples - tows as they've come aboard, which subsampled within a particular commercial drag at the end of the day we would have a weighted composite then. Theoretically, it's a good estimate of the day's catch. At the same time, we've asked commercial fishermen to collect a sample for us at random and put it in the jug, much like they do on a commercial trip. We've assumed all along that these samples that they collect are representative of the day's fishing. Well, it turns out, by analyzing these, they're not similar. So, I guess I was looking for a little more feedback from other investigators on how they relate commercial catch samples to the actual catch that the fleet is producing and how that particular catch relates to your survey samples which theoretically cover the entire population.

Abramson — We don't usually discuss such difficult problems. Yes?

Ulltang — In the Norwegian fishery and west Greenland - we have had during the last two or three years an observer onboard a commercial trawler for one month each summer. And one thing which has struck me is the very big difference say in size composition between integrated samples. That difference is much larger than can be explained by just random sampling. It seems that in one area you can get the larger ones, in another area nearby, you can get the smaller shrimp. It varies. It's really a difficult problem to get a good sampling technique for them.

Abramson — Dr. Carlsson?

Carlsson — Yes. I cannot answer your problem. I'll say when we sample from the commercial fisheries we always use observers. The question what is a good sampling, depends also on what you're going to use the sample for. Because if you start talking about length-frequencies, diagrams and separation of age groups you must take into consideration not only the variation at the depths, the different distribution of different size groups, but also I wonder that nobody else mentioned that catch variation seemed to be quite in accordance of composition of things. We did that, the stratified trawl in 1976, we also made a total weighed sample, we took samples every single haul and weighed the last of them - not only after the total catch had been sampled but also after the variation corrections.

Skuladottir — We had two to four samples taken a week. We have not carried out any weighing yet, but I think there will be weighing for the catch for each month from each area. The sample size we are taking is about 175 animals. I think actually, the commercial samples are quite good at showing what population there is for the fishermen to get. They leave the nurseries alone. So I think those samples are quite representative of the shrimps.

Abramson — I'll just give a brief summary here of what we've talked about, then we'll get back to the question about catch coefficients and any other questions for the panel. I was impressed today by the fact that our technology seems to have improved over a number of years. We've had talks about survey methods, the kind of methods we have been using for a number of years, vessel surveys have become quite sophisticated and also the analysis of catch per effort data is certainly at a high state of the art. Then we had what might be the methods of the future, the photography at random location holds promise and the hydro-acoustics. I suspect that if we had another meeting like this in ten years those would be common methods. Then we had some mention of modeling. That's something traditional that we wouldn't have seen in the fishery ten years ago. One thing I noticed that we didn't have. We have surveys which estimate the stock size, I was wondering how we would incorporate that into setting management regulations. I don't think we got into that. Perhaps that's not a subject for this panel, how we make management recommendations in the absence of any good knowledge. Another thing I would have been interested in hearing about would be anything that people know about independence between various beds or bays of shrimp and whether we have to treat these as separate stocks or whether we can combine them. I haven't heard any mention of icthyo-planktons. So, now could we get back and see if we could answer the questions...about catch coefficients. I know what he's got in mind, because if we make a survey and assume we've slipped everything out of the bed, so how is this information used?

Boutillier That's the last time I tell anybody my catch coefficient (laughter). I think I already pointed out this is one of the two continuous assumptions that we're trying to deal with. What we're looking for now is how to improve. We are all aware of the problems we have when catchability coefficient is 1. That's the only thing we have right now. How are we going to improve that? I don't know. We may be able to improve it with photography. We may be able to improve it with some other method such as hydroacoustics. It's a problem and I'm aware of it. But if you can tell me how to improve it...I'll be happy to try.

Gaffney In using a catchability coefficient of 1, you're not considering what the efficiency of the net is. Now in the formulation of a biomass estimate, you essentially multiply by the catchability coefficient or divide through. Actually, if you have less than one, say you assume you're only catching half the shrimp, a tenth of the shrimp, you're inflating the estimation of the population. Now, let's say in a particular bay you do a survey and assume a catchability coefficient of 1 and you get a population estimation of 10 million pounds. Who knows what the exact population may be? It may be five times that. The point is that these surveys can be used as indices. Used on a relative basis they are comparable to themselves. I think these are the methods that have been used by the department and I am sure other investigators, if you have a long enough catch or survey history to get a relative idea of what the commercial fishery may be in the coming season.

Skuladottir I would like to add something to this sample business that I forgot. Our fishermen, some of them, take samples from each haul. They take an empty 2 pound tin and they count the contents of this. Then they multiply by two and and this is the number per kilo. They write it down in a ledger. We haven't really used that data yet, but we find it very reliable.

Abramson I just wanted to point out that SuzAnne's presentation on the standardized catch per unit effort system, developed by the department. I have had several people ask if we could meet later to get more details on how this standard CPUE system can be used. Perhaps we could do that around nine in the morning on Friday at the Department of Fish and Game in the library for those of you who are interested in further discussion. Any more comments on the swept area methods? Dr. Carlsson?

Carlsson It's just a very short comment on the question of how much the trawl will catch; we have done some of the photographic stations, I don't remember the number of pictures taken at each station. We had made a short haul immediately after the photographing and we were surprised that our biomass estimate from the photographic survey was not very much different from the catch made from the survey. We had only a few days on it, but they were pretty close. I think it was about 10 percent about the trawl catch.

Abramson — That's very interesting. I hope you publish that because that's one of those big unknowns in life.

Carlsson — That's not me, that's my colleague.

Ulltang — I might mention one thing, the technical problems of how to analyze the data. It is pretty critical if one tried to get some absolute biomass estimate from the trawl data. It concerns the logorithmic transformation. Just as a warning if one works with transformed data and gets a mean, then transforms back, then you know that the varients of the transformed data go into that formula. This formula is for the case when the fit of the data are not of a normal distribution. And I worked with some data sometimes that is not shrimp data, what happens if the transformed data are not normal, is that when you transform back you can get a mean value very far from the original. It depends on how the data are distributed, whether it is skewed to the left or the right.

Abramson — The material SuzAnne showed, assumed that it was quite normal distribution, you're saying that if if was not normal then...

Ulltang — What I am saying is that one always has to check that it is normal.

Abramson — If you just make and estimate and don't transform the data you'll be all right with your estimate, but then you can't do an analysis of varients legitimately.

Ulltang — Yes, Yes.

Abramson — Are there any more comments for the audience? Did that help out at all on the swept area? Yes?

Horsted — I think it should just be mentioned that other methods of estimating stock sizes have been tried. They are not being discussed here, but we have in Greenland waters a tagging experiment, as a way of measuring stock abundance and migrations. I won't say that we have come up with any results on stock abundance, but it is a way we are trying to go. Another way that I haven't heard anything about is vessel surveys. I don't know if anybody would have any valuable information on that, or on tagging.

Abramson I certainly think it would be interesting to look at larval surveys between beds. We could find out if there's anything there or if the offspring are gone. Any answers to Sven's question? Is there a lady that had a question?

Kemerer Given places where stocks have been depreciated for some unknown reason, would you care to comment on why you feel that the stock has depreciated or been removed? Is it due to not being able to real-time manage what's being taken from the area, the methods being used, the way we interpret the information we have or is it a natural feeding ground type of cause and effect? Also, once you have a depreciated stock in an area, what do you recommend for that area? Do you recommend fishing that area at a depressed total allowable catch or do you recommend that you leave it unfished and hope that eventually it will come back to a normal state?

Clark I'd like to make a couple of comments about that. Having worked with such a situation and being involved with that situation for sometime now, this being off the Gulf of Maine. We know that the Gulf of Maine stock has fluctuated rather dramatically over time in the past 40 years. I don't think there's any question about this. I think there is general agreement among all people who have studied the Gulf of Maine stock situation that this is partly due to environmental factors. We think that there is a good chance in recent years, I would say a better than average chance, that fishing pressure has been over riding environmental effects. I think that there is adequate data to substantiate this. The question then comes down to, what do we do? Let's say that the Gulf of Maine stock has collapsed, the contention has been made in many cycles that, let's say all right, we do have the stock, it has declined, in response to environmental or fishing effects, but if we make the assumption that environmental effects have been major, then we don't think there's any point in trying to manage this, you might as well fish. I personally disagree with that, I think that when the stock has been depressed to a very low level of abundance, if environmental factors as well as man-made factors are operating, I think that there is a good argument that we should be more cautious rather than less cautious and that we should adopt perhaps a more draconian approach, that is we should be more, rather than less, careful. I've been involved with the state-federal scientific committee with the Gulf of Maine situation for sometime. We have consistently advised a closed season on the Gulf of Maine stock for the past three years. This has been advice that was overruled on two occasions. We did have a closed season last year, I think this did some good although of course, we would need a longer time to determine exactly how much good it has done.

COHORT ANALYSES OF PINK SHRIMP POPULATIONS

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INTRODUCTION

Pink shrimp (*Pandalus jordani*) populations and the impacts of the commercial fishery on those populations were analyzed in preparing the "Fishery Management Plan for the Pink Shrimp Fishery off Washington, Oregon and California" (FMP). The report presents in detail the cohort analyses which are cited in the FMP.*

Cohort analyses were conducted on shrimp in five of the ten Pink shrimp management subunits described in Table 9.4.1 of the FMP. These five are:

Name	Official Designation	Designation Used In This Document
Gray's Harbor	PMFC 74	74
Northern Oregon	PMFC 82 & 84	84
Coos Bay	PMFC 86	86
Port Orford	Oregon 20	88
S. Ore. N. Calif.	Oregon 19 & PMFC 92	92

Analyses were not attempted on other areas where there was a lack of continuity in samples as a result of little or no fishing effort in some years.

The FORTRAN program MURPHY (Tomlinson 1970) was used to calculate fishing mortality, exploitation rates and population sizes for each area. Several runs were made for each

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*Tables referred to in this discussion were not included for brevity. Anyone interested in the tables should write to:

Pacific Fishery Management Council
526 S. W. Mill St.
Portland, Oregon 97201

and request "Cohort Analyses of Pink Shrimp Populations."

cohort and runs with the greatest consistency between cohorts were used to calculate monthly biomasses for each area by year.

METHODS

Length-frequency samples of commercial shrimp landings have been taken in California, Oregon and Washington. Cohort analysis using the MURPHY method requires a fairly complete set of data. The data sets were fairly complete in PMFC areas 74, 84, 86, 88 and 92. These five areas account for most shrimp landings. The samples run from 1955 through 1976 in the longest series in area 92 from 1967 through 1976 for the shortest series in area 74.

Biologists assigned ages to shrimp in samples based on length-frequency modes. Age composition of landings both by weight and by number were calculated from these samples. Tables 1.1, 2.1, 3.1, 4.1, and 5.1 describe the age composition in areas 92, 88, 86, 84 and 74, respectively. Where sampling data for a month was lacking, data from adjacent months was used to calculate the age composition.

The number of shrimp landed by month for a single cohort, an estimate of natural mortality and an estimate of fishing mortality in the last catch interval are the basic data input to MURPHY. Backward calculations were used since the model converges using this method and fairly large differences in estimates of fishing mortality for the last catch interval may result in similar estimates of beginning population size.

The cohort analysis of area 92 was originally undertaken by Abramson and Tomlinson (1972) and updated by Geibel and Heimann (1976). In these analyses, an annual natural mortality rate of 1.44, derived from cruise data, was used (Gotshall 1972). This value when used on the other areas resulted in consistently lower fishing mortalities between age II and age III, and age III and age IV shrimp indicating that the population size estimated by MURPHY was too large for younger shrimp. Consequently, the annual instantaneous natural mortality was lowered to .96 for Oregon and Washington.

In pairing runs from two consecutive year-classes, the fishing mortality rates between age III shrimp of the older year-class and age II shrimp of the younger year-class were compared. The assumptions made were that age III shrimp are fully vulnerable to the fishing gear throughout the season while age II shrimp are close to being fully vulnerable at least during the latter half of the season. Ideally, this would mean that fishing mortality rates for age II shrimp would start the season somewhat lower than for age III shrimp but as the season progresses, the rates would converge. An example of fairly good convergence is in area 92 in 1972. Once good convergence was found for two consecutive year-classes, other year-classes were added on both ends by going backward and forward until the series was complete.

RESULTS

The primary value of the MURPHY method is that it relates consecutive year-classes to each other in an objective and direct manner. The drawbacks to this method are that it requires a knowledge of natural mortality rates, the year-class composition of the landings and a fairly complete series of these data. In areas 92, 88, 86, 84 and 74 the last two criteria are met but there is no reliable method for determining natural mortality rates except for area 92.

A comparison of fishing mortality rates between age II and age III shrimp in California (Table 1.2) and Oregon (Tables 2.2, 3.2, 4.2) and between age III and age IV shrimp in Washington (Table 5.2) shows that PMFC areas 92 and 88 have fairly reasonable correspondence between consecutive year-classes. The other three areas do not show good convergence. The younger shrimp in the three northern areas have much lower fishing mortality rates when compared to older shrimp. This would indicate that the constant annual natural mortality rate of .96 is still too high. A lowering of the natural mortality rate would raise the fishing mortality rates on younger shrimp and reduce the estimated number of age I shrimp entering the fishery. The occurrence of significant amounts of age IV shrimp in Washington certainly points to a gradual reduction in the natural mortality rates from southern areas to northern areas.

Although the biomass and number of age I shrimp calculated by MURPHY for the three northern areas may be too high, ratios constructed from these biomasses should be good indices of differences in sizes of year-classes. An examination of biomass estimates in all five areas shows at least a tenfold difference between the weakest and strongest year-classes within each area. This observation may be of considerably more significance in establishing management plans than accurate estimates of shrimp number and biomass.

A set of four tables for each area are included in this appendix. The first table in each set for an area gives the age catch statistics. The second, third, and fourth table show respectively the fishing mortality rates, exploitation rates, and biomass estimates from the cohort analyses. For area 92 only the recent years are shown, since tables for earlier years are available in Abramson and Tomlinson (1972) and Geibel and Heimann (1976).

RELATION OF BIOMASS TO CATCH PER EFFORT

Least squares regressions using the biomass estimates for area 92 and annual pounds per hour calculated from shrimp trawler logs were run. (Double rig catch per effort was converted to single rig catch per effort). Separate regressions using mid-season biomass of each age group by itself and then combined as total biomass were run. The best fit which has a r^2 of .118 was total biomass to pounds per hour. A plot of the data showed a trend of high pounds per hour at higher biomasses except for three outlying points which undoubtedly caused the poor fit. These three points are 1968 when pounds per hour were the highest while biomass estimates were low, 1971 when biomass estimates were the highest and pounds per hour were among the lowest and 1974 when biomass estimates were moderate and pounds per hour were the lowest of any in the series.

If there were valid criteria (other than being outlier values) for discarding these three data points, the coefficients of determination r^2 would be .84. This is considerably better than the original $r^2 = .118$, but if it were the best fit it would still indicate that more than 16 percent of the variation in catch per effort could not be explained by the biomass. However, since we do not have valid reasons for discarding these three outlier points, the $r^2 = .84$ for the second regression loses its significance and cannot be interpreted in this manner. In addition, the three outlier values represent about 14 percent of the data points. This would indicate that even if there were a fair correspondence between biomass and catch per effort in most years, we might still be faced with extreme departures from this relationship 14 percent of the time or more than one year in ten.

Another least squares regression using CPUE of age I shrimp in August and/or September of years i against total landings in year i + 1. The relationship was:

$$\text{Landings Year } (i + 1) = .1127 + .3762 \times \text{Biomass year } (i), \text{ with } r^2 = .255.$$

Landings and Biomass in millions of pounds (10^6).

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THE DEVIATION METHOD. A SIMPLE METHOD FOR DETECTING YEAR-CLASSES OF A POPULATION OF PANDALUS BOREALIS FROM LENGTH DISTRIBUTIONS

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ABSTRACT

The deviation method is described here in detail. It is especially useful when each animal cannot be aged directly. The method is modified from the method of Sund (1930). It is based on the deviations formed when length-frequency distributions (LFDs) are subtracted from a mean LFD of several years. Positive deviations over one or more length-classes in succession are considered to represent a strong year-class and negative deviations to poor year-classes. As the deviations move to a greater length with time, growth can be detected. Strong year-classes have been followed by this method for up to nine years in the *Pandalus borealis* population of Arnarfjördur, a cold thresholdfiord in northwest Iceland. The deviation method reveals twice as many age-classes as does Petersen's method. The method does not involve complicated calculations. The data seem to fit the von Bertalanffy growth equation to some degree. At present however, it is proposed to form age-classes mainly graphically by knife-edged division from the growth curve as plotted directly from the deviations. But for the largest shrimps, an equation derived from the von Bertalanffy growth equation can be used to approximate a few more year-classes not detected by the deviation method. Two equations are presented for mathematical divisions of length-classes while the shrimps were only measured to a millimeter accuracy.

INTRODUCTION

Many authors have tackled the problem of detecting age-classes of animals which cannot be aged individually by looking at the LFD. The most common was that of Petersen (1892, Ricker 1958) where modes in the LFD were considered to represent age-classes. Many authors use complicated arithmetic methods to assess age-classes from LFDs of large samples. Among the methods used are those of Buchanan-Wollaston and Hodgson (1929), Harding (1949), Cassie (1954), Tanaka (1956), Bhattacharaya (1967), Hasselblad (1966) and Cohen (1966). All these authors use unequal class intervals. Common to all arithmetic methods used by these authors is the necessity for sufficient separation of the Gaussian components. In practice it is known from ageable fish that only the very youngest age-classes can be detected as modes in the LFD. The older age-classes become more and more mixed together and hence the Gaussian components become insufficiently separated (Rasmussen 1953). Finding Petersen's method inadequate at times, he resorted to following unusually strong year-classes in the LFDs for some years for the same area. The deviation method described in detail in this paper is also based on tracking strong year-classes. It is modified from the method used by Sund (1930) on cod. The *Pandalus borealis* population of Arnarfjördur, a threshold-fiord in northwest Iceland, is taken as an example.

MATERIAL AND METHODS

Samples of 150 to 200 specimens were taken randomly from catches of *Pandalus borealis*. The samples were most often measured fresh but sometimes deep frozen samples were used. Shrimps were in that case thawed in warm tapwater. The carapace was measured from the pit of the eye socket to the posterior end of the carapace mid-dorsally to the nearest millimeter. For the deviation method, a LFD was calculated for each sample. Then all LFDs for one month were pooled together in each millimeter group to form a mean LFD of that particular month (Figure 1). The LFDs of the same month for eight years were then pooled (Table 1). The deviations were obtained by subtracting frequencies from each length-class in a particular month from that of the eight years mean LFD of that month (Table 2). Only samples of October, November, February, March and April were used to form a pooled series as samples were collected regularly in these months. When samples were available from other months their LFDs were subtracted from the pooled LFD of their nearest month. The birthday was assumed to be April. The deviations are shown in Figure 2 for all the same months as shown in Figure 1.

A positive deviation is considered to represent a year-class which is above the average in frequency compared with the other year-classes present in the area at the time. When a few months later a deviation is seen just to the right of the position of the one before, it is considered to represent the same year-class. The mid-point of a positive deviation is considered to represent the mean length of that particular year-class. When two year-classes combine as the ones from

V. Skuladottir, 1981

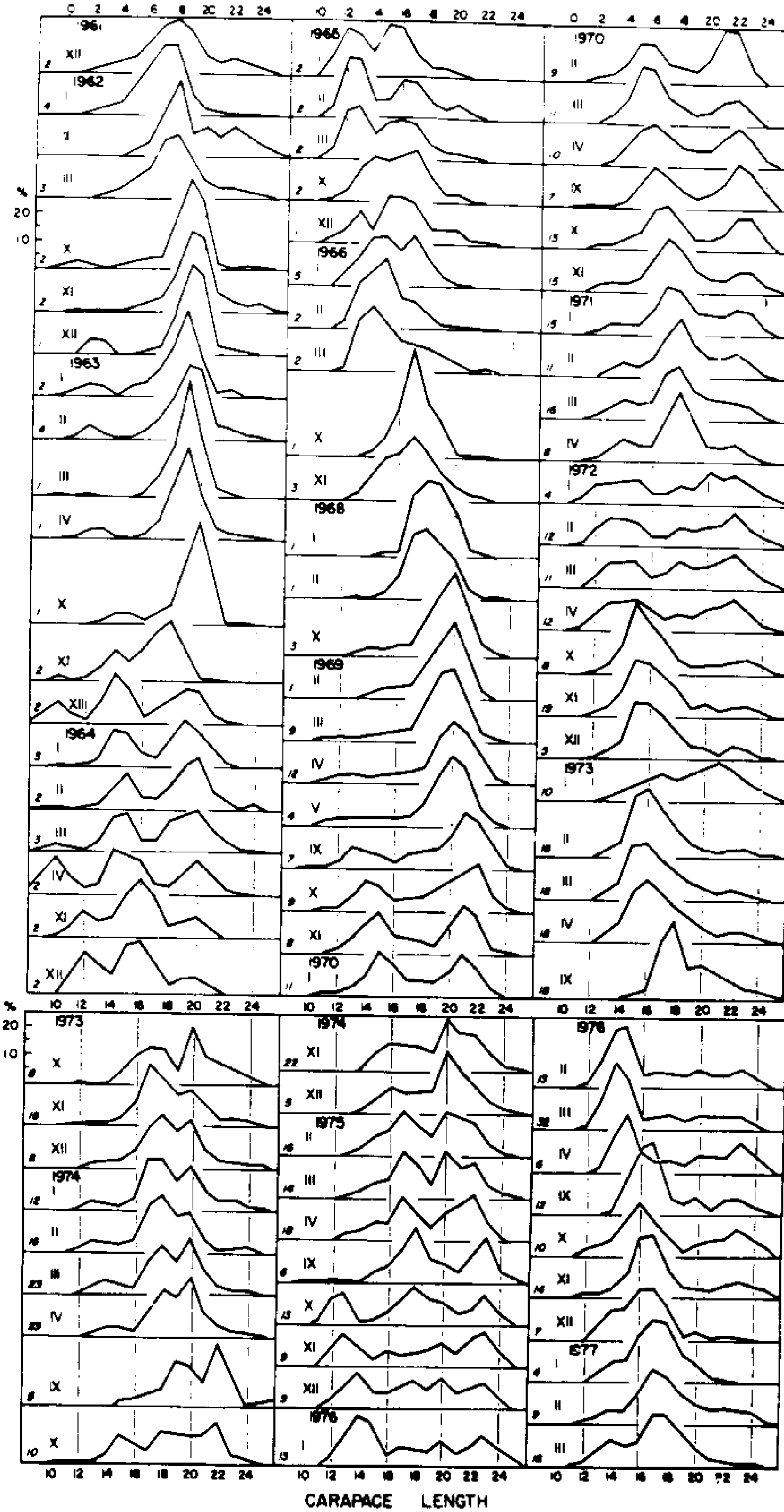

Figure 1. Mean monthly LFDs since sampling started. Italics indicate number of samples and Roman numerals the month.

V. Skúladóttir, 1981

Table 1. Pooling of mean length-frequency distributions (promille frequencies) of every February in the years 1968-1975 to get a mean length-frequency distribution for that period

Length mm	1968	1969	1970	1971	1972	1973	1974	1975	1975 Σ 1968	Mean 0/00
10					1	1	1	2	5	1
11			2	1	12	2	1		18	2
12	4	5	9	4	71	4	18	1	116	14
13	9	5	19	27	98	24	49	7	238	30
14		15	59	48	103	61	38	26	350	44
15	20	35	135	37	79	222	35	66	629	79
16	78	35	133	65	36	246	53	90	736	92
17	229	50	63	158	35	155	183	174	1047	131
18	253	144	50	215	67	102	214	104	1149	144
19	196	209	36	115	63	52	144	70	885	111
20	151	294	76	76	75	33	152	163	1020	127
21	33	174	186	73	83	21	54	132	756	94
22	13	30	176	93	129	32	18	115	606	76
23	9		48	61	77	27	17	30	269	34
24			5	25	45	11	18	9	113	14
25	4		1	1	20	7	4	6	43	5
26		5			5	1	1	2	14	2
27					2		1	1	4	1
Total	999	1001	998	999	1001	1001	1001	998	7998	1001
No. of samples	1	1	9	11	12	16	16	16	82	

Table 2. Deviations in each length group every year from the mean frequency of that length group of all the February months in the years 1968-1976

Length mm	Year 1968	1969	1970	1971	1972	1973	1974	1975	1976
10	- 1	- 1	- 1	- 1	0	0	0	+ 1	- 1
11	- 2	- 2	0	- 1	+ 10	0	- 1	- 2	- 2
12	- 10	- 9	- 5	- 10	+ 57	- 10	+ 4	- 13	- 5
13	- 21	- 25	- 11	- 3	+ 68	- 6	+ 19	- 23	+ 55
14	- 44	- 29	+ 15	+ 4	+ 59	+ 17	- 6	- 18	+161
15	- 59	- 44	+ 56	- 42	0	+143	- 44	- 13	+140
16	- 14	- 57	+ 41	- 27	- 56	+154	- 39	- 2	- 49
17	+ 98	- 81	- 68	+ 27	- 96	+ 24	+ 52	+ 43	- 76
18	+109	0	- 94	+ 71	- 77	- 42	+ 70	- 40	- 97
19	+ 85	+ 98	- 75	+ 4	- 48	- 59	+ 33	- 41	- 72
20	+ 24	+167	- 51	- 51	- 52	- 94	+ 25	+ 36	- 58
21	- 61	+ 80	+ 92	- 21	- 11	- 73	- 40	+ 38	- 42
22	- 63	- 46	+100	+ 17	+ 53	- 44	- 58	+ 39	- 26
23	- 25	- 34	+ 14	+ 27	+ 43	- 7	- 17	- 4	+ 37
24	- 14	- 14	- 9	+ 11	+ 31	- 3	+ 4	- 5	+ 25
25	- 1	- 5	- 4	- 4	+ 15	+ 2	- 1	+ 1	+ 5
26	- 2	+ 3	- 2	- 2	+ 3	- 1	- 1	0	0
27	- 1	- 1	- 1	- 1	+ 1	- 1	0	0	0
28									+ 2
Total	- 3	0	- 3	- 2	0	0	0	- 5	- 3

V. Skúladóttir (1981)

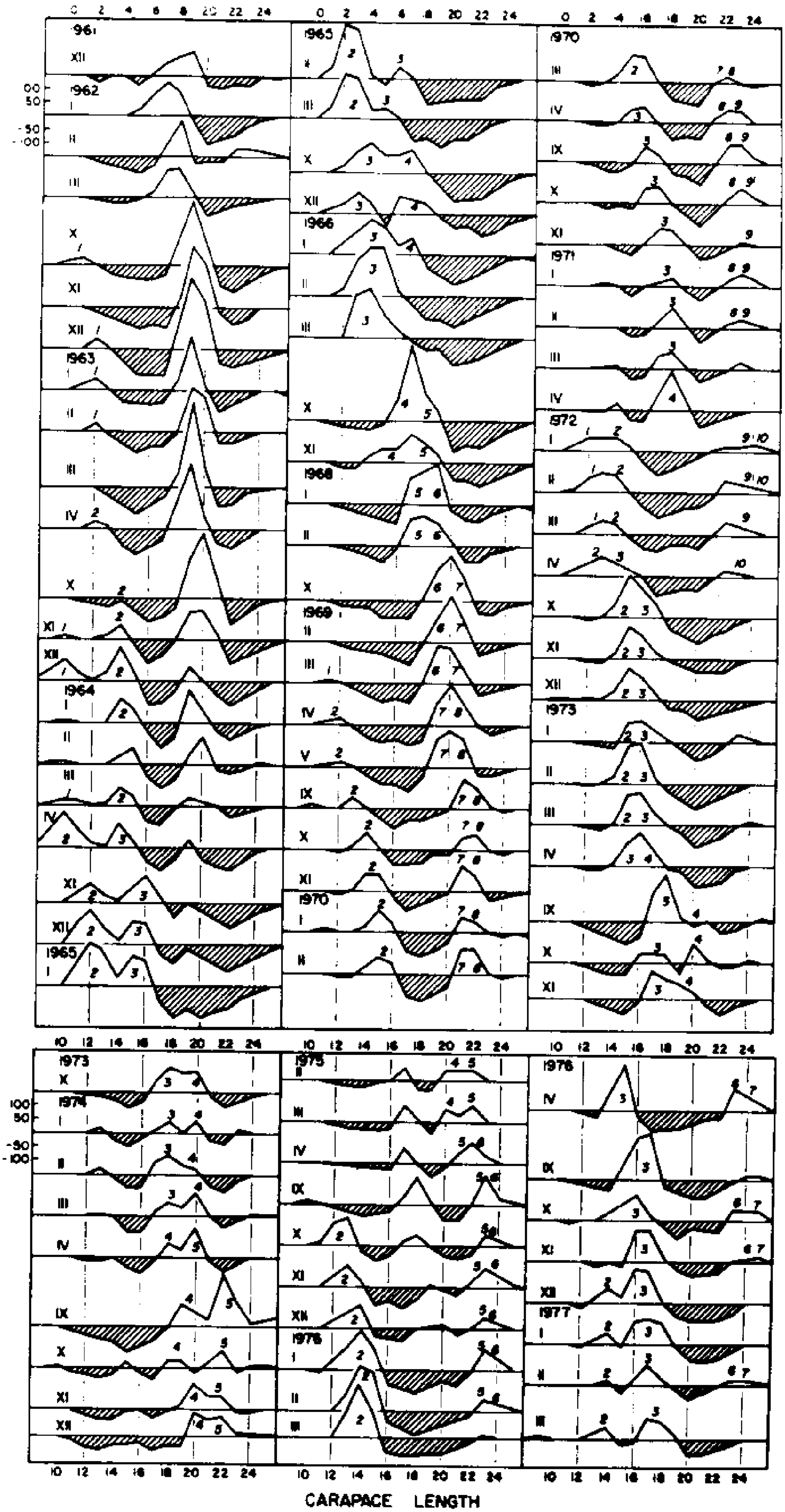

Figure 2. The deviation of mean LFD for every month from mean LFD of the same month for 1968 to 1978 (Table 2). Arabic numbers mark strong year-classes and are placed at the guessed year-class length.

1961 and 1962 seem to have done in January in 1968 (deviation marked 5 and 6 in Figure 2), their respective mean lengths are guessed and position of the numbers (ages) represent the mean lengths guessed.

The method Sund used was a bit different from the method described here. He also used a mean LFD for each month in a limited area, but this was first smoothed and then weighed according to the month's catch in the area. Finally all the mean LFDs of every month were added to form a mean LFD of the whole year. Sund then weighed the LFD of each year with catch per fishing unit and then added these together for a series of years forming an average LFD for 15 years. Deviations each year were then percentages of the 15 year mean frequency in each length-class.

RESULTS

THE DETECTION OF AGE-CLASSES

Monthly mean LFDs are shown in Figure 1, ever since sampling was started. From this one can detect two, sometimes three or four modes, but never five. Looking at these can be very confusing and the conclusion may be that this year's 3-year-old is that much bigger than last year's 3-year-old, as the peaks of the modes hardly ever seem to be of the same length the year after. If, however, the investigator realizes that he is only looking at strong year-classes when considering modes in the LFD, he may be able to deduce the growth of one year-class from the movement of the corresponding mode along the x-axis with time, and follow this for several years as Rasmussen (1953) did. When LFDs are analyzed further by looking at the deviations formed (see Figure 2), the picture becomes clearer as these are seen to move to the right along the x-axis with time. The 1961 year-class (later considered to be from 1960) marked 1 in October 1962 (Figure 2), was the first to be traced. This was followed by the 1962 (later considered to be from 1961) year-class, marked 1 e.g. in December 1963. These two year-classes can be traced separately till January 1966. After that these two seem to combine, the growth being so slow that the normal distributions of the two year-classes apparently completely overlapped. From then, there was only one mode instead of the previous two which could be traced as far as February 1971 when the year-classes were at first considered 8 and 9, later 9 and 10 years old, respectively. In 1972, the quick growing 1967 year-class seems to have combined with the year-classes of 1961 (1960) and 1962 (1961) to form positive deviations over several length-classes. Here the mean length at age becomes guesswork than before. In January 1972 a big deviation appeared, unusually wide, extending over five length-classes. When the mode divided into two in September 1973, and remained split till April 1975, it was considered to represent two year-classes, the 1969 and 1970.

The data obtained from Figure 2 which are presented in Table 3 were fitted to the von Bertalanffy growth equation (von Bertalanffy 1934). At first, however, the 1960 and 1961 year-classes were assumed to be a year younger. The method used in fitting the growth equation was that of Ricker (1958, p. 195) finding the best fit of maximum carapace length by trial values of maximum length (L_∞) in the equation:

$$\log_e (L_\infty - L_t) = \log_e L_\infty + Kt_o - Kt \qquad (1)$$

Where: L = length

t = age

K = the growth constant

This is the von Bertalanffy growth equation after taking logarithms and rearranging. An exponential curve fit program can be used to fit the curve by least squares. The y-axis intercept can be equated to $\log_e L_\infty + Kt_o$ in order to get the value of t_o. As the two year-classes of 1961 (1960) and 1962 (1969) seemed to be a bit divergent in growth rate at the younger ages (Figure 3), the von Bertalanffy growth equation was fitted to one year-class at a time. The results indicated that the 1961 year-class was two years older than the 1962 year-class, judging from the best fit if L_∞ was fixed (Figure 4 and Table 4). This is not supported by Figure 1 or Figure 2, since no mode could be detected which should represent the missing year-class between the two. The year-classes 1967, 1968, 1970, 1973, 1974 appeared to be growing at a similar rate (Figures 3 and 4) and hence the mean length at age was calculated for all those combined (Table 5). Table 6 shows the results when using different number of age-classes. Note the great lowering of K values with increasing values of L_∞. In Tables 3, 5 and 6 the slow growing year-classes are made a year older than in Figure 2 and from now on these are termed 1960 and 1961 year-classes. The values of t_o indicate that these are even older provided the growth follows the von Bertalanffy growth equation from the start. That is, however, considered unlikely. The 1960 year-class appears to follow the von Bertalanffy growth equation reasonably well with L_∞ values perhaps a bit too low for ages 2 to 4, 2 to 6, and 2 to 7 (Table 6). The 1961 year-class does not show sensible values for L_∞. The same is true for the fast growing year-classes unless ages 1 to 6

Table 3. Carapace length at age by the deviation method, estimated at first from Figure 3 and then fitting to the von Bertalanffy growth equation. This suggested that the 1961 and 1962 year-classes were at least one year older than guessed in Figure 3

Age (Years)	Month	Year-classes 1960	1961	1967	1969	1970	1973	1974
1.75	J					11.8		
1.83	F					12.2		
1.92	M			11.2		12.3		
2.00	A			11.6		12.4		
2.08	M			11.8				
2.41	S			13.1				
2.50	O	10.8		14.0		14.7	12.5	
2.58	N		9.8	14.4		14.8	12.9	
2.66	D	12.0	9.8			14.7	13.6	14.0
2.75	J	12.0		15.1	14.0	15.0	14.0	13.9
2.83	F	12.0	9.8	15.2	14.0	15.0	14.2	14.0
2.92	M		10.2	15.4	13.8	15.0	14.0	13.9
3.00	A	12.2	10.0	15.6	14.2	15.3	14.7	
3.41	S			16.2		17.8	16.4	
3.50	O	14.0		16.5	16.2	17.2	15.9	
3.58	N	13.8	12.0	17.3	16.1	17.4	16.6	
3.66	D	13.8	12.1		16.0	17.8	16.5	
3.75	J	14.2	12.2	17.6	16.3	18.0	17.0	
3.83	F	14.4	12.4	17.9	16.3	17.6	17.0	
3.92	M	14.2	12.6	17.7	16.3	18.0	17.6	
4.00	A	14.2		18.0	16.7	18.0		
4.41	S					19.4		
4.50	O		13.8		20.0	18.6		
4.58	N	15.0			19.6	20.2		
4.66	D	15.5	13.0		19.4	20.4		
4.75	J	15.4	14.0		20.0			
4.83	F	16.1	14.2		19.4	20.4		
4.92	M	15.0	13.8		20.0	20.2		
5.00	A				20.0	21.2		
5.41	S				22.4	22.7		
5.50	O	16.5	16.4		22.0	23.0		
5.58	N		15.6		21.9	22.6		
5.66	D	17.0			22.0	23.0		
5.75	J	16.8				23.0		
5.83	F				21.9	23.0		
5.92	M				22.0			
6.00	A				22.3	23.0		
6.41	S				23.6			
6.50	O	18.2			23.6	23.4		
6.58	N	17.8			23.8	24.2		
6.66	D				23.8			
6.75	J		17.6		24.0			
6.83	F		17.6		24.0	23.2		
7.00	A				24.3			
7.50	O		19.0		24.8			
7.58	N				25.0			

Table 3 (con't.)

Age (Years)	Month	Year-classes 1960	1961	1967	1969	1970	1973	1974
7.75	J	19.0						
7.83	F	19.0	19.2		24.2			
7.92	M		19.0					
8.00	A		19.5					
8.08	M		19.6					
8.41	S		21.0					
8.50	O	20.6	21.1					
8.58	N		21.0					
8.75	J		21.0					
8.83	F	20.6	21.1					
8.92	M	20.4	21.5					
9.00	A	20.6	21.6					
9.08	M	20.8						
9.41	S	22.1	22.1					
9.50	O	22.2	22.4					
9.58	N	22.0						
9.75	J	22.0	22.4					
9.83	F	22.2	22.4					
9.92	M	22.3						
10.00	A	22.8						
10.41	S	23.3						
10.50	O	23.5						
10.75	J	23.4						
10.83	F	23.4						
11.75	J	24.5						
11.83	F	24.5						

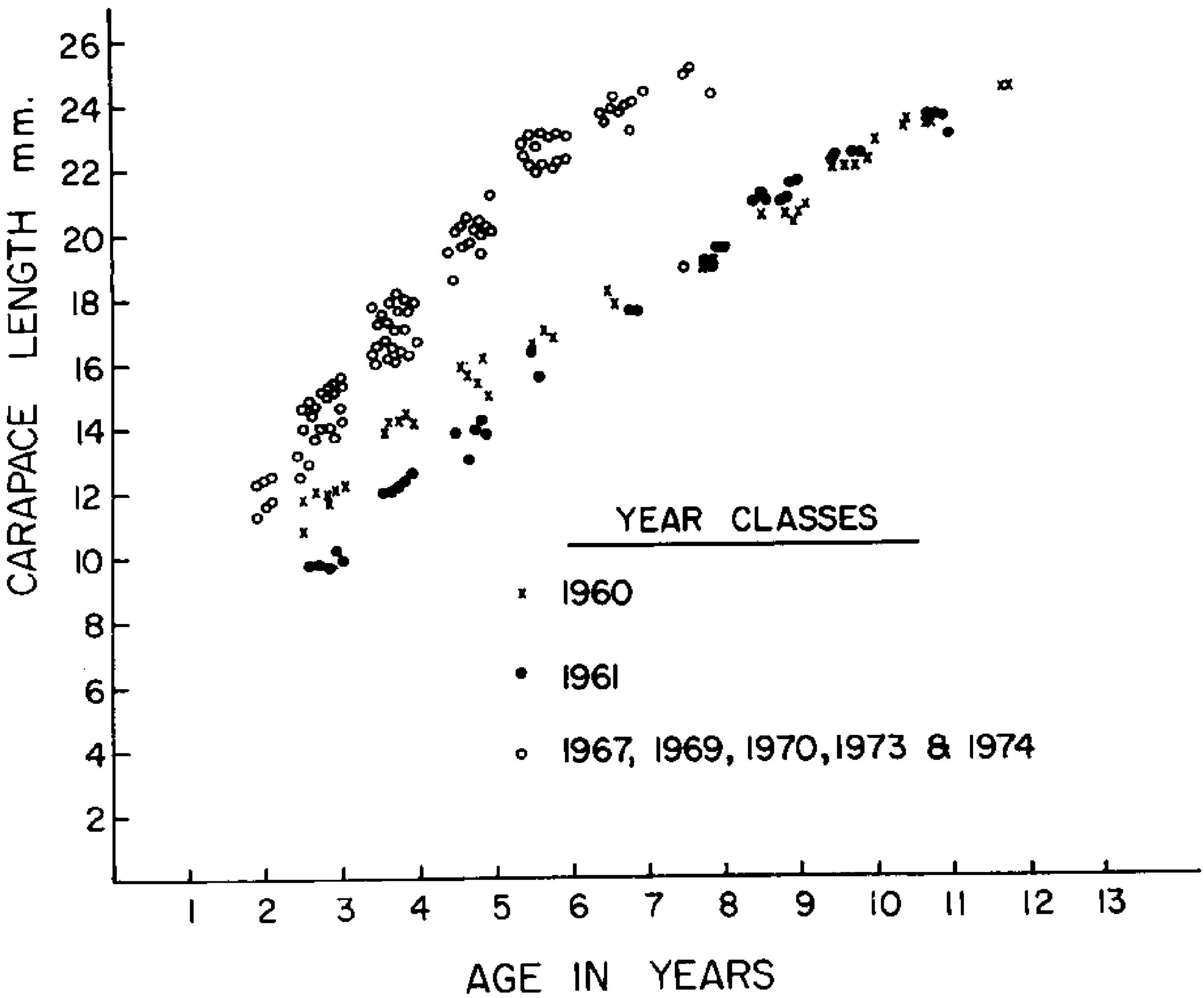

Figure 3. The CL at age estimated by the deviation method from Figure 2. Note that the 1960 and 1961 year-classes are a year older than first mentioned and the figure shows the same results as Table 3 after fitting to the von Bertalanffy growth curve (Table 6).

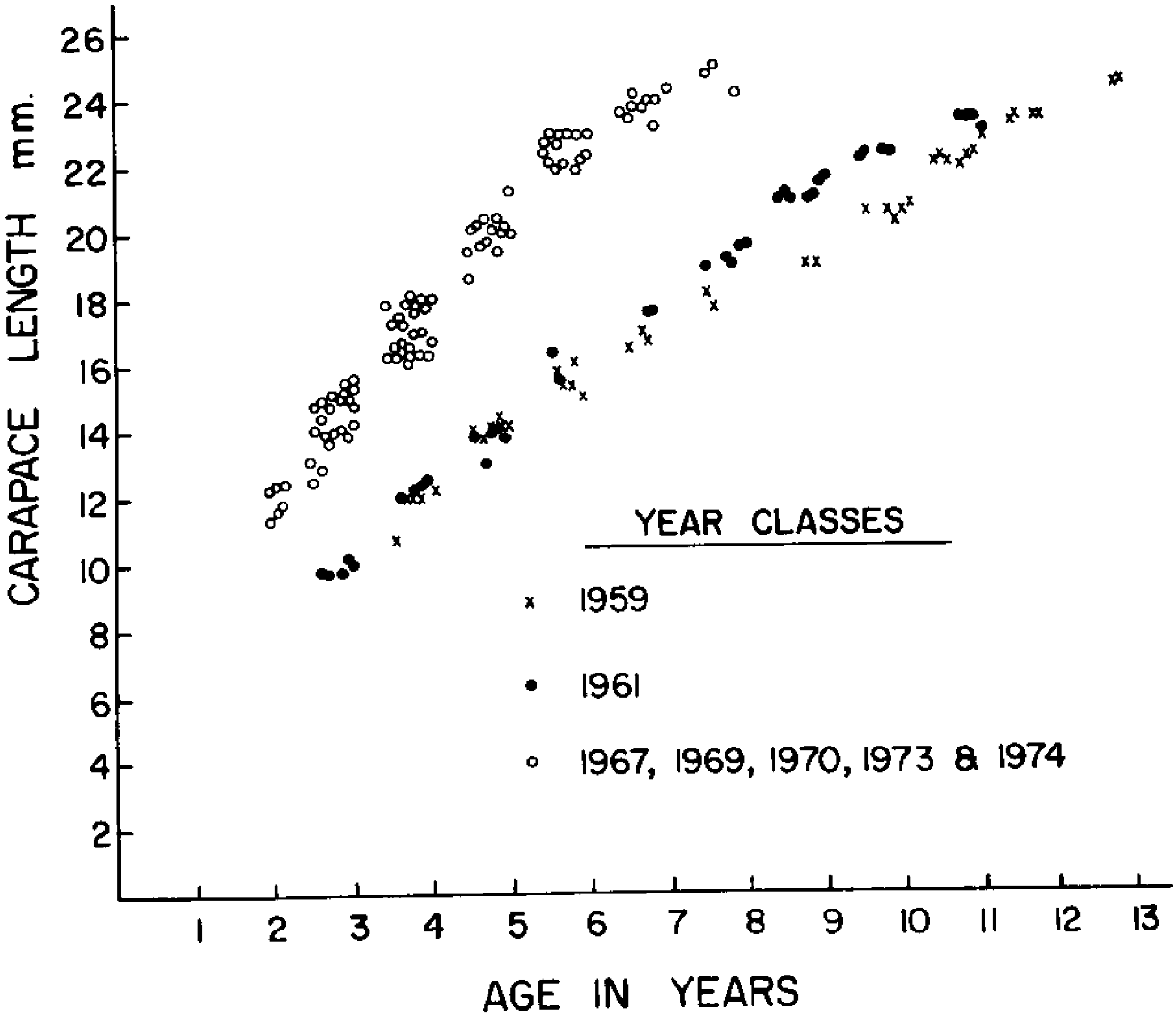

Figure 4. The CL at age by the deviation method where the 1960 year-class becomes the 1959 year-class according to best fit of the von Bertalanffy growth curve with trial L_∞ when L_∞ was fixed (Table 8).

Table 4. Growth constants (fixed L_∞) when calculating for different number of age groups using the deviation method

Ages	$L_\infty = 28$ K	$L_\infty = 28$ t_0	$L_\infty = 30$ K	$L_\infty = 30$ t_0	$L_\infty = 32$ K	$L_\infty = 32$ t_0
1960 year-class						
2-4	0.1264	-1.67	0.1109	-1.85	0.0988	-2.00
2-5	0.1208	-1.91	0.1051	-2.14	0.0931	-2.33
2-6	0.1214	-1.87	0.1051	-2.14	0.0927	-2.35
2-7	0.1162	-2.14	0.0998	-2.46	0.0875	-2.73
2-8	0.1252	-1.69	0.1057	-2.10	0.0915	-2.43
2-9	0.1430	-0.92	0.1179	-1.42	0.1006	-1.81
2-10	0.1527	-0.56	0.1237	-1.12	0.1043	-1.57
1961 year-class						
2-4	0.1175	-1.07	0.1045	-1.19	0.0941	-1.29
2-5	0.1325	-0.57	0.1169	-0.71	0.1046	-0.83
2-6	0.1343	-0.51	0.1173	-0.69	0.1042	-0.84
2-7	0.1425	-0.26	0.1228	-0.49	0.1079	-0.68
2-8	0.1596	+0.21	0.1350	-0.08	0.1172	-0.30
2-9	0.1663	+0.38	0.1385	+0.04	0.1191	-0.23
1967-1974 year-class						
1-3	0.2496	-0.25	0.2149	-0.39	0.1888	-0.51
1-4	0.2528	-0.21	0.2140	-0.40	0.1857	-0.56
1-5	0.2828	+0.13	0.2318	-0.14	0.1970	-0.36
1-6	0.2889	+0.20	0.2301	-0.17	0.1921	-0.45
1-7	0.2796	+0.08	0.2170	-0.25	0.1786	-0.77

Table 5. Mean length at age autumn and spring seasons in two slow growing and a mean of five fast growing year-classes, calculated from Table 3

Age (years)	'60 CL (mm)	'61 CL (mm)	'67,'69,'70,'73,'74 CL (mm)
1.83			11.93
2.58	11.40	9.80	13.87
2.83	12.07	10.00	14.54
3.58	13.87	12.05	16.71
3.83	14.25	12.40	18.53
4.58	15.25	13.40	19.70
4.83	15.50	14.00	20.17
5.58	16.75	16.00	22.45
5.83	16.80		22.53
6.58	18.00		23.73
6.83		17.60	23.88
7.58		19.00	24.90
7.83	19.00	19.32	24.20
8.58	20.60	21.33	
8.83	20.60	21.30	
9.58	22.10	22.25	
9.83	22.33	22.40	
10.58	23.40		
10.83	23.40		
11.83	24.50		

Table 6. The various constants of the von Bertalanffy growth equation at the highest correlation coefficient (r)

Ages	K	L_∞	t_0
1960 year-class			
2-4	0.5873	17	+ 0.71
2-5	0.1305	27	- 1.78
2-6	0.1769	24	- 1.15
2-7	0.2004	23	- 0.89
2-8	0.1252	28	- 1.69
2-9	0.0440	50	- 3.55
2-10[a]	0.1489	28	- 1.35
2-10[a]	0.0735	37	- 3.27
1961 year-class			
2-4	0.1447	25	- 0.83
2-5	0.0539	50	- 1.41
2-6	0.0695	41	- 1.30
2-7	0.0675	42	- 1.30
2-8	0.0523	50	- 1.56
2-9	0.0551	49	- 2.12
1967, 1969, 1970, 1973 and 1974 year-classes combined			
1-3	0.0906	50	- 1.07
1-4	0.0854	50	- 1.30
1-5	0.0974	46	- 1.18
1-6	0.1921	32	- 0.45
1-7	0.2317	29	- 0.18

[a] There are two maxima of correlation coefficients (r) for ages 2-10. Of these r for $L_\infty = 37$ is a bit higher than r for $L_\infty = 28$. (The correlation coefficient here was always higher than 0.99. The data used are shown in Table 4.)

or 1 to 7 are used. Table 4 is presented as a suggestion of fixing L_∞ with regard to what is known to be the largest size caught in the area.

Petersen's method was applied to the data of two winters with 3 and 4 modes in the LFD, respectively. The results are shown in Tables 7 and 8. The growth constants are unrealistic for the 1970-71 data also in the case of fixed L_∞. The results for the 1975-76 data are a good deal better. Note that the K values are higher in both cases at a fixed L_∞ than that of the deviation method. Using Petersen's method on the data of the winter 1975-76 will make a shrimp of 23 mm CL 4 years old, whereas the deviation method would make it 5 years old. The results of the two winters do not seem to agree with one another (Table 9) where 1970-71 shrimps seem to be smaller as 1 year olds but a great deal larger as 3 year olds.

THE FORMATION OF AGE-CLASSES

As it is not certain that the von Bertalanffy growth equation describes the growth sufficiently, it is suggested that age-classes be formed graphically by knife-edged division into unequal length groups down to at least 1/10 mm accuracy by taking into account the frequencies of the length-classes on either side of the length-class that has to be divided. The two following equations can be used for this purpose:

$$P_1 = R_{a-1}S_1/(R_{a-1} + R_{a+1}) \qquad (2)$$

and

$$P_2 = (1 - P_1)\ S_2 \qquad (3)$$

where:

P is the proportion of the frequency of the length-class,

a to be included in an age-class.

S is the fraction of the millimeter at the limit between age-classes.

R is the promille of a length-class.

a is the length-class to be divided.

(Hilmarsson, personal communication)

Table 7. Constants of the von Bertalanaffy growth curve when using Petersen's method for agin two winters (correlation coefficient >0.99 in both instances)

Year	K	L	t_o
1970-71	<0.1393	>50	<-0.45
1975-76	0.3132	28	-0.40

Table 8. Growth constants (fixed L_∞) using the Petersen's method on data of two winters

Ages	$L_\infty = 28$		$L_\infty = 30$		$L_\infty = 32$	
	K	t_0	K	t_0	K	t_0
Winter 1970-71						
1-3	0.4623	+1.11	0.3792	+0.25	0.3223	+0.12
Winter 1975-76						
1-4	0.3132	-0.40	0.2701	-0.52	0.2272	-0.74

Table 9. Mean length at age estimated from Figure 2 by Petersen's method for the spring and autumn seasons of two winters

Age (years)	Carapace length (mm)	
	1975-76	1970-71
1.58	13.40	12.33
1.83	14.30	13.90
2.58	17.00	17.20
2.83	17.55	17.70
3.58	19.90	22.33
3.83	20.00	22.05
4.58	22.90	
4.83	23.00	

This will cover most of the length distribution or as far as age-classes can be detected. For older age-classes the division can be based on the von Bertalanffy growth equation namely:

$$L_1 = L_\infty - (L_\infty - L_0/\exp(K)) \quad (4)$$

Symbols are the same as used in equation (1). The upper limit of the oldest known age-class can be used as a value for L_0 to get the upper limit of an age-class one year older and so on for the rest of the length distribution (Gundmundsson, personal communication).

DISCUSSION

First, it must be stressed that in using the deviation method for aging, only data of one growth stock can be compiled: the growth of a year-class must be the same in the whole population. Hence, the necessity of choosing small areas at first. Later areas can be combined if growth seems to be the same and a particular year-class appears in all areas in question. For aging Pandalus borealis it is better to have many small samples than few large ones as the population is not uniform and sometimes mostly small shrimps are caught and sometimes mostly large ones. When using the deviation method the data are pooled into a month's LFD before attempting any aging, thus decreasing errors and saving time. When using other more complicated aging methods however, each sample has to be estimated before any pooling is carried out. Moreover, the deviation method detects more age-classes, since the negative deviations are meaningful as well, representing poor year-classes. Rasmussen (1953) traced strong year-classes from the LFD using Petersen's method and the assumption that a peak moves a bit to the right along the x-axis with time. This leads to the same results as obtained by the deviation method, only the latter gives a clearer picture of what is unusual. The assumption that the 1969 and 1970 year-classes are two instead of one can be questioned. Some investigators (Rasmussen 1953) suggest that the individuals of a year-class at the age of changing sex have different growth rates, and the ones becoming females are the fastest growing animals of the year-class. The splitting should therefore be due to this. No such splitting was observed in any other year-classes. This would also make the year-class, if it was one instead of two, growing with an even faster growth rate than shown in Figures 4 and 3.

The method Sund used would not give the same results as given by the deviation method described here. As he weighed the LFDs of every year with catch per effort, deviations which are here positive even up to nine years will become negative when catch per effort is low compared to the average catch per effort of a series of years. The method of Sund however, shows better the year-class strength (Sund 1930, Skúladóttir 1979).

Considering that Petersen's method never detected more than four age-classes and often only three even in the period when two year-classes appeared to be growing very slowly, Petersen's method seems pretty useless and even harmful when it comes to yield calculations. There seems to be an over estimation of values of K when L_∞ is fixed (compare Tables 4 and 8) when using Petersen's method. This also causes an over estimation of instantaneous natural mortality which should in turn compensate to some extent for the over estimation of K in yield calculations which are based on the von Bertalanffy growth equation (Jones 1974).

One of the mistakes that can be made in aging from the LFD is that the age of the shrimps when first detected as a strong year-class can not be told. In calculations of the sustainable yield, however, this is unimportant provided growth is similar through a period of several years. The difficulties arise when the rate of growth is dissimilar. Then intermediate age groups need to be formed to bridge the gap between two growth periods for the use of virtual population analysis (Fry 1949, Gulland 1965) or cohort age analysis (Pope 1972). Also, growth rate can be different within the same period as seen in Figure 2 and Tables 3 and 5, where growth of the 1960 and 1961 year-classes is very slow but the growth rate of 1967 year-class is very fast. Here, individual tracking of each strong year-class would be very useful in order to get sensible results in virtual population or cohort age analysis. Another drawback to the deviation method is that only data of year-classes stronger than average have been used till now. During the same period, all other year-classes are assumed to grow at the same rate. Using knife-edged division into age-classes when deciding the total allowable catch will introduce some errors when year-classes are dissimilar in strength. The overlapping will be more effectual onto the normal length distribution of a poor year-class one year younger or older than vice versa. In that way, year-classes may be evened out to some extent, probably involving some errors when year-classes are few in a population.

The author (Skúladóttir 1979) has previously considered knife-edged age-classes in the same stock studied here. There, so-called spring and autumn LFDs were formed by pooling the LFDs of three to four months at a time. The forming of the age-classes was also different as the limits of each knife-edged age-class was decided first from the growth curve graphically. The division was only down to 1/2 mm accuracy. The mean length at age was then assumed to be the midpoint of the age-class. The von Bertalanffy growth equation was fitted in the same manner as here. In this paper, the midpoints of the year-classes are approximated first from the monthly deviations and then a mean length is calculated for every spring and autumn season before fitting to the von Bertalanffy growth equation. The results are also different here because the data of two more years have been added in the fast growing period. As seen in Tables 6 to 8, the value of K decreases as L_∞ increases. As the largest specimens found in Arnarfjördur are 28 mm in both growth periods, the L_∞ is considered to be at least 29 mm where as anything above 35 is considered unrealistic. If L_∞ was known to be 30 mm, there would still be some differences in the results of K for the same year-class depending on the number of ages used. K would, for example, increase from 0.1045 for 2 to 4 years to 0.1385 for 2 to 9 years (Table 4). Even this tiny difference of 0.034 in K values could be important in calculating sustainable yield for the period. Skúladóttir (1979) has shown that K = 0.1545 and L_∞ = 31.5 gave just about 580 tons sustainable yield at optimum effort for the fast-growing period in Arnarfjördur, where as K = 0.1616 and L_∞ = 31 gave about 720 tons when using the cohort length analysis of Jones (1974, 1976). The difference in K values was only 0.0071 there, but instantaneous natural mortality coefficient was the same or 0.2. The sustainable yield of over 700 tons at optimum effort was considered very unrealistic where as the lower value was just about the same as given by the method of Gulland (Gulland 1961, Skúladóttir 1979). The values of K when L_∞ was fixed at 32 mm for the fast growing year-classes are here a great deal higher or 0.1786 to 0.1970 depending on how many ages were used for fitting the growth equation (Table 4). It is also very likely that the inaccurate splitting of length-classes at the time, to 1/2 mm accuracy instead of 1/10 mm used here, was more fateful than the apparent small difference in values of K. In view of this, it is suggested that age-classes should be formed graphically as far as possible from Figure 3. It seems to be safer for the estimation of sustainable yield to use a value of L_∞ rather too high than too low for the formation of the older age-classes, so L_∞ = 32 mm would seem to be appropriate for the fast growing period using equation (4). The K value for ages 1 to 7 would be most appropriate as growth is slowing down. After the age groups have been formed, yield calculation can be carried out using first cohort age analysis (Pope 1972) or virtual population analysis (Fry 1949, Gulland 1965) to get values of instantaneous fishing morality at age and the mean number in the youngest age groups in the sea. After this, catch equation (yield function) or the like methods can be used to get values of maximum sustainable yield, optimal yield and total allowable catch.

It is doubtful that the more complicated methods of Cassie, Bhattacharaya, Harding, Tanaka, Buchanan-Wollaston and Hodgson, Hasselblad or Cohen could be used directly on the data of *Pandalus borealis* of Arnarfjördur. The deviations could be of aid as landmarks for forming normal distribution by those methods for every age-class. More investigation is needed in that direction.

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BIOMASS ESTIMATE, YEAR-CLASS ABUNDANCE AND MORTALITY RATES OF *PANDALUS BOREALIS* IN THE NORTHWEST GULF OF ST. LAWRENCE

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ABSTRACT

Four surveys in April and three in October in the northwest Gulf of St. Lawrence and one survey in October in the Anticosti Channel were conducted between 1974 and 1977. Biomass estimates are presented for each survey: the mean biomass from 1975 to 1977 is 8,640 mt in the northwest Gulf. Higher variability is associated with spring biomass estimates compared to fall estimate. This is probably due to higher availability of shrimp by using size distributions. Proportion of shrimp per age-class is estimated in fitting normal curves on size distribution. Finally, mortality rates are calculated for different age-classes. A mean natural mortality rate of 0.64 is estimated for recruited age-classes.

RESUME

Quatre croisières en avril et trois en octobre ont été effectuées dans le N.-O. du golfe du Saint-Laurent, ainsi qu'une croisière en octobre dans le chenal d'Anticosti, entre 1974 et 1977. Des estimés de biomasse sont présentés pour chaque croisière: la biomasse moyenne dans le nord-ouest du golfe de 1975 à 1977 est de 8,640 tm. Les estimations de stocks faites en avril sont beaucoup plus variables que celles d'octobre, dû probablement à une capturabilité plus forte des crevette en début de saison. Les biomasses obtenues sont transformées en nombre d'individus à

l'aide des distributions de fréquences de longueur et par la suite séparées selon différentes classes d'âge par adjustement de courbes normales. Finalement, des taux de mortalité naturelle moyen de 0.64 est estimé pour les classes d'âge recrutées.

INTRODUCTION

A large increase of fishing effort since 1972 has induced a long term research program on the shrimp population of the northwestern part of the Gulf of St. Lawrence. This program included commercial catch rate analysis, estimation of growth and mortality. The main part of this program was year to year biomass estimation surveys which had two main objectives: give yearly scientific advice on the management of exploitation and accumulate essential data to estimate parameters which could be used in a dynamic pool model to increase the accuracy of this advice.

From 1974 to 1977, spring and fall surveys were conducted on the main commercial fishing ground, west of Anticosti Island.

MATERIAL AND METHODS

Each survey was made using a stratification scheme, produced in 1975, based on catch rates of commercial operations and experimental sets. All stations were selected randomly by computer and the number of stations per stratum depended on the surface of the stratum, the relative abundance of shrimp and the catch rate variation encountered in each stratum in 1974. This method was used since the shrimp density in shallower area was not constant, mainly during the spring where highly concentrated patches of shrimp were found.

Figures 1 and 2 show stratification schemes used, for the most western part (west of Anticosti Island) and for Anticosti Channel. Stratification is based primarily on depth interval of 40 m; the delimitation of the total area (1500 nautical mi^2) is based on our knowlege of the muddy sediment dispersion and the commercial fishing ground.

Trawls used for these surveys were Yankee 36 and 41 with stretched mesh size of 38 mm. According to Carrothers et al. (1969), horizontal openings of these trawls were estimated respectively to 10 and 13.4 m. Vertical opening, measured with a trawl echosounder was approximately 2.7 m.

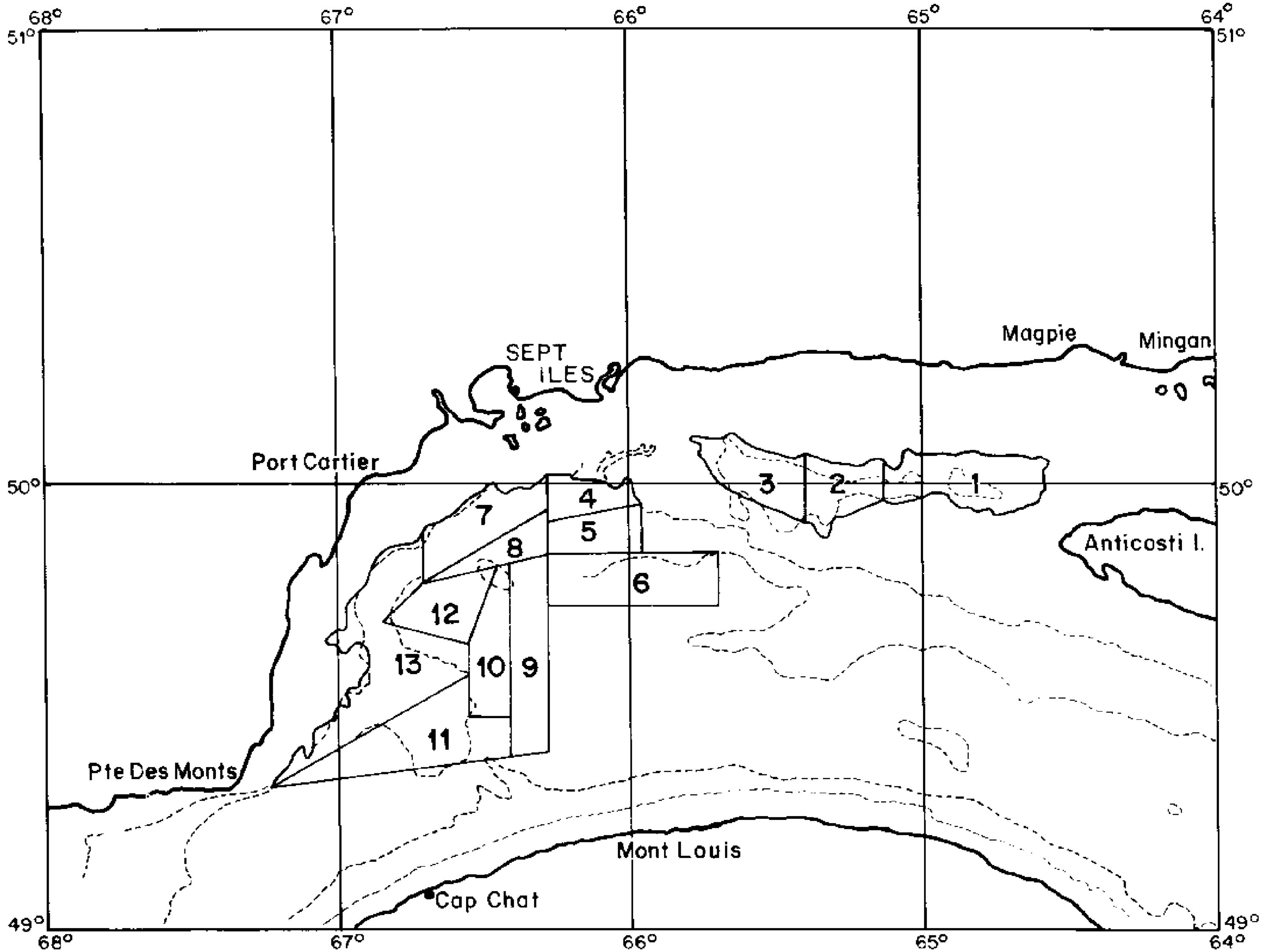

Figure 1. Stratification scheme for the northwest part of the Gulf of St. Lawrence.

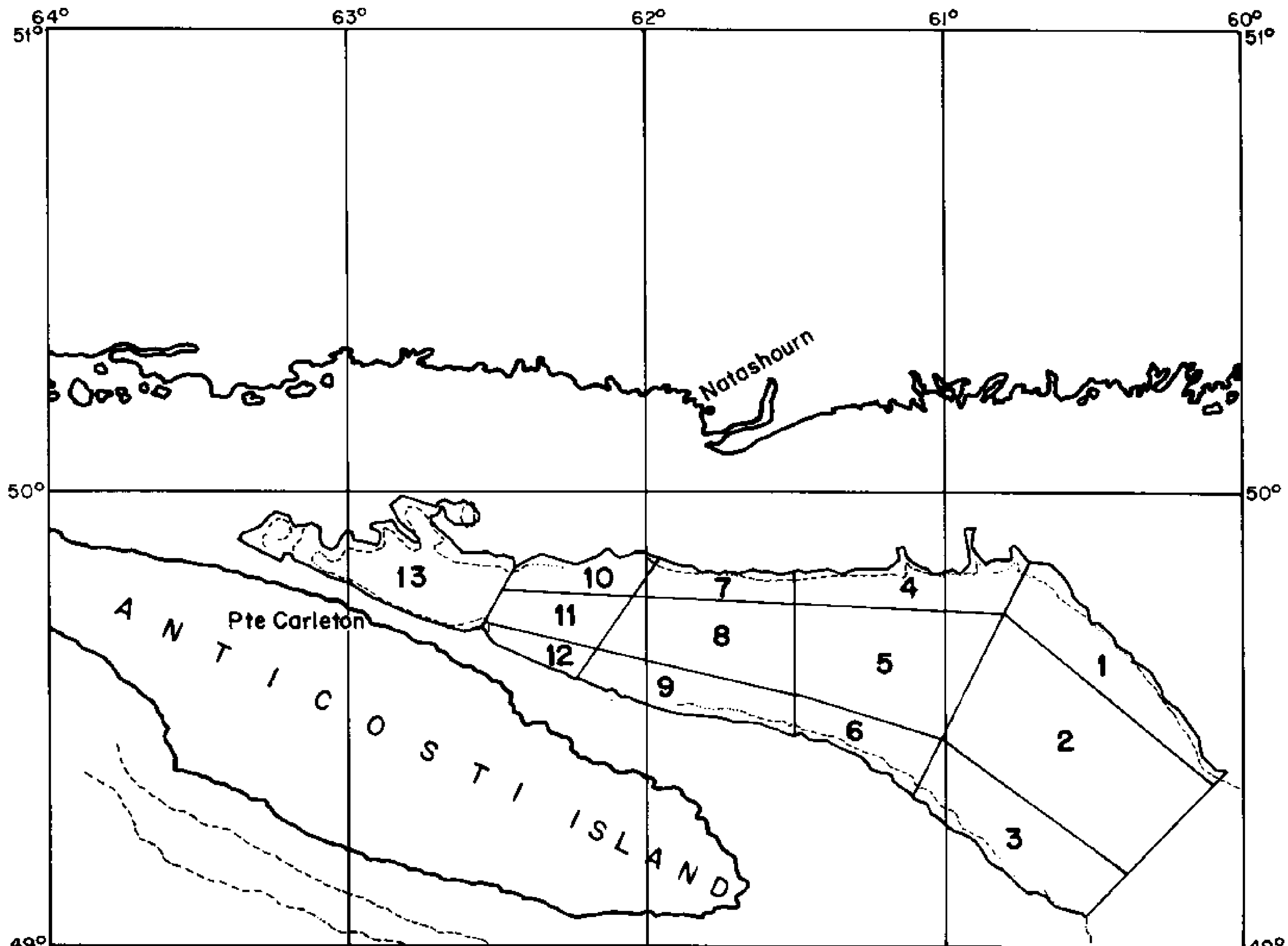

Figure 2. Stratification scheme for Anticosti Channel in the Gulf of St. Lawrence.

From 1974 to 1977, an average of 50 stations per survey were made. At each station, a 30 minute set was made at an average speed of 2.5 to 3.0 knots. To avoid bias introduced by vertical migration of shrimp during the night (Horsted and Smidt 1956; Barr 1970), all sets were made from sunrise to sunset.

For each set, a sample of about 300 shrimp was collected. All individuals were sexed and the cephalothorax measured to the nearest 0.1 mm, from the eye socket to the mid-part of the posterior edge of the carapace.

All size distributions were combined by stratum and grouped in 0.3 mm class intervals. Later, a running average of three adjacent classes was used to eliminate secondary peaks included in size distribution.

BIOMASS ESTIMATES

Total biomass for a survey was estimated by:

$$B = \Sigma B_i$$

and

$$B_i = A_i \frac{\Sigma\, y_{ij} / b_{ij}}{n_i}$$

where

B_i = biomass in stratum i

A_i = surface area in stratum i

y_{ij} = catch per tow j in stratum i

b_{ij} = area swept per tow j in stratum i

n_i = number of tows in stratum i

Swept area method involves knowledge of the real catchability of shrimp as repeatedly reported by several authors. The method used to estimate the biomass excludes those young shrimp which are too small to be retained by the trawl. This in itself, would tend to give an underestimated biomass. The method further assumes that all shrimp (of trawlable size) found within or above the sector swept by the trawl are caught. Some shrimp may be so far off the bottom that they escape the trawl. Finally, it is not known to what extent shrimp may avoid the trawl by swimming over the headline.

Consequently, all biomass calculations were divided by a coefficient of 0.75. This coefficient, in our case, expresses the probable availability of shrimp present in the sampling volume of the trawl, taking into account the vertical distribution. With some scarce preliminary trials made in 1975 with a vertical stage sampler, similar to the one used by Beardsley (1973) on *Pandalus jordani*, we estimated that at least 25 percent of shrimp (in weight) were distributed over the mean height of the headline (2.7 m). This result, based on few sets, is only indicative since this type of sampler appears to be very difficult to use over muddy sediments.

Table 1 shows mean biomass estimates per nautical mi^2 with their associated standard errors for each stratum from 1974 to 1977. The variability inside strata is much higher during the spring. This fact could be explained by the migratory behavior of the shrimp. As demonstrated by Haynes and Wigley (1969) ovigerous females move inshore in shallow water during the winter prior to hatching. This behavior during the hatching period decreases the homogeneous dispersion of the ovigerous females on the ground. As a result, large sporadic concentrations of shrimp in shallower strata (1, 2, 3) contribute to increasing the variability of biomass estimates. This behavior is very well known by fishermen who fish those particular spots. In April, a very high commercial catch rate confirms that fact (Table 2). Even with high availability of shrimp during that time of year, spring is probably the worst period to conduct surveys to estimate the biomass, mainly if we attempt to compare these results with estimates made in other seasons. A better way to compare the shrimp biomass during successive years is to choose a sampling season with lower variability. Surveys conducted in October, when the mean standard error is minimum (lower that 10 percent), seem more appropriate to determine biomass. Under that constraint, it is more than urgent to study the vertical dispersion of shrimp during different periods of the year, and even more important to know in which way the patch behavior can modify stock estimate.

Table 3 presents results of biomass estimates and corresponding annual landings. In 1974, biomass were recalculated using the stratification scheme produced in 1975.

In the northwestern Gulf of St. Lawrence, biomass per square mile is highly variable in shallower strata (1, 2, 3) (Table 1), during the spring (mainly 1974). This high variability might be explained by incidental shrimp patches of very high density. However, if we exclude the April 1974 estimate, spring biomasses are quite similar from year to year and so

Table 1. Mean biomass estimate (B) and associated standard error ($S\bar{x}$) in kg for nautical square mile of shrimp in the northwest Gulf of St. Lawrence, April 1974 to April 1977

Strata	Surface	April 1974		Oct. 1974		April 1975		Oct. 1975		April 1976		Oct. 1976		April 1977	
	n.mile^2	B	$S\bar{x}$	B	$S\bar{x}$	B	$S\bar{x}$	B	$S\bar{x}$	B	$S\bar{x}$	B	$S\bar{x}$	B	$S\bar{x}$
1	138	56,206	24,806	3,786	549	8,140	2,324	7,527	1,035	13,659	1,843	7,227	1,288	15,246	3,130
2	77	9,386	3,366	504	120	5,705	1,683	1,675	960	35,924	26,494	6,620	3,407	9,380	2,464
3	96	22,289	2,526	6,958	2,093	16,827	9,834	8,108	3,538	15,127	3,388	6,579	852	21,182	8,594
4	54	13,504	5,396	4,897	1,258	4,214	1,054	3,179	793	2,365	429	4,378	398	6,936	1,895
5	69	16,969	4,300	3,454	1,191	10,490	5,610	3,425	1,652	5,987	1,216	5,306	1,119	6,156	1,390
6	156	728	174	3,787	536	2,669	1,200	2,636	573	3,407	2,280	2,532	916	2,680	1,428
7	105	9,271	1,254	4,125	1,028	1,425	398	5,634	1,133	4,050	1,640	3,045	530	3,384	265
8	50	7,730	0	3,340	269	2,331	-	4,044	528	2,631	1,414	2,185	368	5,460	2,499
9	130	5,808	105	4,019	650	6,464	-	1,974	241	1,541	438	2,876	336	703	123
10	89	8,417	1,288	4,066	240	-	-	2,256	377	1,730	350	2,131	721	1,400	974
11	191	7,263	2,206	2,562	890	-	-	2,470	770	1,201	545	3,230	1,287	3,769	1,184
12	84	14,182	9,702	5,569	763	3,543	989	5,287	117	4,737	1,418	3,665	525	5,034	811
13	259	10,572	1,275	3,498	488	-	-	6,817	1,787	2,014	537	3,036	352	2,834	269
Mean		13,895	2,408	3,785	240	6,160	-	4,471	431	6,165	1,423	3,898	309	5,873	686

Table 2. Monthly shrimp catches for Quebec trawlers, 1977

Month	Landing	Fishing hours	Catch rate kg/hr
April	606.5	3911	155.1
May	331.0	6250	53.0
June	323.9	7264	44.6
July	331.3	7070	46.9
August	373.4	7375	50.6
September	343.3	7509	45.7
October	145.1	3899	37.2
November	154.7	3853	40.1

Table 3a. Biomass estimate for 1974 to 1979 and corresponding commercial landings in the northwest part of the Gulf of St. Lawrence

Year	Biomass estimate April	Biomass estimate July	Biomass estimate October	Landing (mt)
1974	20,810	5,490	5,960	1,742.8
1975	5,950*		6,700	2,135.1
1976	9,240		5,840	1,840.9
1977	8,800			2,746.5

*Biomass estimate for 13 strata

Table 3b. Biomass estimate in October 1977 and corresponding commercial landing in Anticosti Channel

Year	Biomass estimate	Landing (mt)
1977	October: 11,460	1,185

it is for autumn biomasses; but as mentioned before, within a year, April estimates can hardly be compared to October because of presumably different availability.

As a result, the coefficient of 0.75 used to correct the biomass for each survey should be revised. This coefficient is certainly lower during the spring than during the fall.

Taking into account the inherent variability of the swept area method, the reduction of abundance observed from October 1975 to October 1976, and from April 1976 to April 1977, could hardly be considered as significant. In fact, mean catch rates of shrimpers for those years (Table 4) rather indicate an equilibrium state of this stock. Consequently, we might consider that the mean of biomass estimates from 1975 to 1977 represent the real abundance of this stock. This mean biomass for these last three years is 8,640 mt.

Assuming the constant fishing power of the fleet, if we compare the catch rate at the beginning of the exploitation (1965-1966), which is in the order of 84 kg/hour, with the average catch rate from 1975 through 1977, which is of 50 kg/hour, we can evaluate a virgin stock around 14,400 mt, catch rate being proportional to the stock.

In Anticosti Channel, the biomass estimate is based on a unique survey in October 1977. The very low variability (5 percent) associated with the mean biomass per nautical mi^2 (4,710 kg, $S_{\bar{x}}$ = 265 kg) combined with a very low exploitation rate should give a good idea of the real stock, even of the virgin stock.

YEAR CLASS ABUNDANCE

A cumulative size frequency distribution, which is assumed to be representative of the shrimp population, was available for each stratum. Knowing the shrimp biomass for each stratum, it was possible to relate this biomass to different size groups and even to different age-classes as did Gotshall (1972) for *P. jordani*. Firstly, we had to identify size groups or age-classes in the size distributions.

Figure 3 presents a typical size distribution with class intervals of 0.3 mm (stratum 13 of our stratification scheme, October 76). An annual reproduction cycle (almost 100 percent of females are berried in autumn) and especially a short hatching period permit to identify modes of size distribution, as annual and corresponding to age-classes (II, III, IV+).

Table 4. Catch, fishing effort and mean catch rate from 1965 to 1977 in the northwest part of the Gulf of St. Lawrence

Year	Landing (mt)	Fishing Effort (mt)	Catch rate (kg/hr)
1965	11.1	134	82.8
1966	95.7	1,128	84.3
1967	277.9	4,622	60.1
1968	271.8	5,214	52.1
1969	272.5	6,276	43.4
1970	412.5	9,453	43.6
1971	393.0	9,453	41.7
1972	480.5	11,202	42.9
1973	1,273.4	21,130	60.3
1974	1,742.8	32,820	53.1
1975	2,135.1	43,469	49.1
1976	1,840.9	40,000	46.0
1977	2,746.5	49,509	55.5

However, some problems arise when identifying young shrimp and older females age-classes. First, position of the mode and abundance of the class II (Figure 3) are biased due to the selectivity of the trawl. On the other hand, more than one female age-class is possibly aggregated in IV+ mode since a long ovigerous period decreases the growth rate in these classes.

To overcome the first problem, we determined the selectivity of our trawl in 1976 (Labonté and Fréchette 1978). Figure 4 shows the selectivity curve produced. A mean length (cephalothorax) of selection of 18.6 mm was calculated for the trawl used (Yankee 41, with stretched mesh size of 38 mm).

Subsequently, all size distributions have been adjusted to determine the real abundance of shrimp in each age-class. By comparing Figures 3 and 5, we can see the effect of selectivity on the abundance, mainly for age-class II which is recruited during the fishing season.

Separation of modal classes were made by the Hasselblad (1966) method using the NORMSEP program (Abramson 1971). In addition to mean length of each year-class, NORMSEP gives estimates of the number of shrimp in each year-class.

Knowing that:

$$N_i = n_i \cdot \frac{B_i}{p_i}$$

where:

N_i = total number of shrimps in stratum i

n_i = number of shrimp for the sample in stratum i

B_i = biomass of shrimp in stratum i

p_i = weight of shrimp for the sample in stratum i

We can estimate the total number of shrimp per age-class in each stratum by using the breakdown produced by NORMSEP, with:

$$N_{ij} = \frac{N_i}{100} \cdot K_{ij}$$

where:

N_{ij} = number of shrimp in stratum i of age-class j

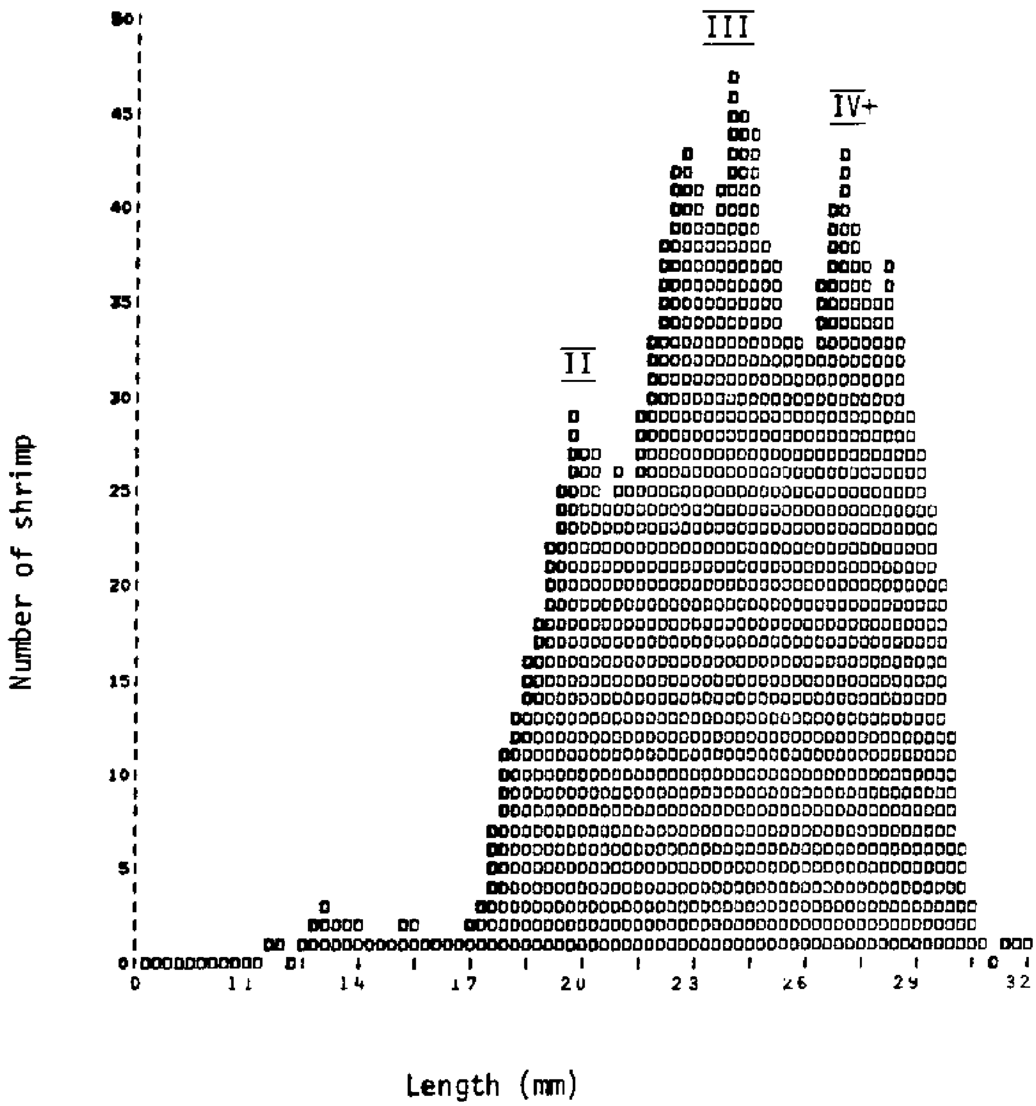

Figure 3. Size distribution of shrimp (stratum 13, October 1976) in the northwest Gulf of St. Lawrence.

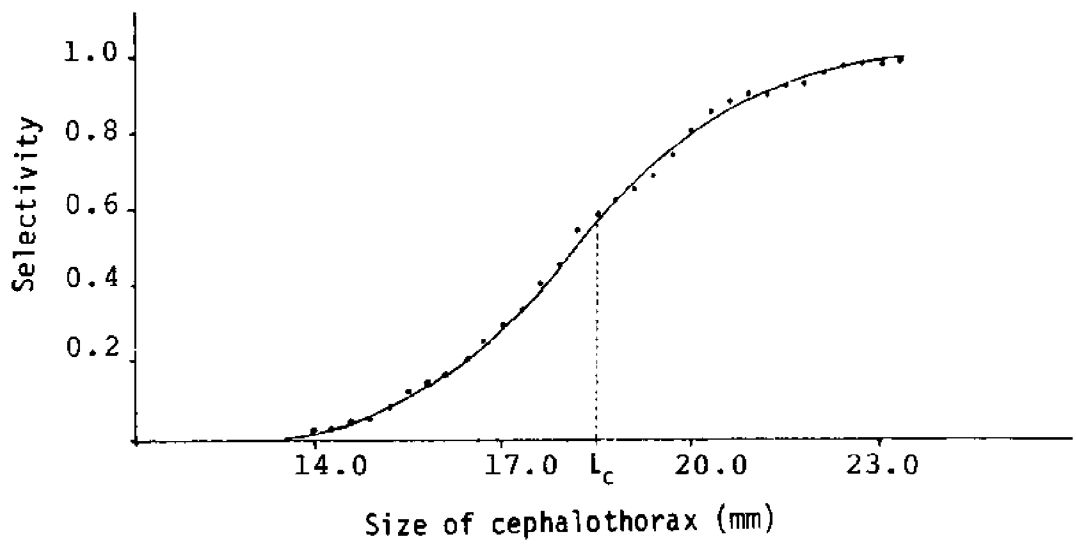

Figure 4. Selectivity curve for the shrimp trawl Yankee 41 with a mesh size of 38 mm. L_c = 18.6 mm.

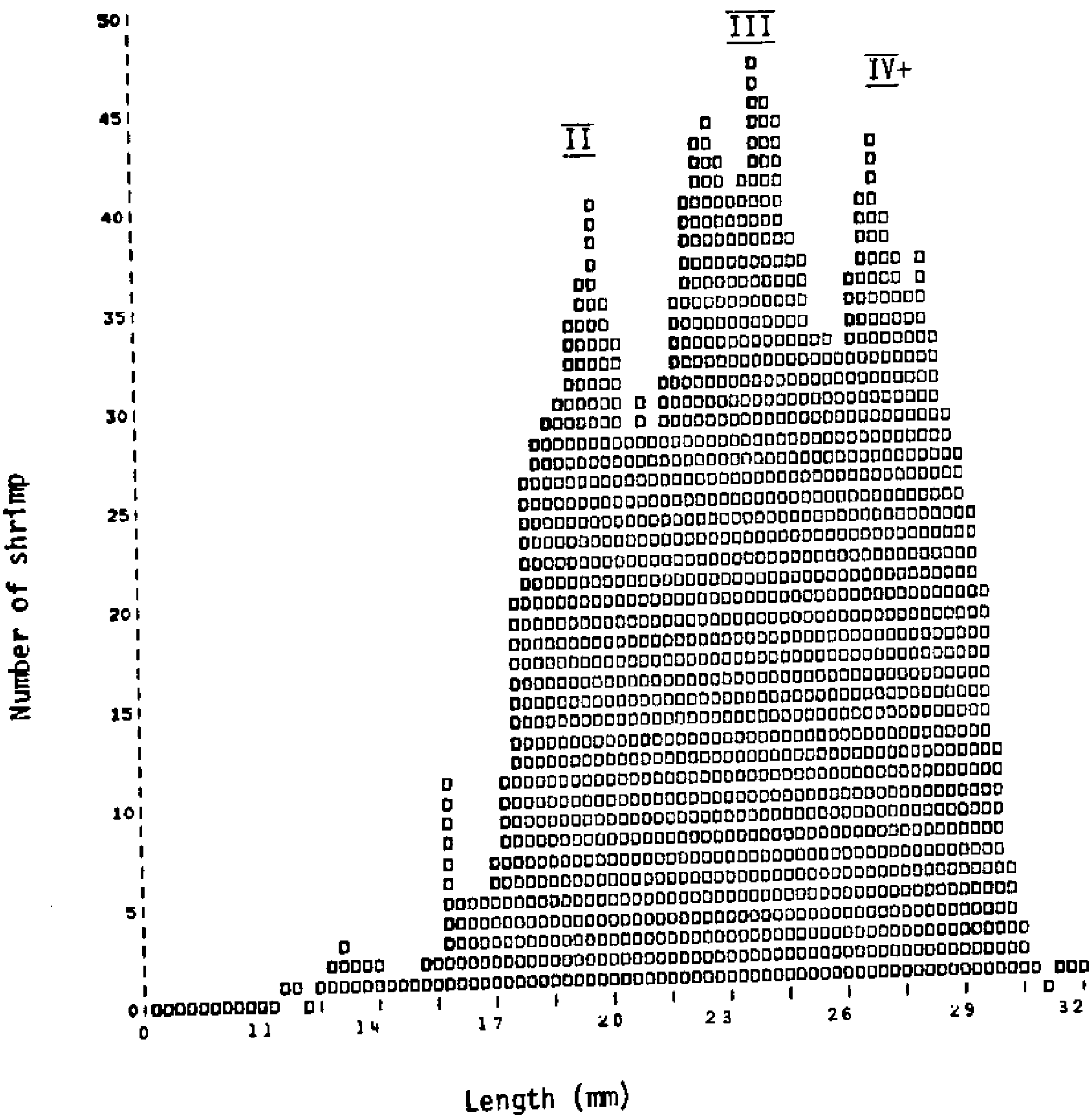

Figure 5. Size distribution of shrimp (stratum 13, October 1976) corrected by the selectivity curve.

K_{ij} = percent of shrimp in stratum i of age-class j (given by NORMSEP)

Table 5 shows the total number of shrimp for each age-class (II, III, IV+) in northwestern Gulf of St. Lawrence.

Age-class II was split in two parts. First, the II NR, which represents age-class II present on the ground during a survey, but not recruited to the fishery. These shrimps have a cephalothorax length lower than 18.6 mm (Labonté, and Fréchette 1978). Second, the II R, which are shrimp of age-class II recruited to the fishery (larger than 18.6 mm).

The vulnerability to the fishery of age-class II, passes generally from approximately 10 percent in the spring to 50 percent by the end of the fishing season. This vulnerability of age-class II is relatively constant from one year to another.

Separation of size distributions into their components is certainly the most important stage when estimating year-class abundance. Hasselblad (1966) method, based on fitting normal curves on modal classes, is certainly powerful when modal classes are well defined. However, when there are important overlaps between modal classes, results could be far from the reality. The method also needs the exact number of year-classes represented in the distribution. This point is questionable for P. borealis, especially for older female age-classes.

These facts indicate the problem of a possible accumulation of several female year-classes in the last mode (IV+). Growth of males is continuous but, as sex inversion takes place, this type of growth is abruptly replaced by a discontinuous one, imposed by the ovigerous period. In the Gulf of St. Lawrence, mature females can molt only from May to October between hatching and egg laying period. Consequently, modes representing age-classes become undiscernable.

Under particular circumstances of sampling time and sampling location, this IV+ mode can be split into two components. The occurrence of this fifth mode is sufficient to question the accumulation of more than two year-classes in that last mode.

In fact, the occurrence of this fifth mode seems to depend for a part on a low exploitation rate. This was the case for the stock of the northwest Gulf of St. Lawrence a few years ago (Simard, Fréchette and Dubois 1975) (Figure 6).

Table 5. Millions of shrimp per age-class from April 1974 to October 1976 in the northwestern Gulf of St. Lawrence

Date	II NR[a]	II R[b]	III[c]	IV+[d]	Total
April 74	1,604.4	214.8	1,020.5	1,003.8	3,843.5
Oct. 74	137.3	124.7	231.8	200.5	694.3
April 75	79.6	0*	393.4*	327.3*	800.2*
Oct. 75	281.9	195.6	322.5	203.9	1,003.9
April 76	272.1	14.1	582.3	465.8	1,334.2
Oct. 76	134.5	180.8	244.7	187.0	747.0

[a] Age-class II present on the ground, but not recruited to the fishery
[b] Age-class II recruited
[c] Age-class III
[d] Age-class IV and older
* Estimates without strata 10, 11 and 12

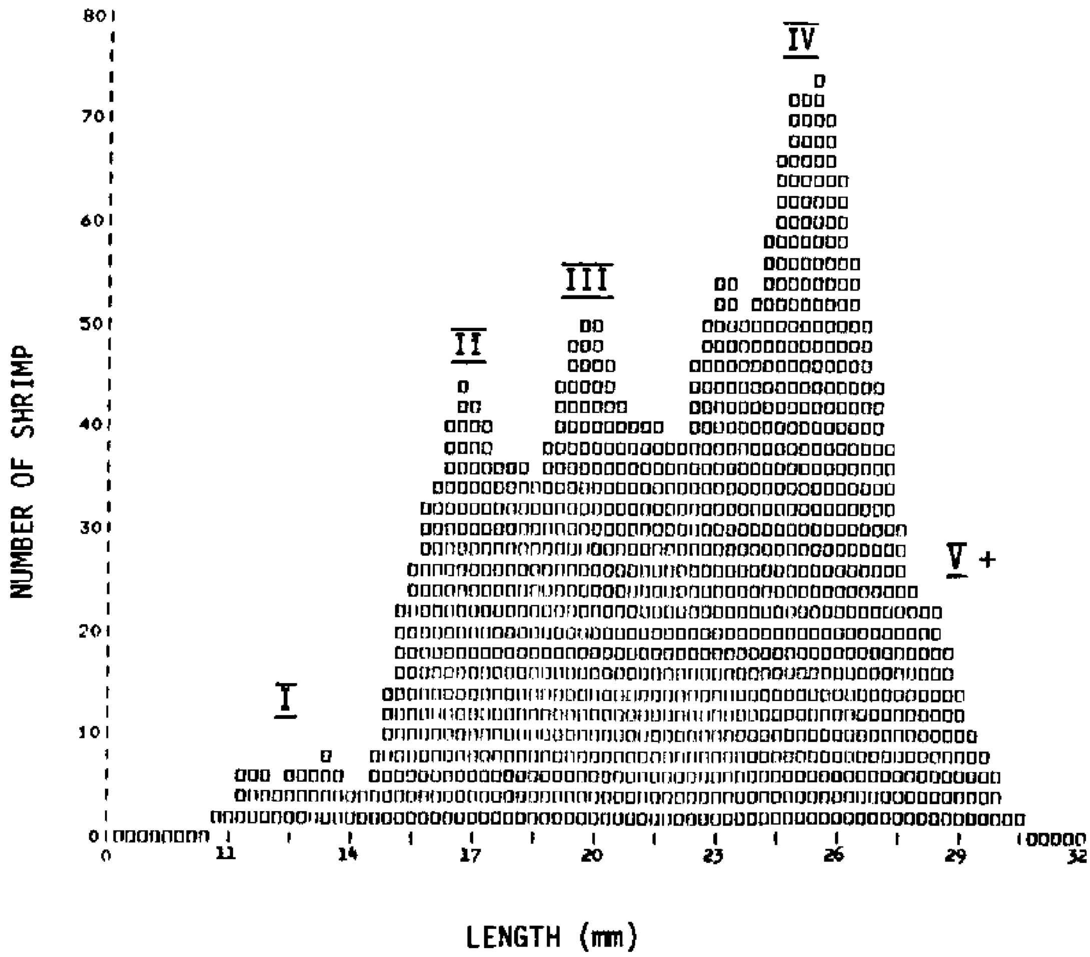

Figure 6. Size distribution of shrimp in May 1971 in the northwestern Gulf of St. Lawrence.

Since 1974, this fifth mode has practically never been observed and this corresponds with higher exploitation rates. However, that fifth mode is not necessarily corresponding to age-class V.

Some preliminary work has been done on weight distribution instead of size distribution. Since length-weight relation is an exponential relationship, increase in weight for a specific interval of time is relatively more important than increase in length for older female age-classes. One might think that year-class separation is easier on weight distribution for larger animals. Figure 7 presents a preliminary trial made according to that hypothesis. From the last unique and large mode on the length distribution (Figure 7a) of females, weight distribution (Figure 7b) reveals several modes.

As a result, if those peaks represent real age-classes, the hypothesis of one year-class in that last peak should be discarded. Before going further, this method of age-class separation has to be improved with more trials. Consequently, with successful results, it could be the easiest way to resolve the age-class separation of old females.

Since there are many sources of error in the calculation of the number of shrimp per age-class, it appears quite difficult to appreciate the reliability of our estimate. We probably obtain a good estimate of the total number of old shrimp compared to the youngest, because they are fully recruited. But the age-class separation is certainly better for the young shrimp.

MORTALITY ESTIMATES

Since population estimates calculated form the spring surveys were highly variable, we only used population estimates calculated from the fall surveys to estimate mortality rates. Knowing the abundance of each age from 1974 to 1976, it was possible to estimate instantaneous total mortality (Z) for each recruited year-class by using:

$$e^{-zt} = \frac{N_t}{N_o}$$

where:

t = time interval

N_o = number of shrimp of one age-class or a group of age-classes at t_o

N_t = number of shrimp of one age-class or a group of age-classes at the end of the time interval t

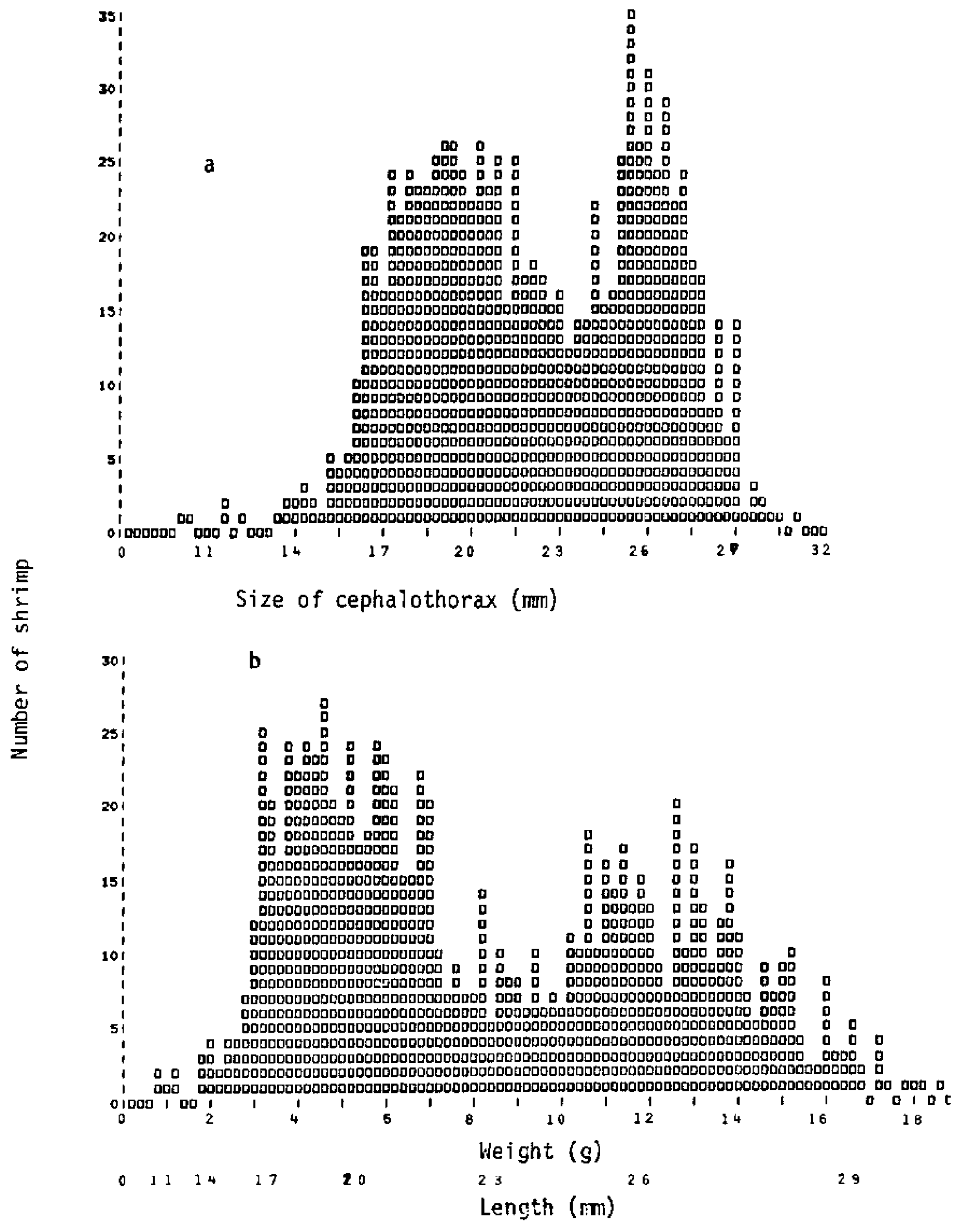

Figure 7. Size distribution (a) and weight distribution (b) for a selected commercial sample of shrimp for the stock of the northwest part of the Gulf of St. Lawrence.

To obtain natural mortality rates for each age-class, we had to calculate the fishing mortality for these age-classes. We did not know the number of shrimp of each age-class caught during the fishing season. However, since the trawls used for our surveys were identical to those in the shrimp fishery, it is probable that the relative proportion of each recruited age-class during the spring and fall surveys represent the relative proportion of each age-class commercially caught at the beginning and at the end of the fishing season. Consequently, the relative proportion of each age-class caught during the fishing season was estimated in taking the average proportion of shrimp per age-class during the spring and the fall surveys. We assume shrimp catches were uniformly spread throughout the fishing season.

Since the total number of shrimp caught during the fishing season was known, it was possible to estimate the number of shrimp per age-class in splitting the total catch by the average proportion of shrimp per age-class during the fishing season.

So the instantaneous fishing mortality (F) for one age-class or a group of age-classes is given by:

$$F_{(t - t_o)} = \frac{CZ}{N_o A}$$

where:

Z = instantaneous rate of total mortality for one age-class or a group of age-classes

C = number of shrimp of one age-class or a group of age-classes caught between t_o and t

N_o = number of shrimp of one age-class or a group of age-classes at t_o

A = annual mortality rate of one age-class or a group of age-classes associated with Z $(t - t_o)$

$t-t_o$ = fraction of the year on which the estimated is based (one year in that case)

Table 6 gives Z, F and M for the shrimp population in the northwest Gulf of St. Lawrence. Mortality rates were calculated for different age-groups. First rates are calculated from the disappearance of shrimp of the age-class group III (females) and IV+ (females) at t_o, to the resulting age group IV+ one year later. Second rates are calculated from

Table 6. Mortality rates in the northwestern Gulf of St. Lawrence, 1974 to 1976

a) Instantaneous rate of total mortality (z)

Years	class $III+IV^{+} \rightarrow IV^{+}$	$III \rightarrow IV^{+}$	$II \rightarrow III$
74-75	0.75	-	-
75-76	1.03	0.54	0.67

b) Instantaneous rate of fishing mortality (F)

Years	class $III+IV^{+} \rightarrow IV^{+}$	$III \rightarrow IV^{+}$	$II \rightarrow III$
74-75	0.27	0.38	0.38
75-76	0.23	0.31	0.28

c) Instantaneous rate of natural mortality (M)

Years	class $III+IV^{+} \rightarrow IV^{+}$	$III \rightarrow IV^{+}$	$II \rightarrow III$
74-75	0.48	-	-
75-76	0.80	0.24	0.39

the disappearance of shrimp of age-class III at t_o to age-class IV+ one year later. And finally, third rates are calculated from the disappearance of age-class II (males) at t_o, to the resulting age-class III one year later.

First rates were calculated for two successive years: October 1974 to October 1975 and October 1975 to October 1976. Second and third rates were calculated only for one year (October 1975 to October 1976) negative values being obtained the previous year, (October 1974 to October 1975).

Taking a first hypothesis in which the fifth mode or plateau observed time to time for poorly exploited stock (Figure 6) might correspond to age-class V, abundance of age-class V being much more lower than age-class IV (practically total disappearance), we calculated the mortality between age-class III and IV+. The natural mortality rate obtained by that way (0.24) is lower than the one resulting from age-class II to age-class III (0.39). This hypothesis seems to be weak. Some elements, as reported before, tend to indicate age-class accumulation in the last peak (Figure 7), and this could explain why we obtain negative rates of mortality for age-class III to age-class IV+ between October 1974 and October 1975.

A second hypothesis, which is more probable, is based on the fact that there is an age-class accumulation in the last mode in the size distributions. Consequently, mortality rates were calculated from the age groups III and IV+ at t_o, to the age-class group IV+ one year later. Natural mortality rates obtained, range from 0.48 to 0.80 with a mean of 0.64. That mean natural used mortality (0.64) has a very good concordance with other rates in the management of populations growing in similar conditions of water temperature (4^o to 6^oC). Natural mortality rates used in the Fladen and Skagerrak fisheries (between Scotland and Norway) are between 0.5 and 1.0 (ICES Working group 1977).

Natural mortality rate (0.39) obtained between age-class II and age-class III is probably only indicative. It depends probably on the availability of age-class II on the ground during the sampling period. This could explain why a negative mortality rate was obtained between October 1974 and October 1975. However, that indicative result tends to demonstrate lower natural mortality rate for younger age-classes.

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A TECHNIQUE FOR ESTIMATING GROWTH AND TOTAL MORTALITY FOR A POPULATION OF PINK SHRIMP *PANDALUS BOREALIS* FROM THE WESTERN GULF OF ALASKA

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ABSTRACT

Carapace length-frequency measurements of *Pandalus borealis* collected annually for seven years were analyzed to determine growth and total mortality. A technique for weighing length-frequency samples and analyzing the resulting plots for dominant year-class modes is presented. Carapace length-frequency modes were separated by a computer program NORMSEP developed from Hasselblad's statistical method. A dominant year class, ascribed to 1971, was followed for seven years to determine the growth and total mortality of this year-class. A von Bertalanffy curve fit of growth data yielded an estimate of 0.18 for K and 29.00 for $L\infty$. The total instantaneous mortality coefficient was calculated as 0.66 for the 1971 year-class.

INTRODUCTION

This paper presents a technique for estimation of growth and mortality rates by analysis of shrimp carapace length-frequencies.

Estimating age, growth and population parameters for pandalid shrimp is difficult because shrimp lack hard parts from which age is frequently determined. The only method available with shrimp is to examine carapace length-frequency data and make assumptions on probable growth patterns. This technique has been used by Rasmussen (1953), Allen (1959), Ivanov (1969), Dahlstrom (1970), and Gotshall (1972) to describe growth and life history patterns on pandalid shrimp. Cassie (1954) developed a technique of separating modal size frequency distributions to distinguish age groups. Minet, Forest and Perodou (1978) applied this technique to the separation of modal size groups of *Pandalus borealis* off Baffin Island. Kitano and Yorita (1978) separated polymodal carapace length-frequency histograms into age components using Hasselblad's statistical method (Hasselblad 1966).

To study fluctuation in year-class strength or to follow a cohort through its life cycle, a long time series of reliably collected data is required. In this study, seven years of *Pandalus borealis* carapace length-frequencies data have been analyzed and year-class specific growth and mortality estimates have been identified.

METHOD

All carapace length-frequency data analyzed in this study were collected on annual National Marine Fisheries Service shrimp resource assessment cruises conducted in the western Gulf of Alaska during August and September of the years 1972 to 1978. A 61 ft high opening shrimp trawl developed by NMFS (Wathne 1977) was used exclusively on these cruises.

A random sample of 300 shrimp were sexed and measured from each survey catch containing at least 100 kg of shrimp. A total of 18,934 (range 286 to 5355) shrimp were sexed and measured during the seven year study. Carapace length was determined by measuring individual shrimp with vernier calipers to the nearest 0.5 mm. Measurements were taken from the posterior edge of the eye orbit to the median posterior edge of the carapace.

All length-frequency data were weighted to size of shrimp catch and combined by geographical strata using the computer program SHRIMP2[1]. For each haul within a stratum, the sexed length frequency distributions were converted to weight caught per size using the weight-length relationship:[2]

$$W = .00104 \times L \text{ EXP. } 2.79160$$

The parameters of this expression are based on unsexed data. The catch in numbers was then determined by the formula:

$$\hat{N}_{i.k} = \frac{C_{.jk} \times \frac{w_{ijk}}{w_{.jk}}}{\sum_j .00104\ l_i^{2.79160}}$$

where:

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[1]Programmed by David Somerton and Alan Lindsay, Center for Quantitative Science in Forestry, Fisheries, and Wildlife, University of Washington, Seattle, WA.

[2]Determined from weight at length observations from NMFS survey data for the Alaska Peninsula region 1972 to 1974.

$\hat{N}_{i.k}$ = estimated number of shrimp of the ith size interval of the kth stratum;

$c_{.jk}$ = total catch by weight of shrimp in the jth tow in the kth stratum;

w_{ijk} = weights of shrimp of length i in the length-frequency sub-sample in the jth tow of the kth stratum;

$w_{.jk}$ = weight of all shrimp in the length-frequency sub-sample of the jth tow in the kth stratum; and,

$.00104\ l_i^{2.79160}$ = weight of an individual shrimp of length i.

The resulting weighted length-frequency plots generated by SHRIMP2 were organized into an annual time series for each strata and visually inspected for dominant size modes. If visual inspection indicated a logical progression of dominant modes (assumed to represent year-classes), then further separation was attempted to quantify the modes.

Polymodal mode separations of length-frequencies were accomplished with the computer program NORMSEP developed by Tomlinson (1971), after the statistical procedure of Hasselblad (1966). Through this program a mean length, standard deviation, and total number of shrimp for each modal length group was estimated.

The Pavlof Bay strata was selected for this analysis because the bay is an important commercial shrimping area and suspected to contain a confined population of shrimp.

RESULTS OF ANALYSIS FOR DOMINANT YEAR CLASSES

Examination of sequential length-frequency plots for the Pavlof Bay strata indicated that a dominant mode occurred in the samples in 1972 (Figure 1a). This mode centered around 10 mm carapace length and was designated to the 1971 year-class based on estimates of *P. borealis* growth rates by Butler (1964), Ivanov (1969), and Fox (1972). A logical progression of this mode was followed in all succeeding frequency plots, including 1978, which correspond to the maximum age hypothesized for *P. borealis* in the Gulf of Alaska (Fox 1972). In 1976, another dominant mode (1975 year-class) entered survey catches and was identified in the 1977 and 1978 frequency plots (Figure 1e, f, g). This mode was of the same relative magnitude as the 1971 year-class mode which appeared in 1972.

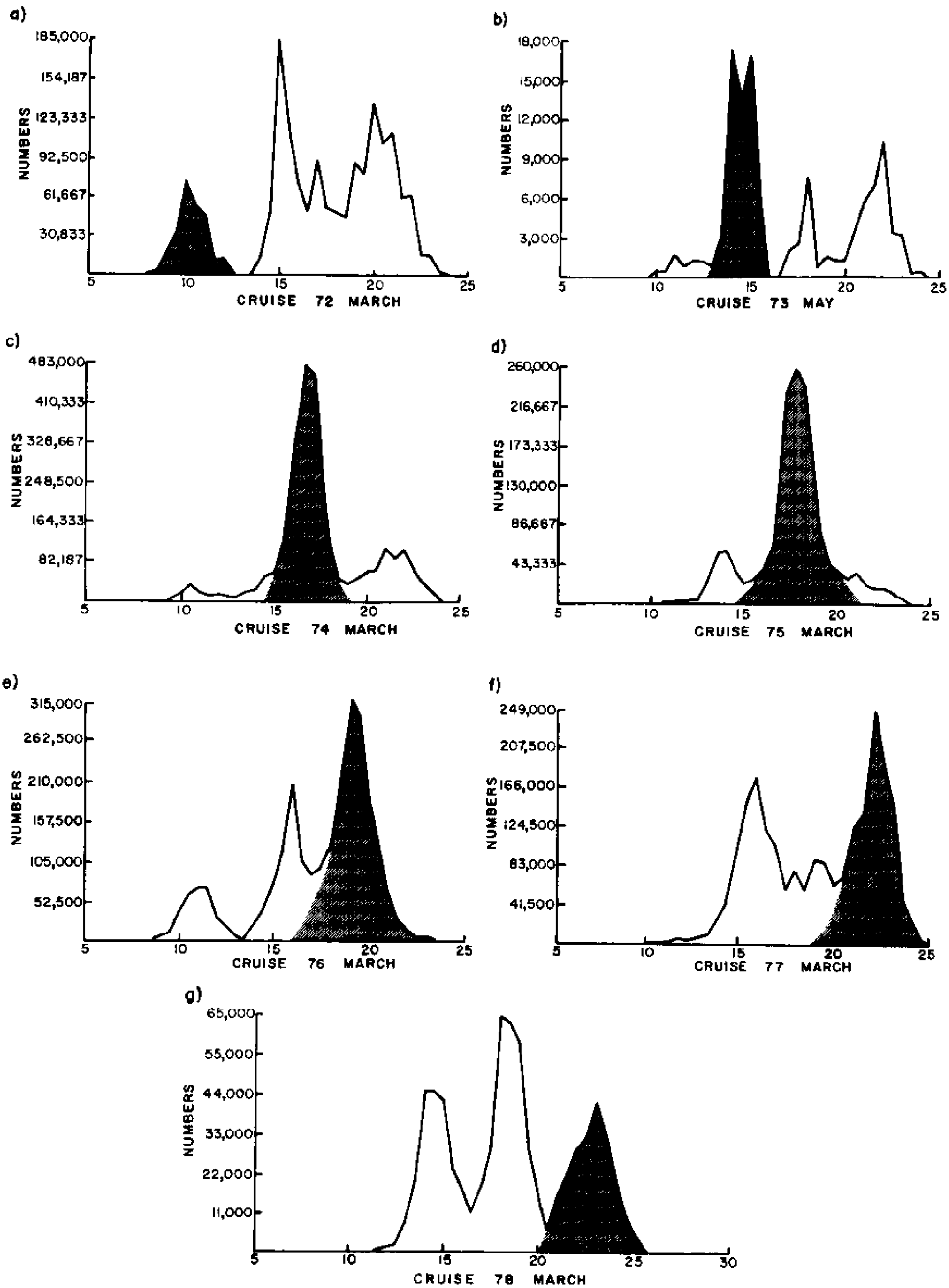

Figure 1. Standardized carapace length-frequency plots of P. borealis from Pavlof Bay 1972 to 1978 (1971 year-class indicated).

These discrete modes were then separated by the computer program NORMSEP to obtain an estimated number with an associated mean and variance for the 1971 year-class for each year for 1972 to 1978. Results of NORMSEP separations for the 1971 year class are presented in Table 1.

ESTIMATION OF GROWTH PARAMETERS

Growth of the 1971 year class from Pavlof Bay was defined using the model:

$$l_t = L_\infty \ (1-e^{-k(t-to)}).$$

Mean carapace lengths (estimated by NORMSEP) were used as input values in this model and resulted in the following values for parameters of the model:

asymtotic length, L_∞ = 29.0 mm

time at zero size, t_o = -1.3

growth completion rate, K = .18

ESTIMATION OF TOTAL MORTALITY

Total mortality was estimated for each year after full recruitment. Full recruitment to the survey sampling gear was assumed to occur between ages 2 to 3 years. Using a technique of Gulland (1969), the fraction of a cohort surviving a one year period is expressed as $S = N_1/N_o$ where N_o and N_1 are the abundances or relative abundances of the shrimp cohort at two known times.

Estimated numbers in modes for the cohort in each year were standardized to survey effort, i.e., numbers captured per nautical mile trawled. Using the basic model for exponential decrease of a stock, $N_t = N_o \ e^{-Zt}$, total instantaneous mortality was estimated as:

$$Z = -\log_e S$$

$$= \log_e (1/s)$$

Table 2 presents total mortality coefficients calculated from numbers standardized on survey effort (total miles towed). A catch histogram (Figure 2) has been constructed from the NORMSEP values.

Table 1. Estimates of mean, standard deviation, and total estimated numbers of 1971 year-class, Pavlof Bay, 1972 to 1977 from Program NORMSEP

Survey year	Estimated mean (mm)	Estimated standard deviation	Estimated numbers
1972	10.57	0.81	$.25 \times 10^6$
1973	14.78	0.57	$.06 \times 10^6$
1974	16.88	0.89	2.00×10^6
1975	17.90	0.76	1.02×10^6
1976	19.51	1.09	1.47×10^6
1977	22.48	0.78	$.78 \times 10^6$
1978	22.96	1.11	$.22 \times 10^6$

Table 2. Total instantaneous mortality coefficients for pairs of age groups of the 1971 year-class, Pavlof Bay, standardized by survey effort*

Year/age	3/4	4/5	5/6	6/7
1974/1975	0.65			
1975/1976		-0.26		
1976/1977			0.66	
1977/1978				1.26

*Effort expressed as total miles towed

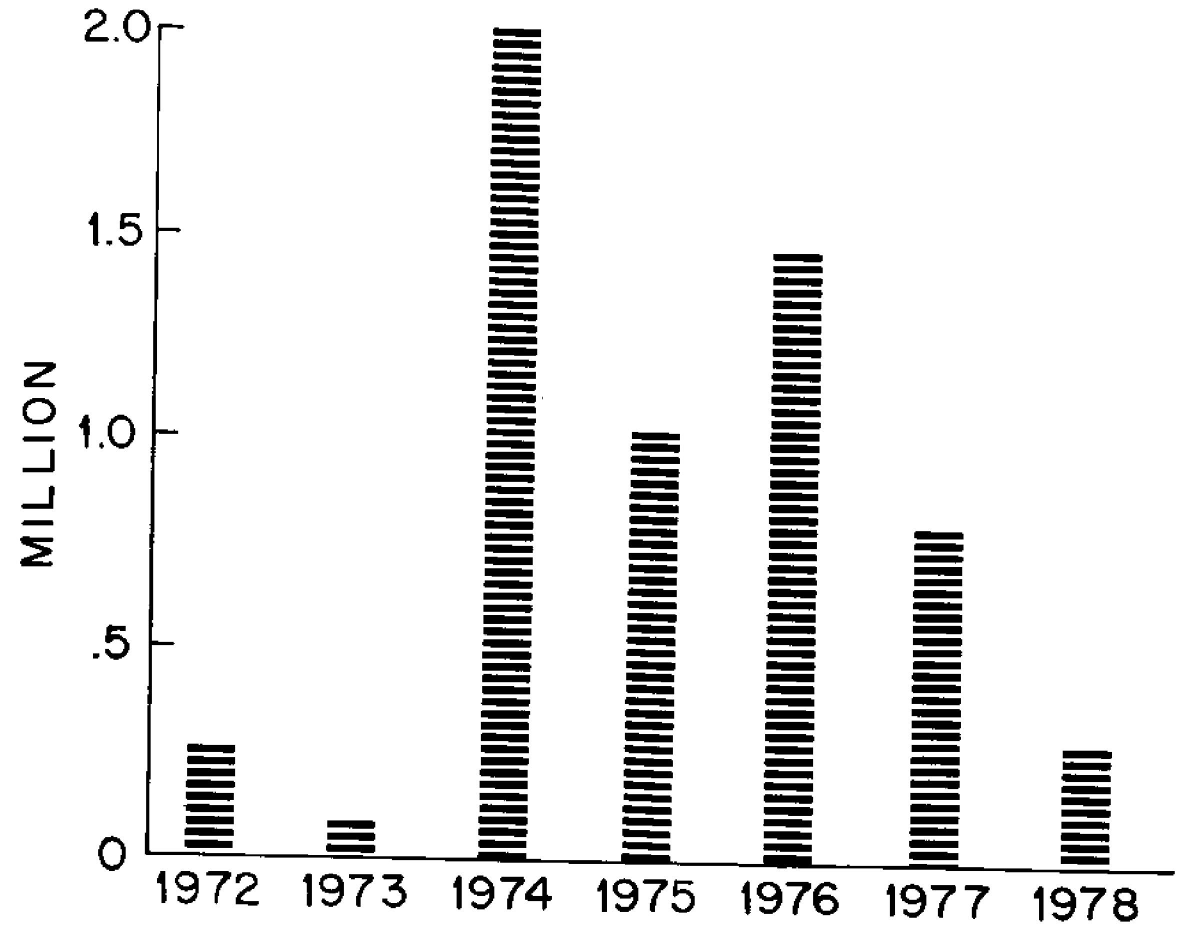

Figure 2. Estimated numbers of the 1971 year-class.

DISCUSSION

Mortality estimates generated show close agreement for their respective pairs of data during successive years. The outlying data point in 1975 has a profound effect on mortality estimates calculated from the negative slope of the catch curve. There could have been a change in availability of shrimp during the 1975 survey that would have led to an underestimate of this age group. In addition, there is also evidence to suggest that the value for the 1971 year-class estimated from the 1976 data is an overestimate. More analysis is in progress to separate fishing from natural mortality.

An interesting point is that while a dominant year-class was easily followed in the Pavlof Bay strata, modes were not easily followed in adjacent strata. I believe I successfully sampled the same shrimp population in Pavlof Bay during each annual survey. Pavlof Bay is a relatively confined body of water with shallow sills surrounding the entrances (Figure 3). These features would confine the shrimp population and allow little interchange from adjacent survey strata. These areas are characterized by high current activity and shrimp could be moved periodically, perhaps due to current displacement. Another explanation might be that our sampling density was not high enough in other strata.

It is possible that the modes identified by visual inspection and separated by NORMSEP do not entirely represent one year-class. The estimated standard deviation for 1976 was noticeably higher (Table 1). High variability could indicate contamination in this modal group and may result in an overestimate of the 1971 year-class. Since modes can be followed logically through time, one might consider monitoring the decay of a particularly strong modal group through time as a cohort and not be concerned about attributing it to any particular age.

It is quite possible that this sequential modal analysis technique could be adapted for use in a commercial catch sampling program, to monitor removals and assess the condition of a shrimp population.

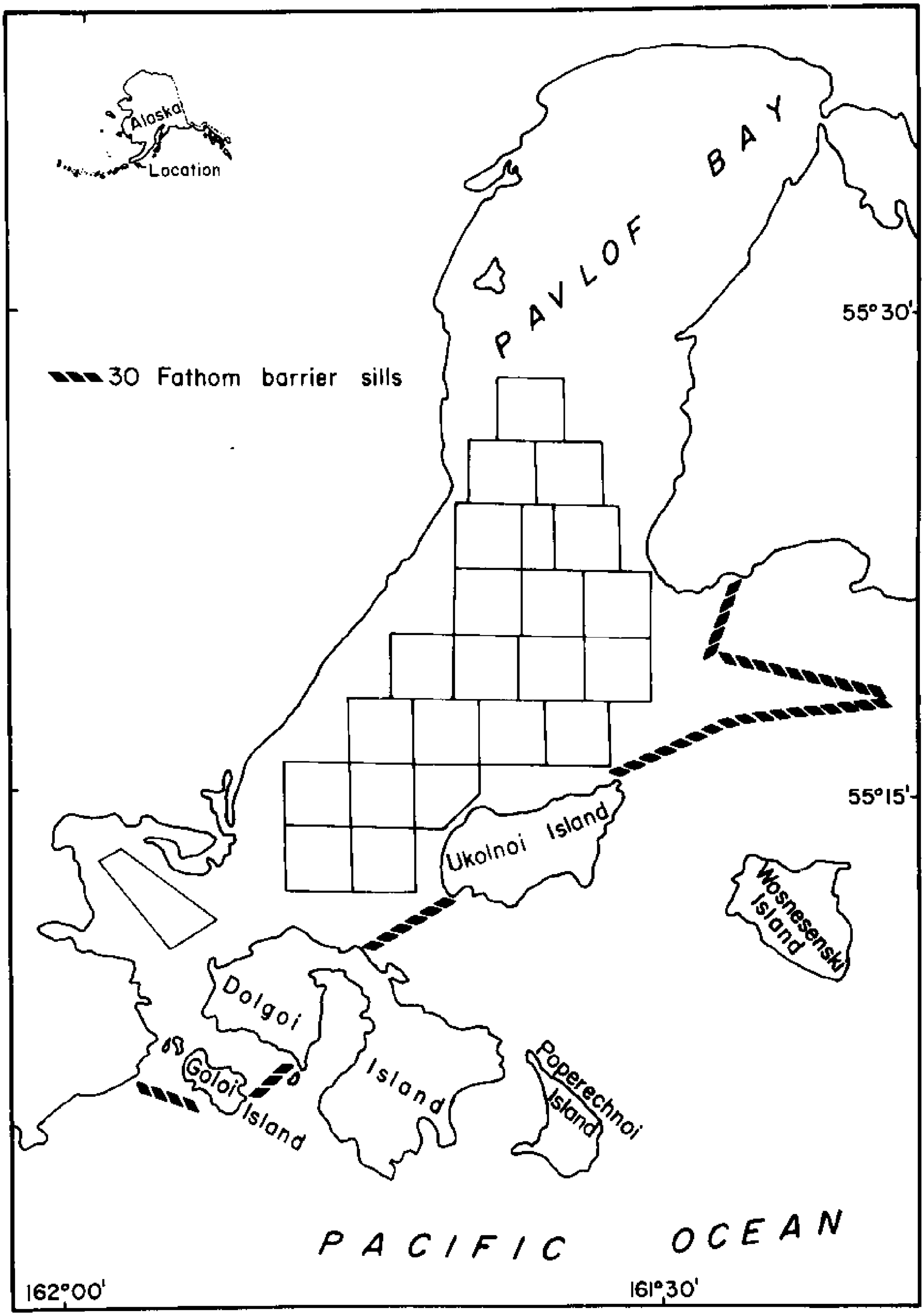

Figure 3. Pavlof Bay showing sampling stations and 30 fm sills.

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QUANTITATIVE YEAR-CLASS ANALYSIS PANEL

Chairman:

Paul J. Anderson (NMFS, Kodiak)

Panel Members:

John Geibel (California Department of Fish and Game)
E. J. Sandeman (Department of Fisheries and Oceans, Canada)
Hiroshi Kurata (Nansei Regional Fisheries Research Lab, Japan)
Svend Horsted (Greenland Fisheries Investigations, Denmark)
Unnur Skúladóttir (Hafrannsoknastofnunin, Iceland)
Jacques Fréchette (Ministry of Aquaculture, Canada)

Other Speakers:

Steve Clark (NMFS, Woods Hole, MA)
Dayton L. Alverson (NMFS, Seattle)
Jack Robinson (Oregon Department of Fish and Game)

Clark — In this bay that you've been studying, this bay system, now you mention a commercial fishery, is there a commercial fishery active in that bay?

Anderson — That's correct. In fact, one of the main reasons that we chose this bay for detailed study was not only did we feel we had an excellent data set for several years running, but also it was a bay of substantial commercial importance. As I mentioned, the fisheries started out rather slowly in 1968, with only a few hundred thousand pounds harvested from the area. Recently, before the population decline was noticed, we had catches in some fishing seasons approaching 26 million pounds and that's total pandalid, so roughly about 13 million pounds of *P. borealis*.

Clark — I thought you were studying another bay in which there was essentially no fishery.

Anderson — That's correct. We were studying another area, the Sanak Island Gully area, which is in this same survey series. However, our data base for that area was not as good, mostly because the shrimp disappeared on us about half way through the study and we didn't have anything to follow after that.

Clark — Any comment on the reasons why that is the case?

Anderson — I wish I knew. Now, are there any other comments? Yes, Dr. Horsted.

Horsted — Yes, I got curious when I saw this in the slide here. I imagine that if you had taken just a sample here and have a normal look at it you would have said these are modes, these are year-classes, probably studies by 2 or by next 2, 3, and 4. Nevertheless, looking then at the movement of that one. It doesn't even follow through four years up to here so instead of just one year between them, you would in your interpretation of that one, if you only had that, have been missing several year-classes.

Anderson — Now, I think it might be interesting to point out right now that our survey sampling modes, of course, have a lot less noise in them than we get from the commercial sampling modes. The reason for that, in my opinion, is the level of sampling. Now we measured the total of almost 20,000 shrimp during the seven year study in Pavlof Bay from our research catches. Approximately averaging about 3,000 shrimp a survey year, or about 300 per tow. In these commercial catch samples, however, we're looking at samples here '77, '78 represent only a few hundred measurements. So that I would just like to point out that good modal definition was, I feel, achieved in this data set, however, I think you could be a lot more certain about your assumptions if your level of sampling is increased. Of course, I like to work my fellows hard when out on a cruise and I don't want them sitting around drinking coffee all the time so we just get down there and measure a lot of shrimp and I think it's paid off for us.

Sandeman — I think that was a very important point you brought out there about measuring a large number. I've certainly been convinced of that for a long time now. I think if you're going to try and use NORMSEP, you must have a very large number. We usually aim at about 300 per set on a research vessel cruise to make 300 measurements and with that sort of distribution I think that usually seems to be adequate to do the analysis. I think I have one question I would like to ask and that is, having derived your series as you have now and being able to follow a year-class, have you tried using the data that you derived through the years in terms of the means for the one you've followed - the means and the standard deviation of the group, and plug it in to, say, your top figure there and see if they do, in fact separate the other groups well.

Anderson — No, I haven't done that. That is a consideration. I think what we're going to try and attempt to do next with this, it's just preliminary data, as I mentioned earlier, but what we plan to do is go back to the commercial catches now and reconstruct all of these modes into virtual population type of analysis. And what we're going to do is simply build up from our research catches what we feel is a representation of the numbers in this mode, as it moves through time - through the years and then also build what has been removed from the commercial fishery via this analysis and simply do a virtual population analysis to determine the natural and fishing mortality. What we have come up with now though is total mortality estimates which run anywhere from about .66 in the early years after full recruitment, to between '77 and '78 of about 1.26 so as the fishery increased we saw an increase also in total mortalities. So, everything seems to be rather logical so far. I'm rather hopeful that we'll come up with a very good estimate of natural mortality from this particular study. Using this as an age-key method definitely, I think, should be examined.

Sandeman — I'd like to make one other comment, still on the same vein, and again thinking about the use of NORMSEP. What I've attempted to do is in the series of data like this is to utilize the data from the major peak that you are following, to break up less frequencies by month and throughout the years. Now it all seems to follow very nicely during the one you're following and I found that it looked very logical and everything in the garden was lovely. However, as soon as I tried to apply the one year-class to other year-classes in a broad scale--what I was attempting to do was to make the whole system much more objective rather than subjective, in fact, get the computer to do the whole job so to speak--this began to fall down. I think the reason why is quite clear and somebody brought it up yesterday. I was interested to hear that, that they were finding extreme differences in growth between year-classes. That's a very significant point, too. So, I'm interested to hear how you get on with this.

Anderson — Yes. We're already detecting that this '75 year-class, which we've identified in three years worth of survey work, '76, '77 and '78 looks like its going to have an appreciably faster rate of growth than the '71 year-class. Of course, this year-class isn't near the magnitude even though it is a relatively strong year-class, it isn't near the magnitude of the '71 year-class. It could be some kind of a density dependent relationship. Yes, Dr. Alverson.

Alverson — Paul, you talked about population discretement and I just have a couple of questions. From the data that I saw you present I think that you gave me substantial evidence that the research vessel sampling is essentially reflecting about the same thing that the commercial fleet is sampling. I think that is not any biological evidence of stock discretement which is something entirely different. We essentially imply the sill formation, which is a physical feature that might lead to stock discretement but on the other hand, the biological evidence from stock discretement is not anything you've presented here. I think you really then have to show something of a genetic characteristic between what's in Pavalof Bay and for what's outside you can't reflect the similar sort of pattern in any of the stocks on the outside. I just didn't see that in your data.

Anderson — That's correct. We tried to utilize the same technique in areas that are adjacent to this survey strata and, of course, we didn't have much success. These areas, of course, are characterized by a higher energy system and we thought that it might, in part, perhaps explain this phenomenon we've seen in this area. But our next attempt at analyzing this sort of data will be to take the survey data in total, generated from the entire survey area and try and see if it fits into any type of a pattern similar to what we found in this bay.

Robinson — Think this is extremely interesting. The technique probably works up here particularly well where you don't have primary females I guess. However, this is in the nature of perhaps a precautionary statement. We've all studied shrimp with a comparatively short life and you see these primaries such as jordani in California and Oregon. We have pretty good data to indicate that a single year-class, particularly a strong one will have divergent growth between those shrimp that change sex to females as one-year-olds and those that remain male. By the end of the summer that year-class will show two very strong modes that are further separated and better separated than many year-classes of an ordinary strength a year apart. So, this can be a problem. You may have two modes in actually a one year-class in some years and in some circumstances. We've seen this several times in Oregon and also California.

Anderson A very good comment and we've also noticed from our data that we've collected around Kodiak Island that its very evident that we have at least two age-classes, possibly more, going through, or two modal groups I should say not age-classes, but let's just call them modal groups through transition at any one time so this leads us to believe there is some kind of a size factor and not necessarily just an age factor perhaps for going through transition. But I think, really, the point of this type of analysis is that O.K. let's say we don't believe anything about age structure at all. Let's say we can't really, if there's people here that don't believe that these represent age groups, then why not approach pandalid management and also our study of population parameters differently. Why not approach it on just monitoring these sequential modes? Now, I'm saying we do have this type of situation and there's probably a good chance that we could just use the sequential mode type of technique to follow a year group through time. And follow the removals through the commercial fleet. I guess if there's no further comments on this particular... Dr. Horsted.

Horsted There are, of course, questions about interpretations of these whether they are really age groups or modes and you're bound to think of something now to overcome it. And one of the steps we're making at present instead of working with probable age groups, we're starting one group of the animals which we are sure will, in terms of assessment, act as an age group. Now we can do that because we are fishing mainly females, the group we are concentrating on at present would be the transitionals. They may consist of faster groups in one age group, and slower growing in an old age group, but they will, in the long term, act in terms of assessment as an age group. We are concentrating studies on these now in order to get an estimate of the annual recruitment to the females stock. Thank you.

Anderson — O.K. I want to thank all our speakers and their responses to the questions that were asked. We're catching up on time, slowly, so I'm going to suggest that we break right now for a 10 minute coffee break.

ENVIRONMENTAL INFLUENCES ON <u>PANDALUS BOREALIS</u> IN THE GULF OF MAINE

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ABSTRACT

Northern shrimp abundance has fluctuated more widely than that of any other commercial species in the Gulf of Maine. Sea temperature trends associated with climatic cycles have been the most consistent abundance influencing factor.

SUMMARY

The northern shrimp *Pandalus borealis* in the Gulf of Maine historically has shown widespread fluctuations in abundance as have two other species which are also at the end of their north-south range. While the northern shrimp is at the southern end of its distribution in the northwest Atlantic, the other two (the hard clam, *Mercenaria mercenaria* and the eastern oyster, *Crassostrea virginica*) at the northern end of their range also fluctuate widely in their abundance (Figure 1). For example, abundance fluctuations in the anomalous growing areas of Maine where the hard clam occurs, the ratio difference between the greatest abundance and the least may be as much as 18,000 to 1. The eastern oyster in Maine fluctuates in the order of 15,000 to 1, while the northern shrimp historically has fluctuated at least as much as 20,000 to 1. All three estimates are conservative and actual numerical fluctuation may be even greater. Such fluctuations contrast drastically with those of other species whose mid-range lies within the Gulf of Maine (Table 1).

In view of these characteristics of "end of their range" species, shrimp, oyster, and hard clam stocks cannot be considered steady state resources and, likewise, management success for stabilized yield has to be considered highly improbable.

The northern shrimp population in the Gulf of Maine is extremely unstable and in contrast with the American lobster is immature and unlikely to be successfully managed. Biological factors appear to be of minor importance and are controlled in that area by dominant abiotic physical factors.

The northern shrimp in the Gulf of Maine is estuarine dependent, a dependency which is associated with sea temperature rather than salinity. Monthly mean sea surface tem-

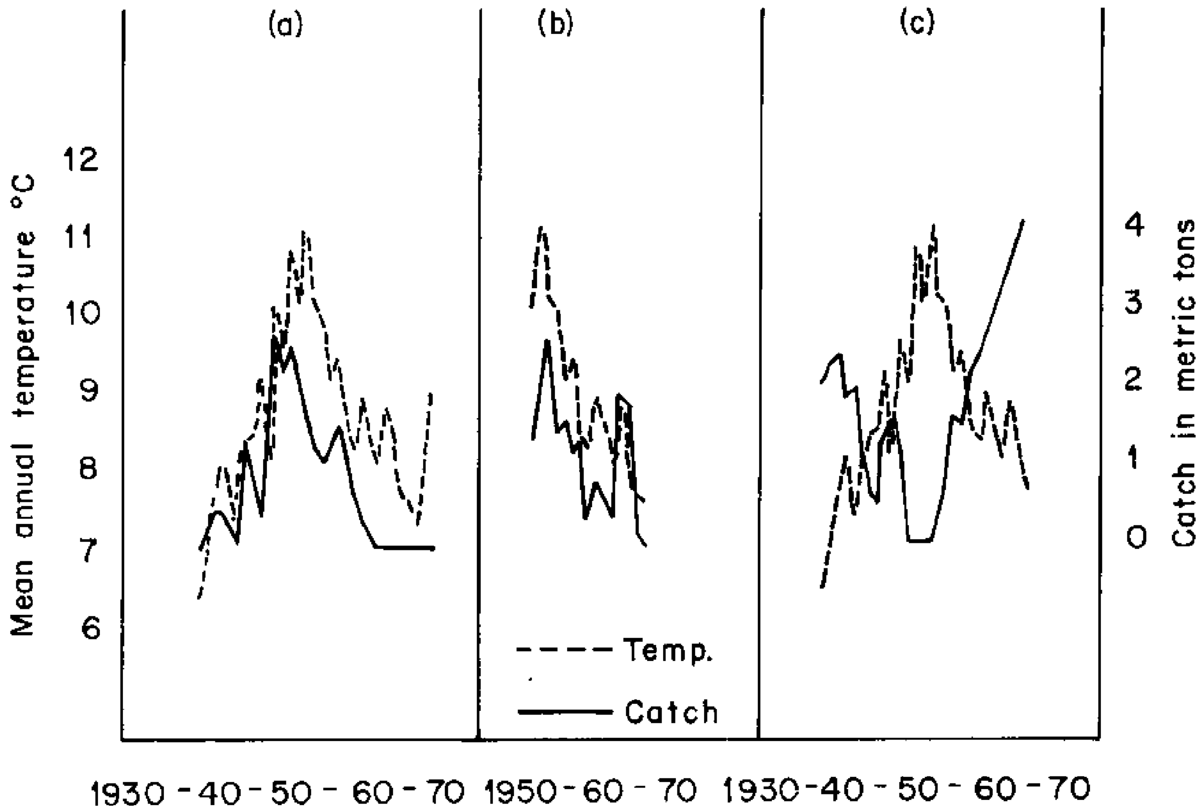

Figure 1. Catch fluctuations of hard shell clams, oysters and shrimp related to temerature from 1930 to 1977. A: hard shell clams, hundreds of metric tons, same year; B: oysters, metric tons, three years later; C: shrimp, log of metric tons, four years later.

Table 1. Estimated range of abundance or availability by species, Maine fisheries

Species	Range
lobster	<2 to 1
gray sole	<4 to 1
menhaden	-
pollock	6 to 1
alewife	5 to 1
sea herring	>3 to 1
winter flounder	>45 to 1
squid	-
smelt	9 to 1
mussels	1000 to 1
shrimp	20,000 to 1
sea scallop	10 to 1
oyster	15,000 to 1
hard clam	18,000 to 1
dab	<5 to 1
cusk	7 to 1
cod	<4 to 1
hake	3 to 1
rock crab	5 to 1
bloodworm	3.5 to 1
soft clam	>6 to 1
sandworm	5 to 1
salmon	>10 to 1
haddock	8 to 1
butterfish	>125 to 1
wolffish	<20 to 1
yellowtail	>60 to 1
whiting	15 to 1
halibut	>15 to 1
sea urchin	6 to 1
periwinkle	25 to 1

peratures as measured at Boothbay Harbor by either the National Marine Fisheries Service or Department of Marine Resources since 1905 have ranged from 18.2°C in July 1911, to -2.2°C in January 1918. Since egg hatching occurs in inshore waters principally in March, it is probable that inshore temperatures are more critical during egg hatching than are temperatures over Georges Bank or in the inner Gulf of Maine.

The earliest New England catch, that of 1924, was reported to be 750 lbs landed at Gloucester, Massachusetts. There were no Maine landings until 1929 when the catch consisted of only 17 lbs. As Table 2 shows, production remained low in both Maine and Massachusetts until the middle 1940s when landings peaked at approximately 264 mt in 1945, followed by a decline to little more than 3 mt in 1950. Improved landings in the next several years were followed by a complete commercial extinction of the fishery from 1950 to 1957.

It was this short-term series of rapid increases followed by equally rapid declines in shrimp landings at Maine ports (Figures 2 and 3) ultimately terminating in the commercial extinction of the fishery in 1954. During this time mean annual sea surface temperature at Boothbay Harbor was ranging from the probable suboptimum second lowest average on record (6.4°C in 1939) to a consecutive seven year period of record high temperatures ranging from 9.6°C to 11.1°C and terminating in 1955. This observation led me to a further appraisal of sea temperature as the most probable influence on fluctuations in shrimp landings.

In the range of <u>Pandalus borealis</u> in the northwest Atlantic, it might be logical that sea temperature is significant in defining range limitations and abundance fluctuations (Figure 4).

Since no inshore egg hatch migrations occurred between 1953-54 and 1956-57, during a period of record high sea temperature, it is likely that sea temperatures influenced migration and dispersion of the stock during that as well as other warm periods in the Gulf of Maine.

Table 2. Gulf of Maine shrimp landings, 1924-1977

Year	Maine	Massachusetts	New Hampshire	Total pounds	Total metric tons
1924		750		750	.34
1927		3,590		3,590	1.63
1928		1,200		1,200	.54
1929	17	3,000		3,017	1.37
1930		4,800		4,800	2.18
1931		1,000		1,000	.45
1932		320		320	.15
1933		40,900		40,900	18.55
1937	200	6,800		7,000	3.18
1938	82,500	23,200		105,700	47.95
1939	18,300	36,100		54,400	24.68
1940	6,700	2,700		9,400	4.26
1941	57,717			57,717	26.18
1942	109,100	2,000		111,100	50.39
1943	291,700	3,200		294,900	133.77
1944	457,900	3,700		461,600	209.38
1945	580,900	1,100		582,000	263.99
1946	161,500	4,400		165,900	75.25
1947	193,800	500		194,300	88.13
1948	27,300			27,300	12.38
1949	9,900			9,900	4.49
1950	7,359	200		7,559	3.43
1951	44,843	13,000		57,843	26.24
1952	103,926	400		104,326	47.32
1953	38,130	<500		38,630	17.52
1954	0	0		0	0
1955	0	0		0	0
1956	0	0		0	0
1957	0	0		0	0
1958	4,899	0		4,899	2.22
1959	11,201	5,000		16,201	7.35
1960	89,899	1,000		90,899	41.23
1961	64,184	600		64,784	29.39
1962	339,996	36,000		375,996	170.55

Table 2. (cont'd)

Year	Maine	Massachusetts	New Hampshire	Total pounds	Total metric tons
1963	529,126	23,068		552,194	250.47
1964	897,740	6,925		904,665	410.35
1965	2,068,180	17,685		2,085,865	964.14
1966	3,695,345	23,000	40,000	3,758,345	1,704.77
1967	6,580,454	22,000	44,000	6,646,454	3,014.81
1968	12,364,576	114,000	95,000	12,573,576	5,703.34
1969	23,552,977	3,909,000	128,000	27,589,977	12,514.73
1970	18,093,726	6,398,000	120,000	24,611,726	11,163.81
1971	17,515,851	6,005,000	112,000	23,632,851	10,719.79
1972	16,998,327	7,726,000	165,000	24,889,327	11,289.72
1973	12,689,104	8,528,000	132,000	21,349,104	9,683.89
1974	10,076,543	7,666,000	81,000	17,823,543	8,084.71
1975	7,306,433	652,980	83,290	8,042,703	3,648.15
1976	1,812,475	974,830	14,109	2,801,414	1,270.71
1977	343,475	260,000	400	603,875	273.92
				180,763,550	81,993.81

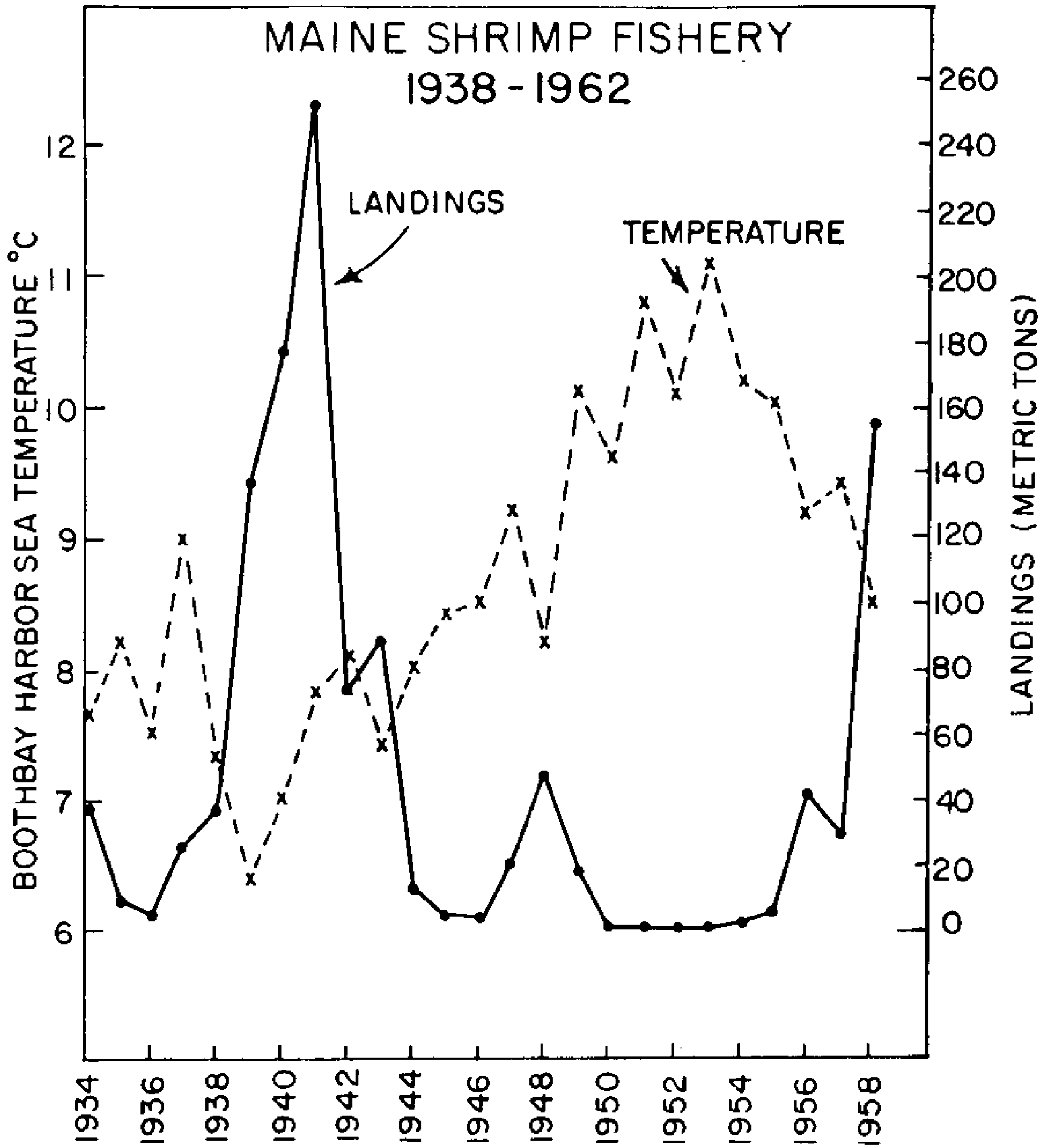

Figure 2. Boothbay Harbor landings related to temperature, 1938-62.

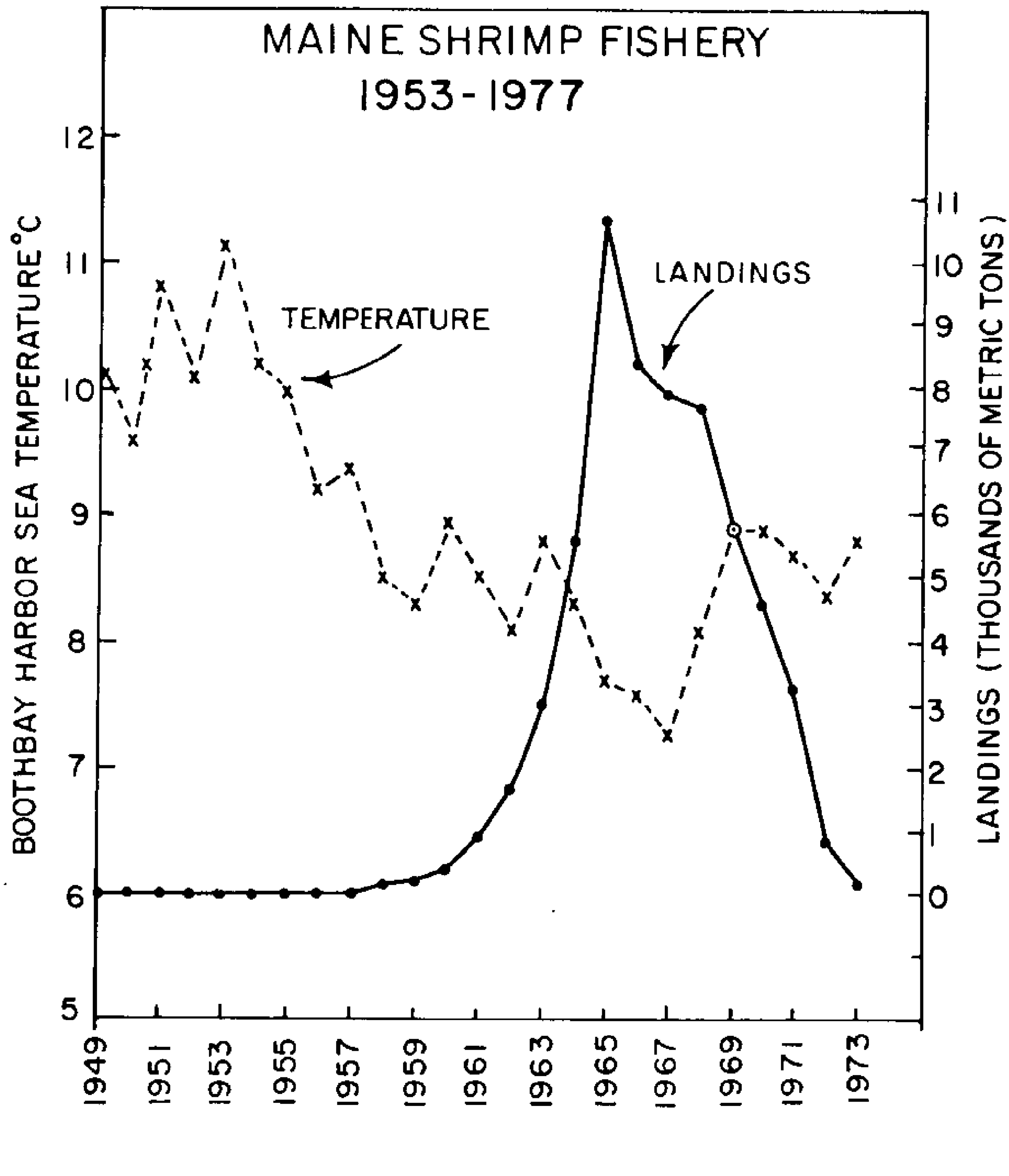

Figure 3. Boothbay Harbor shrimp fishery landings related to temperatures, 1953 to 1977.

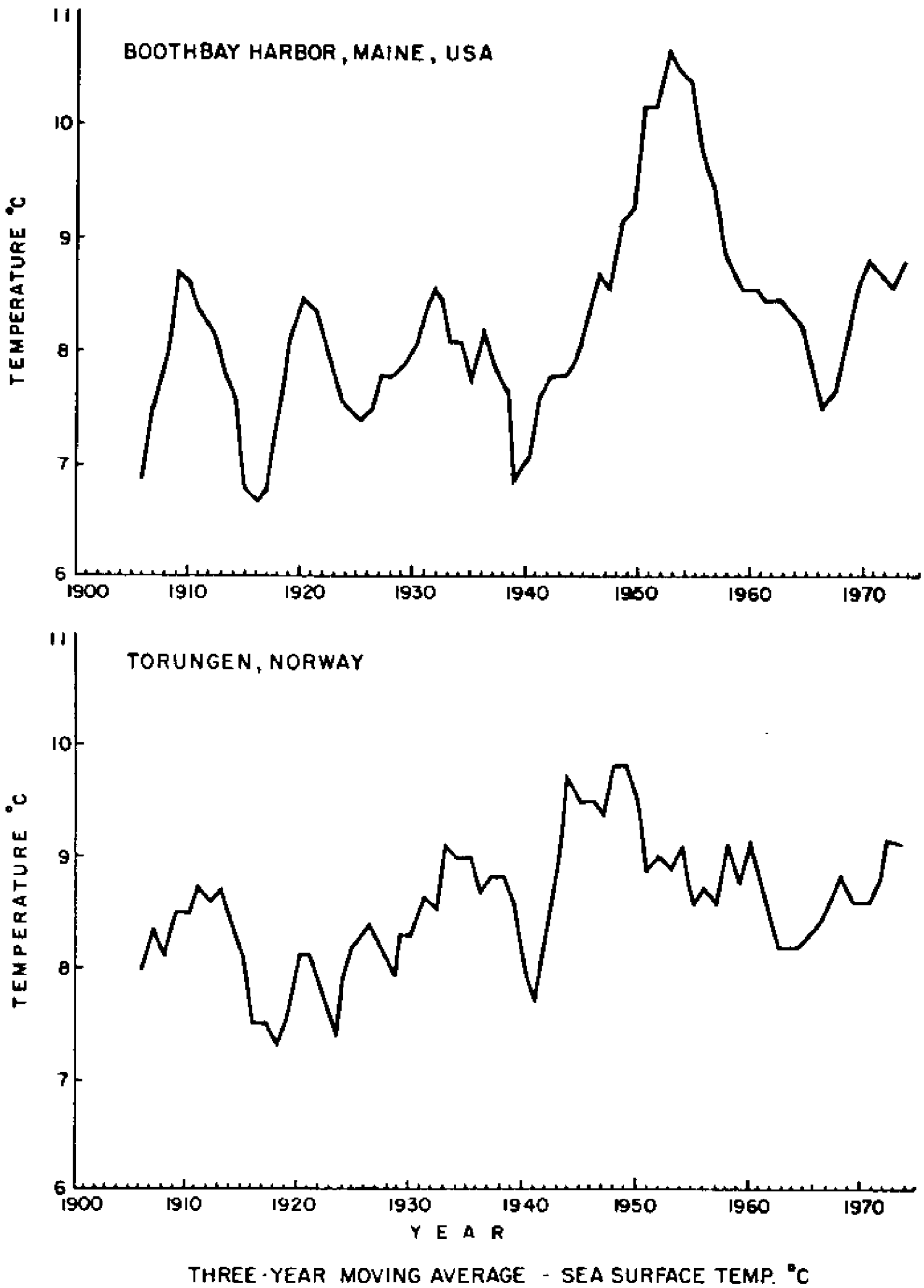

Figure 4. Three year moving averages for sea surface temperatures at Boothbay Harbor, Maine and Torungen, Norway, 1900 to 1975.

ENVIRONMENT OF PINK SHRIMP IN THE WESTERN GULF OF ALASKA

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The Resource Ecology Task Group at the Northwest and Alaska Fisheries Center (NWAFC) of the National Marine Fisheries Service is studying circulation in the Gulf of Alaska and conducting a biological study of ichthyoplankton in the Kodiak Island area. Thus, we welcomed an opportunity to apply some aspects of these studies to a preliminary assessment of the environment of Pink shrimp, *Pandalus borealis*.

Only in the last several years have comprehensive environmental inshore studies been made of the northern Gulf of Alaska. These have been initiated largely by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) sponsored by the Bureau of Land Management and Department of the Interior, in relation to potential hazards of oil exploration and exploitation. Extensive data has been collected from ships and buoys and is being processed, but only limited analyses have been completed; therefore, only tentative conclusions can be made.

I would like to discuss some aspects of the temperature and salinity regimes and coastal flow patterns in the Kodiak area and relate these and other environmental conditions to pink shrimp. First, it is known that Pink shrimp are abundant at three locations--the Kenai Peninsula, Afognak-Kodiak, and Alaska Peninsula-Shumagin Islands (Figure 1). These are located on the western side of the Gulf, which is characterized by a broad continental shelf having an irregular topography of shallow banks and deep troughs. Several years ago it was believed that a rather uniform southwestward coastal flow occurred throughout this area, but recent observations suggest a rather complex coastal flow regime. Our understanding indicates that flow along the southwest coast of Kenai Peninsula penetrates Cook Inlet and moves southwestward through Shelikof Strait. This is largely separate from the predominant coastal flow over the outer continental shelf, where the southwestward flow is well offshore from Afognak and Kodiak Islands, except for exchanges through the passage between the islands where appreciable east-west tidal excursions can occur. The complexity in surface flow over the shelf eastward of the islands and inshore of the predominantly southwestward flow near the shelf edge is apparent in the trajectories of three satellite tracked surface drogues (Figure 2) released on October 22, 1976 (Hansen 1977). One moved northward and

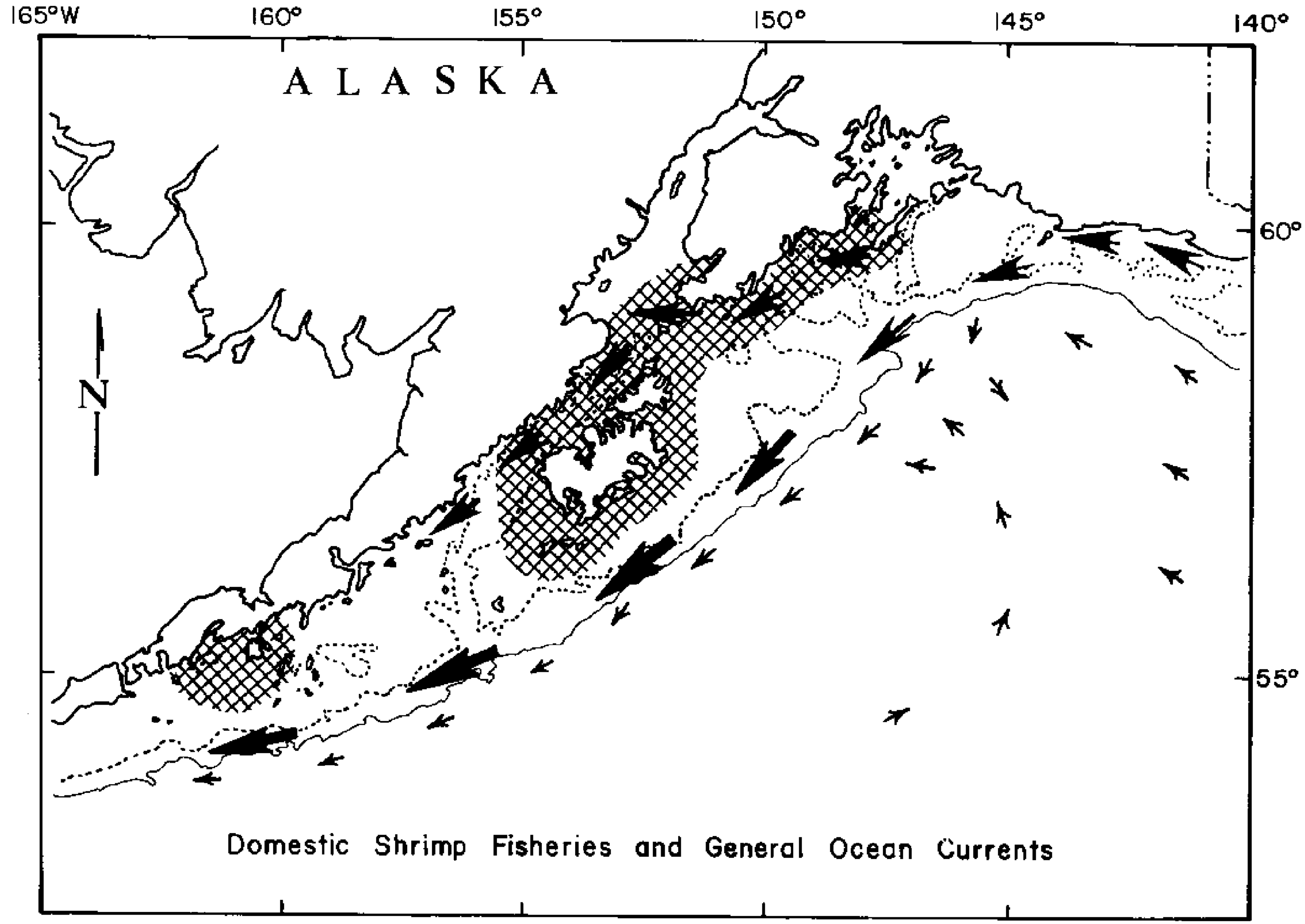

Figure 1. Location of major domestic shrimp fisheries (cross-hatched) and general ocean surface currents (arrows).

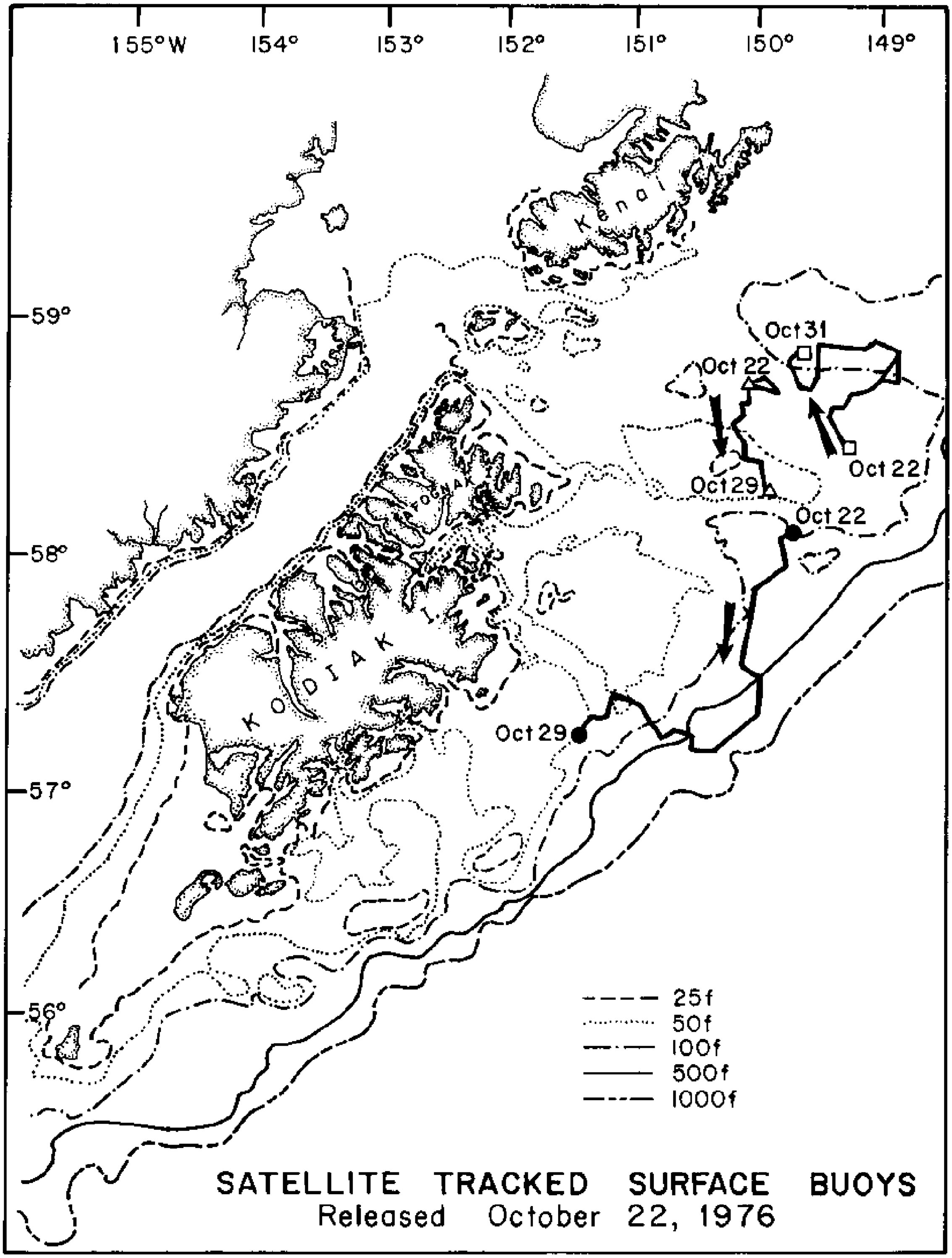

Figure 2. Trajectories of satellite tracked surface bouys showing complex flow on the shelf and swifter southwesterly flow near the shelf break. (after Hansen 1977)

another moved southward while the one at the outer shelf moved three times faster and southwestward. The point here is that if little net flow occurs over the shelf at the east side of the island, this could keep organisms with a planktonic early life stage from being swept out of the area. This may be important because if larvae are swept southwestward out of the Kodiak area, replenishment of the Kenai Peninsula may be unlikely or impossible.

Now, it is generally believed that Pink shrimp spawning occurs in coastal embayments. It is obvious that along the east coast of Kodiak Island the lengths of the bays are extensive (30 to 40 km). This in itself may provide some safeguard against extensive offshore discharges of eggs and larvae during the planktonic stage. But this also exposes them to the variability of the inshore environment. For example, everyone studying resources in the Alaska region is aware of the cold periods in the early 1970s apparent in air temperatures (Figure 3) at Kodiak. But the cold periods are also apparent in bottom temperature data from a fortuitous study we made in May 1972 in the Kodiak area on walleye pollock, Theragra chalcogramma (Favorite and Igraham 1977). Cold bottom conditions were apparent in the coastal regime (Figure 4), but we had few previous data to indicate how unusual these conditions were. However, in the past several years, subsequent OCSEAP studies indicate the May 1972 bottom temperatures of $<2^{\circ}C$ were $2^{\circ}C$ to $3^{\circ}C$ lower than conditions that have occurred since (for example, April 1978).

The effect of low temperatures on P. borealis in this area is not known, but Smidt (1969) reported that the extremely cold winter of 1948-49 in fjords at Holsteinsborg, west Greenland (during which bottom temperatures of $-1.6^{\circ}C$, in contrast to normal temperatures of largely $1.2^{\circ}C$, occurred) killed the stocks of P. borealis. And, of course, there is evidence of a drop in the shrimp catch in the Kodiak area subsequent to this period (Gaffney 1977). However, many factors can be associated with temperature changes and other factors are also involved.

Perhaps also vitally associated with the success of Pink shrimp on the east coast of Kodiak Island are the troughs that extend largely from the mouths of the major bays across the continental shelf. It is well known that the shallow banks are characterized by a rocky bottom, the result of scouring by winter storms, and that shrimp occur in the troughs where sedimentation occurs. However, it is not generally known that winter turnover in the water column does not normally extend to the sea floor in the troughs. Except in extremely cold years, relatively warm ($4^{\circ}C$) and constant year-round temperatures could occur close inshore in contrast to temperatures of 0° to $12^{\circ}C$ at the surface. The shoreward extent of 3° to $4^{\circ}C$ water (Figure 5) in the

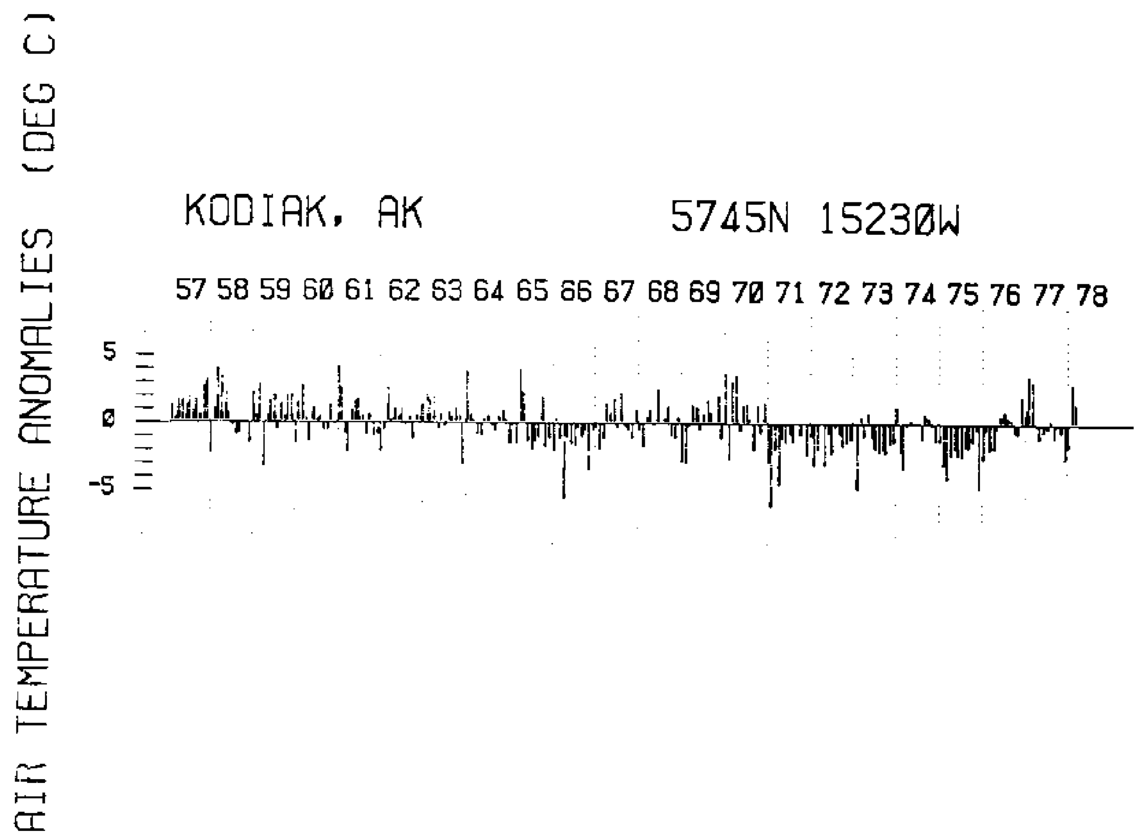

Figure 3. Air temperature anomalies (^{o}C) showing relatively long cold period in the early 1970s. (compiled by D.R. McLain, NMFS, Pacific Environmental Group)

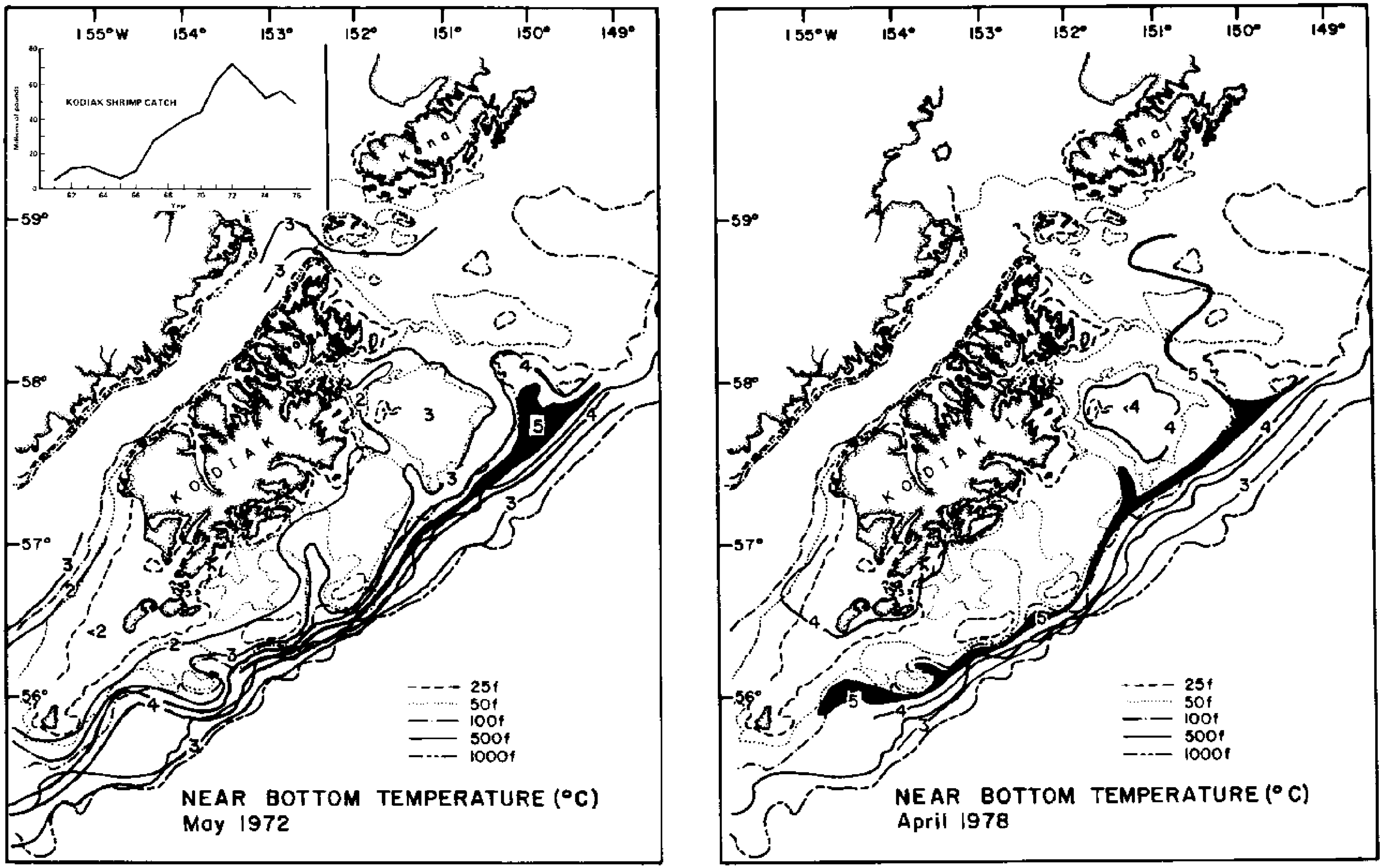

Figure 4. Near bottom temperature (^{O}C) showing extensive winter cooling on the shelf in 1972 compared with 1978.

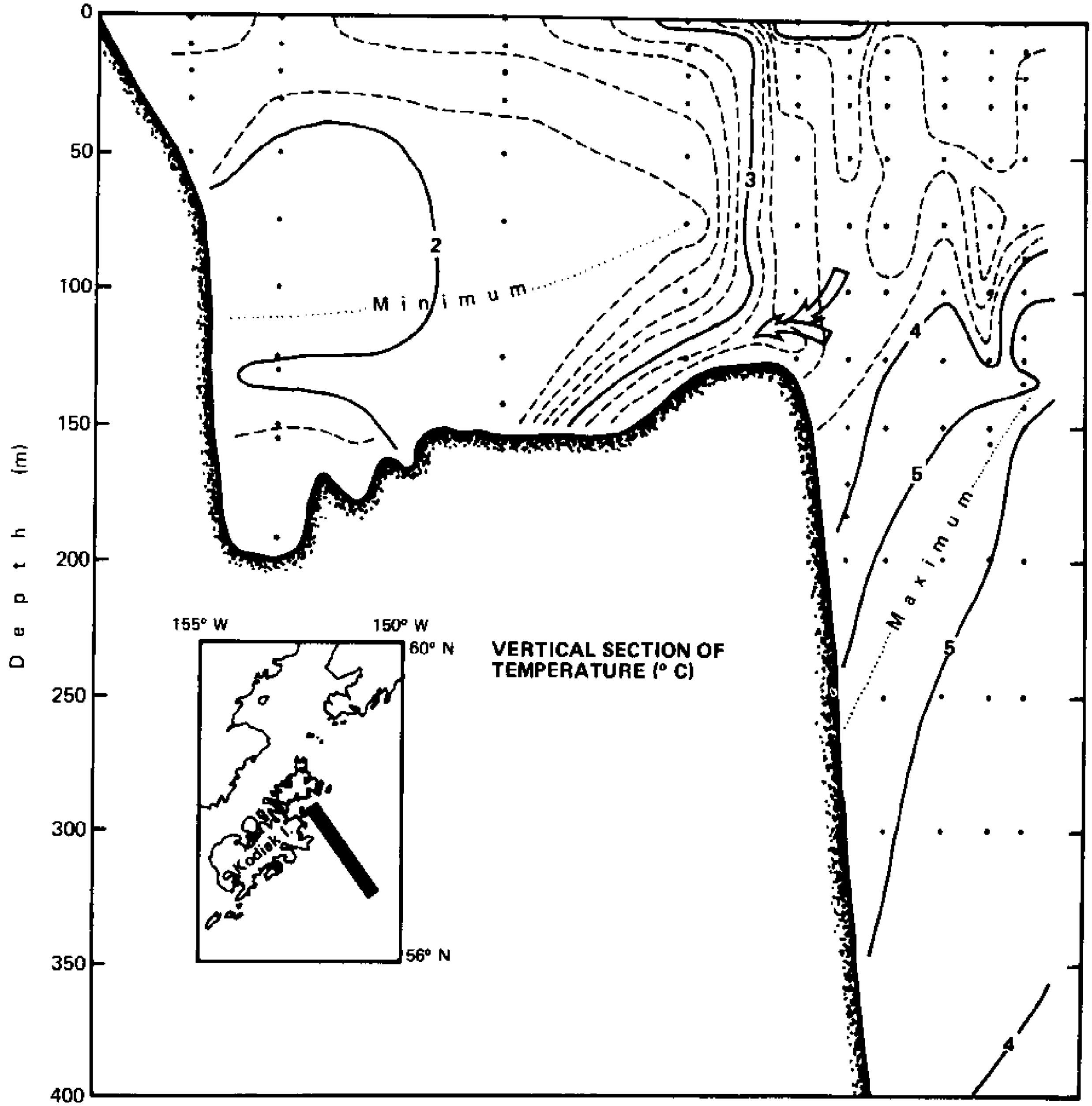

Figure 5. Vertical section of temperature (°C) for May, showing a shoreward penetration of the warmer offshore water near the bottom (about 150 m) in Chiniak trough.

troughs is a function of the severity of coastal conditions and the onshore movement of 4° to $5^{\circ}C$ water from the edge of the continental shelf, where such conditions occur year-round and have been largely constant as far back as oceanographic data is available (several decades). One important aspect of the warm conditions in the troughs is the suggestion that any effects of southwestward surface flow out of the gulf in this area, as a result of increased wind stress from the cyclonic low pressure systems characteristic of the gulf in winter, is apparently not effectively coupled to northwest-southeast flow in the trough. Thus, the trough environment could serve to retard any progressive southwesterly displacement of adult shrimp normally moving upward into surface layers to feed at night, which could otherwise gradually carry them out of the Kodiak area.

Evidence of the integrity of trough conditions, as distinct from those on banks, is suggested in selected release and recovery locations of bottom drifters released by us in spring 1978 (Figure 6) reflecting onshore-offshore movement in the Chiniak Trough. Additional evidence can be found on bottom salinity distribution from an extensive network of stations obtained in October-November, 1977 (Schumacher et al. 1979), wherein pronounced shoreward gradients occur in all troughs. From the salinity distribution it is also apparent that the troughs could also serve to move oceanic plankton across the continental shelf into coastal areas by advection. There is sufficient evidence (Favorite and Ingraham 1977) that this does not occur at the surface because of a sharp shear zone at the edge of the continental shelf. This is quite clear in the surface salinity distribution obtained during a NWAFC cruise aboard the NOAA vessel Miller Freeman in September 1978 (Figure 7), which largely reflects the flow pattern in Figure 1. However, the latter is based on extensive OCSEAP vessel and buoy observations throughout the head of the gulf, not merely implied by surface phenomena. The main discharge from the Copper River is shown to have penetrated southwestward at the shelf edge with little suggestion of any advection westward over the shelf east of Afognak or Kodiak Islands.

We are in the process of formulating and evaluating a two layer H-N (tidal) model of the shelf area around Kodiak Island that we hope will provide insight into the complex flow in this area (Figure 8). H-N models are used extensively with various information. In this case, an N/S surface slope of 10 cm serves as an eastern boundary condition for oceanic flow and the mean tidal curve for Kodiak drives inshore flow. A deep 100 m surface layer is used to investigate differences in flow at the surface and in the troughs. These studies are in progress. In the last few years some insight was gained into inshore flow in the area.

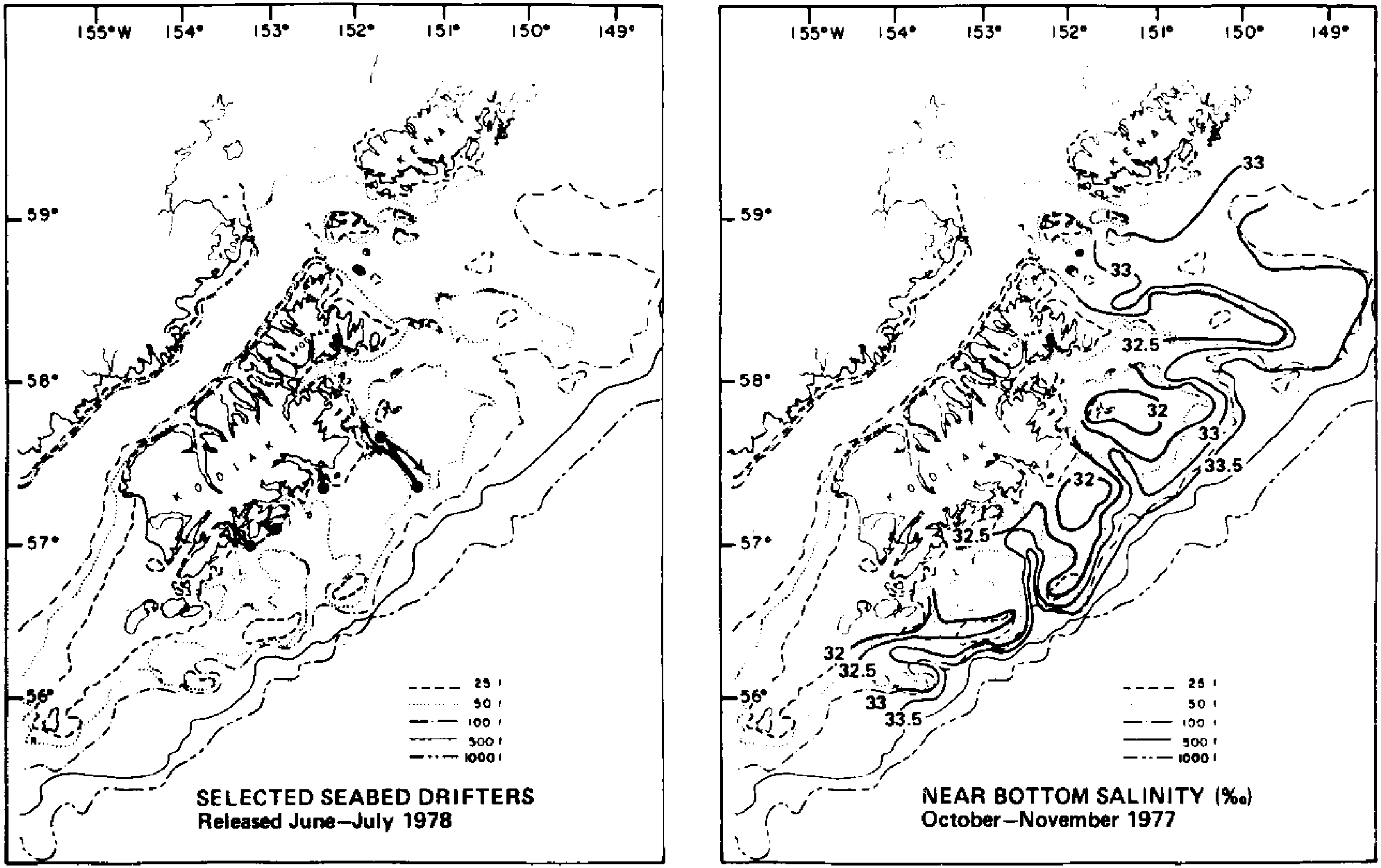

Figure 6. Release and recovery locations of seabed drifters released in June-July 1978, showing cross shelf bottom flow in Chiniak trough; near bottom salinity (^{o}/oo) and penetration of higher salinity water into troughs.

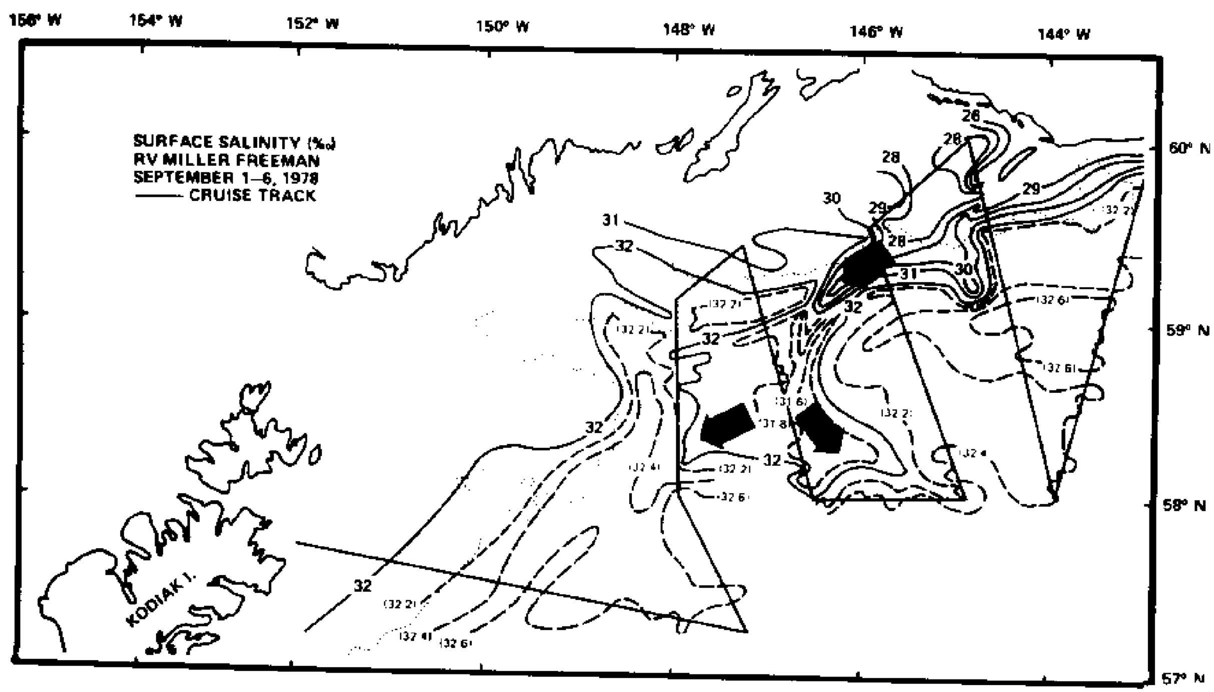

Figure 7. Surface salinity (^{0}/00) September 1978, showing dilute tougue of Copper River water extending south beyond the shelf break.

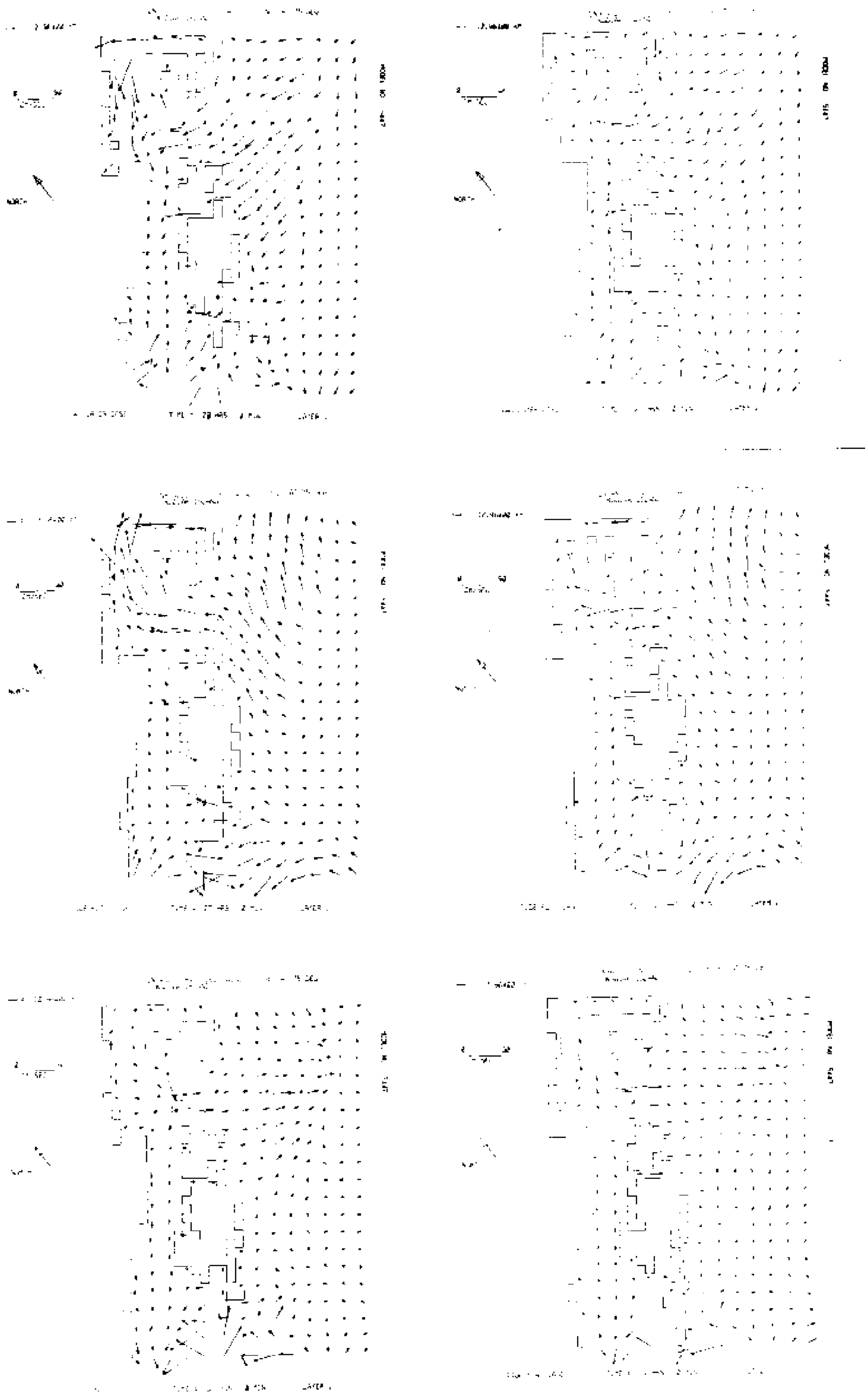

Figure 8. Ocean current vectors (cm/sec) at 23, 27 and 31 hour time steps in both layers of H-N model for Kodiak Island area.

Although direct measurements and vast amounts of data collected are being analyzed, for use in models, one should not lose sight of the larger scale conditions that occur offshore.

Variability in wind stress that drives oceanic currents can be ascertained from sea level pressure data extending back to the turn of the century. The Pink shrimp fishery has not been fully exploited for a long enough period to seek long-term climatic effects, but one can point out that extreme variability does occur in oceanic flow, determined by wind stress transports. Flow in the gulf is largely locally wind driven and a function of winter intensification (Favorite 1967). Changes in wind stress transports of up to 2 1/2 times are evident in calculations for winters 1963 and 1969 (Figure 9). Any such changes are certainly also reflected in coastal conditions. Although the flow indicated for 1969 reflects an intense westerly boundary current which extends below 1,000 m surface conditions can be altered by the location of the Aleutian low pressure system. A surface flow model based on dynamic topography, as reflected by subsurface temperature distribution and by surface wind speed (under development at NWAFC), reflects the changes in surface flow patterns during two periods of high winter wind stress transport: 1959 and 1969 (Figure 10). The former indicates a narrow, intense southwesterly surface flow past Kodiak Island and the latter, a wider, more diffuse surface flow.

Obviously, we are in a period of intensive and accelerated environmental studies in the northern gulf, long overdue but nevertheless heartily welcomed by fishery interests. It will be several years before all of the current OCSEAP data is evaluated. However, one question that is not being addressed at this time is how to monitor conditions after the present studies are terminated. This will not be an easy task and considerable attention should be focused in this area now.

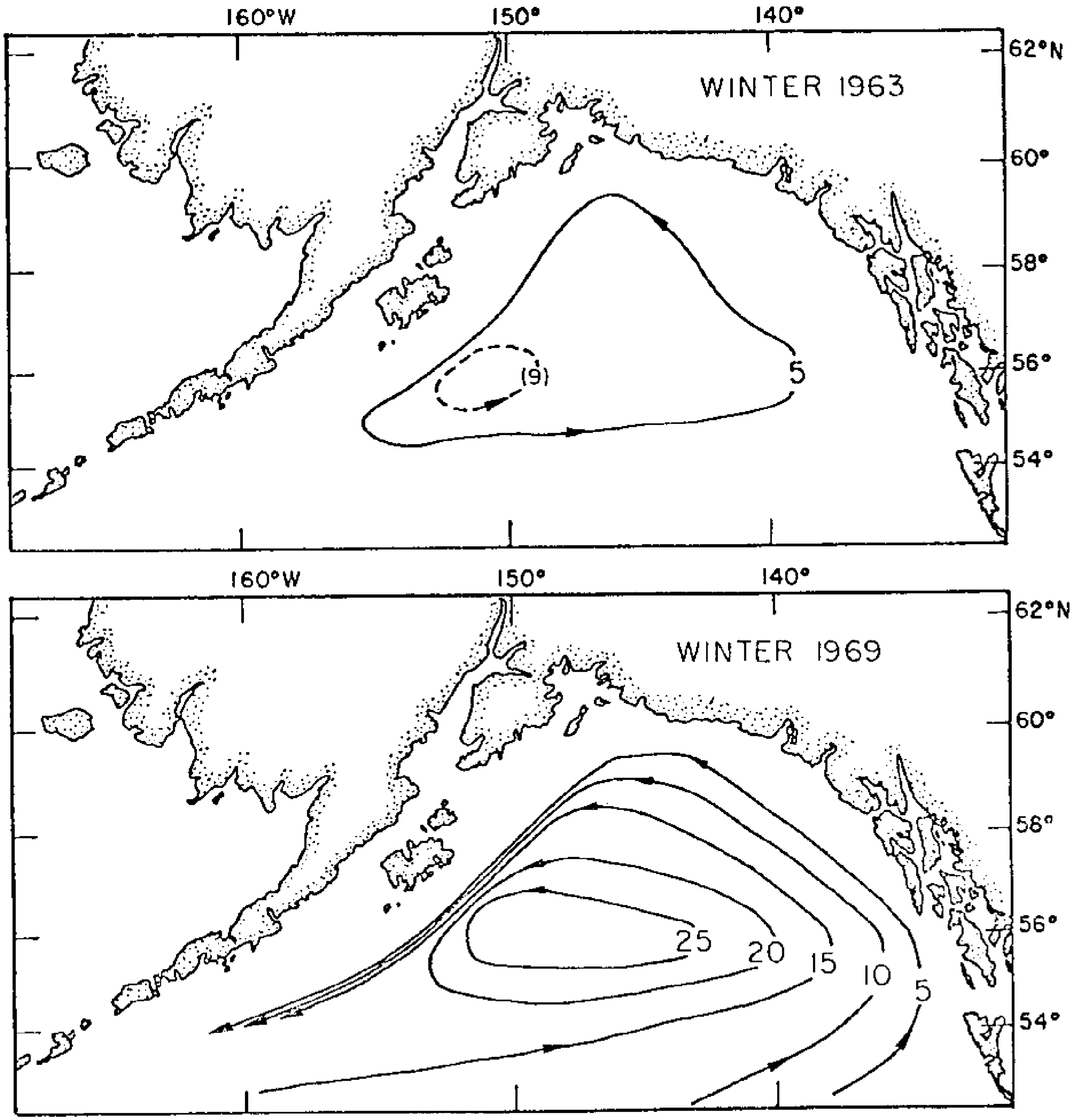

Figure 9. Integrated total wind stress transport showing variability of flow conditions that can potentially occur in the large scale Gulf of Alaska system, for example, the winters of 1963 and 1969.

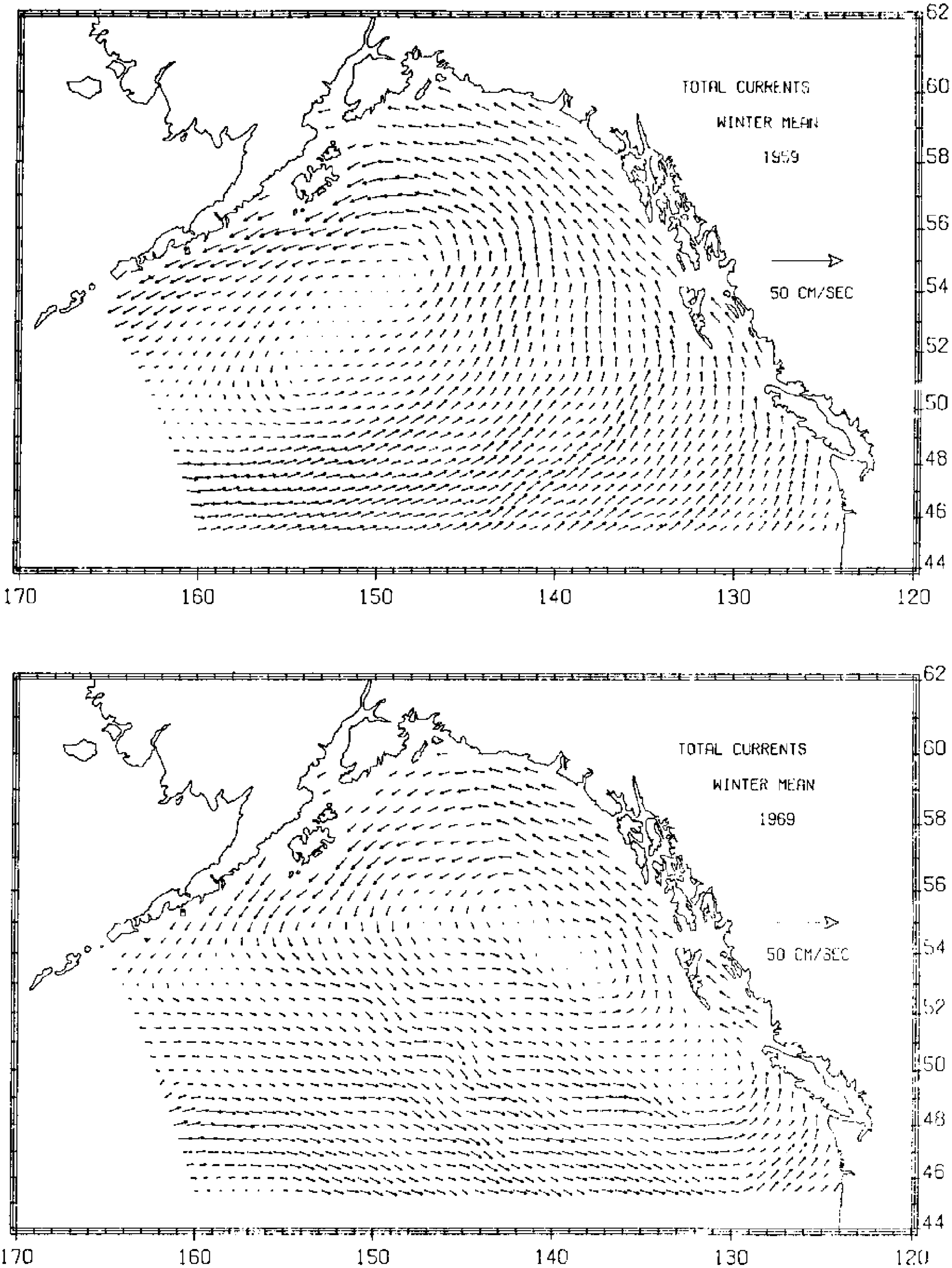

Figure 10. Surface currents (cm/sec) generated in developmental model from sea level pressure and dynamic topography data showing different patterns of surface flow during high winter wind-stress periods of 1959 and 1969.

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OBSERVATIONS ON SEA SURFACE TEMPERATURE CHANGES AROUND KODIAK

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(Ed.'s note: This presentation was transcribed from tape for inclusion in this proceeding.)

The project I am involved with is trying to relate the population and distribution of shrimp to oceanographic parameters, in the Kodiak area. This includes relating shrimp behavior to water temperature and presenting some hypothesis on why temperature has been doing what it has for the past couple of years.

Our project was sponsored by Sea Grant mostly because of the strong decline in the shrimp fishery since the peak in 1971 and '72. Although the decline hasn't been to zero, by Alaskan standards it is a very sharp decline.

It seems the fishery leveled out at about 50 to 60 million pounds. It was only able to hold that level for two or three years, then in 1976-77, it dropped precipitously. The information that I have is that this year the first half of the fishery from December of last year was 19 million pounds. The second half, beginning about a month ago was worse. The season was only open for four days and not even a million pounds were landed, so the fishery was closed.

Sea surface temperatures are among the important parameters we looked at. Using composite temperatures figured from ships going through the area and so forth, we got a graph showing average temperatures from 1963 through 1977, for February to May. The interesting point here is that 1971 is a relatively cool year, I think by air temperature standards too. The bottom fell out in 1975, and has been rising ever since.

I don't have data for 1979, but the indication is that this will be one of the warmest years on record. Mean temperature for these years, 1963 to 1977, is 4.1°C.

Now, I'm not a biologist, so I'm going to be talking in vague generalities about shrimp biology when I offer these hypotheses. One thing that caught my eye was the extremes in temperature, especially in a year like 1975, and their relation to the abundance of shrimp. This led me to back away and look at the larger weather picture for the area in terms of monthly air flow.

A weather picture of a normal winter for the Gulf of Alaska has a strong "steering" air flow at about 10,000 feet. The flow is generally parallel to the lines of equal pressure, the isobars. Low pressure is to the left of the flow in the northern hemisphere, so the flow is counterclockwise. Generally flow is from the west and southwest along the Aleutian Chain to Kodiak. That's an average winter.

If you look at other weather patterns for 1975, we can draw a parallel, then do some speculation on the winter of 1978. The typical weather pattern for the winter of 1974-75, we have flow over the Arctic Ocean, from Siberia and down to the Bering Sea, and over Kodiak. Favorite and McLain have also published data along this line, suggesting that these are reasons why the water temperature was cold in both of these years. The winter of 1971 was similar to this.

There is also data that suggest that in the colder winters, shrimp around Kodiak had more trouble holding onto their egg clutches. It is also possible that clutches were smaller in colder water. If these shrimp are recruited into the fishery two years later, then that's maybe one of the reasons why catches dropped off. That's just a hypothesis.

How about 1978, where all of a sudden temperatures show a strong increase? You have a mean 700 millibar contour for the winter of 1976-77 that's one of the warmest years on record. Here the flow is again parallel to the isobar. It's being drawn over the Pacific Ocean and then almost due north over Kodiak. Indications are that the temperature is perhaps making the shrimp uncomfortable and dispersing them. Perhaps it is just too warm for them on the Kodiak Shelf. I have had indications from some fishermen that they were more successful at finding shrimp if they moved offshore a little, into cooler water. Again, that's a hypothesis. I feel I must add, there's still a chance they were simply overfished. Perhaps the shrimp are cyclic, as some of the crab populations in the Bering Sea have turned out to be.

Another question that arises in my mind is the survival problems in the critical period. What happens to the larvae? Where are they? What stresses are they under? One of the hypotheses was generated in California during work on the anchovy population. It concerns food particle distribution during the critical period. This is a crucial question. When you look at the 1976-77 upper air flow, you'll find there is quite a strong ridge formed over interior Alaska. These ridges block storm paths, so there are a lot of low pressure systems over the Bering Sea and the Gulf of Alaska. If you look at last year, notice the extreme build-up of this ridge, all the way into Siberia and over the Arctic Ocean. That ridge kept storms from entering the Bering Sea and channeled them southward, over the Gulf of Alaska. Those storms turned up the water more. My question is does this have anything to do with the stability of the water column and the ability of the shrimp larvae to survive? It's just speculation that I throw out. I don't really know too much about it, it's just something I've noticed.

One more comment before I leave you is that I was interested in Paul Anderson's comments on the possibilities he was following. I have heard a hypothesis that perhaps in the cold years you have bad recruitment. That data suggests that at least in the winters of 1971 and 1975 the survival rate was good, if not actually showing improvement.

OBSERVATIONS ON TEMPERATURE CHANGES ON THE SHELF OF THE GULF OF ALASKA

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(Ed.'s note: This presentation was transcribed from tape for inclusion in this proceeding.)

A distinct characteristic in Gulf of Alaska ecosystems is a large annual fluctuation in their physical parameters, particularly temperature. The Gulf of Alaska region, as Jim Ingraham and Joe Niebauer just pointed out, is meteorologically and oceanographically dynamic. Year to year variations as well as inter-annual fluctuations in abiotic factors are quite high. This variability may have severe implications for the organisms in the ecosystem, and consequently on the commercial fisheries.

As a hypothetical example, larval survival depends on the success of the young in obtaining an adequate food source. The timing of egg release with abundant primary production is of considerable importance to the successful development of the larvae. As maturation of eggs and larvae are to a large extent temperature dependent, the variation in temperature from year to year may result in larval release at a time not coincident with an abundant food source. The consequence of such an occurrence would be poor recruitment to the fishery.

It is of considerable use to fisheries managers as well as fishermen to have a knowlege of how temperature influences a particular species of commercial value, and then to incorporate temperature variables in the management decisions. Compared with the difficulties and expense of sampling for biological data, the collection of temperature and weather data is relatively easy and in some cases, free.

Our research has focused primarily on the temperature history of the Gulf of Alaska during the past four years. In this presentation I will use some of the results obtained so far, then discuss some possibilities for predicting deepwater temperatures in the region where shrimp are found.

The data that I am going to talk about was obtained from a series of 20 cruises on a line upstream of Kodiak. We feel this area will reflect pretty well the changes occurring around Kodiak. The primary reason for choosing this series of data was because it represents the most complete data set on the Gulf of Alaska, including the time-series type work that's necessary.

In addition, we obtained information from ships passing through the Gulf of Alaska. That data consists of monthly averages of sea surface temperature obtained on a ship opportunity basis. There are several problems associated with this data. I'll just mention them because I can't qualify them. They are not always accurate. It's biased in that the data are collected along primary shipping lanes.

Mean monthly sea surface temperature data is an estimate of the temperature of the mixed layer of the ocean. It's averaged over a month, reflecting mixing processes going on in the ocean. The applicability of the data requires knowlege of the mixed layer which is not always known, and in most cases, is assumed. Some people assume it's 100 meters and other people assume it's 50 meters. I think 100 meters is a little deep, at least from some of the calculation I did on the Gulf of Alaska.

First, let's look at a hydrographic section of temperature along this line. There's a weather station out there too, GAT-5, it's about 50 nautical miles out on the shelf. This figure is a cross section across the survey lines for the years 1975, 1976, and in the bottom 1977. The horizontal scale is on the order of about 200 kilometers, that's about 110 nautical miles, and it covers the whole shelf. The inshore regions are on the left, so this is close to the coast. In fact this is up right at the mouth of Resurrection Bay, for those of you who are familiar with that. Here you see the shelf break, and this is right outside the shelf. All these cruises took place in early November, although the November 1977 cruise took place about ten days later than either one of the first two. What I have drawn here are what we call isotherms. They're drawn at one degree intervals. In between here we have 6°C water, 7°C water and water less than 8°C.

What I would like to draw your attention to is the deeper waters during these three years. Particularly striking is the lack of 6°C water on the inner shelf in 1977. Notice first this broad layer of water that's less than 6°C all across the shelf in '75. In 1977, there's no water less than 6°C inshore here. In '76, it's somewhat intermediate, between these two years. Secondly, I want you to note the inshore distribution of water higher than 7°C in 1975, as opposed to 1976-77. Those years, 1976-77, showed broad and deep distribution of water warmer than 7°C, roughly 43°F. The depth of this layer increases generally as one approaches the coast. Maximum inshore depth is about 225 meters, rises out to this slope here of about 150 meters and then off to about 300, and this region here drops off to about 1,800 meters.

So, what we have here is water that's higher, that's between 7° and $8^{\circ}C$, extending down to about 130 and 150 meters, in 1975. In 1976, inshore, water is higher than $8^{\circ}C$, goes to about 170 meters. In 1977, you kind of have a subsurface pocket of water that's greater than $8^{\circ}C$. One thing I would want to point out is on all these cross sections you'll notice a general downward inclination in the isotherm as you approach the coast. This is due to the downwelling. Beginning in late September and continuing through the fall, winds along the south coast of Alaska were primarily toward the west. The westward blowing winds resulted in the onshore transport of water. As this water approaches the coast, it has to sink. And as it sinks, since the surface water is generally warmer in the early fall, it's bringing warmer water down to deeper waters.

The intensity of this downwelling is a function of the wind direction and the wind speed. So variations in the atmospheric events during the fall could have a profound impact on the distribution of warm water inshore. In addition, the upper layer temperatures are a function of heat exchange. The relative importance of each one of these factors remains to be determined in order to assess what the driving forces are that affect temperature distribution in the gulf.

Returning to comparisons between 1976 and 1977, I think this pocket of warm degree water in 1977 is related to just the difference in times between '76 and '77 cruises. As I said before, the '77 cruise was conducted about ten days later than that of 1976. November is characteristically a month with extremely strong heat flux from the ocean to the atmosphere. So this pocket could be surface cooling.

The intent of our research is to isolate these driving forces that govern the heat content in the Gulf of Alaska. The gulf acts as a vast reservoir of heat for the overlying atmosphere in late fall and early winter. Variations in heat content on the shelf may be attributable to anomalous atmospheric events in the gulf region. However, as Jim mentioned, on the edge of the shelf, the Alaska Stream water provides a movable boundary between the shelf break and the interior Gulf of Alaska. Conceivably, the Alaska Stream may transport heat anomalies onto the shelf. The Alaska Stream is a northward extension of the North Pacific Current which splits off the coast of British Columbia. For those of you not familiar with the general flow in the North Pacific, originating out of Japan is a current that flows toward North America. As it approaches, it splits. Going north is the Alaska Stream, going south is the California Current.

Temperature variations in the Alaska Stream could be a result of modifications within the Gulf of Alaska, or elsewhere in the North Pacific.

Now I would like to talk a little bit about what we can say about deepwater temperatures, based on shallow water temperatures. What I have here are two plots of temperature versus time. Temperature is the coordinate and time is the abscissa. The solid line in each one of these is the least square harmonic fit. It estimates the mean temperature at any point along the time axis. I took the 20 cruises and I made a composite year out of all the temperature data. Then, based on that composite year, I fitted a line for a variety of different depths. Each one of the lines that I fitted was significant at the 1 percent level. This ranges from 0 to 15 degrees, the normal temperature that was observed at 15 meters in February falls at about 3.5°, maximum is about 10.2°C in August. At 100 meters, the minimum is shifted to about April, and that's at about 4°, and maximum was shifted over to early October, and that's at about 5.5°C.

The plot for 15 meters is representative of about the first 25 meters of the water column. The plot for 100 meters is representative of the 75 to 125 meter range. I have only carried this analysis out to GAT-5. GAT-5 is a fairly shallow station, not much deeper than 125 meters. So comments regarding deepwater temperatures can only be considered valid to 125 meters.

The first thing I mentioned was that the change of temperature with respect to time is approximately one to two months out of phase between the upper and lower layers. That is, the lower layer mirrors the change in the upper layer about one to two months later. I think I demonstrated that by pointing out when the maximum and minimum temperatures occur in the two different depths. The second point is that the deviations from the mean in the upper layer do not imply that the deviations from the mean in the lower layer are in any way related. This lack of a vertical correlation means that knowlege of upper layer temperatures at any point in time does not tell us anything about deeper water temperatures. To illustrate this, if I went out and measured temperature in November 1977 at 15 meters, it puts me right about on the mean. But that doesn't mean that is going to tell me anything about what's observed at 100 meters. At 100 meters, I'm about a degree and a half above the mean.

This lack of coherence is not surprising in light of the fact that the response of the upper layers to atmospheric forcing is more rapid than in the deeper waters. The point I want to emphasize is that extreme caution must be exerted in estimating water temperatures and surface layer temperatures when data are collected at a discrete point in time. Bear in mind that the temperature distribution of any two layers may be governed by two distinct forces. That is, the upper layer may be primarily responding to the atmosphere and the lower layer may be affected more by, say, the Alaska Stream. That's something we just don't know.

Next I'd like to focus on this bottom layer, because this is a region where shrimp are normally found. There's no apparent time correlation in the temperature anomaly. For example, if I went out and measured the temperature here in 1975 March and found that it was a half degree above normal, I can't tell anything about how much above or below normal it's going to be in April of 1975. I tested this hypothesis by a test which examines the data set for randomness. The results, significant to the 5 percent level, demonstrate that the time series of deviations are random. But that is without a knowlege of the physical mechanisms that determine temperature anomalies, or a data set of more frequent observations. Temperature predictions cannot be made based on deviations in the same layer.

Now I would like to return to the value of using mean monthly sea surface temperature data to estimate deep water temperature. Recall that mean monthly sea surface temperature reflects the average temperature for the whole month for the mixed layer. If, in spite of the limitations of sea surface temperature data mentioned earlier, this data reflects changes that occur in deeper water, it would be useful to fishermen and management personnel because it doesn't require any effort on their part. It's just a matter of getting on the mailing list.

To examine this possibility we computed the correlation coefficients between monthly sea surface temperature anomalies and 100 meter temperature anomalies. Recall the earlier figure where I showed that the upper layer temperature cycle precedes the lower cycle by approximately one to two months. Based on this observation, we computed correlation coefficients between sea surface temperature and 100 meter anomalies by time-lagging the 100 meter anomaly one to two months behind the sea surface temperature anomaly. None of these correlation coefficients were significant. But if you notice, the one month correlation has a strong improvement in it. This suggested to me that sea surface temperature data may be useful when predicting deeper water temperature, especially when we find out what the important driving mechanisms affecting deep water temperature changes are.

WATER TEMPERATURE, EGG EXTRUSION AND SHIFT IN SEX RATIOS IN THE NORTHERN PINK SHRIMP IN RESURRECTION BAY, ALASKA

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(Ed.'s note: This presentation was transcribed from tape for inclusion in this proceeding.)

As Dr. Niebauer said, I have been working on the biological part of our study. Part of that has been working at the Seward Marine Station laboratory study of the Pink shrimp. Seward is located at the head of Resurrection Bay. The two points that I want to bring out that you should remember are that I'll be talking about the Resurrection Stations Res 1 and Res 5. Of course, to do a laboratory study you need shrimp. To collect them, I caught them out of Resurrection Bay at Agnes Cove which is located at the mouth of the Bay.

During the time that I took the shrimp, I thought my equipment would be ready when I was. Unfortunately, it wasn't. So, it gave me a chance not only to observe that shrimp at ambient sea water temperature, but also to look at the temperature fluctuations at Resurrection Bay. The station at Seward is supplied with a flow-through seawater system. The inlet for the system is located approximately 600 meters south of the station, to a depth of about 70 meters. Inside the stations, temperatures are taken on a daily basis, and this is the chart of the temperatures for Station 1 for 1972 until 1978. Now these temperatures are not meant to be absolute temperature readings. The '75 back to '72 are from Station 1 or were inferred from Stations 2 and 25, which are further into Resurrection Bay. The points for '77 and '78 were taken from measurements within the station itself.

What I want to do with this slide is simply to show that there has been a general warming trend, although it probably isn't that high, from '74-'75 to '77-'78. To show speci- ically the annual trend, the seasonal fluctuation, showing the warming in summer and the maximum in October, then falling down in the winter months. This is a general idea of the temperatures that the shrimp I had at the station were kept in.

For Agnes Cove, this is Station 5, these temperatures are also at the approximate depth at which I did my trawls, showing similar annual increases in temperature and similar seasonal fluctuations. One thing I did notice about the shrimp I had in captivity. I found that the temperatures in Resurrection Bay this year were rather high. The project has only been going on since September, so these are mostly observations on my part rather than any sort of real good results. The temperatures when I arrived in September were 6.5° to 7° and by October it had risen to about 10°C. The last time I was down there, about two weeks ago, it was only down to about 7.5°C. It stayed relatively high throughout most of the time I was there. I went out to trawl on two occasions one being September 20 and the other being October 20 and as you can see by the number of shrimp I caught, I was definitely not meant to be a shrimp fisherman.

I really had no intention of doing anything with the catch data since my main interest was capturing live shrimp. Afterwards when I wrapped this up, I noticed some temperature shift so there is a little artificiality in that these were only for the live shrimp I kept. Hunting and pecking through a mound of shrimp to try to find live ones, I guess, is about as good a sample as you're going to get. What you do see is a very obvious shift in the sexual ratio of this population in just a month. A lot of these trawls were done on the same day, same time of day and at the same depth. So, it's just a general idea of the major shift that has occurred.

When I went back to the temperature that I inferred, since I didn't know temperatures in Agnes Bay, Station 5 was the closest to Agnes Bay. There is a slight increase in the yearly temperature, but again what comes out is the seasonal fluctuations. And from these seasonal fluctuations coupled with the shift in the frequency, I just came up with a couple of hypotheses, which they may never stand up but I had no other way of explaining it.

During my observations in the lab, I found that egg extrusions, for this population at least, started approximately mid-October and ended in late November. From the data that I have seen for Kodiak, it seems that egg extrusion in Kodiak begins in late August and continues on through September. My feeling is that Resurrection Bay shows generally warmer water temperatures than the bays of Kodiak. I'm not sure of the physical reason why. It may be because it's a silled bay and there's not so much interplay with water from the Gulf of Alaska. But the water temperatures tend to be a little higher. It seems that this has delayed the period of egg extrusion a little. The shift in sexual make up of the population may be caused because Agnes Bay is a spawning area for Resurrection Bay and they all congregate there at a a certain time and I just happened to get there when there were more females than males. When I went back in October, which is sort of the middle of the egg extrusion period, I found the majority of the males.

Now this I think could be caused by two things. One, just an intrinsic clock that tells the shrimp to go, and the other being the seasonal fluctuations temperatures. The drop from September into October, you can see it in almost all the years but 1977, may stimulate the movement of males into this area for fertilization. Another one is the diurnal vertical migration of the pink shrimp. The smaller shrimp tend to migrate more than the larger shrimp, the smaller shrimp being the females. This would tend to put the males into the water column and increase predation pressure by mid-water predators. One thing I did notice when I was out trawling. Although not in great numbers, there were noticeable numbers of juvenile pollock. I've been on previous cruises and I found juvenile pollock so I just wrote them off as a predator. I felt that a 15 or 20 millimeter fish would have trouble consuming an adult pink shrimp. Then another graduate student at IMS told me he had cut open some juvenile pollock stomachs from Cook Inlet and found adult Pink shrimp. I realize that these are sort of only observations that I have made, but I felt with only four months of experience and four months of data, I couldn't come up with any anything more solid.

ENVIRONMENTAL CONDITIONS AND SHRIMP STOCKS AT GREENLAND

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ABSTRACT

The water-masses at west Greenland are created by the polar current on the surface and the Irminger current bring up deep warm Atlantic water of high salinity. The Atlantic water enters the deep, open fiords as a warm bottom layer, while the bottom water is permanently cold in the threshold fiords. The temperatures differ considerably from year to year because they are influenced by the strengths of the two currents and by variations in the temperature of the atmosphere, particularly in winter. The deep warm water reaches the highest temperatures in late autumn or early winter, later in the fiords than in the offshore regions.

The depths and bottom conditions vary considerably. Off west Greenland there is a row of more or less shallow watered banks sloping down to more than 1,000 m in southern Davis Strait. The depths between the banks connect the deep offshore areas with the deep inshore areas and fiord systems, where the depths are about 200 to 500 m.

Pandalus borealis is widely distributed in west Greenland, mainly at depths of 200 to 500 m. The offshore stocks are important to the inshore stocks because of intrusion with the deep warm water masses. Variation in stock density correlates with temperature variation, and migration of shrimp into the fiords was confirmed by tagging experiments. The depth limit for shrimps seems to be about 500 m, even when temperatures are favorable, possibly because of scarce food. Low temperatures cause the shrimps to be few and small sized as the females become scarce. Temperatures below -1.6°C are critical, as was the case in fiords where the shrimp stocks perished during an unusually severe winter.

Owing to low temperature in Greenland, growth and development are relatively slow. At age 3, shrimps become males and at age 4 or 5 females, depending on temperature. This is twice the time as in boreal areas where shrimps become females at 2 1/2 years. The big females predominate at deep water while juveniles are most numerous at shallow depths.

The larval development is 4 to 5 months long and larval drift by currents is assumed to be essential to certain stocks. It is likely that larval survival rate is decisive in the recruitment of rich or poor year-classes.

THE ENVIRONMENTAL PHYSIOLOGY OF THE NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN THE GULF OF MAINE

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SUMMARY

The abundance of northern shrimp in the Gulf of Maine seems to be correlated in part with long term temperature changes. Following a series of warmer than normal winters, the abundance of shrimp appears to decline.

This report describes some experiments to determine the effect of water temperature on egg mortality and the rate of embryonic development. Although no significant difference in mortality could be demonstrated among temperatures between 2° and 10° C, the range normally encountered in the habitat, temperature did have a pronounced effect on the rate of development. The relationship can be described by the equation $Y = 240.5 - 155 \log_{10} X$, where Y = incubation time in days and X = temperature in degrees Celsius.

Investigations were also made on a previously unreported parasite which invades and kills the eggs. Infection rates of as high as 30 percent of the egg mass have been observed, but the usual rate is 2 to 5 percent. The parasite, which produces characteristically white and swollen eggs, appears to have affinities with dinoflagellates.

LABORATORY STUDIES ON THE DEVELOPMENT AND SURVIVAL OF *PANDALUS BOREALIS* EGGS IN THE GULF OF MAINE

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INTRODUCTION

The fishery for the northern shrimp *Pandalus borealis* in the Gulf of Maine has been sporadic. Catches may be good to excellent for a few years, deteriorate to virtually nothing, and then some years later return to former levels or better. The history of Gulf of Maine landings since 1940 is shown in Figure 1. Because the first period of "abundance" in 1939-1948 is much less than the second in 1963-1976, a logarithmic scale has been used to emphasize the cyclic pattern. Although these data describe only landings, which reflect several factors including market demand and fishing effort as well as abundance, there is no doubt that the size of the shrimp stocks has been fluctuating. Although most biologists feel the fluctuations are due, in part, to both fishing pressure and environmental factors, there is considerable disagreement on the relative importance of each. The present paper describes experimental observations on the role of temperature and other environmental factors on the development and survival of eggs.

TEMPERATURE CHARACTERISTICS OF THE HABITAT

Two sources of sea temperature data are available: a continuous record of daily surface temperatures at Boothbay Harbor, Maine since 1905, and numerous but sporadic measurements of offshore bottom temperatures from various research cruise reports. The best of the latter are those collected between 1963 and 1978 by the R. V. *Albatross*, National Marine Fisheries Service, Woods Hole, Massachusetts. (Davis 1978 and personal communication).

Neither set of data is entirely suitable. November mean bottom temperatures from the *Albatross* cruises are the most realistic for relating to egg development. They were measured in the habitat of the shrimp, they reflect very nearly the annual maximum bottom temperatures, and they occurred after all the eggs have been extruded but before the ovigerous shrimp have begun their winter migration shoreward. These temperature data extend back only to 1963, however, so some kind of extrapolation is necessary to arrive at habitat temperatures prior to that year.

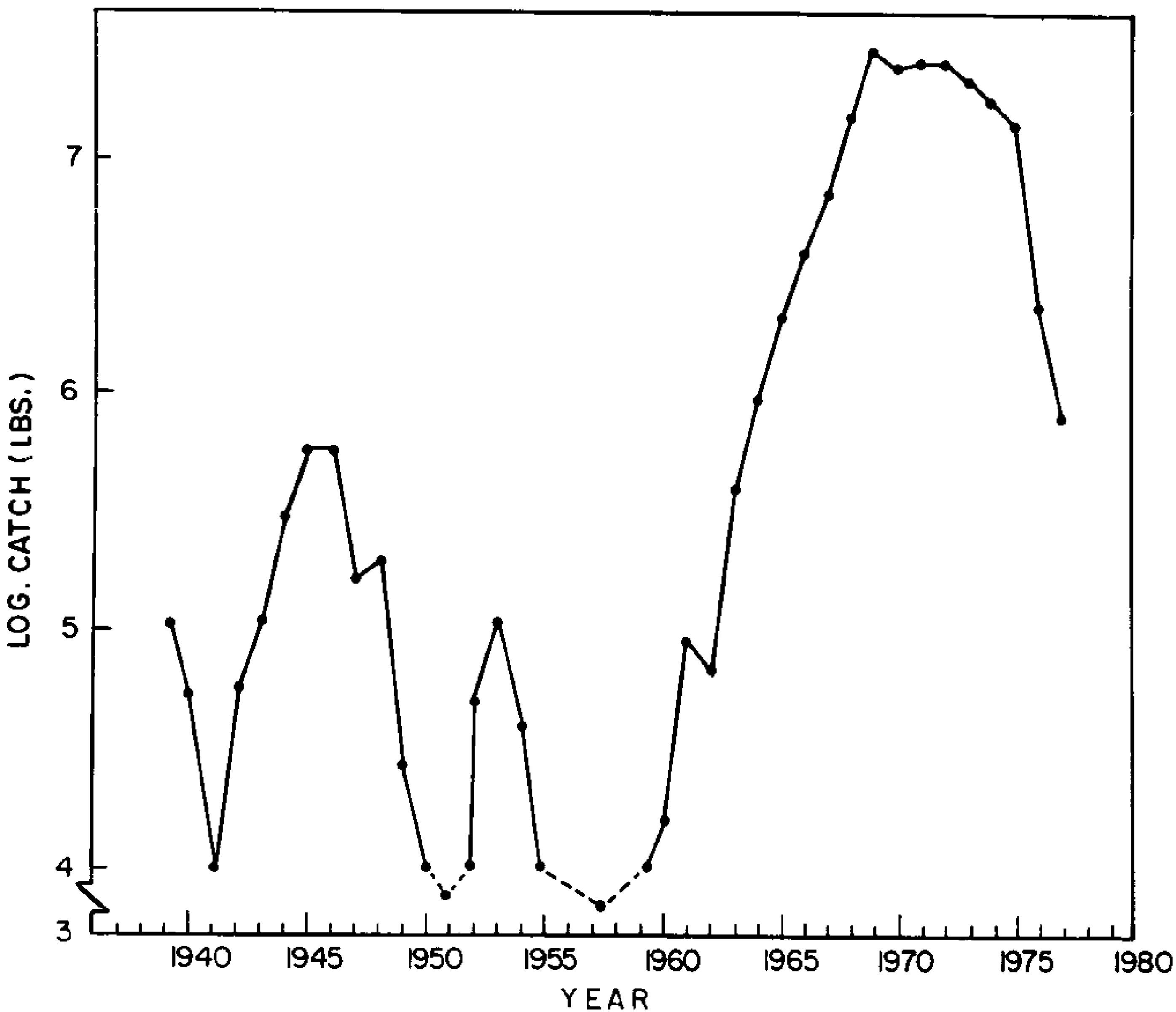

Figure 1. Landings ($\log_{10}$ of weight in pounds) of *Pandalus borealis* in the Gulf of Maine, 1940 to 1977.

I have used the following method to accomplish this. By trial and error, I determined that the November offshore bottom temperatures between 1963 and 1978 correlated most closely ($r = .92$) with the mean August surface temperatures (Boothbay Harbor) for those years (Figure 2). Using this relationship, I have estimated offshore November bottom temperatures for the entire period 1940 to 1978 (Figure 3). Superimposed upon this graph are the actually measured bottom temperatures for 1963 to 1978, indicating a fair degree of correspondence, at least in trends.

With respect to the temperature environment of the ovigerous shrimp and the average incubation temperature of her eggs, the data are even less certain. Not only are observations for other winter months scarce and spotty, but there is no information to indicate that the average bottom temperature would be relevant anyway; it could very well be that the ovigerous shrimp actively seek some specific temperature.

A rather idealized picture of the temperature experience of incubating eggs during a "warm" winter and a "cold" one is given in Figure 4. November and August maxima for offshore and inshore, as well as winter minima were taken from recorded data (1963 to 1978). From these maxima, I constructed two sets of sine curves to represent the seasonal temperature cycles, the left hand one being that for a cold year, and the right, that for a warm year. The thickened portions of these curves show roughly the temperature regions that would affect the ovigerous shrimp, which migrate into shallower coastal waters in the winter. The hatched part of the curve represents temperature during ovogenesis; the black portion, that during incubation of the extruded eggs.

This idealized representation, and averages that were made up from such spotty data as were available, suggest that the mean temperatures of a warm winter and of a cold winter might differ by 2° to 3°C, and the incubation temperatures could very well differ as much.

EXPERIMENTAL METHODS

To study egg development in the laboratory, I procured ovigerous shrimp in the autumn from 100 to 150 m of water about 35 km south of Boothbay Harbor, Maine. They were caught with a small otter trawl and returned to the laboratory in insulated 50 liter containers. At the laboratory they were held at the temperature at which they were collected until used in experiments.

The temperature control system at the laboratory consists of a 35,000 BTU/hr compressor-chiller and a titanium heat

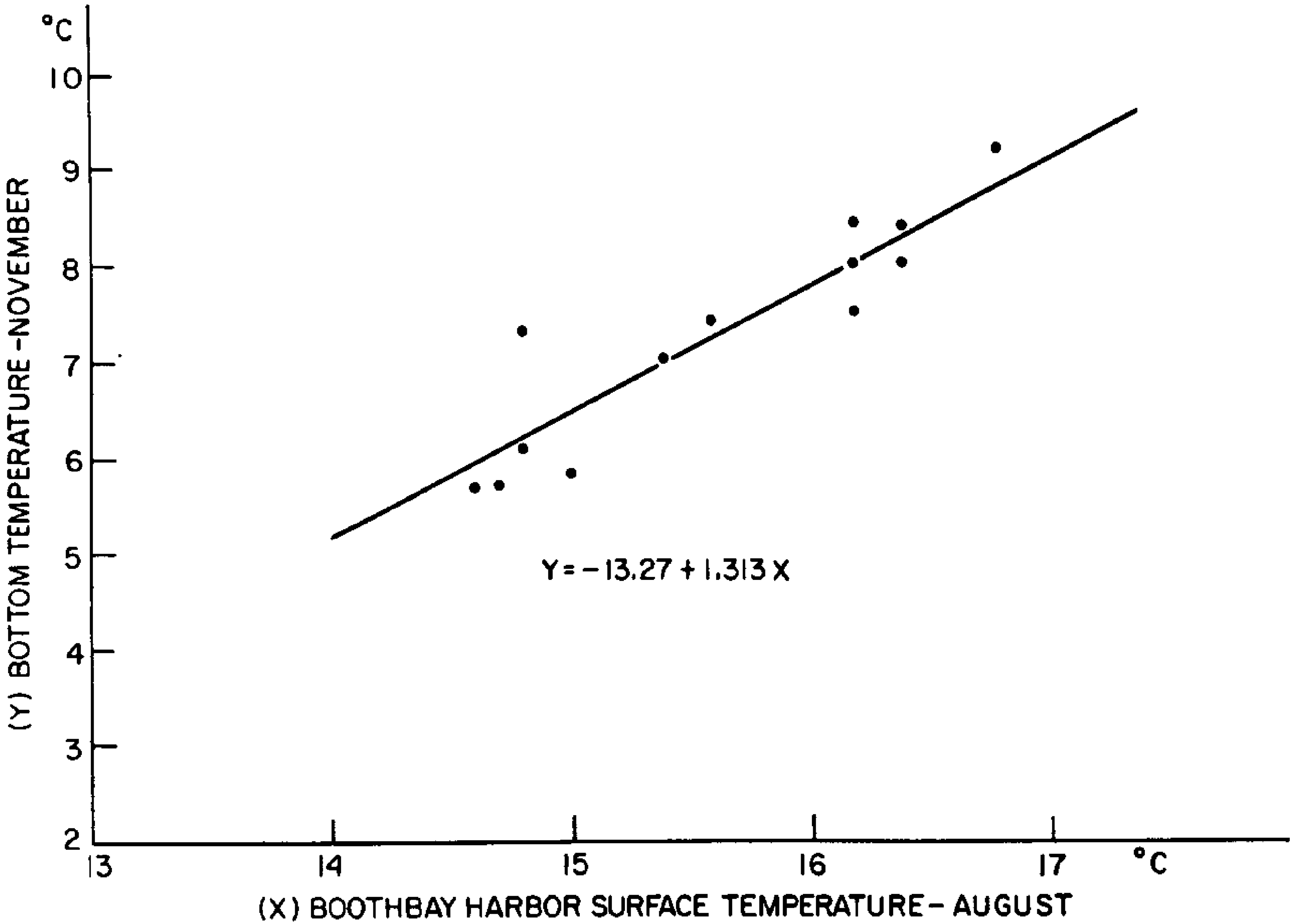

Figure 2. Regression of November offshore bottom temperature in the Gulf of Maine on August harbor temperature at Boothbay Harbor, Maine.

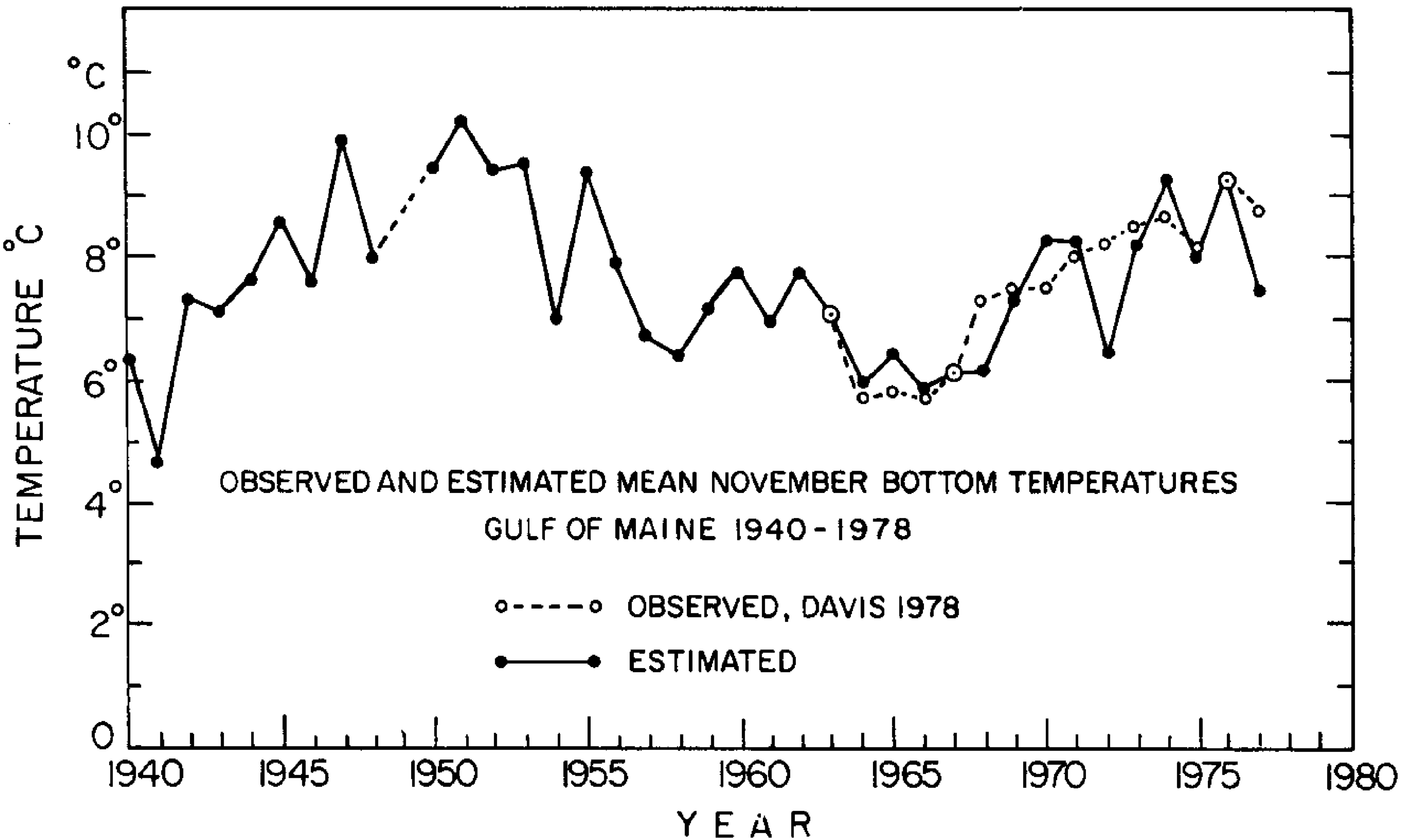

Figure 3. Calculated bottom temperatures for the month of November in the Gulf of Maine, 1940 to 1978.

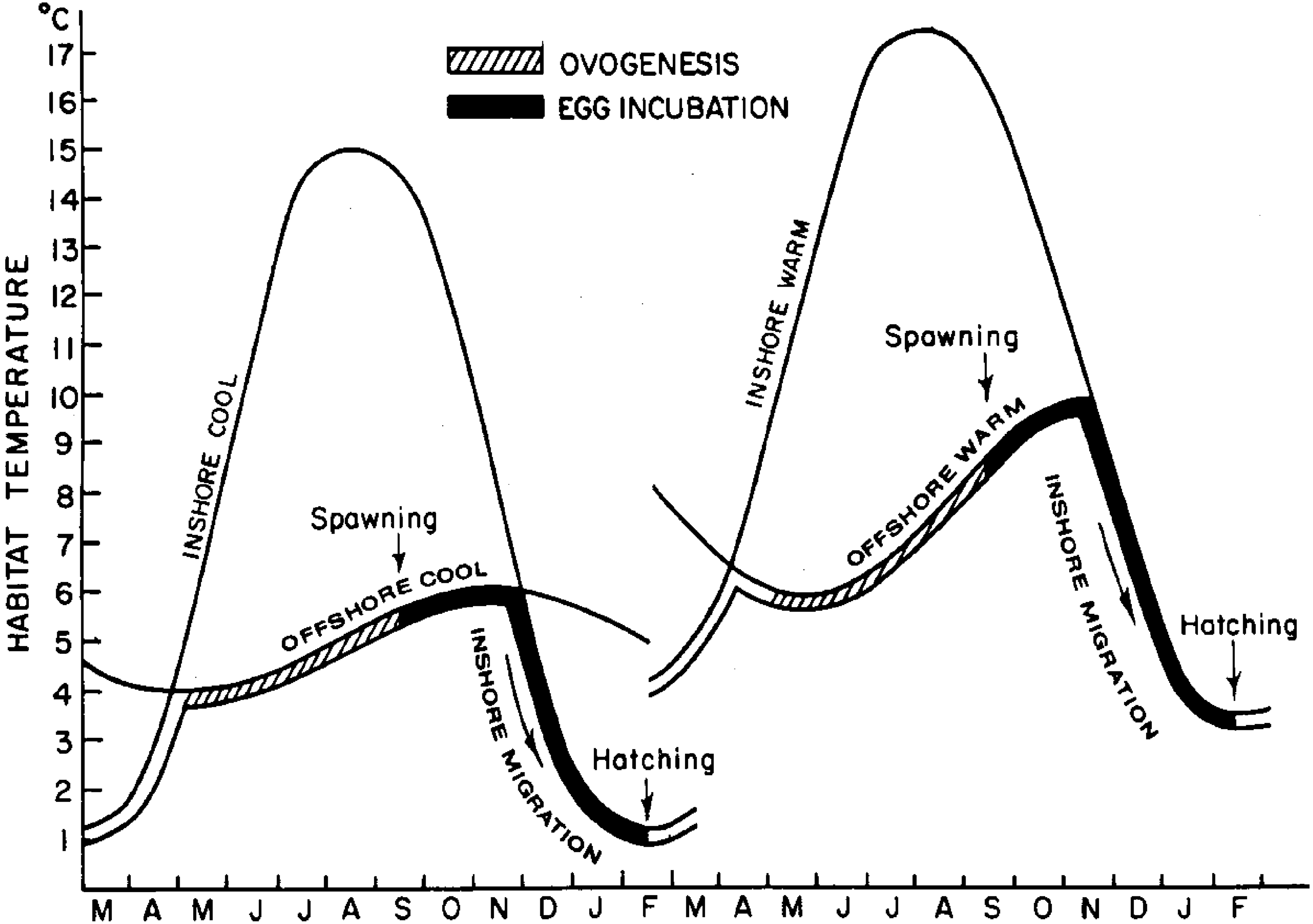

Figure 4. Idealized representation of seasonal temperature cycles, inshore and offshore, for a hypothetical cold year (left) and a hypothetical warm year (right).

exchanger through which the water to be chilled is recirculated. Chilled water of about 2°C is withdrawn from the system as needed and replaced with incoming water pumped from the harbor.

The desired experimental temperatures, from 2° to 20°C, are provided by mixing the chilled water with heated water through thermostatically controlled solenoid valves. Water baths provide several controlled temperatures for standing water cultures.

I used two methods to evaluate the effect of temperature on developing eggs. In the first, the eggs were retained on pleopods of the parents which were held in large trays of flowing refrigerated water at 2°, 4°, 6° and 8°C, 35 to 50 ovigerous females per tray. In the second, eggs were removed from the females, and clusters of 100 to 200 of them held in small plastic baskets suspended in 2.5 liters beakers of filtered sea water. The beakers were immersed in water baths at mean temperatures of 12.5°, 10.3°, 8.1°, 6.1° and 3.9°C (± 0.2°). Unattached eggs in standing water were aerated by recirculating a gentle stream of water over them with a simple air lift device.

The experiments with ovigerous shrimp began on November 12, about 50 days after the eggs had been extruded, and continuing until hatching began at each temperature. As soon as any larvae were observed in the tanks, all females were preserved with their eggs in 5 percent formalin. Because of the difficulty of counting eggs attached to the shrimp before and after the experiment, estimates of mortality had to be made statistically by counting the eggs on a random sample (N = 58) drawn from the original group from which the experimental shrimp were taken. The eggs on the experimental shrimp were counted at the termination of the experiment.

Mortality estimates on small numbers of eggs removed from the shrimp could be easily made by counting living and dead eggs after selected intervals of time. For these experiments, conducted in duplicate, the eggs (all from the same parent for each replicate at all temperatures) were approximately the same age they would be in nature during the warmest part of the season (November) and were observed for seven weeks.

RESULTS

EGGS ON PARENTS

There was no significant difference in the numbers of eggs remaining on parents at the time hatching began at any temperature (Table 1). There was, at each temperature, a significant difference between initial mean number and terminal mean number of eggs carried per female (T all > 2.5, P all $< .05$). This indicates egg loss at all temperatures, the reason for which is not apparent; it may be an artifact of laboratory conditions, or may reflect normal attrition.

EGGS SEPARATED FROM PARENTS

There was virtually no mortality over a seven week period at temperatures of 10°C and below. Mortality at 12.5°C was slight (Table 2).

INCUBATION TIME

Eggs at all temperatures were approximately 50 days old at the start of the experiment (incubation on parents). The remaining incubation time varied with temperature: 56 days at 8°, 62 days at 6°, 82 days at 4° and 100 days at 2°C.

EGG DISEASE

Incubating eggs are prone to attack by parasitic organisms of several kinds. Filamentous bacteria, suctorians and peritrich protozoa commonly attach themselves to the outer coverings of the eggs, sometimes in dense masses. I did not find infections of this sort heavy enough to destroy many eggs. An internal egg parasite, recognized by the white, swollen eggs it produces, appears to be more deadly. A preliminary report on this parasite has been published (Stickney 1978). Although tentatively identified as belonging to an obscure group having affinities with the dinoflagellates, its exact taxonomic position is not known, nor is the life history or mode of transmission.

The infection appears to start with a plasmodium or trophozoite, which feeds on the yolk material and embryo. The plasmodium grows and becomes multi-nucleate, subsequently dividing into daughter plasmodia. The plasmodia continue to proliferate inside the egg capsule until all the yolk is consumed and a final division produces several million unicellular bodies. These shortly develop flagella and become motile. At this time the egg capsule ruptures, releasing them into the water.

A few additional facts about the occurrence of this organism in the Gulf of Maine have recently been learned:

Table 1. Eggs incubated on parents, estimated egg losses from November 12 to hatching

Temperatures	Initial	N	Estimated mean number of sound eggs				
			Terminal	N	Lost	t	% Lost
8^{o}	1,236	58	854	42	382	3.8	30.9
6^{o}	1,236	58	987	35	249	2.6	20.1
4^{o}	1,236	58	994	40	242	2.6	19.5
2^{o}	1,236	58	903	52	333	2.6	26.9

Table 2. Eggs incubated _in vitro_, percent mortality after seven weeks

Replicate	Temperature (^{o}Celsius)					
	12.5	10.3	8.1	6.1	3.9	(+0.2)
1	13	0	1	0	0	
2	0	1	0	0	2	

1. The parasite occurs in the habitat of the shrimp, but not in harbor water pumped to the laboratory. Eggs extruded by shrimp in the laboratory tanks do not become infected.

2. Infection, development in the egg and the ultimate loss of eggs is a continuing process. Both early and late developmental stages of the parasite can be found throughout the season.

3. Development of the parasite is slowed by lower temperature. Hence, white eggs tend to accumulate and may appear to be more numerous or prevalent in older water.

Recent evidence also indicates that the same or a similar parasite infests the eggs of shrimp in the Gulf of Alaska. The same or similar parasites also infest the eggs of pandalid species other than P. borealis.

DISCUSSION

Although I have been unable to demonstrate any mortality of eggs directly attributable to unfavorable temperature, there are aspects of egg development in relation to temperature that may have an effect on recruitment. Low temperatures retard the rate of embroyonic development to the extent that a mild winter with a mean water temperature of 6°C could result in eggs hatching three to four weeks earlier than they would after a cold winter with a mean temperature of 4°C. If larvae are released before suitable planktonic food organisms become sufficiently abundant, early starvation might occur. Preliminary studies of larval food habits and planktonic abundance in the late winter months indicate that may be the case in the Gulf of Maine.

The role of parasitism in egg mortality has not yet been defined, but mortality may be higher than observed incidence of parasitized eggs would indicate, since infection and egg loss seem to be continuing processes throughout incubation.

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ENVIRONMENTAL RELATIONSHIPS TO PANDALID PANEL

Chairman:

Robert L. Dow (Maine Department of Marine Resources)

Panel Members:

Alden P. Stickney (Maine Department of Marine Resources)
W. James Ingraham (NMFS, Seattle)
Henry J. Niebauer (Institute of Marine Science, Fairbanks)
Tsuneo Nishiyama (Institute of Marine Science, Fairbanks)
Hiroshi Kurata (Nansei Regional Fisheries Research Lab, Japan)
Patrick Holmes (Alaska Department of Fish and Game)

Other Speakers:

Cpnt. Ron Kutchick (f/v Captain, Kodiak)
Steve Clark (NMFS, Woods Hole, MA)
Everett Stone (Alaska Department of Natural Resources)
Hank Pennington (Alaska Sea Grant Program)
Tom Weingartner (Institute of Marine Science, Fairbanks)

Dow — Now I would like to throw the discussion open to the entire audience, if you have any comments or questions. Are there any?

Kutchick — Yes. I have one question for that gentleman. You said that you waited until your age group half-hatched to start your season. I wondered if there was any particular reason for opening at the halfway mark instead of waiting until they were totally hatched.

Stickney — Actually, they didn't do that. This was just an idea that was proposed.

Clark — Basically, what I have here are some very preliminary charts. I'm not sure what the best method is to depict temperature and effort trends in the Gulf of Maine, particularly in view of comments made by Alden Stickney. I think that if his work has shown us anything it's shown us a good deal about data. We can take from his work that you have to be very careful looking at temperature and effort and any other data that we want to consider when we talk about the Gulf of Maine and potential landings. Basically, what you see here is a chart of landings in the Gulf of Maine northern shrimp fishery beginning in 1938. You see temperature trends surface temperatures as measured at Boothbay Harbor, and you see standardized effort that we discussed yesterday. You see what I have chosen to do on this is to lag temperatures by a period of four years as Bob did in his earlier charts. One point I would like to make about this is that if you look at the right hand rim of the landings in the mid-1960s, landings were still increasing rapidly. As we discussed yesterday, there is strong evidence that we had, at the same time, an increase in abundance during that period. You'll note the temperatures were in the intermediate range, between the very highs in the early 1950s that were associated with the collapse of stock abundance, and the lows in the late 1950s associated with the peak. If you look at this chart in a little more detail, we have an upswing in the mid-1960s associated with intermediate temperature ranges and we have a pronounced downswing on the other side, again associated with temperatures, in about the same temperature range. To me this is a fairly good indication that not only do we have to consider temperatures in the situation, but we have to take a look at other events over all the system as well, mainly predation and man. It may very well be that fishing has accelerated the decline that would have occurred anyway by natural causes. The point I'm trying to make is that you have to be careful interpretating data. This next chart shows stock abundance. Compared to trends in temperatures, in this case bottom temperatures. You'll note again, not only temperature, but effort is lagged by a period of four years. You'll see the bottom temperatures and effort increased in recent years and stock size reduction was partially responsible. A chart like this points out the difficulty in quantifying the relative impact of the two, especially in view of this recent increase in standardized effort and fishing mortality. If I did have a point to make about this, it is that looking at the associated temperature from '68 through'75 or so, it appears that the temperature in the upper top has been fairly constant varying only by a degree or so. You'll see that effort has increased substantially while stock size has declined. It's going to be pretty hard to sort everything out, but I think there are some indications that increased mortality in recent years has been significant in the decrease in abundance.

Dow — Thank you, Steve. We will not continue this argument (laughter).

Pennington — The National Marine Fishery Service had some areas offshore south of here where there was no fishing effort and in which we also had similar reductions in stock size. Cranking that into the figure, did you have temperature data along with your stock assessment of shrimp offshore, and was it a trend similar with other areas?

Clark — (No mike, answer inaudible).

Stone — I have a few questions for Mr. Stickney, regarding the diseased eggs. I believe he stated it was a dinoflagellate. Does this bear any similarity to the dinoflagellate that is the cause of "red tides" that toxifies some of the shellfish beds on the east coast?

Stickney — It's in that same general group of organisms, but it is not a red tide organism. I think that there is some disagreement even among taxonomists as to whether it is really a dinoflagellate or not. The literature that I have seen seems to indicate that it is. However, I will say this, purely as a matter of speculation: We have found on the east coast in Maine that the dinoflagellate that causes the "red tide" has a resting spore stage in the mud. This organism that I have described apparently has a resting spore stage, but I don't know if it goes into the mud or not. If it did, in a fashion similar to that of the organisms which cause red tides, it would provide a way of infecting shrimp in the area.

Stone — So, there could possibly be a relation between the occurrence of some tidal blooms and the egg disease?

Stickney — Well, the egg disease organism is a parasite and the red tide organism is free-living. So even though there may be some vague taxonomic similarities, I don't believe they are really very close.

Weingartner — Seems to me that if you're going to use environmental data in any sort of study of fisheries, what's required is a long-term data base. I just want to say that with the winding down of OCS in Alaska and soon the probes in the Bering Sea, there is no routine collection of environmental data that will be going on in the Gulf of Alaska or the Bering Sea. I think that's a pretty serious point that should be kept in mind.

Holmes — I concur with Tom's statement. I would like to mention for those of you who are not familiar with some of the abbreviations we've been using: OCS is the Outer Continental Shelf program also known as OCSEAP, a federally funded program to study environmental conditions on the shelf. I think my comments will relate primarily to papers presented by Dr. Niebauer and Tom Weingartner. In relation to Dr. Niebauer's paper, I think looking at physical oceanographic parameters is very important, for example the work that Jim Ingraham and Felix Favorite have assembled from this data. We have heard people talking about climatic changes...these are very important parameters. But, as has been noted by some authors, particularly by Jerry McCrary and also by recent OCS studies in the Kodiak area, it appears that the majority of our P. borealis populations are very closely tied into our bays and fiords. What I can't help but feel is that in terms of recruitment and larval distribution, the physical oceanographic parameters within a bay may have greater importance than fluctuation in offshore work in temperature studies in giving an idea of relative changes in shrimp abundance in an area. But I think that really, before we would want to correlate these data to shrimp abundance, we need to look at some of the comments on data utilization raised by Steve Clark. I think these were important in our area. We've done some preliminary investigation on these yield models and it seems to indicate that in the period prior to state management, we did over harvest these shrimp stocks. We had problems with premature egg loss that have shown up previous to this time. There are many compounded factors relating to abundance and looking at only one parameter is not going to do it. As Dr. Horsted pointed out, we have to consider predator- prey relationships. Really, we have to look at a total ecosystem type of approach, before we can come up with conclusions about P. borealis abundance in Kodiak. I'd like to say briefly, it appears from recent studies, that in the inshore area we have micro-climates, micro-environments within these bays that as far as temperature regimes, might be quite different from what occurs on the shelf. And the key period of the larval release, which probably does fluctuate as Alden has seen in his studies, I think is probably one of the more critical for larval survival and recruitment. Dr. Niebauer touched on some of the comments on the relation of wind--I think we need to look further into physical parameters such as water movement within the fiord. Obviously, with primarily northerly winds, you'd have an outflow and upwelling during the larval hatch period. Recently, as all of you know, we've had a complete change in the weather pictures in this part of the Gulf of Alaska. With the exception of the past week, it has had primarily southerly winds. I could not help but speculate that we might have opposite mechanisms occurring that could affect larval survival and subsequent recruitment, particulary if these are occurring at the time of year of larval hatch. I think your local micro-temperatures and micro-climates, the whole regime, really needs to be considered before anybody can speculate on absolute causes of change or fluctuation in *P. borealis* in an Alaskan area.

Dow If there are no more questions, we'll have a coffee break and then start the next panel. Thank you.

FEBRUARY 15, 1979

INDUSTRY AND MANAGEMENT PANEL DISCUSSIONS

SHRIMP MANAGEMENT CONSTRAINTS ON THE PROCESSING AND FISHING INDUSTRIES PANEL

Chairman:

Chuck Jensen (Pacific Pearl Seafoods)

Panel Members:

Jim Majors (East Point Seafood Co.)
Howard Anderson (Pacific Pearl Seafoods)
Chet Peterson
Alvin Burch (f/v Captain, Kodiak)
Merle Knapp (f/v Captain, Kodiak)
Junior Cross (f/v Captain, Kodiak)
Bob Moss (f/v Captain, Kodiak)

Other Speakers:

Unnur Skúladóttir (Hafrannsoknastofnunin, Iceland)
Svend Horsted (Greenland Fisheries Investigation, Denmark)
Alden P. Stickney (Maine Department of Marine Resources)
W. James Ingraham (NMFS, Seattle)
Bert Clark (f/v Captain, Kodiak)

Jensen — I think probably it would be best to start at the end of the table and introduce ourselves so that everybody knows who we are.

Westman — My name is Ken Westman, I'm the owner-master of the 135 ton shrimp trawler based out of the south peninsula, Shumagin area. I've been in the fishery out there for the past eight years. I was on the vessel that delivered the first pound of shrimp to be commercially processed on the south peninsula. Prior to that, my family was in the shrimp fishery at Kodiak for 18 years, among the first developing the Kodiak shrimp fishery.

Burch — I'm Alvin Burch, I'm manager of the Alaska Shrimp Trawlers. My brother and I started shrimping in 1958 out of Seward. We followed the canneries to the Kodiak area and have been fishing this area and on down through the peninsula area.

Knapp — My name is Merle Knapp. I've been fishing shrimp in the Kodiak area, south peninsula, for the last ten years. My history doesn't go back quite as far as some of the gentlemen in this group, but I have been very active in the shrimp regulation study groups.

Majors — I'm Jim Majors. I came to Alaska in 1961, went into Seward, processed a couple of years in there and then moved to Kodiak Island where the major production of the resource seemed to be, and I'm still here.

Cross — I'm Junior Cross. I came here in 1964 and fished on and off for bottomfish the majority of my career, with a few years in crab and shrimp. I have fished shrimp predominantly for the past nine years. I did some of the early exploratory work in the Chignik Fisheries.

Moss — I'm Bob Moss and I've fished shrimp in the Cook Inlet area with my trawler since 1950, trawling for shrimp since the mid-50s.

Jensen — I'm Chuck Jensen. I work for Pacific Pearl Seafood. I've been in the industry for approximately 25 years.

The title of our panel is rather interesting in one sense, using the word "constraints."

I don't know really how to take that, none of the rest of us did either. We don't know whether this is supposed to be a general bitch session or whether we're supposed to get down to some criticism, constructive criticism. I think we will take the latter approach. I think one of the things we view as a severe constraint on the industry--industry as defined by me, is the fishing effort as well as the processors--and probably the biggest constraint that we have right now, other than the lack of shrimp, is area registration, where we do have the three areas. I would like to throw that open to fishermen first and then to management on the panel. How about Al starting on this one?

Burch

Perhaps you might want to discuss a point of reference, explain to the audience what is involved in the area registration. Do we have more than two hours? Seriously, the area registration, I wish we had a full scale map up here, but basically, our areas are broken into three--Kodiak Island, Chignik, and south Alaska Peninsula. It's set up now, proposed right now, to allow fishing in only one area at a time. And then to require the skipper of the vessel to personally change registration in an office either at Sand Point or Kodiak, which precludes any survey time that may be necessary for the individual skippers. We appreciate the department's problems in covering such a vast area, but constraints imposed on the industry, I think, are severe. The area registration came about a few years ago. It was presented to the group that the department needed to keep track of the boats and the area they were fishing, so they could keep closer tabs when it came close to the end of the quota. At that time, we thought it would be just a call-up on the radio to say where we were. When it came out of the board meeting in Anchorage, it was a mandatory check-in and check-out. We had to physically report to the department. That caused quite a problem for the boats. I went around to the canneries and collected letters explaining some of the problems. The department at that time agreed, as we had before the board meeting, that it would be a call-in. The boats were allowed to call in and change their area except out of the Kodiak area. Now, again this has come up. There are proposals before the board to make it mandatory that the boat representatives appear in person to check in and out of the area. Some of the problems that we have include: If the boats fishing from Kodiak are fishing in the Wide Bay area and decide to go on south, they'll have to come back to Kodiak, get a vessel check, change their area, and then proceed back past the Wide Bay area and on into the next area. An 86 foot boat would use about $800 worth of fuel for that round trip. The medium-sized boats fishing out of this area, it runs about $830. Also, that trip probably takes, in good weather about 20 to 24 hours each way, it would be two days lost fishing time. The way some of the seasons are running now, the season would be over before the boat could get back to town and change areas.

Majors

Well, when it originally came about, we thought we could call in on the radio. I guess our real problem stems from the quota. The quota has created a problem. Some fish tickets were late getting in and, consequently, they needed this information quicker. I see their viewpoint on that, but I really feel that they've gone one step beyond what was needed to still have the same control. These strong controls have made them lose the respect of some of the people they have to deal with. They probably aren't going to get some of the necessary information when it comes right down to it.

I have one problem that's really started to bother me personally since this meeting started. I want to get it off my mind and then we can come back to this area registration. But it's this mortality rate. We've heard .7 and .25 and other numbers have been thrown out. Until we can determine what that mortality rate is in the area where we're at, and I'm sure it will vary with different districts to a certain extent, I am not too sure what good those biomass studies are doing us unless we know what we can put, talking about quota biomass, something we can physically work under. If we're going to lose 70 percent of our total harvest strength for a year, then there's no use saving the juvenile shrimp. If we're not going to lose that 70 percent, but only lose 20 percent of it, then I think we might look at saving next year's class. In other words, if we're losing 70 percent to mortality there's no way we can bank on these shrimps. We can't leave the shrimp harvest to next year. We're going to have to use it at the maximum every year it is available. That's my personal feeling on it.

Jensen

I think the constraints can also be considered in the seasons, in that they do effect both the fishermen and the processor. I think we can address that by possibly explaining the Fish and Game attitude that they don't care when the season is as long as it's biologically right. Basically, I think our seasons now can run from between May 1 until February 20 biologically, although that is also possibly going to be changed this year. The seasons obviously place a great deal of emphasis on the conditions of the shrimp as we receive it. There is also a considerable amount of different thinking on when those seasons should be. Everybody has their own records, each individual plant and fisherman knows when they think the best season is. We should probably continue in the same methods we have now, in establishing through mutual consent of the fishermen, processors and Fish and Game Department. We do feel, I think as a constraint, that the quota system, as it is in use now, may be wrong: wrong in that it establishes each bay as an individual fishery and as such, creates numerous problems for the management people as well as the fishermen. And I'd like at this time to have Junior comment on that and then Mr. Knapp comment on that.

Cross

Well, regarding the quota system and considering each bay as an independent resource, we've created a directed pulse fishery. The pulse fishery has I don't know how many bad connotations and I can think of no good ones. We bring in too much shrimp, too quick, often times in the past few years here. It seems the whole fleet goes out on Monday, the whole fleet arrives back in port on Thursday with a load of shrimp three Kodiaks couldn't take care of in good manner. So it creates an impossible situation for the processor, it puts a shrimp boat captain in a dilemma in that he can't schedule fishing--we can't fish as much as we'd like to. It takes a choice and a judgment away from our fishing, and we don't use our equipment appropriately under a forced fishery, as I see it. If we were to use a broader base in defining our stocks, we could go back to a management system we used relatively effectively a few years ago. Jim Majors would tell his boats, "Don't go there or I won't buy your shrimp." And it worked. We stayed out of bays where you had pinheads, not because we wanted to, but because we had to. Jim never forced us all into the same bay at the same time. We saw a few years ago here, I think, 28 boats for four days in Two-Headed Bay because there was no place else we were allowed to fish. And yet, there were numerous areas on the island that would have taken a boat or two during that period of time, distributed that effort and not hurt any single stock. I'm not saying that effort hurt that stock, but if there is a means to decimate a shrimp stock it certainly is to force an entire modern fleet of double rigged trawlers into a single mile wide cove that's two miles long. This is the extent of the shrimp stock that we were working on at that time and it was fished down to the point where I think there was maybe 300 pounds per hour before it was finally closed. In that particular instance, it wasn't the end of the season, it was the midpoint of the season. It was not appropriate for boats to tie up and call it a winter. Crews had to be maintained, vessels had to be maintained in operative condition. We were only a month away from the January opening, so it was a situation where everybody, economically, had to fish even though it was a losing battle. We'd like to see stocks, even though there might be some justification in assuming stocks are independent in different bays, to consider them on a broader base, and consider that if we take them as a whole rather than independently and manage them as a whole, that the economics of fishing will naturally spread the effort to let shrimp survive on their own.

Knapp: I think I would like to take and expand on what Junior said about the constraint causing the pulse fishing, or the regulations as they stand today. The way I see it, ideally, and this happened years ago before there was this humongus Fish and Game structure and the fleet that we have today, we were able to go out whenever we felt it would be profitable to go and return with the catch that we could be proud of. The way things are arranged at present, it almost makes this impossible. Ideally, a fishermen is the kind of animal that likes to feel his independence. Over the course of the years of shrimp management specifically, we've lost this independence through the constraints of regulation and registration areas which we talked about a little bit this morning. Alot of this has been brought about as a result of biological justification but quite a bit of it has come down to the fishermen and processors as economic consideration too. We try to use, interact both of these together but it causes great problems. But basically, getting back to what Junior said, the pulse fishing is not a good situation. In order to get away from it I feel we ought to get onto a broader base also.

Jensen — Ken, could you expand on that just a little bit according to your area? I think everybody in the audience should know that Ken is from the Sand Point area and does most of his fishing as far out in the Shumagin area when he can. He's probably experienced there as heavy pulse fishing as will be found anywhere in the state.

Westman — Up until about three years ago, the south peninsula-Shumagin area, we'd rather considered it our personal pond. There were only a few vessels out there working on a year-round basis, well virtually year-round except for the biological closure. The canneries in that area are different somewhat from the ones in town here, in that they have to bring in help. They do not have a resident population big enough to support a canning operation or a freezing operation from the local community. So the planning for fishing in that area has to be undertaken quite a bit in advance of the season. If you have a situation of on-again, off-again fishery as far as closures and openings of bays and this sort of thing, it puts the canneries in an impossible situation of trying to hold a crew that's on a guaranteed salary. To send them back to California and Washington and in our particular case, they use a Filipino canning crew many of whom will return to the Phillipines, it cannot be really undertaken during the season. So the main thing we need out there is continuity. We need a season we can depend on, one that will start, open, and close on a planned basis and still allow freedom for the fleets operating out there to go in search of shrimp wherever they can. For the information of the foreign investigators who have come in here, I found out last night that none of them were aware that these vessels that are in this fishery are almost entirely, if not entirely, privately owned. Under the tax rulings from the federal government, the fishermen and their crew members on these vessels, are classified as self-employed fishermen. So they are not eligible for unemployment compensation. Their vessels are not subsidized in any manner by any government body. We are entirely free enterprise. If we're not fishing, nobody's making anything. In addition to that, operating costs are at a certain level. We cannot afford to fish below a certain level of catch. I've arbitrarily figured it at about 10,000 pounds per day, I couldn't make it. I would have to pull out and go into a different area. The matter of grinding a stock down in a particular bay or something, it's not really entering into my thinking because I can't afford to stay there. There's just no way around it. The crew would probably just give up on me there if I tried to push them down to a point where nobody was making anything. And I wouldn't expect them to stay there and I can't afford to operate my vessel under those kinds of conditions. So I would like to see a broader-based management system that gave more freedom to explore to shift our efforts on an economic basis as well as a biological basis. I think that we can, it is the survival of the fittest in the game there, and that's going to work pretty well, dictate how it worked out.

Jensen — Bob, have you got any comments on this?

Moss — Yes. I'm in the other end, the eastern side of the table up here, and geographically the same way. I would briefly like to take a minute or two to go into the geographic locations and the background of the area I'm involved in. Kachemak Bay in Cook Inlet, about 150 miles north and east of here. The area has extreme tidal fluctuations, up to 30 feet range maximum for the year. The fishery was started there in the 1950s. Mid-50s was the first production type fishing and it didn't become intense until 1970. The early fishing was restrained until the 70s by only a single market, a market within the area. At that time, no shrimp were transported to Kodiak. The only shrimp caught out of there were processed in the area. Processing was done on a daily basis with the boats required to deliver each day. Later, this type of fishing changed to one in which the shrimp started to be transported out of the area. At that time, an area limitation was placed down in which boats that registered in that area were unable to fish in another area of Alaska. Kachemak Bay is surrounded by an unproductive area with no other bays close by with a record of commercial harvest. The management that was set up and strived for in those years was one that did away with the so-called pulse type of fishing. There was a yearly quota of 5 million pounds set on the area, starting in 1970. This was divided into two periods, on a summer-winter quota, each with 2.5 million pounds. That quota was obtained for the years 1970 through 1977. In 1978, the catch was increased to 6 million pounds. This fishery was spread pretty uniformly over the five month period between the winter and the summer. This allowed, at least it seemed, that the shrimp were being harvested over a well-represented segment. To further present the history of the area in the fishing year of 1978 and projections of 1979 saw an increase in the number of vessels. The number of vessels because of the market limitations and the area licensing remained relatively small throughout the year. Last year, and the year that's coming up, there seems a large increase in the number of boats and a subsequent shortening of the time period in which the shrimp are harvested. One other constraint that I wanted to mention is if there is an attempt to continue this type of harvest over a broad basis in order not to take too much of any particular segment of the population out. In other words, the direct opposite of pulse type fishing then we're going to have to have further restraints on industry in the form such as more split-quota periods. The area, I might mention is one which had the earliest fishing conflict in Alaska and it also, as a result has been studied to a vastly greater degree than say Kodiak in the form of current reading and diving and such. I believe that we're not in a position to be locked in any one particular form of management on the shrimp and this long term harvest over as broad a spectrum as you can to the year may be one that we'd like to continue. And in return it's going to call for more restraints.

Jensen

One of the things I should explain to the audience also, is the unique cooperation that exists between the Department of Fish and Game and the fishermen and the processors, of course, of the industry. We have established both in Sand Point, Kodiak, and I think Bob has one his area, though it's smaller than ours, a Shrimp Advisory Committee which meets irregularly with Fish and Game to discuss the mutual problems that we have and also to make recommendations, or oppose recommendations made by other portions of the industry on shrimp regulations. One of the things that came out of this study group was a split-season that went into effect about five years ago or so, whereby we saved a portion of the quota until January or February. I was never too sure exactly why that went in. But, the purpose was to split the harvest as well as split the effort up, possibly to get some better shrimp in January or February. The quota was split, as I remember, in a two-thirds to one-third ratio. Since this year it was reduced down to, because of quota restrictions and reducing the quota, approximately 5 percent of the landings of Kodiak Island resulted in the January - February season and that lasted four days up here and I don't know exactly how many boats were in there. At the time, the industry, as a whole, agreed to this and it was pushed through the Board of Fisheries and approved and went into effect. There were some problems associated with that from a processing standpoint. We have to keep our machines ready, we had to keep a crew and the expense of winterizing your machine every month becomes almost unbearable at times. But this is one of the things that was done. We've talked about the quota, we've talked about the season, we've talked about the area registration, sometimes violently. But basically, its a study group that cooperates and works together. We're not always in agreement with Fish and Game, obviously, but we do have our day in court both at the regular board meetings here at Kodiak as well as the Board of Fishery meetings whether they are in Juneau or in Anchorage. I'd like to turn this over to Mr. Majors and let him take some of his constraints up now.

Majors

Well, on this study group session that we had to arrive at the split season, it was a mutual agreement that we would go in and see what happened. As time progressed, it became more evident that we were creating a second pulse fishery on top of our original quota pulse fishery. When it was really researched it was more economical situation from the fishermen and packers point of view than biological. We've had seasons, for example we had a fleet of seven boats fishing for you and you have a second season that's going to last 24 to 36 hours and everyone knows it and you're advised before you even go fishing, "we're going to be there and your first tow's going to determine how long your going to fish." It's pretty hard as a plant manager to say we're going to draw some cards out of this hat, whoever gets number one is first out and whoever gets number seven lost his whole season. So consequently, as a plant manager, you have to gamble, let them all go and if sombody breaks down and somebody tears up a net you make a full trips and it really creates a management problem from a fish buyer's aspect. I agree with Bob, when we used to be able to fish our 11 or 12 months and everybody would go home for Christmas or go see grandma or whatever it was, you could schedule your boats out in the early spring and you just rotated them in and out unless there was a break down they all took their turn and it was a real nice fishery. But as the production decreases, the boats gradually weed out and go to different fisheries, different areas. Until the economics become a hardship on them, you're still going to try to make that fishery go. And I think we're seeing now a decrease in the amount of vessels gearing up for the fisheries. They've gone to the Bering Sea crab fishing. We're starting mid-water herring fishery. As shrimp decrease, I think you're going to be able to see these things happen. But as long as you've got a pulse fishery and somebody able to make 20,000 bucks in a couple of weeks, that boat's going to be here. He's going to gamble he's going to be there on that 20,000 because it's a short-term. He's going to go in, get it, and get out. Now Merle's sitting on the same board, I'll let him say what he has to say.

Knapp

I think it all boils down to, I've been in other fisheries where management is cumbersome but its workable. But in the shrimp fisheries, its coming to a point where its more than cumbersome, it's not workable and I don't think we can point the finger at our management, our state management, and say that they're the culprit. I don't think that that's what we're here to do anyway. I feel that on the constraints that the whole question lies in whether the shrimp stock can be managed. I've heard it stated and repeated several times during the coffee break that possibly it can't be. I don't think that that's going to be a basis for not trying to manage a fishery. It's just not a feasible thing, its hard, something that would be hard to accept. I feel that as far as quotas and the pulse fishing effect, less management might be appropriate at this time. I don't think I can elaborate much more on that.

Jensen

Thank you, Merle. I think originally, the philosophy, I say originally, because I was there when they established the first stage, the Department of Fish and Game, the philosophy of management then was directed primarily at salmon with little thought given to the other resources other than the fact it was nice to have them. The philosophy at that time was biological, economic considerations, social problems, social relationships would not be considered. We've seen a rather drastic reversal two years ago when we established our 200-mile fishing zone one of the prime considerations put into the management of the fishery, of any fishery, in that management area was social constraints. Possibly, one of the problems that we're facing now in our shrimp management in Kodiak Island, Chignik and south Peninsula is that we're looking too strongly at strict biological management reasons and not taking into consideration the fact that we do have a considerable portion of our population dependent upon that resource for a livelihood. The fact that we do have a considerable portion of our population dependent upon that resource for a livelihood, my feeling on this comes as no surprise to Fish and Game in that I feel that there is a necessary elimination of some of the individuals involved in a fishery, individuals also meaning the processor and, that if you're a manager or a good fisherman, then you work hard, you're going to make some money and that's the name of the ballgame. We do have to take into consideration some of these factors of social problems that exist. Kodiak is an example, as I would suspect the total population dependent upon shrimp fisheries, actively involved in somewhere around 800 to 1,000 people, which is one-fifth of our population within the city. Fortunately, most of those are also in or going to other fisheries or in other lines of work within the plants. The more freedom that we give our fishermen to explore, survey, to go into areas that are closed when there is no known shrimp fishery in there, the better possibility we have of maintaining an equal, good living for everyone in the city as well as the state. I do not understand why we close areas when there are no shrimp there, and it happens. For example, this year we've gone in and we hit two new bays, not new bays, but bays that have not been fished and produced almost 9 million pounds of shrimp. Had it not been for the commercial fishermen having a questioning attitude of going in and checking that bay out on the way to wherever they were going, chances are we would not have had that shrimp on the table. Shrimp is a resource that has to be taken care of, has to be harvested and we have to take care of our people. I think Captain Junior Cross has some words about laying shrimp on the table. I'll give it to him for that.

Cross I'm awfully lengthy, so I'm going to watch it. We have, I think a limit on management to catch management, as I see it, and this is the constraint we're discussing. Catch management, I think of it as a proper definition of quota system because we're managing the catch, not the shrimp that are left in the grounds. When we manage catch by a quota, which we divided a quota, re-divided a quota, sub-divided it, numbered and lettered in detail, what we've really done is manage vessels and gear and therefore our effort. It seems to me like the managment of effort has degenerated to a situation where we have a forced and directed focused fishery at often inappropriate times of the year on distinct stocks with complete disregard for exploration and things like the Wide Bay/mainland area where we discovered new, I would say relocated stocks of shrimp. With our focused fishing, I mean focused not only in area by very finely drawn boundaries, but also in very close time frames, we are working on perhaps one portion of one age-class of shrimp in that bay. And those quotas, I won't debate the quotas themselves regardless of what the quotas are, quotas often are partly taken out of one small segment of shrimp family that could, in fact, damage that portion of that resource, without justification, in that it has not been hatched with remaining shrimp. We have to be awfully careful with a focused situation like what we do, perhaps do damage to our resource. I reiterate perhaps because I personally subscribe to the feeling that we cannot damage shrimp in this geophysical situation out of Kodiak because they have lots of places to hide in the majority of our area, I feel its a shrimp sanctuary so that as per trawling anyway with yet the possible damage we have done and are continuing to do in our focus fishing, it seems to me that the complexity of the area and the fleet and the social economic backers that have been taken into account here have proved that effort management, that the effort is an unmanageable force and that management was continually directed into further and further, deeper trenches and situations that might cause damage. It seems to me that we kind of got the bull by the tail because after we define further our stocks and define our efforts in more detail, this situation grows and grows. This record fishing effort also obviously leaves alot of money on the table. Referring to shrimp as a limited resource is misleading. We have many, many minor resources around and they are independent resources. We have many minor bays, minor estuaries, lightly populated offshore areas, some places heavily populated offshore areas with the effort direction we have, we've directed our effort completely past them. The Russians had a substantial fishery in the Shumigan Island area offshore I think in 1967. I had, which was at the time a world's record catch in that same ground 18 miles offshore. If the ground had been unavailable to fishing since that time because of our directed fisheries, we've been directed past, around, every place but there. We haven't been allowed to fish there and I felt at the time, it was a tremendous resource left there. Last winter, again through our fishery focus in time, we had a 2-year-old male population that I wouldn't be so brave to say how much was there, but I'm certain we could have taken 5 to 7 million pounds out of that bay and not noticed a decrease in the catch per unit effort. Due to our complex management schemes we had no system for utilizing that resource. This winter we haven't been able to use it, and if it's not utilized this coming winter, it's going to be left on the table again and of no value to anyone that I know of. If this shrimp was left in the bank so to speak, I'd drop my argument and go along. But I feel to leave that shrimp in the ocean and that mass, it's not money in the bank, it's money wasted. I don't see how we can recover any good from it. It seems to me like it's a travesty in our industry that those many millions of dollars are left. I think that the solution to the thing is that we have to diffuse this effort both geographically and in time. I think that the result of this workshop, as far as our Kodiak management is concerned, should be a real long look at potential methods of diffusing and realigning this effort in such a manner that it's going to be consistent with the preservation of all stocks rather than the few stocks, rather than stocks that we don't fish on now, because I don't think we're preserving the stock we're fishing on. It seems that if a longer harvest period was instituted, I don't mean a month longer, I don't mean a week longer, I mean months longer, that we'll take away the economic impetus that makes me put my boat back into shrimping on the first day of January and fish until the seventh, or I might fish from September 3 until September 20, it's the only time of year, it's the only time I want to fish there. I think that if we had a year-long fishery here or a nine-month-long fishery, I probably couldn't afford to fish in it. But I think we'd have a steady and constant flow of shrimp. It might be a variable flow of shrimp that would vary from the good geophysical years down to the low years. The predator, the efforts and everything else would vary, but nevertheless, it would be a continuing flow if not level and I think that it would evolve into a continuous effort. Therefore a manageable effort and that with that we could probably come up with some biological answers to our shrimp problem. I think that we have to stabilize our fishing effort and I don't mean restrict, it's not the same word, stabilize our effort and diffuse that effort to let our shrimp have a natural chance of survival. I'm done.

Jensen

I think one of the things too, that is a constraint in my eyes, because I'm forced, as a processor, to buy a product that I think it's wrong to sell and particularly wrong to buy. That's the pinhead problem. Pinheads are not normally a problem, but in periods of short supply or where they school in vast quantities, it's entirely conceivable that a vessel will, through neglect, bring in a load of pinheads. It may be my fishermen or it may be somebody else's fishermen. The point I'm making is that I feel that the pinheads are juvenile shrimp and as such should not be taken unless we have a definite number that says they're going to die off. We've heard, as Dr. Alverson asked yesterday, where is the mortality rate, is it somewhere between 25 and 75? If it is, then we've got some severe problems--we've got to manage on what the actual mortality rate is. I suspect in listening to the conversations and talks in the last two days that it varies from area to area and it may range from 25 to 75 percent. But it just causes me personal problems to see us taking juvenile shrimp and then expecting, on that basis, to have a crop next year. I guess its like picking apples, you don't go out in June and pick the apples, you wait until October when they're big and fat and ripe. But, this is a problem that we've talked about in the study groups. I think in part it may be due to the industry's attitude. We've not been able to arrive at a count per pound that would be reasonable for those involved, though I'm sure somebody's going to get hurt when we're talking more than 120 count per pound until we reach 180 count per pound. These are problems that are not constraints by the management people, they're constraints that we have forced upon us, that we are forced to buy those shrimps because if we don't somebody else is going to and it does cause certain problems. I don't think that any of the fishermen like to fish them either. Maybe, Bob, you can comment on that over in your area?

Moss — Well, Chuck, we really don't have them to the extent you people have. In the bay we have, there are of course the juveniles, the pinhead ones, but we've closed that whole section of the bay off. In my earlier remarks a good deal of 260 square miles in Kachemak Bay would be trawlable, but isn't available to the commercial fisheries. That's the larger flat area up above and that's helped quite a bit with that problem.

Jensen — Thank you, Bob. These are one of the problems we're going to work on, we've been working on and I'm sure eventually, we're going to solve it whether we end up the way we are or not is something else again. Kenny, have you got something else on that?

Westman — I have just a few comments. I want to make clear, again for the information of our investigators here, that Fish and Game operates on a biological evidence basis according to their own statement in making their management policies. But, it is possible to put in a management strategy or modify on an economic basis by going over their heads to the Board of Fisheries which directs the Fish and Game. And the reason I mention this situation is that if you're thinking you're criticizing Fish and Game as entirely responsible for directing all of this down on us, it doesn't quite work that way. This monstrosity that's been created as far as the management system right now is, we're probably as much to blame or as much involved in it. Input from us has gone in, down through the last several years, and a couple of cases even on an economic basis. Just going back to one instance it was this private pond thing that we had going out there. When the Kodiak fishery started to decline, the fleets moved more heavily into the South Peninsula area. And they told us that biologically there was no justification to keep them out. So, we go to the Board of Fish and Game and they assisted in some manner, in small ways there in keeping them out. They made it awkward for them for awhile. We've discovered this type of thing complicated management. They're complicating our lives, too. I think we should go back and take a long look at the entire system which includes all of these problems and see if we can come up with a more workable, simplier answer. I think one of the founding fathers of our country said the best government is the least government and I think a paraphrase to that would be pretty appropriate here. Thank you.

Jensen — Thank you, Kenny. I can't help agree with his remarks in that some of these constraints we're operating under are our own fault. I don't want anybody to misunderstand that we didn't have a say in this. We do have a say in it. Hopefully, we'll continue to have a say in the operation of it. I think some of the constraints that I'm concerned about and

I'm sure that Jim is too, is the quality of the product that we get in. Obviously, recovery is one of our major points of interest and it seems that they go hand-in-hand: The better the recovery, the better the product you have. Jim's been in the processing end of this portion of the business much longer than I have and I'd like to turn that over to him.

Majors

When we were able to fish a year round season there were only one or two packers in Kodiak and probably 11 to 15 vessels. Like someone mentioned here, you could tell a vessel to go fishing in such and such an area that you wouldn't take from a different area. Weather seemed to control our recovery more than the actual quality of the shrimp. In other words, I feel that the quality of the shrimp are much better January, February, March than they are probably in June. Due to the weather and the availability for the fleet to get on to the shrimp, due to the size of vessels we were dealing in, and I go back to my records, production must seem to be predominant during the summer months-June, July, September. Once in awhile, you get March checks in there. We probably had a high pressure area setting around here and no real bad storms and it came in second one year. February showed up third in 1973 and so on. Even May showed up once way back when we were looking around all over Kodiak Island for shrimp and didn't see any. But I think that was the year we ended up in Cape Douglas and spent six weeks up there. There just weren't any shrimp around the island. But the thing that falls in place is the recovery. It seems to fall even though we're fishing on possibly not as good a quality of shrimp, as far as firmness. The recovery also seems to fall in those months of June, July, August. Those three months are always in the top four, so I think that's what Chuck asked me to answer.

Jensen

Yeah, that's basically it, Jim. That makes a great deal of difference in the operation of the processing, if the processor has a continuity of supply. I don't want to go into labor costs or anything else of that nature because that has no bearing on this, that's our problem. But, for the efficiency of an operation, you're going to run six days a week, as opposed to one. Assuming you have mediocre or poor shrimp on six days, and excellent-superb shrimp on the one day, the average recovery in my experience is that you have better recovery with the mediocre or poor shrimp than you do with the excellent shrimp. This is merely because you've had the continuity of the operation. This goes back to pulse fishing, being faced with having to run in excess of maybe a half million pounds of shrimp in four days and then have nothing for another week or ten days or two weeks. It does create undue problems for the processing side of the industry. I'm sure that pulse fishing, which was brought back in again, does hurt the fishermen themselves. Al, have you got anything along those lines?

Burch It's just to back up what Jim said there. We were one of the boats, at that time, that couldn't find any shrimp on the island. I think, at that time, there were five boats fishing shrimp. We went completely around the island and to all the bays where we had good fishing in the previous years and previous months; absolutely no shrimp. We ended up by Deep Creek, which is just below Cape Douglas there in 54 fathoms of water. We found a real nice supply of absolutely clean shrimp. Traveling shrimp we called them in those days. We did fish that area for six weeks, it as a little longer run than the areas down on this side of the island. After about six weeks, the shrimp started showing up down here again and the fleet pulled back to this side of the island and we finished off the year over here. Also another time, a different year - in 1960 I think it was, we had the old schooner Celtic - and again there was not many boats yet at that time we went to all the bays on the island, no shrimp anywhere. We ended up 11 miles off Ocean Bay. It was a smooth bottom but fairly hard. It wasn't the green mud that we were used to. We started picking up shrimp. We lasted out there for about three or four weeks and delivered back to Seward at the time. We came over on our fifth trip and the boats from this area were back in the bays again and the shrimp had moved back in.

Jensen I think if nothing else is coming out of this session so far is that we have a great lack of knowledge about our shrimp fishery and where they do go. I was rather tickled yesterday when the question was asked, because I've always wondered where they go, too. I have my own theory about that, they go out into the ocean stream someplace and get blown someplace else, maybe the peninsula or up the mainland or go out in the middle of the ocean for the rest of their lives. It seems to me that the environmental factors, particularly the temperature, wind conditions and change in currents, have influenced the Kodiak Island fishery, possibly the peninsula fishery and possibly the Chignik fishery to a degree that we're not aware of. I realize, after listening for the last two days, that you do have extreme fluctuations in population. But it's something that's uncontrollable. You can't manage it, if you can't manage it because of natural environmental conditions, you certainly can't manage it on a sustained yield basis. I think if we were dealing with a 20-year-old animal, then we would be dealing with something that we possibly could. The fact is, we're dealing with an animal that apparently is somewhere around 6 years old. There seems to be some question on that as to the age of the animals that we're fishing on. I don't feel that, given the environmental conditions that we're living under right now, and we have the last two years, the last three years, and the changes in the environment where water temperatures have risen according to some reports 5^{0}, could not have had anything but an adverse effect on our shrimp fishery. As such, there is nothing we can do to manage that. I think Junior's got something to say on this, so I'll turn this over to him.

Cross I'm not a biologist, I carry no title except fisherman. But, I've practiced that for a long time. I've been conscientious in my endeavors to stay abreast in the latest in electronics and techniques in finding fish and constantly on the alert for better gear and methods. I pride myself on keeping up with the times. Therefore, I feel, and of course you all understand that as a fisherman and as a captain, my sole responsibility is, outside of bringing in my boat and crew home safely, is to find fish. And in finding fish, I also have to determine the extent of the fish. When I leave the grounds with a trip, I have to decide is that an appropriate place to come back to? Was there, in fact, enough fish there for me to return to? My decision is completely selfish, but based on some relatively scientific observations that I make. And in my endeavor to observe the shrimp movements more carefully, just a year ago now, yesterday, I left the grounds with a big load of shrimp a year ago and in the preceding ten days, I discovered a completely new to me aspect to determining the density and population of shrimp. It was my first experience with my net sounding equipment. I had a constant bottom temperature read out at my right hand in the wheel house. I didn't really mean to say this in public because there's going to be a bunch of people use it against me, but what I found was that I could follow the temperature curve in this particular bay. I have a little line in the side of my meter, very similar to my bottomline. The bottomline goes like this as it goes up, I move this way to make it stay in the center and, therefore, I stay on the shrimp, that's a means of staying in shrimp. In this case, I have the temperature. When the temperature varies, I move to make the temperature stay constant. We came up with a 30 thousand pound per hour catch for the three day period. Due largely to that temperature device. It was verified again by Ken Westman. I told Kenny when he was out of the shrimp. We couldn't see the shrimp at that time, our acoustic equipment didn't indicate any shrimp there. And yet we isolated those shrimp, we found the boundaries of that stock clearly with the temperature system, we did it in kind of a partnership, there was only three of us there at the extreme. If we fell off side of that 2.8 centigrade degree boundary the step would fall not by half, but perhaps to one-tenth. So, we kept track with this moving thing, it moved with the tide. We had a lateral movement of perhaps a mile in that thermal boundary and we found that the shrimp very closely adhered to that. But what I'm getting at is this is something that has not been today included in stock assessment in Kodiak Island. Very clearly it points out to me that these shrimp, I might mention the temperatures we were talking about. An inshore temperature that went to a minimum of about 1.8°C where there was a very thin population of these shrimp, an occasional thing, and as we got into 2 1/2°C we got into an area that had reasonably good commercial returns and as we got into 2.8°C and from there to about 3.1°C we had a uniformly, uniquely, dense population of shrimp. I would say the shrimp stayed very close and the boundary was a well defined boundary just as good as an edge to follow and that's where the shrimp were. It indicates to me that shrimp are extremely sensitive to temperature. It doesn't indicate to me necessarily, that they can't survive in another temperature, but it certainly indicates a preference for temperature. I think we have to recognize at this point that it is a very important aspect to shrimp, at least to shrimp concentration. We don't have on hand, apparently, a full enough knowledge of temperature to really use that in projecting perhaps a quota system. To get back to the diffused fishing effort that I like to talk about, what we have now is a very unnatural effort in that it's focused, it's directed. Fish don't all gang up in one bay. I don't think predators have any higher council that insists they go to this place whether there's shrimp there or not. I think what we want to do, we're not trying to change nature, we're trying to live within it and so we should live more naturally. I think a long-term diffused fishery is a very natural way to use a resource. That's how nature does it, feeding a few all year long. So, I think that we could get back to a very natural way of harvesting shrimp that is compatable with nature, compatable within geophysical changes and within the predator control and whatever else affects the shrimp. I think that a low intensity, long-term fishery is very easily scientifically observed, particularly short trends in the population and the health of our shrimp stocks. Whereas, we have no reliable meter at this point. I personally discard----surveys. Our fishing effort is certainly not readily observed because it's not a natural fishery. We show declines, they're not relative necessarily to the stock on hand. In most cases, I think it is in fact more relative to the regulations that were in effect at the time. I think if we were to use a long-term, low-intensity fishery, we might see some overall lowering over a long period of time in the abundance of shrimp on the island. But I do believe the natural method of fishing would soon fall in line with the natural recoverability of the resource and then seek a level. At that point we would have a fishery that was somewhat continuous, we'd have a stock that we leveled within that framework. Then we could take the funds we have towards a catch and quota management system and apply them to scientific research and observation of these animals. Perhaps, at some more opportune time in history, we could try to build these stocks beyond nature. At this point, we should fish them within nature and let the effort be a natural effort in that, as it was pointed out by the people from Maine, the effort will follow the stock on hand. If the stock increases, the effort will increase and it will naturally decrease if the stock decreases because we are all fishing for money. I don't think any of us here are fishing for the sake of history. So, we should certainly consider this fact, to the evidence in my mind at least it is certainly a fact. It was coincidental that I received a brochure on Dr. Ivanov's recording in the Bering Sea. It made me aware of the potential of the machine at my side. It just so happened we were on a stock of shrimp at the time that apparently responded to that parameter almost totally. We know now that we have some very strong forces working on the shrimp, aside from our fishing effort. Our fishing effort is also a strong force, in that it focuses. I think our fishing effort diffused would be something that nature could recognize. Thank you.

Jensen — Mr. Majors, would you like to say something about that? I believe you are also from one of our formerly high producing areas.

Majors — It's pretty hard to follow Professor Cross here, but I have information on the halibut charter that is run by one of the shrimp fisherman's father and has been for many years through the halibut commission. We've kept in touch with him through the bottom temperatures and surface temperatures. I don't have the numbers with When they were in the warmer area he told us it was higher than he'd ever seen it before. So, we'd, once a day or every other day, call him up across the gulf. All the way across the gulf, they didn't have any feeding in the long-line fisheries tests that they were running, until they got clear over to the Cordova district. At that time the water temperature had cooled down quite a bit. We did definitely have a surface temperature and a bottom temperature warmest in the district this year. We founded that fishery in 1972. We worked on it pretty heavily up to 1976. We had a small pollock that moved in on us, six to seven inches long. The next year, pollock and the small black cod (sablefish) moved in on us. There were so many predators feeding in the shrimp that some of the nets even floated as they came off the bottom. In 1978-79 season we didn't catch one shrimp off Marmot Island.

Jensen — Thank you, Jim. Kenny, have you got anything to say?

Westman — One note on the guide there made mention of diversification, it said that was from a fishing standpoint. I, along with many other fishermen like Jim and Junior, am diversified. We're not looking just to shrimp for an entire livelihood either, for vessels or for the crews. In my particular case, during the course of this winter, I have modified my vessels so it can be used as a double rigged shrimp trawler and it can also be switched to a single rigged pelagic and bottom trawl. I got my own thermometer now, so I don't have to look over Junior's shoulder. In the next week, we'll be going into the pollock fishery and we'll follow wherever the wind leads. Wherever other fisheries come along, we'll work them, hopefully into another shrimp fishery in the course of the year.

Jensen — Have you ever got anything Merle?

Knapp — I'd like to say one thing, since Junior kind of let this thing about temperatures out of the bag, or feels he did. This is something that should be understood. Our constraints in managements, or part of the constraint is based on surveys done on the biomass. The allocations are based on surveys. Unfortunately, the survey vessels used aren't competitive with the commercial fleet. Consequently, by the time they're equipped with the machinery it takes to conduct an efficient survey, possibly damage has been done. If you believe in the concept of damage by the fleet or by the fisherman, maybe that's already been done. Maybe in other areas you have predators and we can avoid those predators with more sophisticated machines. Other things are going to come up in the future and I don't think we should base our allocations primarily on the surveys. I have noticed that fishermen are being listened to a little bit more in setting limits the last few years in Alaska.

Jensen — Jim, have you got anything to say?

Majors — Not really. I'd just like to thank the Fish and Game Department and the University of Alaska, National Marine Fisheries Service and all the talent that's here with us discussing the problems.

Jensen — Bob, have you got anything to add to that?

Moss — Well, yes. I believe I have one or two comments. There's one aspect here that hasn't been mentioned. Management used among its tools the catch per unit of effort. I think that they should take a very close look at that, in that the catch per unit of effort in the shrimp fishery is being falsely sustained in some instances much in the same way halibut was with a nylon groundline. We've heard of one ramification of it here right now, the temperature. But that's not the only one. There are many other modern techniques that are used in the shrimp fishery in recent years. There's a wide spread use of sonar, side scanning sonar. This has allowed the boats to move in and fish areas along the reefs and along the normally untrawlable grounds you wouldn't go close to if you were buying your own gear. Prior to this time, those areas weren't fished and they furnished a reserve, if you will, for the traditionally fished flatter broader areas of the bay. In other instances, and I hestiate to speak on really what's taking place around Kodiak, but in our own area under increased fishing pressure, we've gone into areas that we haven't fished before. We've lost a tremendous amount of gear, but it does produce shrimp. But, in doing so, it did two things: It raised the catch per unit of effort, or it kept it up there which our management looked at as one of their criteria and tools. It's also probably depleted some of the stocks that may have been used in the past years for replenishing the resource. In closing, I too, would like to thank the people who have traveled a good long way to come here--the scientific portion of this group--not only to raise questions in some areas, but also they've opened up whole broad areas that completely change thinking about the subject.

Jensen — Thank you, Bob. I believe Mr. Cross has a word or two to add.

Cross — I'd like to say to our ADF&G department, I certainly don't blame you for all the problems I've presented. You have to take your share of them, but certainly the advisory councils and the Board of Fish and Game and other aspects of our regulatory system have to share the burden, including fishermen and some of their selfish interests and so forth that have certainly added to the problem. To talk about catch per unit effort, I agree with Bob that it has certainly been bolstered by technology. I think that technology will be a long time getting into some of the sanctuaries we have. I think anybody that's ever looked into the charted Chignik area for instance, will agree it's hard to get through that area, much less drag a net through it. Then Mr. Dow says we have a 20,000:1 variable in stock in the Bay of Maine. Well, we're not at the extreme northern or extreme southern latitudes of our shrimp populations so we can't use that number. But we are in extreme geophysical changes right now so even a small percentage of that number might influence our fishery 200 percent or 2,000 percent or

200:1. And then the catch per unit effort would be a poor tool to measure the result of the fishing effort because nature has already varied our available resource by perhaps 2000:1. I wonder what would happen if you were to throw that factor into the complex formula we saw yesterday from which we derive our coefficient of catch per unit effort. I think it might invalidate that effort, where again a natural type fishery would back away immediately from economic pressure from a depressed area.

Jensen

Are there any questions? If there are, I'd like to take them up now before I make any closing remarks.

Clark
(NO MIKE)

I have some comments. Since it is a panel on constraints, you have brought this up indirectly, that is the constraint of the quota itself. I'm not going to say that there shouldn't be a quota, but I will remind everybody, I don't think anybody would argue with me that the quota itself originated in a purely arbitrary manner. Since then we've been working with it as though it were something from heaven, I think if we're going to use a quota we should make some effort to determine what the quota is based on actual bio-distribution. We've already heard from this gentleman that the catch per unit effort is not necessarily at all related to the bio-stock. I feel certainly for sure that is the situation we have in the Kodiak area now. Everyone is every day reading about depleting stocks of shrimp and no one ever questions anything. I say that for all I know, they might actually have increased. All I know for certain is that there has been radical migration, much more than usual, in an area where shrimp still haven't migrated. They're dispersed over a much wider area, a little thinner than usual. Consequently, there is a reluctance in this area for shrimps to congregate, in places where we usually catch them with methods we usually use. About the stock itself, I don't think we can make any conclusions. It may have declined. But if it has declined, it certainly has not declined to the degree the numbers in the quotas have declined. Also, one of the tools they use for determining the quota, the catch per effort, is based on an arbitrary situation. They've not only tried to tell us specifically where we can fish in an area, but they've subdivided each area into tiny little groups and directed us there. In many cases, one area is closed and the other one is open and they're in the same area. They've committed the scientific sin of drawing straight lines, although on the bottom of the ocean they don't exist. As one man said, when the naturalist starts drawing straight lines, he must remember that the only straight lines in the ocean are in the naturalist's mind. They have placed us in a totally arbitrary situation and a very fictitious situation. From that point on, we cannot use a catch per unit effort.

Jensen — Thank you, Bert. I'm going to let Junior make a comment on that question.

Cross — I said that we had a catch management system. I defined our quota as a catch-management system. I also pointed out I feel that it is too complex to be managed and that in effect, we have a bull by the tail. I'd like to submit an alternative, manageable alternative and one that protects our resource. I certainly wouldn't want to go into all ramifications of the thing, but I think it would be a relatively simple tool where we use the minimum threshold to maintain a brood stock that would be sufficient to replenish the resource, not at any arbitrary level, but a stock that was obviously or surely large enough to maintain a lineage of _Pandalus_ in our area. With that we could use a natural fishing system. It would preclude quotas. I can't see how a quota would apply. The variety of parameters that have been brought up at the workshop, to me, would preclude quota. I think it's clear we can't predict biomass, we can't even assess it, not with the tools we have in hand. Therefore, we would manage our fishery, not on the basis of how much we have caught or how much was there last year or how much is going to be there next year, but simply to be assured we have a stock available to replenish our resource. That would be consistent with the broader base Merle talked about. We could deline our ocean, since straight lines would not be required to manage our fishery. I think the arbitrary restrictions would be virtually eliminated. Perhaps we would need something to protect juvenile stock. I think Jim Majors would certainly protect the stock his ships fish on. So we might have to put a minimum age restriction up so people who willfully went into a nursery area would lose their license for the next six months, or something of that nature.

Jensen — Thank you, Junior. I guess we're going to answer questions now. Yes, ma'am?

Skuladottir — It seems that you have no restraints on the take of small shrimp and their counts.

Jensen — No, ma'am, we do not. What we have is self imposed restraints upon individual processors as to what count they will accept for their particular operation, there's no state regulation to that effect.

Horsted — My compliments to the panel for a very interesting discussion. I would like to comment on the observation made by Captain Cross on the techniques using stratified testing for estimation abundance and stock sizes. It occurs to me that that parameter, as you said yourself, might have been a little overlooked in our stratification studies of certain areas. Quite naturally, it would fluctuate and make it extremely difficult to take that into account in a stratification study. I was hoping to keep your observation in mind in trying to see whether our approach to this, around that parameter, might be done. I think that it's worthwhile. I do think a similar observation has been made in other areas, in Greenland waters investigations they came up with a map showing the concentrations as they found it. Then they explained it by salt and temperature indicators.

Stickney — I'd like to ask Captain Cross if this very interesting information he has about temperatures is proprietary information, or if it's the type of thing he would be willing to share with the shrimp people.

Cross — Last year I did not do alot of sharing. This year I'll think about it.

Skuladottir — Were those shrimps male or female?

Cross — These shrimp were exclusively male. This a bone I have to pick with our department because they refused to recognize this and they refused to take samples when I asked them about it. This is also the day before that area closed for egg-bearing.

Jensen — Any more questions? Ken, do you have a comment?

Westman — Yes. Just one further thing on that temperature. If there is something to this, I think it should be encouraged on the commercial vessel standpoint. That we, when ever we can afford it, put the temperature recording gear in and start taking samples. We should have some method of reporting this information consistently, where the location was and such. As it came out in the past few days here, there's a tremendous area where they need research and a limited research budget. I'm trying to promote an XBT. I do have the temperature recording gear on my net sounder now. It's a little costly to put a $5,000 transmitter down there, just primarily on a bottom trawl to send back temperature data. I'd like to find some other method. I'd be more than willing to take temperatures and locations I'd like to encourage others to do it too. We may be on the track of something that is worthwhile.

Jensen — Anybody else have questions or comments for the panel? I have some. The question is, yesterday when we were talking about ocean currents and how they effect Kodiak Island. I was just wondering how much influence and how much volume of warm water is actually breaking into the Kodiak area now with the change in temperature we've got. Is the gentleman here? Would anybody care to answer that or hazard a guess? Maybe Junior can be more specific about the question.

Cross — We saw yesterday the inflow of 100 tons in the bottom of the estuary systems that moved into our deep-water trenches on the east coast of Kodiak Island. It seems to me these things could be, have persisted and might prevail that we might run into a situation where we have early egg hatching and larval death because of unseasonably warm temperatures moving in on the bottom of our estuaries. It seems to me as though some of those approach the inner ranks of our estuary system, if I remember correctly. Is that something that we can predict? Is there any way we might detail the activities of the last couple of years to get specific information on our problem?

Ingraham — Some type of monitoring system needs to be looked into. You just have to measure. It wouldn't take too much, it would only have to be done every couple of months.

Cross — There isn't any way to extrapolate that information or something? Is there any computer program that might help? Somebody has here a computer chart of surface flow, is there anything like that relative to the bottom?

Ingraham — There is some work being done in that area, but the technology is not available yet. That's a research job.

Jensen — Thank you. I would make one request of the ADF&G and anyone else that's interested. If they could come up with a reasonably solid number that everybody could agree on for natural mortality. I'd like to thank Hank and the Sea Grant people and the Department of Fish and Game and NMFS who allowed us to take part in this program.

MANAGEMENT STRATEGY PANEL

Chairman:

Fred Gaffney (Alaska Department of Fish and Game)

Panel Members:

Svend Horsted (Greenland Fisheries Investigations, Denmark)
Robert L. Dow (Maine Department of Marine Resources)
James Boutillier (Pacific Biological Station, Canada)
Jerry McCrary (Alaska Department of Fish and Game)
Jerry Lukas (Oregon Department of Fish and Game)
Unnur Skúladóttir (Hafrannsoknastofnunin, Iceland)

Other Speakers:

E.J. Sandeman (Department of Fisheries and Oceans, Canada)
Walter Dahlstrom (California Department of Fish and Game)
Mike Devers (Fisherman, Kodiak)
John Geibel (California Department of Fish and Game)
Tom Northup (Washington Department of Fish and Game)
Jack Robinson (Oregon Department of Fish and Game)
Patrick Holmes (Alaska Department of Fish and Game)

Holmes — At this time I would like to introduce my colleague. Fred Gaffney, the shrimp project leader for the western Gulf of Alaska will be chairing the panel entitled Management Strategy.

Gaffney — Thank you. Dr. Skuladottir is not here yet, but she's on her way. Among our panel here, we have representatives from most of the countries in which there is a management regime set up for harvest of shrimp, P. borealis. I would like to ask each one of the panel members to very briefly list the pertinent regulations in effect in your fishery now. Don't worry about explanations, but just list what you have, size limitations, or quota restrictions, whatever they may be. Once these different regulations are listed, then I'd like to come back and have discussions as to how these particular regulations are used. Dr. Boutillier, would you like to start?

Boutillier — It's just Jim Boutillier, no doctor. British Columbia doesn't have any regulation on P. borealis. We have regulation on P. jordani, a close cousin. The two regulations we have on the fishery right now on the western coast of Vancouver Island include a vessel regulation or a license restriction regulation. We also have precautionary TAC's on the ground. With the original biomass estimate and after monitoring the catches and catch compositions, we then resurvey the grounds and if necessary change our TAC's and open the fishery again.

Lukas — In Oregon we have a season closure that extends for a five-and-a-half month period from October 16 through April 1 of the following year. We have no minimum mesh size regulations. Those are the only two pertinent regulations that apply to this commercial fishery. I might also add the ones from Washington and California. In Washington there is no season period. They do have a minimum mesh size of 1 1/2 inches. In California they have a season closure similar to Oregon's except that it is two weeks earlier than ours. It closes at the end of October and goes through the winter to April 15. They have a minimum mesh size of 1 3/8 inches in the catchable shrimp grounds in northern California.

Horsted — In my initial introduction to Greenland management, I believe I have already outlined the management schemes. We have to distinguish between our inshore waters and the offshore part of the economic zone. The latter being open to other countries, the inshore only to Greenland fishermen. Our inshore waters are principally free fishing. There might be, by mutual understanding among fishermen, such regulation as I spoke about under conditions where, for instance, the free capacity would exceed that of the factories. But to my knowledge, they are presently in balance and the principally free fishing remains. They do also, to my knowledge, keep a minimum mesh size, but it is not a small one. In the offshore fishing, we are regulating by quota systems on advice at present from the International Commission for Northwest Atlantic Fisheries. That quota is broken down into four management areas. The guidelines here more or less have been the availability and abundance of shrimp in each of them. This is apart from the area adjoining the most important inshore areas, where a strict quota is enforced. Furthermore, the quota is agreed to internationally among participating countries. There is also 40 millimeter minimum mesh size in the offshore fishery.

Skuladottir — We have a minimum size for shrimps to be landed, a certain number per kilo (320). Then, we also looked into by-catch. If that exceeds a certain number per pound of shrimp of an important species of fish then the area is closed. We also have a quota system, one for each area. This quota is revised after half of the season is gone, and might be changed. We try to keep the number of boats down. If it's a fiord area, the licenses are given only to those living in the fiord. The offshore areas are for everybody. The government has a size limit for inshore boats of 50 tons. Above this, they don't get a license. We have a closed season. Inshore we start October 1 and the season lasts as long as the quota allows except for over Christmas, the fishermen like to take three or four weeks off. This is also the toughest time of the year and the catches are low. We also have weekly quotas for the processors and packers. In some places the processors and packers like to have only half of the fishermen out each day and the rest of them out the next day. This is to make sure that you can get all the catch in good condition and evenly distributed through the week.

McCrary

There are two major biological management systems in effect in the western Gulf of Alaska. They are the establishment of quotas for known stocks or at least what we feel are manageable units of post-larval shrimp. Many cases the stocks have been established on biological information where there can be a strong argument made on the basis of differences in life history trends and growth patterns that they are in fact separate stocks. In some cases they are strictly based on geographical separation and the fact that it doesn't appear some of these stocks are continuous between days. The other major biological management feature is the protection of females during the egg hatching period. This has been extended where we have depressed stocks to encompass the entire ovigerous period. Maybe everybody will have the same idea I have about egg-hatching closures. In some cases they were established as the first means to limit effort and more recently, for depressed stocks. We thought this idea was a good way to reduce the chance that over-harvest would occur on females. Obviously, there are other administrative regulatory systems in place, including area registration and all the licensing features. But we have no minimum mesh size, no minimum landing sizes of shrimp, no minimum counts per pound and we have no limited entry system.

Dow

There have been two major methods for shrimp management in the Gulf of Maine. The most consistent one is that of minimum mesh size. I explained this the other day and showed a chart with the details of regulation. I haven't read it, but from what I recall and have been told, it's about 1 3/4 inch mesh. And the other has been a general closure with a few seasonal exceptions to that. For example, at the moment, we have a two month open season in February and March. At the conclusion of March, the fishery will be closed and continue to be closed until such time as the board of commissioners decides to reopen it. That represents the three states on the Gulf of Maine. Licenses are required of the fishermen, I think that that's about it.

Sandeman

Mr. Chairman, I think that in eastern Canada, you have not too many types of management or management strategy applied. But there are one or two very clear ones, I think applied quite formally. Maybe the first one which is unrelated to the general topic, but is nevertheless important I think with any small mesh fishery, is by-catch regulation. Because the fishermen fishing shrimp are in fact using small mesh gear, they are only permitted to land a certain percentage, I don't know the details of it, of groundfish, particularly red fish and cod. We do not have any mesh size regulation as such, I think one could say there was a voluntary regulation and that this lay between 1 1/2 inch and 1 3/4 inch mesh size. I haven't seen any smaller than an 1 1/2 inch. As far as a closed season is concerned, we do not have one. This is a winter season to protect the females spawning. The main reason is because this is unnecessary. Most of the area is covered by ice from the middle of January until April. It may be a little earlier, in which case there is a bonanza fishery for the fishermen because the catch efforts are very high at that particular time of year. Also, in some years it can be considerably later than that, towards the end of May, before the fishery opens and even into July before the Labrador ice is melted enough to get into the areas where the shrimps are. The most general regulation is that of a quota. The procedure is generally a TAC suggested by the scientific people working through an organization called the Canadian Arctic Fisheries Scientific Advisory Committee (CAFSAC). This organization is sort of paralleled by IGNAF. It is a form by which scientific assessments are examined by a wide spectrum of people. It is not left to one or two scientists to do their best, but there is quite a strong review process involved in considering the information within CAFSAC. A TAC is established or suggested by CAFSAC to the managing section of the organization and they establish quotas. Quotas are generally of two types. One is the quota that is based on scientific evidence. Admittedly, the scientific evidence is, much the same as here, not always as good as one would like. Nevertheless, it is the best that is available. So we have a quota that is based on scientific evidence. The other type of quota is one that is purely of a proportionary type, in which case a recognition is made that if a lid isn't put on it, that the whole thing might blow up. The quota that is decided by the powers that be, management people, is then allocated. And this, of course, is the difficult process, because the main regulation is by limited entry. Usually a very restricted number of licenses are issued. This process becomes very much a political process and in fact in many cases it is the Minister of Fisheries in Canada who is sort of the ultimate elected person, who with his department makes a decision as to how licenses will be allocated. A good example of this took place over the Labrador fishery in which case 11 licenses were decided upon as a reasonable number. The demand for those 11 was tremendous. There were 42 applications. So it was a political decision, basically. The only other thing I should mention is that we do break down our areas, the major areas, into smaller units. The smaller units tend to be not continuous with one another. There are reasons for considering the stocks of shrimps in each unit as separate.

Gaffney

What I would like to discuss now is the commonality that we have, realizing that there are political and economic differences among the various countries and states. We brought up several topics: limited entry, licenses, limiting processors, seasons, and how they are established. It appears that on the west coast we have a season that is primarily closed based on biological reasons for protection of the reproductive period. The opposite is true in some other countries.

How are quotas established? The cookbook method? Let's talk about the cookbook method that's being used. Mesh size restrictions? What studies have been done to support or reject the mesh size currently in use. By-catch restrictions...I would like to talk a little more about that. Norm mentioned log-books. Could we start with seasons? That seems to be the most common ground for each of the countries. I would like to hear some discussion as to how seasons were set and why they were established.

Dow

Historically, the seasons were established by what was actually the preferred time of fishing. As it's been pointed out in the Gulf of Maine, even though Massachusetts landed the first shrimp, the commonwealth was a very small producer until the end of the 1960s. The Maine boats were small trawler or converted lobster boats, somewhere under 40 feet in length that were used during the 1940s, until the fishery became extinct in the early and middle 1950s. So, I think it was that which promoted, in part, the interest of many fishermen in having a winter open season. The lobster fleet became involved with the fishery that was in conjunction with the silver hake fishery offshore. They were catching of course a measure of shrimp, many of which were 2-year-old mature males. This was what they were interested in landing. Processors were interested in having them up to a point because they felt they had to have a weekly amount of raw material that they could process, irrespective of its quality. I think those are some of the reasons why the season's turned up as they did. The present approach, the February to March open season is a compromise as the last one was, which went from January to May. There was a quota established of 4 million pounds which was not even closely approximated. So any definition of season I think will not be based on biological consideration as much as on fishing practices.

Gaffney

Dr. Skuladottir, I would like you to comment because you have a season which occurs during the egg release periods.

Skuladottir — I think it's just tradition. The fishermen don't like to change it. They're only fishing shrimp for half the year, and it goes to other countries' fishermen the rest of the year. I should have mentioned earlier that we have more restrictions than I have mentioned. The fishermen seem to make restrictions themselves and have suggested that they all start at the same time of day and would like to have two days off a week (laughter).

Gaffney — I would like to hear from the Alaska, Oregon and British Columbia representatives about how their seasons were set and reasons for that.

Lukas — In Oregon, the season is set first in 1964, brought about by concern from the industry. It followed on the heels of a quickly expanding fishery at that time, to 5 million pounds and they felt there was a need for protection. The biological and technical community neither supported nor had any comment on this proposal. As a result the commission decided to go along with it. Because the season, the closure was only four months and females were ovigerous for about three to six months, there was continuing concern. About eight years later, they decided to extend the seasons closure, it's now five and a half months. In California, they have a season closure of the same period, but theirs evolved from the fact that they fish on two-year classes of shrimp and they felt that there was a need for protection of the female shrimp during this period.

Boutillier — We don't have a season at this time. Our regulations are fairly new since the home fishery is new. We didn't feel at the time it was established there was any biological reason. Right now, we don't have one and we decided to keep it open later on in the season, probably to prolong the majority of the growth over the summer.

McCrary — The first season in effect was really in the state's oldest shrimp fishery in southeast Alaska. I believe the first season to protect females was established somewhere in the 1940s. I think some of the thinking behind that was not strictly a motherhood issue, but rather one of a fairly intensive fishery in some of the major producing areas. At least the idea that we needed to protect females during the time of year they were most heavily schooled and vulnerable, a target fishery. In my own work in southeast Alaska, I found that to be quite true, that in fact, females did tend to school perhaps during the late winter and specifically during the hatching period, more intensely than any other time of year. It was common for the fishermen to target just before the hatching closure on these schools of females. We found somewhat of a similar situation on a much broader scale in some of the Alaskan areas where in much of the year, the female population and some mature males were distributed somewhat separately from the major aggregations of the other age groups. Then in the winter period, probably because of environmental conditions, this distribution tended to shrink down somewhat and because of the smaller distribution, we felt that they tended to become more vulnerable and perhaps easier to harvest. So, we applied some of the southeastern knowledge to some of the Alaskan areas in general and thought that the first place logically to attempt to protect the stock that was reaching maximum exploitation was to try to prevent the over-harvesting or targeting of females. We thought one of the more logical times to do this was during the hatching period. But, we do know that females do tend to school for breeding purposes earlier in the year and they are ovigerous for a major portion of the year (six to seven months). In some of the depressed stock situations that the Department of Fish and Game has at least felt we were in. We thought that it was advisable also in those situations, to take even more of the fishing effort off the females by closing during the entire ovigerious period. Again, it's not just the motherhood issue, it's one of vulnerability and potential increased targeting during this period.

Gaffney: The next topic I'd like to talk about is harvest level. How they are set, why are or aren't they used. How are quotas set, modified in season, or why aren't they used. I'd first like to talk about why we have quotas... Dr. Horsted?

Horsted — First, I would like to add to the regulations discussion. In Greenland in the offshore fisheries we have a licensing system, for those participating. I think in the future we may see a tonnage class restriction for those participating in the principally free inshore fishery. To the other question of how quotas are set and introduced, they usually begin as a request from an established fishery. Especially, if the fishery is experiencing rapid expansion, there is a fear on the part of established fishermen that they will suffer if stocks decline because of new exploiting. The first request is a request for a precautionary quota, knowing that is that much easier to expand later than cutting back in a situation where the fishery has expanded beyond the sustainable level. It is also that much more difficult to cut back than it is to expand the whole idea behind precautionary quotas, which is to wait until we have more biological evidence before setting a quota. The present situation is that a good amount of data is available and it's not what I would call a precautionary level now. It is at the level which was discussed in detail, the idea being that we want to reserve for future production a spawning biomass. Whether that should be at one or the other level compared to the observed abundance or the observed total biomass could of course be discussed. But, the general idea behind this is not to reduce the observed spawning stock below a certain level.

Boutillier — I guess the reason for precautionary TAC has just been stated by Dr. Horsted. We were in a situation where in 1976 we had a boom fishery. There was no regulation on the fishery at that time. We had done previous biomass estimates which indicated we had good year-classes coming through. They also indicated some poor year-classes coming up. So, in 1977, regulations were imposed and precautionary TACs were set. Unfortunately at that time, we didn't have alot of the information used in yield models, or stock recruitment models mentioned throughout this whole session. So, our TAC was set at 42 percent of the biomass. Forty-two percent is a number we pulled out of, not exactly a hat, it's von Bertalanffy K, it's been used before as precautionary TAC. Finding natural mortality figures is rather a difficult task, you need a large survey on the stock before it's exploited, you get fishing mortality on top. Mortalities are also going to vary according to age groups and they're not going to be the same constants throughout. Right now, we hope our sampling program and our surveys are giving us some good information for cohort analysis where we might be able to get some total mortality figures, and some mortality figures from some of the nearby fisheries that aren't being exploited.

McCrary — Initially, our quotas were set somewhat on the basis of concerns not only on the part of biologists, but also by fishermen and processors that, in fact, our fishery was at least in the Kodiak area in the mid 70s was overcapitalized and expanding much too rapidly and that it was going to run away with itself. In fact, there was some need, it was felt, to put a lid on things. This was pretty much the way quotas were established, on the historic highs of that time. Perhaps unfortunately, those did turn out to be the historic highs, and pretty much for the rest of our history, it seems to be one of cutting back even further each year. The initial quotas were precautionary, we had little more than exploratory fishing information at the time. Then later on when we did get the first resources assessment surveys, there was the slow realization in the minds of many biologists that the magnitude of the minimum biomass estimates that could be generated in most of the bays we were assessing, simply couldn't justify the harvest levels we had at the time. So, therefore, the department felt that there was a need, in the face of decreasing catch per unit effort during periods when fishing gear was becoming more efficient that there was a need to adjust these quotas further downward.

Skuladottir — We've had experience with over-fishing in Iceland. First, I could mention an offshore area where we had seven processing plants and there was over-fishing, there were alot of young haddock and cod in the by-catch. This had to be closed down because of those two factors. Of course, the processing plants received no materials so they had to close down, too. It is very important that you have the same processing plants year after year. What we try to do is to make quotas that are the same every year. Therefore we don't like over-fishing. We try to work it out by the Gulland model that I mentioned. We intend to go into stock assessment work based on growth but then again we have to find some method of deciding the growth constants, K, and maximum length and I think it would be valuable to take the year-class strength into the picture. We haven't done anything about predator-prey relationsip, that would probably be an idea also.

Sandeman I think the important thing about establishing quotas and/or the next stage after quotas that we use which is effort restriction, I think one has to look at the objectives of this particular management strategy. I think this clarifies the whole matter when you do this. If you're setting a quota there are several strategies you can use in terms of what they're for. If we take setting a quota on scientific grounds because the managers of that fishery think a quota might be needed and they ask for advice, we set TACs, that's one side of it. And I think in the Canadian experience, or the eastern Canada experience, I could summarize this part of it by saying that if we are using an analytical model, and so far I think we have only on one occasion on a shrimp fishery been able to use an analytical model, we generally try to aim it at a pretty conservative type of effort. In fact, our reference point is F 0.1 value that is so often quoted, particularly among ICNAF countries. Usually, in shrimp fisheries, we of course, don't have sophisticated enough data to be able to apply any analytical models and we are left relying on particularly biomass type surveys and estimating standing stock sizes, either once in the year or maybe before and after the fisheries have taken place. In this case, we have done alot of heart searching as to what we should use as a translation between standing stock biomass and what the given quota level should be. We thought about the ICNAF situation and in fact, we're moving toward that. However, I think this transpired through a process of trial and error. The fact that the fishery we have had, the longest experience with which is the Quebec fishery at Seven Islands, we have found that through this trial and error process the fishery has remained relatively stable. Using a quota that consists approximately of 40 percent of the standing stock prior to the beginning of the fishery after the ice disappears. However, if one looks at some of the other objectives that management can be founded on, I think particularly one thinks of socioeconomic objectives, and in fact, in one of our fisheries at least, this is the Estamen Channel one that I am most familiar with, the quota translated into the effort regulation was established purely on socioeconomic grounds. In fact, the fishermen asked for it. Of course, the other side of socioeconomic grounds is the type of precautionary quota Sven Horsted was talking about, and I think this is the other very much overruling part if this in fact is the objective that you're following. Finally, I think there is the combination of both which of course, I think is what at least we in eastern Canada are aiming at. When the managers ask us for advice, we provide them with a series of options on the biological plane. They use them and mold them in with advice on the sociological, political and economical level with discussions with fishermen and processors to come up with a TAC, one that has been modified from the biological advice, tempered very strongly with these others and in many ways more important factors.

Gaffney: I would like to address the other side of the coin now: Why quotas are not necessary, primarily in Oregon, Washington and California.

Lukas: About the only thing I can say is that we have never felt there's been a need for quotas in our fisheries. We've had a good abundance of shrimp with good recruitment through the years. Our biomass estimates, our stock surveys, have tended to show the same rationale Washington now uses for their fishery also. I could comment briefly on the California situation. I think when they instituted the quotas they were intending to prevent a boom-bust fishery. They found that through the years the quota was not working well, they were getting differences of tenfold between their large and small year-classes and they felt that this was more of a detriment to the fishery than anything. The quota was abandoned in 1975 and since then they've had good production from the area. Regulation that now governs the fishery is based on what they call crash protection. If catch per unit effort drops to a pre-prescribed level, then they take steps to cut off fishing. Another criteria is the count per pound. When the number of 1 year olds reaches the 70 percent level, or a level they think of concern, then they take steps to close the fishery.

Sandeman I think there were two points there I would like to question you on. One concerns crash protection. You should have said that when the catch rate drops to a certain level, I think the key point is how is that level determined? Exactly the same type of question I'd like to ask you concerns the second point you made. When the authorities feel that a level is reached, the key point is how are these points determined, biologically or economically.

Dahlstrom Walt Dahlstrom, California Fish and Game. The criteria on catch per effort is 350 pounds per hour per single rig. We are going to develop a standard for double rigs also. We also have a criteria for small shrimp, that is 170 per pound or more than 70 percent 1 year olds in the catch. This is from sampling over a two week period. We feel that the protection of the 1 year olds is necessary because they haven't had a chance to mate as males or spawn as females for that year-class. With the mesh size and the season and these criteria, we hope we can manage the fishery.

Dow — I remembered after my initial comments we did have a quota established one year. I think this resulted probably from apprehension by both the fishermen and the processors that we were in for another extinction of the fisheries as had occurred during the mid-1950s. They thought if they established a quota that this might assuage the situation. The scientific committee at the time recommended a complete closure of the fishery. A short season was opened with a stated quota which was not reached or even approached.

Gaffney — I'd like to broach another topic and spend just five or ten minutes on it, then open the floor for questions. I'd like to know if you have a strategy for rebuilding stocks, stocks that are obviously depressed from historical levels. Also, what do you anticipate management measures are going to be in the future?

Lukas — Oregon does not have a specific strategy for rebuilding stocks. We've never been faced with that problem. In regard to future management measures, all I can say now is that we have drafted a management plan for the regional council to consider, and in that plan we have a number of measures and options. The team itself, has never really come to a consensus on the options we've established. I can't say right now what the feeling of the council will be when they okay the plan and decide what options are best for the fishery.

Horsted — First of all, I don't think we have seen what I would call a depressed stock to the point we would try to rebuild it. Dr. Smidt has said that in open fiord they were wiped out, but grew back again because spawning areas were in the neighborhood. If it should happen, that would probably be the strategy, to insure that as long as possible we could maintain whatever nature left us as a spawning stock. We have at present a depressed cod fishery, partly by foreign fisheries and partly by environmental factors. The advice at present is save what there is now of the spawning stock. We always assume that we can recover. This would be the advice, to keep that spawning biomass in the neighborhood.

McCrary I perhaps said far too little about some of the previous subjects, that had bearing on the current rebuilding strategy. I should have said a little more about the quota system at work in the western gulf. The Department of Fish and Game, for the most part, has not had a very systematic method of going from the minimum biomass estimate to the TAC quota. We have generally been dealing in the historic fisheries with situations where a quota was established after the first year or two of exploitation, and have generally felt it was necessary to adjust downward, in those situations because our minimum biomass estimates were also declining. But, largely we have dealt with a flexible harvest level range in terms of quota levels for larger bays. Ordinarily, the harvest level range is produced as sort of an indicator of what the fishery can probably expect to take during the course of the season. We look at preseason surveys' small shrimp problems, catch per unit effort during the season then again adjust accordingly, even though these adjustments are largely a system of collective value judgments that we adjust to perhaps the mid-point of the original harvest range. When we talked about some of the management strategies, I failed to mention a couple. We have had in two instances, one of which has been abolished and one that is currently in effect. Instances of established nursery areas which are closed throughout the season in an effort to take fishing effort off immature elements of the stock. We had one area established in the Kodiak region. There were mixed reactions among the fishermen and within the scientific community about that closure. It seemed that on one hand it could be argued small shrimp were protected, but you were also giving up a large area in which there were also large shrimp available. You could also argue that regardless of the closure, shrimp are migratory enough in that particular area that you could fish over the course of the season at some point in the bay and subject all the stock to fishing effort. So, it's my judgment that we could not demonstrate any good coming from that particular nursery area. It was kind of a thorn for enforcement and was troublesome to the fishermen in many respects, so we abolished it. There is one other nursery area in effect in Cook Inlet and Kachemak Bay where the area is closed year round. On to the subject of rebuilding strategies. We have had a couple of incidents where we've felt the stocks have been severely depressed, perhaps for a combination of reasons. Our response to that in one instance has been total closure. One bay on Kodiak Island was judged to be depressed both by fishing and environmental conditions. It has been closed for about six years now. The population has remained low, but stable, showing slight improvement. In recent times we have talked about rebuilding strategies that would reduce the fishing season drastically. It would be in the summer, in effect protecting the entire mature stock throughout the breeding and ovigerous period. Admittedly, probably a higher quality shrimp can be produced during the winter period, I think perhaps in the fall, when the population does actually achieve maximum biomass, but we still feel that because of the distributional features of the stocks in general, that the reduced season and protecting during the fall-winter period this provides less opportunity for targeting one segment of the population or another. Primarily from the standpoint that the schooling behavior in the summertime is less pronounced by any segment of the stock and also during the summer period, the maximum amount of area is inhabited, the maximum distribution is achieved. We've gotten rather mixed concern over the establishment of nursery areas primarily because they were hard to identify. One cannot make the statement that at all times of the year only small shrimp or immature shrimp occupy these areas. We have also been somewhat afraid that if we protect some of these more inshore grounds that typically do have large quantities of small shrimp, that we'll shift too much effort onto the mature portions of the stock and that we really have no guarantees that this is a reasonable alternative. So, even though nursery areas have been proposed rather early by the fishermen and processors, we've been reluctant to get into a management system that involves trying to enforce small inner bay closures and not knowing what effect that will have by shifting emphasis to the older segment of the stock.

Gaffney — Any specific questions from the audience?

Devers — I am a shrimp fisherman in Kodiak. I have a question for some of the people who have minimum mesh sizes in their areas. Has there been any study on how effective this is and what is the mortality of small shrimp going through the net?

Dow — The minimum size mesh established in the Gulf of Maine is based on a series, a rather extensive study of the selectivity of the various mesh sizes. I can't give you the information off hand, but I'll be glad to send you a copy of that report.

Sandeman — In my own experience, we haven't done any mesh selection work ourselves, but there is a lot of literature that has been worked on in the U.K. and Norway, I think. There are at least eight papers on selectivity in shrimp. Many of these experiments have used the covered cod end technique which means putting a cover over your cod end so you can see the size of the shrimp that are indeed getting through. When this has been done, there have been very little evidence of mortality from passing through the meshes.

Boutillier — I had a question for Sandy. Which fishery is managed on an F 0.1 and how is it working out?

Sandeman — I think that in the case of the Quebec fishery, we haven't actually managed it on that one, but that model has been used as part of the developing of the 40 percent that we have been using in other fisheries.

Boutillier — That's the fishery you have the most information on P. jordani, I was wondering if they've noticed any increased availability of ovigerous females as is found in P. borealis. I haven't noticed it that much in catches of small fisheries.

Geibel — I think what we have is less primary females with higher biomass.

Boutillier — I was just wondering if the availability of ovigerous females of P. jordani are variable through the year?

Geibel — We do tend to see them school up in the fall.

Boutillier — How about Washington, though? Ours school up in the fall too, but they're not ovigerous at that time, so they're still available to the fishery.

Northup — We have a fishery on P. jordani. Of course, our landings are quite small in the winter due to weather, I think that's primarily why we've left that fishery open. We don't have any documentation that the ovigerous females are more or less vulnerable to the nets than shrimp of any other kind. There are times, of course, when the bulk of landings will be ovigerous females...this isn't always true. I really don't have much concrete information.

Geibel — I think there's no question in anybody's mind who has followed the fishery for any number of years, that there are problems with using catch per effort by itself to estimate population sizes. What I did do with the biomass estimates, I got from cohort analysis was to compare them to catch per effort in California. The total number of points I used for 14 years, the correlations coefficient was .12 which is low. But, there are outlying points that threw us off. When we took them out we got a figure of .84. However, physically, you can't eliminate your outlying points and give any meaning to your correlation coefficient. But the outlying points were in 1968 when the pounds per hour were among the highest of any year until this last year, and the biomass estimates were low. In fact, this is the year when the quota was reached and the Department looked at the area the fishermen were catching in, it was a very small area. When they got outside it, the catches would drop. On this basis, they did not allow the fishermen to catch many more. In 1971, my biomass estimate was high and the pounds per hour were low, I don't have any way to explain this. Again in 1974, the biomass estimates were moderate and pounds per hour were low, I think there are any number of reasons for this. It does occur often enough that you have to be careful when using catch per effort. I think fisheries scientists and fishermen are aware of these problems. I'll say one other thing, in California where we're using catch per effort as a means of crash protection, our main concern is protecting a significant portion of the 1-year-old shrimp. If the catch per effort drops and it's by and large 2-year-old shrimp, we're not really that concerned. Our primary emphasis was on the percentage of 1 year olds being caught.

Robinson: I'd like to make a comment on this matter of catch per effort. Our fishermen's panel I think brought this up and rather sharply defined the problem. The problem is, I think, catch per effort, under normal circumstances in most years, is probably fairly indicative of the abundance of shrimp, particularly off Oregon, Washington and California, where you do not have the type of concentrations you may have in the bays in Alaska. Catch per effort can be strongly influenced by other conditions, including for example, economic conditions, imposed on the fishermen themselves. For example, in 1971, catch per effort off Oregon was also low, or relatively low, as it was in California. However, one of the strongest year-classes that we've seen off that region was present as 1 year olds on most of the counts. What was happening for one thing was the processors did not want to buy these shrimp. There were economic reasons, they weren't easy to process and they're not all saleable. As a result, fishermen were spending a lot of time hunting and pecking, trying to avoid 1 year olds and not very successfully I might add. Most places on the grounds they went there were a lot of ones. This somewhat artificially depressed CPUE. The second thing is that we had almost the same type of situation in 1965, also coastwide off the lower 48. There were virtually nothing but 1 year olds, also a strong year-class. That year, California and Oregon happened to have a survey where Oregon surveyed off southern Oregon and California surveyed off area "A" just adjacent to Oregon at about the same time. They came up with something like over 95 percent 1 year olds for a number in that area. The following year the fishery had 90 to 95 percent 2 year olds. The point is that catch per effort was quite low in 1965 also, but there were a lot of shrimp, a lot of 1 year olds without a whole lot of biomass. So CPUE does have to be handled very carefully. I think those two years were real exceptions, but there were about 10 or 12 others since then that have been fairly indicative of biomass.

Gaffney

I believe we are about out of time for this panel. I'm sure we want to get to the key question here so unless there are any questions I'll turn things back over to Hank.

IS THERE A NEED FOR MANAGEMENT?

Chairman:

Nick Szabo (Alaska Board of Fisheries)

Panel Members:

Robert L. Dow (Maine Department of Marine Resources)
Norm Abramson (NMFS, Tiburon Laboratory)
Svend Horsted (Greenland Fisheries Investigations, Denmark)
Paul J. Anderson (NMFS, Kodiak)
Chuck Jensen (Pacific Pearl Seafoods)
Fred Gaffney (Alaska Department of Fish and Game)

Other Speakers:

Alden P. Stickney (Maine Department of Marine Resources)
Steve Clark (NMFS, Woods Hole, MA)
Jerry Jurkovich (NMFS, Seattle)
E.J. Sandeman (Department of Fisheries and Oceans, Canada)
Øyvind Ulltang (Greenland Fisheries Investigations, Denmark)
Unnur Skúladóttir (Hafrannsoknastofninun, Iceland)
Oral Burch (f/v Captain, Kodiak)
Kenneth Parker (Alaska Department of Fish and Game)
Jack Robinson (Oregon Department of Fish and Wildlife)
Patrick Holmes (Alaska Department of Fish and Game)

Szabo — I'm Nick Szabo. I was glad Ken Westman pointed out that all the problems that fishermen have incurred in the past few years haven't been because of the Department of Fish and Game, it's been because of the Alaska Board of Fisheries, of which I have been a member for the past four years. It appears in my conversations that Alaska has a regulation system unique in the world, in that the actual regulations are made by a board. When Alaska became a state some 20 years ago, the legislature, in its wisdom, thought they didn't want the fish and game resources regulated by a bunch of scientists or bureaucrats. They decided they would have a board composed of the general public. Of course, the system has changed a little bit as far as the composition of the board in the last 20 years. Presently, it is a seven member board that's appointed at large by the governor from the public in general. Myself, I came to this area 14 years ago and derived all my employment from the local fishing industry. (Tape Erasure)

Dow — I believe you can realize from our conversations here the past several days, that I am opposed generally to regulation. I cannot see, as far as the Gulf of Maine fishery, a year-round fishery. I think this would be a waste of the resource. So, I can see the need for some limited management. I think it should be entirely experimental. I don't think it should be, as we have done in Maine. Some of our laws are completely assinine and have been for 100 years. But, and this is one of the problems you have to watch, once a law is on the books for 10 years, it becomes essentially sacred. Some foolish things can be done. In Maine, the biologists are ignored completely. The fisheries are regulated as a compromise between the industry and the legislature. And you know what a compromise is: Cutting the fish in half and saying, "Well, at least we'll save half the population."

Abramson — I think we have to differentiate between regulation and management. I think the fisheries of the world are way too heavily regulated and not too well managed. It's clear, too, that our methodology both for estimating parameters about the population and the models or devices we have to manage it, are far from perfect. I guess the question now is should we use the imperfect devices? Are they better than nothing? Is it better to err on the conservative side or the over-harvesting side? I just know that I'm not familiar with all the fisheries in the world, but there were alot of large fisheries that were pretty clearly over-harvested, they weren't carefully managed. For example, the California sardine used to have three-fourths of a million tons landed and now frankly nothing is landed, the Pacific mackerel in California, which was a moderately large fishery, fell to almost nothing, the Peruvian anchovy disappeared from a large fishery. Those are pretty clearly fisheries, I think, that were over-harvested. As the fishery built up, the pressure to harvest more and more did too. On the other hand, there's a fishery like the yellow fin tuna which probably was under-harvested for quite a few years, but there's still a viable tuna fishery. I think that's the sort of thing we have to look at: which side should we err on? If we eliminate one of these stocks, it's not clear that the stock will come back, because something may replace it. In southern California, probably the California anchovy occupied the place of the sardine. There's a large biomass, but it's not near as valuable as the sardine was. I think those are things we have to be careful of when we consider the question of management fisheries. I guess in a sense, fisheries agencies are responsible for managing them for the future as well as the present.

Horsted Immediately when I saw I had to participate in the panel here, I thought, why? Because I make my living advising and I wondered why nobody ever asked if there was need for management. So I don't think it's really up to me as a biologist, to say whether there is a need or not, but to just take these requests for advice and say, "O.K., there must be a need." I could speak as a consumer and then say, "Well, I want to be able now and in the future to buy reasonably good seafood at a reasonably good price." It may be necessary to have some management and regulations. I wouldn't like to give the impression though, that these regulations are actually initiated in a stricter sense by biologists. We are advising, but we're not conservationists that will try to, for any sake, keep a certain amount of shrimp in the ocean. We are requested by the fishermen themselves, by the fishing industry, by the public. We come in as advisors on these resources simply because they are living resources, supposed to be studied by biologists. If I may speak instead of the biologist,as the consumer, in certain areas there will possibly, because of social reasons, be a need for management. In my own area, it is the only type of living for many people. It is a necessity to have a management that will insure a steady employment situation throughout the year. That's one of the reasons we're not operating with seasons. It may be necessary, but as far as possible it's not used. It is necessary to maintain as far as possible, certain levels to keep resources, employment and the community going. So my immediate answer as a consumer knowing these conditions, is that there is a certain need for management.

Anderson: Dr. Horsted stated eloquently what really I had in mind to say myself. Like Chuck mentioned this morning in that first panel, we as managers and biologists really need to thoroughly integrate the economic and social concerns and ideas into our management strategies. I feel like perhaps in the past we have really fallen down on this, integrating these other concerns into our strategies and it's something that we are taking steps to remedy right now. As biologists though, we owe it to everyone that we serve to deal with the facts as we see them and can interpret them and deal with them as fairly and unbiasedly as possible. I think this really gets to the heart of the matter. As biologists, we have to make an assessment of the situation, provide this to the proper body that can integrate these factors, social and economic, into the administration, and then come up with something that will satisfy management for the common good. Another thing I'd like to indicate real quickly. I think when we're talking about economic factors and such, we should try and maximize our ability to harvest our resource economically. We're faced now with restraints on energy resources, allocation on personal and other resources. This ought to be adequate reason to do so.

Jensen

My position is probably well recognized. I don't feel we need too much management. I feel that there are certain management techniques that should be used. We obviously talked about this previously this afternoon and over the past 4 to 6 years. I'm not totally sure that anything can manage a shrimp fishery. I think that, I am reminded of the T.V. commercial that says, "Don't mess with mother nature." Whether closed seasons, protection of juveniles, protection of egg-bearing females, is going to assure us of a continued shrimp stock is beyond me. But I, as a processor, would certainly support and advocate much more liberal regulations rather than management techniques right now, than what we should have in future. The things that come to mind right now are closed seasons, protection of juveniles, dispersal of fleets, avoiding pulse fishing, allowing the fishermen to develop new areas, giving more control to the industry in the sense of quality and the type of shrimp received. I think that management is necessary, but that it should be of an absolutely minimum nature.

Gaffney

The panel which I was involved with...the management strategy one, the thing I found interesting was that in all areas there are various degrees of regulation that are in place. So apparently, the people in those communities, as well as the biologists and the managers, assume that management is needed on shrimp resources. I think too often there's a tendency as a biologist to want a complete data base, to be able to analyze this, interpret this correctly and make the right recommendation to the managers. Most of the time we don't get that. So if we are going to have error, let's err on the side of conservation. Realizing that precautionary harvest levels are established, precautionary limits and other regulations are established. I think it's a little too simplistic in the ecosystem to assume that fishing has little impact or is not the contributing factor in the decline of many of these resources. Many of us tend to look for one single answer such as a single environmental factor that may change--temperature or current circulation. Certainly these are very important, but the ecosystem is tremendously complex and just a single factor standing by itself is much too simplistic in my opinion to look at and explain away all the variations. That's the bulk of my feeling.

Szabo — Any questions from the floor?

Stickney — I've heard a lot of proposals for various kinds of management discussed in these sessions and I've heard the distinctions between regulation and management, but what I haven't heard yet is any kind of proposals for management that are postive. That is, something that can be done for the stock without putting restriction or constraints on somebody or some group. In sport fisheries and wildlife, very often positive steps are taken toward management--restocking, habitat improvement and things like that. It's not putting restraints on anybody. Is there anyway management of this type can be included in management of shrimp?

Dow — Yes, by selective breeding, make the shrimp anadromous.

Horsted — A considerable part of my years spent in fisheries in my own land, has been developing the fisheries: finding the resources and advising in a factual capacity on the number of boats and so on in a developing community. However, there is a limit and when you reach that limit, of course, then you have to make a decision. Then also from outside you get an enormous development in distant water fleets. Then you are forced to give advice on what is best for protection and so on. Then the regulations start, not for regulation sake, but to prevent damage.

Clark — The subject is, "is management necessary?" I fished shrimp in 19 countries and 17 states over the last 30 years and I personally have never seen the degree of management that I see here. Excuse me, regulation. I have never seen so much regulation in any fishery as exists in the Alaska shrimp fishery. Neither have I seen the availability of product as we have here. I personally have never seen such a small percentage of the biostock exploited. Now, if I take all I hear, which I do not, that the shrimp stocks are depleted to the degree that I have heard they are, if I assume that, which I do not, I still hold the position that if we ever are going to say these shrimp stocks are depleted, increased or whatever, we're first going to have to make a survey. We have not, at this time, done so. From that time on, maybe we can say they have increased or decreased. If I assume that this is true, that these stocks are depleted, then in the world's most regulated fishery, I must say that you have failed.

Szabo — One of the questions we were trying to arrive at as a final goal of this workshop, Fred spoke to it a little bit, is can man have a positive effect through regulation by either sustaining a shrimp population over a longer period of time or rebuilding a shrimp population, or if we hadn't had the management Bert referred to, would the thing have crashed sooner or later, if you assume that it has crashed. Can man really do anything about it, is one of the questions we're trying to discover an answer to.

Jensen — I think Jerry McCrary mentioned this morning one of the bays on the island we've had closed for six years, and in seven years the population has not changed much, there's been no legal activity that we know of in there, very little illegal activity. We've also got bays developed this year that weren't barren, but were certainly not known as producers, that all of a sudden produced more than 50 percent of the total landings for the island. We have other areas that we've moved in and out of that were formally large producers that aren't producing this year and didn't produce last year. We have areas on the island formally produced at a particular time of the year and did not produce at that time this year. Reports that we get now indicate the shrimp have moved in. I think my point on less regulation and more management is to locate the existent stocks and allow the industry to fish in them. It's inconceivable to me that we could lose in a matter of months literally tens of millions of pounds of shrimp. I am reminded of one time on the Marmot Bay area where our quota was 15 million and then it was cut to five million. They did a survey 30 days later and pulled it back up to 15 million, based on an increase of biomass by 100 percent in a period of 30 days. This does not seem to me that a strict management regime is necessary for the management of the shrimp industry.

Anderson — I would like to address both Chuck Jensen and Bert by saying that we have, in the Bering Sea, a very good example of an essentially unregulated pandalid shrimp fishery. During the 60s, the Japanese and the Soviet foreign distant factory fleets harvested a great deal of shrimp in this area, northwest of the Pribilof Islands. From all indications from our biological surveys, which I will be the first to admit, I feel some of our survey last summer was inadequate in a sense that we didn't cover as large of an area as I wanted to. However, the fact that we did not find any appreciable commercial densities of shrimp kind of indicates that the assessment the biologists put on the area is holding pretty true. The fact of the matter is that area has been open for domestic exploitation ever since the extended jurisdiction legislation went into effect, and we've only seen one small landing from that area so far. I'd like to deal with the facts, and the facts are, we didn't cover a huge area like we should have. But in a small area we still assessed it as being a depressed stock. It's still open for domestic exploitation. If somebody wants to go out there and locate the stock for us, we're waiting. We haven't seen it. And here's an area where that wasn't going to happen. It will take more study certainly, but this is just an indication in an area where there really was no management. I just wanted to throw that out for possible discussion.

Gaffney — I'd like to continue on with that. That's a particularly scary thing on the shrimp resources in Alaska. The example of the

Bering Sea, that was severely hit by exploitation and has not bounded back. We've had an area closed on Kodiak Island that was a very high producing area. It has not bounded back. I don't think we have seen the bottom line yet on our stock assessment of various bays around Kodiak Island and along the Alaska Peninsula all the way up to Unalaska. Where the bottom is, I don't know. It's my personal feeling that the regulatory regime put into effect, in other words the guideline quotas were too high when they were instituted. I think it's a problem of too little too late. At that point when the fishery peaked out, especially around the Kodiak Island area, in 1971-72, I believe the quotas were in excess of what the maximum sustainable yield was. I can demonstrate this from data, from facts that we have. They started survey results for the past year, we are looking at allowable catch calculated then same way it's done in many parts of the world using Gulland's technique, of about 25 million pounds for the entire westward area. So I don't think that we're out of reason or out of bounds with the management decisions that have been made in the past few years. Also, I think if the fishery were allowed to go totally unmanaged, that is, with no quotas, I think it would have collapsed much more rapidly. It was over-capitalizing very quickly in the late 60s, early 70s. I think that by restricting the catch, the community enjoyed several more years of reasonable economic return on this fishery. It's my feeling that it would have collapsed regardless. I think you did over fish it too heavily and too quickly. Of course, that's conjecture on my part.

Szabo — Thank you, Fred. I'd like to discuss that theory. Chuck?

Jensen — I'm not going to refute that theory. However, I feel very strongly that many of the restrictions that have been placed on the fishery in the westward area, have been at least partially responsible for the collapse. I think that I can use the pulse fishing in various bays as a good example. I don't think that's good for the stocks. I don't think that assigning a quota to one bay is good because everybody has to rush down there and get his share, his percentage, of that quota in the particular bay. I'm not sure you're right. We may not be in a collapse, we may not be facing one right now if it isn't a total collapse, in our eyes, not in the eyes of the rest of the world. But on the other hand, we don't know that we couldn't still have 100 million pounds a year coming out of here if we had allowed our fishermen, our catchers, to go out and disperse themselves throughout the areas rather than being concentrated in one. All I'm really advocating is that we tried a system for the last several years, and so far it's had detrimental results to the fishery. We haven't built up any stocks. Most stocks have been reduced. I think your estimate of 25 million pounds as a total biomass for the area may be right. But it also could be 450 million pounds. The environmental conditions that we've had around Kodiak Island in the last 2 1/2 years, and I'm sure out the peninsula, have had to have some severe effect on the stocks that we've normally fished. I feel reasonably sure, in my mind, that this has been the cause of the lack of results in the surveys in the known areas that we've gone back into. I don't know how we can explain the fishery in bays this year that have never been producers. I don't understand why I get reports from fishermen, fishing crab pots no less, that tell me there's all sorts of shrimp down at the south end of the island. Now what I'm saying basically, is that the shrimp have migrated or moved either for natural reasons or environmental reasons. I don't think our present management regime allows for that potential.

Szabo — Thank you, Chuck. It's quite apparent that everybody is pretty much frustrated by these shrimp not being available to the gear anymore, whether that availability is a function of the abundance of the resource or just because the shrimp have dispersed through the water temperatures or currents or some other environmental factor. What I guess we are still trying to agree on, although I'm not sure we can agree, is to come to a consensus on whether we've been on the right track or contributed to this nonavailability of shrimp or is there a better way to do it? Norm?

Abramson — I think answering your question would be presumptuous of anybody right now. If I were a fisheries manager in Alaska, I would be interested in seeing some kind of experimental management set up. Perhaps some areas could be managed under a given regime and other areas on another, and then be observed. As a biologist, I would certainly be interested in seeing the results of that to point out just what we can do with management and what is necessary. Actually, tests like that have never been made on a comparison basis.

Clark — I'd like to reply to two of them. First, Paul talked about the management in the Bering Sea and posed a hypothetical question. Suppose I take my boat out to the Bering Sea and indeed find a beautiful stock of shrimp and bring it up? Unless somebody puts a plant on the barge and brings it out there, nothing. If he does and if it is indeed unmanaged and unregulated, I will find enough shrimp to satisfy me and my boat. Because I don't need the quantity of shrimp you have around here, I only need the lack of regulation. In answer to Fred, in those years where we had peak production he must admit that there were much fewer regulations at that time than there are now. I think he will have to agree that one of the greatest tools for stock assessment is catch per unit effort. I will only say that if he puts me in a position where I can only fish here at this time and there tomorrow, along with everyone else, my catch per unit effort is not a sound thing to base anything on. If you're going to use a catch per unit effort, you have to use it in a much more real situation than this, or you have to base your biomass estimate on the whole Alaska area, not just those portions in which they catch shrimp.

Szabo — Jerry, did you have a comment?

Jurkovich — I recall during our shrimp separator work up in Oregon around Port Oreford which at one time produced a great deal of shrimp. I can't recall the year, but I think Jack can probably bear this out and tell you more about it. But it was suddenly a desert with nothing. I think it remained that way for a two or three year period. Suddenly the shrimp reappeared and it's a viable producing area now.

Szabo Any further comments from the floor or the panel? Fred?

Gaffney I'd like to pursue the suggestion made by Norm having ultimate management strategies by area. I think this is a reasonable way to go. The only problem I see is perhaps Nick, you could be instrumental in this, we're obliged by the state constitution to manage based on a maximum sustainable yield concept. If we do a test tube case in a bay, allow totally unregulated take, it would give us an idea of what the bottom line would be. All of us have wanted to know this strictly from a laboratory approach. So we're dealing with the real world. If this were possible through our regulatory procedures to institute something like this, we have an example of what a closed area does to a resource, perhaps an example of an area much open for exploitation year round to see what happens in that particular instance. Perhaps two or three other types of management strategies could be instituted or directed by the Board of Fisheries?

Szabo I can respond to that a little bit. The board presently, I can think of about seven or eight legal actions that are pending against the board for porported mismanagement and misuse of the resource and that type of thing. I would assume that you always run the risk that someone who is very environmentally oriented would or could file suit against the state for mismanaging something by just leaving it open and not trying to protect it. However, I guess if you could justify it by saying you were trying to provide more information as far as whether you can have any positive effect by regulation and management, it might be worth the risk. At least it may lay some of these things to rest once and for all. I think it's probably worth exploring. Perhaps people in different scientific fields might be able to develop some type of alternative system. Chuck?

Jensen I think one of the things that has not been brought to light here, and I'm referring to a conversation that I had with another processor less than a week ago. In talking about the lack of shrimp around the island. This is not the first time that's happened. It happened in 1973 or 1974, maybe earlier. I do know we've gone through this before, as an area. The thing that saved us at that particular time was that the fishermen had the ability to go someplace else and look for their product, which they did. If we're going to look at alternate management systems, which I am all in favor of, first of all it has to be an area big enough to do what we have to do. Secondly, it can't be a small bay. It has to be a large area, it has to be a producer and it has to go in with certain restrictions. I think the thing we ought to look at for restrictions are closed seasons, protection of females during the egg bearing season and protection of juveniles. With those two or three limitations, in a large production area for a long period of time, meaning two or three or four seasons, would conceivably then give you an idea of what is the best management tool available at the present time. One of those will admit possibly that we're doing the best job we can. I'm sure that the people that are managing it and the scientific work are doing just that. Its results and their interpretations that I have a problem with occasionally. We're looking for solutions to a problem. I think we all are. I certainly, as a processor, do not under any circumstances, want to run out of shrimp. We have too big of an investment here. I don't think any of the fishermen want to run out of shrimp. Certainly the management people don't want to run out of shrimp because when we run out of shrimp, we're all out of jobs. But if we're going to look at this alternate management system, let's do it on a scale that will do us some good.

Szabo Mike?

Mike — I just have one comment Chuck, and I guess that refers to some of the things that have been mentioned before. It was referred to about this fluctuation that's occurred in the past around the island in regard to availability of shrimp. When I first went to work for Jim Majors, 14 years ago unloading boats, I think there were only two plants operating in town. I think there were a total of 10 boats, the largest of which was a wooden vessel about 70 feet long with a capacity of 100 thousand pounds. There were only three major areas at that time, going down as far as Chignik was unheard of. Not to mention now going down to Pavlof Bay and Unalaska and the Pribilofs. I think the problem is you can't compare the situation now directly with what was in effect 13 or 14 years ago, because we have had here at one time 60 to 70 boats operating, modern steel double rigged vessels that have undergone tremendous development both in gear technology and electronic locating technology. We're taking a greater risk now than we did before. Before we could afford a 12 month open season with little regulation. Now we're faced with high powered fleets that can roam from one end of the Gulf of Alaska to the other. I think that's the problem we're faced with now. There's more risk involved now by even going to experimental area.

Holmes — I would definitely concur with that. I think some of the things being discussed by the panel that perhaps need a little bit better breadth in our stock assessment and our predator-prey relationship studies. In many panels we've talked about trying to look at all the factors in our judgment, I think in comparison, that we can look to the California and Oregon fisheries for *P. jordani* for analysis techniques but as their experience related to *P. borealis*, I think it's a case of apples and oranges: they both grow on trees, they're both eaten by humans, they're both collected by hand, but there are differences ences in life history that effect that type of fishery, it's management. I think also we need to explore all the contributing parameters. I address this point to the discussion of the Bering Sea and Ugak Bay. The

Bering Sea first. In that discussion of development of a management plan, it appears that yes, there hasn't been any great change or great rebuilding. Some of the catch per unit effort data, most recently received from the Japanese, indicates a very slight trend, but I doubt there's strong correlation there. I think the one thing that should be addressed in terms of the P. borealis fishery in the Bering Sea are the considerations of environmental factors, how they change through the years: are they the same? do they effect recruitment? Or more importantly, do they effect by-catch? Not only by-catch with P. borealis, but of P. borealis. It has been estimated by the Japanese that that's one percent of their cod fishery, pink shrimp. If you extrapolate that out, it very easily exceeds what the calculated maximum sustainable yield for the Bering Sea should be. I think that in the case of the discussion of Ugak Bay, saying that it has been closed for six or seven years and hasn't shown a sign of change, perhaps in the light of looking at the fact that all the other bays on Kodiak have crashed and this bay is still holding a biomass of 2 to 4 million pounds might be an indicator of a positive effect on management.

Sandeman — I have one general comment I think. We've been talking throughout these last few days about whether a management system that is in place has failed. I think that's what it comes down to. We've been asking why, if it has indeed failed, as most people here seem to think it has, we've asked the question why? The answers have been either environmental or over fishing. I am simplifying very much, of course. I think the question that I raise now, having listened to the comments of the last few minutes, is whether if, under the constraint of maximum sustainable yield, your management system was bound to fail. We struggled with the maximum sustainable yield for 15 years or so and managed finally to throw it out. It's only since we threw it out that we've managed to see stocks increase again. I think the experience throughout the world in many fisheries is that if you try to manage with maximum sustainable yield, you are bound to fail.

Szabo — Why is that?

Sandeman — I think there are many reasons for it. Most of the reasons have to do with the fact that we're talking of a single stock. You cannot maximize a single stock when you are actually catching many others. I think that is the fundamental reason, but there are others.

Szabo — Can you expand on that? What kind of management would you use?

Sandeman — I am probably not the best person here to answer that. I suspect that I should hand it over to Svend or Øyvind Ulltang there. It's a matter of trying to find some level, some critique which will allow you to set a yield, a quota that will allow stocks to build. The way we tackled this was the so-called, if you're using an analytical model, the F 0.1. If you want to go into detail on that, it's a level which through time has shown that you will get stock rebuilding. If you want more detail, I'll have to pass to Ulltang there because I'm really not a top-power stock assessment biologist, at least not now.

Szabo — What I get from what you're saying is that the harvest levels that we set were probably too high, that they should have been lowered. Is that what you're saying? Yes? O.K.

Gaffney — That's the question I had. If you're going to toss out maximum sustainable yield concepts, I don't disagree with that. Unfortunately, that's our mandate now. If you're going to attempt to rebuild stocks then you're going to be harvesting less than equilibrium yield out of a stock in order to build it back again. So we're talking about a significant reduction in current stock in order to build it back again. So we're talking about a significant reduction in harvest levels.

Horsted — I agree with Dr. Sandeman, that the maximum sustainable yield concepts are probably not the best ones for several reasons. I think that he pointed out the major reason. Another reason was that we didn't see it for a time, there was some lag time in response of course. Then there was the problem that in order to manage at a MSY level you need a strict system of control and very good statistics, all factors must be right, as you thought they were. So, there are some uncertainties about the levels we are setting. One of the reasons for leaving the MSY system was also economic and social reasons to keep a stable economy in fleets and so on. We had not seen any re-building before that was left. We were finally asked to advise on levels other than the MSY level. Most of them at levels below that, and some questions were asked of scientists there wanting alternative options for MSY. Objectives were set by the commission then we were asked to investigate those. I do not feel either that capability in science of stock assessment, so if you want to ask other persons to whom you have addressed your question to comment, I would like that.

Ulltang — I find myself in a rather difficult situation, being asked why you shouldn't use maximum sustainable yield concept and you are discussing management of shrimp stock. If you had asked me about this for fish stocks, long-living fish stocks, it would have been much easier to explain. We have experience from fish stocks that by trying to fish at a lower rate to stabilize a high spawning stock, then you have both a stable yield and you can get better assessment because you are not so dependent on good estimates of incoming year-classes. I'm afraid (if I am wrong you must correct me) we have not yet experienced from the management of the shrimp stock where we have seen it gradually built up as a result of this management. But I would agree with Sandeman that one should probably, not trying to use the maximum sustainable yield concept, try to estimate some at maximum values for example from yield per food crop when setting TAC's. I would more tend to the approach which has been chosen for example in the west Greenland fishery, where we have, as a stopping point, looked at the spawning stock and how much that should be reduced. The problem is, of course, that we have no data that gives us a strong indication of how much a spawning stock can be reduced without reducing the recruitment.

Skuladottir — I was going to say that maximum sustainable yield is not the same with a different model. If you are using cohort analysis, that type of catch equation, that type of yield per recruit, you are getting already, flat tract maximum sustainable yield. It seems you can increase that almost indefinately if you have high "n" values, and you always get maximum sustainable yield. Whereas, if you use the Gulland model this is a very well-defined maximum. We try to keep below this maximum, so as to be on the optimal side. We have had experience in one place where there was over fishing and we cut the quota down by two-fifths, approximately. When we had a new, very strong year-class coming into the fishery, we got a tremendous build during this one year.

Szabo — Any other comments from the panel or audience?

Anderson — I think it's quite obvious from our conversation this afternoon that we're going to need a great deal more study conducted on pandalid populations before we'll be able to make the right assessment of population conditions. I just think that if I can just paraphrase what we've said, we're just going to need a heck of a lot more in terms of research before we can determine some of these important questions; what the level of shifting should be and how the stocks fluctuate through time. I think we're only now technologically getting to the point where we can really study these things adequately.

Abramson — I'm not surprised that we didn't reach a definitive answer to the question for this session.

Szabo — Any more comments from the panel? Any questions from the audience? Oral?

Burch — I would like to see one scientist or one biologist who can take a shrimp and pitch him back in. This is all supposition. The only way you're ever going to learn anything about these animals is not like you're doing it now. You fish three days of the year in one place. Those three days could be a total bomb. I can go around this island, and I hate to say how many years I've been fishing here, but you can name any bay you want to and I can tell you whether you'll catch shrimp there. So far we've heard all this discussion and it's a lot of baloney. There's a simple reason. I have pictures here of bays where you can catch a year long quota and just a little while later you won't catch a shrimp there. It's tides, currents or whatever, but the only way the surveys are made now, after just a few days of fishing, nobody is ever going to understand what the shrimp are doing. There's nobody on this earth who can sit at this table or in an office and figure out where the shrimp are going to be. You can make a total one way--say 20 thousand pounds which doesn't sound like much with regular catches of four or five tons. We have alot to learn about shrimp, and I have been fishing strictly shrimp for over 20 years. Anybody in research or anybody in this room who says that they know what a shrimp is going to do in the next two minutes or in the next day is just a nut.

Parker

I've fished the north end of the island most of my life since I've been up here with my dad and uncle. There isn't much, well they've got a quota on the north end of the island, but it is always open because there's not much shrimp caught out of there. At times there are a lot of shrimp there, but it's all in one big area. I'm like Oral, I think that the quota bay-for-bay is really wrong, because you have the whole fleet in one bay. On the north end of the island, that many people don't know about that because it's a hard area to fish. It's open right now and there's no shrimp fishing up there. I think there's been two boats up there in the last couple of months. One boat just brought back a trip of shrimp out of there, just like he does every year at this time. The shrimp were there and there's been no heavy fishing there, because most of the people can't make it that far north. They go in there and they can't find anything, so they leave it alone. But people that work there, if I were shrimp fishing right now, I'd be able to make a living off it up there because I'd be there all the time. What I'm trying to say is that if you let the whole works open up and fish it, the problem will work itself out. If the shrimp go downhill, people will stop looking for them. They'll move out, go somewhere else, and the pressure will be off. When they go back up, more boats will come, and you can regulate it from there. But I don't believe in any quotas in any bay.

Gaffney — I believe it was yesterday, perhaps it was Dr. Sandeman, alluded to marked recapture experiments that have been done on P. borealis. Does anyone have a successful way of marking and then recapturing P. borealis? I'd like to hear a little dialogue on that because that is a key issue.

Horsted — Yes, I do think we have some experience in that. I have done some experiments tagging at a time. Actually, we did control it by having these tagged shrimp in a shrimp pot at the bottom, bringing them up daily to feed them and down again to see how they reacted. That was just a small steel wire around, between the abdomen and carapace. That was at a time when the state of Greenland had only one factory in the fiords so it was rather easy to recover the tags. I don't think that the tagging itself is a critical factor. It is the detection and probably recaptures that are a great hindrance in using these for assessment of fishing mortality. They may give you indices if you have good specific statistics or are close to the fishermen. But I doubt that by recaptures here they could be detected at the proper time. I doubt you could use any of the values, they may be captured but I doubt it. You wouldn't be able to tag much of the stock, whereas, our catches are small enough that we can tag a good percentage of our stock. But we do not have good results in Disko Bay where they are peeled by machines. Recapture rates there are about one to two percent. In the former experiment I was turning about a ten percent recapture rate.

Robinson — I think Sven's right. A few years ago in Oregon, we became interested in trying to mark P. jordani to follow migration, try to better define which stocks were which.

Before we did that, we decided to set up a laboratory study to develop a method. The methods were used were largely those from the Gulf of Mexico on pandalid shrimp where successful marking experiments have been done, with a very much larger recovery of shrimp which is caught at low volume and handled by hand. We were able to mark these shrimp injecting dyes. The problem was that in capturing shrimp to bring into the aquarium, for every shrimp that was brought aboard, perhaps a 200 pound trawl, 2,000 shrimp, we were lucky to get 20 or 30 that were viable. Now that was one problem. That would say that to mark these critters you would have to mark an enormous number. I think the bottom line is if you are able to mark enough shrimp to get a meaningful recovery, you might not have any shrimp left. That was our conclusion and we gave it up.

Szabo — Thank you, Jack. Any further comments?

Dow — I would simply ask about the capture of shrimp for tagging or otherwise marking if you tried traps rather than trawls?

Szabo — Jack, do you want to respond to that?

Robinson — I think I can because another research study we did was with traps, although for a different purpose. Very likely that would considerably increase the percentage of survival. But the other problem, on the west coast and in Alaska, would be recovery. I think that would probably be hopeless, with the amount of shrimp brought in, and machine peeled. You still have to mark an incredible number of shrimp, that, too, I think with pots, you still wouldn't be able to mark enough shrimp. The capture rate would be too low.

Szabo — Any further comments? I'd like to thank all of you for turning out for the panel. I'd also like to thank you for the opportunity for me to take part in it.

EVOLUTION OF COMMERCIAL FISHING GEAR AND TECHNIQUES

Chairman:

Gary Loverich (Nor'Eastern Trawl Systems, Inc.)

Panel Members:

Jerry Jurkovich (NMFS, Seattle)
Oral Burch (f/v Captain, Kodiak)

Other Speakers:

Bob Moss (Homer)
Patrick Holmes (Alaska Department of Fish and Game)
Junior Cross (f/v Captain, Kodiak)
Unnur Skuladottir (Hafrannsoknastofnunin, Iceland)
Bert Clark (f/v Captain, Kodiak)

Loverich — This panel might be anti-climatic after all the heated discussions on management problems with shrimp. We are going to discuss the evolution of commercial fishing gear on the west coast and in particular in Kodiak. I happen to be lucky enough to have been in the Kodiak area for 12 years. I remember what the shrimp boats were like. If you were to point out the one most significant change in the fleet in the last 12 years, I think you'd have to say besides the volume and the catch it was the presence of the double rigged shrimp trawl. I'm going to have Oral Burch say a few words about how the double rigged trawl evolved and why it's such a good vessel and possibly what he sees for it in the future.

Burch — I had the first stern ramped double rigged shrimp trawler up here. I was fortunate to have this. It worked to the extent that I could go in 200 fathoms of water and start the winches up. Sixteen minutes later, I have 10, 20, 30, 40, 50 thousand pounds of shrimp on deck. Sixteen minutes later that gear is back on the bottom fishing. I started out the hard way with a single rig, we spent a lot of time repairing and when we did get a good tow, it took up to five hours to get it aboard. It's 16 minutes now. Let's put it up to a half hour. But we can get it off the bottom, get it on deck and get it back on the bottom. As you can see, you gain alot of time. This is a gear panel, and you're looking at the world's expert. I've got years and years of experience.

Loverich — A few years ago I came from the Seattle area, most of the boats down there are single rigs. We heard quite a bit about the double rigged boats and how well they were adapted to any sort of fishing. Apparently, there's no vessel existing that can follow an edge as well as a double rigger. This is besides being able to haul the gear quickly. Certainly this is one of the most important things that has developed up in this area, that is that fishing on the edges and following the edge in an area where single rigged boats cannot compare. I'm sure there are a lot of people that would back that up. I'm going to say a few words about the development of trawl gear, the gear that goes in the water and that nobody sees. The early trawl gear used on the west coast consisted mostly of Gulf of Mexico style shrimp trawls. They were flat heads and balloon nets and wooden doors. This gear is pretty much well known all over the world. Now the first strong impetus to change the gear came from the need to eliminate pinheads and also to eliminate the high incidental catches. In the shrimp fishery off Oregon, you don't want to forget that the commercial fishing has always had an ever present desire to improve fishing gear. The first significant change in net design was supported by a good effort from the Bureau of Commercial Fisheries in Seattle when that unit existed. In many cases the Oregon fishermen were looking for somebody to do the research for them and the BCF was quite responsive. They did a considerable amount of work on shrimp behavior and net behavior and then around 1971 the emphasis of that unit was changed and shrimp research was brought to a standstill. With the introduction of the double rigged shrimp vessel sometime around 1970, the trawl gear development went on almost exclusively by innovative fishermen financed by their own economic gain or losses. There was very little support from government units. During this time, however, the initial research done by BCF was used to direct the development of trawl gear into two basic types of nets that are now used almost exclusively, from California to Alaska. I don't mean to say there are only two types of nets, there are many variations of these two basic types. It depends on localities and the net shops that are building the nets and on personal preference of the fishermen. The first type of net is the box trawl with headrope and footrope essentially the same length. The net can be fished upside down or right side up, there's no difference. The other type of net would be the higher opening balloon net. Because of the pure catches of shrimp in the Kodiak area coupled with the fact that the shrimp are vertically distributed off bottom, we don't really know what the distribution is, but somewhere between zero and 30 feet has been allotted shrimp. It may go up higher than that. I don't know if anybody has any information on that. But due to the clean catches and the vertical distribution, the high opening balloon net was developed in the Kodiak area. By high opening I mean compared to four or five years ago then a good portion of the nets would open from 12 to 15 feet high. These are big nets with openings to 20 feet. The Oregon box trawl proved to be popular in Oregon and Washington mainly because down there they have smelt mixed with the shrimp. It's a very difficult and laborious process to separate the two. So, the box trawl having the headrope the same length as the footrope allowed cleaner catches, at least that was the idea to start with. Rather than the higher opening, the box trawl is more popular in the Lower 48. We also saw a trend that these box nets would get more vertical uplift than the old style. Because there were many Oregon fishermen attracted to the Kodiak fishery in the early 70s and because they return to Oregon with their Kodiak experience, there has been a great amount of mingling of gear between Alaska and Oregon. The development of trawl gear had gone hand in hand with the evolution of the double rigged boat. I would believe the double rigged is one of the most efficient shrimp boats in the world, the one that is fished here in Kodiak. Lately, in the past few years, there's been a down trend in net size from very large to very small shrimp nets. I think probably the major reason for it is the fact that the small nets are easier to control, easier to repair and they probably perform better than the larger nets. In the long run, they are more consistent than the larger ones. I don't know if it's been indicative of the change of behavior of shrimp. That's a possibility. Now all during this last ten years of rapid gear development, there's been a considerable knowlege of the behavior of gear and reaction of the shrimp to it. This is very important, to know how the shrimp react, then you can build the gear specially and I'd like to discuss a few of those points. If you are to look at a shrimp net as an engineered object...one of the most prominant characteristics of the shrimp net is its large drag.

Anytime you have a net with a large drag, it takes a lot of power to tow it. You tow it fast. If you compare a fish trawl, which is a relatively low drag net, to shrimp trawls, the shrimp trawls are towing quite slow. As the gear developed on the west coast, getting bigger and bigger, because the power of the vessel stayed within a fairly small range, the speed of the net went down. In fact, probably the average speed was between 1 1/2 and 2 knots. What this large drag means is that the nets don't follow the bottom real well. We noticed, guiding some of the nets, that just a small increase in speed would cause a large increase in drag and this increase in drag would lift the doors the net and everything as much as 15 feet off bottom. It would stay up there until the speed was again lowered. I'm sure most of these shrimp fishermen already know this. What that does, whether it's a sampling net or a commercial net, is put the net out of the reach of where the shrimp are anytime that the currents increase or the vessel is churning or moving. Because the shrimp nets have a relatively large drag they require large doors. One other thing about the high drag in the nets is that the water going into the net has to come out. Most of it comes out right in front, the intermediate or just before the crowding of the net. This causes the nets to balloon. Lately this has caused considerable concern about mesh size, that this is a place where there could be a significant amount of shrimp that escape. If you take smaller nets as have been developed in the past two years, the ballooning back toward the intermediate might not be, I'm certain it is not nearly as severe as on the big nets. This may be one of the reasons why the smaller nets seem to catch just as much and maybe more of the shrimp as the large nets. The second thing we might notice about shrimp nets is the shape. The shape has a lot to do with the way the net behaves relative to the bottom. For instance, the box net which has equal head-rope and footrope is hydrodynamically unstable. It doesn't really know where it wants to stretch. This has been proven by several observations of mine, diving around the nets, and also by a lot of the fishermen who fish the box nets. At one time the box nets seem to want to dig and another time they seem to want to fly. They are very sensitive to rigging. Fishermen have got around this problem by rigging them very closely to the doors, so that the doors force the box nets to stay. In one instance where we were diving on the box nets, it was digging just like a bulldozer in sand and mud coming up. Five minutes later it was flying 5 or 6 feet off bottom. This happened to be on a double rigger, that switched back and forth between a balloon net and a box net, looking at the two, and the balloon net just stayed about 18 inches above bottom, continually throughout the tow. The box net was over there oscillating up and down. Certainly the shape of the net has a lot to do with how often it tears. If you have a very short, blunt trawl, alot of times it can eliminate quite a few of your tears, because there is so much strain in all the little individual meshes. I would like to say something about mesh size. It is possible to build a shrimp net so that all the meshes along the side are closed, closed so tight that the pinheads have difficulty getting through. It's also possible to build a shrimp net so all the meshes are wide open and all the pinheads go out. Ian Ellis, NMFS in Seattle, has been for the past few years working on mesh size and observing what the optimum mesh size is for Pink shrimp. Fortunately, there hasn't been much published on it and nobody seems to know much about it except me because I helped him. I spent many hours helping him measure mesh sizes and going over the results, particularly in the back end of the net where the meshes tend to be wide open, he found out that anything, mesh sizes with an aperture between the knots of greater than 1 1/4 inches, it was possible to lose as much as 50 percent of the marketable shrimp (15 millimeter carapace length). He did several cruises on this and he had quite a bit of good results. Unfortunately, he's gone now so we don't have anything else to say except that his results figure that 1 1/8 inches on the mesh size was probably the optimum for retaining shrimp. I think this is a fairly significant thing because, the other day we were talking about sampling nets where the assumption is that you catch everything that goes into the net. And here, on the other side of it they're coming out again. So there's really nothing that takes this into account. Like I say, the work hasn't been concluded either so we're just drawing a simple conclusion. One other thing that I should mention is the development of shrimp doors. We find that because the large nets had to be towed relatively slowly we knew we had to have a large spreading force because of high drag. But when you tow heavy doors slowly, they tend to tilt over on the bottom. I can cite many cases where we were diving off shrimp trawls and we saw how the doors tipped over on their sides. It's kind of exasperating trying to get out of cold water and you have to come up again and start over. The shrimp fishermen developed a large steel v-door which turned out to be quite light compared to bottomfish doors and I would say that's one of the characteristics of the shrimp doors, that they are light. In Oregon you see a lot of square doors. They are hydrodynamically more efficient than an elongated door although I don't believe that's the reason they went to square doors. Most shrimp fishermen are interested in getting vertical height out of their nets. By taking the surface area, redistributing it high, and close coupling the net onto the doors, you get a higher vertical opening. The problem was that when you do this, the higher you go with the door, the more surface area you get out of it, and that increases the drag. You can also overspread your net, so your Oregon fishermen decided to use wooden slats. It gives the same surface area over a bigger area, allows for increased height, but the slats between the doors reduced the effect of lifting areas of the doors, reducing the drag. So in Oregon you see a lot of doors that are square and wooden with spaces between the slats. I'd just like to say a few things about the latest developments of shrimp gear. I don't think we've seen the last of the shrimp gear development. It's like I said before, we're seeing smaller trawls with longer shaped bodies and they are more responsive to the maneuvers of the boats, they follow the bottom much better and because they have longer bodies there might not be this mesh size problem at the end of the intermediate where the shrimp try to get out. I've been involved in seven nets that are different in the last few years. Those nets are using 3 inch mesh up in the front body of the net. They're being used in this area and so far, everybody is quite pleased with them and haven't notices any reduced catch. Now the first thing to be said is that this refutes what I just said about mesh size, that with a mesh size larger than 1 1/4 inch you're losing 50 percent or a significant number of your shrimp. But that's only in the back area of the trawl. Up in the front area, all of the netting is pretty much parallel with the direction of motion. Apparently, the shrimp don't feel restricted enough or they don't hit the netting enough that they go through. It's only in the back of the net. So I would say from the preliminary results with these seven nets, it's a possibility that we will see larger mesh sizes in the front end of the net. Such a development would result in decreasing the drag, better fuel consumption, a net that follows the bottom much better, and it would result in a net that's much easier to repair. Because a double rigged shrimp dragger is so efficient, doesn't mean that the single rigger is extinct. There are still people who use single rigged shrimp trawls. Whatever the reason, a lot of the skippers have come to me and asked what could be done to raise the efficiency of the single rigged trawlers. We looked at the total system and tried to pick out what its strong points were and develop those into a net that would be more efficient for a single rigger. We believe that we've done it, although we don't think we'll ever increase the efficiency to the point that the double rigger has. So we've seen a development in the single rigger of not using the standard anymore, or some of them aren't. There's good results. You increase catch and reduce down time. I would say that pretty much sums up the new development over the past eight to ten years. I don't believe we're going to see a lot more gear development until there are higher shrimp runs in this area. The Kodiak area seems to have had the fastest and the greatest gear development. It seems to be a center for gear development. Until we get a lot of boats and you get feedback on the different types of gear, it's hard to pinpoint any certain type of gear as the more efficient. I'd like to talk about sight scanning sonar...Oral, did you have anything to say about how the use of sonar has effected your operation?

Burch

The main thing I see in my adaptation of sonar is navigation. In other words, I don't see shrimp and I don't tune it up to a high enough pitch that I can, say, see a salmon. But I will be towing along and I come along an edge and this is hard, that sonar squawks and I veer away from it. I am fishing for bottomfish now instead of shrimping, the 4 1/2 inch mesh against the 1 1/2 mesh seems to be tender, very tender. The bottom-fish I've fished for 20 years and I probably know it like the back of my hand. Suddenly, in the last month and a half I've torn it on ten drags. The sonar never said one word about it. It's on good bottom, I knew it was good bottom and I didn't have to pay any attention to it. Well, all of a sudden I come up with...one of the last repair jobs was 200 pounds of 4 1/2 inch mesh, 42 or 54 thread...it would cover this building I'm sure. Just repairing the bottom of the nets, and I towed for 10 to 15 years. I could have put that same square footage of lead, I could have had a lot of shrimp nets, you just don't tear them up. But whether it is due to the large mesh size or what, I don't know. The sonar is a beautiful tool, it is priceless. We did without it, but I'd hate to go back to fishing without it after getting used to it. I can't say the sonar helped me catch any shrimp, definitely, I cannot see shrimp on it, but I can see the bottom. I've been towing Alitak down here for more years than I care to remember. We have a tow down there within half a mile of the beach. We just got the sonar and I knew it was a totally safe bottom. I come along this edge and the sonar starts chuckling, I thought, "Boy, this is sure an update." It was telling us it was a hard bottom, but I didn't have enough brains to respect what it was saying. Right now, if that thing chuckles, I don't go there. As far as finding shrimp, I've only used it for dragging. I haven't had an opportunity or a set that sensitive. I know you could use it for fish, but I haven't. All I want it for is to check the bottom. With it I can go along as safe as sitting at this table here.

Loverich — Now we're going to have Jerry Jurkovich from NMFS, in Seattle, tell us something about how the original research which resulted in the NMFS sample net that's used up here to sample the shrimp stocks.

Jurkovich — I have worked in a pure research unit with the National Marine Fisheries for the last 15 years. We first got involved in the shrimp work in trying to eliminate the incidental fish taken with shrimp. We got an idea from reading a paper on work with a fish-shrimp separator trawl I believe begun by the French in 1963. The idea was to pull a net along the bottom with a bigger net that would allow shrimp to go through it. It has a loose flap at the bottom, and a pair of cod ends installed, one over the other. The shrimp would attack the web and go through the 2 inch mesh and the cod end at the top and the fish would go through the bottom one which the web had blown away from and end in the bottom. But we made the panel and proceeded to Newport, Oregon and Harold Jones I think is sitting here. We went out on his vessel, he volunteered his time and money and we proceeded to the grounds with my boss, Richard MacNeely. When we got to the grounds, Harold let two men take a vacation and we each had to take a winch. We were listed as crewmen. That installation proved to be a total failure. We ended up picking fish like crazy until midnight every night. MacNeely looked at me with his glasses down over his nose and said, "Jerry, there's got to be an easier way." We had trawls given to us that were 2 inch mesh that were entirely too large to retain shrimp and they were the Gulf of Mexico style shrimp trawl. On this trawl we installed five pieces of lead that were 9 feet square, 3/4 inch mesh on the outside. But we put them in so they were hung on 4 1/2 foot square. It produced a blister that looked like a B-29 bubble, one forward on the side panel, one in the bosom, right in the middle, and one aft just forward of the intermediate on the side, one on the top of the forward intermediate on the side and one back on the cod end. In these panels, towing it several dozen times, we averaged 31.2 shrimp that passed through this 4 1/2 square foot panel into the blister on the front side. The one at the top in the bosom, we had 14 shrimp and at the side of the body, back just ahead of the intermediate we found 66 shrimp and in the top of the cod end we found three shrimp and in the back portion of the body we found six shrimp and we deduced then that 87 to 92 percent of the shrimp escape the trawl sideways as opposed to vertically. As a result of this, we used the same trawl, removed these panels and inserted a small mesh panel down the entire side, which terminated into a small mesh cod end at the side. We did the same at the other side and left the original cod end in the middle. So we had three. We dragged this one and we found that we got 66 percent of the shrimp in the side with a little contamination from some small hunter sole, but we lost 33 percent through the center which you could either tie or close and in the center one we got up to 4,900 pounds of shrimp, trash and shrimp, maybe six to eight hundred pounds of shrimp. Then we repeated this by removing those side panels and putting a cod panel over the entire top of the trawl and we only achieved about 20 percent shrimp that came out through the top and I presume that most of those escaped through the back portion of the net where it was stretched down just ahead of the intermediate. Then we constructed several styles of separator trawls. One of which we called a wing separator trawl which is a wing, and it's an inner panel of 2 inch mesh with a slight taper to it, and another panel that would retain the shrimp that was in 1 1/4 inch mesh. These terminated at the aft end of the body and at the bottom of the net we had a small trash chute that would allow fish to escape out through the body. With this net we achieved 95 percent clean shrimp. We had very few small fish but at the time there were no smelt. Smelt are a difficult problem. We did remove most of them. This trawl had one short-coming. When you got 2,000 to 2,500 pounds of shrimp, it quit fishing. We could have probably made adjustments with rim lines and such to fish more, but coupled with this, we modified a 57 foot Gulf style shrimp trawl in which we removed the overhang and hung equal length footrope and headrope and installed a 2 inch mesh panel across the mouth, a small crab chute, and adjusted it with floats and chains and we got it to work beautifully and we got that 92 to 95 percent level when we tested it. We started the first experiments in April, the weather was sunny and the water clear. We had success comparable to others in the area. We thought we had the answer. We went back and removed all the chains that we'd stuck on there and distributed a nice balance of chain around the footrope. We went back in June and the weather was 90 percent cloudy and rainy and it failed miserably. We'd make a tow for 500 miles and we'd catch 2,500 to 3,000 pounds around us. So we couldn't figure out what happened. I read all the data from the first trip and finally I said the only difference is the weather. MacNeely agreed that was the answer. He said we evidently had a high degree of light penetration even though it's 90 fathoms of water in April, the shrimp were tighter to the bottom and as a result we did profit. When we came back this time the degree of light penetration was less, the water was less clear, so the shrimp must be higher than our trawl would fish. Then we decided to try a new study in which we constructed an 8 foot square aluminium frame and we divided it into three vertical segments and six 1 foot intervals up and down. Each of these 1 foot by 2 foot segments had an individual panel web about 9 feet long which fit into it perfectly. We towed this with 15 fathom dangling lines and a set of doors as we dived on it in shallow waters and saw that it was stable. It fished within 3 inches of the bottom. We took this to the grounds and we proved that we needed a higher ladder so we put a 6 foot extension in the center and it still remained stable. We got shrimp in commercial numbers to a height of approximately 8 feet. They were scattered throughout the upper layer but there's a lot of good skim-off from this experiment. Once we were able to put a separator panel over one panel and two panels and this proved conclusively that with a separator panel the shrimp had to pass through before they could get into the individual bag, it would make catches of 80 to 85 percent of what the open ones would get. Regardless of what position it was, in the middle or to the sides.

Second, we found that pinhead shrimp were found mostly in the bottom 2 foot increments. Third, we attached a tickler chain in the front to assess their value in the fishery. At no time whether it was cloudy or sunny--when it was cloudy then the shrimp would be dispersed throughout the ladder network in the individual compartments, but they were found mostly in the upper ones, when it was sunny there would be more at the bottom. The tickler chain did not drive the shrimp further up the water column, it just doubled the take in each individual bag. So that's what we found out about the tickler chains. The fact that with the separator trawl 80 to 85 percent. As a consequence, we made a trawl that was about 50 feet on the head- and footrope and the vertical opening achieved through diving was about 10 feet. I think the horizontal spread was 28 or 29 feet. We tried everything, but we couldn't get it to work. Then we turned it over to Captain Ben Hodge running out of Newport, I believe that was 1970. He caught from 750 to 800 thousand pounds of shrimp with the trawl. He had some real amazing methods. He would go with the tide and come up with a 3,500 pound tow and then he would reverse and go back up current and get 500 and reverse and go back again and catch 3,000, so he finally just started running and changing direction. It worked effectively. Two of these trawls were made by a supply company in Seattle for two firms in Alaska. I don't recall the year, but they were approximately 70 feet. They had a 2 1/2 inch separator panel. It was put together wrong but I fixed it when it was up here for a Kodiak Community College panel. We tried it in Kelson Bay and caught 1,500 pounds of sidestriped shrimp and only 17 herring. The boat along side came up with a bunch of fish, looked like sole. Anyway, this net was tried later following the removal of the separator panel, this net is now being raised to approximately 18 to 20 feet and proved to be a very effective fishing net. So, this gave us the idea that maybe this box side trawl was the way to go. Later, in a 61 foot trawl, we used a 1 1/4 inch mesh throughout. We had a 240 mesh deep side and the little trawl fished at approximately 12 1/2 feet in the center and 10 feet at the sides (TAPE BROKE).

Jurkovich ...I think you should use them. (tickler chains). I don't think it drives them higher in the water as proven by the vertical distribution sampler. It just gets them higher up in the air so you can scoop them. I think that they are a necessity. We found from diving on them that most of them that are installed right at the wing tips can even be 3 inch chains hung almost vertically, then turn almost a square corner, and just a small area of the thing is working in front of the bosom. To circumvent this, we put the chain in in that manner, it was 5 feet shorter than the footrope and then we tied a line about 5 feet back in the terminal front end of the thing across to the other side, 5 feet back and determined what was optimum, then we cut a piece of chain and inserted it in there. No matter which direction we dragged that, the tickler chain was about 75 percent efficient picking them up so that was another offshoot of the experiments. I'll summarize this by saying there's many new trawl concepts improved on since 1961. They were bigger trawls, even the small ones are very effective. I think it would probably be more effective here than down there from the standpoint there's alot of bad light here in the winter time and the high opening version would be the one that will be the most efficient. Trawls are very complex. I find that we make our own nets as opposed to having them made outside, because there was too wide a spread between ordering the same net from one distributor to another. We thought that we saw a higher degree of continuity if we made them ourselves. Now we've gotten to a point where we nitpick when you sew a wing onto the body, arguing whether that half-mesh ought to be included in the wing or included in the body. I decided that it didn't make any difference, we'd just leave it in there. Mesh size is another thing I would like to mention. I really don't think it is a necessity in the shrimp fleet because nobody would use a real small mesh size. What it really boils down to is the ultimate design of the trawl. We could design one so a 3 inch mesh would catch pinheads. Although shrimp taken with fish are a much higher quality than the others. I heard a shrimp packer in Oregon say he had to keep them on the floor two days longer with shrimp taken from a separator trawl, because it was harder to get the shells off. They do hold up better if fish are not in them. Even though this is not applicable in a high volume fishery as you have in Kodiak, maybe some day it will be something just to fall back on. Ian Ellis, of National Marine Fisheries Service, has conducted four years of experiments on optimum mesh size, I think he came up with 1 1/4 inch mesh, probably permits the escape of up to 50 percent of 120 to 140 pounds per hour. Gulf style trawls do not open properly in the sides. They're really bad on any mesh size when these panels are maintained at the present level of height. I think later evidence proved that if you make a real high panel, even if it's placed in an erroneous way, it will open up. That's all I have to say. As I mentioned, this is passé, we haven't done anything on this since about 1972.

Loverich — I'd like to ask if anybody has a question, Bob?

Moss — I'd like to make a real short contribution to this panel. References made earlier in one of the panels to diversification in the fisheries. This area I am touching on is somewhat different from what's been covered so far. We can expect transition of vessels from one fishery to another that will probably increase as time goes on. It's not unreasonable to expect that vessels, other than full time shrimp vessels, specialized in shrimp fishing will move into shrimp fishery when other fisheries are not available to them. However, there is certainly no question about the double rigged vessel being the most efficient type. There will be a certain number of single rigged vessels that will go into it. There are some modernizations that occurred in those in addition to Gary's comments on the nets. This is in the form of handling the shrimp trawls aboard these vessels. One that has taken place recently is the application of a track vessel to a shrimp-type fishing without the use of stern ramps, yet handling the trawl over the stern. Crab vessels with the tracks on the gear-matics that allows a trolley to be run up and down the length of the boom can be used in conjunction with a reel to handle the trawls over the stern without the trawl actually being dragged aboard. The reel can be flush mounted on the stern without being raised and without a ramp being cut into the vessel and the loss of a stern. The trawl can be also handled and split just the same way as it would be in any other single rigged method with a splitting and shucking of the shrimp by the use of the reel and then the reel bring into the split, bringing the split into the stern, lifting it up then running down the boom with a trolley and tripped on deck. This would have a definite application and is in use in weather where it is almost essential for the vessel to be headed into rather than laying in the trough, the usual method a single rigged vessel has for handling a trawl. In areas with a high crab pot concentration, it allows the vessel to remain underway and it definitely cuts down on the amount of gear that's fouled up in the crab fishery.

Loverich — Anymore questions? Pat?

Holmes — I'd like to ask your further comments on a couple of points that are important to us as investigators and managers. I'd like to go through both of these points, then leave it to the panel for discussion. The first of these is in terms of sonar and its effectiveness in increasing fishing power for shrimp draggers. I think that while, as Oral has noted, that side scanning sonar doesn't help you find shrimp, but you know the type of habitat you are in and it lets you fish much closer to the margins, much closer to the edges where there are fair concentrations. This combines with the ability to fish newer areas in which the towing areas are much smaller and much less defined. Many areas that we fish have very poor charts and this allows the shrimp fishermen to work in new grounds within a bay system that haven't really been highly developed before the sonar which allows better navigation in areas of hazard. The reason I mention this is because this, in my opinion, would allow for a significant increase in fishing power. This effects our analysis of CPUE, in that I think we saw that when we do go to side scanning sonar that the individual skippers rates did pick up. I think as a general observation that the side scanning sonar seems to have an appreciable increase in the ability of a vessel to more timely locate shrimp and locate shrimp in more marginal areas that haven't been fished before. My other comment, or question is in terms of Jerry's and Gary's comments on handing of meshes. This is the point that came out in our local shrimp study group in which several times we talked about mesh size restrictions as a possible solution for taking pinheads or in focusing on specialty fisheries, other species of pandalid. It was pointed out by Oral and several of the other people having a considerable gear-net experience, that we could academically define mesh size restrictions But unless they were really gross, that even though some of Gary's research work shows you can hang a net very precisely and determine what escapement you would have with certain mesh sizes. But unless those nets are hung precisely to those same specifications, you're not going to get the same escapement of smaller shrimp. If a person wishes to hang a net in a different manner than the ideal specification, then you could possibly end up getting an entirely different escapement than you would if you were trying to have a minimum mesh size that would afford protection to small shrimps. Could you perhaps elaborate on this line?

Loverich

On the mesh size I think that as an example, if you had a very blunt trawl, one that came, one that was very blunt in the flow of the net, then those meshes would be wide open and taking the maximum area possible to let the water through and that shape is a square. Because if you go to a net that's got a much longer, tapered body, than those meshes don't open up. They open up more like diamonds so you have less area that the shrimp could go through. On top of that, when your netting is very blunt to the flow, the shrimp hit it, and may hit it several times. They might go through again. Whereas, with the long, tapered net, the shrimp may hit it but they don't have a tendency to be forced through. So, in that respect, regardless of mesh size, as long as there's not a gross difference in mesh size between the two conditions. I hope that answers your question.

Holmes — I think it does. What I was trying to get at was that with mesh size, unless you had some very stringent definitions to go along with those mesh sizes, my personal interpretation is that it would be very difficult to really enforce and to get the desired result on a mesh size restriction unless you really accompanied that with a dock side sampling program. Simply saying that a 1 1/2 inch mesh will be required for all vessels you'd almost have to say depending on the size of trawl, how the meshes might be put into the net. You then could very well end up taking a large portion of the smaller shrimp year-class that you might not desire.

Loverich — One thing I'd add is that we have made nets out of 1 1/4 inch mesh and nobody likes to work with 1 1/4 inch mesh because your fingers don't go through it. I would say it would be natural that as long as you're catching shrimp with 1 1/2 inch netting, nobody would want to go to 1 1/4 inch because it's too hard to repair and work with. Junior?

Cross (NO MIKE) — Personally, I'm using the 3 inch mesh and I wouldn't mind seeing it go to 1 1/4 inch.

Burch — When we originally started way back when, we used cotton nets. Nylon nets were not any good. We used 2 inch. We'd drop it in and you'd have a shrimp peeking out of every window. We'd tow for a few minutes and you couldn't tow longer, you'd be dragging the deck practically through the water. I think you killed more shrimp than it caught. The 1 1/2 inch...there's no mesh size here and Junior has his preference and I think he hit the nail on the head, that you shouldn't deliver small shrimp. But a 2 inch mesh, especially the cotton, you'd just put it down for a half hour you couldn't tow it longer.

Then you'd bring it up and by the time we cracked that split three or four times you wasted more shrimp than you caught. The 1 1/2 inch mesh, over the last 20 or so years, seems to be a happy medium.

Jurkovich — One time we made a big box trawl for mid-water. The only web available was 1 1/2 inch. We developed a way to put it in so we could open the meshes. This was made primarily as a mid-water net. It was sent to Kodiak and people were able to come up with tows of 20 to 25 thousand pounds. That net never came up with more than 5,000. Of the 5,000, I bet there were 60 count per pound shrimps, they were huge, it just screened everything through. As a result, we got that one back in Seattle and we never used it again. If you use nets like that which open properly with 1 1/2 inch, I'd venture to say you wouldn't get one shrimp.

Cross — NO MIKE

Clark — I'd like to throw in here something about double trawls as opposed to single trawls. I'd like to mention what to me is the biggest asset, it's ability to turn right around and run right through the same spot again in a period of five minutes. The other thing I want to mention is about the speed of the trawl. This is a function of the engine rate. (NO MIKE). The other thing was the effect of the balls in dragging the net down. One way we got around that is simply to use bigger balls because the residual drag on the ball is proportional to its circular area. So going to lighter balls is perhaps one way to troll faster. NO MIKE FOR REST.

Jurkovich — I could say that we put divers into trawls and wherever the diver carried a current meter into the trawl and wherever the trawl was under water he could measure a current. When he got back to the intermediate areas, he could measure nothing. Nothing would show up on the meter at all. Maybe the thing has a sieving effect at that point. That dissipates the water a little easier over a longer area. Maybe that would effect the drag a little bit and make it spread a little more.

Loverich — I think one comment on that is we had about three or four different cod end lengths that we use in our fish trawls and none of the lengths make any difference on how far the net opens. Something else seems to be happening here.

Skuladottir — Have you tried bobbins on the nets?

Loverich — I had bobbins on my list and skipped it. There are some Kodiak draggers that use bobbins on their shrimp trawls. I'm not quite sure if they use them to go over rougher bottom or just to reduce the tears in the net. It's not really too prevalent.

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