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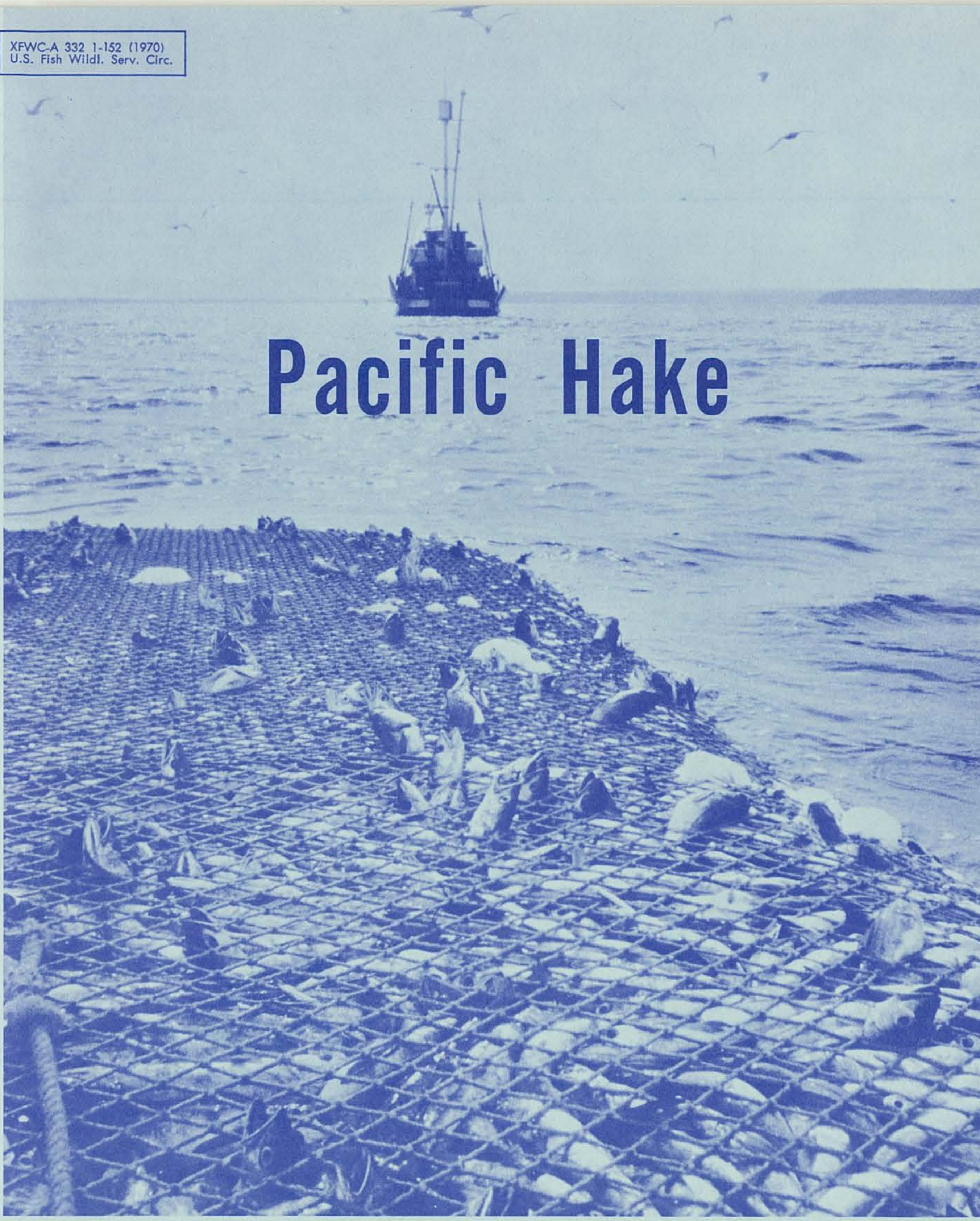

Pacific Hake

UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

Circular 332

Cover—A large catch of hake breaks the surface behind a trawler.

UNITED STATES DEPARTMENT OF THE INTERIOR
Walter J. Hickel, *Secretary*
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for Fish and Wildlife, Parks, and Marine Resources
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Pacific Hake

Circular 332

Washington, D.C.
March 1970

FOREWORD

Hakes, densely schooling, codlike fishes, are a valuable resource for many of the world's commercial fishing fleets. In 1967, hakes contributed about 1.6 million metric tons, or 3.4 percent of the world marine catch.

In recent years, the Pacific hake, *Merluccius productus,* has been studied extensively by the Department of the Interior's Bureau of Commercial Fisheries. The resulting information on harvesting methods, economics, biological considerations, and aspects of utilization will assist both the fishing industry and management agencies in wise and profitable use of this resource.

This Circular provides a ready summary of present knowledge of the Pacific hake. Included are papers describing the worldwide hake resource and operations of the Soviet hake fleet off our Pacific Coast.

Leslie L. Glasgow

Leslie L. Glasgow
Assistant Secretary for Fish and
Wildlife, Parks, and Marine Resources

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Importance of the Worldwide Hake, *Merluccius*, Resource

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ABSTRACT

Aspects of hake taxonomy, biology, and world fisheries are reviewed from the literature. Of the 11 nominal hake species, 6 represent a substantial segment of the total gadoid species landed in the world and play an important role in world fisheries economy. The historical development of the fishery for six species of hake is discussed.

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Published February 1970.

INTRODUCTION

Hakes of the genus *Merluccius* (fig. 1) are represented in all coastal areas throughout the Atlantic and Pacific Oceans, except the northwest Pacific, and their increasing importance in the world fisheries has resulted in a proliferation of literature describing the biology and the fisheries of various species. We have reviewed pertinent literature with the aim of summarizing the general biology of the commercially important species and the development of current hake fisheries.

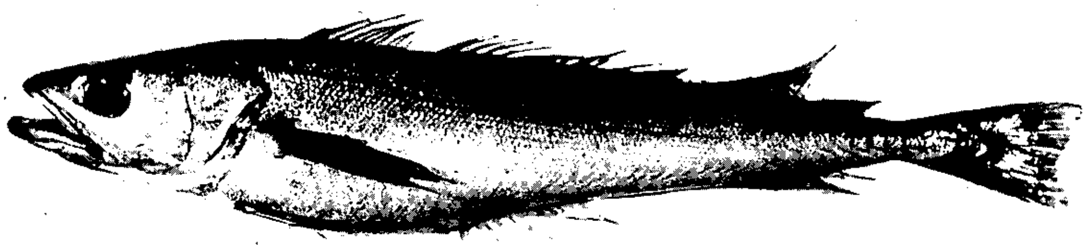

Figure 1.–Photograph of an adult Pacific hake taken off the Washington coast (BCF staff photo).

TAXONOMIC STATUS

Of the several commercial codlike species taken from the cooler waters of the Northern and Southern Hemispheres, the genus *Merluccius* has rapidly become important in world fish catches. Marshall (1966) provided the most recent interpretation for the systematic position of merlucciid fishes, distinguishing family Merlucciidae from other groups of anacanthine fishes: *Melanonus*, Muraenolepidae, Bregmacerotidae, Gadidae, Moridae, and Macrouridae. The reader is referred to Svetovidov (1948) and Norman (1966) for other systematic reviews of merlucciid fishes.

Norman (1937) recognized seven species of worldwide hake:

1. *M. merluccius* (Linnaeus) - Europe, North Africa
2. *M. hubbsi* Marini - Eastern South America
3. *M. productus* (Ayres) - Northeastern Pacific
4. *M. gayi* (Guichenot) - Southeastern Pacific
5. *M. bilinearis* (Mitchill) - Northwestern Atlantic
6. *M. capensis* Castelnau - South Africa
7. *M. australis* (Hutton) - New Zealand, South America

Ginsburg (1954) increased the number of species to 11 by recognizing 2 previously described ones and describing as new 2 more. He recognized *M. albidus* from the northwestern Atlantic, formerly in the synonymy of *M. bilinearis;* and *M. angustimanus* from the central Pacific, formerly in the synonymy of *M. gayi.* He described *M. magnoculus* from the Gulf of Mexico and M. *polylepis* from the tip of South America (the latter had been recorded from South America as the New Zealand species *M. australis*).

Including and subsequent to Ginsburg's (1954) work, descriptions have been made of species, subspecies, and independent stocks of hake off the European, African, and North American continents (see Cadenat, Doutre, and Franca in Cabo, 1965). Cabo (1965) recognized and provided a summary of 8 species and 10 subspecies of hake throughout the world.

The taxonomy of *Merluccius* remains unclear. Svetovidov (1948) pointed out that by existing standards of evaluation, species referable to Merlucciidae lack the distinctive characters of other gadoid species and even subspecies. He stated that, within the limits of their recorded range, forms of this genus apparently are not isolated from nearby forms. This lack of isolation helps to maintain a close systematic identity, and in reality there may be fewer than three worldwide species (Baxter and Pruter[1]).

Lacking the necessary evidence to evaluate published work, we arbitrarily follow Cabo's (1965) summary, with minor modifications (table 1; fig. 2).

Table 1.—Species of genus *Merluccius*, their common names, and area of occurrence

Species	Common name	Area of occurrence (fig. 1)
M. merluccius	European hake	Europe and North Africa (including the Mediterranean and adjacent waters)
M. capensis	Cape hake (Stockfish)	South Africa
M. bilinearis	Silver hake	Atlantic coast of the United States and Canada
M. albidus	Offshore hake	Atlantic coast of the United States
M. magnoculus	--	Gulf of Mexico
M. hubbsi	Argentine hake (Merluza)	Argentina
M. polylepis	--	Chile and Tierra del Fuego
M. gayi	Chilean hake	Chile
M. angustimanus	Panamanian hake	Southern California to Panama
M. productus	Pacific hake	Baja California, Pacific coast of the United States and Canada
M. australis	New Zealand hake	New Zealand

ASPECTS OF HAKE BIOLOGY

The biological similarity among hake species is as remarkable as their alleged systematic closeness.

SCHOOLING BEHAVIOR

Hake tend to form large schools over the Continental Shelf and are found usually near the bottom during daylight (fig. 3). Their appearance in schools appears to be related to availability of food. Hickling (1927) elaborated on the availability of European hake as related to euphausiid, *Meganyctiphanes norwegica,* concentrations. Alton and Nelson (1970) have also reported on the availability of Pacific hake related to the species of forage organisms.

DIEL MOVEMENT AND FEEDING BEHAVIOR

Hake undertake diel vertical migrations in which they move away from the seabed at night and return to the bottom near dawn. This migration is associated directly or indirectly with feeding behavior. Hickling (1927) reported that European hake move off bottom at night in apparent pursuit of euphausiids and other food organisms, which themselves undertake nocturnal migrations. Rattray (1947), Davies (1949), and Jones (1967) report the same behavior for cape hake; Bigelow and Schroeder (1953) and Leim and Scott (1966) for silver hake; Angelescu and Fuster de Plaza (1965) for Argentine hake; and Poulsen (1958) and Vestnes, Strom, and Villegas (1965) for Chilean hake.

The feeding behavior of hake clearly demonstrates their opportunistic habits. Bigelow and Schroeder (1953) reported on the opportunistic feeding behavior of silver hake, and Best (1963) on Pacific hake. In line with this theory, Alton and Nelson (1970) have suggested that the predominance of a single food organism in the stomachs of Pacific hake reflects more on the availability of that organism than selection of any particular species.

[1] Baxter, J. L., and A. T. Pruter. 1965. Background resume for Pacific hake workshop meeting. Bureau Commercial Fisheries Exploratory Fishing and Gear Research Base, 2725 Montlake Blvd. E., Seattle, Wash. 98102. Unpublished manuscript.

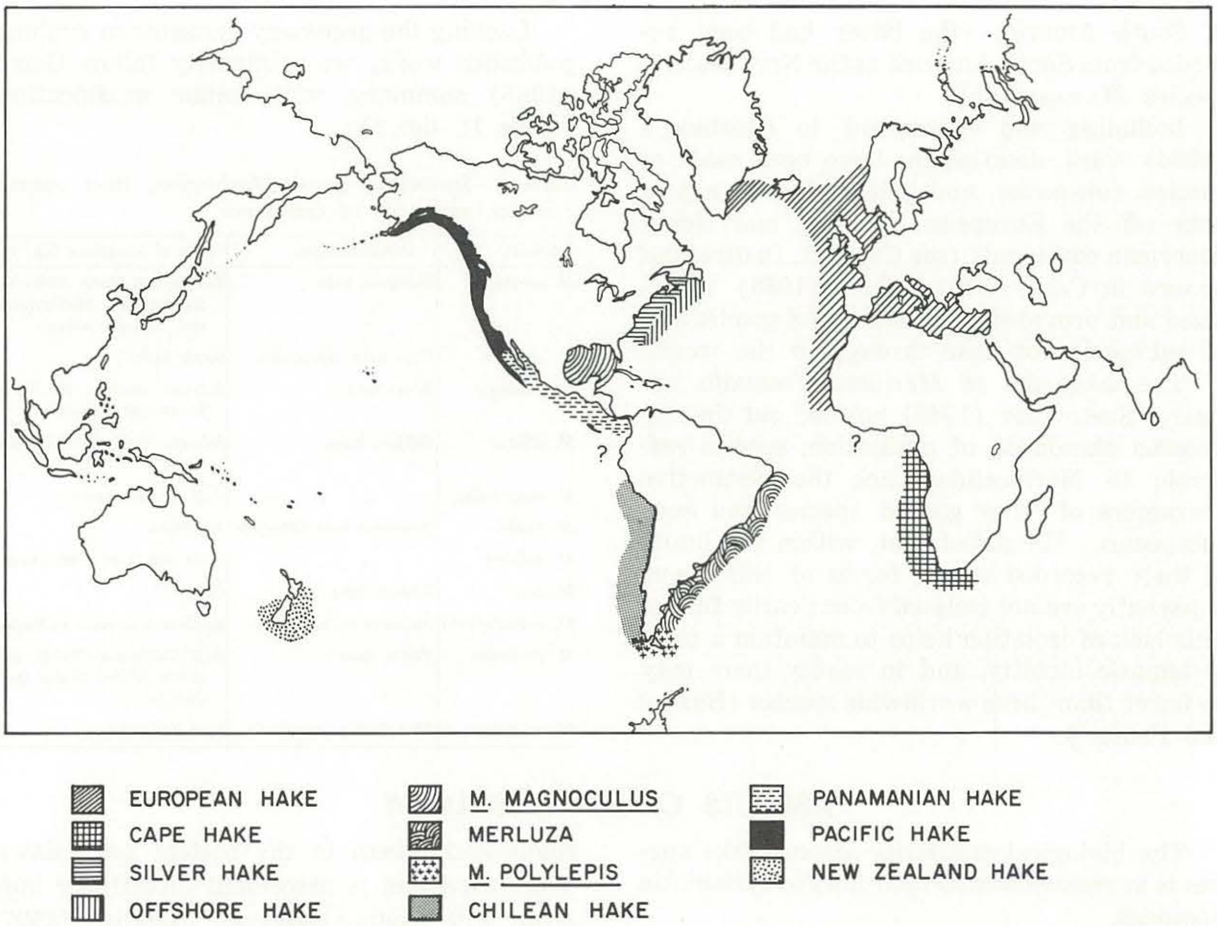

Figure 2.–Worldwide distribution of hake, genus *Merluccius*, modified after Cabo (1965).

SEASONAL AND DEPTH MIGRATIONS

Nearly all commercially important hake species exhibit a seasonal onshore-offshore depth migration. Generally, adult and juvenile European hake move inshore during the spring, adults for spawning and juveniles for feeding. After spawning the adults move back into deep water and are later joined by the juveniles in wintering areas (Hickling, 1927). Although European hake usually move into shallow water to spawn, Hickling (1927; 1930) stated that some adults spawn in deep water. Adult silver hake and merluza display a bathymetric pattern similar to that of the European hake. It is likely, however, that merluza spend more time in the deepwater portion of their depth range than do European hake because of the long spawning period of merluza (Hart, 1947; Bigelow and Schroeder, 1953; Angelescu, Gneri, and Nani, 1958; Fritz, 1960; de Ciechomski, 1967). Cape hake and apparently Pacific hake exhibit a reversal of the seasonal spawning cycle outlined above. These two species apparently spawn offshore in deep water during the winter (Rattray, 1947; Roux, 1949; Dreosti,

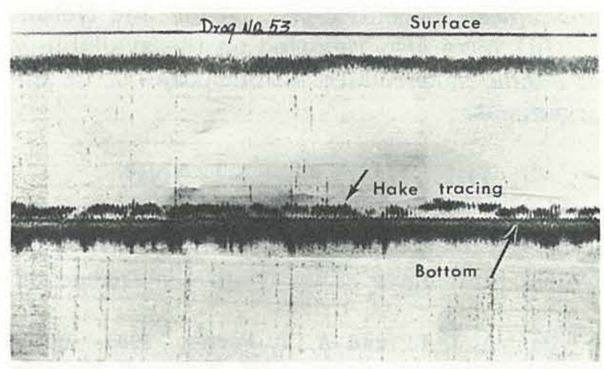

Figure 3.–Echogram showing concentrations of Pacific hake off the Washington coast (BCF Staff photo).

1967; Best and Nitsos;[2] Jones, 1967; Nelson, 1967). The migratory habits of the Chilean hake are unique among hakes in that sexually mature specimens of intermediate length move offshore to spawn during the spring and subsequently return to shallow water (Poulsen, 1958; Vestnes, Strom, and Villegas, 1965; Lengerich N., 1965).

Circumstantial evidence suggests that Pacific hake undertake a latitudinal seasonal movement in addition to the apparent depth migration. During the fall the bulk of the population shifts toward the south, off California, and then returns to more northerly waters of Oregon and Washington during the late spring, summer, and early fall (Nelson, 1967; Tillman[3]). Leim and Scott (1966) suggested the same type of migration for the silver hake. Irrespective of their spawning migrations, however, the presence of Pacific hake inshore appears to coincide with feeding activity in upwelling productive areas (Tillman, see footnote 3).

REPRODUCTIVE BEHAVIOR

Unlike inshore demersal schools of Pacific hake, offshore spawning populations are often found concentrated or dispersed at intermediate depths within the water column and apparently do not exhibit marked diel vertical movements. A physiological change might be responsible for this lack of diel movement, which has been observed for both the coastal and Puget Sound populations of Pacific hake (Nelson, 1967).

Hickling (1927) and Hart (1947), respectively, stated that the European and Argentine hakes stop feeding before spawning and feed ravenously afterward. This behavior corresponds to observations on spawning populations of hake in Puget Sound (Nelson, 1967).

In spawning schools of Pacific hake sex ratios favor males. Tillman (see footnote 3) pointed out that the percentage of males in spawning populations may be twice that of inshore, feeding populations for coastal Pacific hake. Larkins, Shippen, and Waldron[4] found similar sex ratios for spawning Pacific hake in Puget Sound and offered the explanation that males concentrate on the spawning grounds while the females are transient (i.e., the latter arrive, ripen, spawn, and then move out).

With the exception of the two dominant South American species, reports indicate that hakes have brief annual spawning seasons variable by species throughout the year. Most species spawn from spring to early fall (Hickling, 1933; Raitt, 1933; Bigelow and Schroeder, 1953; Fritz, 1960; Leim and Scott, 1966; Jones, 1967; Marak, 1967). The European hake in the Adriatic, cape hake, and the Pacific hake, however, spawn during winter (Ahlstrom and Counts, 1955; Paul, 1960; Basioli, 1965; MacGregor, 1966). Hickling (1927) suggested that the spawning time of geographically distinct populations of European hake varies clinally by latitude — the more northern populations spawn later in the year than the southern. The same phenomena has been reported for the Pacific hake (Larkins et al., see footnote 4).

The Argentine and Chilean hake appear to spawn continuously or several times each year. Although the Argentine hake shows a pronounced increase in reproductive activity from November to February (Hart, 1947; Angelescu, Gneri, and Nani, 1958; de Ciechomski, 1967), and the Chilean hake, a pronounced peak during October and November (Poulsen, 1958; Fischer, 1959), both appear to spawn from July through April.

EGG AND LARVAL DEVELOPMENT

The European hake (Graham, 1956) cape hake (Matthews and de Jager, 1951), silver hake (Bigelow and Schroeder, 1953), Chilean hake (Poulsen, 1958), and Pacific hake (Ahlstrom and Counts, 1955) apparently produce transparent, spherical pelagic eggs that hatch

[2] Best, E. A., and R. J. Nitsos. 1966. Length frequencies of Pacific hake *(Merluccius productus)* landed in California through 1964. California Department of Fish and Game, Fisheries Laboratory, Terminal Island, Calif. Unpublished manuscript, 7 pp.

[3] Tillman, Michael Francis. 1968. Tentative recommendations for management of the coastal fishery for Pacific hake, *Merluccius productus* (Ayres), based on a simulation study of the effects of fishing upon a virgin population. Masters thesis. University of Washington, 197 pp.

[4] Larkins, Herbert, Herbert H. Shippen, and Kenneth D. Waldron. 1967. Features of a northern Puget Sound hake population. Bureau of Commercial Fisheries Biological Laboratory, Seattle, Wash. Unpublished manuscript, 19 pp.

into pelagic larvae. The incubation period of the eggs is from 2 to 14 days. Graham (1956) reported that eggs of European hake hatch 10 to 14 days after fertilization. Artificially fertilized and reared eggs of cape hake hatched after 2 days of incubation (Matthews and de Jager, 1951). Bigelow and Schroeder (1953) assumed that the incubation period of silver hake eggs was 2 days at 44.6° to 55.4° F., whereas Marak (1967) concluded that the incubation period of offshore hake eggs was 6 to 8 days. Chilean hake eggs required 4 days to hatch when artificially incubated at 54.5° to 59.0° F. (Poulsen, 1958).

Newly hatched larvae of hake generally are undeveloped. Pacific hake emerge before a functional mouth develops and before the ocular pigment appears (Ahlstrom and Counts, 1955). The time between hatching and the development of a functional mouth is 7 to 14 days for the European hake (Graham, 1956), 36 hours for the cape hake (Matthews and de Jager, 1951), and 4½ days for the Chilean hake (Fischer, 1959). During the early stages of their postembryonic existence hake are apparently sustained by nutrients from their large yolk-sacs.

LENGTH OF PELAGIC EXISTENCE

The length of pelagic existence for young hake varies among species. The eggs and larvae of the European and cape hake have prolonged pelagic existence; they settle to the bottom at the end of their second year of life (Hickling, 1933; Rattray, 1947; Graham, 1956). Among other hake species, however, a long pelagic life is not apparent. Silver hake descend to the bottom near the end of the first summer or during the first autumn, after they complete their larval development (Bigelow and Schroeder, 1953; Fritz, 1960). Young Chilean hake spend 2 to 3 years in deep water where they are spawned then move shoreward to enter the demersal inshore population (Poulsen, 1958). Juvenile Pacific hake apparently have a pelagic existence for at least 1 or 2 years (Tillman, see footnote 3).

GROWTH

Generally, male hake grow more slowly than females. For European hake the differential growth rate between males and females does not become readily apparent until the third year of life (Bagenal, 1954). The growth rates of silver and Chilean hakes are comparable to that of the European hake (Bigelow and Schroeder, 1953; Poulsen, 1958), whereas cape hake grow more slowly than do the other species (Jones, 1967). The length at maturity of Chilean hake varies clinally by latitude — shorter toward the north (Poulsen, 1958). Best (1963) stated both sexes of Pacific hake mature at about the same age and length (3-4 years at 15.75 inches); Tillman (see footnote 3) indicated that Pacific hake exhibit sex-specific rates of growth in which females ultimately become larger than the males.

SIZE COMPOSITION

Studies have shown that hake separate according to size. Tillman (see footnote 3) reported that only mature Pacific hake are found at the northern end of their distribution (excluding Puget Sound), whereas mature as well as younger and smaller specimens appear more southerly. Reports on other hake populations indicate that the largest specimens are generally in deeper waters (Bagenal, 1954). Poulsen (1958) reported that small and very large Chilean hake are found offshore in deep water, whereas medium to large specimens predominate in coastal waters.

HISTORICAL DEVELOPMENT OF THE WORLD HAKE FISHERIES

Relatively large commercial fisheries have been established for at least six different kinds of hakes, whereas the five species listed below are generally unreported in world fishery statistics.

1. Offshore hake, *Merluccius albidus* (Mitchill).

Distribution.—Along the Atlantic coast of the United States from Georges Bank southward, overlapping areas occupied by the silver hake beyond the 50-fathom isobath (Cabo, 1965; Leim and Scott, 1966; fig. 2).

2. *M. magnoculus* Ginsburg.

Distribution.—Gulf of Mexico (Ginsburg, 1954; fig. 2).

3. *M. polylepis* Ginsburg. - (including records of *M. australis* (Hutton) from South America).

Distribution.—Off Chile and the tip of South America (Ginsburg, 1954; fig. 2).

4. Panamanian hake, *M. angustimanus* Garman.

Distribution.—Ranges north along western Central and North America, from the Gulf of Panama into the Gulf of California (Lavenberg and Fitch, 1966) to offshore from Puristima, Mexico, (Cabo, 1965) northward to Del Mar, Calif., (Ginsburg, 1954; fig. 2).

5. New Zealand hake, *M. australis* (Hutton)

Distribution.—Known from Chatham Island, South Island of New Zealand and northward to East Cape on North Island (Hart, 1948; fig. 2).

EUROPEAN HAKE FISHERY

Species: *Merluccius merluccius* (Linnaeus) - including subspecies *M. m. atlanticus* Cadenat; *M. m. mediterraneus* Cadenat; *M. m. senegalensis* Cadenat; *M. m. candenati* Doutre.

The European hake fishery was simultaneously developed by several western European nations, and European hake was an important constituent of the diet for people throughout western Europe during the latter half of the past century (Hart, 1948). By the turn of the century, its popularity decreased in Britain when the church relaxed emphasis on lenten fare and improved fishing technology provided greater quantities of more choice gadoid species from northern waters. This decline of the hake popularity reversed when modern trawling, especially steam trawling, began to overexploit nearby fishable stocks, and when fried-fish shops improved the demand for codlike fishes (Hart, 1948).

France, Portugal, and Spain, unable to capitalize on distant fisheries, relied on the local hake resource, particularly throughout the Mediterranean (Hart, 1948). At the beginning of World War I European hake stocks were greatly reduced. During the war, however, these stocks showed signs of recovery, and catches began to increase. The cycle of depletion and recovery was repeated up to and during World War II, (Hickling, 1946; Hart, 1948; fig. 4). Since then hake landings have decreased in the United Kingdom to a level comparable with Italy (fig. 4).

Italy's 1958 entry into the fishery illustrates the expansion and shift of effort from traditional European grounds to areas off the coast of Africa and adjacent Mediterranean countries (Hart, 1948; Food and Agriculture Organization of the United Nations, 1966). Spain, Portugal, and France lead the western European nations in hake landings, apparently as the result of greater effort on the new fishing grounds (fig. 4).

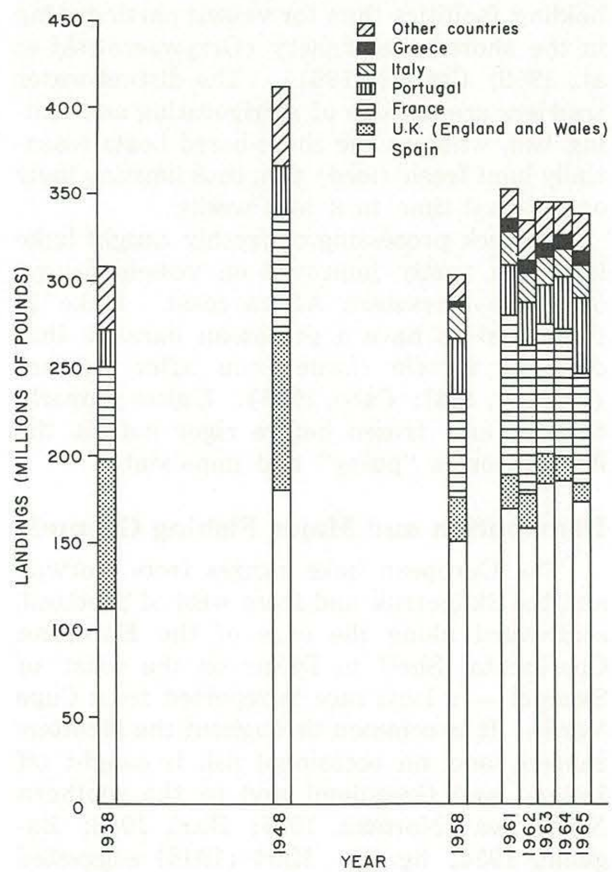

Figure 4.–Landings of European hake, *M. merluccius*, by country (Food and Agriculture Organization of the United Nations, 1966).

Fishing Methods and Fleet

The European hake fishing has kept pace with modern technology. During the early stages of the fishery handlines and nets were used. Fish taken by handlines brought higher prices than those taken by nets (Hart, 1948). Handlines continue to provide high-quality hake in Spain (Capont, 1961), and a midwater longline fishery has been reported off Tarbert (Bagenal, 1954). Trawlers have been modified in various ways and have evolved from smacks to the modern refrigerated vessels that constitute today's offshore fleets (Grzywaczewski, Huelle, Szmid, and Swiecicki, 1959; Cutting, 1961; Remy, 1961; Capont, 1961; Houk, 1961). To harvest African hake stocks, some western European nations have designed large offshore trawlers that have a greater range and can remain at sea for longer periods than their predecessors. This change has created a need for more skillful crews and more elaborate holding facilities than for vessels participating in the shore-based fishery (Grzywaczewski et al., 1959; Cutting, 1961). The distant-water trawlers are capable of refrigerating and salting fish, whereas the shore-based boats essentially haul fresh (iced) fish, thus limiting their operational time to 2 to 3 weeks.

On-deck processing of freshly caught hake has been vastly improved on vessels fishing off the northeastern Africa coast. Hake in these waters have a protozoan parasite that destroys muscle tissue soon after capture (Cutting, 1961; Cabo, 1965). Unless properly dressed and frozen before rigor mortis, the flesh becomes "pulpy" and unpalatable.

Distribution and Major Fishing Grounds

The European hake ranges from Norway and the Skagerrak and from west of Scotland, southward along the edge of the European Continental Shelf to Dakar on the coast of Senegal — a local race is reported from Cape Verde. It is common throughout the Mediterranean, and an occasional fish is caught off Iceland and Greenland and in the southern North Sea (Norman, 1937; Hart, 1948; Bagenal, 1954; fig. 2). Hart (1948) suggested that the wide range probably results from the diverging current systems off the west coasts of Europe and North Africa; to the north are relatively warm currents that move northward off Europe, whereas a relatively cold current flows southward along the northwestern Africa coast.

Major fishing effort is expended on concentrations that occur along the west coasts of Scotland, Ireland, and the northwest coast of Africa, at depths to 300 fathoms (Graham, 1956; fig. 2) and in the Mediterranean (Hart, 1948; fig. 2).

Management

Because of international participation in the western European hake fishery, cooperation of all nations using these stocks is necessary for effective management. Unlike other international fisheries, full cooperation was not achieved until the stocks were seriously depleted (Hickling, 1946; Graham, 1956; Engholm, 1961). During the 1930's, British biologists unilaterally adopted a scheme of regulating mesh sizes as a means of managing the hake fishery (Graham, 1956). This management practice was designed to increase the size of the stocks and their subsequent yield by increasing the survival of the youngest age groups (Gulland, 1956; Engholm, 1961). The scheme was approved in principle by an international conference held in 1936 and 1937, and adopted by the International Conference on Overfishing in 1946. The latter conference established a Permanent Commission with powers to define and enforce regulatory measures. In 1954 a minimum mesh size was adopted and was required for boats fishing between lat. 48° N. and 62° N. and long. 42° W. and 32° E. In 1956 the minimum mesh size was again increased following selectivity experiments by the International Council for the Exploration of the Sea, the scientific body adopted by the Permanent Commission as its investigative arm (Engholm, 1961).

Increased use of European hake stocks from traditional areas together with fishing on new grounds created a need for the Northeast Atlantic Fisheries Convention in 1959. This meeting resulted in the expansion of the management area southward to lat. 36° N. and eastward to include the north coast of the Soviet Union (fig. 2). The Permanent Commission was given power to regulate by other measures, such as seasonal restrictions, area closure, or catch quotas. The traditional European hake grounds are now regulated by an international convention; new grounds, however, are excluded and management in these areas is at the discretion of the participating countries (Engholm, 1961; fig. 2).

CAPE HAKE OR STOCKFISH FISHERY

Species: *Merluccius capensis* Castelnau - including *M. m. polli* Cadenat; *M. m. paradoxas* Franca.

At the end of the 19th century, South Africa began the fishery for cape hake or stockfish. A new inland market created by technological advances in cold storage facilities and improved railway transportation led to the import of steam trawlers from the United Kingdom (Dreosti, 1961).

The cape hake, despite its poor keeping quality, is the most valuable commercial species landed in the Union of South Africa (Food and Agriculture Organization of the United Nations, 1966). Fish are headed, gutted, and iced for fresh fish markets; heads and offal are reduced to white-fish meal; and vitamin A is extracted from the livers (Dreosti, 1961). The best of the trawl-caught fish are filleted and smoked. In addition quantities are salted, dried, and canned (Dreosti, 1961). Smoked fillets and frozen blocks of hake are exported to European markets (Marchand, 1935; Pacific Fisherman, 1966). During the last decade, quick-freeze plants have been developed to produce home convenience products, such as frozen fillets and fish sticks (Dreosti, 1961).

The cape hake fishery began off Cape Peninsular and then moved northward to the Luderitz grounds (about 800 miles north of Cape Town) as foreign vessels began to participate in the fishery. Part of the South African fleet was diverted to the northern grounds but there the catch rates declined and the fishery was not profitable (Jones, 1967; fig. 2). The fleet soon returned to the Cape region.

Landings of cape hake have increased steadily during recent years (fig. 5). In the early 1960's Japanese and Spanish exploratory vessels appeared along the western coast of Africa, preceding the beginning of a large

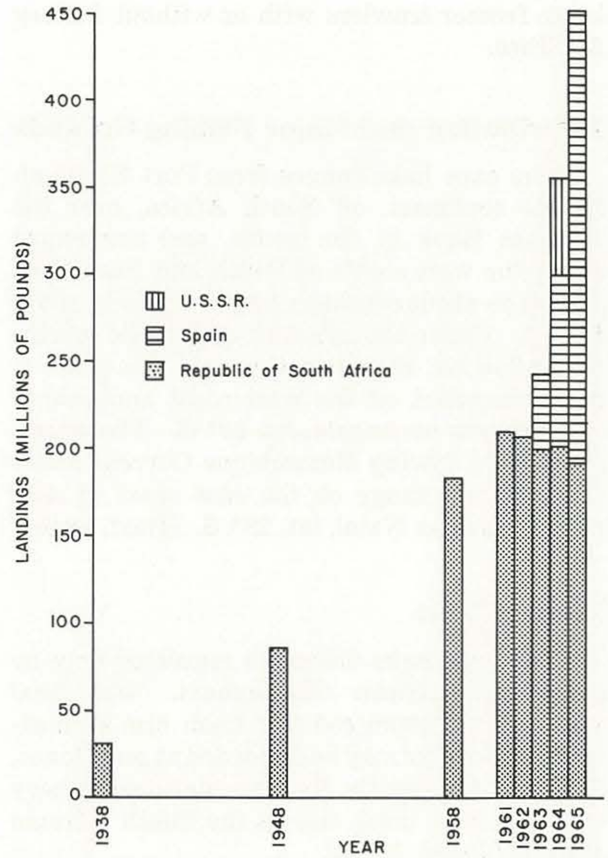

Figure 5.–Landings of cape hake, *M. capensis*, by country (Food and Agriculture Organization of the United Nations, 1966).

foreign fishery for hake off the continent. Soon the U.S.S.R., Israel, West Germany, Portugal, Poland, and Greece joined the foreign fleet. As a result the total landings have increased from 100,000 tons in 1961 to over 200,000 tons in 1965 (Jones, 1967; fig. 5).

Fishing Methods and Fleet

During the early developmental stage of the cape hake fishery, bottom trawlers competed with handliners in shallow water (40-80 fathoms) for the resource, but now trawlers completely dominate the fishery and a considerable portion of the catch comes from 100 to 300 fathoms (Marchand, 1935; Smith, 1961). Jones (1967) reported that most of the South African fishing fleet is equipped primarily for a nearshore fishery, whereas the foreign fleets are equipped for an offshore fishery and have large freezer trawlers with or without factory facilities.

Distribution and Major Fishing Grounds

The cape hake ranges from Port Elizabeth in the southeast, off South Africa, over the Agulhas Bank in the south, and northward along the west coasts of South and Southwest Africa to about southern Angola (Jones, 1967; fig. 2). Under the influence of the cold, northward flowing Benguela Current, this hake is most abundant on the west coast and ranges as far north as Angola, lat. 10° S. The warm, southward flowing Mozambique Current limits its northern range on the east coast to only as far north as Natal, lat. 28° S. (Hart, 1948).

Management

The cape hake fishery is regulated only by the South African Government. For local trawlers minimum cod end mesh size is in effect and no hake may be discarded at sea (Jones, 1967). Apparently the international fishery uses the same mesh size as the South African fishery (Jones, 1967).

SILVER HAKE FISHERY

Species: *Merluccius bilinearis* (Mitchill).

Prior to the mid-19th century the silver hake or whiting was discarded as trash because of its poor keeping qualities. Silver hake did not salt well, and the flesh became soft and tasteless unless refrigerated or eaten very soon after capture (Jensen, 1967). In about 1840 the New England fisherman began catching silver hake for the local fresh fish markets; later it was used as bait in a hook and line fishery for spiny dogfish, which was intended for guano and oil (Jensen, 1967). A limited fishery for hake continued during the 1920's, mostly to supply fried-fish shops in north-central United States. An active food fishery began in the 1930's when a market for frozen hake was developed (Jensen, 1967). This market continued to grow, and by 1940 nearly half of the annual catch was being frozen and represented as much as 11 percent of the total frozen fish produced in the United States (Hart, 1947).

In recent years, silver hake have been made into meal for the animal food and other industrial markets (Fritz, 1960; Jensen, 1967), but human consumption still accounts for the greatest proportion of the U.S. catch. Silver hake are frozen in the round, headed and gutted, or filleted (Fritz, 1960).

Product diversification provided the basis for the expansion of the fishery into the second most important industrial species on the east coast (Fritz, 1960). The entry of the U.S.S.R. in 1962 further expanded the fishery, which is now the world's largest hake fishery in weight landed (fig. 6). The United States landings have remained relatively constant during the last decade, but the Soviet high-seas fleet now catches over six times that amount (fig. 6).

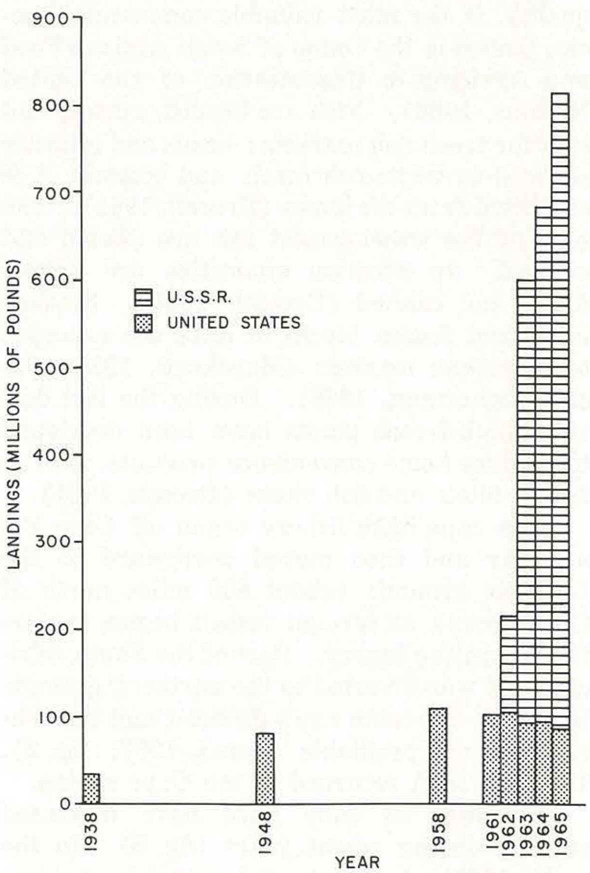

Figure 6.—Landings of silver hake, *M. bilinearis*, by country (Food and Agriculture Organization of the United Nations, 1966).

Fishing Methods and Fleet

The silver hake fishery began inshore with pound and trap nets. As the market grew during the 1930's, the New England trawl fishery expanded to meet increased demands for frozen hake (Hart, 1947; Fritz, 1960). During the 1940's, an increasing number of U.S. trawlers began to harvest hake along the entire coast, inshore as well as offshore (Taylor, Bigelow, and Graham, 1957; Fritz, 1960). The Soviet effort is strictly a high-seas operation. To compete with Soviet fishing the United States fleet has undertaken a program of gear and vessel modernization.

Distribution and Major Fishing Grounds

The silver hake ranges along the Atlantic coast of Canada and the United States from the southern and eastern part of the Gulf of St. Lawrence and southern Newfoundland to off South Carolina (Ginsburg, 1954; Leim and Scott, 1966; fig. 2). Hart (1948) linked the northerly, abundant part of the distribution with the major hydrographic feature of the area, the Labrador Current. The silver hake is caught commercially along the inshore waters of the North Atlantic coast over Georges Bank, rarely in depths over 100 fathoms (Fritz, 1960; Leim and Scott, 1966).

Management

Should it become necessary, in face of the intensified effort by the Soviets and United States, the ICNAF (International Convention on Northwest Atlantic Fisheries) has the authority to apply regulatory measures to conserve the silver hake stocks within the ICNAF area (Engholm, 1961).

ARGENTINE HAKE OR MERLUZA FISHERY

Species: *Merluccius hubbsi* Marini.

The fishery for the merluza or Argentine hake began in the 1920's as a small, shallow-water trawling industry at the mouth of the Rio de la Plata. Landings were first marketed in Montevideo, then in Buenos Aires, following the failure of the Uruguayan enterprise (Hart, 1947, 1948). From its inception, the fishery for merluza was based on a fresh-fish market (Anonymous, 1961), but its growth was limited by two factors — merluza were infested with a protozoan parasite, which affected their keeping quality (Angelescu et al., 1958), and investment capital was not available for the fishery. Thus the technology required for proper delivery and storage of high-quality seafood products did not develop. A flourishing fresh-fish market, however, did develop in Buenos Aires where quality fish could be obtained from nearby fishing grounds (Anonymous, 1961).

Although the industry was technologically depressed in its early stages, refrigeration and quick-freeze facilities have become available within the last decade, and the city of Mar del Plata has become a center for frozen fish (Anonymous, 1961). At first frozen fillets were used for local consumption (Anonymous, 1961), but later, additional quantities were prepared for export to the United States as frozen fish blocks (Pacific Fisherman, 1966). Total catches have continued to increase in recent years (fig. 7).

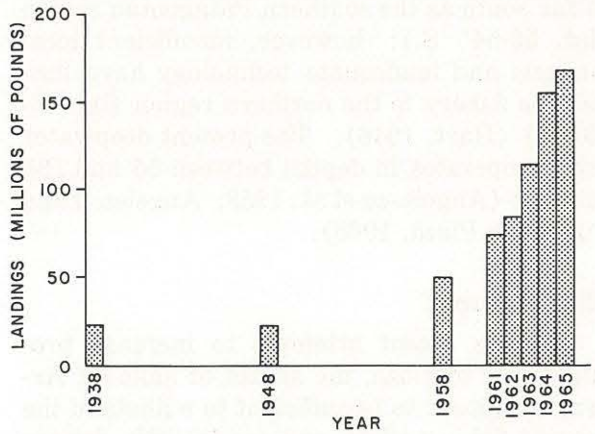

Figure 7.—Landings of merluza, *M. hubbsi*, in Argentina (Food and Agriculture Organization of the United Nations, 1966).

Fishing Methods and Fleet

The merluza is caught principally by the Argentine trawl fleet, which is relatively small and is divided between an inshore and an offshore operation. Vessels in the coastal fishery have 44 to 130 gross tonnage, whereas the offshore trawlers have 144 to 372 gross tonnage (Anonymous, 1961). To supply increased market demands, the offshore fleet tried new trawling techniques. Fishermen soon took large catches of merluza when the gear was fished off bottom. Occasionally two-boat trawling has been undertaken (Argentina, Secretaria de Marina Servicio de Hidrografia Naval, 1966).

Distribution and Major Fishing Grounds

Hart (1947), Angelescu et al. (1958), and Cabo (1965) set the Straits of Magellan and Tierra del Fuego as the southernmost limit of merluza distribution. It mixes there with the Chilean hake, *M. gayi* and *M. polylepis* (Cabo, 1965) and ranges north along the east coast of South America to the convergence of the inshore Falkland and offshore Brazil currents (Hart, 1948). This convergence of northerly flowing cold water and southerly flowing warm water varies seasonally but generally occurs at about lat. 30° S. off southern Brazil (fig. 2).

Most of the fishing is on the Bonaerense section of the northern Argentine Continental Shelf (Anonymous, 1961). Exploratory surveys have shown that the species is abundant as far south as the southern Patagonian region (lat. 50-54° S.); however, insufficient local markets and inadequate technology have limited the fishery to the northern region (lat. 42-46° S.) (Hart, 1946). The present deepwater fishery operates in depths between 55 and 135 fathoms (Angelescu et al., 1958; Angelescu and Fuster de Plaza, 1965).

Management

Despite recent attempts to increase production of merluza, the stocks of hake off Argentina appear to be sufficient to withstand the present fishing effort and are in little danger of overexploitation (Pacific Fisherman, 1966).

CHILEAN HAKE FISHERY

Species: *Merluccius gayi* (Guichenot) - including *M. gayi peruanus* Ginsburg and *M. g. gayi* (Guichenot).

During the 1940's the Chilean hake was marketed only as a fresh food item (Lengerich N., 1965). In the mid-1950's the demand for fish meal became so great that the demands of the fresh market were not filled. German fishing vessels with modern trawl gear were called in by fish meal plants to supply the increased demand (Poulsen, 1958). In the early 1960's a large reduction industry developed in two areas: a site in northern Chile produced fish meal for export, and another in central Chile prepared fish meal for feeding to local pigs and poultry. Landings show the rapid development of these industries (fig. 8).

The Chilean Government imposed catch limits that suppressed the meal industry (Tilic and Maschke, 1965). Although a market exists, the supply continues to lag behind demand (Tilic and Maschke, 1965; Tilic and Mery, 1966). As a result of these production limits, the Chilean hake industry is now seeking a greater economic return by processing frozen hake and fish protein concentrate, and deemphasizing reduction. New plants are freezing hake for export; more plants are being built for this purpose. With existing production quotas, investors believe that they will receive greater economic return by supplying the frozen fish market than the fish meal market (Tilic and Maschke, 1965).

In Quintero, Chile, a plant uses hake to produce fish protein concentrate and canned fillets (Institute of Marine Resources, 1965). The high-quality, inexpensive, flourlike concentrate derived from hake is suitable as a human diet supplement. The product is odorless and tasteless and can be readily transported and

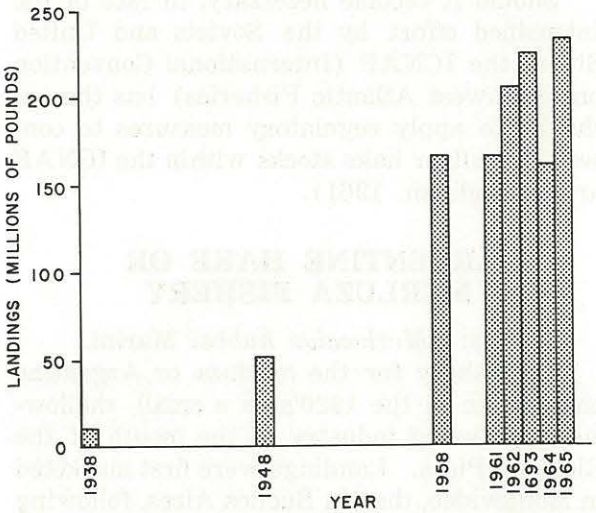

Figure 8.–Landings of Chilean hake, *M. gayi*, in Chile (Food and Agriculture Organization of the United Nations, 1966).

stored for use in programs supported by the National Health Service of Chile (Allen, 1963). Because Chile is relatively poor in protein (Tilic and Maschke, 1965), this new use of hake may bring about another possible change in emphasis on the use of hake.

Fishing Methods and Fleet

Before 1951 the hake fishery consisted of Chilean fishermen working from small boats with nets or hook and line. The Chilean hake fishery is principally land-based and is now operated by fewer than 50 trawlers of less than 110-gross ton capacity (Institute of Marine Resources, 1965). An inshore, summer fishery is operated by small boats using handlines (Vestnes, Strom, and Villegas, 1965).

Distribution and Major Fishing Grounds

Influenced by the cold, northerly flowing Peru Current, the Chilean hake is distributed along much of the west coast of South America. Hart (1948) set the northern limit at Paita in northern Peru at lat. 4° S., and Cabo (1965) set the southern extreme of its distribution at the Straits of Magellan and Tierra del Fuego. In the south the Chilean hake apparently intermingles with other hake species (fig. 2).

Throughout its range, the Chilean hake is known to be concentrated only in northern and central Chile where it is the basis of an extensive trawl fishery (Hart, 1948; fig. 2). Although the complete depth distribution is not known, dense schools of Chilean hake are fished between 28 and 83 fathoms (Poulsen, 1958). Large stocks of hake have been reported from the southern region; this area, because of its wide Continental Shelf, offers promising trawling grounds (Institute of Marine Resources, 1965). The Chilean Government is now studying the feasibility of developing the potential to the south (Vestnes, Strom, and Villegas, 1965; Vestnes, Strom, Saetersdahl, and Villegas, 1965; Vestnes et al., 1966; Del Solar, 1968).

Management

Owing to the rapid development of the hake fishery during the late 1950's, landings became so large that extinction of the hake stocks was feared by the Chilean Government. Although this fear was unfounded biologically, it continued to exist, and in 1961 limits were imposed on production of the fish meal plants as a means of conserving the stocks (Tilic and Maschke, 1965).

PACIFIC HAKE FISHERY

Species: *Merluccius productus* (Ayres).

Until recently, fishermen regarded the Pacific hake as an abundant nuisance. The presence of hake has been evident for at least the past one thousand years (Soutar, 1967). Fishermen trawling for other species often have shifted to grounds with no large schools of hake (Jones, 1960) and gill netters have been plagued by surface-feeding schools at night (Clemens and Wilby, 1961). Exploratory surveys by the United States and the Soviet Union showed that Pacific hake was a large undeveloped resource, and that it was the most abundant gadid (by weight) in the northeastern Pacific Ocean. The U.S. estimate of the standing stock of Pacific hake in waters from Oregon to British Columbia is about 1.5 billion pounds (Alverson, 1968). Alverson, Pruter, and Ronholt (1964) showed in trawl surveys off Oregon and Washington that the hake was the most abundant species at depths between 50 and 99 fathoms and was always one of the three most abundant species taken between 100 and 299 fathoms.

CalCOFI (California Cooperative Oceanic Fisheries Investigations) surveys off the California coast showed that hake larvae represent 19 percent of the total larvae taken for a 15-year period (Ahlstrom, 1954) and rank second in abundance to northern anchovy larvae (Ahlstrom, 1965; MacGregor, 1966). A standing stock of 4 to 8 billion pounds of hake has been estimated from these surveys (Ahlstrom, 1968).

Obviously industry did not bypass the hake resource for lack of abundance. In northern California, a small industry based on incidentally caught trawl species ground and froze fish to be fed to pets and fur-bearing animals (Best, 1959; Nitsos and Reed, 1965). Hake accounted for about 25 percent of the total California animal food catch (Radcliffe, 1920; Best, 1961;

fig. 9). During the 1930's, the use of Pacific hake for pet and mink food declined. Bones were difficult to grind up and often became lodged in the throats of animals fed processed or raw hake (Baxter and Pruter, see footnote 1). A diet high in raw hake caused "cottonfur", an abnormality of domestic fur bearers, which resulted in an economic loss to the farmer (Stout, Oldfield, and Adair, 1960). Unless hake were heated and treated with acid, they had to be mixed with other types of food. This requirement limited the amount of hake that could be used in the animal food industry.

The development of the Pacific hake fishery, like other hake industries, required costly handling procedures or special refrigeration equipment to provide a palatable product for the fresh or frozen markets. Without such treatment, Pacific hake will have poor texture and flavor (Paul, 1960; Heimann, 1963; Ahlstrom, 1965). An infestation of myxosporidian parasites apparently causes enzymatic proteolysis and a softening of the infected tissue shortly after the death of the fish (Patashnik and Groninger, 1964; Baxter and Pruter, see footnote 1).

A new industry for Pacific hake began in 1965. Figure 9 provides catch data for the Pacific hake from its use in a multispecies animal food industry to the new technologically

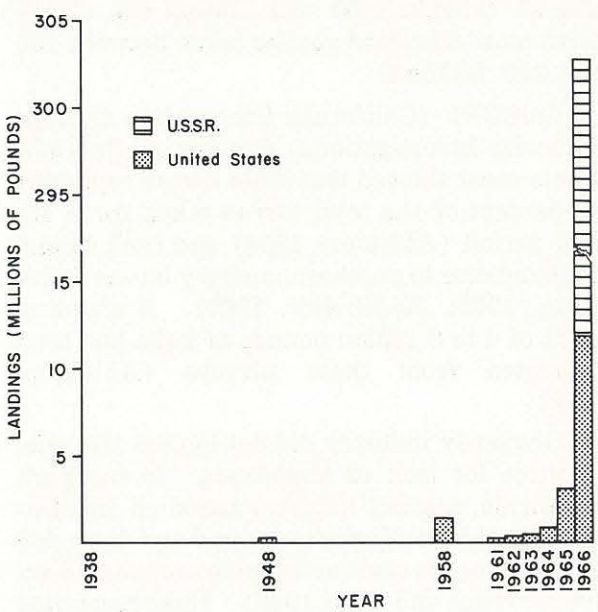

Figure 9.–Landings of Pacific hake, *M. productus*, by country (Lyles, 1968).

advanced fishery off Washington and Oregon jointly enjoyed by the Americans and Soviets. Unlike the development of other world hake resources, this industry grew rapidly following extensive research. The intensive fishing effort was prompted by the increased demand for fish meal in the United States and food fish in the Soviet Union (Nelson, 1967). Further interest in Pacific hake resulted when the U.S. Food and Drug Administration approved regulations governing interstate sale of fish protein concentrate as a diet supplement for human consumption.

Fishing Methods and Fleet

The fishery on Pacific hake has been exclusively by trawling. At the beginning of the fishery off Washington, Oregon, and British Columbia, a technologically advanced extraction process was developed (Hipkins, 1967; Johnson and High, 1970; and Nelson, 1970). Large schools were located by the use of echo sounders, and catches were made with midwater trawls (McNeely, Johnson, and Gill, 1965; Hipkins, 1967; Nelson, 1967). Small multipurpose United States trawlers and large distant-water Soviet vessels now participate in the fishery.

Distribution and Major Fishing Grounds

The Pacific hake ranges from the Gulf of Alaska to the Gulf of California and occurs from shallow shelf waters to depths of 490 fathoms (De Witt, 1952; Clemens and Wilby, 1961; Nelson, 1967). It mixes with the Panamanian hake throughout the southern extent of its distribution (fig. 2). According to Alverson et al. (1964), major concentrations appear to be associated with the California undercurrent system, which lies between lat. 23° and 48° N., of the Pacific coast of North America (Sverdrup, Johnson, and Fleming, 1961). In the northerly part of its range the Pacific hake seldom is taken and throughout much of the Gulf of Alaska it is apparently replaced by Pacific cod and walleye pollock (Alverson et al, 1964).

The Pacific hake fisheries are concentrated in waters off the northern California, Oregon, and Washington coasts and in the inland waters of Puget Sound. Most of the catch is taken at depths of 35 to 80 fathoms (Hipkins, 1967; Nelson and Larkins, 1970).

Management

The Pacific hake fishery has not yet become complicated by conservation management problems. In joint Soviet-American meetings, biologists agreed upon a range of yield estimates in which the upper limit exceeds the landings currently taken by both fleets (Alverson and Larkins, 1969).

THE WORLDWIDE HAKE RESOURCE

In the past decade, codlike fishes contributed about 12 percent to the total world fishery landings and were second only to herringlike fishes (Food and Agriculture Organization of the United Nations, 1966). Hake of the genus *Merluccius,* in turn constituted nearly 15 percent of the 1965 total codlike fish production and has had steadily increasing landings since 1938 (table 2). Important hake fisheries occur off the coasts of Europe, North and South Africa, and North and South America.

Table 2.–Contribution by hake to the world production of codlike species

Year	Codlike fishes	Hake	
	Millions of pounds	*Millions of pounds*	*Percent*
1938	742,950.2	408.1	5.5
1948	795,860.6	654.1	8.2
1958	989,865.4	818.2	8.3
1961	1,113,323.0	904.5	8.1
1962	1,221,348.4	1,049.6	8.6
1963	1,309,532.4	1,530.7	11.7
1964	1,327,169.2	1,703.8	12.8
1965	1,424,171.6	2,012.4	14.1

Source: Food and Agriculture Organization of the United Nations (1966)

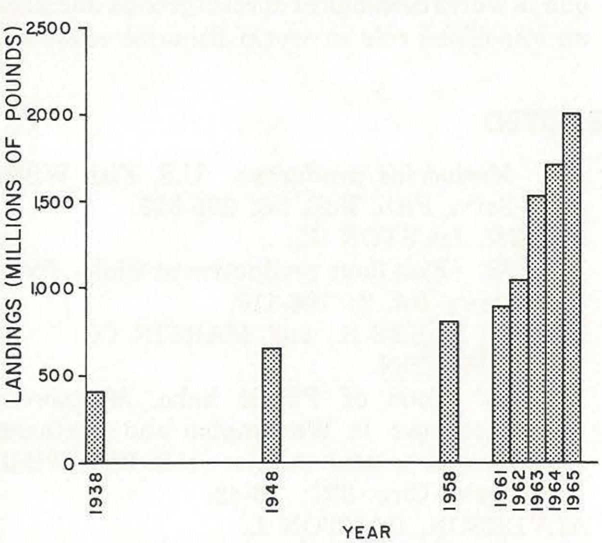

Figure 10.–World hake production, 1938-65.

Hake landings continue to increase worldwide; in 1965 the total production was over 2 billion pounds (table 2, figs. 10 and 11) for a value of nearly $60 million (fig. 12). The massive Soviet offshore fleet fishing silver hake was primarily responsible for the most recent escalation in landings (fig. 11). Excluding its value to the U.S.S.R., hake have contributed

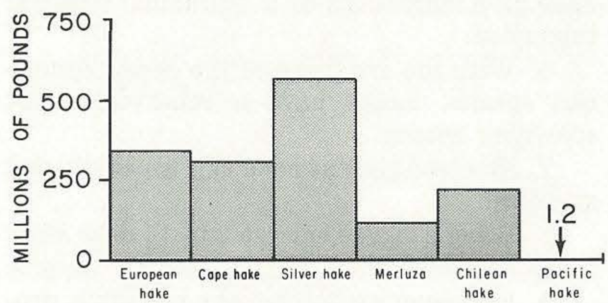

Figure 11.–Annual average hake production by fishery 1962-65.

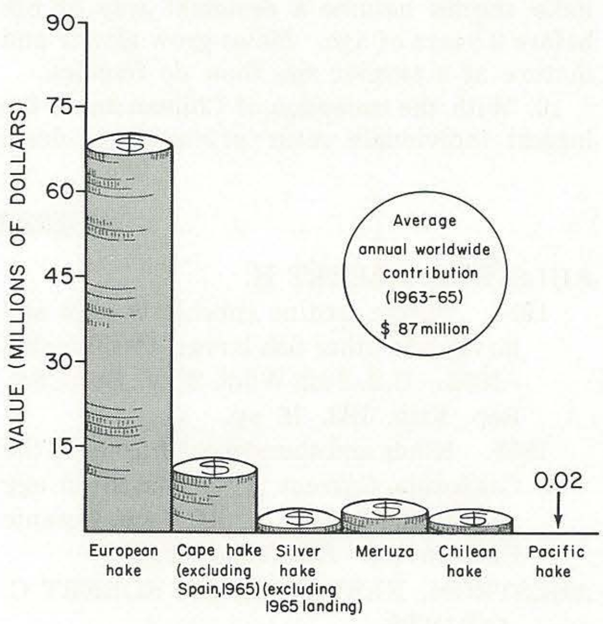

Figure 12.–Average annual economic contribution by hake fishery 1963-65 (excluding U.S.S.R.).

an average of $87 million annually to the world market, 1963-65 inclusive (fig. 12). Its value in the U.S.S.R. must be enormous to warrant the operation of a costly high-seas fleet.

SUMMARY

1. Eleven nominal species of hake are recognized in this paper. Further study may result in fewer valid species.

2. Hake are represented in all coastal areas of the Atlantic and Pacific Oceans in both hemispheres except the northwest Pacific.

3. Biologically and taxonomically, hake throughout the world are remarkably similar.

4. Hake essentially concentrate seasonally and migrate geographically and bathymetrically or both.

5. The Pacific hake and possibly the silver hake give indications of a latitudinal seasonal migration.

6. With the exception of the South American species, hakes have a relatively short spawning season.

7. The transparent hake egg is pelagic and spherical.

8. Pelagic larvae emerge 2 to 14 days after fertilization and have nonfunctional mouths.

9. European and cape hake exhibit a prolonged pelagic existence, settling to the bottom at the end of their second year of life. Other hake species assume a demersal way of life before 2 years of age. Males grow slower and mature at a smaller size than do females.

10. With the exception of Chilean hake, the largest individuals occur primarily in deep, offshore waters. Larger individuals of the Pacific hake are found at the northerly part of their onshore range.

11. With the exception of the European hake fishery which was carried on by several nations, fisheries on other hake species have been initially harvested by nearby shore-based fisheries.

12. As traditional hake fishing grounds have become overexploited, many nations have turned to resources farther afield. Russia and Spain have become dominant in the Atlantic; also, the Soviets undertake large-scale fishery operations in the Pacific.

13. Hake are taken by a variety of harvesting techniques; however, electronic detection and guided trawling have emerged as the most efficient. Improved processing techniques and larger, more sophisticated modern vessels have escalated hake landings.

14. European, cape, and Chilean hake fisheries have been variously influenced by fishery management. The European hake has been managed internationally, whereas the cape and Chilean hakes have been managed locally. The remaining three hake fisheries have not been managed, and catches reflect a balance between supply and demand.

15. Gadoid fishes (including hake) rank second in world landings of species groups and play an important role in world fisheries economy.

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MS. #1865

Distribution and Biology of Pacific Hake: A Synopsis

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ABSTRACT

Pacific hake occur from the Gulf of Alaska to the Gulf of California. Genetic studies suggest that a single population inhabits the ocean region from British Columbia to Baja California.

Studies of the abundance of hake larvae have shown that spawning is mainly during December to April in offshore areas along the coasts of southern California and Baja California. The morphological characteristics of larvae are comparable to other fish with pelagic eggs. Larvae are most often encountered within or near the thermocline at temperatures of 47.5° to 65.3° F. Little is known about the distribution of juvenile (ages 1-3) hake.

Except when spawning, adult hake are primarily residents of the upper Continental Slope and Shelf. It is hypothesized that adult hake undertake an annual migration northward in the spring and summer and southward beginning in the fall to the offshore spawning region. During the late spring to fall, feeding adult fish are found from British Columbia to northern California and are most abundant off Washington and Oregon. By December most fish have moved out of the Vancouver Island-Oregon area.

Adult hake feeding in inshore areas during the spring to fall period characteristically form long narrow schools just off bottom. They make pronounced diel vertical migrations. Hake feed on a large variety of fish and invertebrates. In the Washington-Oregon region, euphausiids appear to be their primary food.

Hake grow rapidly to age 6. Preliminary age composition analysis suggests that after age 5 their annual natural mortality rate is about 43 percent. Apparent fluctuations in year class strength have been observed.

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Published February 1970.

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INTRODUCTION

The Pacific hake, *Merluccius productus*, is one of the most abundant species of fish in the northeastern Pacific Ocean, but, until recent years, it has not been extensively fished. Until recently, few data were available on the size of the hake resource off the west coast of the United States, although trawls commonly took hake, and fishermen generally considered them a nuisance. Surveys of fish eggs and larvae off California and Mexico by CalCOFI (California Cooperative Oceanic Fisheries Investigations) provided the initial indication of the size of the hake resource (Ahlstrom and Counts, 1955). Early surveys with midwater trawl and echo sounder (Schaefers and Powell, 1958) had indicated that adult hake might be available in large quantities. The actual commercial potential of the hake population was not appreciated until 1964, however, when large catches were made during midwater trawl surveys off Washington and Oregon (Alverson, 1967; Nelson, 1967). In 1966 United States and Soviet fishermen began harvesting hake off the west coast of the United States. Alverson (1967) and Nelson (1967, 1970) have discussed the development of the U.S. coastal hake fishery.

This paper summarizes available information on the distribution and biology of the Pacific hake. In addition to published works, it relies largely on material gathered in recent years during resource assessment, gear research, and biological studies by the BCF (Bureau of Commercial Fisheries) Exploratory Fishing and Gear Research Base and Biological Laboratory, Seattle, Wash.

Samples of hake used in biological and population studies were collected from the landings of a small experimental fishery off Warrenton, Oreg., in the summer of 1965 and from U.S. commercial landings at Aberdeen, Wash., in the summers of 1966 and 1967. This material is supplemented by information gathered during cruises of research vessels from 1963 through 1967. At irregular intervals during the fishing season, individual random samples of 100 to 400 fish were taken from the hold of the fishing vessels. Length and sex were recorded for each fish, but weights and otoliths for age interpretation were taken from stratified subsamples. Although the sampling period varied among years (late August to mid-October 1965, mid-July to early October 1966, and late May to early August 1967), the areas fished were generally the same—Columbia River to southern Vancouver Island. Most samples were from off the coast of central Washington.

Because of the relatively small amount of population data currently analyzed, only a cursory treatment of the population dynamics of hake has been attempted. Detailed age composition and growth studies now being undertaken will be reported on in a future publication.

Much of the material presented here has also been reported by Tillman.[1] He worked closely with us and our colleagues and used BCF data to develop a preliminary simulation model of the possible effects of fishing on the Pacific hake population.

[1] Tillman, Michael F. 1968. Tentative recommendations for management of the coastal fishery for Pacific hake, *Merluccius productus* (Ayres), based on a simulation study of the effects of fishing upon a virgin population. Master's Thesis, University of Washington, Seattle, 197 pp.

Although this paper is concerned with the hake resource of the open ocean, for comparative purposes limited reference is made to information on the recently harvested hake population in Puget Sound discussed by Hipkins (1967); Larkins, Shippen, and Waldron;[2] Millikan;[3] Nelson (1967); and DiDonato (1968).

RANGE AND SYSTEMATICS

Pacific hake has been reported from the Gulf of Alaska (Goode, 1884; Wilimovsky, 1954; Clemens and Wilby, 1961; Alverson, Pruter, and Ronholt, 1964) to the Gulf of California (Starks and Morris, 1907). It is apparently most abundant in that part of its range influenced by the California Current and California Undercurrent Systems. North of Vancouver Island the hake is largely replaced in the roundfish community by Pacific cod, *Gadus macrocephalus*, and walleye pollock, *Theragra chalcogrammus*, (Alverson et al., 1964).

Genetic studies suggest that a single population inhabits the oceanic region between British Columbia and Mexico (personal communication, Fred M. Utter, Chemist, Bureau of Commercial Fisheries Biological Laboratory, Seattle, Wash., September 1968). Among hake collected throughout this region, gene frequencies reflected by each of two enzyme systems show insignificant intersample variation. Analysis of these enzyme systems indicates, however, that Puget Sound hake, which have a much slower growth rate than ocean fish, form a genetically distinct population. The apparently minor stocks of hake north of Vancouver Island are not dealt with in this paper; their racial composition is unknown.

The systematic position of Pacific hake relative to other species of Merlucciidae in the Western Hemisphere was discussed by Ginsburg (1954). Grinols and Tillman (1970) discussed systematic relationships among the commonly recognized species of *Merluccius*.

REPRODUCTION AND EARLY LIFE HISTORY

This section considers the maturity, the fecundity, and the egg and larval development of Pacific hake.

MATURITY

Pacific hake live up to at least 13 years, and the maximum total length recorded is 31.5 inches (Best, 1963). Generally, fish 4 years old and older (mean length about 17.7 inches) are mature. Best (1963) found that in samples from California, all hake over 15.7 inches were mature and concluded that most 4-year-old fish and the larger 3-year-old fish would spawn. All fish sampled from the Washington-Oregon coastal fishery have been mature (either they had spawned or would spawn the following season). Three-year-old fish made up less than 0.5 percent of samples from the fishery. Four-year-old fish as small as 14.2 inches have occasionally been caught by research vessels in the area of the fishery.

FECUNDITY

The fecundity of Pacific hake has not been studied in detail. MacGregor (1966) examined 22 females with well-developed ovaries taken in March off Baja California. The number of advanced eggs varied from 80,000 in the smallest specimen (13.8 inches standard length) to 496,000 in the largest (27.2 inches standard length). Because of the nature of the frequency distributions of yolked eggs and the hake's relatively short spawning season, MacGregor concluded that spawning likely occurred only once a year.

[2] Larkins, Herbert, Herbert H. Shippen, and Kenneth D. Waldron. 1967. Features of a northern Puget Sound hake population. Bureau of Commercial Fisheries Biological Laboratory, Seattle. Unpublished manuscript, 19 pp.

[3] Millikan, Alan E. 1967. Catch and effort statistics for the 1966-1967 Puget Sound mid-water trawl hake fishery. Supplemental Progress Report. Marine Fisheries Research and Management, Groundfish Investigations, Washington State Department of Fisheries, Research Division, 10 pp.

EGG AND LARVAL DEVELOPMENT

Ahlstrom and Counts (1955) described the egg and larval stages of Pacific hake. The hake egg is pelagic, spherical, and transparent. It has a single oil globule, a tough unsculptured shell membrane, and an unsegmented yolk. The diameter of the average egg is 0.044 inch. The length of the larva at hatching is about 0.094 inch. The time required for embryonic development (from fertilization to hatching) of eggs from the Puget Sound hake population, reared under controlled laboratory conditions, was 3.1 days at 61.9° F. and 9.2 days at 47.1° F. (Rodman[4]). These temperatures were similar to the temperature range in which hake larvae have been found in the spawning area off southern California and Mexico (see below).

Like most fish larvae from pelagic eggs, newly hatched hake are relatively undeveloped. Hatching occurs before the mouth is formed and before the eyes are pigmented (Ahlstrom and Counts, 1955). The end of the larval stage is not well defined. Fin formation is completed at a length of 1.2 to 1.4 inches, when the full complement of pectoral rays is attained. Complete larval development requires more than a month.

GEOGRAPHIC AND DEPTH DISTRIBUTION

In this section, we discuss the distribution of eggs and larvae, juvenile hake, and adult hake.

DISTRIBUTION OF EGGS AND LARVAE

Pacific hake spawn primarily during the winter and early spring off the coasts of California and Baja California. Hake larvae consistently rank second to anchovy in annual estimates of the relative abundance of fish larvae collected in the CalCOFI survey area (Ahlstrom, 1959 and 1965).

Ahlstrom and Counts (1955) found that in 1951 and 1952, 98 percent of the total number of hake larvae in their monthly plankton collections were taken from February through April; 50 to 60 percent were taken in March. In certain portions of the spawning region, data on the abundance of larvae indicate that spawning is well underway by January (personal correspondence, Paul E. Smith, Fishery Biologist, Bureau of Commercial Fisheries Fishery-Oceanography Center, La Jolla, Calif., January 1968). It is reasonable to assume, however, that little spawning occurs between April and December. Temporal changes in the relative abundance of adult hake in inshore areas (discussed below) also indicate that the spawning season is restricted mainly to January through April.

Although hake larvae have been found as far north as Cape Mendocino, Calif., the effective northern limit of spawning is probably near the latitude of San Francisco, Calif. Ahlstrom and Counts (1955) found hake larvae distributed throughout the area from Cape Mendocino to Cape San Lucas, Baja California. Larvae were encountered as far as 302 nautical miles offshore. Abundance was centered in the southern California-Baja California portion of the spawning range. No hake eggs and larvae were encountered during surveys between Cape Scott, Vancouver Island, and Cape Mendocino (Ahlstrom, 1959; and personal communication, Kenneth D. Waldron, Fishery Biologist, Bureau of Commercial Fisheries Biological Laboratory, Seattle, Wash., September 1968). An extensive egg and larval survey of this entire area, extending seaward 360 nautical miles, was made in the spring of 1967. Other surveys in selected areas along the coast from Washington to northern California were made in 1965 and 1968.

The vertical distribution of hake eggs and larvae and its relation to water temperature are described by Ahlstrom and Counts (1955) and Ahlstrom (1959). They found eggs and larvae mainly near or within the thermocline at depths of 25 to 55 fathoms. The greatest depth at which they took eggs and larvae was 120 fathoms. Larvae were taken at tempera-

[4] Rodman, Duane T. 1969. Development of eggs and larvae of Pacific hake at three water temperatures. Bureau of Commercial Fisheries Biological Laboratory, Seattle. Unpublished manuscript, 7 pp.

tures from 47.5° to 65.3° F., but most were caught between 51° and 59° F.

DISTRIBUTION OF JUVENILE HAKE

Little information is available on the distribution of hake between the end of the larval period and the time, at about age 4, they are recruited to the adult population. The age at which larvae abandon their pelagic life is unknown.

Juvenile hake (ages 1-3) from 4.7 to about 13.8 inches long have been captured in inshore areas (primarily on the Continental Shelf) along the southern Oregon and California coast by shrimp trawls (Morgan and Gates, 1961), in otter trawls used by the California animal food fishery (Best, 1963; Best and Nitsos, 1966), and in trawls during various surveys with research vessels (BCF, unpublished data[5]). Juvenile fish have been captured also off Baja California by the California Department of Fish and Game (Best, 1963). Juveniles have not been observed off the coast between northern Oregon and Vancouver Island, even though U.S. research surveys in this region have used trawls with ½-inch mesh cod-end liners. Also, specimens smaller than 15.7 inches constituted less than 0.1 percent of fish taken in the Washington-Oregon hake fishery, whereas 18 percent of hake samples from the California animal food fishery were in this size range (Best and Nitsos, 1966). This difference occurred despite the fact that the cod ends of the trawls have meshes of 4½ inches in the California fishery and 2¼ inches in the Washington-Oregon fishery.

Because of gear selectivity, it is difficult to use commercial catch data to determine the degree to which young hake remain apart from adults in the southern Oregon-California area. Research vessels have made catches containing only juvenile fish and catches in which adults and juveniles were mixed. Data on the relative abundance of age groups, however, suggest that through age 1 juvenile fish do not mix significantly with the adult stock.

DISTRIBUTION OF ADULT HAKE

Although most often caught on the Continental Shelf (Best, 1963; Alverson, 1967; Nelson, 1967), adult hake have been observed over a wide depth range. Clemens and Wilby (1961) state that hake (presumably adults) have been captured as deep as 491 fathoms off California. Ermakov and Polutov[6] reported that Soviet investigators found hake to depths of 547 fathoms in the region from Vancouver Island to Oregon. In the same area commercial concentrations were not found beyond a depth of 219 fathoms (Anonymous[7]). Alverson (1951, 1953) caught small numbers of hake at 300 fathoms off Washington, and Alverson et al. (1964) reported that north of Washington, hake were absent in waters deeper than 300 fathoms. De Witt (1952) observed on the northern California coast hake stranded in the surf while chasing prey, and Van Hyning and Ayres[8] observed hake in brackish water in the Columbia River estuary.

Schools of spawning adult hake have been observed infrequently. From 1963 through 1966 a BCF vessel surveyed with an echo sounder off southern California and Baja California during the hake spawning season. In 1968 three vessels surveyed the area with both echo sounders and sonars. During all surveys fishing was done with midwater trawl gear with an electrical depth telemetry system. Search tracks covered areas where hake eggs and larvae were abundant. Except for one occasion when a 1-hour haul yielded 20,000 pounds, no dense concentrations of hake were observed. Rather loosely aggregated hakelike signs were occasionally seen on the echo sounder but trawl catches of hake were usually less than 100 pounds per hour. Most fish were beyond the Continental Shelf at depths of 125

[5] Trawl catch data are on file in Seattle, Wash., at the BCF Biological Laboratory or BCF Exploratory Fishing and Gear Research Base.

[6] Ermakov, Yu K., and A. N. Polutov. 1967. Fishery and biological description of the Vancouver Island and Washington-Oregon regions. Pacific Research Institute for Fisheries and Oceanography (TINRO). Unpublished manuscript, 38 pp. + figs.

[7] Anonymous. 1965. Brief review of scientific research carried out by TINRO in the Vancouver-Oregon area. Pacific Research Institute for Fisheries and Oceanography (TINRO). Unpublished manuscript, 26 pp. + figs.

[8] Van Hyning, J. M., and R. J. Ayres. 1960. Observations of anchovy mortalities in 1960. Oregon Fish Commission, mimeo report, 7 pp.

to 225 fathoms over surface-to-bottom depths of over 550 fathoms.

The observed availability of spawning adults has been less than would be expected from knowledge of the abundance and distribution of eggs and larvae. There is little reason to suspect that this apparent paradox is due to anything other than a lack of knowledge of the spatial and temporal distribution and behavior of spawning hake and its implications as regards to methods of detection. In addition to the egg and larval data, the relative scarcity of adult hake in the January to March landings of the California animal food fishery (Best and Nitsos, 1966) and their absence from December to April in the Vancouver Island-Oregon region (Nelson, 1967) indicates that the adult population spawns during the winter and early spring primarily in waters beyond the Continental Shelf off California and Mexico.

Knowledge of the distribution and relative abundance of adult hake during the period between spawning seasons (May-December) has increased substantially as a result of United States and Soviet exploratory fishing and biological investigations carried out since 1964. Further information has been obtained from observations of Soviet fishing activities and analysis of United States catch and effort data. Much of the available information on the distribution of adult fish during spring through fall is discussed by Alverson (1967) and Nelson (1967, 1970), and see footnotes 6 and 7.

Adult hake first appear on the upper Continental Slope and Shelf during April and early May in areas off central and northern California and southern Oregon. In May they are abundant on Heceta Bank off Newport, Oreg. By late May fish are also present along the northern Oregon and Washington coast. During June and July large dense concentrations of hake are between the 20- and 75-fathom isobaths off southern Washington between Cape Elizabeth and the Columbia River, and in Oregon waters adjacent to the Columbia River estuary.

About the middle of July the relative abundance of hake begins to change noticeably. They become more abundant on the outer Continental Shelf and along the central Washington coast. The size of individual hake schools tends to decrease, and the schools become more widely distributed. We assume this change in relative abundance results mainly from movement of fish already in the Washington and northern Oregon coastal area and not from the arrival of new fish. As the summer progresses, however, new fish apparently move onto grounds off northern Washington and southern Vancouver Island in areas usually sparsely populated earlier in the season. Also, there apparently is additional movement of fish onto Heceta Bank and adjacent banks along the Oregon coast.

By the end of September hake have begun to move out of the Vancouver Island-Oregon region into deep water overlying the Continental Slope. By December, most hake have left the Vancouver Island-Oregon area.

MIGRATION HYPOTHESIS

Knowledge of the relative abundance and distribution of the different life history stages of hake has led to the hypothesis that adult hake engage in an annual coastwise migration. This migration involves a northward movement of adult fish in the spring and summer to inshore feeding grounds primarily on the Continental Shelf and a southward return movement beginning in the fall to the offshore spawning region. As a result of this migration, adult hake are most abundant in the Washington-Oregon region from spring to fall. Local concentrations of adult hake are also available off northern and central California in this period. In the winter, adults are essentially confined to offshore waters along the California-Mexico coast.

Although the summer coastwise segregation of adult and juvenile fish is obvious, the degree to which adult age groups become stratified along the coast is poorly defined. There is some indication that of the total number of 4-year-old fish in the population, only a small proportion of them migrate into the fishing area off Vancouver Island, Washington, and Oregon. Among fish 5 years old and older, the proportion of the larger, generally older fish tends to increase in the northerly fishing areas. Detailed long-term studies are needed, however, to evaluate geographic differences in age and size composition because environmental factors can be expected to produce year-to-year changes in the distribution of adult fish.

Tillman (see footnote 1) commented on the fact that all other commercial species of *Merluccius* engage in an annual bathymetric movement rather than a latitudinal (actually latitudinal and bathymetric) one such as that hypothesized for Pacific hake. Even without the racial data now available, he considered the case for a bathymetric migration by Pacific hake (in the Vancouver Island-Oregon region) to be weaker than that for a latitudinal migration.

BEHAVIOR

Some general observations on the behavior of Pacific hake have been reported by Alverson (1967) and Nelson (1967). During the day, adult fish on the Continental Shelf characteristically school in long, dense, relatively narrow bands. Rather than being completely continuous, these bands are usually composed of distinct clusters. The long axis of a school is nearly always parallel to the isobaths. Because of this orientation, any one school rarely occupies a bottom depth range of more than 3 fathoms. On the Continental Shelf, schools are usually within 10 fathoms of the bottom and have heights of 3 to 6 fathoms; the lower side of a school is often within a fathom of the bottom. Hake, like cod, haddock, and various rockfishes, is probably best described as a semi-pelagic species (Saetersdal, 1967).

BCF surveys have shown that schools of hake near the edge of the Continental Shelf or over the Continental Slope show more variation in their schooling characteristics than those found on the shelf. Over the slope, hake schools are well off the bottom without definite orientation to bottom contours. Also, fish are in many small groups, as opposed to continuous schools. Schools over the edge of the Continental Shelf are often at a constant depth from the surface but aligned perpendicular to isobaths in such a manner that the offshore portion of the school is much farther off the bottom than the inshore portion.

Hake schools rise and disperse in the water column during the evening. During darkness hake are scattered throughout the water column, and midwater trawls catch only small numbers of fish. By dawn, schools have regrouped near the seabed but not necessarily near the areas from which they had dispersed.

Few data are available on the behavior of spawning schools. Actively spawning fish apparently do not engage in the pronounced vertical migration typical of adult fish that feed in inshore areas from spring to fall. This lack of vertical movement is also characteristic of the spawning population in Puget Sound.

INTERSPECIFIC RELATIONS

Hake and the remains of hake are found in stomach contents of a wide variety of mammals and fishes. Best (1963) reported on observations of hake as prey. Young hake served as food for rockfishes; albacore, *Thunnus alalunga;* and flounders. Large hake were found in Pacific lancetfish, *Alepisaurus richardsoni;* bluefin tuna, *Thunnus thynnus;* sablefish, *Anoplopoma fimbria;* lingcod, *Ophiodon elongatus;* and sharks. Otoliths of hake were recovered from the stomachs of sea lions, seals, and porpoises. Fiscus and Kajimura (1967) found hake to be the dominant food of fur seals collected off the west coast of the United States in 1964. Shippen and Alton (1967) reported that spiny dogfish, *Squalus acanthias,* prey on hake in Puget Sound.

Best (1963) noted that stomachs of adult hake contained a wide variety of organisms including flounders, small hake, anchovies, clams, squid, and euphausiids. Juvenile hake fed on euphausiids; red crabs, *Pleuroncodes planipes;* and small squid. He mentioned that little was known about hake food habits and suggested that the hake was an opportunistic feeder. Pink shrimp, *Pandalus jordani,* also appear to be an important food of hake (Willis[9]).

The euphausiids, *Euphausia pacifica* and especially *Thysanoessa spinifera,* dominate the food of hake caught off Washington and Oregon (Alton and Nelson, 1970). Pandalid shrimp, smelt, and other crustacea and fish were also found in the stomach contents, but their contribution to the total weight of food was relatively minor. Alton and Nelson (1970) indicated that hake are primarily nocturnal or crepuscular feeders or both.

POPULATION DYNAMICS

This section presents information on age and growth, natural mortality, and standing stock and yield estimates for the hake population.

AGE AND GROWTH

Hake collected from the Washington-Oregon commercial fishery in 1965 and 1966 averaged about 20.3 inches in fork length (range 14.2-31.5 inches) and 2.2 pounds in weight.

The age composition of the catches (fig. 1) for 3 years (1965-67) of fishing has been determined from annual growth patterns observed in otoliths.[10] Few fish younger than 4 years or older than 10 years have been taken in the commercial fishery; ages 5 through 7 have dominated the catches. Pacific hake apparently grow rapidly during their first 6 or 7 years. Thereafter, growth in length and weight becomes slower and may cease in old age (fig. 2). Females tend to grow faster than

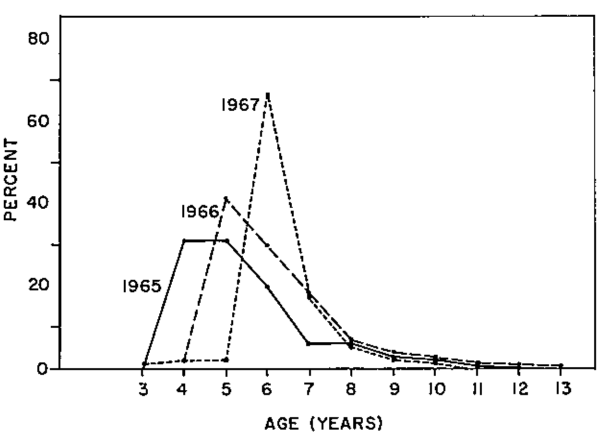

Figure 1.—Age composition of Pacific hake taken in Pacific Northwest commercial fishery, 1965-67.

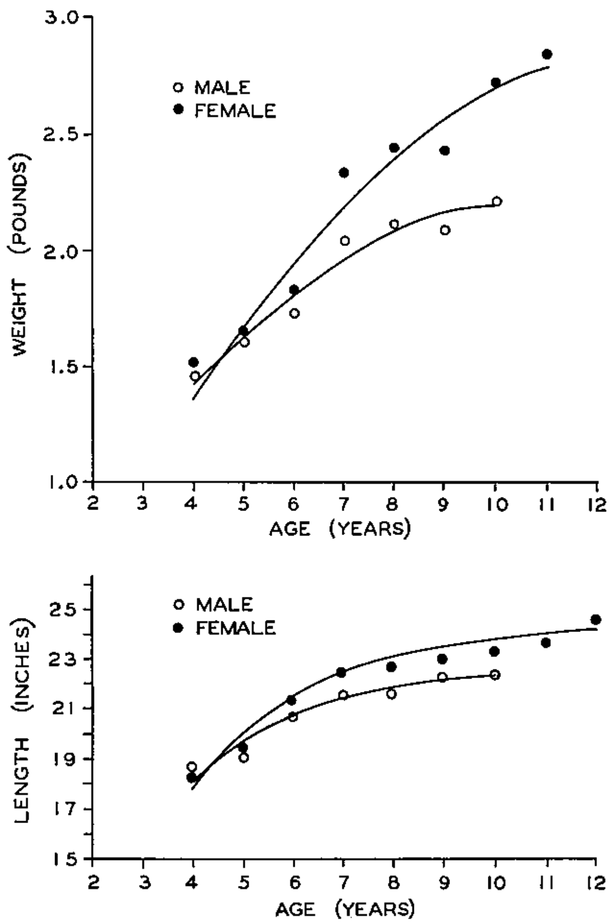

Figure 2.—Growth of Pacific hake off the Washington coast.

[9] Willis, Mel. 1966. Cruise report 66-S-5. California Department of Fish and Game, Fisheries Laboratory, Terminal Island, California. Unpublished manuscript, 2 pp.

[10] The validity of these annual growth patterns has been substantiated from studies on the otoliths of young, fast-growing Pacific hake, during that portion of their life when age groups I, II, and III can be readily separated by length frequency distributions. Examination of the growth patterns on otoliths from such fish reveal an obvious annual mark consisting of a wide, opaque summer growth zone followed by a narrow, translucent winter growth zone. The fact that Pacific hake spawn during late winter (i.e., during the period the winter growth zone is being laid down on the otolith) suggests that false annuli, caused by spawning, should not affect annuli counts in adults.

males and at any age after 4 years are slightly longer and heavier.

NATURAL MORTALITY

The short history of the hake fishery and very small catches in relation to the size of the harvestable population preclude our using the annual change in catch per unit of effort by age class to estimate natural mortality. We can, however, make an estimate by assuming the observed age composition (consisting of several year classes) of an unfished stock to be parallel to the changing abundance of any year class as it advances in age. Natural mortality is then estimated by the slope of the right limb of the observed age curve. When we apply this method to the age groups (5-7) that appear to have been fully recruited and amply represented in the 1965 and 1966 samples, annual natural mortality is about 43 percent.

The model shown in table 1, based on annual survival rate of 57 percent and the weight at age given in figure 2, shows that the biomass of a hake year class decreases substantially each year after age 5.

Table 1.—Changes in biomass with age of a hypothetical hake year class

Age	Population[1]	Average weight[2]	Biomass	Change in biomass
	Number	*Pounds*	*Pounds*	*Percent*
5	1,000	1.66	1,660	--
6	570	1.89	1,077	−35
7	325	2.10	682	−37
8	185	2.25	416	−39
9	105	2.36	248	−40
10	60	2.46	148	−40

[1] At each age, survivors consist of 57 percent of the preceding year.
[2] Estimated from figure 2.

STANDING STOCK AND YIELD ESTIMATES

Recently, attempts have been made to estimate the standing stock and potential yield of Pacific hake. Alverson (1968), in summarizing the results of demersal trawl surveys in the northeastern Pacific, estimated the size of the standing stock of adult hake between southern Oregon and Cape Spencer, Alaska, at 1.5 billion pounds. He estimated the maximum sustainable yield from this stock at 300 to 540 million pounds. Ahlstrom (1968) estimated the size of the standing stock of adult hake between Cape Scott, Vancouver Island, and Cape San Lucas, Baja California, at 4 to 8 billion pounds. His estimates were based on the abundance of hake larvae and relations between larval populations of hake and jack mackerel, *Trachurus symmetricus*. Both authors explicitly pointed out the tentative nature of their estimates and the fact that they were derived primarily to evaluate resource potentials on a relative basis.

At the present state of development of the Pacific hake fishery, any estimate of potential yield is preliminary. The variation in age composition during 1965 through 1967 suggests that recruitment (and perhaps growth and natural mortality) is not stable. The age frequencies in figure 1 have a distinct mode that advances to the right each year; in 1965, ages 4 and 5 dominated; in 1966, 5-year-olds were dominant; and in 1967, 6-year-olds were dominant. The main feature here is the lack of younger fish coming into the fishery. Whether this feature is due to a distributional anomaly that affected our sampling or a natural failure in one or two year classes cannot be determined now. Until we obtain further knowledge of the nature of the hake population with regard to fluctuations in year class strength, a basis for management cannot be fully developed.

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Food of Pacific Hake, *Merluccius productus,* in Washington and Northern Oregon Coastal Waters

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ABSTRACT

Examination of the stomach contents suggests that Pacific hake feeds principally on pelagic organisms during its seasonal residence (spring to fall) off the Washington and northern Oregon coasts. Euphausiids, *Thysanoessa spinifera* and *Euphausia pacifica,* were the leading food items of Pacific hake in both frequency of occurrence and contribution by weight. Other important forms were fish and pandalid shrimp. Similar to Pacific hake, several of the prey of hake (euphausiids, pandalid shrimp, and *Sergestes similis*) undergo a vertical movement during the evening and early morning. A high incidence of empty stomachs in fish captured late in the day may suggest that hake resume feeding sometime between sunset and the following morning.

CONTENTS

INTRODUCTION

The recent development of a hake fishery in waters off Oregon and Washington has stimulated our interest in the food habits of this species and in the relation between its food supply and its availability. This preliminary report provides a base for future studies on the food of the Pacific hake.

Our investigation is the first intensive effort to study the food habits of Pacific hake. In the past, information on the food of Pacific hake has come from random observations on several hundred fish in California waters (Best, 1963) or in conjunction with studies by the California Department of Fish and Game on the pink shrimp, *Pandalus jordani,* found in hake stomachs (Willis[1]). Best (1963) lists the following organisms as food of Pacific hake: red crab, *Pleuroncodes planipes*; euphausiids;

[1] Willis, Mel. 1966. Cruise report 66-S-5 shrimp. California Department of Fish and Game, Fisheries Laboratory, Terminal Island, Calif. Unpublished manuscript, 2 pp.

Published February 1970.

squids; clam, *Solemya panamensis*; anchovies; small Pacific hake; queenfish, *Seriphus politus;* sanddabs, *Citharichthys* spp.; slender sole, *Lyopsetta exilis;* curlfin turbot, *Pleuronichthys decurrens*; and pink seaperch, *Zalembius rosaceus.*

Various marine mammals and fishes feed on Pacific hake. Fiscus and Kajimura (1965) found that hake was a leading food item in the stomachs of fur seals taken off California, Oregon, and Washington in 1964. Shippen and Alton (1967) reported that in Puget Sound the spiny dogfish, *Squalus acanthias,* preyed on Pacific hake.

METHODS

Bureau of Commercial Fisheries personnel obtained samples of hake during exploratory fishing and commercial fishing for Pacific hake from May to September in 1965 and 1966. Random samples were collected whenever feasible from catches obtained from midwater and bottom trawls with 2- to 3-inch stretch mesh. Stomachs were removed and preserved shortly after the catch was brought aboard the vessel.

Stomach contents were examined by two methods — cursory and detailed. In the cursory method the stomach contents were examined at sea and then discarded. Food organisms were classified into broad categories such as fish, euphausiids, shrimp, and unidentifiable remains. Specific identifications were made for the readily identifiable animals, such as anchovies and herring. Recorded were the degree of fullness of stomach, state of digestion of the contents, and types of prominent food. In the detailed method the stomach contents were preserved in 10 percent Formalin and were examined later at shore facilities. Organisms were identified, usually to species, counted, and weighed. Individual items were placed on blotting paper to absorb excess liquid, and then weighed to the nearest 0.1 g. The total weight of the contents of each stomach was obtained by adding the weights of individual items.

Little information was taken on length, sex, and maturity of the hake used in this study. Consequently, we did not examine in detail the relations between these variables and feeding habits. This deficiency, however, is not considered serious because in the coastal waters off Washington and northern Oregon only nonspawning adults are caught. Usually they are from 4 to 10 years old and 18 to 26 inches long.

Table 1 gives the sampling effort by area, year, and month. The number of fish examined per haul was from 1 to 99, but varied usually between 10 and 20. In the subsequent discussion a sample refers to stomachs examined from one haul. Most samples were obtained from hauls made on the Continental Shelf off Washington over bottom depths of 30 to 85 fathoms. Sampling was restricted to daylight (0800-1900 P.s.t.).

ANALYSIS OF HAKE FOOD DATA

We examined a total of 552 stomachs from 23 samples in which both the numbers of fish with and without food were recorded. Of this total, 327 (59 percent) contained food and 225 (41 percent) were empty. An additional 102 stomachs containing food were collected from 18 hauls in which no record of the proportion of empty stomachs was kept. Hence 429 (327 + 102) stomachs containing food were examined (table 1).

The stomachs in table 1 refer to those examined with either the detailed or cursory method and do not include a sample of 125 stomachs for which we did not try to determine either the frequency of occurrence or contribution by weight of food types. This latter sample is referred to in the discussion of diel changes in feeding habits.

FOOD OF PACIFIC HAKE

Euphausiids were the most frequently encountered food, followed by fish and pandalid shrimp (table 2). On the basis of weight the order of importance was the same, but owing to the small size of euphasiids, the fish and pandalid shrimp contributed relatively more to the total weight of food than they did in terms of frequency of occurrence (fig. 1).

Euphausiids

Two species of euphausiids, *Thysanoessa spinifera* and *Euphausia pacifica,* were ident-

Table 1.—Sampling effort by area and month in 1965 and 1966

Area	Month	Year	Samples	Stomachs containing food		
				Method of examination		Total
				Cursory	Detailed	
			Number	*Number*	*Number*	*Number*
Off Washington	Sept.	1965	1	18		18
Lat. 47°40'-48°30'N.	Aug.	1966	1		10	10
	Sept.	1966	2	25		25
Off Washington	Sept.	1965	2	54		54
Lat. 47°15'-47°40'N.	June	1966	1	21	12	33
	July	1966	1	6	6	12
	Sept.	1966	9	91	4	95
Off Washington	May	1965	6	30	6	36
Lat. 46°21'-47°15'N.	Aug.	1965	1		1	1
	Sept.	1965	1	10		10
	June	1966	4		10	10
	July	1966	3	6	30	36
	Aug.	1966	1		14	14
	Sept.	1966	1	8	2	10
Off Oregon	May	1965	2	20		20
Lat. 46°01'-46°21'N.	Aug.	1966	4		25	25
	Sept.	1966	1		20	20
Total			41	289	140	429

ified in the stomachs of hake. *T. spinifera* was more abundant and occurred more frequently than *E. pacifica.* Of the 140 stomachs examined in detail, 98 (70 percent) contained *T. spinifera* and 58 (41 percent) contained *E. pacifica.* *T. spinifera* made up 49 percent of the total weight of euphausiids from these stomachs; *E. pacifica,* 7 percent. The remaining 44 percent were euphausiids that could not be identified to species because they were mutilated or partially digested.

Both identified euphausiids were in 14 (58 percent) of the 24 samples examined in detail and in 49 (39 percent) of the 126 stomachs with euphausiids. *T. spinifera* was more abundant in 12 of the 14 samples that had both species.

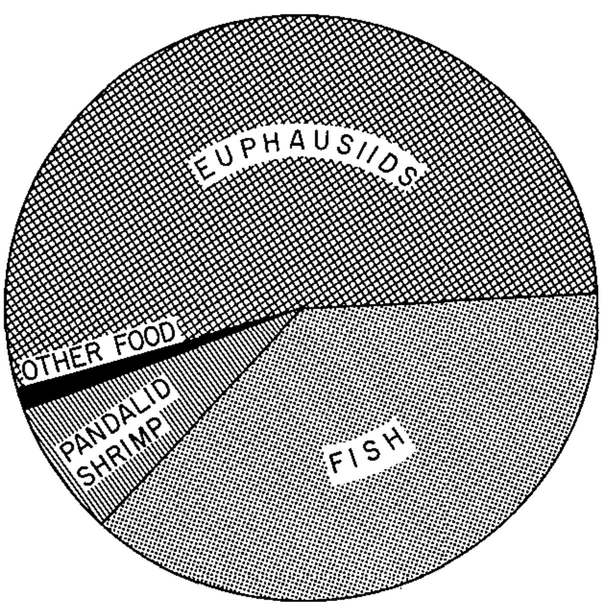

Figure 1.—Contribution of food types to the total weight of food found in stomachs of Pacific hake.

Table 2.—Occurrence of various foods in the stomachs of Pacific hake from the coastal waters of Washington and northern Oregon (May-September 1965 and 1966)

Types of food	Stomachs examined in detail		Stomachs examined cursorily	
	Number	*Percent*	*Number*	*Percent*
CRUSTACEA	137	97.9	274	94.8
Euphausiids	126	90.0	268	92.7
Thysanoessa spinifera	98	70.0	--	
Euphausia pacifica ..	58	41.4	--	
Pandalids	12	8.6	6	2.1
Pandalus jordani ...	8	5.7	1	0.3
Sergestes similis	7	5.0	--	
Cragonids	3	2.1	--	
Crab larvae	5	3.6	--	
Mysids	1	0.7	--	
Crustacean remains ...	12	8.6	--	
FISH	35	25.0	7	2.4
Smelt (unidentified) ..	6	4.3	--	
Thaleichthys pacificus .	7	5.0	--	
Engraulis mordax	5	3.6	--	
Ammodytes hexapterus	2	1.4	--	
Anoplopoma fimbria ..	1	0.7	--	
Clupea harengus pallasi	--		1	0.3
Fish remains	14	10.0		
SQUID	1	0.7	--	
Stomachs containing food .	140		289	

Fish

Fish were in 25 percent of the stomachs examined in detail and in 2 percent of the stomachs examined cursorily. Small fish, especially those that were partially digested, were probably overlooked at times in stomachs that were cursorily examined. In stomachs examined in detail, smelt, mainly *Thaleichthys pacificus*, were the fish that occurred most frequently. Other species of fish occurred infrequently (table 2).

Pandalids and Other Organisms

Hake stomachs had five other identifiable crustaceans besides the euphausiids. Pandalids and the penaeid shrimp, *Sergestes similis*, occurred frequently. Identification of the pandalids to species, *Pandalus jordani*, was possible in 9 of 18 occurrences of this group. Only 5 of the 140 stomachs examined in detail had crab larvae, and only 3 stomachs had cragonid shrimps.

One stomach had a squid.

SEASONAL ASPECTS OF HAKE FEEDING

Information on the feeding of hake was examined seasonally by dividing the period of sampling into early summer (May-July) and late summer (August-September). Food organisms were placed into four categories: euphausiids, fish, pandalids, and other organisms.

The percent frequency of occurrence and percent weight of each food category remained about the same in each period (fig. 2)—the euphausiids occurred most frequently. On the basis of weight the relative importance of fish increases, but this category still ranked second to the euphausiids in each period. The pandalids and other organisms were of minor importance.

The average number of food types per stomach was also similar for both periods. The average for "early summer" was 1.1, and that for "late summer" was 1.2, reflecting the high frequency of a specific food item, euphausiids, in both periods.

DIEL FEEDING PATTERN

A tendency to feed at night has been reported for various species of *Merluccius*. Hickling (1927) found that European hake, *M. merluccius*, captured near midnight had a greater mean weight of stomach contents than fish taken during midday. His data were obtained during continuous sampling over 24- and 48-hour periods. Hickling also found stomach contents appeared freshest in hake taken in the morning and most highly digested in fish taken later in the day. He concluded that European hake was primarily a nocturnal feeder.

Angelescu, Gneri, and Nani (1958) reported that Argentine hake, *M. hubbsi*, feeds both night and day. With the beginning of night, it ascends to near-surface waters where it feeds on nektonic forms such as anchovies and squids. During the day this species schools near the sea bottom and feeds on demersal fish (Nototheniidae and Macrouridae). Hickling (1927) rarely found bottom-living forms in the stomach of European hake.

Because no samples were obtained during darkness, we used an indirect approach to determine if Pacific hake tend to feed during a particular period of the day. The incidence of empty stomachs was related to the number of hours after sunrise when the hake were captured. The higher incidence of empty stomachs late in the day (table 3) suggests that hake resume feeding sometime between sunset and the following morning.

Table 3.—Proportion of hake stomachs that were empty as related to the number of hours after sunrise

Hours after sunrise[1]	Samples	Stomachs examined	Empty stomachs
	Number	*Number*	*Percent*
2-4	4	82	22
5-7	9	147	29
8-10	5	105	53
11-13	5	218	50
Total	23	552	41

[1] Sunrise varied between 0400 and 0600 hours depending upon time of year.

Another approach to determine if hake have a specific time of the day when they feed would be to relate the degree of digestion of stomach contents to time of day. Except for three samples in which the contents apparently had been recently ingested, it was not feasible to attempt to categorize the relative degree of digestion of stomach contents. The three samples with freshly ingested food were taken on different days and at different times (0900, 1400, and 1900 hours). The stomachs of

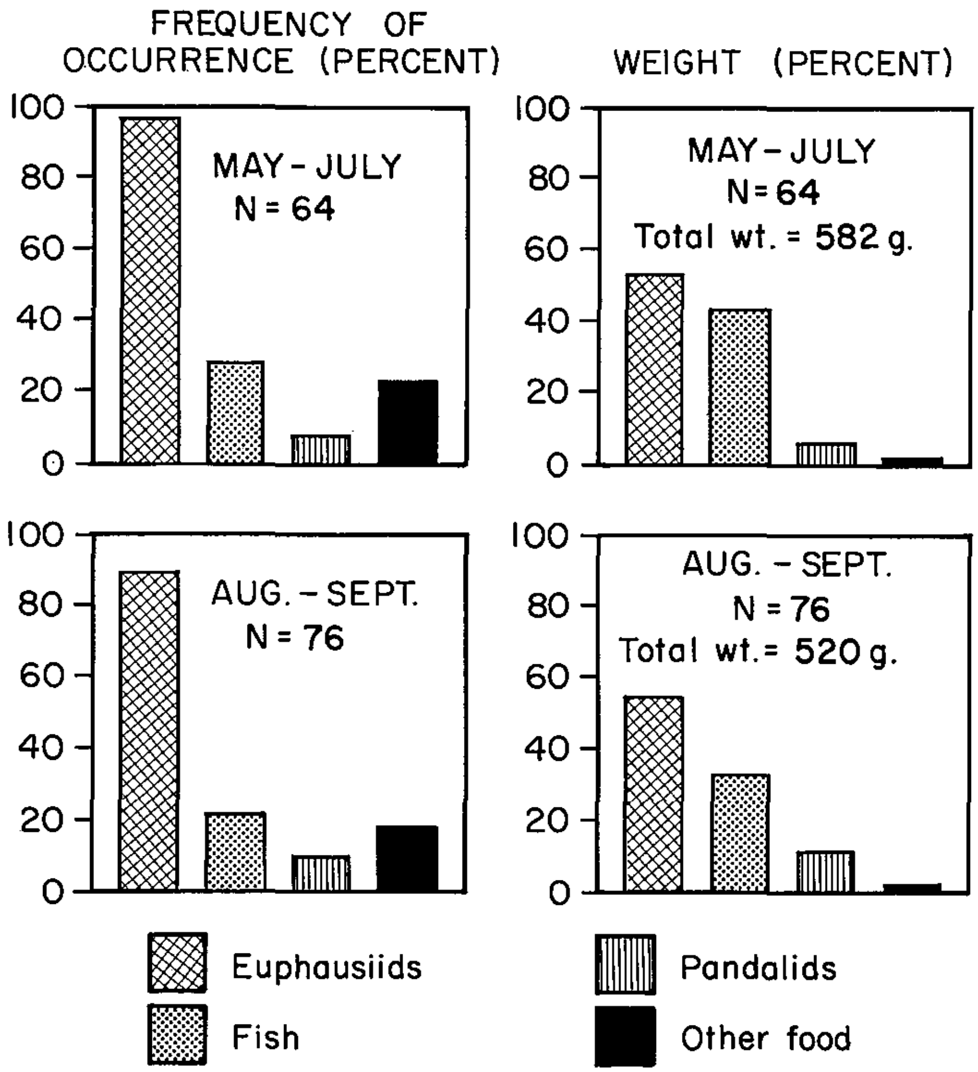

Figure 2.—Percentage frequency of occurrence and percentage weight of major food categories of Pacific hake for May-July and August-September. Data combined for 1965 and 1966.

hake from samples taken at 0900 and 1900 hours contained euphausiids, and these times agree with a possible crepuscular or nocturnal feeding period; however, the fresh condition of the food in the sample taken at 1400 hours appears to contradict a crepuscular feeding period. The catch of the haul at 1400 hours consisted of 125 hake mixed with about 300 pounds of herring, anchovies, and smelt. Twenty pounds of freshly ingested herring, anchovies, smelt, and pink shrimp were removed from the 125 hake stomachs. It is possible that the hake may have been feeding opportunistically on the animals while in the trawl. The catch was small, and the net may have had ample space for the hake to move around and feed. This, of course, is conjectural.

The main evidence to suggest that the hake feed principally during the hours of twilight and darkness is the high incidence of empty stomachs late in the day.

RELATION OF FOOD HABITS TO SIZE OF HAKE CATCH

The limited amount of material available precludes a detailed investigation of the relation between importance of food types and the size of hake catches. It is pertinent to note, however, that the relative contribution of euphausiids in the stomach contents of hake increased markedly in the large catches (table 4). Although this phenomenon needs further documentation, the preliminary data suggest that hake caught in large quantities had fed predominantly on euphausiids and, conversely, hake captured in small numbers had fed on a greater variety of food types, although euphausiids were still important.

Table 4.—Relation between size of hake catch and quantity of euphausiids in stomach contents

Item	Catch range (lbs./hr.)	
	10-5,000	5,300-62,400
Number of stomachs	99	41
Average weight (g.) of euphausiid contents (A)	2.8	7.6
Average total weight (g.) of stomach contents (B)	8.8	12.6
(A/B) x 100	31.8	60.3
Percentage of stomachs in which euphausiids were 80 percent or more of the weight of contents	70.7	85.3

FOOD AVAILABILITY AND OPPORTUNISTIC FEEDING

Best (1963) considered the hake to be an opportunistic feeder because of the variety of its prey. In Washington waters the fact that hake appear to feed predominantly on euphausiids might be considered as evidence that hake prefer these crustaceans. Because of their temporal and spatial distribution and abundance, however, euphausiids may be more available to hake than other potential prey. Euphausiids have diel vertical movements that tend to coincide in direction and time with those of hake. These movements may make the euphausiids more available to hake, especially during that period of the night when euphausiids are concentrated in near-surface waters.

Evidence from macroplankton surveys suggests that euphausiids are abundant in coastal waters during the spring and summer. Day[3] reported that euphausiids constituted 90 percent of the total organisms captured during macroplankton surveys over the Continental Shelf and slope off Washington during spring and fall. Their relative abundance was markedly greater in the spring than in the fall. Of interest is that *Thysanoessa spinifera* and *Euphausia pacifica*, the only euphausiids identified from the stomachs of hake, made up 99.6 percent of the euphausiids captured. On the average about 2,000 euphausiids were captured per 30-minute tow with a 3-foot Isaac Kidd trawl.

Euphausiids are also an important item in the diet of salmon off the west coast of the United States. Silliman (1941) found that during May and June euphausiids made up the largest proportion by weight of the stomach contents of silver salmon, *Oncorhynchus kisutch*, caught off the coast of Washington. In California waters chinook salmon, *O. tshawytscha*, also feed to a large extent on euphausiids. Euphausiids were the dominant food organism by volume in chinook salmon captured during April and May and were second in importance in the diet of salmon in June (Merkel, 1957). From the reports by Silliman and Merkel, euphausiids appear to be most available to salmon in the spring and early summer. Merkel identified only two species of euphausiids, *T. spinifera* and *E. pacifica*, from the stomachs of chinook salmon. The former species, which has been seen in great schools at the surface off southern California, occurred most frequently in stomachs of chinook salmon.

VERTICAL MIGRATIONS OF FOOD ORGANISMS

In Washington waters several of the food organisms of hake make a daily vertical movement. This movement has been well documented for euphausiids (see Brinton, 1962, for extensive literature on this subject). *E. pacifica* has been reported to undergo a daily change in depth. Off southern California, Brinton (1962) found adults of *E. pacifica* from

[3] Day, Donald S. 1966. Macroplankton and small nekton in the coastal waters off Vancouver Island and Washington, spring and fall of 1963. Bureau of Commercial Fisheries Biological Laboratory, Seattle, Wash. Unpublished manuscript, 96 pp.

the surface to a depth of 219 fathoms during the day, but caught most of them above 44 fathoms at night. Immature specimens and larvae of *E. pacifica,* however, were found near 22 fathoms in the daytime. Bary (1966) showed evidence that euphausiids, mainly *E. pacifica,* have a diurnal vertical migration in Saanich Inlet on the east coast of Vancouver Island, British Columbia.

Diurnal vertical migrations have been reported for several species of *Thysanoessa* (Brinton, 1962; Ponomareva, 1963) and pandalid shrimp. Day (see footnote 2) showed some evidence that *T. spinifera* in Washington waters has a diel vertical movement, whereas Brinton (1962) found no evidence of such a movement of *T. spinifera* in waters off southern California. Pandalids have been found to rise from the sea bottom to midwater depths. During a pelagic survey by the vessel, *John N. Cobb,* off Vancouver Island, pink shrimp were captured 5 hours after sunset at a depth of about 50 fathoms over bottom depths of 109 to 121 fathoms (Schaefers and Johnson, 1957).

Evidence of a nocturnal vertical movement in species of the genus *Sergestes* has been reported by Sund (1920), Welsh, Chace, and Nunnemacher (1937), Waterman, Nunnemacher, Chace, and Clarke (1939), and Yaldwyn (1957). Pearcy and Forss (1966) reported that *S. similis,* a food organism of the hake, also has this type of migration.

Thus many of the main food species of Pacific hake move toward the surface waters in the evening. That hake also move toward the surface might be interpreted as a cause and effect relation; that is, the hake respond to the vertical movements of its prey. Such a relation cannot be demonstrated. The diel behavior of the hake may be an endogenous rhythm and would be exhibited whether or not prey were available.

ACKNOWLEDGMENTS

Olaf Angell, skipper of the commercial trawler *Baron,* helped collect data. This investigation was supported in part by the United States Atomic Energy Commission Agreement No. AT(49-7)-1971-Modification No. 1.

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MS. #1866

Pacific Hake Fishery in Washington and Oregon Coastal Waters

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ABSTRACT

In 1966 both United States and Soviet vessels began harvesting hake from coastal waters. Egg and larvae and trawl surveys have shown the hake resource to be large and capable of supporting a sizeable fishery. In offshore waters hake are fished from May to November between northern California and Vancouver Island. Four U.S. vessels participated in the offshore fishery in 1966, and 10 vessels in 1967. Total U.S. catches reported by fishermen were 3.7 million pounds in 1966 and 18.5 million pounds in 1967. The increased U.S. production in 1967 was due to increased fishing and increased catch-per-hour-trawled. Most of the U.S. production came from the region between lat. 46° and 48° N. in waters between 20 and 80 fathoms deep. Highest catch rates were during June and July. As the season progressed the fishery shifted to the north and to deeper water. Conspicuously few species were mixed in with the hake catches. The size of the offshore fishery is difficult to predict and will be greatly influenced by economic factors and fluctuations in stock abundance.

CONTENTS

INTRODUCTION

The Pacific hake, *Merluccius productus*, is abundant in coastal waters from Vancouver Island, British Columbia, to Baja California, Mexico. Before 1965, the only hake landings of any consequence were those incidentally caught by U.S. otter trawl vessels fishing off central and northern California. For the period 1959-65 the average annual hake catch in California was 495,000 pounds (California Department of Fish and Game, 1960, 1961, 1963, 1964, 1965; Greenhood and Mackett, 1965, 1967). The catch landed in California ports has been used by fur and pet food industries (Best, 1959). Until recently most hake caught incidentally by the Washington and Oregon trawl fleets were discarded; how-

Published February 1970.

ever, Herrman and Harry (1963) found that hake was the most abundant species of roundfish encountered during sampling of the catches of Oregon trawl vessels at sea.

The fishery specifically for Pacific hake is a recent development. The first fishery began in the fall of 1965 in Puget Sound, Wash. Since 1966 both United States and Soviet vessels have harvested hake from coastal waters. The Soviets have operated every year since 1966 between northern California and southern Vancouver Island, British Columbia. U.S. vessels on the other hand only fished hake commercially in 1966 and 1967, operating between northern Oregon and southern Vancouver Island, British Columbia.

Pacific hake are utilized in various ways. In Puget Sound they have been ground and frozen for pet food or reduced to fish meal. The United States ocean hake catch is reduced to a high-grade fish meal used primarily as a poultry diet supplement whereas most of the Soviet catch is quick-frozen and subsequently sold for human consumption.

This paper documents events leading to use of the ocean hake resource by U.S. fishermen in coastal waters of Washington and Oregon. I also describe the U.S. fishery and summarize the statistics on catch and effort for 1966 and 1967. The Puget Sound hake fishery has been discussed by Hipkins (1967), Larkins, Shippen, and Waldron,[1] Millikan,[2] Nelson (1967), and DiDonato (1968). References on the general biology of Pacific hake include Best (1963), Tilliman,[3] and Nelson and Larkins (1970).

BACKGROUND

In this section I discuss the potential of the hake resource and the events leading up to the development of the coastal hake fishery.

EVIDENCE OF RESOURCE POTENTIAL

Until the early 1950's there was little awareness of the size of the Pacific hake resource. Incidental catches taken in various fisheries (Jones, 1960; Clemens and Wilby, 1961) indicated that hake were widely distributed and locally abundant at times. Most sport and commercial fishermen regarded the hake as a pest. Because of its poor keeping qualities it was not marketed as a food fish, and the available data on its distribution and abundance suggested that it could not be economically captured on a large scale for potential industrial markets.

The CalCOFI (California Cooperative Oceanic Fisheries Investigations) provided the first evidence that the hake population in the northeastern Pacific was large (Ahlstrom and Counts, 1955). The studies showed that hake was the second most abundant fish larvae taken in the CalCOFI survey area off California and Mexico (Ahlstrom, 1959 and 1965). Recent surveys of the adult hake stock in Oregon to British Columbia coastal waters support inferences made from knowledge of the abundance of larvae. Alverson (1968) has made a preliminary estimate that the sustainable yield may be as great as 540 million pounds.

DEVELOPMENT OF THE FISHERY

The possibility of harvesting hake in the Oregon to British Columbia region was not given serious consideration by U.S. interests until 1964. During the summer of that year BCF (Bureau of Commercial Fisheries) research vessel, *John N. Cobb*, and the BCF chartered vessel, *St. Michael*, made exploratory fishing surveys off the Washington-Oregon coast while testing the efficiency of pelagic trawls equipped with electrical depth telemetry

[1] Larkins, Herbert A., Herbert H. Shippen, and Kenneth D. Waldron, 1967. Features of a northern Puget Sound hake population. Bureau of Commercial Fisheries Biological Laboratory, Seattle. Unpublished manuscript, 19 pp.

[2] Millikan, Alan E. 1967. Catch and effort statistics for the 1966-1967 Puget Sound midwater trawl hake fishery. Supplemental Progress Report. Marine Fisheries Research and Management Groundfish Investigations, Washington State Department of Fisheries, Research Division, 10 pp.

[3] Tillman, Michael F. 1968. Tentative recommendations for management of the coastal fishery for Pacific hake, *Merluccius productus* (Ayres), based on a simulation study of the effects of fishing upon a virgin population. Master's thesis, University of Washington, Seattle, 197 pp.

systems (McNeely, Johnson, and Gill, 1965). Large schools of hake were found in Continental Shelf waters along the Washington-Oregon coast. Pelagic trawl catches as great as 60,000 pounds per ½-hour haul were taken, and catches of 15,000 pounds per hour were made consistently.

The 1964 surveys demonstrated that hake were in dense schools over a large area off the Washington and Oregon coasts and suggested that they might be economically harvested by a midwater trawl fishery. After these surveys BCF expanded the program to assess the distribution, relative abundance, and availability of the hake resource throughout the northeastern Pacific. Through 1967, this program involved about 27 exploratory fishing and gear research cruises along the Pacific coast from Mexico to Vancouver Island and in Puget Sound.

In 1965, the feasibilty of establishing a commercial fishery for hake along the Washington-Oregon coast was evaluated by commercial fishing trials. BCF chartered the 72-foot commercial trawler, *Western Flyer,* from July through October. The fishing trials of this vessel provided valuable information on methods of detection, catching, and handling and on the short-run production potential of the resource. The effectiveness of midwater trawling was thoroughly tested. The electrical depth telemetry systems were durable enough to be used by commercial vessels under conditions of sustained fishing.

VESSELS AND FISHING METHODS

Most vessels that have fished for hake are multipurpose seiner-type trawlers. These vessels are typical of the Pacific coast trawl and seine fleets. They have the house forward and a large clear deck space aft on which is mounted a powered reel used to set, retrieve, and store the trawl. Hanson (1955) described a typical seiner-trawler, often referred to as a West Coast seiner or combination vessel. Drum (reel) trawling has been discussed by Wathne (1959), Alverson (1959), Lippa (1967), and High (1968). Vessels in the hake fishery have been 59 to 96 feet long. They have had 150- to 525-horsepower main engines and carrying capacity from 35 to 125 tons of uniced hake.

Hake have been fished commercially with either midwater trawls (various models of *Cobb* pelagic trawl) or a trawl designed to fish either on or off bottom (BCF Universal trawl). Depth of the trawl is monitored by an electrical depth telemetry system (Lusz, 1967). Conventional bottom trawl nets have been used in the Puget Sound fishery, but they have not been as successful as midwater trawls. In the first season of the Puget Sound fishery catch rates by bottom trawls were generally much lower than those by midwater gear with depth telemetry systems (Hipkins, 1967). Johnson and High (1970) have described the development of the midwater trawling gear and fishing techniques used in the hake fishery.

Relatively little effort is required to handle hake catches. Because the hake are reduced to meal, preservation of the catches is not a problem unless vessels remain at sea for extended periods. Normally vessels are away from port for 3 days or less, and the catches are neither refrigerated nor iced. Sorting of species is minimal because catches usually contain only small amounts of other species. When landed, the catch is pumped directly from the vessel hold to the reduction plant.

THE COASTAL HAKE FISHERY

In offshore waters hake are fished from May to November. The U.S. fishery operates in the Oregon-Vancouver Island coastal area between lat. 45° and 49° N. (fig. 1). Fishing by U.S. vessels is done almost exclusively in Continental Shelf waters; i.e., inside the 100-fathom isobath.

In 1966 the season was July 5 to October 8. Three vessels fished throughout the season; a fourth vessel fished during August and September. Vessel owners were loaned BCF depth telemetry systems but built their own midwater trawls based on BCF designs.

Shortly after the 1966 season began it became evident that there was severe competition between United States vessels and a large Soviet trawl fleet, which had begun to catch hake and rockfishes (*Sebastodes* spp.) off the Oregon-Washington coast. The American vessels were not successful at first, and it soon was apparent that they would be forced to discontinue fishing. Because BCF considered it important to develop methods to compete effectively for the hake resource, it chartered the U.S. vessels from late July to the end of August. Later, at the request of the Grays Harbor (Washington) Regional Planning Commission, the EDA (Economic Development Administration of the Department of Commerce) financed continuation of the charters so that it could learn whether the hake fishery was economically feasible. BCF administered the charters.

The 1967 season began May 15 and ended August 6. EDA chartered 10 vessels through technical assistance grants. Vessels were loaned BCF depth telemetry systems and experimental trawls.

During both years each vessel kept detailed fishing records in a log designed for the hake fishery. For each trawl haul the information recorded included: vessel, trip number, date, location, duration of haul, bottom depth, net depth, length of trawl cable, performance of net and depth telemetry system, engine revolutions per minute, and estimates of the weights of hake and other important species caught.

FISHERY STATISTICS

The catch figures reported herein are those submitted by the fishermen and differ slightly from landing statistics obtained from the reduction plant. Total U.S. offshore hake catches were 3.7 million pounds in 1966 and 18.5 million pounds in 1967. The increase in production in 1967 was due to increased fishing (from 559 hours trawled in 1966 to 1,845 hours in 1967) and increase in the catch-per-hour-trawled (from 6,700 pounds to over 10,000 in 1967). The increased catch-per-unit-effort may have been caused by increased abundance of hake, greater fishing power of the United States fleet, or decreased competition from the Soviet fleet.

In contrast to 1966, the United States fleet in 1967 was free of Soviet competition inside the 12-mile limit and within an area (beyond the 12-mile limit) where Soviet fishing was not permitted.[4] Also, in 1967 the U.S. fishery began operating in the spring when hake are abundant close to the coast. Furthermore, scouting was more efficient because of more U.S. vessels.[5] Still another factor possibly contributing to increased landings by the U.S. fleets was the use of Universal trawls, which effectively caught hake schools near the bottom.

DISTRIBUTION OF FISHING

Owing to the newness of the fishery and the changing conditions only limited between-year comparisons of the data can be made (table 1). Also, it is premature at this time to detail the nature of the area-time, time-depth, and other interactions observed during analysis of the statistics on catch and effort. Some of the more important changes in the distribution of fishing effort occurring during the fishing period are mentioned below. Nelson (1967) made a preliminary analysis of geographic and bathymetric changes in fishing effort occurring during the 1966 season.

Hake production by the U.S. fleet, which is partially influenced by the location of processing facilities at Aberdeen, Wash., has been limited primarily to the region between lat. 46° and 48° N. in waters between 20 and 80 fathoms deep. Little fishing is done at distances greater than 20 nautical miles from the coast. Over 90 percent of the total catch and the total fishing effort has been recorded from the zone between 20- and 60-fathom contours in areas 2 and 3 (table 1, fig. 1).

[4] During the 1967 season, as a result of United States-Soviet Union negotiations, Soviet vessels were restricted from fishing between the 12-mile fishing limit and the 60-fathom isobath (12-20 nautical miles offshore) in the area off southern Washington between Grays Harbor and the Columbia River.

[5] In fishing for hake, a large proportion of the time usually is spent searching for fish. Consequently, using hours trawled as a measure of fishing effort results in the catch-per-unit-effort statistics (pounds-per-hour-trawled) being a less representative measure of average stock abundance than one that is a function of both fishing and searching time. However, to date no attempt has been made to adjust the effort data.

The highest catch rates in the fishery were during June and July 1967. The differences between these catch rates and those for July 1966 undoubtedly reflect the inexperience of the small United States fleet during the initial weeks of the 1966 fishery, as well as the fleet's inability to compete with the large Soviet vessels on the more productive fishing grounds. The high rate of production during June and July of 1967 confirmed the results of United States research vessel surveys during 1965-67 and observations by BCF Enforcement and Surveillance Program of Soviet fishing in 1966. During these months, hake form large schools close to shore (inside and just outside the 12-mile fishing limit) off the southern Washington coast (area 3, and especially area 2; fig. 1).

As the season progresses the fishery shifts to the north and, in general, to deeper water. Figure 2 shows this trend by month during the 1967 season. Most noteworthy is the magnitude of the distribution changes from month to month. Figure 2 also indicates the value of the 12-mile limit and the U.S.S.R. agreement area to the United States fishery. In 1966 a somewhat similar northward and offshore shift in fishing effort occurred (Nelson, 1967).

CATCHES OF OTHER SPECIES

One of the most conspicuous features of hake fishing is the lack of other species in the catches. This phenomenon occurs partly because most hake fishing takes place off bottom and because the large midwater trawls are towed at relatively slow speeds. However, bottom hauls made in areas where hake concentrate also often produce only small catches of other species.

Table 2 shows the fish caught by one vessel, *Washington*, during the 1967 fishery. Catches of this vessel were selected because the crew meticulously sorted and identified the species taken. The *Washington's* total catch of fish was 2,196,000 pounds, of which only 24,000 pounds or 1.1 percent of the total was species other than hake.

Catches of fish other than hake are rarely significant; however, jellyfish have quite often been caught in such large numbers that they interferred with fishing. In 1966, when jellyfish were particularly abundant, the four vessels in the fishery caught 285,000 pounds. Catches of jellyfish in 1967 were much smaller; e.g., the *Washington* caught 9,300 pounds.

Table 1.—Fishing effort, catch and CPUE (catch-per-unit effort) by month, area, and bottom depth in 1966 and 1967

Item	1966				1967			
	Effort		Catch	CPUE	Effort		Catch	CPUE
Month	*Hours*	*Percent*	*Pounds*	*Lbs./hr.*	*Hours*	*Percent*	*Pounds*	*Lbs./hr.*
May	--	--	--	--	207.6	11.2	1,064,716	5,129
June	--	--	–	--	812.9	44.1	9,171,902	11,283
July	132.8	23.6	691,066	5,238	679.4	36.8	7,165,509	10,547
August	287.0	51.4	1,836,009	6,397	145.0	7.9	1,078,160	7,436
September	115.0	20.7	978,161	8,454	--	--	--	--
October	24.0	4.3	228,802	9,533	–	--	--	--
Total	558.8	100.0	3,734,938	6,684	1,844.9	100.0	18,480,287	10,017
Area[1]								
1	1.6	0.3	4,500	2,813	44.9	2.4	454,200	10,116
2	371.4	66.4	2,144,643	5,774	1,543.8	84.3	14,996,126	9,714
3	82.5	14.8	1,008,878	12,379	215.6	11.8	2,649,051	12,287
4	41.5	7.4	294,967	7,107	27.4	1.5	303,000	11,054
5	61.8	11.1	281,950	4,562	--	--	--	--
Total	558.8	100.0	3,734,938	6,684	[2]1,831.7	100.0	18,402,377	10,047
Bottom depth (fm.)								
< 20	2.6	0.5	500	192	16.9	0.9	105,200	6,225
21-40	256.3	47.3	1,493,360	5,827	1,004.5	54.8	9,604,561	9,562
41-60	81.0	15.0	289,839	3,587	803.6	43.9	8,680,116	10,802
61-80	162.7	30.1	1,656,777	10,183	6.7	0.4	12,400	1,851
81 >	38.6	7.1	160,012	6,736	2.6	<0.1	100	38
Total	[3]541.2	100.0	3,600,488	4,145	[3]1,831.7	100.0	18,402,377	10,047

[1] See figure 1.
[2] Location data not available for 13.2 hours of effort in 1967.
[3] Bottom depth data not available for 17.6 hours of effort in 1966 and for 13.2 hours of effort in 1967.

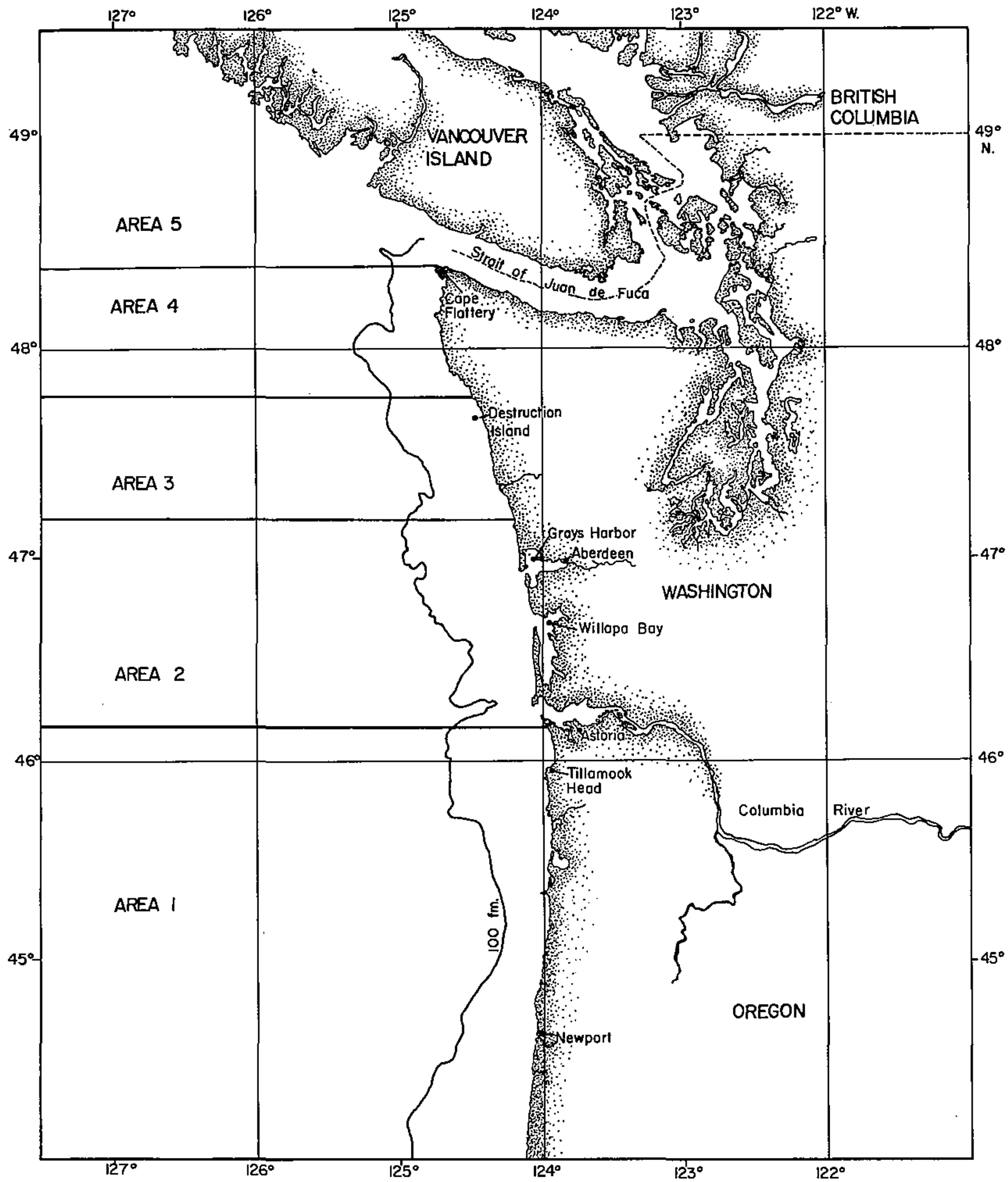

Figure 1.—Washington-northern Oregon coastal region fished by U.S. hake vessels in 1966 and 1967. Most fishing was inside the 100-fathom isobath in the area between lat. 46° and 48° N.

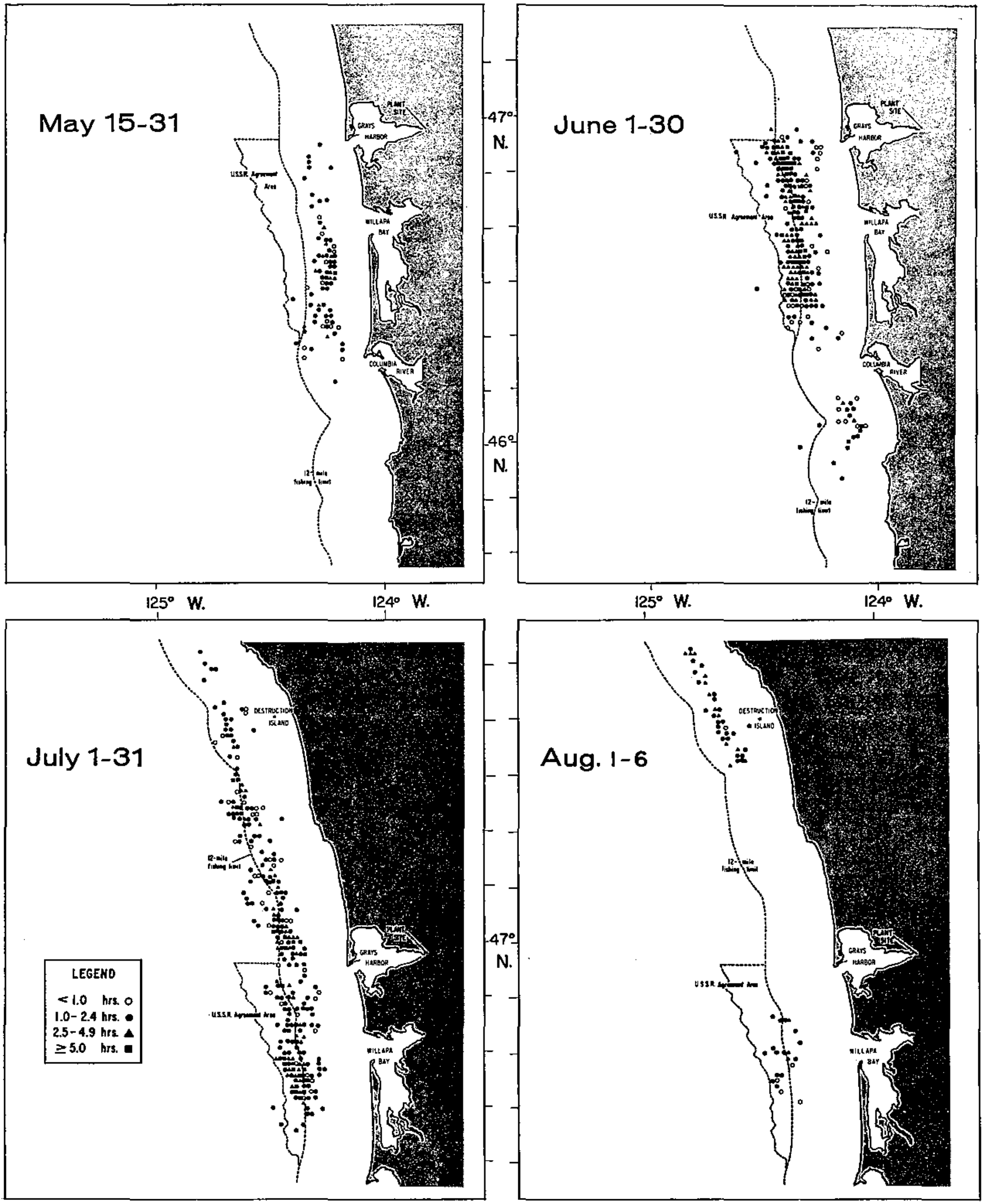

Figure 2.—Distribution of effective fishing effort by U.S. hake fleet, 1967. Effective fishing effort includes the time trawled during those hauls, regardless of duration, in which at least 2,000 pounds of hake were caught.

Table 2.—Catch of fish taken in 147 hauls (203.9 hours of trawling) by vessel *Washington* during 1967 ocean hake fishery

Family and species	Frequency of occurrence in trawl hauls		Total weight
	Number	*Percent*	*Pounds*
Squalidae			
Pacific dogfish, *Squalus acanthias*	25	17.0	2,350
Rajidae			
Skates, *Raja* spp.	2	1.4	200
Salmonidae			
Unidentified salmon	1	0.7	5
Merlucciidae			
Pacific hake, *Merluccius productus*	145	98.6	2,172,000
Scorpaenidae			
Widow rockfish, *Sebastodes entomelas*	19	12.9	4,590
Yellowtail rockfish, *Sebastodes flavidus*	68	46.3	9,275
Black rockfish, *Sebastodes melanops*	1	0.7	50
Unidentified red rockfish	12	8.2	1,450
Anoplopomatidae			
Sablefish, *Anoplopoma fimbria*	12	8.2	90

Family and species	Frequency of occurrence in trawl hauls		Total weight
	Number	*Percent*	*Pounds*
Hexagrammidae			
Lingcod, *Ophiodon elongatus*	46	31.3	1,125
Bothidae			
Sand dabs, *Citharichthys* spp.	29	19.7	505
Pleuronectidae			
Arrowtooth flounder, *Atheresthes stomias*	16	10.1	336
Pacific halibut, *Hippoglossus stenolepis*	3	2.0	11
Petrale sole, *Eopsetta jordani*	33	22.5	415
English sole, *Parophrys vetulus*	44	29.9	1,415
Dover sole, *Microstomus pacificus*	40	27.2	836
Rex sole, *Glyptocephalus zachirus*	51	34.7	700
Butter sole, *Isopsetta isolepis*	2	1.4	750
Total			2,196,103
Total (excluding hake)			24,103

FUTURE DEVELOPMENT OF THE HAKE FISHERY

The U.S. hake fishery is just beginning to develop, and it is difficult to predict its future. Many factors influence the fishery's potential for development.

The depressed condition of the market for fish meal is the most critical problem facing both fisherman and processor at the present time, and one that will continue to be important at least in the near future. Technology has progressed to the point where, by most standards, the cost of harvesting the hake resource is relatively low, but the price paid to fishermen for hake has generally been insufficient to attract vessels into the fishery (Pereyra and Richards, 1970).

In addition to the economic issues just mentioned, the problem of management of the hake resource is of concern. Statistical data are limited, but the evidence gathered to date suggests that stock abundance can be expected to fluctuate significantly, regardless of fishing intensity. Of course, this situation is normal in many fish populations. Rough estimates of the maximum sustainable yield of the hake resource are between 300 and 540 million pounds. These estimates are necessarily based on limited growth and mortality data and crude methods of calculating annual recruitment. Also they assume that the population will exist in a state of equilibrium. Despite these qualifications, such estimates represent a significant step forward in the process of determining the potential of the hake resource and have been used as a basis for international negotiations. A test of the accuracy of these estimates may be provided as a result of the Soviet hake fishery. Soviet hake catches were about 300 million pounds in 1966 and about 350 million pounds in 1967. It is now particularly important to monitor the hake population to determine the response(s) to this level of exploitation.

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MS. #1872

Operation of the Soviet Trawl Fleet off the Washington and Oregon Coasts during 1966 and 1967

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ABSTRACT

A large Soviet fishing fleet has been trawling for Pacific ocean perch and Pacific hake off the northwestern coast of the United States since April 1966. This report describes the types of vessels making up the fleet and the fishing techniques used.

The fleet comprised side trawlers, stern trawlers, and support ships. Details are given on the SRT, SRTR *Okean*, SRTM *Mayak*, RT *Pioneer*, BMRT *Pushkin* and *Mayakovskii*, RTM *Tropik* and *Atlantik*, *Skryplev*, and seven support ships.

The entire fleet worked as a unit with a command ship that directed the scouting and harvesting. It moved into the area in April and left in December. In 1966 the fleet reached a peak of 111 ships in July, and in 1967 it peaked at 114 ships in May.

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INTRODUCTION

In April 1966 a large fleet of Soviet vessels appeared off the Washington and Oregon coasts and began an intense trawl fishery for Pacific ocean perch, *Sebastodes alutus*, and Pacific hake, *Merluccius productus*. By the end of 1966 the Soviets had caught an estimated 141,400 short tons of Pacific hake and 11,000 short tons of Pacific ocean perch, and in 1967 they harvested an estimated 124,000 short tons of Pacific hake and 8,300 short tons of Pacific ocean perch from these grounds (Commercial Fisheries Review, 1968). This was the first time a foreign country had ever harvested large quantities of bottomfish in waters adjacent to the States of Oregon and Washington although Soviet and Japanese fleets have been active throughout the northeastern Pacific since the latter part of the 1950's.

Published February 1970.

The Soviet Far Eastern Fisheries, a government administration body with headquarters in Vladivostock, has many fishing fleets in the Northern Pacific (Kravanja, 1964). Its first major operation in the eastern Pacific was in 1959 when part of the Atlantic fleet was transferred to the North Pacific to begin full-scale fishing in the Bering Sea (Alverson, Pruter, and Ronholt, 1964). A few years later the Soviets expanded their operations into the Gulf of Alaska, then to southeastern Alaska and British Columbia, and finally off the coasts of Washington, Oregon, and California (Chitwood, 1969).

Soviet fleets operating off the Washington and Oregon coast have fished mainly for Pacific ocean perch and Pacific hake. This paper describes the fishing fleet and the technique used by the Soviets to catch the Pacific hake.

FISHING FLEET

The Soviets classify fishing and support vessels by types and classes. The types are referred to by letters that denote the activity in which they are engaged. The classes are referred to by the name of the first vessel of a specific series. An example is the 20 side trawlers built in England for the Soviets between 1956 and 1958. The first of these vessels was named *Pioneer;* therefore, they are referred to as an RT of the *Pioneer* class. The RT denotes a fishing trawler (Rybolovnyi trauler).

The following list gives the major types of Soviet fishing vessels observed off the Washington and Oregon coasts during 1966 and 1967:

- RT (Rybolovnyi trauler) - Fishing trawler
- SRT (Srednii rybolovnyi trauler) - Medium fishing trawler
- SRTR (Srednii rybolovnyi trauler refrizherator) - Medium fishing trawler with refrigeration
- SRTM (Srednii rybolovnyi trauler morozil'nyi) - Medium fishing trawler with freezer
- BMRT (Bol'shoi morozil'nyi rybolovnyi trauler) - Large freezer fishing trawler
- RTM (Rybolovnyi trauler morozil'nyi) - Fishing trawler with freezer

These vessels can also be grouped into trawlers and support ships. The latter are those vessels that do no fishing but are necessary to provide logistic support. Trawlers which do the fishing can be categorized as side and stern trawlers.

SIDE TRAWLERS

Side trawlers (fig. 1) are vessels that set, tow, and haul their trawls from the side, usually from the starboard. They have the house aft, fore and aft gallows frames, and a large trawl winch partially covered by the bridge. The engineroom is below the house, and the fish hold is forward.

The Soviets have used four types of side trawlers for fishing hake off the Washington and Oregon coasts; the SRT of at least 3 classes, SRTR *Okean*, SRTM *Mayak*, and RT *Pioneer*. Figure 2 shows the profiles of the basic types and table 1 lists their dimensions, tonnages, and other pertinent data.

The trawling hookup for side trawlers is standard. Towing cables are led forward from the winches through bollards and then to blocks on the gallows frames, where they go aft to a towing block (fig. 3). When being hauled, the towing cable is reeled onto the winch drums. When they arrive at the gallows, the doors are secured and the towing cable is then freed from the doors. The rest of the cable including the net bridles are spooled in until the net wings reach the gallows. The catch is then brought aboard over the rail (fig. 1). The SRT and the RT *Pioneer* have gallows frames on both sides, enabling them to tow from either side, whereas the SRTR *Okean* and SRTM *Mayak* can only tow from the starboardside. The winches are electric and vary in drum capacity, pull, and speed by vessel type (table 1).

A number of different trawls used by these vessels have been described by Lestev and Grishchenko (1959), Andreev (1962), and Sysoev (1964). SRT's and SRTR's tow nets with head rope lengths of 50 to 80 feet, whereas the SRTM's and RT's tow trawls with head rope lengths of 80 to 115 feet.

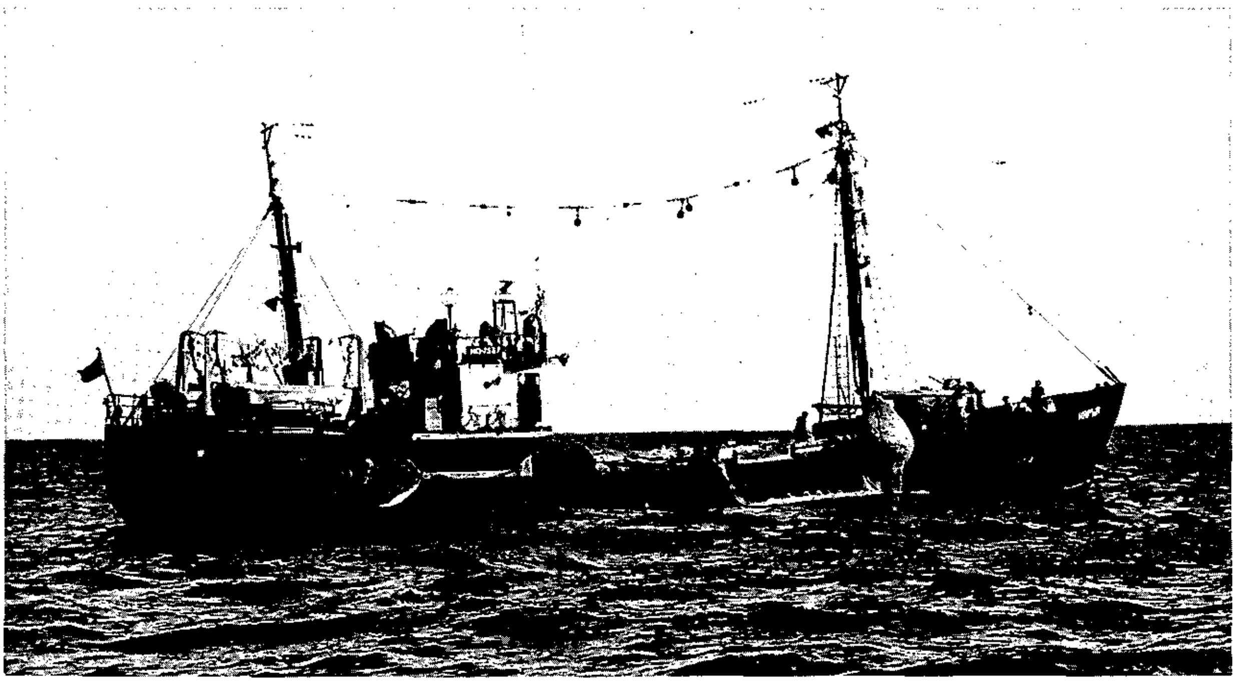


Figure 1.—A Soviet side trawler of the SRT 300 class, lifting a split of hake aboard while fishing off the Oregon coast.

Andreev (1962) documented the accessory gear used on these trawls. Floats on the headrope are usually of metal and have a diameter of 8 inches. Roller or bobbin gear are of three standard types: wood wheels, 8 inches in diameter and 8 inches wide; steel spheres of two sizes, a 16-inch diameter sphere that weighs 88 pounds and a 24-inch sphere that weighs 215 pounds; and rubber wheels, 8 inches in diameter, 2 inches wide, and about 4½ pounds in weight. The standard trawl doors aboard these vessels are the Matrosovos slotted trawl boards that are of two sizes. The small one weighs about 1,200 pounds and is 8 feet long, 5 feet high, and the large one weighs about 2,100 pounds and is 10 feet long and 6 feet high.

The trawls aboard the SRT's and SRTR's off our coast fish three different ways: on bottom, just off bottom, and in midwater. The

Table 1.—Dimensions, tonnages, and other pertinent data on types of Soviet side trawlers operating off the west coast of the United States in 1966 and 1967

Item	SRT	SRTR *Okean*	SRTM *Mayak*	RT *Pioneer*
Length overall (ft.)	125-144	167	178	190
Beam (ft.)	24-25	29	30	32
Draft (ft.)	9	11	10	14
Displacement tonnage (long ton)	380-490	730	920	1,280
Dead weight (long ton)	. .	197	302	433
Gross tonnage	230-264	507	929	675
Horsepower	300-400	650	800	1,100
Propeller	Fixed	Controlled pitch	Controlled pitch	Fixed
Speed (knots)	9-10	11	11.6	12.3
Refrigerated hold temperature (° F.)	None	24.8	—0.4	. .
Freezing capacity (short tons/day)	None	None	7	None
Total hold capacity (cu. ft.)	. .	12,150	12,540	17,200
Trawl winch pull (tons)	4	4	7 or 9	9
Hauling speed (f.p.m.)	. .	197	197 or 148	195
Trawl cable diameter (in.)	0.82	0.83	0.79	0.94
Trawl drum capacity (fm.)	. .	656	984	1,200
Crew (no.)	22-26	26-28	30	44
Country built	E. Germany	E. Germany	U.S.S.R.	England
Year built	1949-59	1958-60	1962-still building	1956-58
Estimated number built	1,000	171	Unknown	20

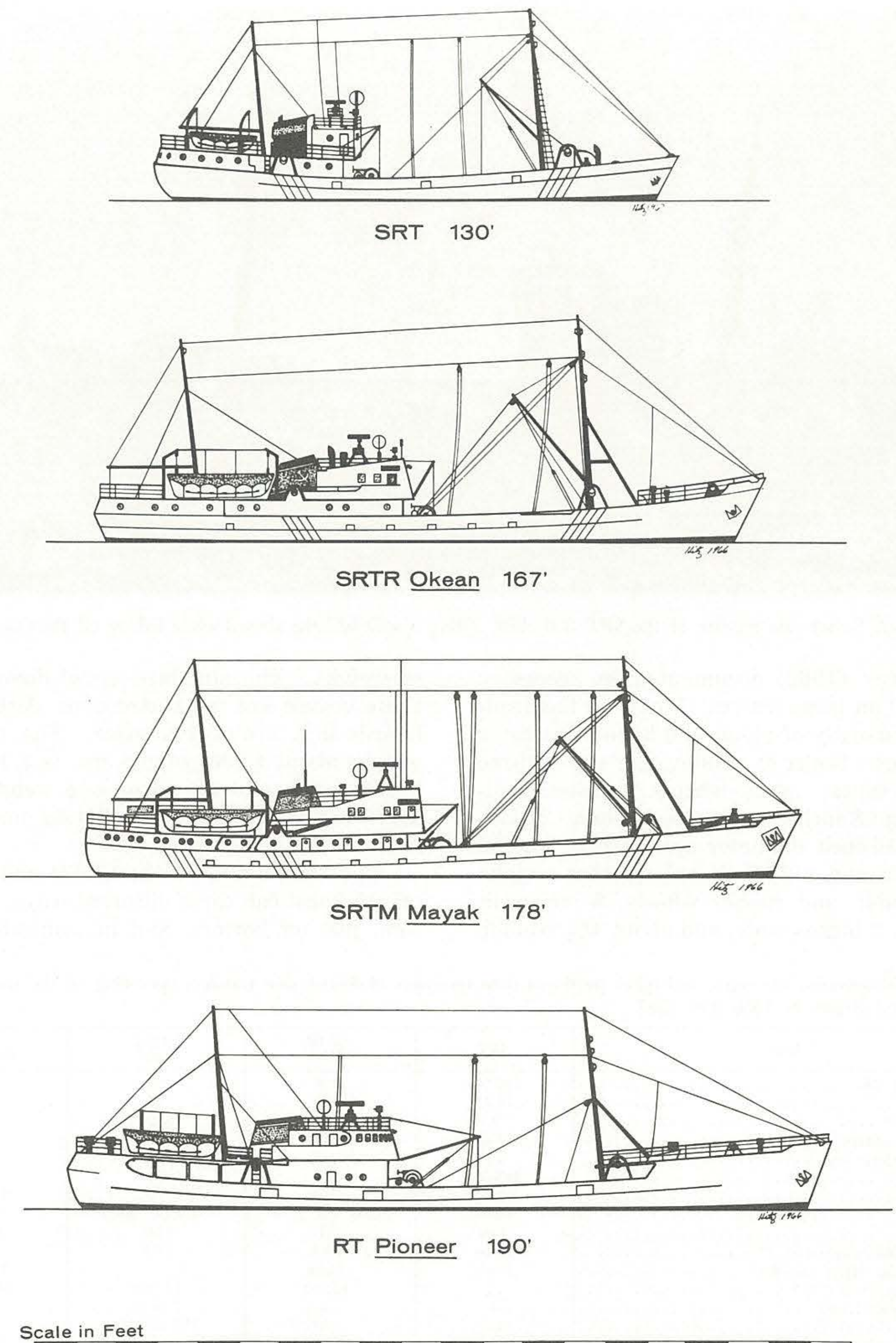


Figure 2.—Profiles of the four basic types of Soviet side trawlers that have operated off the Washington and Oregon coasts.

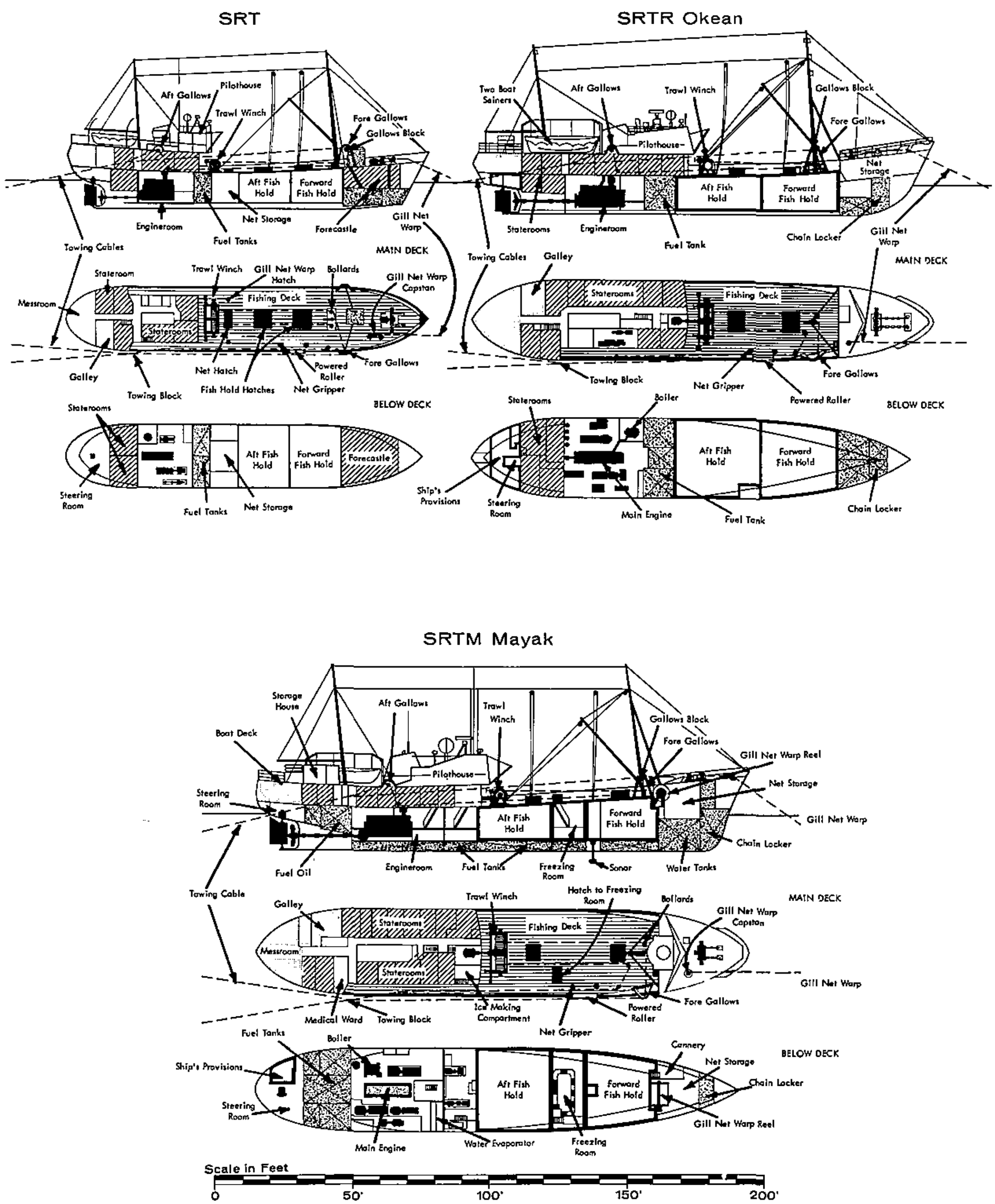


Figure 3.–The basic arrangement of the Soviet SRT, SRTR *Okean*, and SRTM *Mayak*.

on-bottom trawls are rigged in the conventional way with or without rollers and usually have a large number of floats on the headrope to create a large vertical opening, which is advantageous in catching hake and Pacific ocean perch. The just-off-bottom trawls have weights attached to the footrope, and once on bottom the net floats up so that it fishes just off bottom (Pruter, 1962). The midwater trawl is a very large net, which is towed by two trawlers. Each vessel has a single towing cable attached to one of the wings of the net. One vessel tows from the starboardside and the other tows from the portside while following a parallel course some 250 yards apart. A third vessel often is just aft of the two boats towing the net and apparently checks the net's depth with an echo sounder during the tow. At the end of the tow the cables are reeled in. One vessel then disconnects its cable and passes it to the other trawler, which takes the trawl and catch aboard.

STERN TRAWLERS

The BMRT *Mayakovskii* class (fig. 4) is the most common stern trawler off the Washington and Oregon coasts. This class of BMRT is described by Diomidov and Margolina (1959). It has a stern chute, a stern bridge over the chute, kingposts on the afterdecks, a trawling bridge, and cargo booms on the foredeck. The engineroom is in the center of the ship, and holds are forward and aft.

In contrast to side trawlers the stern trawlers set, tow, and haul their trawls from the stern. The winches are under cover of the house and face aft instead of forward. The towing cable leads aft from the winches to a fixed sheave called a guide pulley and then through the gallows blocks from which the net is towed. When the gear is hauled, the towing cable is spooled onto the trawl drums until the doors are brought to the gallows. The towing cable is disconnected from the doors, and the net bridles and catch are hauled up the stern chute (fig. 5).

Stern trawlers and side trawlers use the same kind of trawl gear. The bottom trawls have headrope lengths of about 115 feet, and new midwater trawls have headrope lengths of 105 feet and 124 feet (Sysoev, 1964). The oval doors and the accessory gear such as floats, bobbins, and bridles are also the same for both trawlers.

On stern trawlers, extra nets and accessory gear are stored in holds on each side of the stern chute. Extra doors are stored on the fishing deck.

These vessels have comfortable staterooms, large messrooms, a small hospital, a first-aid room, an office for ship's business, and a research laboratory for gathering biological data on the catch. Crew members have one-, two-, or four-man staterooms and are fed and entertained in the messrooms.

These vessels are also known as factory trawlers because the catch is processed below decks in a factory. The edible fish in the catch are separated and cleaned in the processing room, frozen in the freezing room, boxed in the packing area, and stored in the freezer holds. The waste and scrap fish are processed in the meal and oil plant and then stored.

Five different classes of Soviet stern trawlers have been seen off the Washington and Oregon coasts: the BMRT *Pushkin* and *Mayakovskii*, the RTM *Tropik* and *Atlantik;* and the *Skryplev*. Figure 6 shows the profiles of these vessels, and table 2 lists their basic dimensions, tonnages, and other pertinent data.

The *Mayakovskii* class dominates the Soviet's Far Eastern trawler fleet. This class was in full production during the early part of the last decade, and 12 to 24 ships probably were completed each year (Kravanja, 1964). Between 1960 and 1963, 21 of these trawlers were delivered to the Far East Fisheries (Kravanja, 1964); today about 40 of them work out of the Soviet Far Eastern ports. The *Itelmen* (BMRT 399) brought home a record catch in December 1965 (Commercial Fisheries Review, 1966b). The trip lasted 3 months, and 4,499 short tons of ocean perch were caught off Vancouver Island. This catch was processed into 2,392 short tons of frozen products packed in 77-pound cases, 408 short tons of fish meal, and 18 short tons of oil.

The *Tropik* class trawler was designed to use a variety of gear and to fish in both tropical and temperate seas (Dorin, Arakelyan, Logachev, and Nikolaev, 1963). These vessels are able to trawl, seine, gill net, longline, and pole and line, as well as to fish with electricity com-

BMRT Mayakovskii

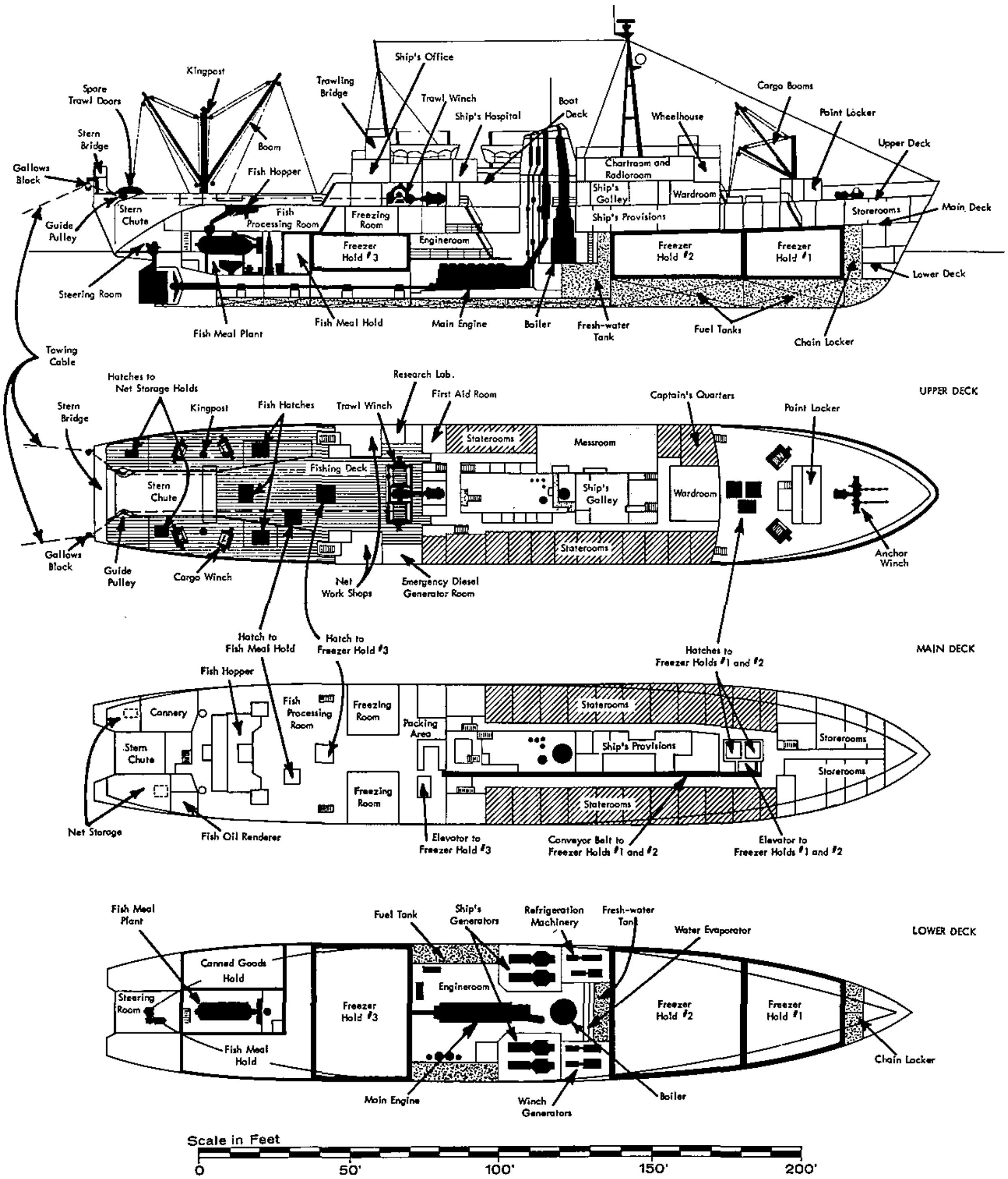


Figure 4.–The basic arrangement of the Soviet BMRT *Mayakovskii.*

bined with night lights and pumps. The after deck is close to the water line so that platforms can be rigged for tuna fishing with bait. The dories on the foredeck are used for seining and trolling. The main trawl winch has three drums which enable it to be used as a seine winch, and the vessel has mechanical devices for hauling gill nets and longlines. A few *Tropik* class vessels have been seen fishing off the Washington and Oregon coasts. Construction of this class was discontinued in 1966 when the *Atlantik* class replaced it.

The *Atlantik* appears to be designed for trawling only (World Fishing, 1965). Her design differs from the rest of the stern trawlers: the superstructure is U-shaped so the bridge can be used as both a trawling and ship's bridge. The stacks are paired, one on each side

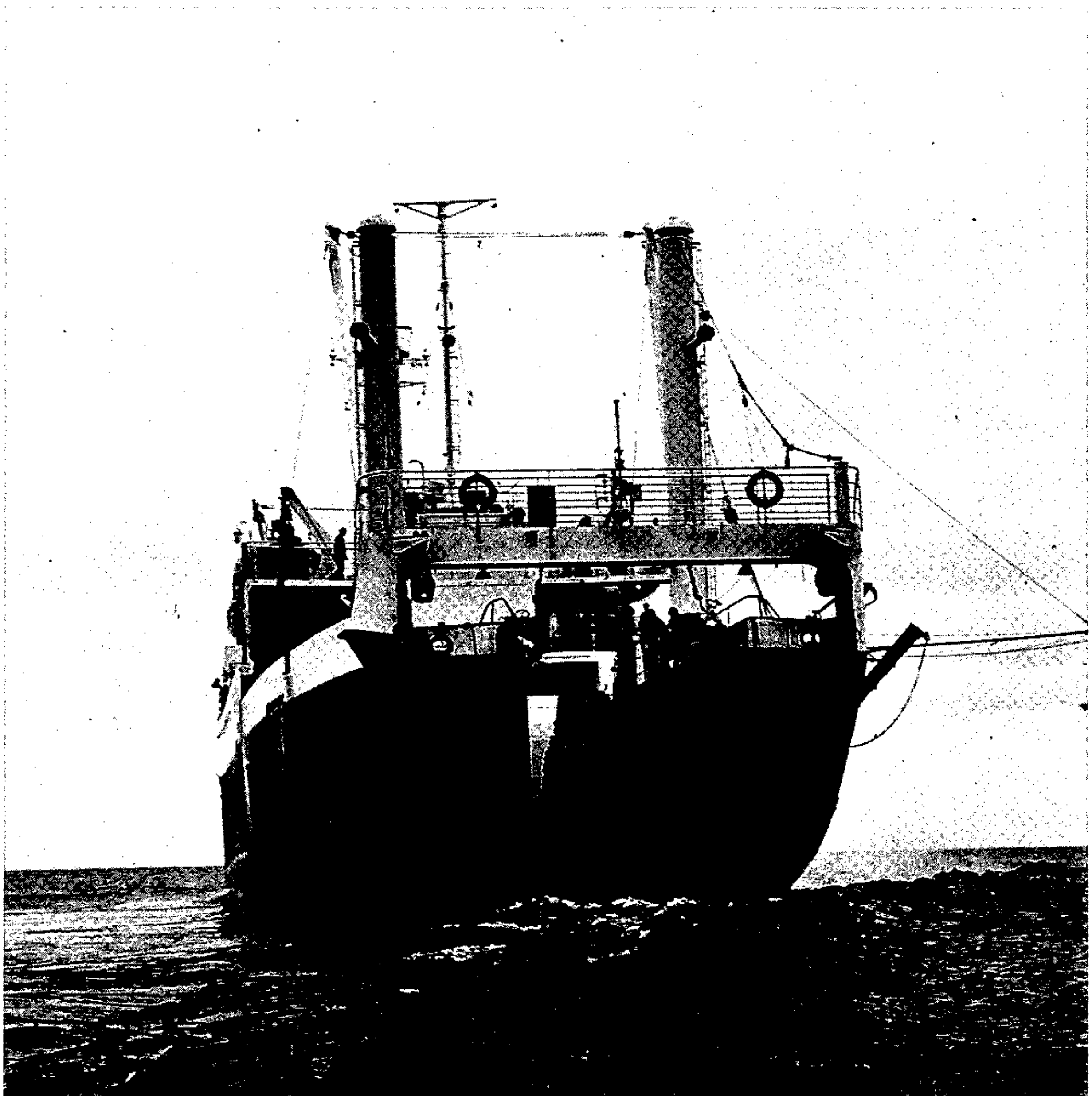


Figure 5.–A Soviet stern trawler of the *Mayakovskii* class hauling a catch of hake up the stern chute while fishing off the Washington coast.

Table 2.—Dimensions, tonnages, and other pertinent data on classes of Soviet stern trawlers operating off the west coast of the United States in 1966 and 1967

Item	BMRT		RTM		
	Pushkin	*Mayakovskii*	*Tropik*	*Atlantik*	*Skryplev*
Length overall (ft.)	277	278	262	270	335
Beam (ft.)	44	46	43	45	52
Draft (ft.)	17	18	18	..	17
Displacement tonnage (long tons)	3,482	3,653	3,210	3,149	5,492
Deadweight (long tons)	1,220	1,280	780	..	2,510
Gross tonnage	2,550	3,170	2,435	2,760	4,700
Horsepower	1,900	2,000	1,650	2,630	3,000
Propeller	Fixed	Controlled pitch	Controlled pitch	Controlled pitch	Controlled pitch
Speed (knots)	12.5	13.7	12.5	13.0	11
Refrigerated hold temperature (° F.)	—0.4	—0.4	—13.0	..	—13.0
Freezing capacity (short tons/day)	44	33	33	50	55
Fish meal capacity (short tons/day)	25	22	22	39	33
Total hold capacity (cu. ft.)	57,068	58,658	37,080	45,140	120,070
Freezer hold capacity (cu. ft.)	47,639	46,968	33,195	39,000	..
Fish meal hold (cu. ft.)	5,297	6,000	3,885	5,750	..
Fish & liver oil storage (cu. ft.)	4,131	5,686	..	390	..
Trawl winch pull (short tons)	10	13	13	13	16
Hauling speed (f.p.m.)	197	197	197	197	..
Trawl cable diameter (in.)	1.0	1.0	1.0	1.0	1.1
Trawl drum capacity (fm.)	820	1,367 or 1,640	1,094	..	1,370
Crew (no.)	125	114	76	80	102
Country built	W. Germany	U.S.S.R.	E. Germany	E. Germany	Denmark
Year built	1954-56	1958-still building	1962-66	1966-still building	1962-63
Estimated number built	42	..	52	..	4

of the ship, with the pilothouse between them. A few of these vessels are now appearing in Soviet Pacific fleets, and several have fished off Washington and Oregon coasts. These vessels may have been new vessels assigned to Vladivostock and were fishing on their way to their home port after passing through the Panama Canal (Commercial Fisheries Review, 1967a).

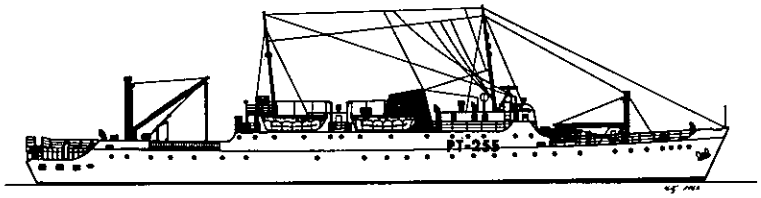
The largest Soviet vessels (fig. 7) observed trawling off our Pacific coast were originally designed as freezer ships to receive catches from other vessels (Kravanja, 1964). They have a stern chute, up which the bags of fish left floating by trawlers could be hauled aboard with a small winch. Of the four ships built, three were allocated to the Far East fleets in 1962 and 1963. These vessels are known as freezer ships of the *Skryplev* class. After four of these vessels were built, the design was altered slightly to allow them to fish as a stern trawler. This new series is known as the *Grumant* class (Brady, 1966) and is described by Kamenskii and Terent'ev (1964). Apparently the *Skryplev* class vessels were later modified to tow trawls because they have been seen trawling a number of times off the Washington and Oregon coasts.

All of these stern trawlers are designed to fish independently along foreign shores thousands of miles from their home ports. To increase their efficiency as well as to use the side trawlers on the more productive grounds, the Soviets operate their vessels in fleets with the aid of support ships.

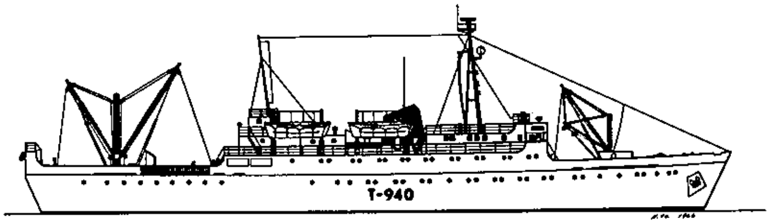
SUPPORT SHIPS

Many types of support ships have been observed with the Soviet trawl fleet off the Washington and Oregon coasts. The support ships are basically tankers, cargo ships, rescue tugs, refrigerated transports, and freezer ships. Tankers (fig. 8) deliver fuel oil and fresh water (Commercial Fisheries Review, 1967c); cargo ships (fig. 9) deliver the necessary dry goods and personnel to the fleet. Rescue tugs stand by the fleet to aid the vessels in case of an emergency. Refrigerated transports receive frozen catches from processing vessels, such as BMRT's, SRTM's, and freezer ships. The freezer ships, on the other hand, receive raw products from catchers, which cannot preserve their own catch, such as the SRT's, and then process, freeze, and stow them in the holds for transportation to the home port at the end of the season, or offload to a refrigerated transport during the season.

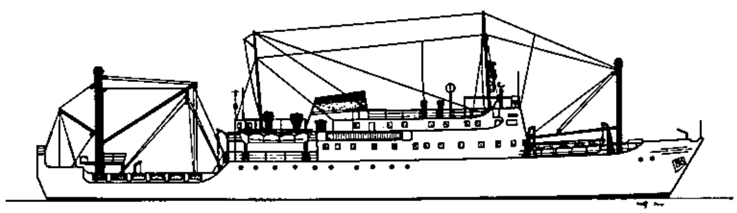
Because the ships are loaded and unloaded at sea (fig. 10) they must be heavily built and



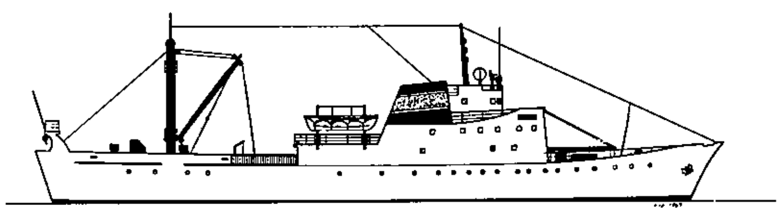
BMRT Pushkin 277'



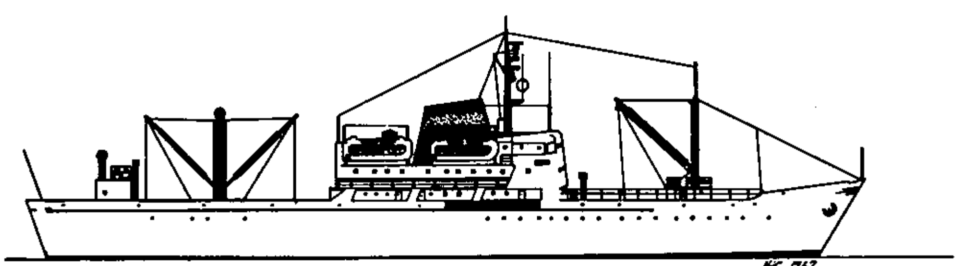
BMRT Mayakovskii 278'



RTM Tropik 262'



RTM Atlantik 270'



Skryplev 335'

Figure 6.—Profiles of the five basic Soviet stern trawlers that have operated off the Washington and Oregon coasts.

devices must be used to prevent the vessels from colliding with each other in rough weather. Deepwater anchoring equipment is installed to aid in the transfer, and large rubber fenders made of sponge rubber (Commercial Fisheries Review, 1958) or old tires are placed between the ships. Some of the freezer ships have stern ramps up which they can haul the bags of fish left floating by the catchers.

The tankers, cargo ships, and refrigerated transports stay with the fleet for only a few days or weeks while they are carrying out their mission, whereas the rescue tugs and freezer ships stay throughout most of the season.

Rescue tugs (fig. 11) are built on the lines of ocean-going salvage tugs and are used to assist the vessels of the Soviet fleet or any other vessel in distress (Gudimovich, 1962). They are well equipped for emergencies with high-powered radio, diving and fire-fighting equipment, emergency pumps, and salvage gear, as well as a six-bed hospital.

Six classes of freezer ships have been observed operating off Washington and Oregon. They are: the *Refrigerator, Bratsk, Tavriya, Pervomaisk, Sevastopol,* and *Spassk* classes (fig. 11). Table 3 lists their dimensions, tonnages, and other pertinent data. The *Refrigerator, Bratsk* (Mekenitskii and Liberman, 1961), *Tavriya* (Kozyrchuk and Yusupov, 1961), and *Pervomaisk* class freezer ships are very similar in design. All four have the engineroom and house aft with holds forward. On the other hand the *Sevastopol* and *Spassk* classes have the pilothouse forward. The *Spassk* class is unique because it has a stern ramp for receiving the catch and can preserve fish by freezing, canning, or salting. The reduction plant aboard can handle 55 short tons of raw material per day.

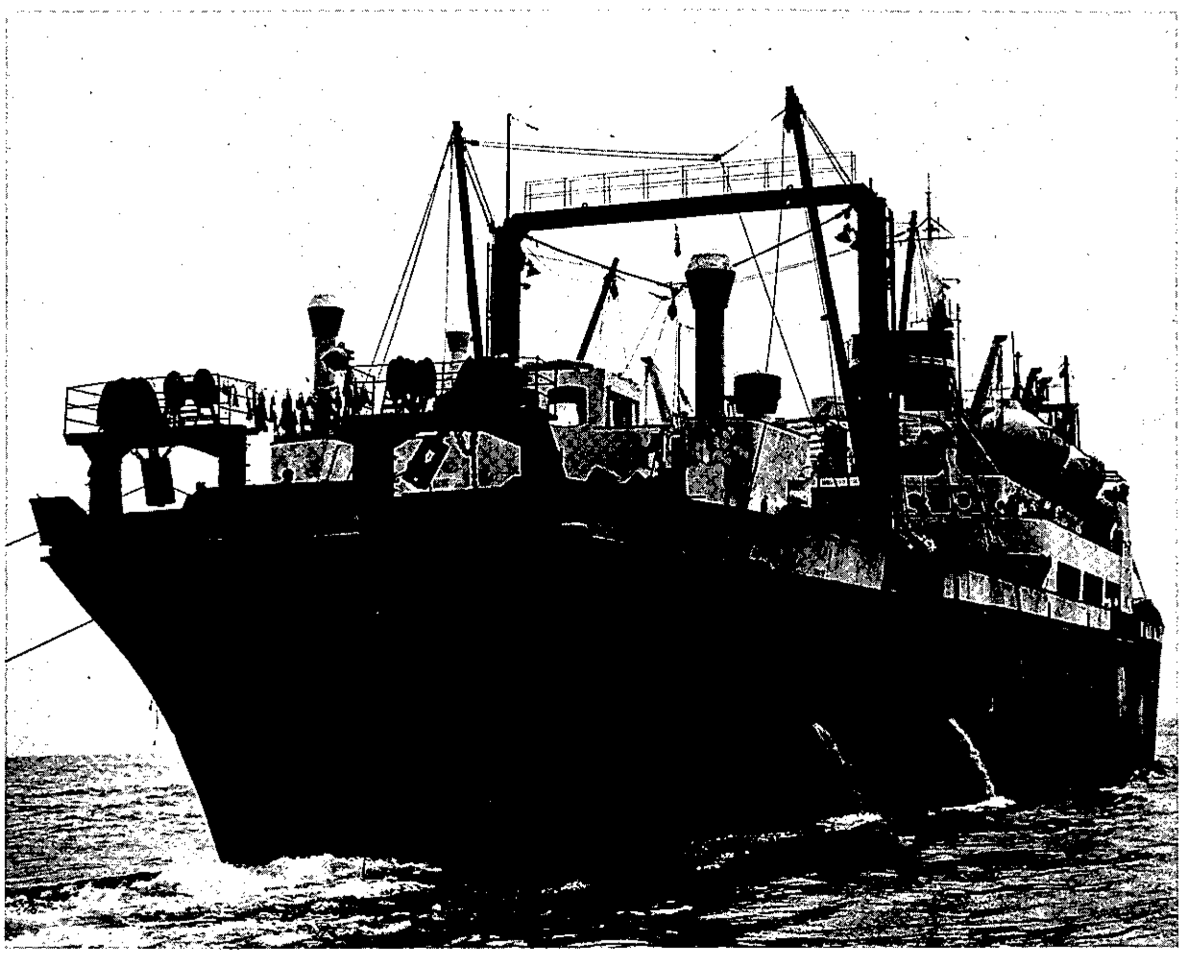


Figure 7.—The freezer ship *Skryplev* trawling off the Washington coast.

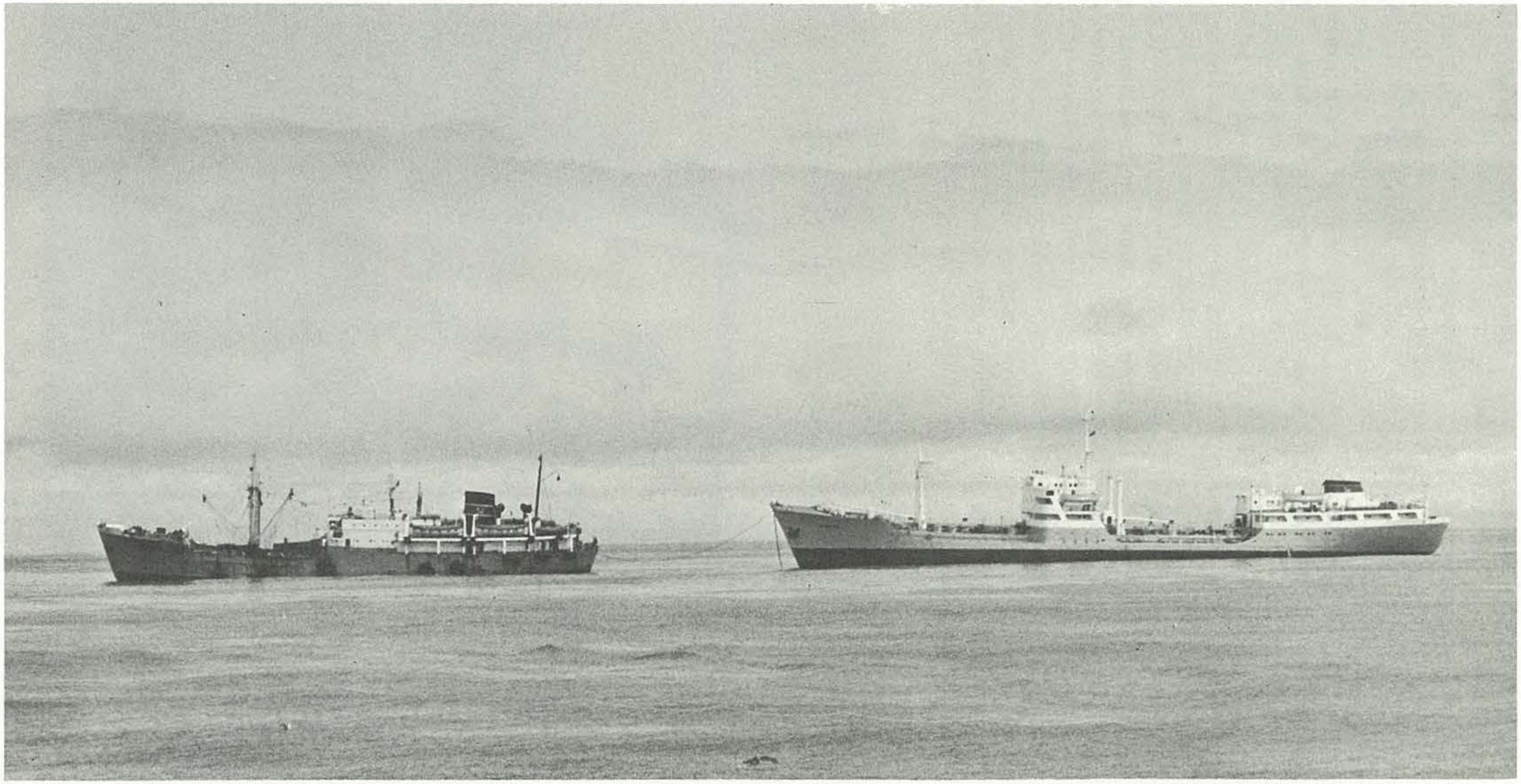


Figure 8.—The Soviet fresh-water tanker, ***Erebus***, replenishing a freezer ship of the ***Refrigerator*** class off the Washington coast.

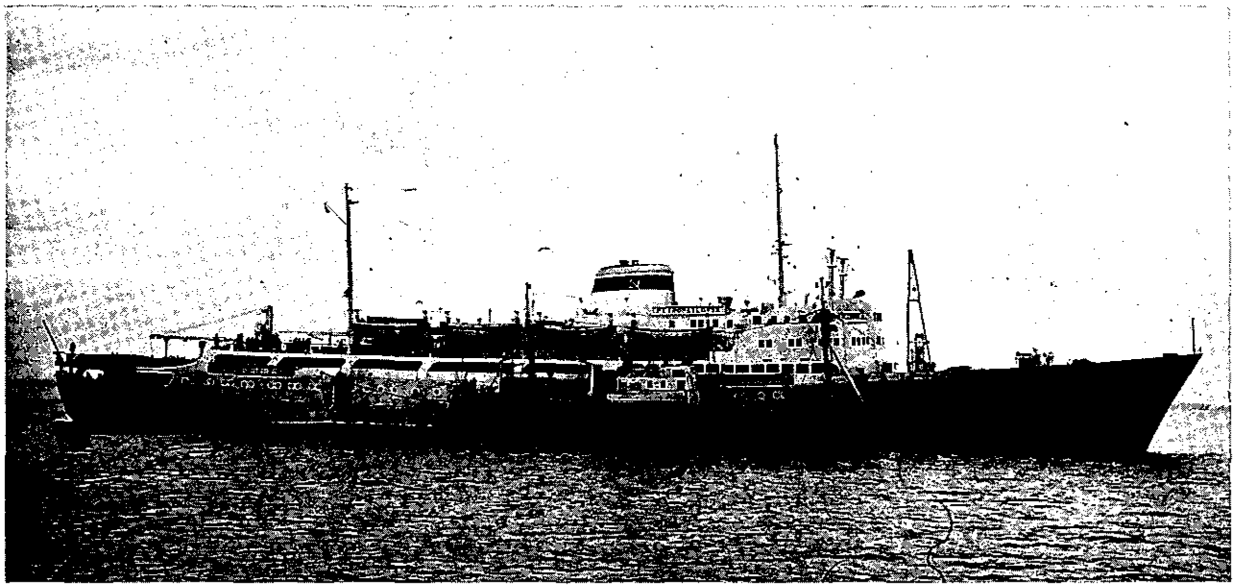


Figure 9.—An SRTR alongside the Soviet cargo ship, *Petropavlovsk*, in waters off the Washington coast.

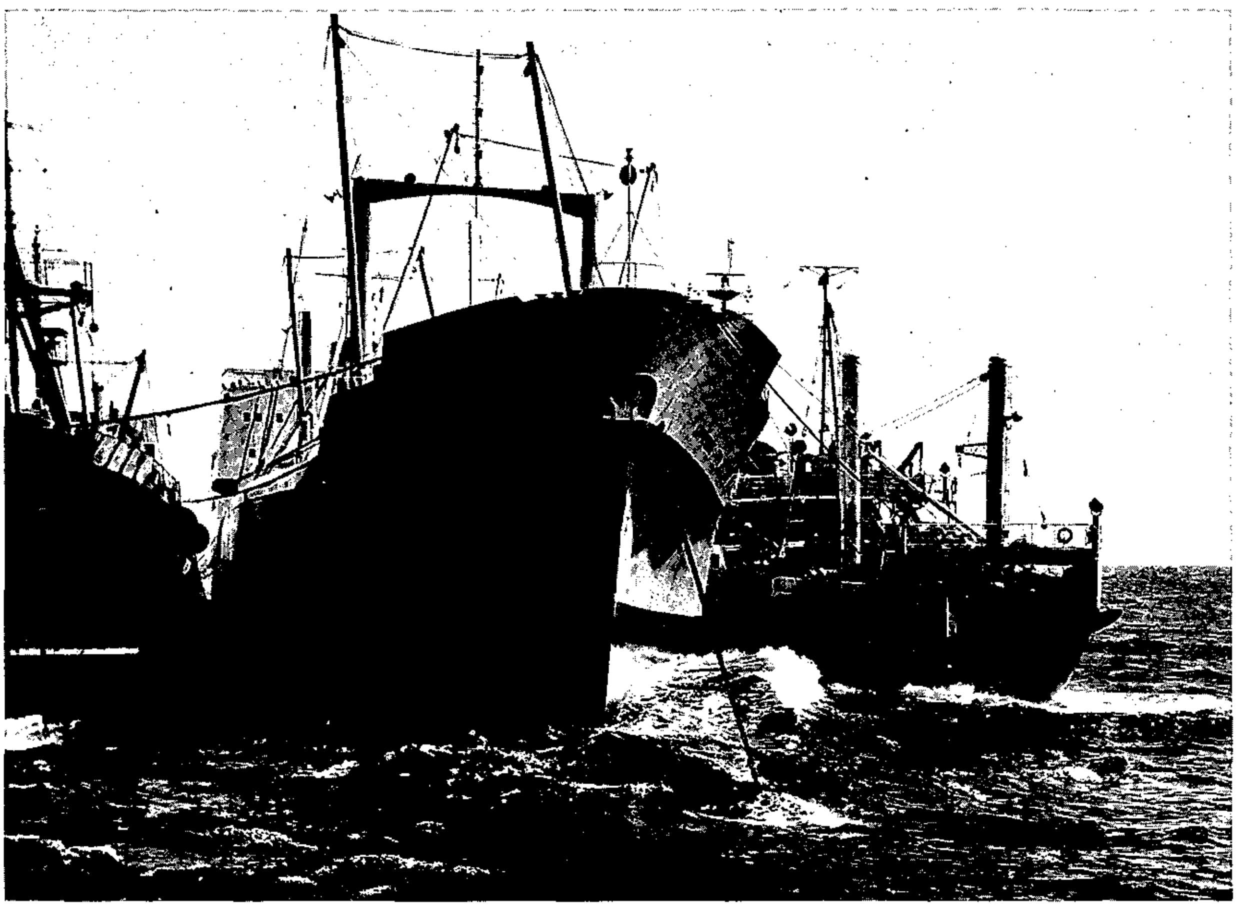


Figure 10.—The 497-foot freezer ship, *Kamchatka Gory*, anchored off the Washington coast with a *Tavriya* class freezer ship and *Mayakovskii* class BMRT alongside.

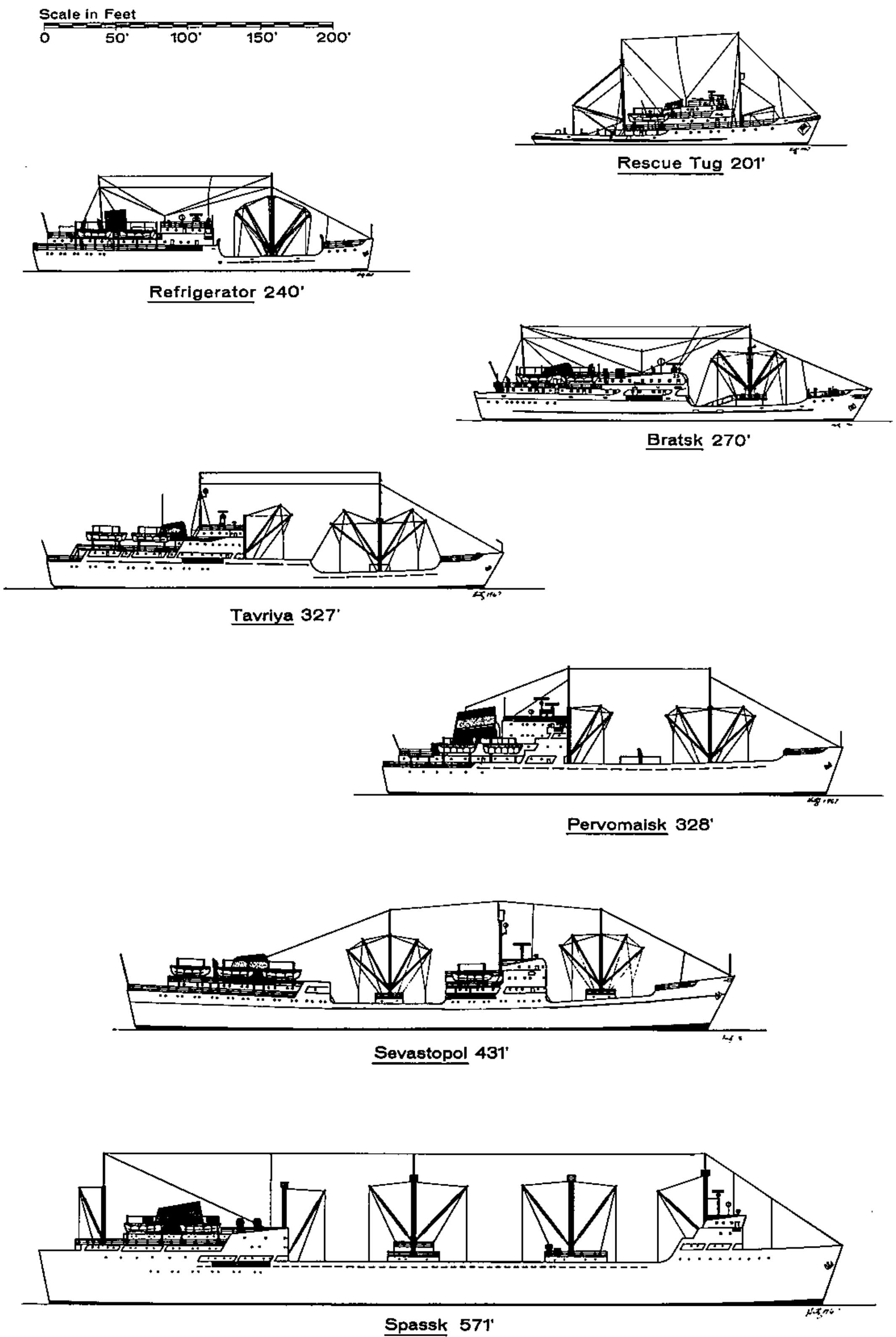


Figure 11.—Profiles of the seven types of support ships seen off the west coast of the United States.

Table 3.—Dimensions, tonnages, and other pertinent data of some of the Soviet support ships operating off the west coast of the United States in 1966 and 1967

Item	Rescue tug	Freezer ships					
		Refrigerator	*Bratsk*	*Tavriya*	*Pervomaisk*	*Sevastopol*	*Spassk*
Length overall (ft.)	201	240	270	327	328	431	571
Beam (ft.)	39	38	43	46	47	54	79
Draft (ft.)	15	14	17	18	28	..	..
Displacement tonnage (long tons)	1,452	..	2,456	5,315	..	10,088	..
Dead weight (long tons)	..	..	1,292	2,500	..	4,077	9,800
Gross tonnage	..	1,680	2,500	3,230	3,300	5,525	19,000
Horsepower	1,700	1,000	1,300	4,000	1,920	7,200	5,500
Speed (knots)	13.5	10.7	11.0	13.6	12.7	16.5	14.0
Flake ice production (short tons/day)	None	None	None	13	..	..	53
Hold temperature (° F.)	None	−0.4	−0.4	−0.4	−22.0	−0.4	−22
Freezing capacity (short tons/day)	None	..	55	55	..	110	220
Total hold capacity (cu. ft.)	..	..	63,566	116,538	..	190,699	441,434
Crew (no.)	37	..	82	82	..	170	280
Country built	Finland	Denmark	E. Germany	U.S.S.R.	Denmark	U.S.S.R.	Japan
Year built	1957-60	1952-56	1959-61	1959-still building	1959-60	1956-still building	1965-66
Estimated number built	15	10	10	..	..	..	8

FISHING TECHNIQUE

The Soviet ships are used in fleets that work as units to harvest the ocean's fish resources. Each fleet is assigned a region of operation, a commander, and an annual catch goal.

Fleets operating in the Pacific Ocean are directed by a single regional administrative body, the Main Administration of the Far Eastern Fisheries at Vladivostok (Kravanja, 1964). Its decisions on where a fleet will operate are based partly on scientific data gathered during exploratory surveys by TINRO[1] and partly on catch statistics of the fleet and information received from scouting expeditions of the fleet. During this planning, the fleet and each vessel are assigned a specific goal and an incentive goal. If the latter is reached, the crew of the vessel receives a bonus (Williamson, 1963; Commercial Fisheries Review, 1965).

Movements of the Soviet fleet and ships off the United States coasts have been observed by BCF (Bureau of Commercial Fisheries).[2] The information collected by BCF is published in the Commercial Fisheries Review each month under "Foreign Fishing Activities off the U.S. Coasts." A review of the information published on the Soviet fleet's activities off our West Coast, specific data obtained from the BCF Enforcement and Surveillance Program at Seattle, and observations made by scientists aboard BCF research ships give a good picture of the Soviet's fishing strategy off Oregon and Washington. This information is presented in three parts: (1) Research Activities; (2) Movement of the Soviet Fleet; and (3) Fishing Method.

RESEARCH ACTIVITIES

The first report of Soviet fishing vessels off the Washington and Oregon coasts was in the early summer of 1962 (Commercial Fisheries Review, 1963). The two vessels seen were probably similar to TINRO's exploratory vessel, *Krym* (S-250), which was operating off the Washington coast in mid-July 1963 (Pacific Fisherman, 1963). This vessel is an SRT converted for research.

Since 1962, a number of TINRO research ships have carried out some form of fishery research off the West Coast. Some of the more common ones are the RT *Pioneer* class, *Ogon* and *Adler;* the SRTR *Orlan;* the SRTM *Iskatel;* and the BMRT *Akademik Berg.* They systematically investigate the resources, map the fishing grounds, test gear, and gather biological, oceanographic, and meteorological data that enable them to estimate and set preliminary quotas on the stocks available.

The technique used in exploring the Continental Shelf was observed when the *Alder* was

[1] Tikhookeanskii Nauchno-Issledovatel'skii Institut Rybnogo Khozyaistva i Okeanografii (Pacific Scientific Research Institute of Marine Fisheries and Oceanography).

[2] Many observations have been made from U.S. Coast Guard vessels and planes.

sighted off the Washington coast on May 18, 1965 (Hitz, 1965). The vessel sounded along a depth range, apparently mapping the bottom and searching for suitable trawling grounds as well as fish. When suitable grounds were located, a trial trawl haul of 1 hour was made to determine whether the grounds were fishable and to see what species were available. After the gear was aboard, the catch was analyzed and a hydrographic cast was made for water temperatures and salinity.

Novikov and Chernyi (1967) reported the results of the TINRO investigations in the eastern Pacific Ocean from the Equator to southeastern Alaska. The northern part, which extends south to Cape Mendocino, Calif., was rich in raw materials for both trawl and pelagic fisheries. They recommend that efforts be directed at developing the trawl fisheries on rockfishes, *Sebastodes* spp.; Pacific hake; the sablefish, *Anoplopoma fimbria;* and the Dover sole, *Microstomus pacificus.*

Three species of rockfishes were abundant at certain seasons to justify a trawl fishery. Pacific ocean perch was found to be the most numerous of the rockfish group especially in the most northern sections. They were concentrated throughout the year. In the winter and spring they were found at depths between 100 and 200 fathoms, whereas in the summer they were between 80 and 165 fathoms. In the more southern sections, concentrations of the splitnose rockfish, *Sebastodes diploproa,* and the blackmouth rockfish, *S. crameri,* were caught during spring and summer at depths between 100 and 200 fathoms.

Pacific hake were found in great numbers forming dense schools at depths of 100 to 200 fathoms. Catches from these schools ranged from 8,800 to 22,000 pounds per haul. These fish were mostly from 16 to 24 inches long and weighed between 1 and 3 pounds.

Sablefish were found throughout the entire area but were generally concentrated in the shallow depths between 75 and 200 fathoms. The catches were from 6,600 pounds to 22,000 pounds per trawl haul. The fish were from 18 to 28 inches long and weighed from 1 to 3.3 pounds.

Dover sole and rex sole, *Glyptocephalus zachirus,* were caught especially at depths between 100 and 300 fathoms. In the summer catches of these flatfish were from 440 to 1,980 pounds per haul and in the winter from 4,400 to 6,600 pounds per haul.

The authors concluded that 80 to 90 SRT's and SRTM's could successfully operate in this northern area because the average catch of 4,530 pounds of all species per exploratory haul indicated a sufficient resource. Apparently the higher authorities agreed, and the Soviet's official catch plans for 1966 provided for at least 33,000 short tons of hake to be taken in the northeastern Pacific (Commercial Fisheries Review, 1966a).

MOVEMENT OF THE SOVIET FLEET

The Soviet fleet working in the northeastern Pacific has a characteristic pattern (fig. 12) of building up to 150 to 200 ships in winter and spring and declining during summer and fall (Alverson et al., 1964; Naab, 1965). The effort of this fleet within the northeastern Pacific was shifted in the spring, summer, and fall of 1966 and 1967 from Alaska waters to off the Washington and Oregon coasts (fig. 12).

The average number of vessels participating in the hake fishery off Washington and Oregon by month for 1966 and 1967 is shown in table 4. In 1966 the buildup was gradual until the fleet reached a peak of 111 ships in the third week of July (Commercial Fisheries Review, 1966c); in 1967 the buildup was rapid and the peak of 114 ships occurred in the second week of May (Commercial Fisheries Review, 1967b). The decline was gradual in 1966 until December when the vessels departed, whereas the decline was sharp in 1967, with one-half the fleet remaining after August.

The fleet comprised BMRT's, RT's, SRTM's, SRTR's, SRT's, and support ships. Although the number of each type varied from month to month (table 4), generally 60 percent of the vessels were SRT's; 20 percent support ships; 14 percent BMRT's; and 6 percent SRTR's, SRTM's, and RT's.

The buildup and decline of BMRT's differed from the pattern of the rest of the fleet (table 4). In 1966, an average of 14 BMRT's were fishing in the area during May when the fleet was just starting to buildup. In 1967 instead of the decline near the end of the year, there

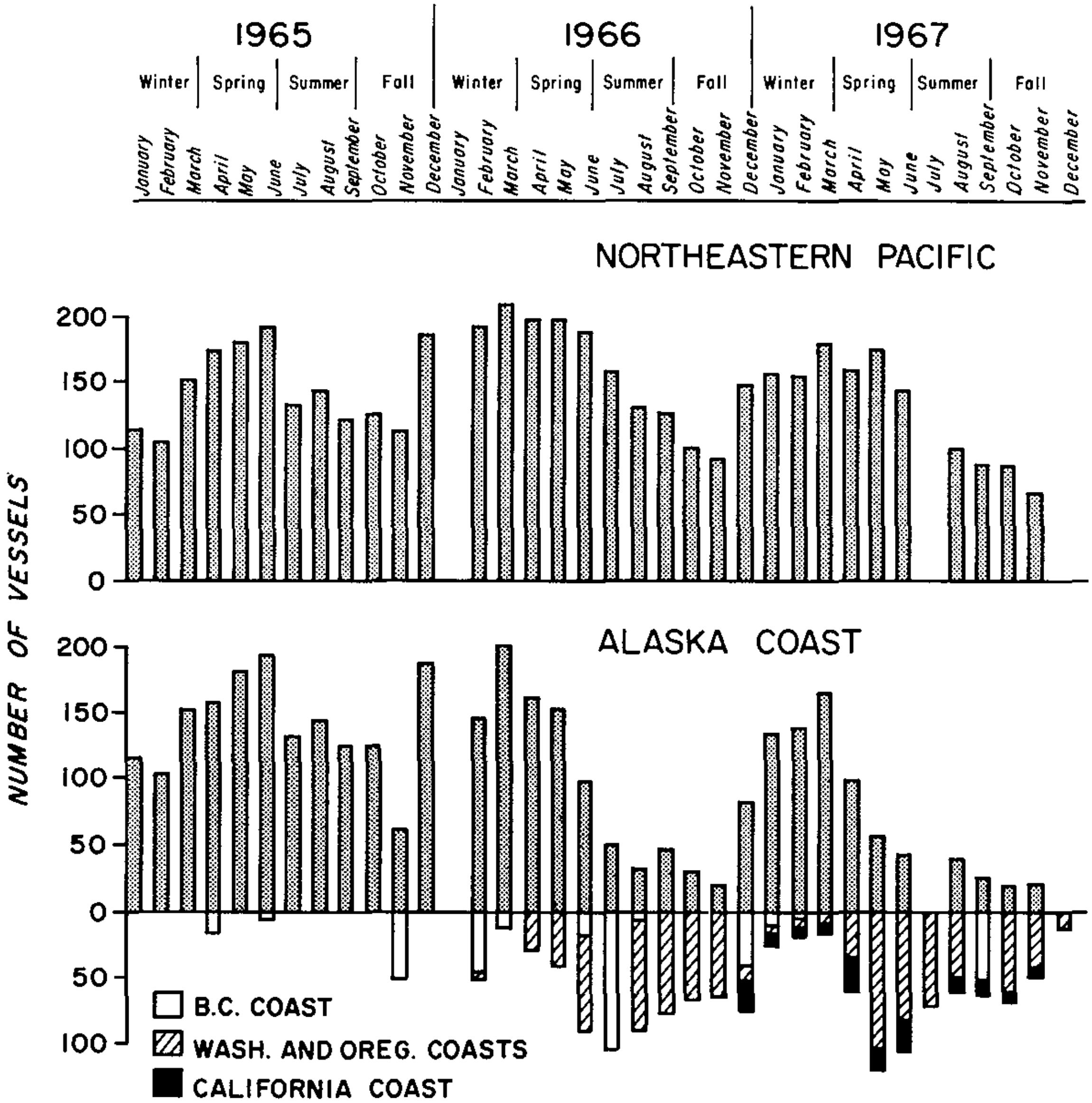


Figure 12.–The monthly frequency of Soviet vessels operating in the northeastern Pacific Ocean during 1965, 1966, and 1967 with a breakdown by region. (Source of data: Commercial Fisheries Review.)

Table 4.–The average number of Soviet vessels by types operating off the Washington and Oregon coasts by month (Source: BCF Enforcement and Surveillance Program at Seattle)

Month	BMRT		RT, SRTM & SRTR		SRT		Support ships		Total vessels	
	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
Jan.	--	1	--	0	--	0	--	0	--	1
Feb.	--	2	--	2	--	1	--	1	--	6
Mar.	--	2	--	1	--	2	--	1	--	6
Apr.	3	2	3	4	20	21	3	7	29	34
May	14	7	4	7	18	64	6	28	42	102
June	9	7	4	6	48	54	12	18	73	85
July	9	6	3	4	73	46	20	14	107	70
Aug.	7	3	3	4	64	33	19	12	93	52
Sept.	7	13	4	3	50	25	17	13	78	55
Oct.	8	24	3	2	42	21	15	12	68	59
Nov.	8	18	4	2	37	15	15	8	65	44
Dec.	4	4	1	2	7	0	3	0	15	6

was a buildup in September until an average of 24 BMRT's were operating in October.

Throughout the season the fleet worked on various grounds but a general pattern developed in 1966 and 1967 (fig. 13). During April and May the fleet fished off the Oregon coast; in June and July it shifted north to the Washington coast. During August and September the shift was again to the south off Oregon, and in October and November the shift was back to the north off Washington, except for the BMRT's which stayed off Oregon.

The Soviet fleet, when working off the Oregon coast, was generally off Cape Foulweather or Heceta Head (fig. 14). In 1966 the fleet fished near Stonewell Bank, whereas in 1967 it was slightly south near Heceta Bank.

When the fleet was off the Washington coast, the vessels were found anywhere from Cape Johnson to the Columbia River (fig. 15). In 1966, the vessels were spread out along the entire coast, fishing in shallow water during the first part of the season (April-June), moving out slightly in midseason (July-September), and moving to deeper water in the last part (October-December). In 1967, the fleet did not work in the shallow areas, but the vessels were clustered at different areas of the Continental Shelf during the season.

FISHING METHOD

The Soviet fleet works as a unit, and a command ship (fig. 16) directs the operation. This vessel receives the catch reports and helps direct activities of the fishing vessels each day. When concentrations of fish are not found, the fleet spreads out and slowly fishes in one direction. Each vessel appears to be assigned a specific area to explore for fish and suitable trawling bottom. A number of trial sets apparently are made in each area even when fish did not show on the sounder. The resulting catch, the location, and information on gear damage is said to be passed on to the command ship, where the information is plotted on a chart. If the catch is poor, the vessel is assigned another area. If the catch is fair, the vessel continues to fish. If the catch is good, other vessels are dispatched to the area to help in the harvest, and if very good, most of the fleet is called in.

When a large number of vessels are called together on a confirmed school of fish, a characteristic pattern is set up. Each vessel takes its turn setting its gear at a so-called "starting line." Then it tows downwind along the depth contour for an hour or two. At the end of the tow, the gear is hauled and the catch brought aboard in the so-called "end zone." The vessel moves back to the starting line by moving outside the path of the vessels with gear out. As long as the catch rates remain high, the pattern is continued. The SRT's pull out one at a time to deliver their catch to freezer ships anchored nearby (fig. 16) and then return to the pattern. The BMRT's continue fishing while processing their catch. If the catches are so great that processing cannot keep up with the catch, they pull out of the pattern to process their catches elsewhere. Once the catch rates drop, most of the vessels are pulled out of the pattern. They are assigned other areas to explore or are dispatched to areas where the catch rates are higher.

The independent vessels such as the BMRT's and SRTM's and at times a freezer ship with a few SRT's will explore areas some distance from the main fleet.

ACKNOWLEDGMENTS

Members of BCF Enforcement and Surveillance Program Office at Seattle, particularly G. W. Hilsinger and Bruce A. Yeager, provided much essential information.

Observations of BCF scientific and vessel personnel while they were working among the Soviet vessels were also valuable, particularly the office memorandum by Miles S. Alton and Richard L. Major.

Charles D. Gill took the photos used in figures 1 and 16; William L. High, figures 5 and 7; A. T. Pruter, figures 8 and 9; and Miles S. Alton, figure 10.

Paul T. Macy helped locate the pertinent English translations of Soviet articles.

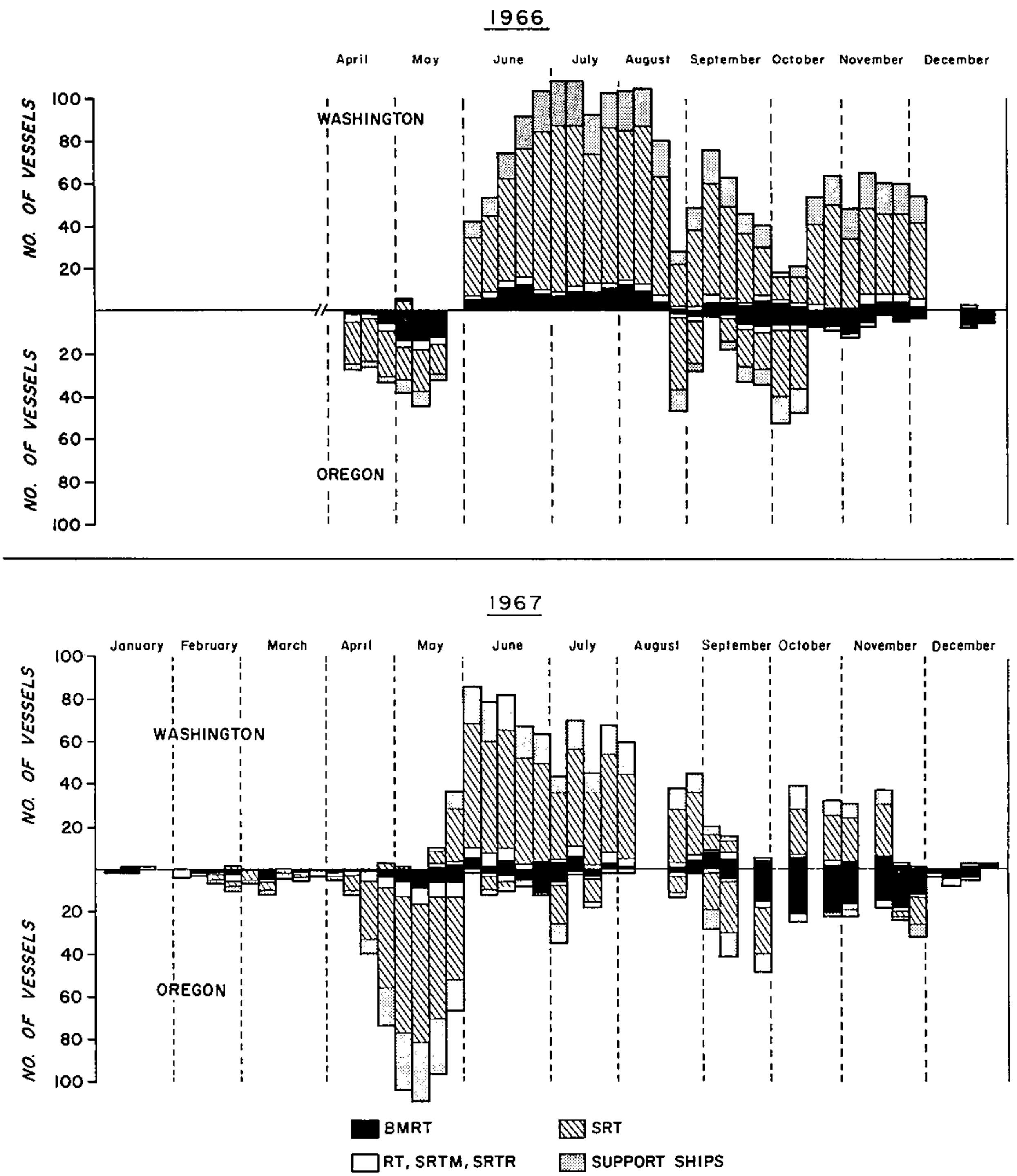


Figure 13.—The weekly number of Soviet vessels operating off the Washington and Oregon coasts during 1966 and 1967. (Source of data: BCF Enforcement and Surveillance Program, Seattle.)

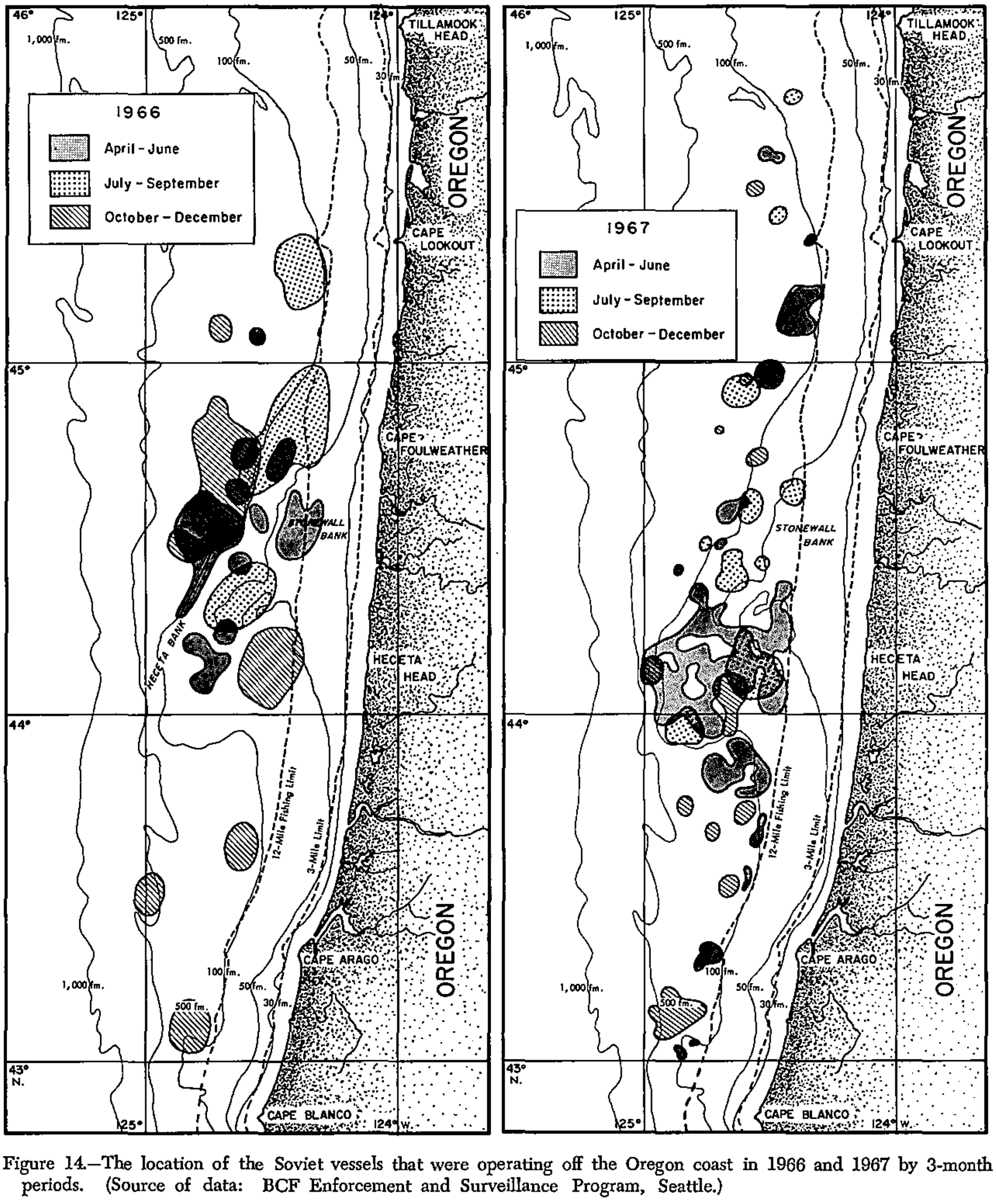


Figure 14.—The location of the Soviet vessels that were operating off the Oregon coast in 1966 and 1967 by 3-month periods. (Source of data: BCF Enforcement and Surveillance Program, Seattle.)

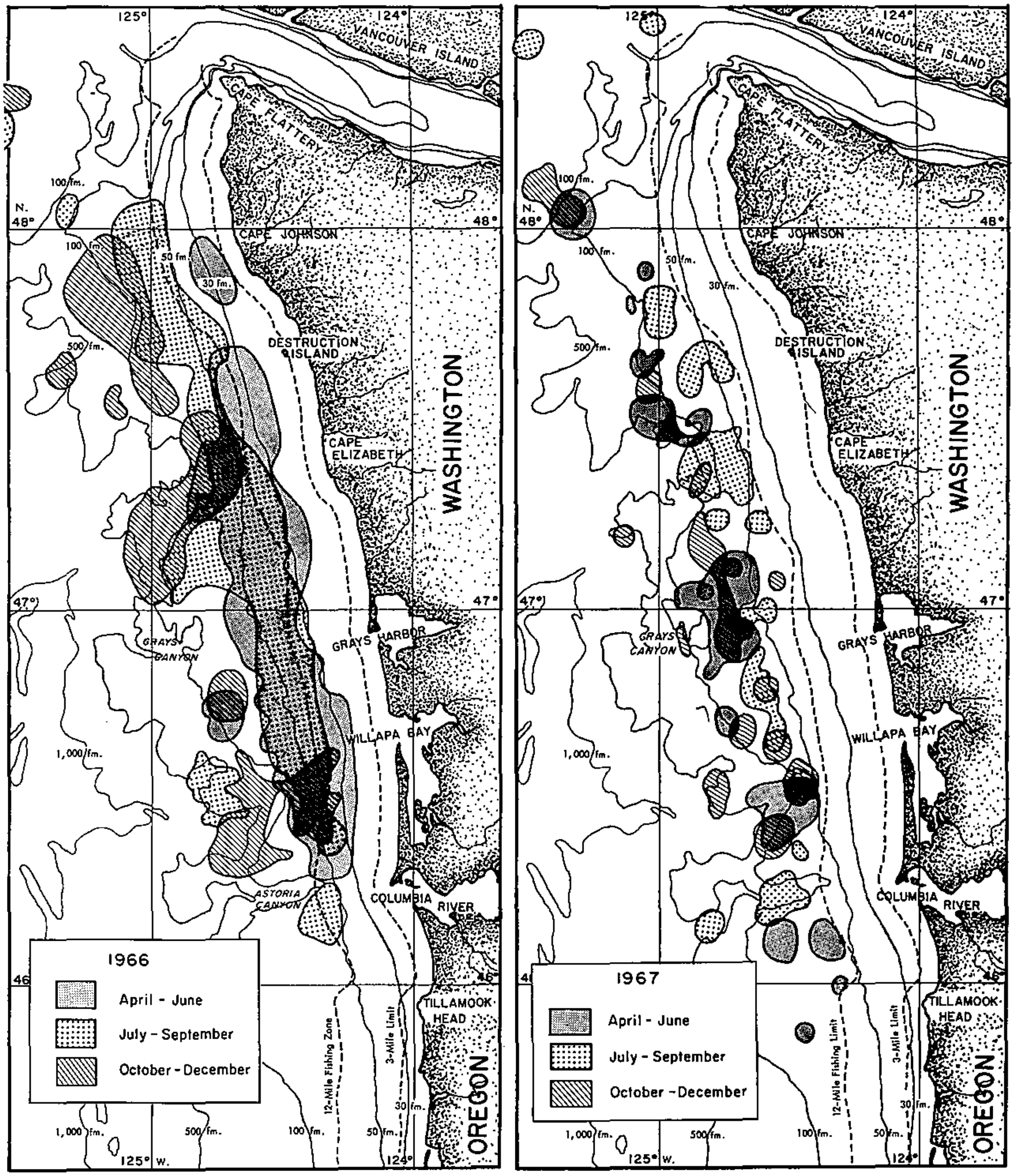


Figure 15.—The location of the Soviet vessels that were operating off the Washington coast in 1966 and 1967 by 3-month periods. (Source of data: BCF Enforcement and Surveillance Program, Seattle.)

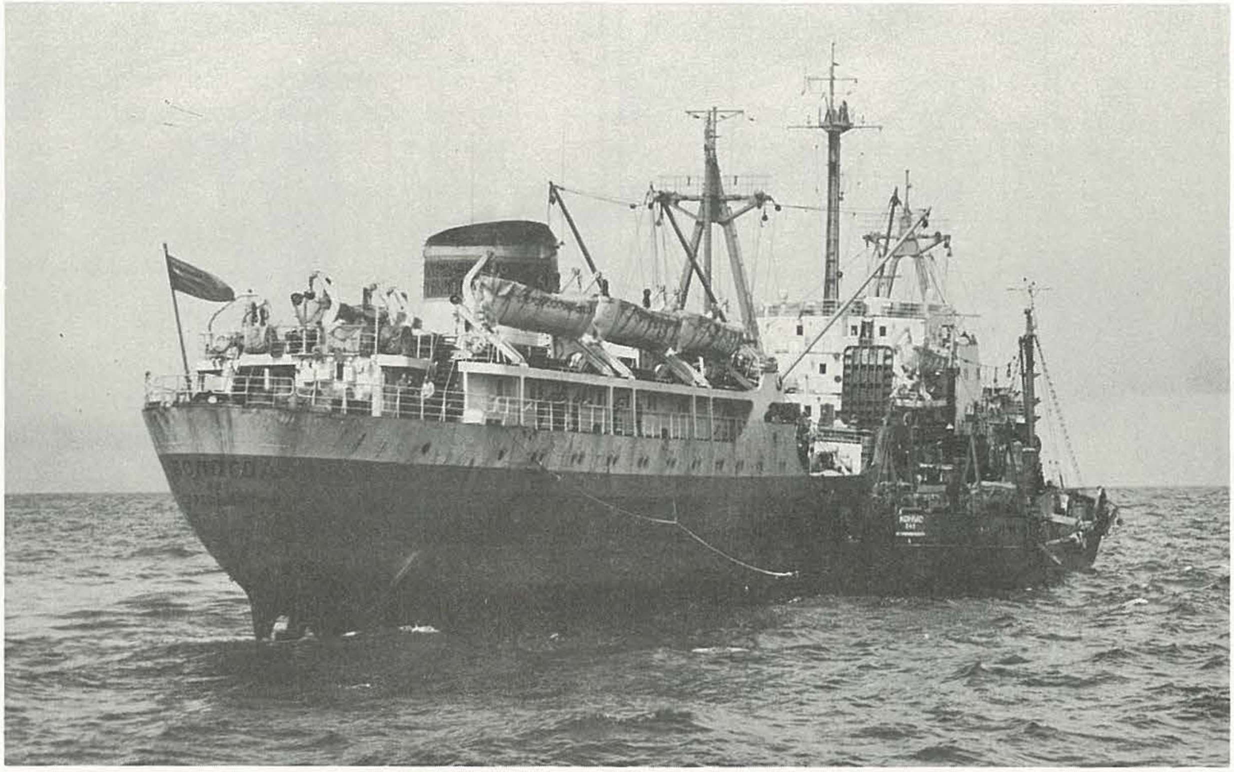


Figure 16.—An SRT alongside a Soviet *Sevastopol* class refrigerator ship which was used as a command ship during part of the fleet's operation in the northeast Pacific.

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MS. #1870

Midwater Trawling Equipment and Fishing Technique for Capturing Hake off the Coast of Washington and Oregon

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ABSTRACT

The Bureau of Commercial Fisheries has designed and developed midwater trawls, special otterboards, and a system to continuously indicate trawl depth. Cobb pelagic trawls have caught hake in midwater and the BCF Universal trawl has caught hake both on bottom and in midwater while being towed by Pacific Northwest trawlers at only 1.6 to 2.3 knots. Both Cobb pelagic otterboards and China V-doors have been used to spread the trawls. The trawls were designed to open 40 to 80 feet. Comparative fishing trials have shown that trawls of lightweight monofilament catch more fish than trawls of multifilament nylon. To trawl effectively for hake in midwater the fisherman must invest about $16,000 for equipment—two trawls, two depth telemetry systems, otterboards, cable meters, and 20-inch diameter trawl blocks.

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Published February 1970.

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INTRODUCTION

The BCF (Bureau of Commercial Fisheries) Exploratory Fishing and Gear Research Base at Seattle, Wash., started investigating Pacific hake in 1964. One of the aims was to develop equipment for harvesting this fish economically. In this paper we describe the midwater trawls, otterboards, and trawl depth telemetry system (fig. 1) used to capture Pacific hake.

First attempts to catch hake used midwater trawling equipment developed between 1961 and 1964 to sample midwater marine life. In summer 1964 this equipment was fished on the *John N. Cobb*, the BCF 93-foot research vessel, and the *St. Michael*, a 73-foot commercial trawler. These vessels made large catches of hake.

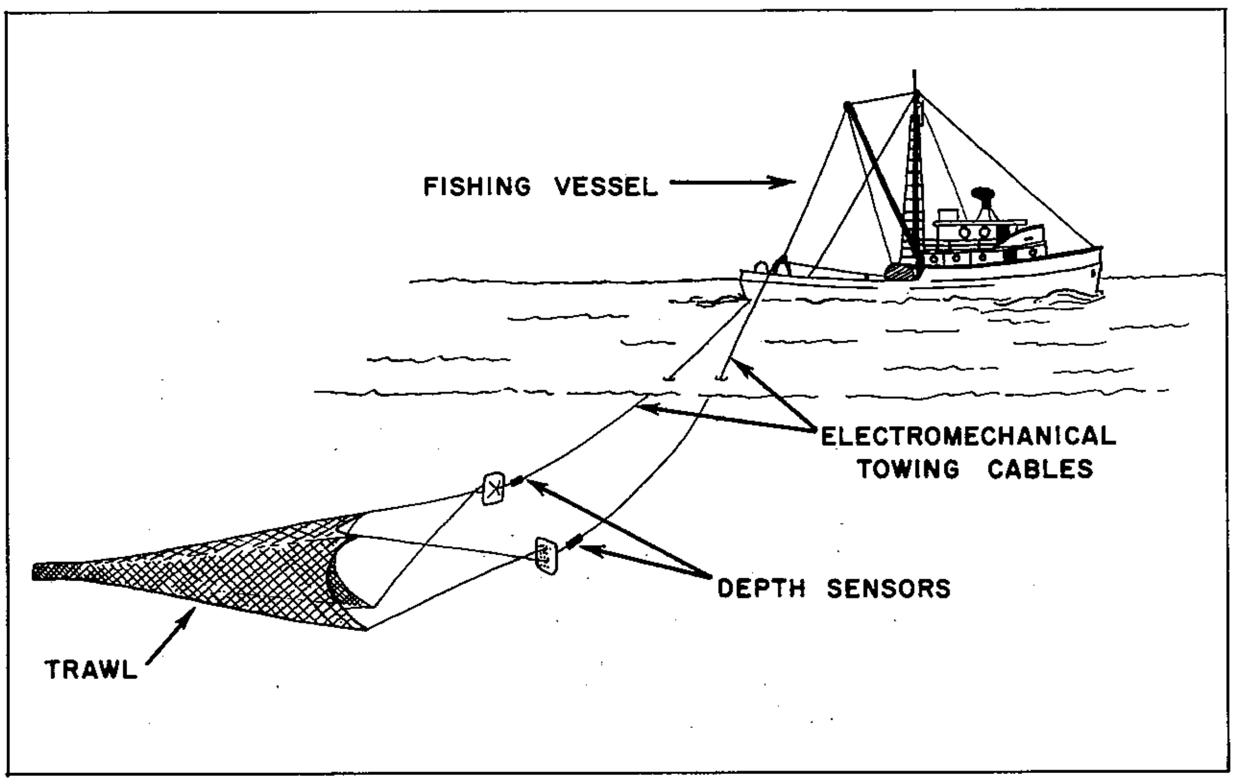


Figure 1.—A Cobb pelagic trawl, special otterboards, and two depth telemetry systems are used to catch hake.

COBB PELAGIC TRAWLS

In 1960 a partially built two-boat surface trawl designed to catch tuna was purchased by the Base from a commercial fisherman who had abandoned pelagic trawling. After the trawl was assembled, tests showed several defects that required extensive changes.

The trawl was redesigned and rebuilt with long tapering wings, and the webbing along the corner riblines was hung-in (i.e., the length of stretched webbing was longer than the line to which it was hung). The trawl first was used to catch salmon near the surface and later to catch other fish in midwater.

Between 1962 and 1967, Base personnel designed and tested seven more models of the Cobb pelagic trawl. The trawls differed from each other in amount of webbing, size of twine, size of mesh, size of wings, length of cod end, and hang-in of webbing on the riblines. The design of these trawls was based on earlier trawls used to sample midwater marine life. All seven trawls have the same shape and were called various versions of the Cobb pelagic trawl. Major characteristics of these trawls are shown in table 1.

600 MONOFILAMENT COBB PELAGIC TRAWL

In late 1962, the 600 monofilament Cobb pelagic trawl was built. Three-inch (stretch mesh) lightweight (0.043 inch by 0.023 inch twine size) monofilament webbing was used to reduce drag and visibility of the trawl. The design of this trawl is the same as the Standard 18 Cobb pelagic trawl shown in figure 2 except for the webbing. The bottom panel of this trawl was later replaced with 36-thread, nylon multifilament webbing.

STANDARD 18 COBB PELAGIC TRAWL

The Standard 18 Cobb pelagic trawl was similar to the 600 monofilament Cobb pelagic trawl except for twine size and webbing material. This trawl was made in early 1963 with 18-thread (10,080 denier) 3-inch (stretch mesh) continuous filament nylon. The webbing on this trawl was hung-in greater on the corner ribline in the forward part of the trawl than in the back. Wingtip webbing was hung-in 16 percent (percent of hang-in = $\frac{\text{excess webbing} \times 100}{\text{total webbing}}$). Each section of webbing aft of the wingtips was hung-in less than the section forward of it. Webbing just forward of the cod end was hung-in only 9 percent. This trawl was designed to open 75 feet both horizontally and vertically. The 18-thread nylon proved to be much stronger than the lightweight flattened monofilament used on the 600 monofilament Cobb pelagic trawl; however, the wingtips and bottom panel had to be replaced with 36-thread webbing.

Tests showed that this trawl had several deficiencies. A 325-horsepower vessel could tow it at only 1.7 knots. Strong tides sometimes carried the trawl off the desired course,

Table 1.—Characteristics of Cobb pelagic trawls and BCF Universal trawl

Trawl	Designed mouth opening	Meshes across trawl mouth	Mesh size[1] in body	Twine size[2] used in: Top and sides	Twine size[2] used in: Wings	Twine size[2] used in: Bottom	Vessel for which trawl is suitable
	Feet	*Number*	*Inches*				*Horsepower*
Cobb pelagic trawls							
600 monofilament	75 x 75	600	3	0.043 x 0.023 inch monofilament	No. 21	No. 36	500
Standard 18	75 x 75	600	3	No. 18	No. 36	No. 36	630
440	55 x 55	440	3	No. 18	No. 18	No. 18	330
2/3	50 x 50	600	2	No. 18	No. 18	No. 18	380
600-21	75 x 75	600	3	No. 21	No. 36	No. 36	650
640 monofilament	80 x 80	640	3	0.043 x 0.023 inch monofilament	No. 21	No. 36	530
648	68 x 68	648	2½	No. 21, No. 12	No. 21, No. 12	No. 21, No. 12	500
BCF Universal trawl	68 x 40	650	2½	No. 21	No. 36	No. 36	350

[1] Stretch measure, center of knot to center of knot.
[2] Twine numbers are equivalent to following deniers: No. 12, 6,300; No. 18, 10,080; No. 21, 12,600; No. 36, 20,160; No. 72, 40,320; No. 96, 57,960; No. 120, 70,560.

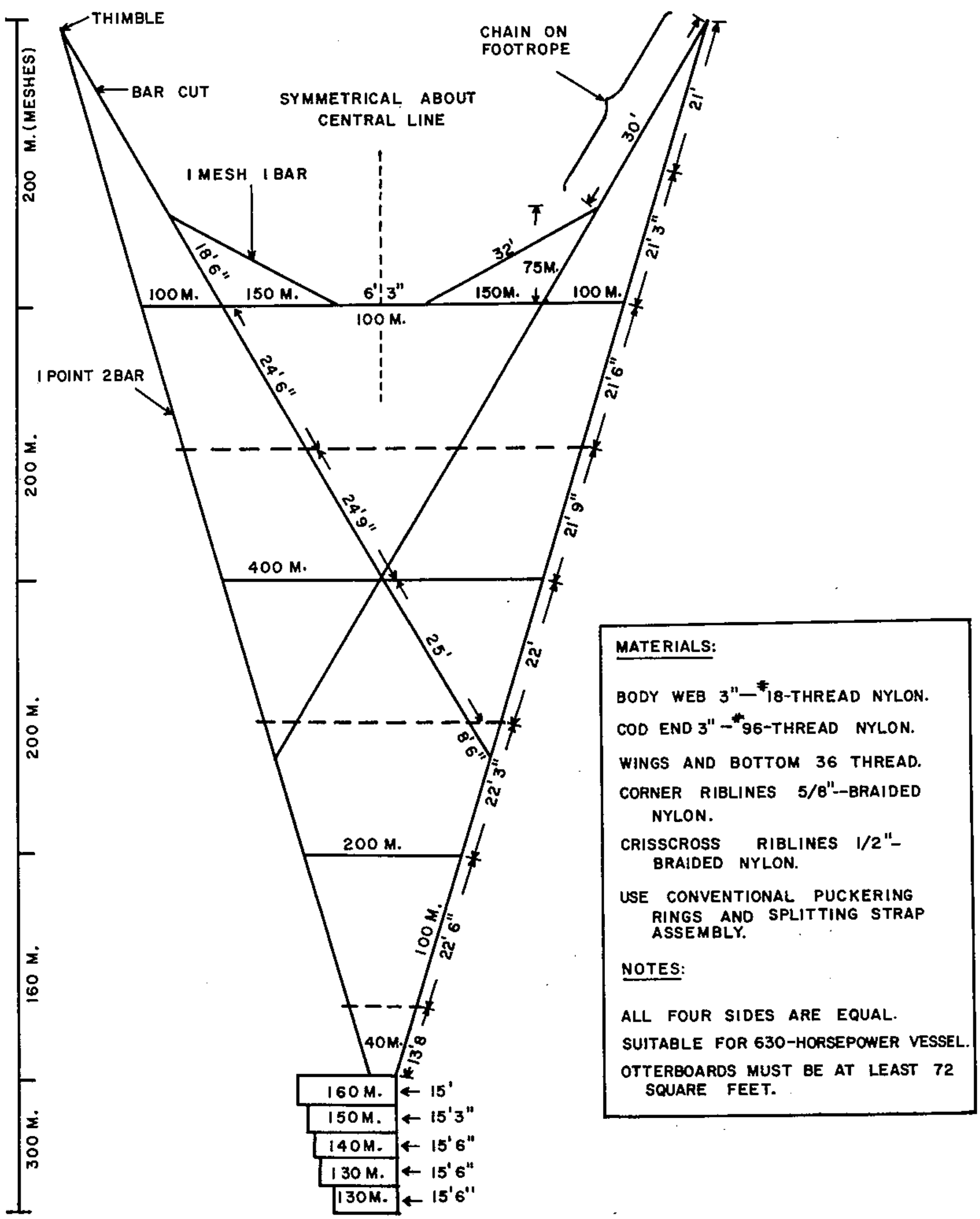


Figure 2.—Standard 18 Cobb pelagic trawl.

and hake gilled in the 3-inch mesh, particularly in the aft 50 feet of the body of the net.

During summer 1965 the chartered trawler *Western Flyer* was used to compare the effectiveness of a 600 monofilament and a Standard 18 Cobb pelagic trawl. The vessel made 34 tows with the 600 monofilament Cobb pelagic trawl and 105 tows with the Standard 18 trawl. The monofilament trawl caught 60 percent more fish per hour than the Standard 18 trawl. To determine whether this difference was caused by differences in availability of hake, we studied each echo-sounding tape and estimated the fish abundance. The echo-sounding tapes appeared to show slightly more hake present when the 600 monofilament trawl was used than when the Standard 18 trawl was fished. We concluded that the 600 monofilament trawl catches about 50 percent more hake per hour of towing than the Standard 18 trawl when equal quantities of hake are present and 40-square foot otterboards are used with a 250-horsepower vessel.

440 COBB PELAGIC TRAWL

After tests with the 600 monofilament and Standard 18 Cobb pelagic trawls, the staff at the Base decided that smaller trawls were needed that could be towed easily by vessels with about 350 horsepower, the amount of power which most West Coast trawlers have. The 440 and 2/3 Cobb pelagic trawls, scaled down versions of the Standard 18 Cobb pelagic trawl, were made in 1965.

The 440 Cobb pelagic trawl (figs. 3 and 4) was similar to the Standard 18 Cobb pelagic trawl except for its size. The 440 Cobb pelagic trawl was only 440 meshes wide at the mouth and had only 55 percent as much web as the Standard 18 trawl. It was designed to have a mouth opening of 55 feet by 55 feet.

The 440 Cobb pelagic trawl was easier to control than the Standard 18 trawl. A 325-horsepower trawler can tow this trawl at about 2.3 knots. The small twine (18 thread) in the wings and bottom wore out quickly indicating that heavier twine should have been used in these places. Small hake gilled frequently in the aft 40 feet of webbing.

Results of 14 comparative tows with the 440 and Standard 18 Cobb pelagic trawls, spread with 40-square foot otterboards and towed by 250-horsepower vessels, showed that both trawls caught hake at about the same rate. Larger otterboards and more powerful vessels could have been used with both trawls. We should have used 48-square foot otterboards to spread the 440 trawl and 72-square foot otterboards to spread the Standard 18 Cobb pelagic trawl.

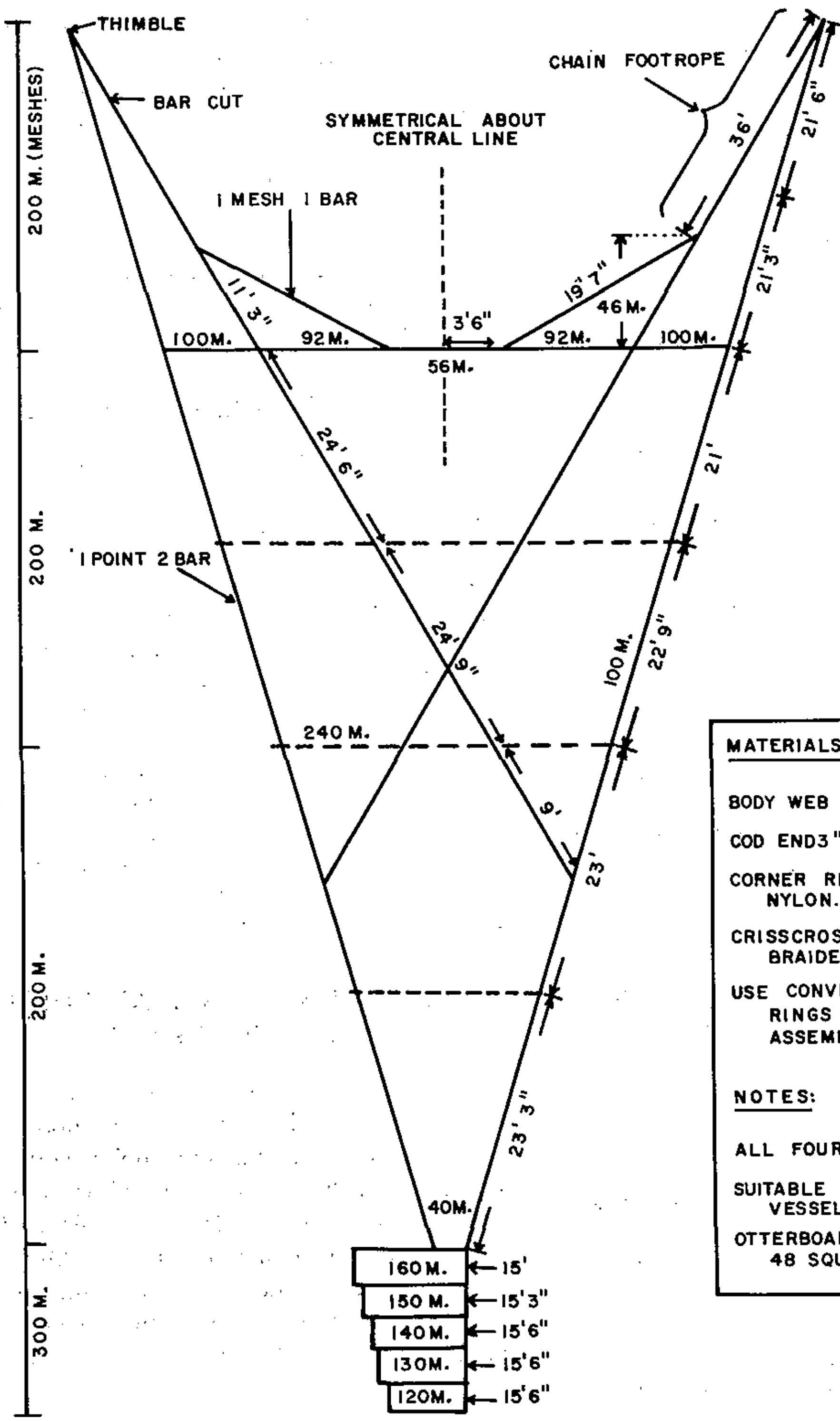
⅔ COBB PELAGIC TRAWL

The 2/3 Cobb pelagic trawl was similar to the Standard 18 trawl except all dimensions and mesh size were scaled to two-thirds size. The 2/3 trawl was made of 18-thread nylon and designed to open only 50 feet by 50 feet (fig. 5). A 325-horsepower vessel can tow this trawl at 2.1 knots. The 2-inch mesh completely eliminated gilling of hake.

Results of six comparative tows with 2/3 and Standard 18 Cobb pelagic trawls spread with 40-square foot otterboards and towed by 250-horsepower vessels showed that these trawls caught hake at about the same rate. Again the tows would have been more meaningful if larger otterboards and more powerful vessels had been used.

640 MONOFILAMENT COBB PELAGIC TRAWL

Because the 600 monofilament trawl caught more hake than the Standard 18 Cobb pelagic trawl, the 640 monofilament Cobb pelagic trawl was made in late 1965. This trawl was similar to the Standard 18 Cobb pelagic trawl except that 3-inch monofilament webbing was used instead of multifilament nylon webbing and the trawl was 640 meshes wide at the mouth instead of 600 meshes. This net was the largest of the Cobb pelagic trawls and was designed to have an opening of 80 feet by 80 feet. This trawl caught hake effectively; however, it had the same deficiencies as the 600 monofilament trawl. The webbing was weak, hake gilled in the after body of the net, and the trawl was difficult to control.



MATERIALS:

BODY WEB 3"—*18-THREAD NYLON.

COD END 3"—*96-THREAD NYLON.

CORNER RIBLINES 5/8"–BRAIDED NYLON.

CRISSCROSS RIBLINES 1/2"–BRAIDED NYLON.

USE CONVENTIONAL PUCKERING RINGS AND SPLITTING STRAP ASSEMBLY.

NOTES:

ALL FOUR SIDES ARE EQUAL.

SUITABLE FOR 330-HORSEPOWER VESSEL.

OTTERBOARD MUST BE AT LEAST 48 SQUARE FEET.

Figure 3.—440 Cobb pelagic trawl.

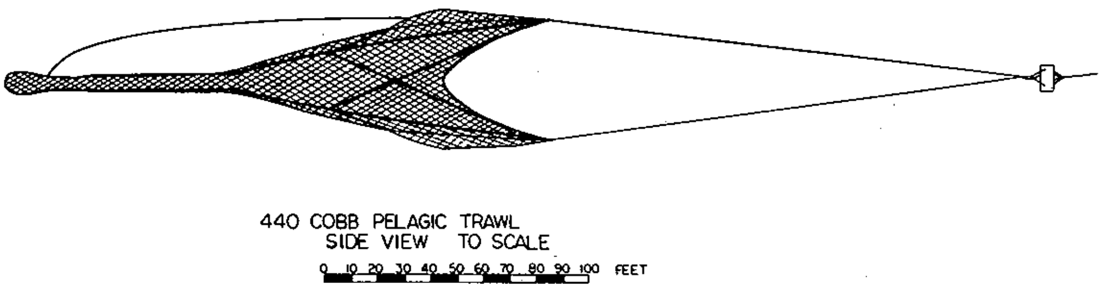


Figure 4.—440 Cobb pelagic trawl, side view, to scale.

648 COBB PELAGIC TRAWL

Performances of various Cobb pelagic trawls during the 1965 hake fishery led to the design of the 648 Cobb pelagic trawl (fig. 6). Made of 2½-inch mesh and 12-thread web, it was designed to open 68 feet by 68 feet. Three of these trawls were tested in the 1966 hake fishery. A 325-horsepower vessel can tow this large trawl at only 1.8 knots. The 2½-inch mesh completely eliminated gilling of hake. The 12-thread webbing in the body was too weak and required frequent repair.

600-21 COBB PELAGIC TRAWL

The 600-21 Cobb pelagic trawl was similar to the 600 monofilament trawl except for twine size and webbing material. This trawl was made of 21-thread, 3-inch (stretch mesh) continuous filament nylon. Use of 21-thread nylon rather than 18-thread nylon reduced the amount of mending necessary.

BCF UNIVERSAL TRAWL

The BCF Universal trawl was designed and made for the 1967 hake fishery (figs. 7 and 8). As schools of hake were usually between 15 and 30 feet thick, the side panels on this trawl were designed to open 40 feet, in contrast to 50 to 80 feet for the Cobb pelagic trawls. By cutting body webbing on the bar instead of on a one point two bar taper, we made the trawl much shorter than the Cobb pelagic trawls. A wingtip added to the center of both side panels allows the trawl to be opened vertically with a minimum number of floats. Use of 36-thread webbing in the bottom and wingtips minimized mending. This trawl requires less mending than any of the Cobb pelagic trawls. The 2½-inch mesh eliminated gilling of hake.

This trawl had less drag than any of the Cobb pelagic trawls except the 440 Cobb pelagic trawl. The BCF Universal trawl was well suited for a vessel with 350 horsepower. It can be towed 2.2 knots and maneuvered fairly easily by a 325-horsepower vessel.

During the summer of 1967, 10 charter vessels fished hake off the Washington coast. They were provided with Cobb pelagic trawls, Universal trawls, and depth telemetry equipment. Each vessel supplied its own set of otterboards.

Although the primary aim of these charters was to determine the commercial feasibility of fishing hake, the catch data collected made it possible to determine the relative catch rates of various trawls. Records kept of each tow included: vessel name, haul number, date and time of day tow started, latitude and longitude of catch, bottom depth, net depth, duration of tow, amount of cable out, engine r.p.m., trawl used, otterboard used, and the catch.

A computer program was written that matched all tows and printed out those tows made within 1 minute of longitude and 1 minute of latitude within an hour of each other. All tows in which a depth telemetry system did not function properly and all tows shorter than 0.6 hour and longer than 1.8 hours were disregarded.

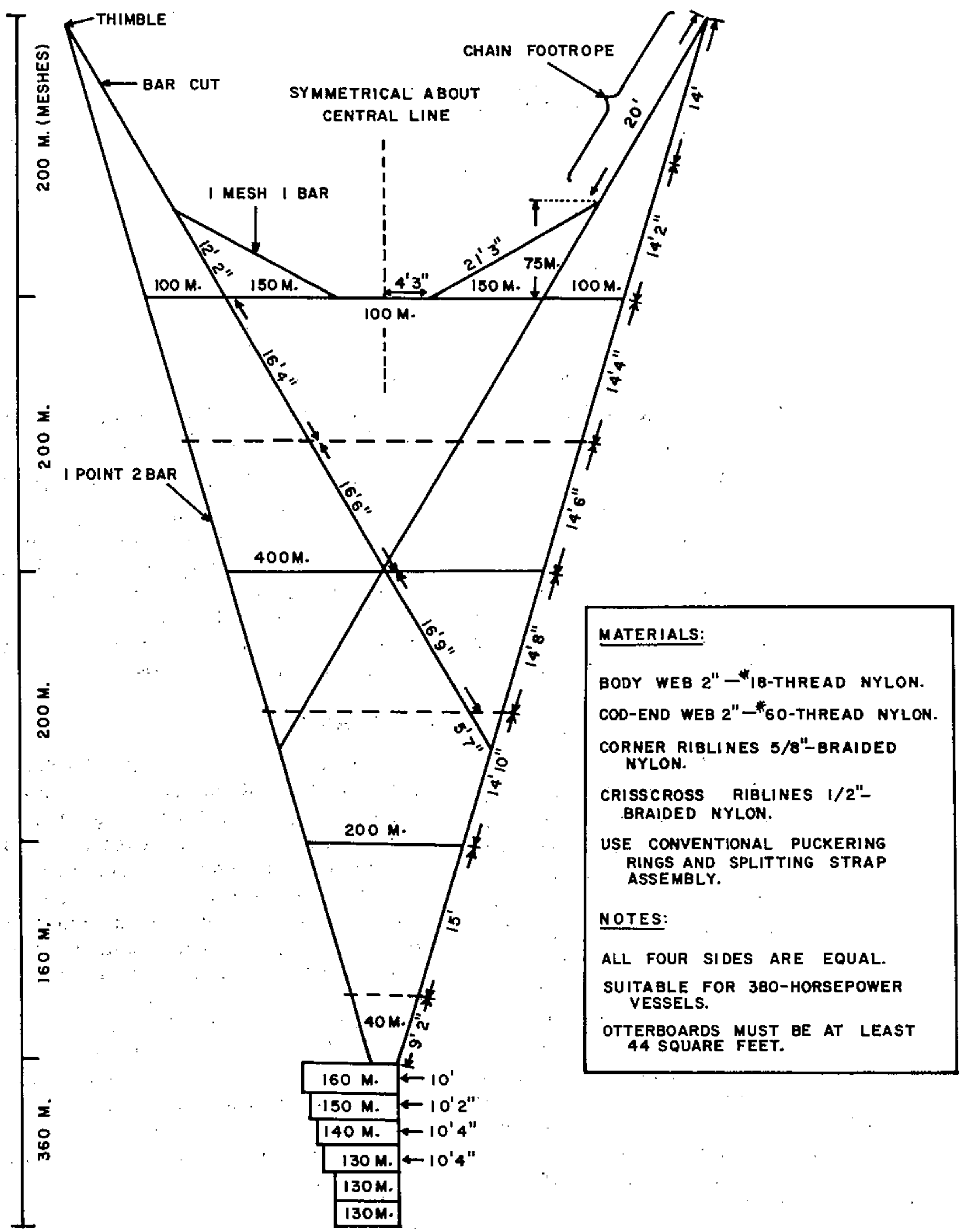


Figure 5.–2/3 Cobb pelagic trawl.

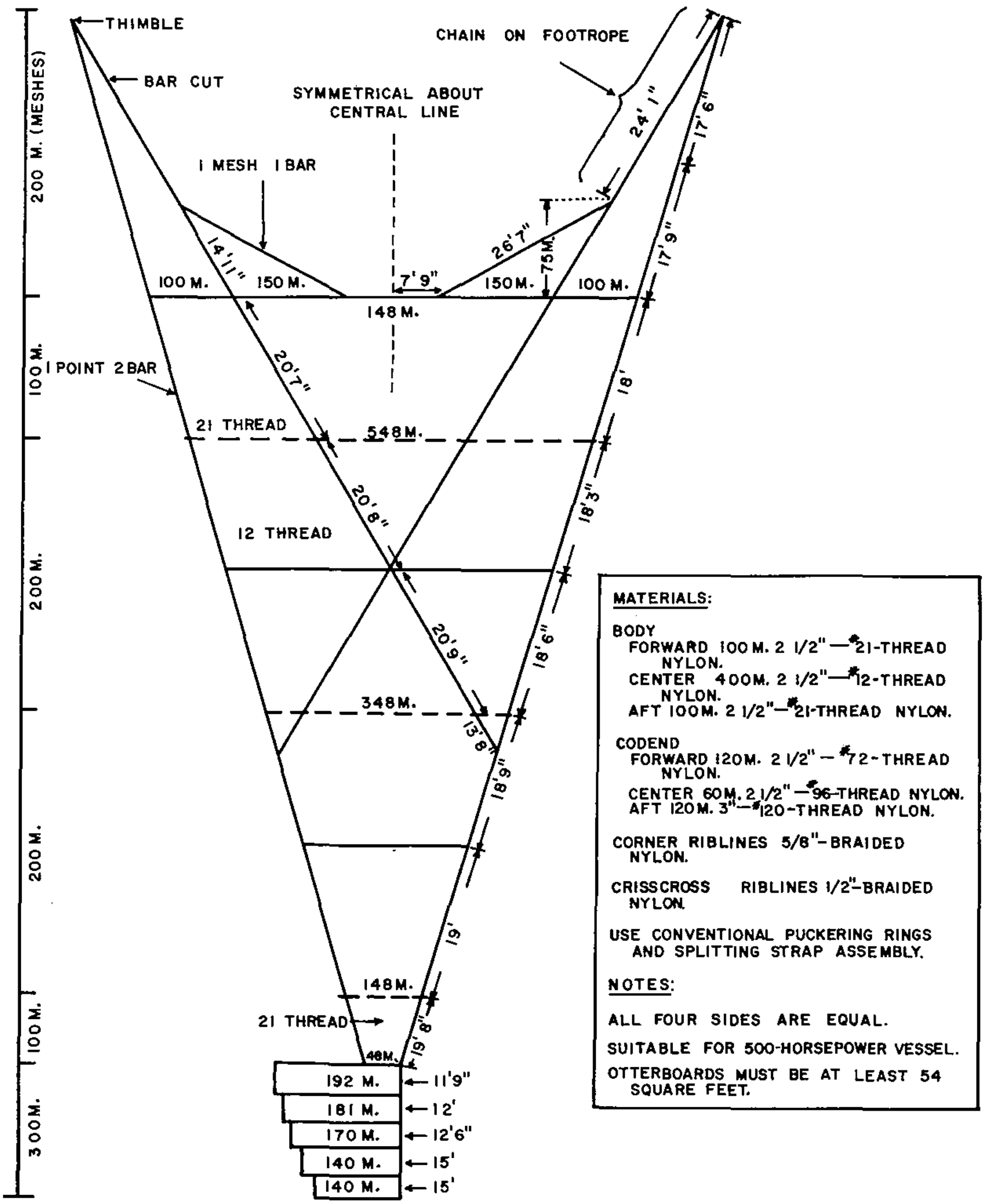


Figure 6.—648 Cobb pelagic trawl.

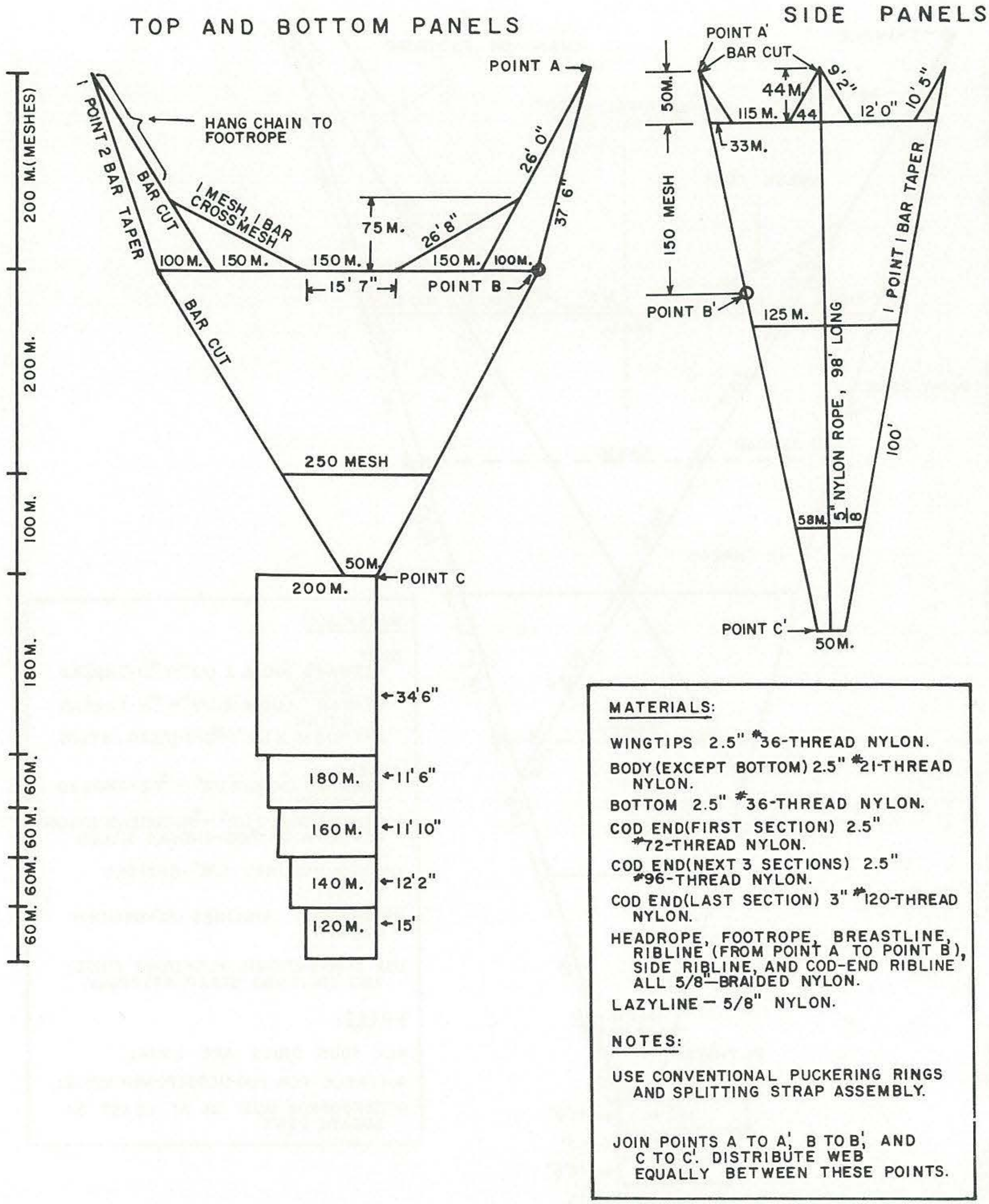


Figure 7.—BCF Universal trawl.

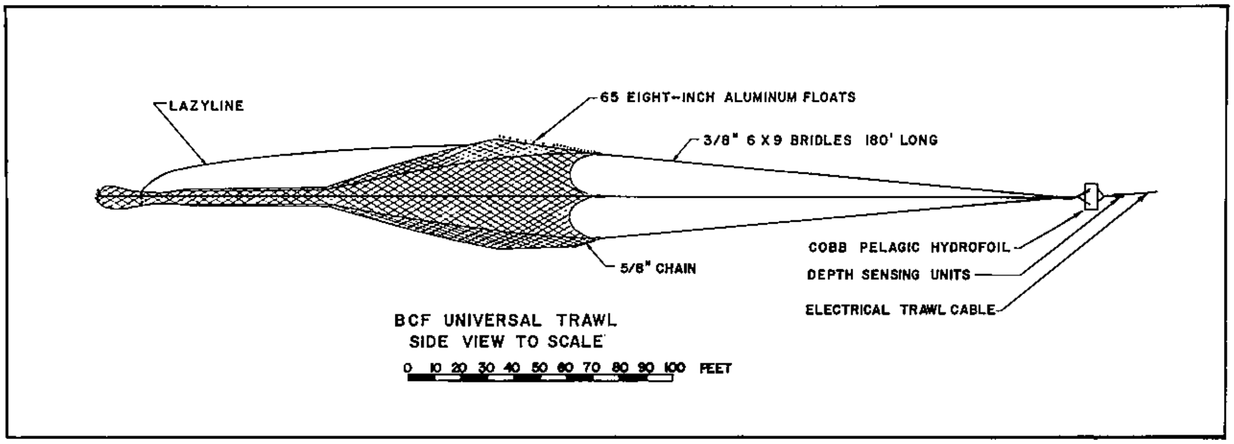


Figure 8.—BCF Universal trawl, side view, to scale.

The relative catch rates shown in table 2 were computed in the following manner. The comparative tows were listed:

Vessel and otterboards	Trawl	Catch per hour	Vessel and otterboards	Trawl	Catch per hour
A	1	m	B	4	n
A	2	o	B	4	p
A	3	q	B	4	r

The relative catch rate of trawls 1, 2, and 3 when used on a vessel with power of vessel A and doors of size used by vessel A would be:

Trawl	Relative catch rate
1	$\frac{mr}{nq}$
2	$\frac{or}{pq}$
3	1.0

Table 2.—Relative catch rate of 640 monofilament, 648, 600-21 Cobb pelagic trawls, and BCF Universal trawl. All trawls were towed by the *Baron*, a 500-horsepower vessel using 54-square foot steel V-doors

Trawl	Tows made	Relative catch rate
	Number	
Cobb pelagic trawl		
640 monofilament	24	1.46
648	97	1.04
600-21	31	.74
BCF Universal trawl	7	.83

As several vessels usually fished nearby, a tow by each vessel provided several paired tows. In table 2, only the number of tows by the *Baron* is shown, not the number of paired tows used to determine relative catch rate.

On many occasions the trawler *Baron* towed the 640 monofilament, 648, 600-21 Cobb pelagic trawls, and BCF Universal trawl next to other vessels towing Universal trawls. By comparing catch rates it was possible to determine the relative catch rate of the four trawls fished by the *Baron*. The *Baron* used 54-square foot V-doors for all tows. Table 2 shows that trawls of lightweight web catch appreciably more hake than similar trawls of heavier web. Catch rate was about inversely proportional to twine diameter, i.e., the smaller the twine, the greater the catch.

Another chartered trawler, the *St. Michael*, towed both the 600 monofilament Cobb pelagic trawl and the BCF Universal trawl next to vessels towing the Universal trawl. Results of 47 comparative tows showed that the *St. Michael* had a 36 percent better catch rate with the 600 monofilament trawl than with the Universal trawl.

OTTERBOARDS

Three types of otterboards were used during the 1967 hake fishery—Cobb pelagic otterboards, V-doors, and flat plywood otterboards.

COBB PELAGIC OTTERBOARDS

The Cobb pelagic otterboards (figs. 9 and 10) are characterized by an airfoil cross section and an aspect ratio $(\frac{\text{height}^2}{\text{area}})$ of 1.6. These characteristics give this otterboard a higher lift-to-drag ratio than flat wooden otterboards. Wind tunnel tests by Zimmerman (1932) of

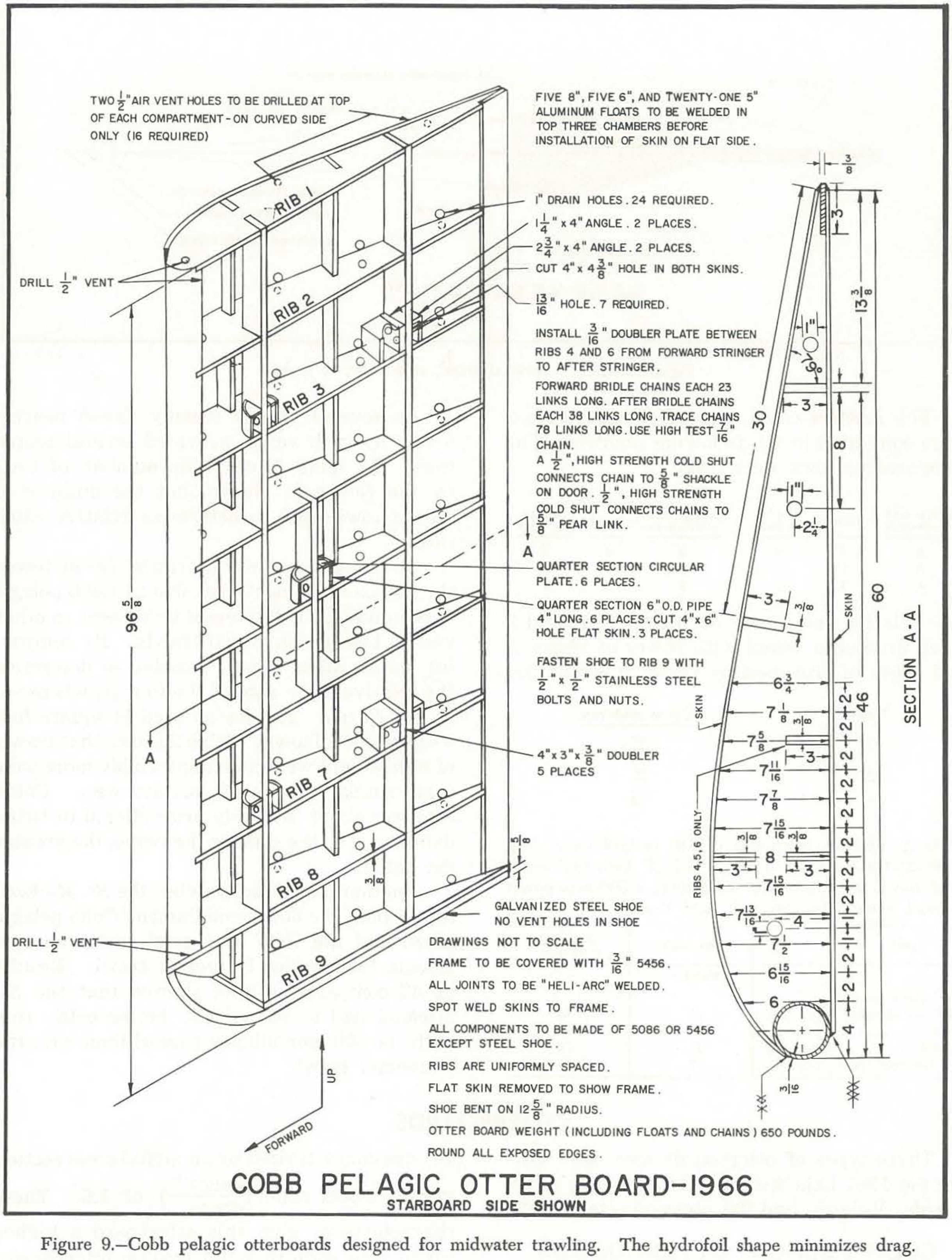
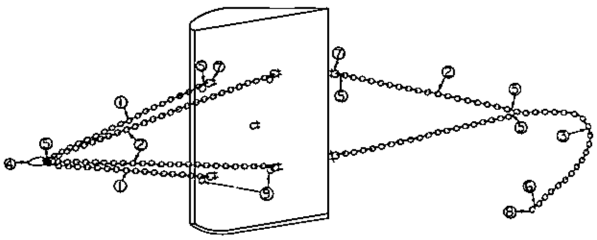


Figure 9.–Cobb pelagic otterboards designed for midwater trawling. The hydrofoil shape minimizes drag.



NO	NEEDED	MATERIAL SIZE
1	2	ALLOY STEEL CHAIN- GALVANIZED 3/8", 30 1/2" LONG
2	4	ALLOY STEEL CHAIN-GALVANIZED 3/8", 48" LONG
3	1	ALLOY STEEL CHAIN-GALVANIZED 1/2", 160" LONG
4	1	PEAR SHAPED MASTER LINK-GALVANIZED 1/2"
5	12	HAMMERLOCK CONNECTING LINK, GALVANIZED 3/8"
6	1	HAMMERLOCK CONNECTING LINK, GALVANIZED 1/2"
7	7	SHACKLE, HEX HEAD BOLT, GALVANIZED 5/8"
8	1	G-HOOK, GALVANIZED
9	4	SEINE RINGS GALVANIZED 1/2"X 3"

Figure 10.—Bridle hookup for Cobb pelagic otterboards.

a Clark Y airfoil, which is very similar to the airfoil of a Cobb pelagic otterboard, indicated a lift-to-drag ratio of 4.1 and a coefficient of lift of 1.1 at a 21° angle of attack, a near optimum angle of attack for this airfoil. Coefficient of lift is defined by the following equation:

$$\text{Coefficient of lift} = \frac{2\ (\text{lift})}{(\text{otterboard cross sectional area})\ (\text{density of water})\ (\text{speed})^2}$$

Dale and Moller (1964) have shown that the lift-to-drag ratio is 2.4 for a flat otterboard without fittings and with aspect ratio of 0.5 at 21° angle of attack. The coefficient of lift is 0.72. The lift-to-drag ratio is 1.7 and the coefficient of lift is 0.98 at 30° angle of attack, the approximate angle at which these otterboards would normally be fished. We would expect the Cobb pelagic otterboards, then, to have less than half the drag of the same size flat wooden otterboards with aspect ratio of 0.5.

Cobb pelagic otterboards, however, have several disadvantages. If they are not set at the proper speed, they may cross. They are not as easily set on the guard as other otterboards because the hydrofoil otterboards have to turn 90° to set on the guard. They cannot be set as fast as other otterboards because they must be allowed to fill with water. Although primarily designed to be towed in midwater, these otterboards were sometimes towed on bottom. Like other otterboards, they sometimes fell over and lay flat on the bottom rather than stood upright. Unlike other otterboards, the Cobb pelagic otterboards did not immediately come back upright when the vessel was speeded up. They continued to lie flat on the bottom. They are also more expensive than either the V-doors or flat wooden otterboards. The 8-foot by 5-foot otterboards proved too small to spread fully the large trawls used. A Cobb pelagic otterboard as shown in figure 9 weighs 650 pounds including chains.

V-DOORS

V-doors (fig. 11) have three worthwhile features. They are very rugged, are less expensive than the Cobb pelagic otterboards, and rarely cross. They did not cross in 400 recent drags while fishing for offshore hake.

Two vessels participating in the 1967 hake fishery used 9-foot by 6-foot V-doors that had several deficiencies. They were heavy (1,100 pounds each), resulting in a small scope ratio (warp length divided by trawl depth) and a reduced horizontal trawl spread. They were not galvanized, which caused severe corrosion of the galvanized electromechanical tow cables. Also, they were too small to open fully the very large trawls used.

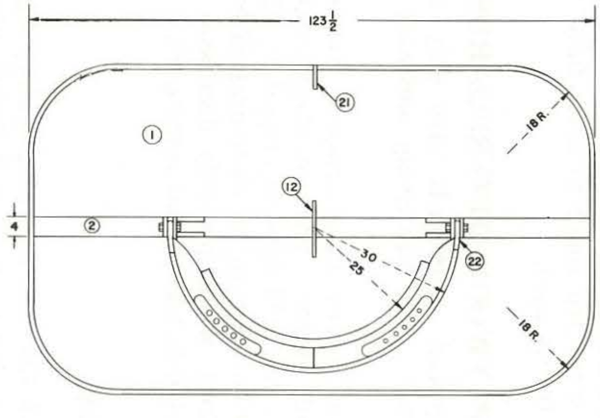
FLAT PLYWOOD OTTERBOARDS

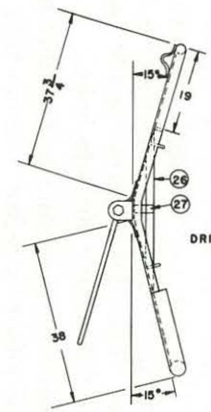
Flat plywood otterboards have only two good features: they are cheap and easy to make.

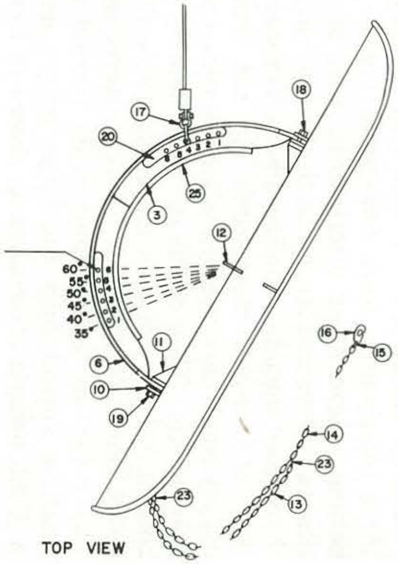
They have several disadvantages. The plywood is easily broken. Trawl webbing catches on the bolts that hold the doors together. The otterboards have a ratio of lift to drag of only about 1.5 to 1, which probably decreases as the plywood gets nicked and roughened.

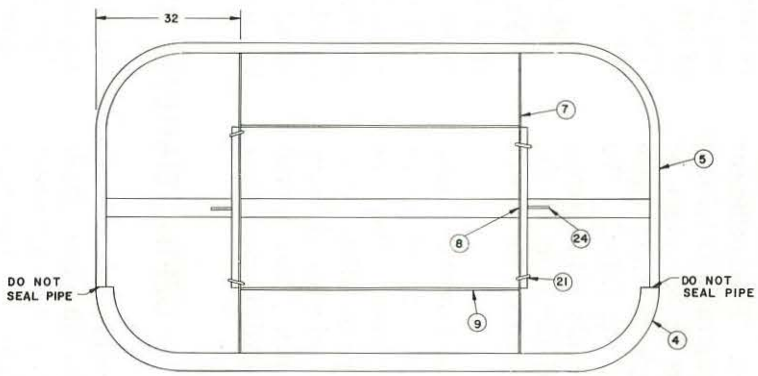
DEPTH TELEMETRY SYSTEM

An accurate depth telemetry system is required for successful midwater trawling. Such a system enables a fisherman to tow his trawl at the depth of fish indicated on the echo sounder. In 1957 the BCF Exploratory Fishing and Gear Research Base at Seattle developed a depth-sensing system (Lusz, 1967). Trawl depth is indicated continuously on a









6'X10' CHINA V-DOORS				
NO.	NAME	MATERIAL	SIZE	REQ'D
1	PLATE	STEEL (ASTM A514)	36 X 120 X 3/16	2
2	PLATE	STEEL (ASTM A514)	120 X 4 X 1/2	1
3	PLATE	STEEL (ASTM A514)	40 X 10 X 3/16	2
4	ROD	STEEL (C-1018)	2 1/2" DIAMETER X 144	1
5	PIPE	ASTM A53, GRADE B	1 1/2" SCHED 40 X 192	1
6	ROD	C-1018	1" DIAMETER X 95	1
7	PLATE	STEEL (C-1015)	2 X 3/8 X 37	4
8	PLATE	STEEL (C-1015)	2 X 3/8 X 4	2
9	PLATE	STEEL (C-1015)	2 X 59 X 3/8	2
10	PLATE	STEEL (ASTM A7)	4 X 4 X 3/4	4
11	PLATE	STEEL (ASTM A7)	6 X 4 X 3/4	4
12	EYE	STEEL BARSTOCK	1" DIAMETER	1
13	CHAIN	ALLOY STEEL, GALVANIZED	3/8" CHAIN, 70" LONG	2
14	CHAIN	ALLOY STEEL, GALVANIZED	1/2" CHAIN, 130" LONG	1
15	COUPLING LK.	ALLOY STEEL, GALVANIZED	1/2" HAMMERLOCK LINK	1
16	G-HOOK	DROP FORGED STEEL, GALV.	5/8" THICK	1
17	SHACKLE	STEEL, GALVANIZED	5/8"	2
18	BOLT	GALVANIZED	1 X 3 1/2	2
19	NUT	GALVANIZED	1	2
20	PLATE	STEEL (ASTM A514)	3 X 17 X 1/2	2
21	EYE	STEEL BARSTOCK	3/4" DIAMETER	5
22	PLATE	STEEL (ASTM A7)	4 X 7 X 3/4	2
23	COUPLING LK	ALLOY STEEL, GALVANIZED	1/2" HAMMERLOCK LINK	4
24	EYE	STEEL BARSTOCK	1" DIAMETER	2
25	PIPE	ASTM A53, GRADE B	1 1/2 SCHED. 40 X 60	1
26	PIPE	ASTM A53, GRADE B	1 1/2 SCHED. 80 X 35	2
27	PIPE	ASTM A53, GRADE B	1 1/2 SCHED. 80 X 4	2
28	NUT	STEEL	5/8	5

NOTES

- ALL JOINTS TO BE WELDED.
- DOOR WEIGHT WITH CHAIN – 1050 LBS. EACH.
- ALL DIMENSIONS IN INCHES.
- SANDBLAST TO BARE METAL. PAINT WITH ONE COAT DIMETCOTE 6 AND ONE COAT AMERCOTE NO. 86 TIE COTE. COVER WITH AMERCOTE NO. 33.
- STAMP NUMBERS 1 THROUGH 6 NEXT TO BOLT HOLES AS SHOWN.
- THESE DOORS ARE SUITABLE FOR VESSEL USING 550 S.H.P.
- AFTER DESIGN BY HU LOO CHI, TAIWAN

Figure 11.–Diagram of V-doors that work well both in midwater and on bottom.

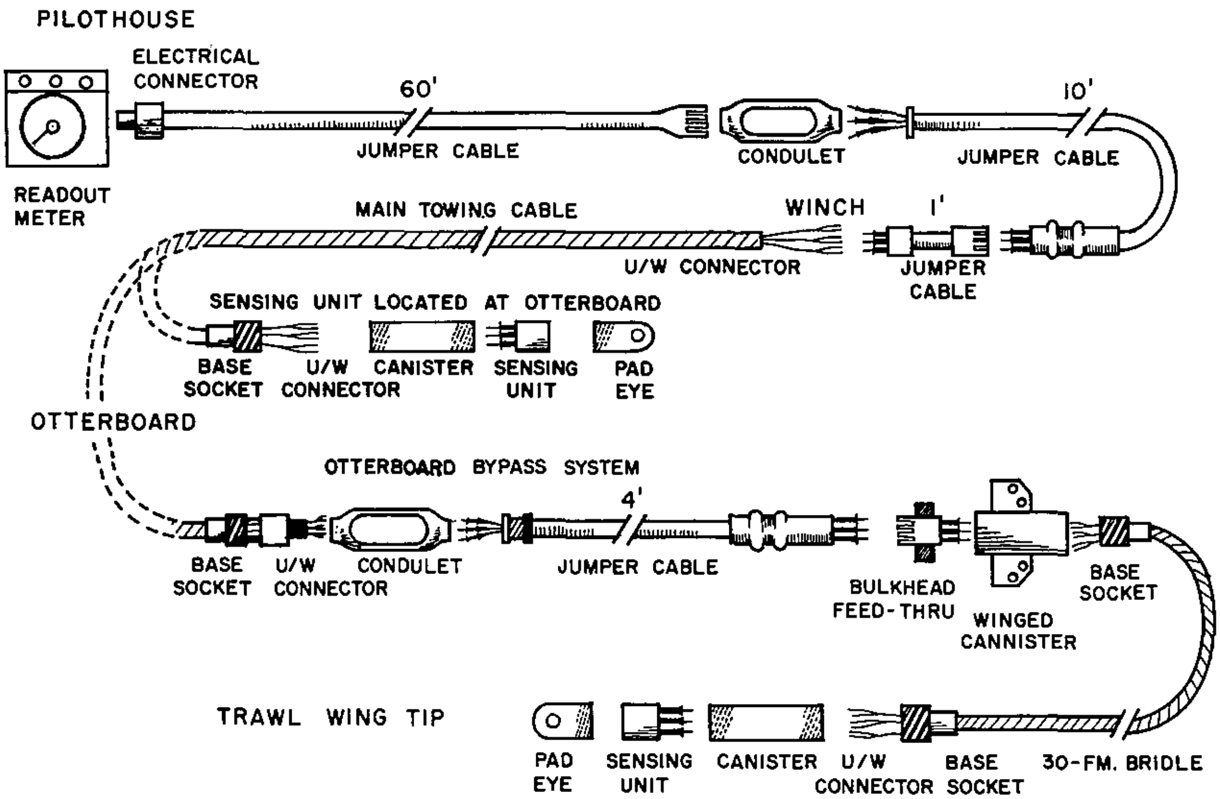


Figure 12.—The depth telemetry system consists of a readout located in the pilothouse, electrical core trawl cable, sensing unit, several rubber cables, and a sensing unit case. To place the sensing unit at the trawl instead of at the otterboard, the extra components shown in the bottom half of this drawing are needed.

readout mounted in the pilothouse. Since 1957, many improvements have been made to the system.

The system has a pressure sensor, electrical core trawl cable, connectors, and a readout (fig. 12). The pressure sensor is in a watertight case and consists of a pressure-sensing element, voltage regulator, and amplifier. The modular construction of the system allows rapid replacement of parts at sea.

Several types of readouts were tested. Strip chart recorders provide an accurate and permanent record; however, they were expensive, required more space in the pilothouse, were less reliable than other readouts, and were sometimes difficult to read quickly. A voltmeter was successfully used but was only accurate to 2½ percent of full scale. A digital readout has been tested. It was more accurate and easier to read than a voltmeter; however, the digital readout was more expensive than the voltmeter.

The depth telemetry system had to be calibrated before use. It was calibrated by first lowering the sensors to the depth of the echo sounder transducer (about 10 feet). The depth sensing units were then lowered to the ocean bottom, and the readout adjusted to give the depth indicated by the echo sounder.

The electrical core trawl cable, developed especially for this project by United States Steel Corporation,[1] provided an electric circuit between the trawl and pilothouse and served as a towing cable (fig. 13). The cable has worked well. Conductors inside the cable have failed only when the cable has been accidentally kinked severely. Galvanizing on the armor has been badly corroded when ungalvanized steel

[1] Trade names or corporations referred to in this publication do not imply endorsement of commercial products.

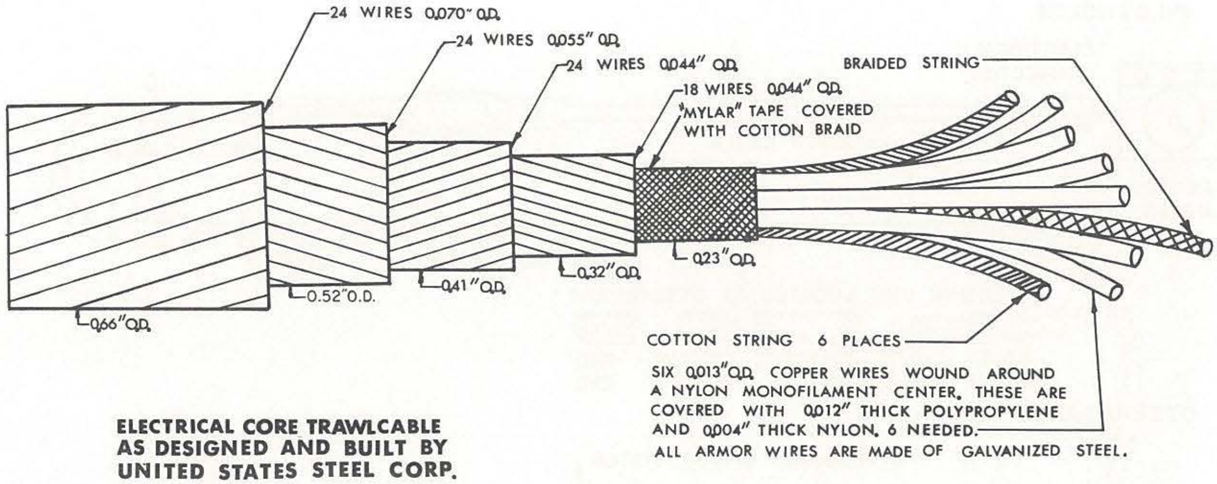


Figure 13.—Construction of six-conductor electrical core trawl cable that provides a circuit between the trawl and pilothouse.

otterboards were used. Otterboard bridles of ungalvanized steel and telemeter sensor cases of stainless steel have caused some corrosion of galvanized armor. The cable should not be led over a block of less than 20-inch diameter. Ideally 24-inch or larger blocks should be used to prolong the life of conductors.

Connectors at the winch had to be disconnected when the drum was turned. A jumper cable was used instead of a slip ring because it provided a low-cost, reliable method for connecting and disconnecting electrical core trawl cables on a variety of winches.

In tests to date the equipment has not been reliable. During the 1967 trials by 10 vessels, one of the two systems did not function properly in 15 percent of the tows. A BCF technician was stationed at the fish meal plant to fix depth telemetry systems. One-third of the failures resulted from use of the otterboard bypass systems described below. All vessels had dual systems so that fishing could continue after one unit failed. After the reasons for system failures were analyzed, the equipment was modified by purchasing different underwater connectors, increasing the radius of the base sockets, using larger set screws in the cannister, and using a digital readout.

The simplest and most reliable location for the depth sensor is just forward of the otterboard; however, otterboard depth instead of trawl depth is then indicated. When the depth sensor is just forward of the otterboards, it is essential that the proper weight of chain be placed on the footrope so that the center of the trawl is at the same depth as the otterboards.

By using an electrical core trawl cable bridle and underwater plug-ins to connect the tow cable to the bridle at the otterboard, we sometimes placed the sensing unit at the net wingtip (fig. 14). A "guygrip," which consists of long, preformed spirals of steel that grip the cable tightly when tension is applied, connects an otterboard to a towing warp. Although this hookup allows precise control of trawl depth, the bypass connectors often failed.

We used another method of bypassing otterboards aboard two vessels. Two preformed guygrips placed 30 fathoms up the main tow cable served as connecting points for the otterboard and bridles (fig. 15). The 30-fathom portion of main tow cable, which has a depth sensor attached at its end, served as the footrope bridle. The guygrips and bridles were wound onto the main winch, and the net transferred to the net reel at the wingtips. Damage occurred to the electrical core trawl cable when the guygrips caught in the winch or block. This system worked satisfactorily only on those vessels with large open winches in which guygrips did not hang up on the winch.

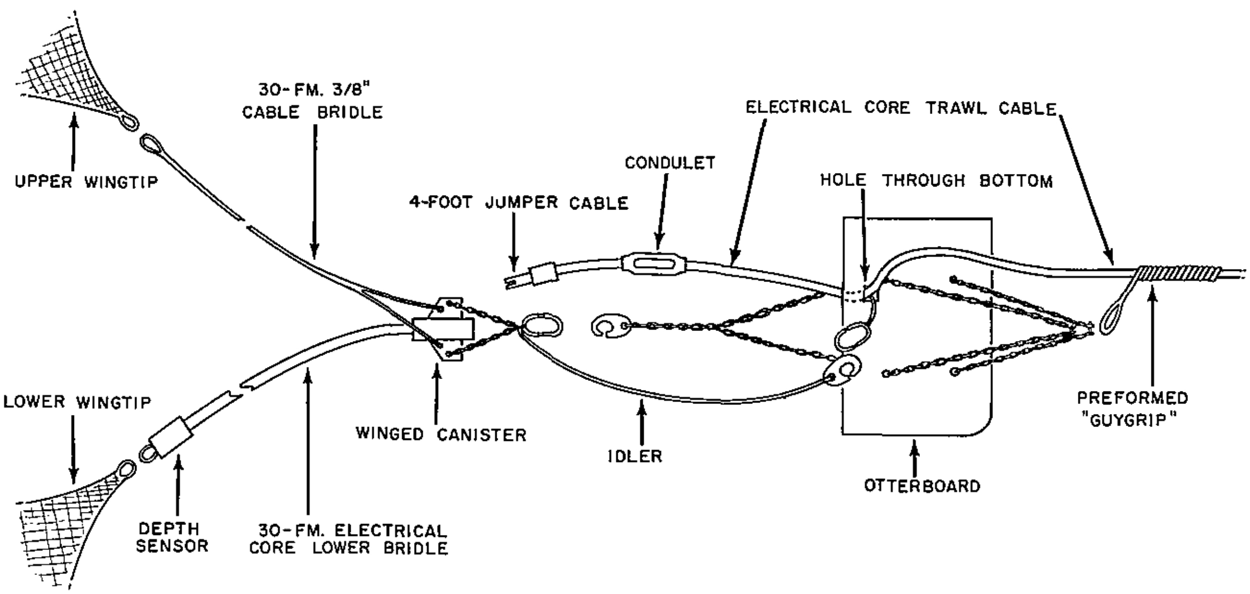


Figure 14.—The depth sensor placed at the wingtip using a guygrip, underwater plug, winged cannister, and electrical core trawl cable bridle.

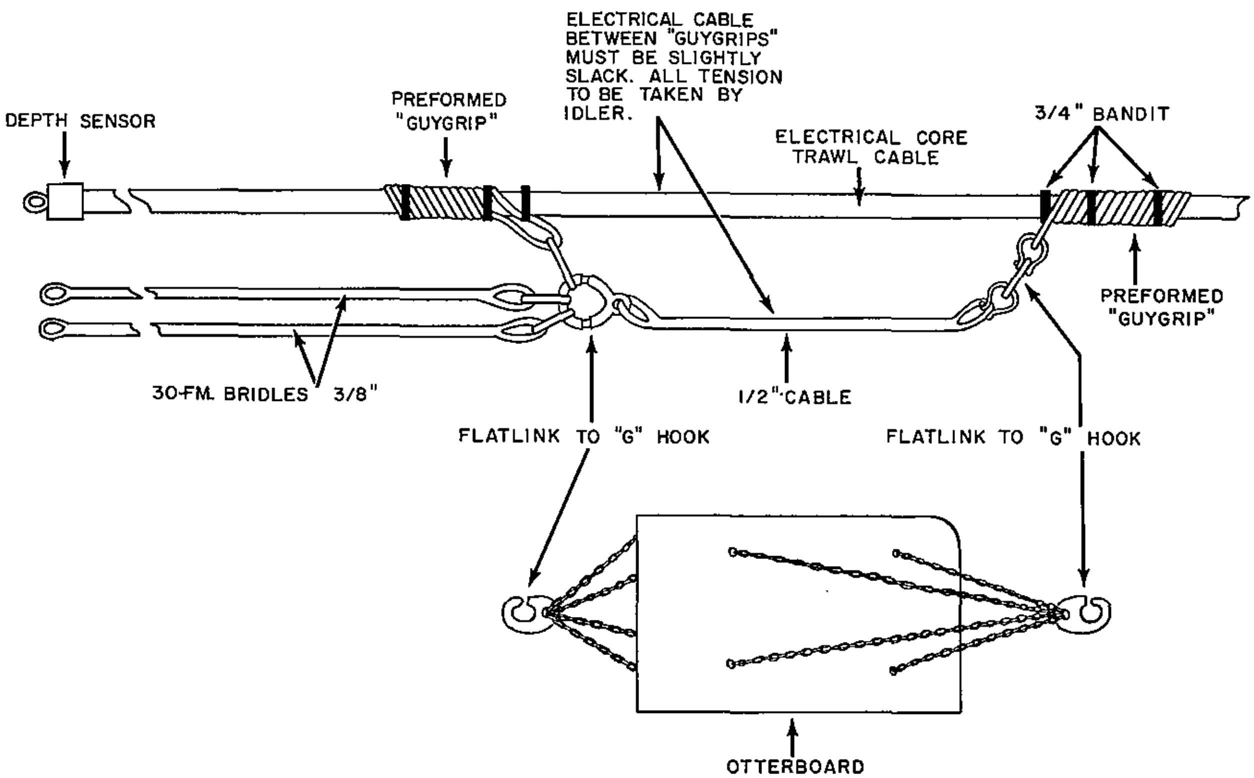


Figure 15.—Method of placing the depth sensor at the wingtip using two guygrips and idler cable.

COST AND AVAILABILITY OF EQUIPMENT

Estimated costs are listed below. When requested, we will supply information on suppliers for this equipment.

Standard 18 Cobb pelagic trawl (complete with chain and floats)	$4,500
BCF Universal trawl (complete with chain and floats)	$3,400
2/3 scale Cobb pelagic trawl (complete with chain and footrope)	$3,000
Depth telemetry system (does not include cable or installation, two systems recommended)	$1,900 each
Electrical core trawl cable (two pieces, 300 fathoms each)	$1,100 each
Aluminum hydrofoil otterboards, 40-square feet (one pair, complete with chains)	$2,000
Steel V-doors, 9 feet by 6 feet, (one pair, complete with chains)	$1,000
Aluminum V-doors, 9 feet by 5 feet (one pair, complete with chains)	$1,800
Trawl cable meters (two required)	$ 385 each
Trawl block, 20-inch pitch diameter with wide throat (two or four required)	$ 200 to $ 245 each

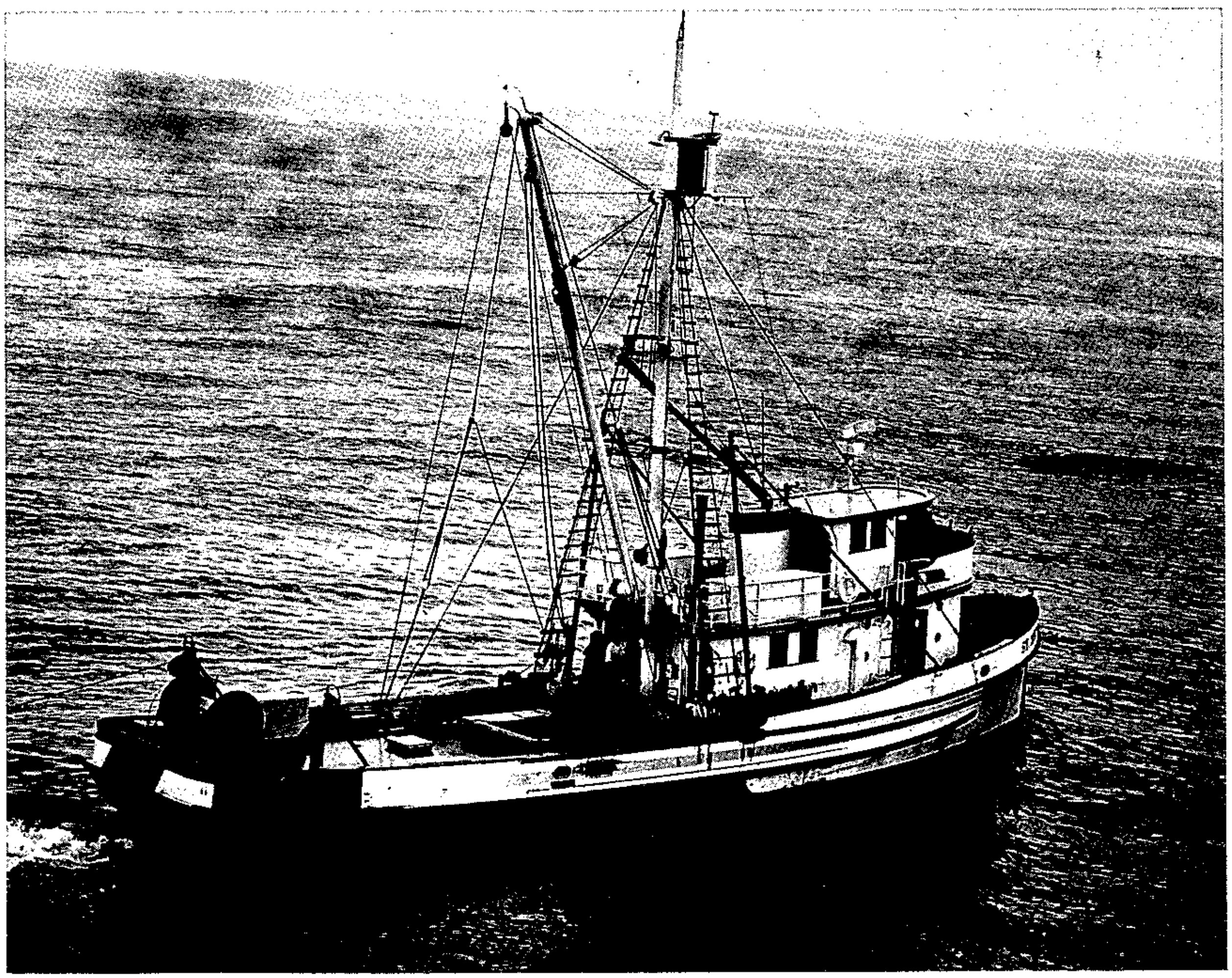


Figure 16.—The *St. Michael*, typical West Coast trawler.

All Pacific Northwest trawlers are rigged to fish from the stern. Almost all have the house forward with an open afterdeck (fig. 16). The 10 vessels, which fished for hake in 1967, were from 49 to 96 feet long and had 35- to 125-ton capacities. Two vessels were schooner type but fished as stern trawlers.

VESSEL HOLD

Partitions in the hold are needed to prevent hake shifting in rough seas. All conventional Northwest trawlers use removable pen boards to section the hold into numerous icing pens. These removable pen boards are placed athwartship in the hold. Small blocks inserted into the fore-aft board channels prevent pen boards parallel to the shaft alley from dropping closer than 2 feet from the hull, creating a gap between center and side sections. Pen boards should reach no higher than 2 feet below the deck beams. The hold must be nearly watertight, because water is added to the hold when fish are pumped out.

Deck plates are useful to fill the hold corners. Otherwise the hold is difficult to fill because hake do not slide easily.

POWERED DECK GEAR

Conventional trawl winches are used on vessels rigged to trawl in midwater. Although older vessels have a center-mounted winch originally used for seining, new and refitted vessels often have separate winches (fig. 17) on each side of the vessel. Use of two side winches permits the cable to lead directly aft through the stanchion block, thus extending cable life and allowing fishermen to reach the afterdeck without stepping over the towing warp.

A powered net reel is necessary to handle the Cobb pelagic trawl or the Universal trawl. Usually the reel is driven hydraulically.

Use of hydraulic boom winches, instead of the gypsy power takeoff from the center winch, significantly shortens the time needed to bring the fish aboard.

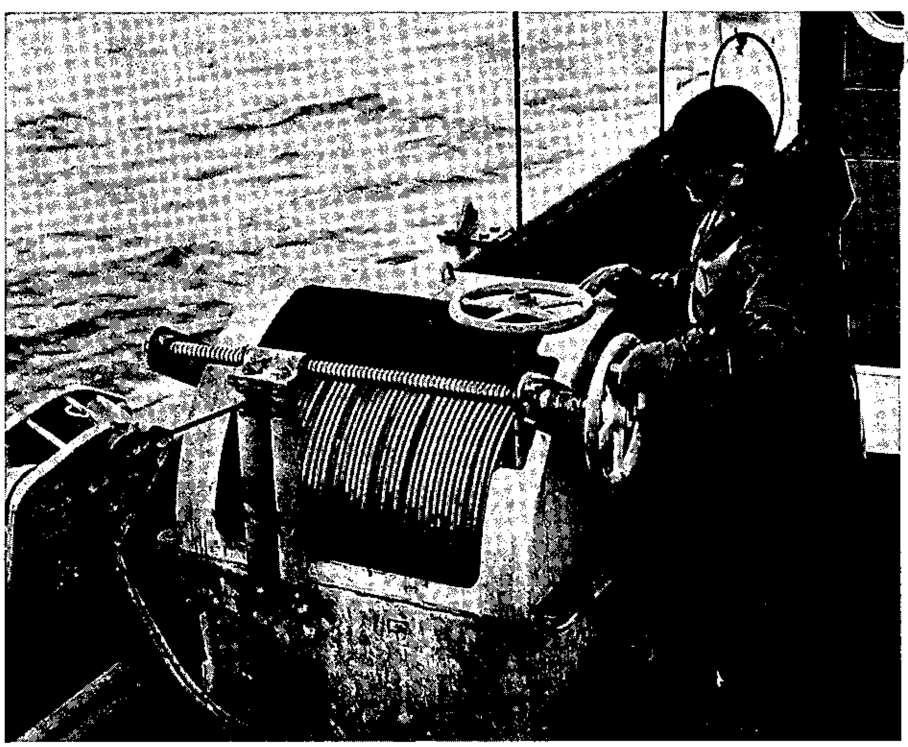


Figure 17.–A side winch leads cable directly through the stanchion block. The cable meter shows amount of warp payed out.

To catch hake economically, it is necessary to locate them quickly, to set the equipment properly, and to keep the trawl at the depth of fish.

LOCATING FISH

It is often difficult for one or two vessels to locate hake quickly. Once located, the schools of hake are easily lost when the vessels return to port to unload fish.

Search time is reduced considerably when a number of vessels operate as a team. In 1967, the 10 fishing vessels were usually able to stay on hake schools because they did not all return to port at the same time. Whenever the hake schools were lost, the vessels spread out and searched along tracklines at oblique angles to the coast.

SETTING THE TRAWL

A midwater trawl is set in the same manner as a bottom trawl. While the vessel is running at slow speed, the net and bridles are unwound from the net reel. The "G" hook behind the otterboard is attached to a flat-link where the net bridles join together. As the idler chains between the bridles and net reel are wound off, strain is transferred to the otterboards and tow cable. The idler "G" hook is then disconnected from the net reel flat-link and hung on a conveniently located ring or flat-link on the otterboard. At this point the trawl has been connected to the tow cable, and setting is continued. Vessel speed is increased, and 10 fathoms of cable are released. The drums are stopped for a few seconds until the otterboards begin to spread. If Cobb pelagic otterboards are used, an additional 20 to 40 seconds are needed to allow them to fill with water and sink. Port and starboard tow cables are payed out at about the same rate and are adjusted to equal lengths (within one-half fathom) to assure equal strain on trawl wings. The winch operator must stop the winch at the proper place so that the telemetry jumper cable can be plugged-in. After the brake has been set, the locking dogs are positioned to prevent movement of the drum. The brakes are then released.

KEEPING THE TRAWL AMONG FISH

The amount of cable needed to position a trawl at a desired depth depends primarily on horsepower of vessel, weight of otterboard, weight and diameter of cable, and drag of the trawl. After several tows, a captain can draw a curve showing the relation between scope ratio (warp length divided by trawl depth) and trawl depth for his own equipment (fig. 18).

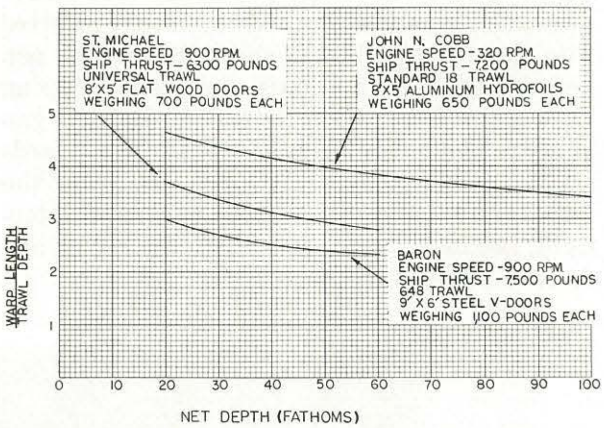


Figure 18.–The relation of warp length divided by trawl depth to trawl depth for three vessels with different trawls.

Trawl depth can be changed quickly by altering engine speed (fig. 19). The distance between horizontal lines in figure 19 represents 2 minutes. This recording shows the trawl being lowered 12 fathoms in only 4 minutes at the start of the tow. In the middle of the tow it was raised 5 fathoms in 4 minutes.

Because the trawl is usually about 1,000 feet behind the vessel, the captain has 4 or 5 minutes to raise or lower the trawl to the depth of fish shown on the echo sounder. Normally, the trawl can be raised between 7 and 10 fathoms in 4 minutes or lowered 12 fathoms in 4 minutes.

At the start of a tow the captain usually must adjust the throttle several times until the trawl stays at the desired depth.

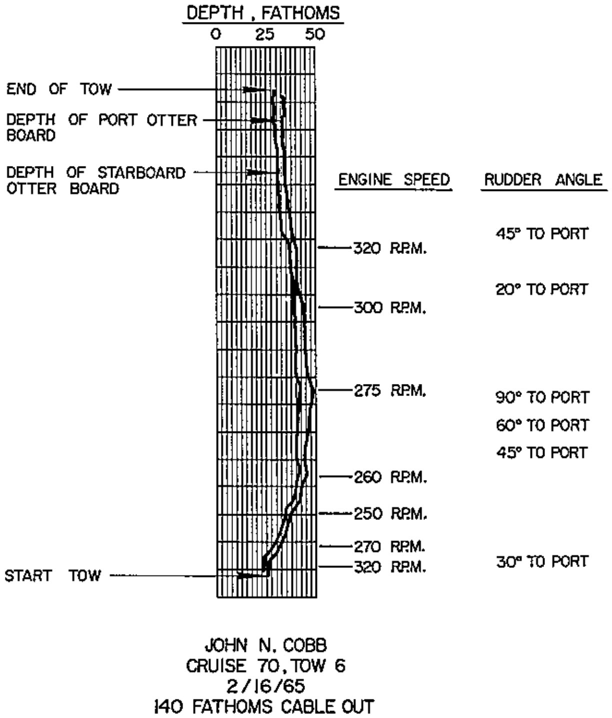


Figure 19.—Strip-chart recording shows the depth of both starboard and port Cobb pelagic otterboards. The starboard otterboard is nearer the surface than the port otterboard because the trawl banks like an airplane when the boat turns. When the turn becomes tighter, the net banks more. The trawl rose up in the water as engine speed was increased.

RETRIEVING THE TRAWL

When a trawl is retrieved at the end of a drag, it usually sinks to the bottom. No special precautions are necessary to prevent damage to the web when the trawl is fished over smooth bottom. On rocky bottom, however, the net must be kept from hitting the bottom; therefore, at the end of a drag, the engine speed is increased to maximum and towing continued for several minutes. This maneuver raises the net well above the ocean floor. The trawl warps are then wound in. When fishing near bottom in depths greater than 75 fathoms, only 25 fathoms of warp are brought in. The vessel tows again for several minutes to bring the trawl well clear of the bottom, and the trawl is then wound in. The load is transferred to the net reel. Usually two men lead the trawl evenly onto the net reel so that the large midwater trawl fits onto the reel. Also, strain is equalized on all riblines to prevent bags of fish from accumulating in slack intermediate webbing.

The hake catch is then split aboard with two hydraulically driven boom-mounted winches (fig. 20). A cod end closing device called a "Holland Clip" (High, 1966) has increased the speed at which the hake catch can be split aboard by 30 percent above that when a puckering string and knot are used.

RECOMMENDATIONS

Certain recommendations can be made as a result of testing midwater trawls, otterboards, and various models of a depth telemetry system during the last 6 years.

TRAWLS

To catch hake effectively, the trawl must be the proper size to match the vessel's horsepower so the trawl should have the correct sizes of twine, mesh, and vertical openings. It also must have the correct number of floats and proper weight of chain.

Twine Size

Comparative fishing trials in 1967 showed that trawls of lightweight web significantly outfished similar trawls of heavy web. Lightweight webbing, however, broke easily and required frequent trawl repair. Our experience indicates that either number 18 thread (10,080 denier) or number 21 thread (12,600 denier) should be used for the top and side panels. Number 36 thread (20,160 denier) is needed in the wingtips. The bottom panel should be made of heavy twine. Number 36 thread has proved heavy enough, but number 30 thread (17,640 denier) may be heavy enough.

Mesh Size

Two and one-half-inch stretched mesh is the largest size that can be used in the aft portion of the trawl and still not gill small hake that are sometimes found off Washington and Oregon. We recommend 2½-inch mesh in the

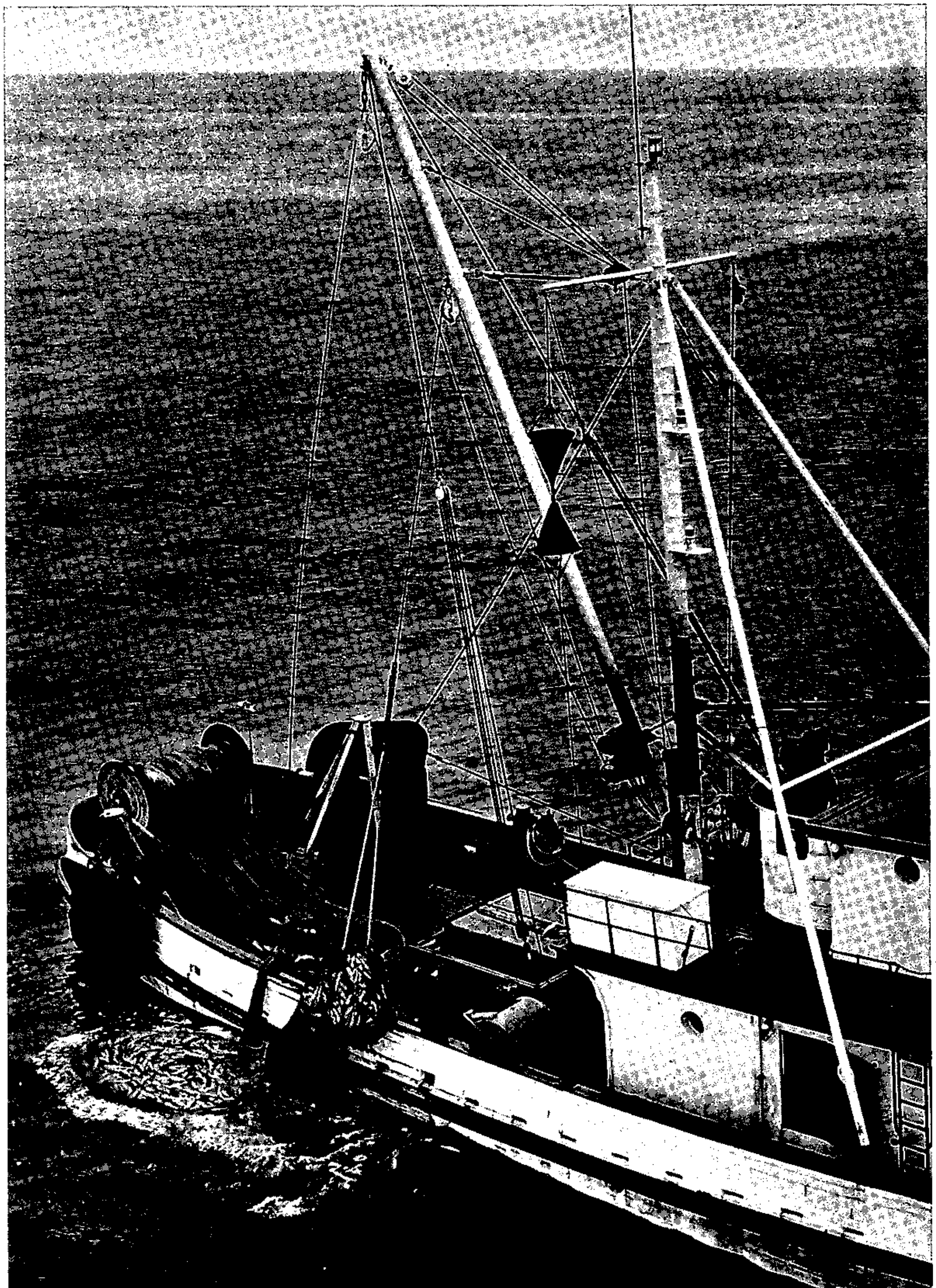


Figure 20.—Hake catch is split aboard with two hydraulically driven boom-mounted winches.

aft 40 feet of the trawl and 3½-inch or 4-inch mesh forward.

Vertical Opening

Although schools of hake are usually about 15 feet thick and are rarely thicker than 30 feet, hake trawls should open about 40 feet at the wingtips. Several factors necessitate having a vertical trawl opening considerably larger than the thickness of hake schools:

1. The 5-inch voltmeter readout is only accurate to within 2½ percent of full scale (however, accuracy is improved with a digital readout).
2. The underwater connectors and the sensors have small inaccuracies.
3. An error is caused by the trawl being either above or below the otterboards where the depth sensors are usually placed.
4. Hake are not at a constant depth; it is impossible to adjust the net depth precisely as the depth of hake changes.
5. Fish that enter the trawl near the top or bottom may sense the presence of the trawl and swim out.
6. The echo sounder reading, with which the depth telemetry system must be compared, has a varying error.
7. The system is sometimes inaccurately calibrated.

Most of the Cobb pelagic trawls are capable of being opened to a greater height than is necessary to capture hake (table 3).

Table 3.–Size of mouth openings for the Cobb pelagic trawls and BCF Universal trawl

Trawl	Horizontal and vertical wingtip openings
	Feet
Cobb pelagic trawls	
600 monofilament	75 by 75
Standard 18	75 by 75
440	55 by 50
2/3	50 by 50
600-21	75 by 75
640 monofilament	80 by 80
648	68 by 68
BCF Universal trawl	60 by 40

Number of Floats Needed

The number of floats needed to open fully the trawls depends on the power of vessel, length and weight of bridles, buoyancy of each float, and vertical opening of trawl. Table 4 lists the length of bridles and number and diameter of floats needed to open fully the various trawls. Usually 8-inch diameter aluminum floats with a static buoyancy of 6.25 pounds and a maximum working depth of 550 fathoms were used. Because trawls lack room for more than about sixty-five 8-inch floats, 10-inch diameter floats should be used on trawls towed by the more powerful vessels. When 75- or 80-foot opening is not needed, fewer floats than are shown in table 4 should be used on the large trawls.

Initially, floats were spaced evenly along the headrope; however, divers reported that this spacing caused a large vertical opening at the center of the mouth and a small opening at the wingtips. We now place about 35 percent of the floats on each wingtip, spaced only 4 inches apart. The remaining 30 percent of the floats are spaced evenly along the rest of the headrope.

Weight of Chain Needed

Chain is attached to the forward portion of the wingtips to counterbalance the floats. To keep the center of the trawl at the same depth as the otterboards, the total weight of chain on the footrope should equal 1.15 times the

Table 4.–LB (length of bridles) and number and diameter (in inches) of floats needed to open fully the trawls

Trawl	Designed vertical wingtip opening	Thrust of vessel at 0 speed with engine speed normally used while trawling																							
		6,000 lbs.			8,000 lbs.			10,000 lbs.			12,000 lbs.			14,000 lbs.			16,000 lbs.			18,000 lbs.			20,000 lbs.		
		LB	Floats		LB	Floats		LB	Floats		LB	Floats		LB	Floats		LB	Floats		LB	Floats		LB	Floats	
	Feet	*Fm.*	*No.*	*In.*	*Fm.*	*No.*	*In.*	*Fm.*	*No.*	*In.*	*Fm.*	*No.*	*In.*	*Fm.*	*No.*	*In.*	*Fm.*	*No.*	*In.*	*Fm.*	*No.*	*In.*	*Fm.*	*No.*	*In.*
Cobb pelagic trawls																									
600 monofilament	75				30	47	10	30	58	10	30	69	10	60	44	10	60	50	10						
Standard 18	75							30	58	10	30	69	10	60	44	10	60	50	10	60	55	10	60	59	10
440	55	30	58	8	30	35	10	30	44	10	30	52	10												
2/3	50	30	53	8	30	32	10	30	40	10	30	47	10												
600-21	75										30	69	10	60	44	10	60	50	10	60	55	10	60	59	10
640 monofilament	80							30	61	10	60	38	10	60	47	10	60	53	10	60	59	10	60	63	10
648	68				30	43	10	30	53	10	30	62	10	60	40	10	60	45	10						
BCF Universtal trawl	40	30	48	8	30	64	8	30	36	10	30	43	10												

buoyancy of floats on the headrope minus one-half the weight of all bridles to the trawl minus the weight of shackles on the wingtips, and minus the weight of cable footrope.

OTTERBOARDS

Otterboards of the proper size, weight, and type are needed to catch hake effectively.

Suitability of V-Doors, Cobb Pelagic Otterboards, and Flat Plywood Otterboards

We recommend V-doors or Cobb pelagic otterboards be used to spread the Cobb pelagic trawls and BCF Universal trawl. We recommend steel V-doors when heavy and inexpensive otterboards are desired. When a large trawl is towed by a low horsepower vessel, lightweight otterboards are needed. To make lightweight steel V-doors, it would be necessary to make the plate undesirably thin, so we recommend aluminum hydrofoil otterboards or aluminum V-doors. To decrease the chances of the aluminum hydrofoil otterboards crossing, the shoe should be of 1-inch steel instead of the 5/8-inch stock shown in figure 9.

Flat plywood otterboards are not recommended. Although they are cheap, they are too weak. The plywood also becomes badly nicked.

Size of Otterboards

We recommend that the size otterboards shown in table 5 be used.

Table 5.—Recommended size of otterboards for Cobb pelagic trawls and BCF Universal trawl

Trawl	V-doors	Cobb pelagic otterboards
	Sq. ft.	*Sq. ft.*
Cobb pelagic trawls		
600 monofilament	70	64
Standard 18	79	72
440	53	48
2/3	52	48
600-21	88	80
640 monofilament	75	68
648	62	57
BCF Universal trawl	68	62

Weight of Otterboards

Proper weight of otterboard depends primarily on vessel power. Steel otterboards (including tail chains and bridles) should weigh 1.9 pounds (in air) per shaft horsepower. Aluminum V-doors with steel chains should weigh 2.4 pounds (in air) per shaft horsepower. Cobb pelagic otterboards should weigh 2.25 pounds (in air) per shaft horsepower plus the weight and buoyancy of internal floats. Wooden otterboards should weigh 1.65 pounds (in water) per shaft horsepower.

DEPTH TELEMETRY SYSTEM

Great care should be taken in making cable terminations and putting equipment together. If care is not taken, the system will not be reliable.

We recommend that sensors be placed just in front of the otterboards rather than at the trawl. The extra hardware necessary to put the depth sensors at the trawl wingtip causes additional failures. If one wishes to put the sensors at the wingtips, the hookup shown in figure 14 should be used. This hookup requires a large capacity open winch to ensure that hardware does not foul inside the drum.

We recommend using a digital readout rather than a strip chart or voltmeter.

SPEED OF TRAWLS

The Cobb pelagic trawls, being much larger than conventional bottom trawls, can be towed at only 1.6 to 2.3 knots by a 325-horsepower vessel. We used a current meter to measure the speed at which the 2/3 and 640 monofilament Cobb pelagic trawls and the BCF Universal trawl were towed. None of the trawls was open fully when its speed was measured. We calculated the speeds at which the other trawls could be towed by comparing the amount of web, mesh size, and twine diameter of these trawls with those of the trawls whose speeds had been measured—we assumed that these trawls were only partially opened, so the calculated speeds are comparable to the measured speeds (table 6).

Table 6.—Speed of trawls towed by 325-horsepower vessel

Trawl	Speed	Trawl	Speed
	Knots		*Knots*
Cobb pelagic trawls		Cobb pelagic trawls—Con.	
600 monofilament	[1]1.8	600-21	[1]1.6
Standard 18	[1]1.7	640 monofilament	1.8
440	[1]2.3	648	[1]1.8
2/3	2.1	BCF Universal trawl	2.2

[1] Speed of trawl was calculated. Calculation is based on amount of web, mesh size, and twine diameter of these trawls.

POWER NEEDED TO TOW TRAWLS

Vessels should have sufficient power to tow the Cobb pelagic trawls or Universal trawl at about 2¼ knots when the trawls are fully open (table 7).

RELATION OF POWER OF VESSEL AND SIZE OF OTTERBOARDS TO CATCH

The vessels with high towing power and large otterboards caught significantly more hake than vessels with low power and small otterboards (table 8). This was determined by analyzing catch data from all tows made with the Universal trawl when two vessels fished within 1 minute of longitude and 1 minute of latitude and within an hour of each other. All tows in which a depth telemetry system did not function properly and all tows shorter than 0.6 hours and longer than 1.8 hours were disregarded.

Table 7.--Power needed to tow trawls 2¼ knots when trawls are open fully

Trawl	Power of vessel
	Horsepower
Cobb pelagic trawls	
600 monofilament	500
Standard 18	630
440	330
2/3	380
600-21	650
640 monofilament	530
648	500
BCF Universal trawl	350

Table 8.--Relation of power of vessel and size of otterboards to catch

Vessel	Tows made	Power main engine	Size of otterboards	Relative catch rate[1]
	Number	*Horsepower*	*Square feet*	
Recruit	25	525	54	1.25
Washington	19	375	40	1.00
Junior	19	320	45	0.85
St. Michael	20	380	40	0.77
Coolidge II	28	300	40	0.55
Tordenskjold	20	240	40	0.49

[1] See discussion immediately before table 2.

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MS. #1880

Economic Aspects of the 1967 Offshore Pacific Hake Fishery

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ABSTRACT

The study was carried out to ascertain the economic performance of existing trawl vessels when fishing for hake with modern midwater trawl gear. Cost and revenue aspects of the 1967 operation are presented, and the economics of the fishery are discussed relative to the establishment of a viable Pacific hake fishery.

CONTENTS

INTRODUCTION

As part of a continuing program by the BCF (Bureau of Commercial Fisheries) to assist in the development of a fishery on the offshore hake stocks along the Pacific coast, a study was initiated in 1967 in cooperation with the EDA (Economic Development Administration) to investigate the economics of hake fishing. This study was carried out to provide vessel owners, fishermen, and fish processors with the information needed to determine the performance of existing trawl vessels when fishing for hake with modern midwater trawl gear. The performance of these vessels with regard to prices that the processors can pay for fish will ultimately determine the success of a reduction fishery for Pacific hake.

This paper presents the cost and revenue aspects of the 1967 fishery and discusses the economics of this fishery as it pertains to the establishment of a viable fishery on Pacific hake. A viable fishery must provide adequate

Published February 1970.

returns to both labor and capital. The variables that determine these returns are fishing success, fishing costs, fish price, and sharing arrangement between labor and capital. In this study we use samples of large- and medium-sized trawlers to estimate fishing success and fishing costs. The methods of obtaining and organizing these data are described first, then followed by a summarization of costs, revenues, and investment. This information provides the basis to compare the return to labor and capital with various fish prices and sharing arrangements. The return on investment for present fish prices and sharing arrangement is determined with and without the government charter. Following this section, the interaction between fish prices and sharing arrangement is discussed with regard to the establishment of a viable hake fishery. These comparisons are based on an extrapolation of the results from the limited 1967 fishery to that which might be anticipated in a mature reduction fishery on hake.

Detailed analyses of the distribution of catch and effort and the gear used in the 1967 fishery are not given here because these topics are discussed in this Circular by Nelson (1970) and Johnson and High (1970). Nelson and Dyer (1970) briefly discuss the economics of the hake reduction operation.

BACKGROUND

Since 1966, BCF and EDA have helped the Grays Harbor Regional Planning Commission to develop a fishery on Pacific hake. In 1967, EDA provided $200,000 at the request of the Planning Commission for a project entitled, "A Study to Determine the Economic Feasibility of Establishing a Commercial Hake Fishery." The project was designed to assist in the development of a fishery for Pacific hake in Grays Harbor County of Washington. BCF administered the funds and used them to charter 10 trawlers with crews to fish hake for a fish meal plant at Aberdeen, Wash. This plant, owned and operated by Pacific Protein, Inc., had a maximum processing capacity of 600 tons of hake per day.

The primary aim of the EDA-financed study was to determine the economics of a commercial reduction fishery on Pacific hake, and in particular, to determine the relative success of different-sized vessels in this fishery.

This project was justified on the basis of the detrimental effects on the embryonic United States hake fishery (including processing facilities) by the massive Soviet fishery in 1966. United States vessels were in severe competition with the Soviet fleet during the 1966 season. Besides harvesting 80 times the amount of hake taken by United States vessels (the Soviet and United States catches were 300 million and 3¾ million pounds, respectively), Soviet fleet operations often dominated productive fishing grounds and made it difficult, if not impossible, for United States vessels to fish in the same area.

Further justification for the fishery development project in 1967 was the need to develop fishing gear that would catch fish effectively either on or off the seabed. During 1966 the vertical distribution of hake schools was unlike that observed in previous years. A high percentage of schools was found on bottom, whereas in former years most of the schools were found above the seabed (Nelson, 1967). This information led the Bureau to design a new trawl (the BCF Universal trawl) that could be fished either on or off bottom. This gear was extensively tested during the 1967 season.

The small scouting effort of the U.S. fleet in 1966 — at the most four vessels and for most of the season only three vessels — also contributed to low U.S. production. In comparison, the Soviet scouting activity was enormous. Participation by a larger U.S. fleet was felt by Bureau scientists and fishermen to be advantageous in increasing the overall efficiency of U.S. vessels in the fishery.

Certain international developments after the end of the 1966 hake season promised to reduce greatly the competition between the United States and Soviet fishing fleets. In November the U.S. Government adopted a 12-mile fishery zone, which made it illegal for foreign vessels to fish within 12 miles of the U.S. coast. Further reduction of competition for hake was assured by terms of a negotiated agreement whereby the U.S.S.R. agreed to stay seaward of the 60-fathom depth between the north side of Grays Harbor and the south side of the Columbia River. Because the area inside 60 fathoms within this region had been a major trawling ground for hake by the Soviets in 1966, this agreement increased the chances for a successful operation by United States fishermen in 1967.

CHARTER FLEET

A fleet of 10 chartered vessels participated in the 1967 offshore hake fishery. To obtain the services of the vessels it was necessary to negotiate a charter paying vessel owners a fixed price per day in addition to all landing receipts. Three charter rates — $200, $310, and $360 per day — were established on the basis of vessel size (table 1). Although vessels were selected by competitive bid, vessel owners were unwilling to commit their vessels at a lower rate owing to the poor showing by vessels in the 1966 offshore hake fishery. The charter fee per day was paid whenever a vessel was actively engaged in the fishery; i.e., the vessel was fishing, running, or unable to fish because of weather. Charter fees were not paid for any time lost owing to breakdowns except when BCF gear failed.

The composition of the hake fleet varied considerably. The vessels were 49 to 96 feet long and could carry 35 to 125 tons of hake. As a whole the fleet could carry 770 tons. Because the catch was not iced, fish had to be delivered within 3 days of being caught. Of the 10 vessels in the fishery, 8 were seiner-draggers and 2 (the *Lady Olga* and *Tordenskjold*) were schooners. All vessels fished with three-man crews except the *Baron* and *St. Michael,* which used four crewmen. On several of the three-man vessels an additional man was rotated weekly. In this way, although four men were engaged in the fishery, only three would be fishing at any one time.

In the charter contract all vessels agreed to provide the BCF with catch, effort, and haul data, and economic data on their operations in the fishery. The appendix shows the forms used to acquire the economic data.

It is important to recognize that the primary interest is not in measuring the economic performance of these 10 vessels per se, but in using cost data from these vessels as representative of trawl vessels that could participate in the hake fishery. Consistent with our desire to measure relative success of different-sized vessels, we made no attempt to select only vessels that we would expect to perform well in this fishery because of the relative success of various types of vessels in similar reduction fisheries. For example, we would expect that the larger and more powerful vessels would perform better because they carry more fish and have the power to tow the large midwater trawls. To obtain representative results we had to adjust certain data. For example, even though some sample vessels were fully depreciated by their owners, we estimated depreciation costs on a basis that we believed was more representative than if we used data exactly as reported by the sample vessels. We explain later these adjustments of the data.

Table 1.—Vital statistics of 10 vessels in 1967 Pacific hake fishery

Vessel name	Vessel length	Main engine	Carrying capacity	Began fishing	Ended fishing	Days fished	Charter rate
	Ft.	*H.P.*	*Tons*			*No.*	*$/day*
Baron	96	510	125	May 15	Aug. 6	79	360
St. Michael	78	380	95	May 17	Aug. 6	76	310
Recruit	76	525	125	May 15	Aug. 6	80	310
Tordenskjold	75	220	60	June 7	Aug. 6	54	310
Coolidge II	70	300	65	June 6	Aug. 6	59	310
Voyager	70	155	75	May 29	July 1	34	310
Junior	65	320	75	May 18	Aug. 6	77	310
Washington	63	375	65	May 29	Aug. 6	67	310
Lady Olga	63	220	50	May 27	Aug. 6	68	310
Peter E.	49	150	35	May 27	July 19	40	200
Total			770			634	

BUREAU PARTICIPATION IN PROJECT

The Bureau provided direct and indirect assistance to the project. Besides administrating this project, the Bureau furnished, installed, and serviced midwater trawls, depth telemetry systems, and electromechanical cables. Bureau personnel also showed the crews how to use this equipment. In addition to this direct assistance, the Bureau's exploratory fishing vessel *John N. Cobb* and charter vessel *Commando* made reconnaissance surveys for hake in areas not being fished by the fleet.

ECONOMIC ANALYSIS OF VESSEL OPERATIONS

We made an economic analysis of vessel operations to determine the relative success of different-sized vessels. Because the smallest vessel in the fishery, the *Peter E.*, was plagued with an abnormal number of breakdowns and thus was not representative of vessels of this type, the data for this vessel were excluded from comparative analyses. To evaluate the effects of vessel size, we grouped the vessels into large (*Baron, Recruit,* and *St. Michael*) and medium (*Coolidge II, Junior, Lady Olga, Tordenskjold, Voyager,* and *Washington*).

Income from the catch was distributed according to a typical lay agreement. The following form of this agreement is the basis for determining the vessel and crew shares in many fisheries:

Gross stock − Operating costs = Net stock
Net stock × Vessel share percentage = Vessel share
Net stock − Vessel share = Crew share
Vessel share − Vessel costs = Vessel return

Although vessel share percentage in the hake fishery was 30 to 53, most vessels used percentages of 40 to 45 (table 2). If the captain does not own the vessel, 10 percent of the boat share is given to the captain, in addition to his share as a member of the crew.

GROSS STOCK

The gross stock consists of all revenues earned in the fishery. In the 1967 hake fishery this stock included earnings from fish receipts at $16 per ton plus charter revenues. Total revenues for the 10 vessels in the fishery were slightly over $350,000 (table 2). Of this total, $195,780 came from charters.

Large vessels generated more revenue per charter dollar than the medium vessels. Total revenues of the large vessels were about $50,000 per vessel of which about 50 percent were from charter income. Revenues of the medium vessels were about $32,000 per vessel, and charter fees were 65 percent of this total.

OPERATING, VESSEL, AND BCF GEAR COSTS

Operating costs included fuel, lubrication oil, and filter expenses. Icing costs were not incurred as the fish could be kept up to 3 days without refrigeration. With no ice expense, the fishing grounds relatively close to the plant (2-7 hours' running), and the fish unloaded by pump, operating costs averaged only about $29 per day for the large vessels and $20 per day for the medium vessels (table 3).

Table 2.—Distribution of vessel income, 1967 offshore hake fishery

Vessel category (Carrying capacity in tons)	Vessels in category	Vessel days	Crew	Landings	Revenue			Share			
					Fish	Charter	Total	Vessel	Vessel	Crew	Salary per day
	No.	*No.*	*No.*	*Tons*	*Dollars*	*Dollars*	*Dollars*	*Percent*	*Dollars*	*Dollars*	*Dollars*
Large (95-125)											
Total	3	235	11	4,512.2	72,194.68	76,800.00	148,994.68		59,398.37	82,742.41	
Average		78.3	3.7	1,504.1	24,064.89	25,600.00	49,664.89	41.7	19,799.46	27,580.80	96.21
Medium (50-75)											
Total	6	359	18	5,003.7	80,059.12	110,980.00	191,039.12		78,619.84	105,256.07	
Average		59.8	3.0	834.0	13,343.19	18,496.67	31,839.85	41.5	13,103.31	17,542.68	97.73
Other (35)	1	40	3	131.2	2,099.20	8,000.00	10,099.20				
Grand total ..	10	634	32	9,647.1	154,353.00	195,780.00	350,133.00				

Table 3.–Average operating and vessel costs (excluding labor), 1967 offshore hake fishery

Vessel category (Carrying capacity) in tons)	Average vessel days	Average costs													
		Operating		Maintenance, supplies and repairs		Insurance		Depreciation		Payroll taxes		Other costs		All costs	
		Total	Per day	Total	Per day	Total	Per day	Total	Per day	Total	Per day	Total	Per day	Total	Per day
	Number	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Large vessels (95-125)	78.3	2,284.82	29.17	1,217.74	15.55	1,472.88	18.80	1,834.15	23.41	676.89	8.64	817.39	10.43	8,303.86	106.05
Medium vessels (50-75)	59.8	1,193.81	19.95	1,557.33	26.03	763.49	12.77	1,058.21	17.69	568.24	9.50	662.56	11.07	5,803.63	97.05
Combined	66.0	1,557.48	23.60	1,444.13	21.88	999.95	15.15	1,316.85	19.95	604.46	9.16	714.17	10.82	6,637.04	100.56

Vessel costs included depreciation, insurance, maintenance and repairs, payroll taxes, and certain miscellaneous expenses such as interest costs. Because several of these costs are fixed yearly expenses, only part of the costs could be charged against the hake fishery. The percentage of charge was 12 to 30 percent, depending upon the length of time a vessel was in the fishery, and included a portion of the yearly haul-out period when the vessel would undergo repairs. We assumed that vessels would be gainfully engaged in other fisheries at other times of the year. Availability of such fisheries as groundfish, shrimp, and crab makes this assumption reasonable.

Depreciation costs were calculated in the same manner for each vessel. We considered salvage value to be 15 percent of the market value of the vessel. We then used the straight line method to depreciate over 15 years the market value less salvage. New vessel components, trucks, cars, buildings, and office equipment were depreciated at other rates as indicated by the vessel owners.

Fixed vessel costs, exclusive of gear costs, for both large and medium vessels were about $75 per day (table 3). Owing to the high maintenance and repair costs for several of the medium vessels plus the unequal cost of payroll taxes between vessel categories (see following section on salaries), vessel costs did not differ between large and medium vessels as one might expect.

As one part of the developmental aspect of this program, the BCF furnished trawls, depth telemetry systems, and electromechanical trawl cables for the vessels. Approximate cost for these components are: trawl - $3,000, telemetry system - $3,000, and electromechanical cables - $2,000. None of these components has a salvage value. On the basis of an 80-day season, which is the longest time that any one vessel participated in the 1967 fishery, a midwater trawl should last three seasons and the telemetry and cables five seasons. We estimate the depreciation cost for this gear at $2,000 per vessel per season or $25 per day in the fishery. For vessels participating only part of the season, depreciation cost was charged on the length of time the vessel was fishing. We considered that maintenance and service costs associated with the gear were research and development costs, and thus we did not include them in the analysis.

SALARIES AND VESSEL RETURN

Salaries before grocery expenses and tax deductions were $80 to $128 per man-day. This wide range in salaries was caused not only by differences in gross stock but also by differences in vessel operating costs, crew sizes, and vessel share percentages. In addition, several of the medium vessels operated only during the period when catches were large; therefore, these crews earned disproportionately high salaries.

Included in the category of vessel return is return to the owner's investment, risk (that was not insured), and management. Vessel owners who ran their own boats received a return for their labors at fishing but this return was considered as salary and not as vessel return.

Over $92,000 return was generated by the nine vessels in this analysis (table 4); the top earning vessel made about $14,500. Return for all vessels averaged about $155 per day while they were in the fishery. Large vessels earned about $176 per day, and medium vessels $142. Had BCF not supplied the gear, return for both categories would have been lowered by $25 per day.

Table 4.–Distribution of total costs, 1967 offshore hake fishery

Vessel category (Carrying capacity in tons)	Vessels in category	Vessel days	Operating, vessel and labor costs		Vessel return[1]		BCF gear costs		All costs	
			Total	Per day	Total	Per day	Total	Per day	Total	Per day
	Number	*Number*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Large vessels (95-125)										
Total	3	235	107,654.00		41,340.68		6,000.00		154,994.68	
Average		78.3	35,884.67	458.10	13,780.23	175.92	2,000.00	25.53	51,664.89	659.55
Medium vessels (50-75)										
Total	6	359	142,042.82		50,960.98		9,500.00		200,538.80	
Average		59.8	23,673.80	395.66	8,493.50	141.95	1,583.33	26.46	33,423.13	558.60
Combined total	9	594	249,696.82		92,301.66		15,500.00		355,533.48	
Average		66.0	27,744.09	420.37	10,255.74	155.39	1,722.22	26.09	39,503.72	598.54

[1] Return for the vessel owner's investment, uninsured risk, and management, but not for his labor in fishing when he ran his own boat. His salary is considered a labor cost.

DISTRIBUTION OF COSTS PER TON

Table 5 shows distribution of costs per ton of fish landed for large and medium vessels. Total cost for large and medium vessels was more than $34 and $40 per ton, respectively — over half of this cost charged to labor and one-quarter to return to vessel owner (fig. 1). The lower costs per ton for the large vessels were due mainly to the higher productivity of labor on the large vessels and lower maintenance and gear costs per ton produced. In the absence of government assistance (i.e., no charter revenue and the vessel owner supplies all gear), total costs are fixed at $16 per ton with over half the costs again charged to labor (fig. 2). Under both conditions (with and

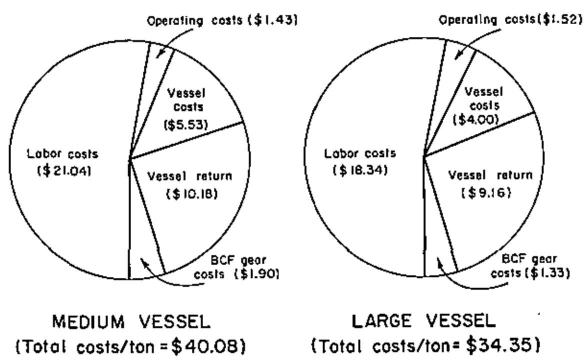
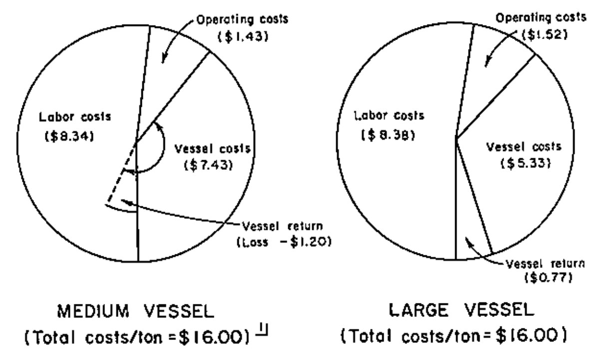


Figure 1.–Distribution of total costs per ton of fish landed in 1967 offshore hake fishery by medium and large vessels under conditions of charter revenues and gear supplied by the Government.



[1] Under these conditions the price per ton was $16 but the cost of fish was $17.20 and medium vessel owners would absorb a loss of $1.20.

Figure 2.–Distribution of total costs per ton of fish landed in 1967 offshore hake fishery by medium and large vessels under conditions of no government assistance (no charter revenues and owner supplies all gear).

Table 5.–Average costs per ton landed for medium and large vessels, 1967 offshore hake fishery. Figures in parenthesis are percentages of line totals

Vessel category (Carrying capacity in tons)	Labor	Operating	Supplies, maintenance and repairs	Insurance	Payroll taxes	Other	Depreciation	Vessel return[1]	BCF gear	Total[2]
	Dollars									
Medium (50-75)	21.04 (52.5)	1.43 (3.6)	1.87 (4.7)	0.92 (2.3)	0.68 (1.7)	0.79 (2.0)	1.27 (3.2)	10.18 (25.4)	1.90 (4.7)	40.08
Large (95-125)	18.34 (53.4)	1.52 (4.4)	0.81 (2.4)	0.98 (2.9)	0.45 (1.3)	0.54 (1.6)	1.22 (3.6)	9.16 (26.7)	1.33 (3.9)	34.35
Combined (50-125) ...	19.35 (52.9)	1.46 (4.0)	1.29 (3.5)	0.94 (2.6)	0.55 (1.5)	0.65 (1.8)	1.23 (3.4)	9.51 (26.0)	1.58 (4.3)	[2]36.56

[1] Return to the vessel owner for his investment, uninsured risk, and management.
[2] Fish income $16.00 (42.8%), charter income $19.73 (52.8%), and BCF gear $1.63 (4.4%).

without government assistance) vessel costs (including gear costs) account for less than half of the total costs per ton. At $16 per ton the performance of the medium vessels is so poor that they show a loss instead of covering all costs of vessel operation.

ECONOMIC PERFORMANCE IN THE ABSENCE OF GOVERNMENT ASSISTANCE

If charter fees were eliminated (i.e., gross stock included only fish income at $16 per ton) but BCF supplied gear, salaries per day would have been $27.80 to $58.20. Under these conditions, two vessels would have shown a loss, one would have broken even, (i.e., no return to the vessel owner), and six would have operated with a return to the vessel owner. The vessel with the best performance would have returned almost $4,500 to the owner.

With no government assistance (i.e., no charter and the vessel owners supplying their own gear), four vessels would have shown a loss, one would have broken even (i.e., no return to the vessel owner), and four would have provided a return. The best performing vessel would have earned about $2,500 for the vessel owner. Allowing a 15 percent return[1] for investment, uninsured risk, and management, an investment of slightly more than $55,500 would be justified by the most profitable operation (with no government assistance and $16 per ton fish price). Less profitable vessels, of course, would only be able to cover a smaller owner investment. Returns of this size indicate that $16 per ton is inadequate or the sharing arrangement between crew and vessel is inappropriate to attract adequate capital into the hake fishery. We later will consider both possibilities.

Participation of vessels in the fishery during and after the EDA charter period also provides some insight into interest in the fishery in the absence of government assistance. On August 6, at the end of the charter period, 8 of the original 10 vessels were fishing for hake. At that time the only buyer of fish, Pacific Protein, raised the price of fish from $16 to $18 per ton in an attempt to keep boats in the fishery. Despite this offer, the *Tordenskjold* and *Washington* left the hake fishery and returned to the bottomfish fishery to protect their winter markets while the *Coolidge II* and *Lady Olga* geared up for albacore trolling, which is more suited to smaller vessels and which showed signs of being good in late summer and early fall. The *Baron, Junior, St. Michael,* and *Recruit* attempted to stay in the fishery after August 6 but were forced to leave a few weeks later because of difficulty in finding fish. Several vessel captains said that the difficulty in finding fish was due primarily to reduced scouting efficiency of the smaller fleet.

COMPARISON OF PERFORMANCE OF LARGE AND MEDIUM VESSELS

To realistically compare the performance of large and medium vessels in the fishery, we had to simulate a situation in which all nine vessels were in the fishery for the entire 80-day season. This approach minimized bias resulting from varying availability of fish during the season. We assumed that operating costs per day for each vessel were constant with time and that vessel fixed costs were apportioned on the basis of 30 percent of the yearly total. The availability of fish differed by month; thus all landings were weighted by the monthly availability of fish (table 6). The average monthly landings of the three large vessels, which fished for almost the entire 80-day season, were used as an availability index to estimate the expected landings from vessels during months in which they did not fish or fished very little. (For a detailed account of the availability of hake during the season, see the paper by Nelson (1970) in this Circular.) The price of fish was fixed at $16 per ton, and all vessels were credited with 80 days of charter revenues for the simulated comparison.

[1] In this situation a 15 percent return is not unreasonable to expect because (1) the hake fishery is an undeveloped fishery, so deserves high risk considerations and (2) investment return is prorated to cover only the period when vessels were hake fishing (i.e., we assumed that vessels have an alternative use when not fishing for hake). This return, in technical terms, we assume to represent the opportunity costs of the owner's capital and management.

Table 6.—Projected landings by month and total value of the Pacific hake catch, assuming that all vessels operate for an entire 80-day season

Vessel	May	June	July	August	Total	Value
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Dollars*
Baron	118.0	661.5	639.2	156.5	1,575.2	25,203.20
Recruit	129.5	775.4	596.6	38.3	1,539.8	24,636.80
St. Michael	153.2	712.0	563.4	47.0	1,475.6	23,609.60
Washington	126.6	600.2	431.5	64.0	1,222.3	19,556.80
Junior	121.1	464.5	425.2	83.3	1,094.1	17,505.60
Voyager	88.3	512.4	393.8	65.9	1,060.4	16,966.40
Lady Olga	58.7	393.3	440.8	55.2	948.0	15,168.00
Coolidge II	75.1	453.6	341.8	35.2	905.7	14,491.20
Tordenskjold	53.1	318.8	253.9	83.8	709.6	11,353.60
Peter E.	14.2	81.6	178.5	10.5	284.8	4,556.80
Total	937.8	4,973.3	4,264.7	639.7	10,815.5	173,048.00

If all vessels had fished the entire season (with appropriate charter fees included), average salaries would have been slightly below $100 per day on the large and medium vessels (table 7). It must be remembered, however, that two of the large vessels used a four-man crew. Had they used three-man crews, the average salary of the large-vessel group would have been slightly over $100 per day.

The owners of the large vessels would have averaged about $3,000 more profit than those of the medium vessels ($13,100 and $9,800, respectively). Despite these differences, the average percentage return would be slightly higher for the owners of medium vessels. The owners of medium vessels had an average investment of about $62,000, whereas owners of large vessels had an investment of $111,000. With these investments the annual return on investment and management for medium and large vessels would average 52.7 and 34.9 percent, respectively. Although the annual rate of return is high, the period for which it applies is only 30 percent of the year. The difference between medium and large vessels would not be quite as large if the charter money had been allocated on the basis of fishing performance. It will be recalled that the fixed nature of the charter payment scheme resulted in the medium vessels receiving higher charter revenues per ton landed than the large vessels.

Although the performance of large and medium vessels did not differ as one would expect in this high-volume, low-unit-value fishery, the economic performance of the large vessels should have improved had the fishery continued past August 6. Records from the past years show that hake become more available off the northern Washington coast in late summer and early fall (Alverson, 1967; Nelson, 1967). The fish would then be at a greater distance from the Aberdeen plant, thereby favoring the large vessels with their larger carrying capacity.

Table 7.—Comparison of performance of large and medium vessels during 1967 season, assuming all vessels fished for Pacific hake for entire season

Category	Landings		Charter revenue	Gross stock	Operating costs	Vessel costs[1]	Salary per day[2]	Vessel return[3]
	Amount	Value						
	Tons	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Large vessels								
Low	1,475.6	23,609.60	24,800.00	48,409.60	2,001.60	5,207.46	87.02	11,493.40
High	1,575.2	25,203.20	28,800.00	54,003.20	2,479.48	8,915.77	117.58	14,269.90
Average	1,530.2	24,483.20	26,133.33	50,616.53	2,295.09	7,064.34	95.91	13,122.96
Medium vessels								
Low	709.6	11,353.60	24,800.00	36,153.60	912.80	6,605.34	74.76	5,171.80
High	1,222.3	19,556.80	24,800.00	44,356.80	2,068.00	7,862.54	119.16	14,234.50
Average	990.0	15,840.00	24,800.00	40,640.27	1,573.80	7,186.39	95.56	9,801.50

[1] Vessel costs do not include BCF gear. Payroll taxes are 5 percent of crew share.
[2] Four-man crews were used on two of the large vessels.
[3] Return includes return to investment, uninsured risk, and management.

ECONOMIC CONDITIONS NECESSARY FOR A VIABLE FISHERY

To complete the economic analysis, conditions necessary for a viable and self-sustaining fishery will be projected. For the purposes of this discussion we will assume that:

(1) vessels, which fish for hake, are able to engage in other fisheries at other times of the year;

(2) during the hake season vessels can be used in other activities (e.g., groundfish fishery, shrimp fishery, and salmon packing);

(3) a hake fishery is prosecuted for at least 100 days during the summer season;

(4) average cost and production figures obtained from the 1967 fishery are representative of those that would exist in a continuing hake fishery;

(5) adequate processing and marketing facilities are available to handle all fish landed.

Cost and revenue factors for the 100-day season were projected on the basis of those experienced in the 1967 season. Previously we showed that operating costs were $29 and $20 per day for large and medium vessels, respectively. Vessel fixed costs, which were calculated by subtracting interest and payroll tax costs from fixed cost figures given in table 3 and adding BCF gear costs of $25 per day, were $87.50 per day for both large and medium vessels. Vessel payroll taxes, which we estimated at 5 percent of the crew share, were added to vessel costs in each case to get the total vessel costs for alternative fish prices and sharing arrangements. Large vessels averaged about 20 tons per day, and medium vessels about 13½ tons per day in the 1967 fishery (table 8). On the basis of these catch rates and the preceding assumptions, a large vessel would be expected to land 2,000 tons in a 100-day season while a medium vessel would land about 1,350 tons in this same period. Because the size of the boat share percentage directly determines the apportionment of the net stock, projections will be made at several percentages of boat share to compare the influence of sharing arrangement on the economic sustainability of a Pacific hake fishery.

Table 8.–Production of hake per day by month for all 10 vessels engaged in 1967 offshore hake fishery[1]

Vessel	May	June	July	August	Average
	Tons per day				
Baron	6.94	22.05	23.67	26.08	19.66
Recruit	7.62	25.85	22.10	6.38	19.25
St. Michael	9.28	23.73	20.87	7.83	18.61
Washington	14.83	20.01	15.98	10.67	17.26
Voyager	3.07	17.08	—	—	15.60
Junior	35.80	15.48	15.75	13.88	14.03
Lady Olga	2.20	13.11	16.33	9.20	13.30
Coolidge II	—	15.12	12.66	5.87	13.01
Tordenskjold	—	10.63	9.40	13.97	10.45
Peter E.	0.86	2.72	6.61	—	3.64
Average	7.25	17.18	16.59	11.74	15.30

[1] Production per day was calculated on the basis of monthly landings adjusted to include only fish actually taken during a particular month. For instance landings made at the beginning of a month might have included some catches taken on the last days of the preceding month. Such landings then were apportioned to each month on the basis of the individual haul records.

With the assumed catch in a 100-day season along with operating and vessel costs as determined by sample data, it is possible to vary the price per ton and the vessel share percentage to ascertain their effect on return to vessel owner and crew salary (figs. 3-6). Under price and share percentage conditions that existed in the 1967 fishery ($16 per ton for fish and an average vessel share percentage of about 41.5 percent), we see that without government assistance the fishery would fail because of the poor return to vessel owners. A large vessel could expect to receive slightly more than $2,500 for investment and management, whereas a medium vessel could expect

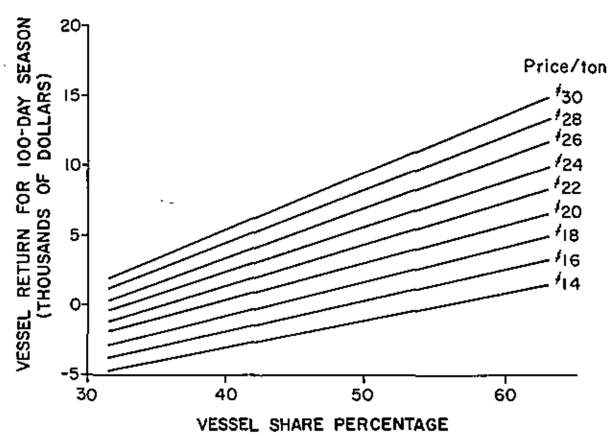


Figure 3.–Vessel return for 100-day season (return to investment, uninsured risk, and management) for medium vessel operations as a function of vessel share percentages at fish prices of $14 to $30 per ton.

to operate at a loss — no return to investment and management (figs. 3 and 5). Despite the poor vessel return, crew salaries are good ($57 per day) on a three-man large vessel, but only fair ($38 per day) on a three-man medium vessel (figs. 4 and 6). (On a four-man vessel crew salaries would be 0.75 of those on a three-man vessel of the same size.)

With the average investment in the 1967 fishery at $111,000 for large vessels and $62,000 for medium vessels, annual returns of $16,650 and $9,300 would be needed, respectively, on the basis of a 15 percent return to investment, uninsured risk, and management to justify participation in the fishery. Of course, since only 30 percent of the vessel's yearly activities can be charged against the hake fishery, returns of only $4,995 and $2,790 for large and medium vessel operations, respectively, would be required. At $16 per ton, a large vessel would need nearly a 50 percent share to earn a return of this magnitude (fig. 5), whereas a medium vessel would need almost 62 percent (fig. 3).

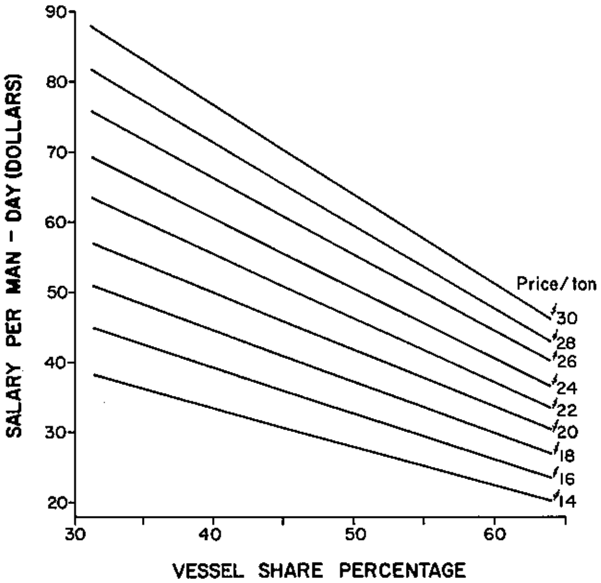


Figure 4.—Salary per man-day for three-man medium vessel operations as a function of vessel share percentages at fish prices of $14 to $30 per ton. Salary for four-man operations is 0.75 of that for three-man operations.

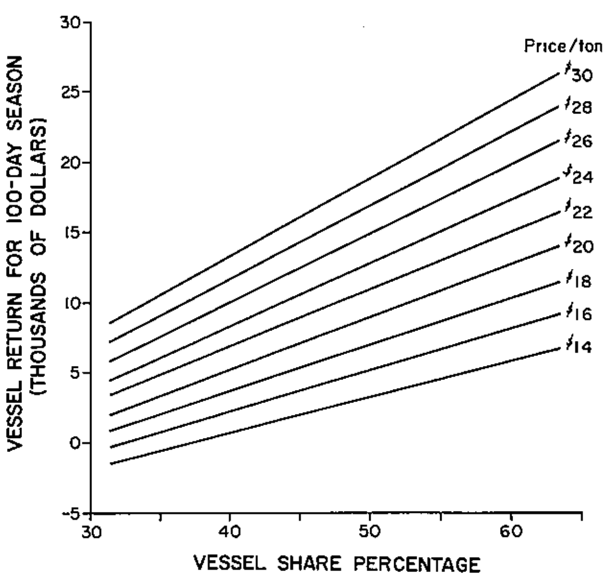


Figure 5.—Vessel return for 100-day season (return to investment, uninsured risk, and management) for large vessel operations as a function of vessel share percentages at fish prices of $14 to $30 per ton.

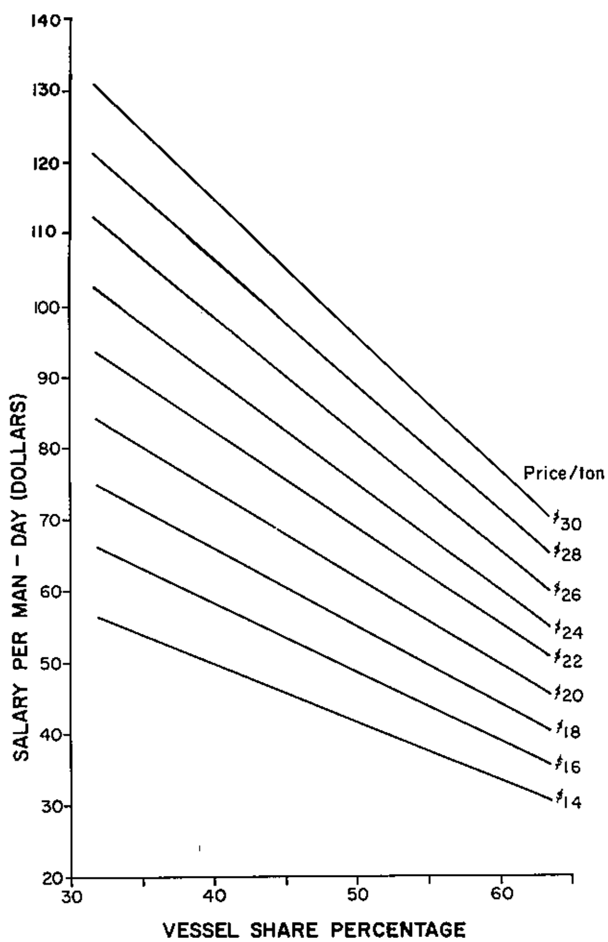


Figure 6.—Salary per man-day for three-man large vessel operations as a function of vessel share percentages at fish prices of $14 to $30 per ton. Salary for four-man operations is 0.75 of that for three-man operations.

At these high vessel share percentages, salaries would be reduced considerably.

We can estimate the fish price and vessel share percentage needed to meet minimum conditions of a 15 percent annual return on investment and a daily salary of about $50. These minimum conditions are necessary to attract capital and fishermen into the hake fishery against the reasonable alternatives that are available (i.e., opportunity costs). Figure 7 shows that a price per ton of $22 and a vessel share percentage of about 45 percent will be needed to attract medium vessels with three-man crews. On the other hand, three-man large vessels, due to their higher productivity, are attracted at a lower price per ton ($17) if a higher vessel share percentage of about 50 percent is allowed (fig. 8). Because two of the three large vessels in the 1967 fishery had four-man crews, a crew of four men may be considered as normal for these larger operations. If this were the case, a price per ton of about $20 and a vessel share percentage of 40 percent would be required (fig. 8).

Under the above conditions, gross stocks for medium vessels would be $297 per day (13.5 tons of fish per day at $22 per ton) and gross stocks for large vessels would be $400 per day (20 tons of fish per day at $20 per ton). As discussed previously, at vessel share percentages of 45 and 40 percent respectively, these gross stocks are sufficient to provide the minimum vessel return and salaries to attract three-man medium and four-man large vessels into the fishery (figs. 9 and 10).

In our foregoing discussions we have assumed a fixed production rate as indicated by the sample data. If the production rate is increased, then the gross stock needed to generate minimum earnings can be obtained at a lower fish price because gross stock is a function of both quantity and price. For example,

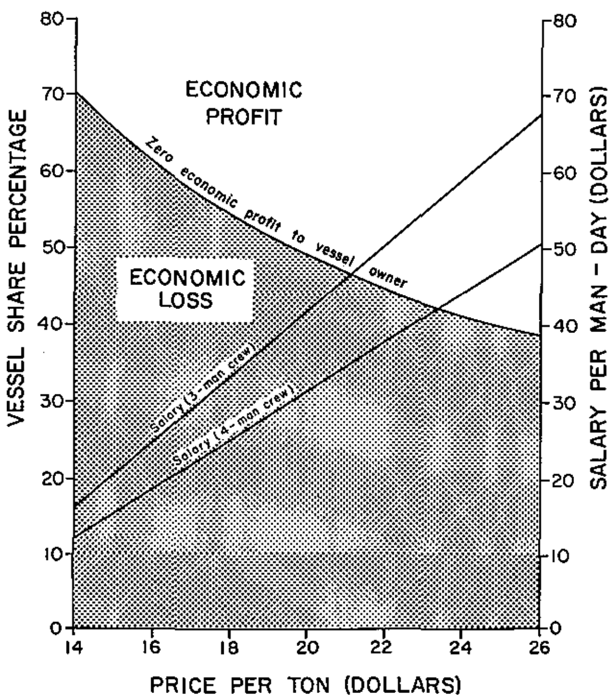


Figure 7.—Vessel share percentage required for medium vessel operations to generate income sufficient to cover all economic costs (i.e., zero economic profit), including a 15 percent annual return for investment, uninsured risk, and management during a 100-day season; and salary per day for three-man and four-man crews as a function of price per ton when vessel share percentage is adjusted so that all economic costs are covered.

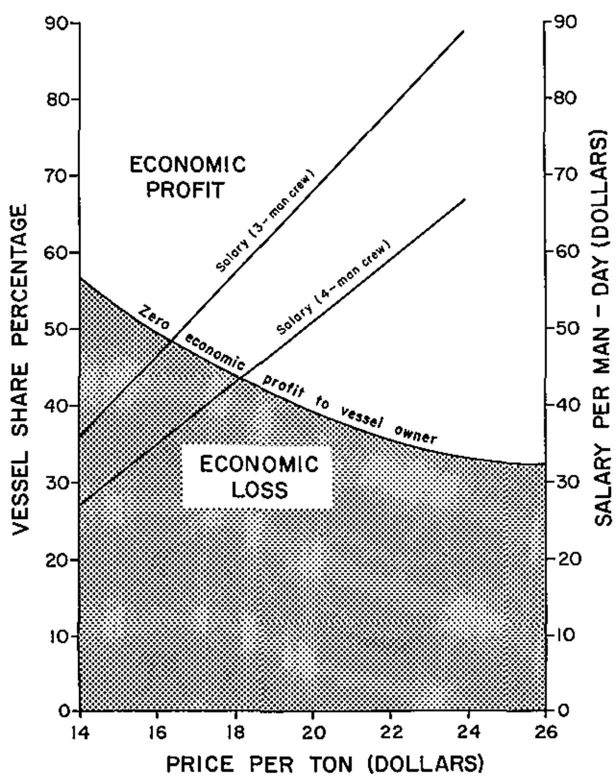


Figure 8.—Vessel share percentage required for large vessel operations to generate income sufficient to cover all economic costs (i.e., zero economic profit), including a 15 percent annual return for investment, uninsured risk, and management during a 100-day season; and salary per day for three-man and four-man crews as a function of price per ton when vessel share percentage is adjusted so that all economic costs are covered.

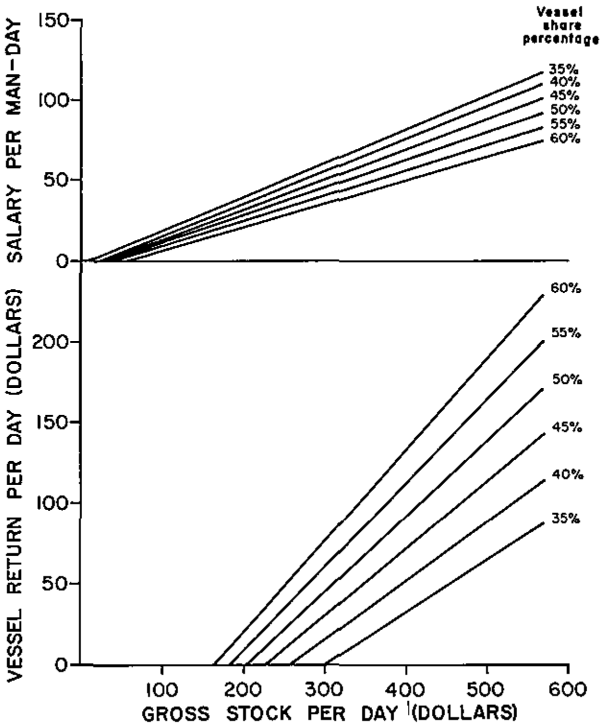


Figure 9.—Salary and vessel return per day as a function of gross stock for three-man medium vessel operations at vessel share percentages of 35 to 60 percent. The salary per man-day for four-man crews is 0.75 of that for three-man crews.

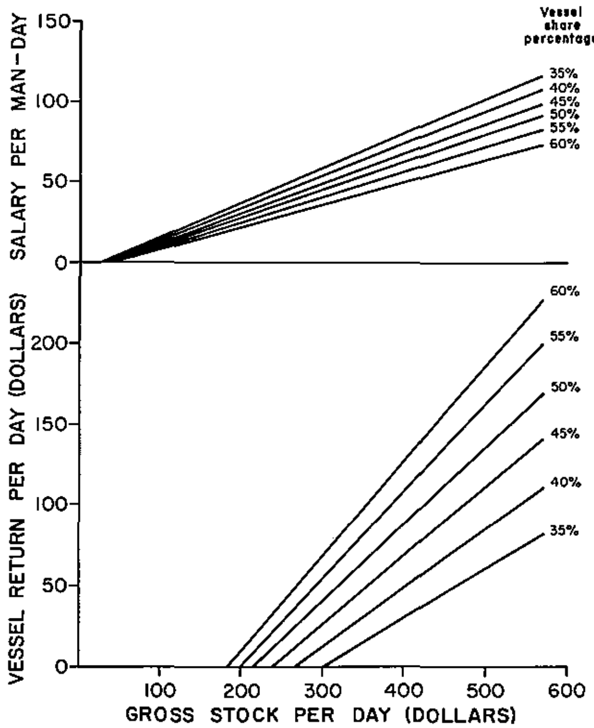


Figure 10.—Salary and vessel return per day as a function of gross stock for three-man large vessel operations at vessel share percentages of 35 to 60 percent. The salary per man-day for four-man crews is 0.75 of that for three-man crews.

we just showed that with a 40 percent vessel share the minimum required vessel return for large vessels was provided with a gross stock of $400 per day (fig. 10). If the production rate can be increased 25 percent to 25 tons per day, then the price of fish need only be $16 per ton to generate the $400 per day minimum gross stock. With the fish price at $20 per ton, a gross stock of $500 would result at the higher production rate (25 tons per day at $20 per ton). At $500 per day, the minimum vessel return ($5,000) for the hake season needed to attract large vessels into the fishery could be obtained with a lower vessel share percentage of slightly under 35 percent (fig. 10). Under these conditions crew salary on a four-man large vessel would be slightly over $75 per day.

SEASONALITY OF THE HAKE FISHERY AND COMPETITION FROM OTHER FISHERIES

Other factors are important in determining an adequate price to encourage a successful fishery. Because the hake fishery is seasonal, operating only during the summer, we assumed that vessels in the hake fishery would be used in other fisheries when they were not fishing for hake. Hence, only 30 percent of the yearly fixed costs (i.e., insurance, depreciation, and maintenance costs) were charged against revenues earned in the hake fishery. On the other hand, if owners of vessels in the hake fishery cannot find suitable use for their vessels at other times of the year, then vessel returns would be proportionately lower. In this case, to bring the rate of return up to the level needed to make the fishery attractive to the boat owner, either the return on investment and management would have to be increased by raising the vessel share percentage or the gross stock would have to be increased either by improving productivity or raising the price per ton of fish. Of course if the vessel share percentage were increased, the resulting lower salaries might be insufficient to attract the necessary crewmen. The ability of the fish buyer to raise the price per ton depends on the use and value of the raw product, and the efficiency of plant operation. The ability of a reduction operation on hake to pay more than $16 per ton is briefly discussed by Nelson and Dyer (1970) in this Circular.

There are indications that even though a vessel and crew in a four-man large vessel operation could be successful in the reduction fishery on hake at $20 per ton, they might be reluctant to get involved owing to the possibility of reduced employment during other periods of the year. Trawlers that might readily engage in the hake fishery would be active in the fisheries for bottomfish and shrimp. A vessel owner who took his boat out of the trawl fishery during the summer to fish for hake might find it difficult to reestablish his market after the hake season. Thus, the owner might consider that the risk of losing a winter market does not justify the gain in summer earnings resulting from participation in the hake fishery.

Competition from other fisheries is the other factor that influences the price per ton needed to make the hake fishery competitive. Even though a vessel and crew could increase their present earning capacity fishing for hake at $20 per ton, they would not enter the fishery if the earning prospects were even more attractive in other fisheries. For example, with moderate fishing success and an unlimited market for bottomfish or shrimp during the summer, boats would not be attracted into the hake fishery at the $20 per ton price. The probability of large earnings in the fisheries for bottomfish and shrimp would be higher during the summer, and their participation in these fisheries would protect their winter market. Under these circumstances the risk would be lower and the earning expectation higher in these fisheries than in the hake fishery.

The impact that competition from other fisheries and the need for year-round markets can have on the actual participation of vessels in the hake fishery was indicated strongly by developments that led to the failure of the 1968 hake fishery. Although the price per ton of fish was $20, which should have been sufficient to attract vessels, too few vessels were willing to fish for hake thereby forcing the reduction plant at Aberdeen to remain closed in 1968. The main reasons why most trawlers were reluctant to fish for hake were (1) the bottomfish market was strong during the spring and showed signs of remaining strong throughout the summer of 1968; and (2) shrimp fishing, which had been good in 1967, was better in 1968 as was the shrimp market. Therefore, in both of these fisheries, the vessel owners and crew could make more money than they could anticipate in the hake fishery. Also, although several of the vessel owners felt that these markets probably would not sustain themselves indefinitely, they could not afford to pass up these more lucrative markets for a possible expanding market for hake.

Despite the failure of the offshore fishery to establish itself with a fish price of $20 per ton, a limited inshore fishery has operated for the past several years on the Puget Sound hake stocks where the fishermen have received from $13 to $20 per ton (Hipkins, 1967; DiDonato, 1968). This inshore fishery is prosecuted during the winter when earning expectations are lower in other fisheries; therefore, even though the production rates might not differ from those in the offshore fishery, the fishermen would be willing to fish the inshore hake stocks during the winter at $20 or less per ton.

The events surrounding the failure of the 1968 fishery point out the difficulty of operating a new plant when raw material supplies depend on independently owned vessels and traditional sharing arrangements. To assure a minimum quantity of fish for a reduction plant to operate economically, the plant owners may need to have a controlling interest in a sufficient number of vessels to provide the minimum required for efficient fishing and processing. Besides assuring a minimum supply of fish to the plant, such an arrangement would also allow plant owners to exercise sufficient control over their boats to provide a minimum scouting effort for the fleet, which is important in the hake fishery. This scouting activity should increase total landings to the plant and thereby increase the profitability of the entire operation.

SUMMARY AND CONCLUSIONS

An EDA grant to the Grays Harbor Planning Commission in 1967 and active participation by the BCF helped develop a fishery on Pacific hake. This fishery operated out of Aberdeen, Wash. Ten vessels were chartered between May 15 and August 6 to fish for hake with experimental trawls and depth telemetry gear. Vessels averaged more than 15 tons of hake per day for the entire season. Production by the large vessels averaged about 19 tons per day for the season but reached as high as 21 to 26 tons during June and July.

Total revenue in the fishery was slightly over $350,000. The economic analysis involving 9 of the 10 vessels revealed that operating costs averaged about $29 per day for the large vessels (95-125 tons of carrying capacity) and $20 per day for the medium vessels (50-75 tons of carrying capacity). Excluding gear costs, vessel costs were about $75 per day for large and medium vessels. BCF gear costs were about $25 per day, regardless of vessel size. Before grocery costs and taxes were deducted, average salaries were between $80 and $128 per man-day. Over $92,000 in return to vessel owners was generated by the nine vessels, averaging about $155 per day. Total economic cost per ton of fish in the 1967 fishery was over $37 — over half charged to labor and one-quarter to vessel owner return.

From the results of this study the following conclusions can be drawn:

1. U.S. vessels were able to catch large tonnages of Pacific hake.

2. The larger and more powerful vessels appeared to have an advantage if operated during the entire season due to the need for high production rates and large carrying capacity. This advantage increases as the distance between the plant and the fishing grounds increases.

3. Operating costs were low because (1) icing or refrigeration was not required, (2) fish were pumped from the vessel to the plant, and (3) the fishing grounds were relatively near to the plant.

4. Assuming conditions similar to those existing in 1967, appropriate sharing percentages, and the opportunity for the vessel to operate in a profitable fishery at other times of the year, we believe that an exvessel fish price of at least $20 per ton will be needed to generate a gross stock large enough to attract large vessels into a hake reduction fishery and a fish price of $22 per ton will be needed to attract medium vessels. Competition from other fisheries and the desire for maximum annual vessel income are the most important determinants of the actual amount of participation in the fishery at any price level and will influence the needed fish price.

5. Although the efficiency of processing was not included in this analysis (see Nelson and Dyer, 1970, in this Circular), fish prices are largely dependent on efficient processing. Efficiency of processing in turn depends on a sufficient number of vessels throughout the season to provide adequate use of plant capacity to permit an efficiency that will allow paying maximum fish prices. A viable hake fishery, therefore, depends on efficient processing that permits fish prices adequate to attract the necessary number of vessels to optimize scouting efficiency and plant operation. The interrelation of these variables along with the necessary labor costs indicates that all factors need to be considered simultaneously to determine the fish price and sharing arrangement (given fish distribution and availability) that will attract the necessary labor and capital for a successful fishery on Pacific hake.

6. Because of the competition from other fisheries, reduction plant owners may need to have controlling interest in a sufficient number of vessels to ensure a minimum supply of fish for the plant.

ACKNOWLEDGMENTS

The captains and vessel owners provided the data which made this report possible. Personnel of Pacific Protein, Inc., also helped provide data, especially landing statistics.

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MS. #1869

APPENDIX

Forms used to obtain economic data in the 1967 offshore hake fishery.

ECONOMIC DATA ON VESSEL OPERATIONS:

A. Variable Costs:

1. Vessel repairs and maintenance ____________________

2. Vehicles (if any) charged to vessel operation:
   a. trucks and cars (percent charged to fishing)
      fuel and oil expense........____________
      repairs...................____________
      insurance.................____________
      other.....................____________

3. Building (if any) charged to vessel operation:
   a. rent........................____________
   b. owned
      maintenance...............____________
      taxes.....................____________
      insurance.................____________
      other.....................____________

4. Miscellaneous expenses
   a. telephone expense.............____________
   b. electricity, utilities, etc....____________
   c. unions........................____________
   d. business trips................____________
   e. other.........................____________

B. Fixed Costs

Item	Original Cost	Deprecia-tion Rate	Age	Annual Deprecia-tion	Depreciated Value
Vessel					
Engine					
Equipment (list sepa-rately or group)					
Buildings					
Dock					
Truck					
Car					
Nets					
Office Equipment					
Vessel Insurance					
Total					

C. Any other items normally reported as expense (for tax purposes) not listed in A or B above ____________________

D. What % of total yearly fishing time did you spend in coastal hake fishery ____________%/

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HAKE FISHERY TRIP SETTLEMENT RECORD

VESSEL ______________________________ SETTLEMENT NO. __________

SKIPPER ______________________________ FROM __________ 19 ____

SOLD TO ______________________________ TO __________ 19 ____

______________________________ TRIP NOS. __________ TO ____

DATE __________________ 19 ____ NO. OF DAYS __________

TRIP NO.	DATE FROM	DATE TO	POUNDS	PRICE	AMOUNT	
			GROSS STOCK			

GROSS STOCK		
LESS TRIP EXPENSE		
NET STOCK		
LESS % BOAT SHARE		
CREW SHARE		
LESS GROCERIES GLOVES		
NET CREW SHARE		
NO. IN CREW MAN SHARE		

TRIP EXPENSES		
FUEL — OIL — GREASE		
ICE — SALT		
LICENSES PHONE U.S. CUSTOMS		
SETTLEMENT FEE		
OTHER		
TOTAL		

BOAT SHARE RECAP		
BOAT SHARE		
NET CHECK		

DEP.	NAME	MAN SHARE		SOC. SEC.		FEDERAL WITH. TAX		STATE WITH. TAX		ADVANCES				NET PAID	
	TOTALS														

GPO 992-360

Proximate Chemical Composition of Pacific Hake

By

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ABSTRACT

The composition of ocean hake varied seasonally, and fat varied most. Whole fish had about 1.5 to 3.5 percent fat during March to July and about 4 to 6 percent fat during September to November. They had 13.4 to 15.0 percent protein during March to July and 14.4 to 15.6 percent protein during September to November. They had about 3 percent ash during all periods. In contrast to the edible fillets, the waste portion had lower moisture, lower protein, and substantially higher fat contents.

The composition of Puget Sound hake varied seasonally, and again fat varied most. The fat content of whole fish was highest (6.4-7.4 percent) from about October through January. The average fat content of Puget Sound hake was higher than that of ocean hake, being 73 percent higher in the whole fish, 56 percent higher in fillets, and 68 percent higher in the waste portion. The protein content of whole fish ranged from 12.3 to 13.4 percent in early April to 16.1 percent in July. During the period January through May and during October, the livers were high in fat, averaging 44 percent fat in females and 58 percent fat in males.

The average protein content of ocean hake fillets was 16.5 percent and that of Puget Sound fillets was 16.1 percent.

CONTENTS

INTRODUCTION

Pacific hake, *Merluccius productus*, has been found in commercial quantities off the coasts of California, Oregon, and Washington. A smaller but commercially important population also exists in Puget Sound, Wash.

The potential use of hake in both food and industrial products was selected for investigation by the BCF (Bureau of Commercial Fisheries) Technological Laboratory at Seattle, Wash. The products considered included fresh

Published February 1970.

or frozen fillets, frozen fish fillet blocks, minced flavored products, mink food, pet food, fish protein concentrate, and industrial products (fish meal, oil, and solubles). To determine the most effective way to use the resource, the average composition of hake and its variation had to be known. Therefore, we began sampling offshore ocean hake in spring 1964 and Puget Sound hake in summer 1965. Our purpose was to obtain proximate analysis data in relation to our study of the potential for using both hake resources.

Although we recognized that the proximate composition varies with factors such as the size, sex, and stage of maturity of the fish, and the season and place of capture, these factors were not evaluated in detail owing to the limited scope of this investigation. For our immediate needs, we were concerned more with the average values and their limits of variability.

MATERIALS AND METHODS

Standard procedures were used in the collection, preparation, and analysis of samples.

COLLECTION AND PREPARATION OF SAMPLES

Samples of ocean hake were taken by the BCF research fishing vessel *John N. Cobb* while on exploratory and gear research cruises off the Washington, Oregon, and California coasts. These samples, which were collected from 1964 through 1966, were frozen in polyethylene bags within a few hours after capture. They were held at 0° F. on board the vessel and in the laboratory cold storage until examined.

Prior to analysis, the ocean hake samples were withdrawn from frozen storage and thawed at 35° F. After thawing, the individual fish were weighed and filleted. The fillets and waste products (heads, tails, viscera, frames, and skin) were collected separately, blended in a Hobart silent cutter,[1] and packed in 1/2-pound cans. Samples for proximate composition analysis were frozen at −20° F. and stored pending analysis.

During 1965 and 1966, hake samples were also obtained in Puget Sound by both research and commercial fishing vessels. These samples were transported from the vessel to the laboratory where they were iced, examined, and processed within 48 hours after being caught.

METHODS OF ANALYSIS

All samples were analyzed in duplicate for moisture, protein, fat, and ash using the standard procedures of the Association of Official Agricultural Chemists (Horwitz, 1955: 104, 311, 347). Sodium and potassium analyses were made by a flame photometric method (Thurston, 1958).

RESULTS AND DISCUSSION

Tables 1 to 5 summarize the proximate analyses of offshore ocean hake and Puget Sound hake taken from 1964 through 1966. The percentage of edible fillets and waste for both populations are given in table 6.

OFFSHORE OCEAN HAKE

Tables 1 to 3 summarize the results. Data in table 1 represent seasonal averages for the first 16 months of the study. Tables 2 and 3 present overall average values for whole hake and for the edible fillets and waste portions and their range of variation of average values during the 3-year study.

The data in table 1 (Dyer, Nelson, and Barnett, 1966) indicate that hake caught during the spring and early summer 1964 and 1965 (March-July) had low fat contents of about 1.5 to 3.5 percent. Subsequent data obtained from early season catches during 1966 con-

[1] Trade names referred to in this publication does not imply endorsement of commercial products.

tinued to have the same pattern. In contrast, hake sampled during the late summer and fall of 1964-66 (September-November) had high fat contents of about 4 to 6 percent. The protein content, on the other hand, had less seasonal variability. In 1964-66, the protein content was 13.4 to 15.0 percent during March to July periods, whereas it was 14.4 to 15.6 percent during September to November periods. The ash content for the same periods was relatively constant at about 3.0 percent. The high water content during the spring and early summer was offset by the low total fat and protein contents. The low water content in the late summer and fall was similarly offset by high combined fat and protein contents.

Table 1.—Proximate composition of whole Pacific hake, *Merluccius productus*, from coastal waters of Washington and Oregon, 1964-65[1]

Season	Moisture	Protein	Fat	Ash
	Percent	*Percent*	*Percent*	*Percent*
Spring 1964	[2]81.4±1.41	14.3±1.03	1.6±0.21	3.2±0.45
Summer-fall 1964	78.2±1.78	15.2±0.34	5.0±0.73	2.9±0.11
Spring 1965	80.7±0.80	14.0±0.61	2.3±0.42	3.2±0.15

[1] These data are seasonal averages based on 14 samples of about 12 fish per sample (Dyer, Nelson, and Barnett, 1966).
[2] Mean ± standard deviation.

The average values for moisture, protein, fat, and ash in tables 2 and 3 may be considered to reflect the average composition of hake harvested during May to November. The ranges in tables 2 and 3 may be considered the likely limits of variation in composition of the hake during this same period. In table 3, we note that the waste portion in contrast to the edible fillet portion has a lower moisture, lower protein, and a substantially higher fat content.

The adverse flesh texture characterizing ocean hake seriously limits its use as a food fish despite its high protein content (16.5 percent) and otherwise high nutritional quality. Flesh texture of hake is discussed in detail in this Circular by Dassow, Patashnik, and Koury (1970).

To be economically profitable, an industrial fish (fish used in production of meal and oil) has to have a high fat content. The nature of Pacific hake is such that the high fat content develops only during late summer and fall, which may somewhat limit the full utilization of this fish for meal and oil.

Table 2.—Proximate composition and potassium and sodium contents of whole Pacific hake, *Merluccius productus*, from coastal waters of Washington, Oregon, and California, 1964-66[1]

Item	Moisture	Protein	Fat	Ash	Potassium	Sodium	Size of fish	
							Length[2]	Weight[2]
	Percent	*Percent*	*Percent*	*Percent*	*Mg. %*	*Mg. %*	*Inches*	*Ounces*
Average	[3]79.7±2.21	14.7±0.65	3.2±1.47	3.0±0.28	318±25.2	146±33.7	20.3	32.8
Range	72.9—83.4	13.4—16.0	1.4—6.0	2.3—3.8	297—372	109—200	11.8—24.8	6.0—52.9

[1] Data on composition and size of fish are the averages of 30 samples of about 12 fish per sample taken from January 1964 through October 1966. The potassium and sodium data represent seven samples taken during 1964.
[2] If we disregard two samples — one of extremely large size fish and one of extremely small size fish — from California, the ranges of the length and weight are narrowed respectively to 15.7 to 22.8 inches and to 15.3 to 47.4 ounces.
[3] Mean ± standard deviation.

Table 3.—Proximate composition and potassium and sodium contents of edible fillets and waste portion of Pacific hake, *Merluccius productus*, from coastal waters of Washington, Oregon, and California, 1964-66[1]

Item	Moisture		Protein		Fat	
	Fillets	Waste	Fillets	Waste	Fillets	Waste
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Average	[2]81.5±1.29	79.1±2.05	16.5±0.87	14.4±0.64	1.6±0.74	3.5±1.76
Range	79.4—84.0	75.3—83.4	14.0—17.8	12.7—15.5	0.5—3.1	1.4—7.5

Item	Ash		Potassium		Sodium	
	Fillets	Waste	Fillets	Waste	Fillets	Waste
	Percent	*Percent*	*Mg. %*	*Mg. %*	*Mg. %*	*Mg. %*
Average	1.1±0.18	3.8±0.13	385±44.4	269±23.9	77±18.6	173±35.0
Range	0.5—1.5	2.3—4.7	335—470	237—304	51—103	135—228

[1] Composition data represent the average of 30 samples of about 12 fish per sample taken from January 1964 through October 1966. The potassium and sodium data represent seven samples taken during 1964.
[2] Mean ± standard deviation.

PUGET SOUND HAKE

Tables 4 and 5 show the average composition and the variation of average values for a year. The seasonal trends previously noted for whole ocean hake were similarly apparent for the Puget Sound hake but were slightly out of phase. The fat content of whole hake was highest from October 1965 through January 1966 and ranged from 6.4 to 7.4 percent; intermediate from February through April 1966 — 4.5 to 7.0 percent; and lowest from May to July — 2.5 to 5.0 percent. The average fat content of Puget Sound hake was higher than that of ocean hake, being 76 percent higher in the whole fish (5.7 vs. 3.3 percent), 56 percent higher in the fillets (2.5 vs. 1.6), and 69 percent higher in the waste portion (6.4 vs. 3.8).

The variation in protein content appeared to be related to the spawning cycle. The protein content was 13.6 to 14.7 percent from January through March. With the start of spawning in early April, the protein content dropped to 12.3 to 13.4 percent. During May, protein increased from 13.2 to 14.9 percent, and by July, the protein had increased to 16.1 percent. By November and December as the fat reached its maximum, protein dropped again to the 13.8 to 14.9 percent range noted early in the year.

Because the liver is known to be high in fat at certain times of the year, we analyzed male and female livers. For the period January through May and during October, the average fat content of female livers was 44 percent (33-49 percent) and that of male livers was 58 percent (34-68 percent). Male livers averaged 31 percent higher in fat than female livers. The liver generally is about 5 to 7 percent of the body weight so it represents a major contribution to the fat content of the whole fish.

The flesh quality of the Puget Sound hake has been found to be superior to that of the offshore ocean hake, mainly because the abnormal (mushy) flesh texture frequently found in ocean hake is a relatively minor problem with the Puget Sound hake so it can be more readily used in food-type products. The proximate composition of some of the abnormal parasitized hake is given in this Circular by Dassow, Patashnik, and Koury (1970).

The average protein composition of the ocean hake fillets was about 16.5 percent and that of the Puget Sound hake fillets about 16.1 percent, making them both excellent food fish from a nutritional standpoint. Once the abnormal textural condition is completely resolved, hake will have great demand as a high-quality food fish. The abnormal texture does not affect the availability of its high protein.

Table 4.—Proximate composition of whole Pacific hake, *Merluccius productus*, from Puget Sound, 1965-66[1]

Item	Moisture	Protein	Fat	Ash	Size of fish	
					Length	Weight
	Percent	*Percent*	*Percent*	*Percent*	*Inches*	*Ounces*
Average	[2]77.9±1.60	14.0±0.86	5.7±1.34	3.0±0.61	14.2	13.7
Range	75.1—80.8	12.3—16.1	2.6—7.4	2.4—5.2	9.8—25.6	3.5—64.6

[1] Composition data are based on 19 samples of about 25 fish per sample taken during July 1965 to October 1966. Samples were largely from Port Susan and Saratoga Passage but also from Carr Inlet and Hood Canal and off Everett and LaConnor.
[2] Mean ± standard deviation.

Table 5.—Proximate composition of the edible fillets and waste parts of Pacific hake, *Merluccius productus*, from Puget Sound, 1965-66[1]

Item	Moisture		Protein		Fat		Ash	
	Fillets	Waste	Fillets	Waste	Fillets	Waste	Fillets	Waste
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Average	[2]81.3±0.78	78.5±3.06	16.1±0.95	13.7±0.89	2.5±0.85	6.4±2.11	1.1±0.19	3.8±0.83
Range	80.2—83.1	72.6—82.7	14.0—18.7	11.7—15.3	1.2—3.8	1.6—9.8	0.9—1.7	3.1—7.0

[1] Composition data are based on 19 samples of about 25 fish per sample taken during July 1965 to October 1966. Samples were largely from Port Susrn and Saratoga Passage but also from Carr Inlet and Hood Canal and off Everett and LaConnor.
[2] Mean ± standard deviation.

FILLET YIELD

The average fillet yield (hand filleted) was 30.0 percent for ocean hake and slightly less or 27.7 percent for Puget Sound hake (table 6).

Table 6.—Percentage of edible fillets and waste of Pacific hake

Item	Hake from coastal waters		Hake from Puget Sound	
	Fillets	Waste	Fillets	Waste
	Percent	*Percent*	*Percent*	*Percent*
Average	[1]30.0±3.24	70.0±3.24	27.7±2.00	72.3±2.00
Range	25.6—36.1	63.9—74.4	23.2—32.4	67.6—76.8

[1] Mean ± standard deviation.

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MS. #1895

Characteristics of Pacific Hake, *Merluccius productus*, That Affect Its Suitability for Food

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ABSTRACT

The expanding population and the increasing dependence of the United States on imported food fish necessitate a continuing study of latent protein sources such as the undeveloped fishery for Pacific hake off the Pacific coast. Direct use of hake in food products is desirable to encourage diversification of the fishing industry. Hake, long considered an undesirable species, has been studied for potential application in fresh, frozen, and processed products. The factors studied include color, odor, flavor, texture (including the cause of mushy texture), keeping quality, composition, and food value. We believe that the best use of species such as hake is in processed-food products for which frozen minced fish flesh can be prepared with suitable additives that help it have desirable flavor, texture, and keeping quality.

CONTENTS

INTRODUCTION

The world's rapidly increasing population and the limits to the productivity of agricultural lands leave little doubt that we must seek more food from the sea.

Published February 1970.

From 1957 to 1967, the total annual supply of fishery products in the United States increased from 7.2 to 14.2 billion pounds. During the same period the percentage of imported fish increased from 33 to 71 percent of the total supply (live-weight basis). It has become obvious that we must increase our harvest and use of the underutilized species to expand our domestic food fisheries and reduce our dependence on imported fish.

In examining the underutilized species that are abundant off our coasts, however, we find that they are considered unsuitable as food fish or are held in low regard. In the North Pacific, these fish include Pacific hake, *Merluccius productus;* walleye pollock, *Theragra chalcogrammus;* several species of flounders, such as arrowtooth flounder, *Atheresthes stomias;* and starry flounder, *Platichthys stellatus;* several species of rockfishes, *Sebastodes* spp.; and spiny dogfish, *Squalus acanthias.* The fish in this group make up a large segment of our underutilized species. They also present major problems in food preservation and acceptability.

Hake was selected for our initial study largely because its potential harvest is great. Hake are regarded by most Pacific coast fishermen and processors as a nuisance fish with a reputation for poor keeping quality. Yet, hakes of the genus *Merluccius* are valuable commercial food fishes in U.S.S.R., Spain, Chile, South Africa, Argentina, and the United States (Food and Agriculture Organization of the United Nations, 1967).

At the same time that the BCF (Bureau of Commercial Fisheries) Exploratory Fishing and Gear Research Base at Seattle, Wash., was finding large concentrations of hake, domestic processors were beginning to examine the possibilities of manufacturing a fish block that is more economical than the conventional cod block. They were considering imported or domestic hake to satisfy the expanding need for a low-priced fish block. Further, the possible use of hake in processed-type products such as fish sausage and seafood spreads offered an opportunity to encourage diversification of the industry. Therefore, experimental studies were needed to assess the possibilities of using Pacific hake for food.

EXPERIMENTAL STUDIES

The aims of our experimental studies were, first, to determine the technological characteristics of hake and, second, to evaluate the suitability of hake for food. Studies on the production of FPC (fish protein concentrate) from hake were already underway in another BCF laboratory, so we omitted such research. The study of the characteristics of hake included color, odor, flavor, texture, keeping quality, composition, and nutritive value.

We obtained most samples of ocean hake aboard the BCF research vessel *John N. Cobb* during exploratory and gear research cruises off Washington and Oregon during 1965. Samples of Puget Sound hake were obtained from both research and commercial fishing vessels during the winter of 1965-66. We also obtained a few hake samples from California waters.

Raw and cooked fillets of hake were prepared and examined aboard the vessel and at the BCF Technological Laboratory in Seattle. Fresh hake were held on deck uniced and iced in small quantities so that we could compare the keeping qualities of the fresh whole fish. Several small lots of hake were filleted and frozen as individual fillets and in blocks. Fish that were to be studied for texture, proximate composition, and nitrogenous constituents were frozen aboard the vessel within a few hours after capture, packaged in polyethylene bags, and held at 0° F. until transferred to the laboratory cold storage at −20° F.

CHARACTERISTICS OF PACIFIC HAKE

In the study of the characteristics of hake, we soon found that several factors affect keeping quality and texture unfavorably. Yet, we found also desirable factors in the color, odor, flavor, and texture. Some unexpected results requiring further study developed relative to the cause of the abnormal mushy texture sometimes found in hake fillets.

COLOR

Although color of the flesh varies from an off grey-white to pink, it is within the normal range of color found in the various Pacific coast species that are now filleted and marketed.

ODOR

The raw flesh has a neutral odor. The whole hake, however, develops a strong, persistent odor on the skin in less than 1 day if uniced. The fish must be iced immediately aboard the vessel to avoid the development of these strong odors, which are more evident on the ocean hake than on the Puget Sound hake.

FLAVOR

Really fresh hake that is properly cooked has a bland flavor that consumers consider desirable. For many types of frozen prepared foods, such as precooked breaded fillets, this mild flavor permits modification with small amounts of additives.

TEXTURE

In our preliminary evaluation of the potential use of hake, fishermen and processors commented unfavorably on the soft, sometimes mushy, texture of hake. Our first concern was to determine the normal texture of really fresh hake, then evaluate the problem of the abnormal mushy texture.

Normal Texture

The normal texture of hake flesh is moist and tender but not mushy. Most testers find it quite similar in texture to that of Dover sole, *Microstomus pacificus*, and English sole, *Parophrys vetulus*.

Abnormal Texture

Early in our investigation, we noted a high incidence of abnormal mushy texture in cooked samples of hake caught off the coasts of Washington and Oregon. This texture adversely affected the acceptability of the hake as food. We observed that the mushy condition of cooked hake was often associated with a microscopic myxosporidian parasite, *Kudoa* sp., in the muscle similar to that reported in other fish species by Willis (1949), Fletcher, Hodgkiss, and Shewan (1951), and Patashnik and Groninger (1964).

Effect of parasite.—The muscle portions seriously infected with the myxosporidian parasite appeared to have a serious proteolysis of the tissue with accompanying liquefaction and mushiness. In some samples of fresh hake, we found levels of proteolytic activity up to 14 times greater than those in normal-textured, uninfected controls. On investigating the stability of hake-muscle enzyme extracts toward heat and using hake fillets that had high proteolytic activity, we observed that 10 minutes completely inactivated the proteolytic enzyme. The texture of the heavily parasitized hake (fig. 1) almost always was abnormal and mushy, but that of the slightly parasitized hake was frequently normal. These latter fillets required close inspection to detect the parasites. Usually, the moderately parasitized condition did not significantly affect the proximate composition of hake. In extreme cases, in which we could see that the flesh had deteriorated, the proximate composition appeared to be significantly altered. For example, the muscle from a single excessively parasitized hake taken from Puget Sound was 11.1 percent protein in contrast to an average of 16.1 percent and a low value of 14.0 percent protein for all samples of Puget Sound hake (see table 5 of Patashnik, Barnett, and Nelson, 1970).

Significance of parasite.—Myxosporidian parasites, *Kudoa* sp., have been found in hake samples taken off the coasts of Washington, Oregon, California, and Argentina and are relatively common in certain species of marketed fish in other parts of the world. The incidence of the parasite has varied commonly from 20 to 40 percent of the hake in a sample, but 100 percent of the hake were infected in some samples, depending on the area of catch and the size of the fish. From a commercial standpoint, a high incidence of infestation in a catch would preclude its use for fresh or frozen fillets, owing to the probable mushy texture. At levels of low incidence, hake fillets of good quality could be produced with appropriate handling and inspection to eliminate any abnormal fillets. Figure 1 shows a normal hake fillet and two heavily parasitized fillets. The dark hairlike cysts in the muscle are readily visible in the heavily parasitized fillet, but they may be colorless and barely visible in a lightly parasitized fillet. The individual *Kudoa* spores within the cysts are microscopic in size, ranging from 6 to 18 microns (1 micron is about 1/25,000 inch) in diameter. A large cyst may have millions of spores.

With heavy commercial harvesting of the resource, the parasite problem may be substantially reduced. Forrester (1956), discussing a similar myxosporidian infection in lemon sole (English sole), observed that the incidence decreased from 21 percent in 1951 to less than 1 percent in 1954, as harvesting reduced the stock to about half its initial number.

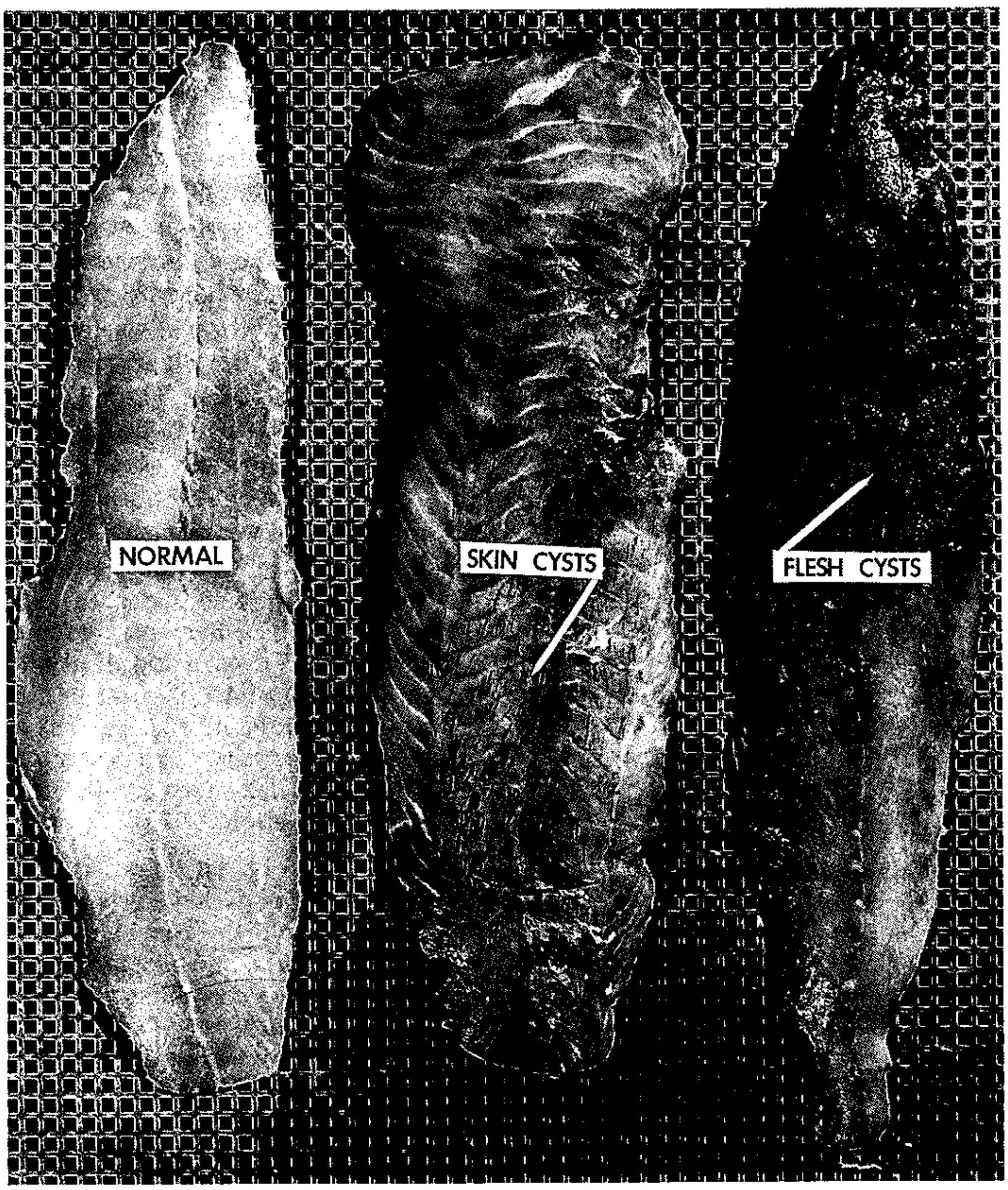

Figure 1.—A normal hake fillet in contrast with heavily parasitized fillets.

There is no evidence that the myxosporidia can cause illness or infection in man. No health problems related to these organisms have been reported from areas, such as Japan, where raw marine fish are frequently consumed. This absence of infection is not surprising, since the organism and related genera occur only in fishes and invertebrates. Furthermore, cooking readily destroys the organism, if it is present in the fish muscle. Apparently our main concern is the relation of the organism to the textural quality and aesthetic acceptability of the fresh and frozen hake fillets.

Texture Improvement

Hake fillets of otherwise good quality tend to show a significant amount of drip when held under refrigerated storage, frozen and thawed, or cooked. For hake to be used as fresh fillets or frozen blocks, reducing the drip and firming the muscle texture would be desirable. Treatments with polyphosphates and salt are used in other meat products for such purposes. Based on the experiments in our laboratory with treatment of other fish, we set up a few experiments to determine the effectiveness of a combined 7.5-percent sodium tripolyphosphate plus 2-percent sodium chloride dip treatment with chilled hake fillets.

Separate groups of hake fillets were selected at random from a single lot, treated as above, and stored with untreated controls up to 11 days at 33° and 36° F. In comparing the treated fillets after being stored for 11 days, we found no free drip, whereas the control group had 2.3 percent drip. On being cooked, the treated samples continued to show lower drip (3 percent vs. 5 percent). Objective evaluation of texture by means of a hydraulic shear instrument (Dassow, McKee, and Nelson, 1962) showed the treated samples to have a firmer texture — for example, treated fillets had 1.7 times greater shear resistance than the untreated fillets.

In another experiment we prepared for preference tests two lots of frozen hake blocks — one in which the fillets were treated as above before freezing and the second an untreated control. Cooked seasoned portions were prepared from these treated and untreated blocks and were evaluated by a sensory panel[1] on a 9-point preference hedonic scale. Results were as follows:

	Treated	Untreated control
Number of judgments	34	34
Average score	6.67	6.02

From these tests, the use of a sodium-tripolyphosphate and sodium-chloride dip apparently improves both the water-holding capacity and the acceptability of fresh and frozen hake.

KEEPING QUALITY

The keeping quality of whole hake was evaluated objectively by the electronic fish tester of Hennings (1965), which is reported to be useful for detecting early changes in the freshness of sole and other species (Nelson and Barnett, 1964). A trained sensory panel of four members of our laboratory evaluated the keeping quality of iced fillets and frozen blocks.

Whole Fish

In one typical experiment, lots of 20 hake iced immediately after being landed aboard the vessel were compared with hake iced 18 hours later (stored at 60° F. ambient temperature on the deck). The effect of a delay of 18 hours in icing hake reduced the freshness value by about one-half.

This and similar tests showed that Pacific hake should be iced or processed without delay, mainly because the storage life of whole hake is very limited. Owing to the nature of the hake fishery, trawl catches will be large. To chill these large-volume deck loads rapidly and to avoid significant loss of quality, a slush-icing system, such as is used in the poultry industry, or mechanically chilled brine tanks may be required. Hake iced immediately after catching were found to remain in rigor up to 3 days but to lose quality rapidly soon after. From a quality standpoint, the need for rapid processing, including machine heading and gutting aboard vessel or in shore plants closely adjacent to catch areas, will have to be considered seriously.

[1] Sensory panel tests were made through the cooperation of the Sensory Evaluation Unit, Department of Food Science, Oregon State University, Corvallis, Oreg.

Iced Fillets

In an experiment that simulated commercial conditions, hake delivered by the BCF vessel *John N. Cobb* were iced within 6 hours and filleted within 24 hours. The resulting fillets were stored in 25-pound fillet cans at 32° to 36° F. The keeping quality was judged by the odor and the flavor of the cooked fillets. Results with icing of fillets showed, most surprisingly, that chilled hake fillets prepared from adequately iced, fresh hake can remain acceptable as long as 2 weeks. This finding indicates that, contrary to local industry expectations, the marketing of fresh, high-quality hake fillets may be practical.

Frozen Blocks

During storage tests at 0° F. of frozen blocks of hake, the texture and flavor of the lean flesh showed little adverse change, but the fatty surface flesh had early oxidative rancidity (table 1). Although unglazed hake portions stored at 0° F. became rancid within 2 weeks, ice-glazed portions stored at the same temperature were acceptable for at least 10 weeks. If glazed and stored at −20° F., the portions were acceptable for up to 24 weeks. With suitable antioxidants and packaging, we obtained even further protection from oxidation.

The strong oxidative rancidity that developed in unglazed hake portions stored for only 2 weeks at 0° F. demonstrated that the lipids in the surface fatty layer of hake are highly labile. The limited tests made do show, nevertheless, that blocks of frozen hake can be packaged and stored successfully at lower temperatures. Inasmuch as glazing is normally not feasible in blocks (most blocks are cut into portions and breaded), the use of approved antioxidants and packaging films with low oxygen-transmission characteristics should be investigated.

COMPOSITION OF HAKE

In planning the preliminary studies of the gross chemical composition of hake, we selected two aspects of immediate importance — the proximate composition and the nitrogen constituents (including nitrogenous and nonprotein nitrogen contents) of the edible portion.

Proximate Composition

Proximate composition of the edible portion was needed in the calculation of food value. We presumed from the size and distribution data provided by the initial biological studies that the protein and oil contents of hake would vary with size of fish and the season. As food, hake fillets are generally in the low-fat category, about 1 percent, and in the moderately high-protein category, about 16 percent on the average. This composition is similar to that of Pacific coast "sole" fillets. A more detailed discussion of hake composition is provided in an earlier paper of this Circular (Patashnik et al, 1970).

Nitrogenous Constituents

The nitrogenous constituents in hake were determined in order to ascertain its potential use in processed-type products. On the assumption that the protein of hake is moderately high and nutritionally complete (as is all fish protein), it seemed to us that the application might be to re-form or process the edible portion into a more suitable product form. If so, some knowledge of protein characteristics would be helpful. Also, some leads might develop that would help to explain the texture

Table 1.—Development of rancidity in hake portions stored at 0° and −20° F. with and without glaze

Storage conditions		Sensory score (rancidity[1]) of hake portions after storage for (weeks):											
		0	2	3	4	5	7	10	13	18	24	30	36
0° F.	Unglazed	8.3	4.3	5.3	4.0	4.6	4.0	3.5	2.7	3.3	2.0		
	Glazed	8.3	7.3	5.6	8.0	7.0	6.0	6.7	4.7	4.3	5.7	3.0	
−20° F.	Unglazed	8.3	6.0	7.7	7.7	6.6	8.7	7.7	6.0	5.7	4.7	5.0	3.5
	Glazed	8.3	8.3	8.0	6.0	6.3	6.6	8.0	6.7	5.7	6.3	4.3	4.0

[1] A score of 10 indicates no detectable rancidity; scores from 9 to 6 indicate increasing rancidity with an overall acceptable rating; underlined scores of 5 or less indicate rancidity with an overall unacceptable rating.

and moisture-holding characteristics of the flesh.

The methods used to determine nitrogenous constituents were as follows: Sections of muscle below the dorsal fin were cut from individual fish and analyzed within 2 weeks after being landed. Major protein fractions were determined by the method of Dyer, French, and Snow (1950), which involves extraction of protein soluble in 5 percent salt solution and a cold precipitation of the myofibrillar protein. Nonprotein nitrogen was determined on another aliquot of the salt extract by the trichloroacetic acid method. Sarcoplasmic nitrogen was determined indirectly by subtracting the myofibrillar and nonprotein nitrogen contents from the nitrogen content of the salt-soluble extract. Stroma protein was determined by a modification of the method by Lowry, Gilligan, and Katersky (1941). The nonprotein nitrogen fraction was further analyzed by accepted procedures for urea, creatine, volatile bases, trimethylamine oxide, trimethylamine, purine bases, and ninhydrin-positive material (free amino acids) (Dyer, 1945; Dyer, Dyer, and Snow, 1952; Jones, 1955; Rosen, 1957; Dahl, 1963; Minari and Zilversmit, 1963).

Distribution of Nitrogenous Constituents

The amount of total nitrogen and the distribution of the major nitrogenous constituents found in hake caught at different locations and at various times of the year varied considerably among lots of fish (fig. 2). The constituents most affected are the myofibrillar- (muscle fiber portion) and sarcoplasmic- (fluid portion) protein fractions. The absolute values of the nonprotein nitrogen and stroma-protein nitrogen do not vary significantly.

In hake taken from the outside or coastal waters (fig. 2 — Columbia River, Destruction Island, and Vancouver Island) between July and November, the degree of variation among lots of fish and among individual fish within a lot is extensive. Generally, smaller hake had a lower ratio of myofibrillar protein to sarcoplasmic protein.

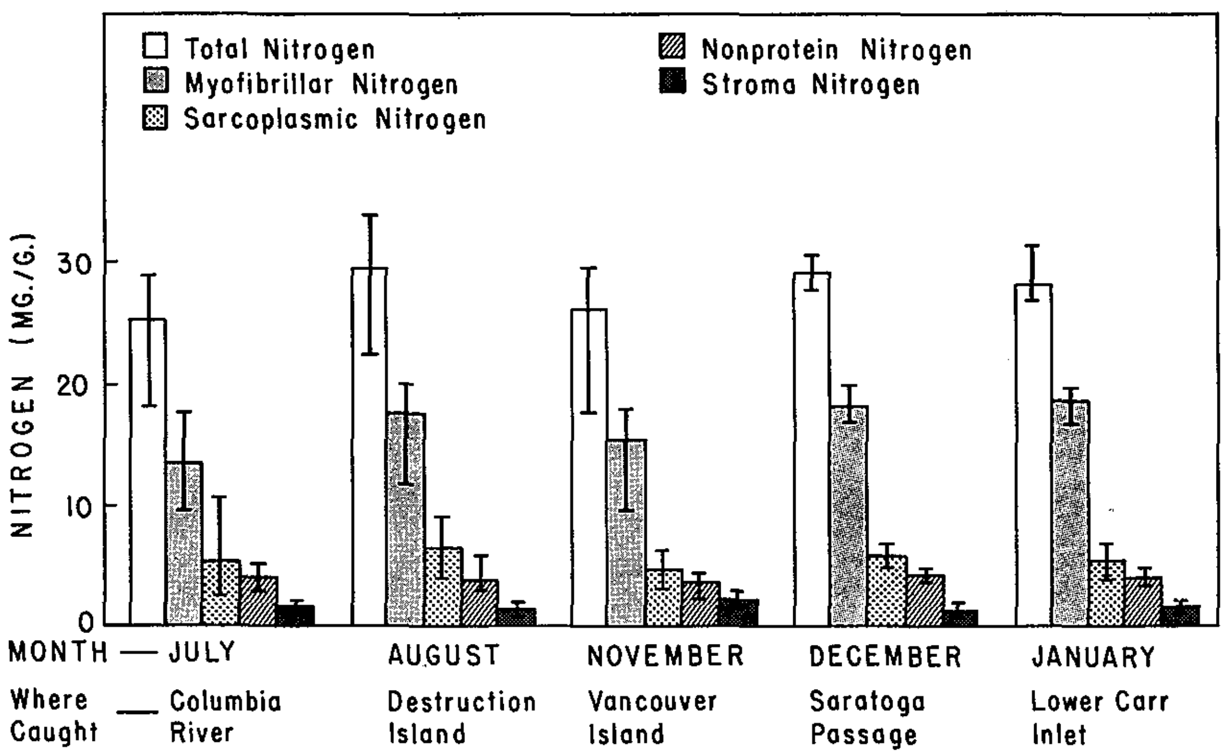

Figure 2.—Nitrogen content of Pacific hake. (The top of the histogram indicates the average value, and the vertical line denotes the range of values.)

In hake caught in December and January in the inside waters of Puget Sound (fig. 2 — Saratoga Passage and lower Carr Inlet), the myofibrillar protein content was significantly higher than that found in outside hake although the inside hake are smaller in size as compared with the outside hake. The degree of fish-to-fish variation was much less in the inside hake. It should be noted that the inside fish grow more slowly and are small for their age, a factor that might affect their protein content and distribution.

The effect of the sarcoplasmic protein on the water-holding capacity of fish is considered to be negligible when compared with the effects of the myofibrillar protein. Outside hake have a low (for July and August) variable ratio of myofibrillar to sarcoplasmic protein. This ratio is higher and more uniform in inside hake. These findings may be related to the observation that, in general, inside hake show better freeze-thaw characteristics with regard to drip loss and texture. These protein variations might also be a factor in the poor water-holding capacity noted in some fresh hake fillets. A rigorous comparison of these protein variations is not possible with the present limited sample groups; therefore, more work is needed if these variations are to be related to seasonal and biological factors in hake growth.

A comparison was made of the distributions of the major nitrogenous components in hake and two other commercially important species — Pacific Ocean perch and English sole (fig. 3). The data indicate that on an absolute basis, hake contain significantly less myofibrillar protein. This difference may explain why both Pacific Ocean perch and English sole show superior freeze-thaw characteristics with regard to drip-loss and ultimate product texture.

Nonprotein Nitrogen Content

The concentration of nonprotein nitrogen in hake is about 4.0 mg. nitrogen/g., or about 15 percent of the total nitrogen. A preliminary investigation of the components present in the nonprotein nitrogen fraction indicated that about 80 percent of the nonprotein fraction could be accounted for as follows: creatine, 34.6 percent; trimethylamine oxide, 23.4 percent; urea, 10 percent; purine base, 9.1 percent; free amino acids, 6.1 percent; volatile base, 5.5 percent; creatinine, 1.4 percent; and trimethylamine, 0.01 percent.

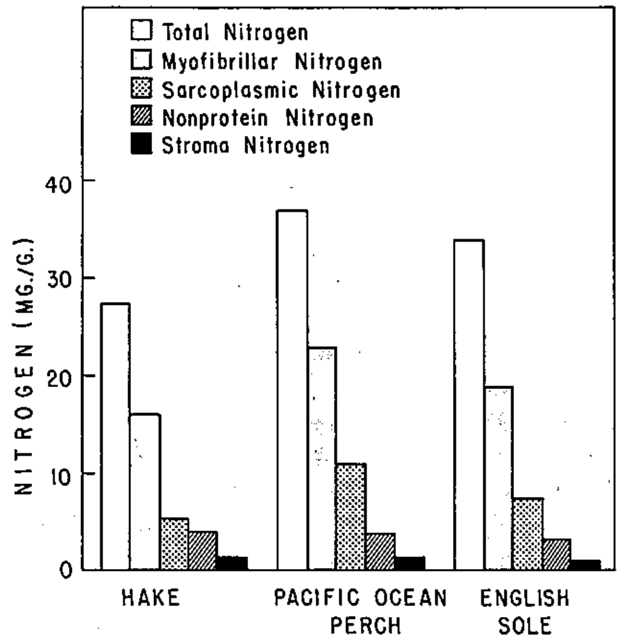

Figure 3.—Nitrogen content of three Pacific coast species.

NUTRITIVE VALUE

The proximate composition indicated that hake fillets should be classed in the low-fat, moderately high-protein category for fish. Amino acid analyses and protein availability tests of experimental whole hake meal by the Nutritional Unit of the BCF Technological Laboratory, College Park, Md., showed that hake meal is a high-quality protein that contains the essential amino acids, typically present in other high-quality fish meals.

SUITABILITY OF HAKE FOR FOOD

This initial evaluation of the significant characteristics affecting the suitability of hake for food has indicated several problem areas concerned with texture and keeping quality. The production of blocks of frozen hake fillets for institutional use would be the most promising food use in the present market. However, until the relatively high incidence of hake with abnormal texture is greatly reduced and quality control guidelines can be applied, it will not be feasible to use hake for this purpose. More tests are needed to establish the guidelines for quality control of hake to be be used as frozen fillets or in blocks, particularly in relation to the texture problem.

Further studies should be oriented toward diversified types of products that can take advantage of the softer texture of the hake. The food technologist and the fish processor must consider using hake as a protein base for processed or re-formed food products. We believe strongly, however, that hake food products must compete in quality and acceptability as well as in price.

Our preliminary study has demonstrated that to use neglected species like Pacific hake, either we must plan processing and handling methods to overcome species deficiencies or must develop new and modified products that can utilize the resource. Quality control and process technology may be more critical and costly on the production line; however, these drawbacks will have to be offset by a large volume of fish and by a lower price of landed fish. The alternative is to use these underutilized species only for the industrial products, such as fish meal and oil, which would provide a lower economic return. This alternative does not appear to be currently practicable to maximize the return to the industry. Probably we need to develop both the food uses and industrial product uses to permit the greatest volume of hake to be harvested, depending on seasonal availability. Use of hake as a food offers the greatest potential for economic return, so our developmental efforts should be largely concentrated in this area.

The Japanese are now examining the possibility of using hake as a "surimi." This product — consisting of minced, washed, and frozen flesh — is used as a raw material for subsequent processing into food products like kamaboko or fish sausage in Japan. The possibility of adapting this modified raw material for processing into foods suitable for U.S. consumer tastes is under study at our laboratory. Research data indicate that the problem of abnormal texture may be overcome by extremely rapid processing or freezing of the hake at sea.

Obviously, the solution to complete utilization of the little-used species lies in their use as fresh or frozen fish, whenever practicable, as well as use in processed foods. Once the decision is made to consider processed foods, we must be ready to discard conventional processes like canning and smoking that change the basic form of the fish very little. One new approach is to produce modified, ground, reformed foods in which flavor and texture can be controlled. Products similar to the spun vegetable proteins must be examined for possible application to this vast reserve of fish protein. Extracted dry protein concentrates, protein hydrolysates, enzymatically modified proteins, and microbiologically converted proteins, although intended for products largely in the future, are in the food research laboratories now. In all these products, the food chemist and process technologist must work more closely with professionals in food nutrition and marketing. We believe that the initial research on the characteristics of Pacific hake has demonstrated promising possibilities for using a substantial share of the resource for a variety of food products.

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MS. #1867

Production of Meal and Oil from Hake

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ABSTRACT

The chemical and physical properties of Pacific hake indicate that it is suitable for production of meal and oil. The oil content is sufficiently high so that wet rendering should be used to produce a high-quality fish meal. A plant built at Aberdeen, Wash., has operated successfully from a technical standpoint but has experienced difficulty obtaining enough hake to enable it to operate profitably and at prices the plant could afford to pay.

CONTENTS

INTRODUCTION

The preceding sections in this Circular indicate that the Pacific hake resource can support a substantial volume fishery. Several factors established early in the research by the BCF (Bureau of Commercial Fisheries) Exploratory Fishing and Gear Research Base at Seattle, Wash., were used as the rationale for building a reduction plant at Aberdeen, Wash. These facts were: (1) Pacific hake is found in concentrated schools off Washington and Oregon from about May to October; (2) these fish can be caught efficiently by the recently developed midwater trawl; (3) the resource is large enough to support a high-volume fishery; and (4) the fish are usually available within a few hours running time from Grays Harbor, on the Washington coast.

Once these facts were substantiated, the BCF Technological Laboratory at Seattle, Wash., in cooperation with several reduction plants, undertook to determine the suitability of Pacific hake for the production of meal and oil. Primary goals of the laboratory were to determine the proximate composition of the raw material, variation in composition with season, processing characteristics of hake, and characteristics of the meal and oil from hake.

Hake offers the possibility of reviving the fish-reduction industry on the Pacific coast. The amount of fish meal produced domestically is less than one-third of the amount consumed, and future production estimates for menhaden meal, the major domestic meal, have not been encouraging. On the Pacific coast the reduction fishery based in California formerly produced an average of 85,000 tons of meal annually. After 1945, however, the decline in the Pacific sardine resource reduced this production to an annual 18,000 to 25,000 tons of meal primarily from tuna and mackerel waste.

Published February 1970.

Other reduction industries such as those producing whale meal in California and herring meal in Washington and Alaska have also showed declining production.

To utilize the hake resource, Pacific Protein, Inc., built a reduction plant at Aberdeen, Wash. It began operation late in the 1966 season. Although the plant had minor startup problems, it was an immediate success. Unfortunately, the supply of fish has been a continual problem. Fishing vessel owners have been reluctant to venture into hake fishing without a financial guarantee. The major deterring factors include: (1) competition from many large foreign trawlers dominating the prime fishing area, and (2) the low price offered for hake. The price of fish meal controls the price of hake. Evidently, fishermen are not convinced that the low price per ton can be offset by the large catches possible with the midwater trawl. They cannot expect a substantial increase in price when 5 to 6 tons of raw material are required to produce 1 ton of finished fish meal normally selling for $120 to $170 per ton.

The discussion that follows deals with the production of hake meal and oil primarily from the technical standpoint. Economic factors are discussed because their omission would leave the reader grossly uninformed about the industry.

FEASIBILITY FOR REDUCTION

We pointed out earlier that Pacific hake meets the major requirements for a reduction fishery from the standpoint of the resource. There are enough hake available to permit efficient harvesting close to port over a fishing season of 5 to 7 months.

The next set of conditions to be met are those for processing.

The physical and chemical characteristics of the raw material are important factors in determining the type of process, process equipment, and processing conditions for fish reduction.

Proximate composition of the hake is of primary importance, because the amounts of protein, oil, ash, and water control the potential yield of meal and oil. Protein content is especially important in relation to the composition and value of the final product. Oil content is an important consideration in the selection of the type of process to be used — wet or dry rendering. If the concentration of oil in the raw fish is above 2 percent, wet rendering is ordinarily used to produce a finished meal in which the concentration of oil is below the maximum acceptable level of 10 percent.

Oil content of hake varies seasonally. Hake obtained during the spring and early summer have an oil content of 1.5 to 3.5 percent. In late summer and fall the oil content increases to 4 to 6 percent.

The protein content ranges between 13 and 16 percent during the spring to fall period. Variation may be related to the spawning cycle as the protein content is lower in the spring and higher in the summer and fall.

The keeping quality of the raw fish affects the reduction operation in at least two ways: (1) partially decomposed fish do not have the same processing characteristics as fresh fish, and (2) decomposition, especially autolysis, results in losses of solids and oil before the fish reach the first step in processing. Hake decompose very rapidly after being captured. The length of time that fish are held uniced aboard the vessel and in the plant, then, is an important factor. As quality decreases, the flesh becomes extremely soft and the fish become difficult to handle. The belly walls may rupture, and body fluids escape. Between the time of capture and the time of processing losses of protein from autolysis of the fish may exceed 20 percent of the total protein. Thus, factors of fundamental importance in hake reduction are the length of time the vessel is at sea and time required to deliver, unload, and begin processing.

Figure 1 shows an idealized material flow diagram for the hake reduction process.

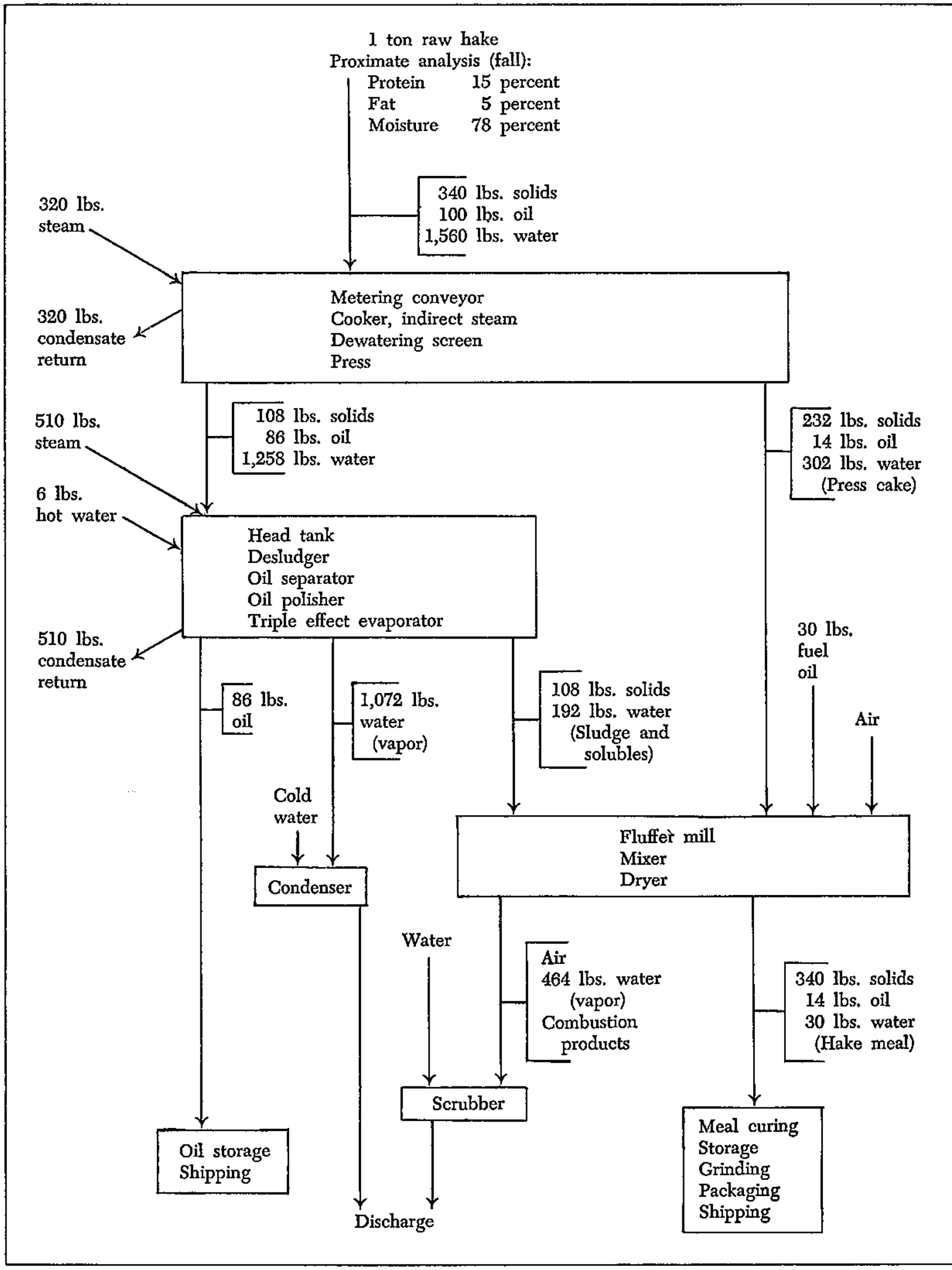

Figure 1.–Material flow diagram for reduction of Pacific hake caught in the fall.

PROCESSING

The wet-rendering process can be used to convert hake to meal, oil, and solubles. Early trials with dry rendering were unsuccessful because the partially dry meal jammed the press used to remove excess oil and resulted in a meal containing an excessively high oil content. Recently, one processor has reported a successful dry rendering of hake.

The successful reduction operation at the Pacific Protein, Inc., plant is based on a conventional, large-scale, wet-reduction system. The cooker is a 25-ton-per-hour capacity, indirect steam cooker with a screw conveyor. Cooking at a high temperature results in a press-cake that is mushy and tends to jam the press or produce a wet press-cake.

The dryer installed at the Pacific Protein plant is a gas-fired, direct-hot-air dryer. Odor emissions are controlled by recycling the moist air discharged from the dryer through a cold-water scrubbing tower, then back into the furnace and through the dryer again. Only enough fresh air is introduced into the furnace to support combustion. Air passing through this cycle system is discharged from the primary combustion zone of the furnace at about 1,400° F. Thus, the odor compounds are largely burned to odorless compounds before being discharged into the atmosphere.

CHARACTERISTICS OF HAKE MEAL AND OIL

The composition of hake meal and the results of nutritive studies are given elsewhere in this Circular. Its composition is very similar to that of British Columbia herring meal, which can be considered a good standard.

Data on the proximate composition of a fish meal indicate the total amount of protein in the product but do not indicate the relative quality of that protein. Analyses of the protein fraction to determine which amino acids are present and their relative quantity are important in estimating the nutritional value. The protein fraction of five samples of hake meal from experimental production runs was assayed for amino acid composition. Table 1 shows the ranges of concentrations of the amino acids found.

The properties of the oil produced from a reduction operation are also important because temperature of solidification, ability to oxidize, and polymerize, color, and other properties dictate how the oil can be used. The oil obtained from Pacific hake has an iodine value of about 160. It is composed of about 26 to 33 percent saturated fatty acids and 15 to 19 percent polyunsaturated fatty acids with 4, 5, or 6 double bonds.

Table 1.—Amino acid analyses of protein from Pacific hake meal

Amino acid	Range of five samples
	Percent of total protein
Lysine	7.9- 8.6
Histidine	2.0- 2.3
Arginine	6.3- 6.8
Aspartic acid	9.7-10.3
Threonine	4.1- 4.5
Serine	4.0- 4.1
Glutamic acid	14.3-14.8
Proline	4.3- 4.9
Glycine	6.6- 7.8
Alanine	6.1- 6.7
Valine	5.0- 5.5
Methionine	3.0- 3.3
Isoleucine	4.5- 4.9
Leucine	7.4- 8.0
Tyrosine	3.1- 3.7
Phenylalanine	4.1- 4.4

ECONOMIC FACTORS

In the idealized flow diagram (fig. 1) we show a yield of 384 pounds of dried hake meal and 86 pounds of oil per ton of raw hake processed. In a practical situation where we take into consideration normal plant losses in processing, seasonal variation of raw material, condition of the fish due to autolysis since catch, and other factors, an average yield per ton of hake will be about 350 pounds of meal and 30 pounds of oil.

If we examine the economics of this hake-reduction operation for various prices of hake and fish meal, the profit and loss potential is about as figures 2, 3, and 4 show. The top boundary of the shaded area represents the cumulative total cost of production of hake meal for the year including fixed plant cost, operation cost, and the cost of the hake at the prices indicated. The dashed lines represent gross income from sales of meal and oil at the meal prices indicated per UP (unit of protein). The oil prices are shown as constant at $0.04 per pound. Allowance has been made for 2½ percent brokerage fee. The assumption that plant operating costs are proportional to the tonnage of hake processed, is somewhat idealized, and we consider that the assumption is completely unreliable below 10,000 tons of hake processed per year.

Break-even points are estimated in table 2 for such a plant designed for 20-ton-per-hour capacity. These break-even points are the intersections of the total cost of production with the lines representing gross income (from figs. 2, 3, and 4) at the fish prices shown.

Table 2.—Break-even points in thousands of tons per year for hake reduction at various prices for hake and meal

Price of fish meal	Plant capacity for raw fish	Price of hake at plant		
		$16 per ton	$20 per ton	$24 per ton
Dollars per unit of protein	*Tons per hour*	*Thousands of tons per year*		
2.00	20	37	N[1]	N[1]
2.25	20	21	49	N[1]
2.50	20	14	24	72
2.75	20	11	15	28
3.00	20	9	12	18

[1] N - Never; losses increase with each ton processed.

Figure 5 shows the variation of fish meal prices starting at $2 per UP in 1962, generally rising to a peak of $2.10 in the autumn of 1965, and dropping back to levels more in line with the previous general trend through 1966 and 1967. An examination of the period 1959-61 shows a high of $2.67 per UP in March 1959 and a low of $1.50 per UP in the first half of 1961.

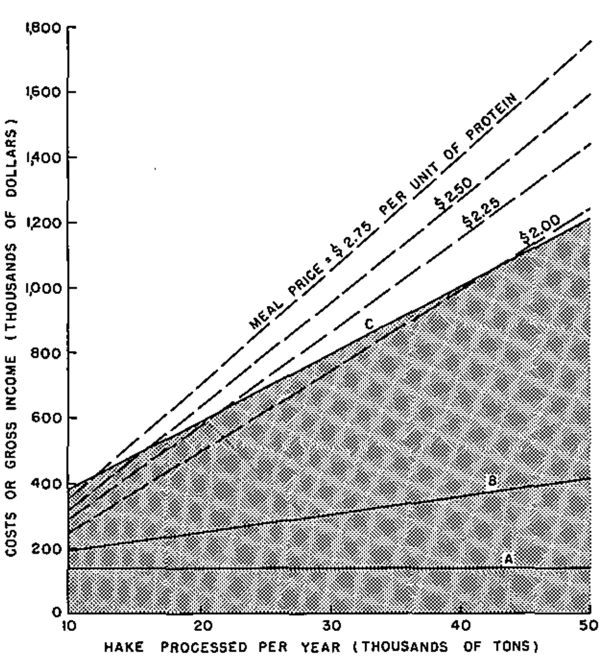

Figure 2.—Economic study of a hake reduction plant with 20-ton-per-hour capacity based on meal prices from $2 to $2.75 per unit of protein, oil price at $0.04 per pound, and hake price at $16 per ton. Line A represents fixed plant cost; B, fixed plant cost plus operation cost; and C, total production cost.

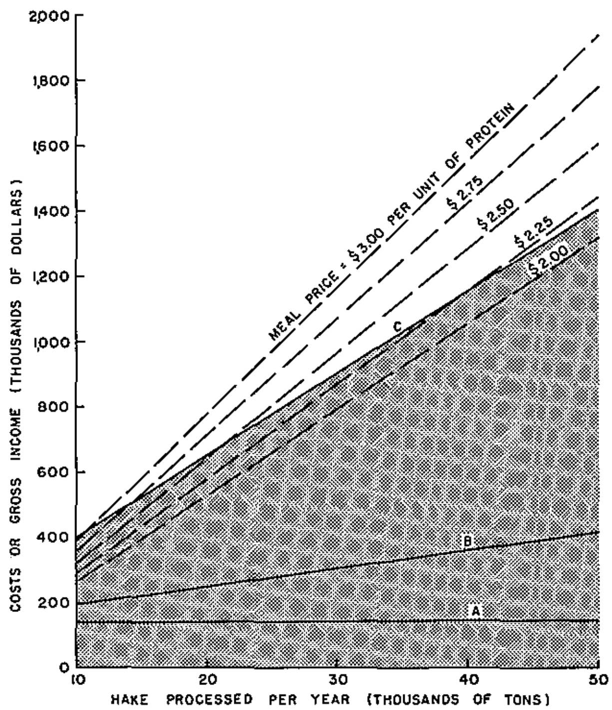

Figure 3.—Economic study of a hake reduction plant with 20-ton-per-hour capacity based on meal prices from $2 to $3 per unit of protein, oil price at $0.04 per pound, and hake price at $20 per ton. Line A represents fixed plant cost; B, fixed plant cost plus operation cost; and C, total production cost.

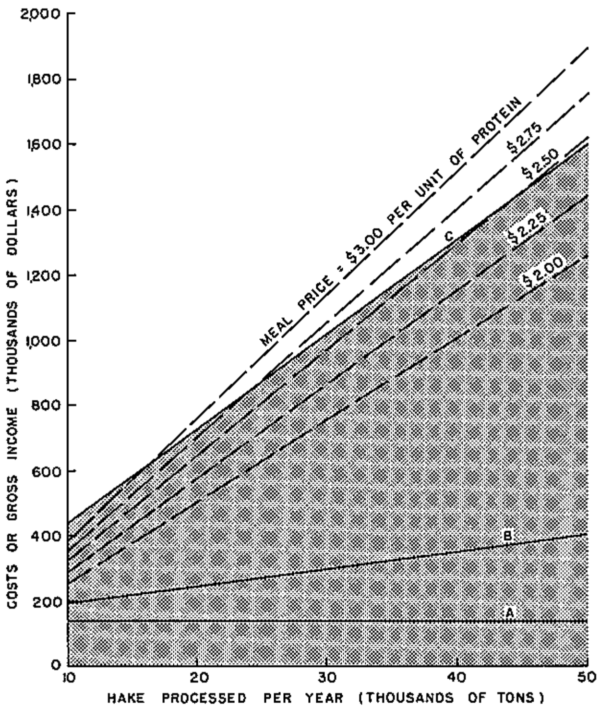

Figure 4.—Economic study of a hake reduction plant with 20-ton-per-hour capacity based on meal prices from $2 to $3 per unit of protein, oil price at $0.04 per pound, and hake price at $24 per ton. Line A represents fixed plant cost; B, fixed plant cost plus operation cost; and C, total production cost.

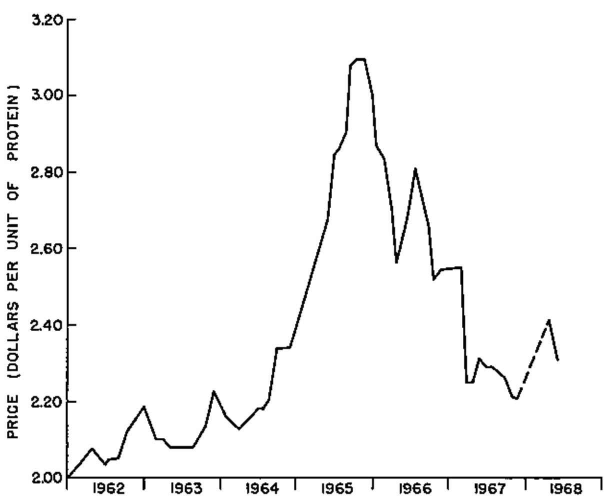

Figure 5.—Price of menhaden meal, f.o.b. east coast ports, quoted at New York, N.Y., January 1962 to June 1968. From BCF Market News Service, Fishery Products Reports.

If we apply the foregoing charts and tables to the situation as it developed at Aberdeen, Wash., we can see more clearly what happened. The operation at Aberdeen was planned in 1965 when rising meal prices were conducive to an optimistic outlook (see fig. 5). The plant was put into operation in July of 1966 when fish meal prices were still high, though declining. Had the price held at the peak for a year or had the plant started operating a year earlier, the hake fishery might have started on its own.

The cost of harvest is high at the start of a new fishery when fishermen are learning about the habits of the fish; the methods of harvest are still being adapted from other fisheries; spotting techniques are being developed and organized among the various boats; participating boats are too few to be effective in cooperative scouting of schools of hake; and the logistics of getting fish from the sea to the plant are still being converted from those based on food-fish concepts. As these problems of pioneering a new fishery are overcome, the cost of hake to the processor can be reduced or the fishermen get a better return or both. Figures 2, 3, and 4 and table 2 show that the buildup in volume of the fishery should result in more total return for the processor and the fisherman; however, the gross income to the processor at meal prices below $3 per UP is too low to support a "bootstrap" startup of this fishery where the initial catch is below 16,000 tons of hake per year.

A healthy fishery for hake reduction is not likely to be achieved without a "priming" operation by some source that can afford a heavy, long-term investment and at the same time apply strong incentives for increased efficiency. Any letdown on pressures for improvement in harvesting efficiency during this pioneering period could end in continued losses of money for both fishermen and processors. The safest approach suggested so far would be through at least a nucleus of processor-owned or controlled fishing boats to gain the utmost in cooperative effort of the fish processor, the fisherman, and sources of capital, the probability of developing the volume of catch necessary to sustain this industry would be improved.

MS. #1871

Preliminary Studies of the Nutritive Value of Hake Meal for Poultry

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ABSTRACT

As new fish meals such as Pacific hake meal are produced and offered to the feeding industry, the value of such meals as ingredients in poultry rations needs to be determined. During 1966 and 1967, meals became available from initial hake reduction operations on the Pacific coast. The composition of three samples of hake meals and their nutritive value in poultry rations were studied. In comparative tests with British Columbia herring meal, all meals promoted good growth when added at the 5 percent level to a basal ration for broilers.

CONTENTS

INTRODUCTION

Fish meals are recognized as excellent sources of proteins, amino acids, vitamins, minerals, and food energy in rations of various types of poultry.

Only 20 percent of the U.S. requirement for fish meal is produced domestically; the rest is imported. The proportion of imported fish meal used in the Pacific Northwest is much higher than the national average.

Because increased production of poultry in the Northwest results in an increased demand for fish meal, it is important that the domestic fish meal production be increased by using species of fish available in North Pacific waters. Production of meal from Pacific hake, *Merluccius productus*, is a step in this direction.

NEED FOR EVALUATION

As new meals such as hake meal are produced and offered to the feeding industry, the value of such meals as ingredients in poultry rations needs to be determined. The information needed includes (1) complete chemical composition of the meal and (2) the results of biological testing. Biological testing is necessary to compare the nutritional worth of the new meal with that of an established fish meal such as herring meal.

Published February 1970.

At this point, I emphasize that the results of our tests should not be interpreted as necessarily typical of commercial Pacific hake meals. At the time our studies were planned, the Pacific hake reduction industry was new and not fully established at a commercially productive level. For reasons not related to our research, the commercial production of hake meal has not been fully developed up to the present. Our tests were made with the meals available from the initial operations; however, confirmatory biological tests should be undertaken when a complete series of meals can be obtained throughout the hake reduction season.

Three samples of hake meal produced by Pacific Proteins, Inc., at Aberdeen, Wash., were studied at the Western Washington Research Center, Puyallup, Wash. The first sample was prepared from fish caught near the end of the 1966 fishing season. No antioxidant was added to the meal. A 1-ton sample of this meal was obtained in March 1967, and biological testing began soon thereafter. The second and third samples of hake meal were prepared from fish caught in June and August 1967, and biological testing began soon after preparation. These samples had 0.04 percent ethoxyquin added as an antioxidant. These three samples of hake meal have been compared with a sample of British Columbia herring meal obtained in the open market in March 1967.

CHEMICAL COMPOSITION OF HAKE AND HERRING MEALS

Table 1 shows the chemical composition of the three samples of hake meal and of the sample of herring meal used in the tests. The composition values for the three samples of hake meal are quite consistent and indicate no substantial differences in composition due to time of capture of fish.

The composition of the hake meal samples was similar to that of the herring meal sample with few exceptions. Both meals contained 74 percent protein. The hake meal was higher than the herring meal in ash content and, as a result, higher in calcium and phosphorus. The hake meals averaged 5.7 percent fat, as determined by ether extraction, whereas the herring meal contained 10.3 percent. The values for the vitamins assayed in hake and herring meals were similar in most instances. An exception was riboflavin; it appears that hake meal contains less of this vitamin than herring meal. The hake meal contained 5.7 mcg./g. of riboflavin as compared with a value of 11.6 mcg./g. previously established as a mean for several samples of herring meal (March, Biely, and Tarr, 1962).

The amino acid compositions of the hake and herring meals were similar except that the herring meal contained about twice as much tryptophan as the hake meals. That this was peculiar to the one sample of herring meal is indicated by the average value of 0.648 percent tryptophan previously established as the mean for several samples of herring meal (March et al., 1962). The latter value was practically identical with the mean of the three samples of hake meal. The amount of sulfur amino acids in the two meals was similar with some suggestion that it may be slightly lower in hake meal. This is particularly true if the cystine value for herring meal (0.45 percent) is considered to be low when compared with the mean of 0.725 percent previously reported (March et al., 1962).

No striking difference in macro or micro element content between the hake and herring meals is noted except for calcium and phosphorus as previously noted. There is an indication (table 1) that hake meal contains more strontium and less fluorine than herring meal.

BIOLOGICAL TESTS

In a test to compare the 1966 sample of hake meal with a 1967 herring meal as an ingredient in practical broiler rations, comparisons were made with diets containing varying levels of meat meal, fish meals, and cottonseed meal (table 2). Each ration was fed to three groups of 75 one-day-old birds until they were 8.5 weeks old. At end of the test, the mean

Table 1.–Composition of hake and herring meals

Component	Hake meals 1966 sample	Hake meals June 1967 sample	Hake meals August 1967 sample	Hake meals Average of 3 hake meals	Herring meal
Vitamins (mcg./g.)					
Biotin	0.576	0.595	0.505	0.559	0.393
Niacin	77.8	82.0	68.4	76.1	75.0
Folic acid	0.532	0.364	0.452	0.449	0.404
Vitamin B_{12}	0.189	0.230	0.204	0.208	0.258
Riboflavin	5.82	6.12	5.36	5.77	8,64
Choline chloride	4.82	3.81	4.14	4.26	5.68
Pantothenic acid	16.1	18.4	21.9	18.8	21.9
Vitamin B_6	4.00	4.28	3.20	3.83	----
Amino acids (percent of meal)					
Lysine	5.91	5.58	4.89	5.46	4.67
Arginine	3.88	4.04	3.46	3.79	3.67
Methionine	1.41	1.66	2.01	1.69	1.87
Cystine	.56	.56	.50	.54	.45
Histidine	1.56	1.37	1.30	1.41	1.31
Tryptophan	.59	.61	.71	.64	1.16
Aspartic	6.59	6.77	6.44	6.60	6.69
Threonine	2.73	2.81	3.84	3.13	3.94
Serine	2.61	2.70	2.68	2.66	2.67
Proline	3.33	3.31	3.12	3.25	3.17
Glycine	5.09	5.38	4.83	5.10	4.18
Alanine	4.66	4.76	3.96	4.46	4.14
Valine	2.98	3.10	3.49	3.19	3.59
Leucine	4.89	5.00	4.86	4.92	5.08
Isoleucine	2.64	2.73	2.67	2.68	2.59
Tryosine	1.80	1.98	2.11	1.96	2.19
Phenylalanine	2.38	2.46	2.59	2.48	2.68
Glutamic	9.41	9.58	10.20	9.73	8.67
Fatty acids (percent)					
C-10	0.00	0.00	0.10	0.03	0.19
C-12	0.11	0.22	0.19	0.17	0.15
C-14	3.14	3.16	2.81	3.04	7.40
C-15	0.28	0.53	0.39	0.40	0.58
C-16	49.40	39.50	33.45	40.78	30.06
C-16:1	9.21	11.00	8.78	9.66	8.48
C-17	1.07	1.37	0.35	0.93	0.00
C-18	6.92	8.26	8.47	7.88	5.61
C-18:1	28.10	33.20	33.86	31.72	29.02
C-18:2	0.76	1.17	5.75	2.56	1.82
C-18:3	0.44	0.35	2.55	1.11	8.74
C-20:4	0.53	1.18	3.19	1.63	7.90
Composition (percent)					
Moisture	4.0	3.2	6.4	4.5	7.2
Ash	14.5	16.0	13.3	14.6	10.6
Fat by either extraction	5.5	5.4	6.3	5.7	10.3
Fiber	0.9	0.8	0.7	0.8	0.5
Carbohydrate	0.0	0.0	0.0	0.0	0.0
Protein	74.5	74.6	74.7	74.6	74.1
Nonprotein nitrogen	1.86	1.32	1.60	1.59	1.60
Urea	<0.1	<0.1	<0.1	<0.1	<0.1
Ammonia	0.16	0.34	0.28	0.29	0.22
Minerals					
Sulfur, percent	1.26	1.23	.98	1.16	1.10
Calcium, percent	3.30	4.00	3.00	3.43	2.30
Phosphorous, percent	2.20	2.50	1.90	2.20	1.80
Potassium, percent	1.80	1.60	1.60	1.67	1.20
Sodium, percent	.64	.66	.60	.63	.42
Magnesium, percent	.11	.14	.13	.13	.12
Cobalt, p.p.m.	<0.5	<0.5	<0.1	<0.3	<0.1
Aluminum, p.p.m.	48	74	65	62	40
Barium, p.p.m.	2.0	4.9	3.5	3.5	<1.0
Iron, p.p.m.	140	107	102	116	172
Strontium, p.p.m.	113	175	125	138	38
Boron, p.p.m.	11	13	6.3	10.1	6.3
Copper, p.p.m.	4.6	6.6	6.9	6.0	5.5
Zinc, p.p.m.	92	99	84	92	108
Manganese, p.p.m.	7.1	7.1	7.0	7.1	6.5
Chromium, p.p.m.	<3.0	<3.0	6.5	4.1	3.7
Iodine, p.p.m.	1.0	0.75	0.68	0.81	0.50
Fluorine, p.p.m.	248	290	370	303	500

Table 2.—The effect of hake and herring meals on growth and feed efficiency of fryers[1]

Diet variables				Body weight at:		Feed/unit gain at:	
Meat meal	Hake meal[2]	Herring meal	Cottonseed meal	5 weeks	8.5 weeks	5 weeks	8.5 weeks
Percent	*Percent*	*Percent*	*Percent*	*Grams*	*Grams*		
0	5.0	--	--	875	1,796	1.86	2.38
--	--	5.0	--	880	1,805	1.89	2.42
5.0	2.5	--	--	898	1,778	1.82	2.41
5.0	5.0	--	--	908	1,787	1.80	2.35
5.0	7.5	--	--	903	1,796	1.82	2.39
5.0	--	2.5	--	908	1,842	1.85	2.37
5.0	--	5.0	--	912	1,837	1.78	2.32
5.0	--	7.5	--	898	1,801	1.78	2.30
5.0	5.0	--	5.0	894	1,760	1.85	2.42
5.0	--	5.0	5.0	908	1,778	1.82	2.42
7.5	5.0	--	--	908	1,816	1.81	2.36
7.5	--	5.0	--	903	1,816	1.81	2.34

[1] Average of three groups of 75 chicks of mixed sex.
[2] 1966 hake meal secured from Pacific Proteins, Inc.

weight of the birds fed the rations with hake meal was 1,787 g. compared with 1,814 g. for those fed rations with herring meal. The advantage for herring meal was small but significant at the 2 percent level of probability.

Herring meal tended to promote slightly better feed efficiency than hake meal. The differences between the fish meals were small, however, and open to question because of abnormal sex distribution in some of the pens.

In a similar feeding trial, rations were fed to three groups of 75 one-day-old birds until 8 weeks of age. Three samples of hake meal and one herring meal were compared by adding 5 and 10 percent fish meal to a corn-soybean meal basal diet containing 5 percent meat meal. Also included in the test for comparison were diets with Peruvian anchoveta meal of unknown age, a Puget Sound hake meal of high-fat content made in 1967, and a Pacific coast hake meal of June 1967 with 2 percent added hake oil. Table 3 shows results of the study. Adding 5 percent of any of the fish meals to the basal ration resulted in a significant increase in growth and feed efficiency. There was no significant difference between fish meals; all promoted equally good growth. Increasing the fish meal to 10 percent did not increase growth in any instance. The weight gain of chicks fed rations containing 10 percent of either the June or August 1967 Pacific coast hake meals was not significantly different from that of the chicks fed the basal ration alone. There was a definite trend, however, for rations with the 10 percent fish meal levels to promote increased feed efficiency. Addition of 2 percent hake oil to the ration depressed growth and prevented

Table 3.—Effect of kind and level of fish meal on the growth of fryer chicks

Kind of fish meal	Fish meal	Weights at 8 weeks[1]		Feed/gain[2]
	Percent	*Pounds*	*Grams*[2]	
None	0	3.759	1,705 a	2.223 a
1966 hake meal, Pacific coast	5	3.865	1,753 bc	2.133 bc
1966 hake meal, Pacific coast	10	3.872	1,756 bc	2.107 cd
June 1967 hake meal, Pacific coast	5	3.864	1,753 bc	2.170 b
June 1967 hake meal, Pacific coast	10	3.740	1,697 a	2.143 bc
August 1967 hake meal, Pacific coast	5	3.925	1,780 c	2.167 b
August 1967 hake meal, Pacific coast	10	3.820	1,733 ab	2.147 b
British Columbia herring meal	5	3.865	1,753 bc	2.153 b
British Columbia herring meal	10	3.914	1,775 c	2.093 d
June 1967 hake + 2 percent hake oil[3]	5	3.770	1,710 a	2.160 b
Puget Sound hake meal	5	3.864	1,753 bc	2.207 a
Peruvian anchoveta meal	5	3.873	1,756 bc	2.170 b

[1] Average of three groups of 75 chicks each.
[2] Values followed by the same letter are not significantly different ($P < .05$).
[3] 2 percent hake oil added to the total ration.

Table 4.—Effect of hake and herring meals in diets for turkey poults

Diet variables				Average weight at 4 weeks[3]	Average feed/gain	Cases of perosis[4]
Meat meal	C.S.M.[1]	Hake meal[2]	Herring meal			
Percent	*Percent*	*Percent*	*Percent*	*Grams*		
--	--	--	--	665	1.57	5/30
--	--	2.5	--	686	1.56	1/30
--	--	5.0	--	679	1.55	2/30
--	--	7.5	--	660	1.54	7/30
--	--	--	2.5	678	1.53	3/30
--	--	--	5.0	690	1.53	3/30
--	--	--	7.5	701	1.49	4/30
7.5	--	2.5	--	676	1.51	3/29
7.5	--	5.0	--	691	1.45	5/30
7.5	--	7.5	--	689	1.53	5/30
7.5	--	--	2.5	656	1.46	5/30
7.5	--	--	5.0	693	1.47	8/30
7.5	--	--	7.5	696	1.49	5/30
5.0	5.0	2.5	--	656	1.55	3/30
5.0	5.0	5.0	--	682	1.52	2/30
5.0	5.0	7.5	--	671	1.52	5/30
5.0	5.0	--	2.5	675	1.54	4/30
5.0	5.0	--	5.0	678	1.53	6/30
5.0	5.0	--	7.5	689	1.50	7/30
Average of all fed hake meal				679	1.53	33/269
Average of all fed herring meal				684	1.50	45/270
Average corn-soybean basal				682	1.53	20/180
Average corn-soy-meat basal				684	1.49	31/179
Average corn-soy-meat-cottonseed basal				675	1.53	27/180

[1] Cottonseed meal containing 44 percent protein.
[2] Sample of hake meal of June 1967.
[3] Average of three groups of 10 poults each.
[4] Number of cases/number of poults.

pigment deposition in the flesh and horny tissue of the bird.

Table 4 presents the results of a test designed to compare hake meal with herring meal in diets of turkey poults. This study ended at 4 weeks. The average weight of the poults fed diets with hake meal was 679 g., and for those fed diets with herring meal was 684 g. This small difference was not significant. There was a corresponding small improvement in feed efficiency with herring meal, which was not statistically significant.

Hake and herring meals promoted similar growth of White Leghorn pullets (table 5). In this test, diets containing 5 and 10 percent of the June 1967 sample of hake meal have been compared with herring meal as protein supplements in diets for raising White Leghorn pullets through the growing period and the early stages of the egg laying period (table 6). There was essentially no difference in rate of development of the birds on the two fish meals as expressed by average body weight and age at 50 percent lay. In addition, rate of lay to 28 weeks of age was the same with both meals.

Table 5.—Comparison of hake and herring meals in promoting growth of White Leghorn pullets

Fish meal in ration		Body weight[1] at:				Mortality during 16 weeks
Kind	Amount	4 weeks	8 weeks	12 weeks	16 weeks	
	Percent	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Hake	5	0.572	1.40	1.94	2.42	0.59
Hake	[2]10	0.574	1.41	1.98	2.48	0.0
Herring	5	0.596	1.43	2.03	2.49	1.19
Herring	[2]10	0.596	1.44	2.02	2.51	0.59

[1] Average of three groups of 50 birds each.
[2] Changed to 7.5 percent after 8 weeks.

Table 6.—Comparison of hake and herring meals in rations of White Leghorn laying pullets.

Fish meal in ration		Body weight[1] at:		Feed consumed per bird		Age at 50% lay	Lay		Mortality	
Kind	Amount	20 weeks	28 weeks	0-20 weeks	20-28 weeks		20-24 weeks	24-28 weeks	0-20 weeks	20-28 weeks
	Percent	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Days*	*Percent*	*Percent*	*Percent*	*Percent*
Hake	5	2.67	3.56	14.15	10.30	170	14.5	76.6	2.41	1.87
Hake	10	2.71	3.56	13.76	10.14	170	17.4	74.3	0.62	0.00
Herring	5	2.72	3.61	14.50	10.01	171	12.9	74.4	1.79	3.60
Herring	10	2.75	3.66	14.23	10.13	170	14.3	74.2	2.36	2.43

[1] Average of three groups of 50 birds each.

ACKNOWLEDGMENT

This research was done under contract no. 14-17-0007-935 with the Bureau of Commercial Fisheries, under PL-88-309, and the Washington State Department of Fisheries.

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MS. #1897

Feeding Pacific Hake to Mink

By

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ABSTRACT

Pacific hake offers considerable potential as an economical protein source for mink rations. Early research demonstrated that a serious problem, "cotton-fur," a manifestation of iron deficiency, was caused by feeding raw hake to mink. This problem was identified and surmounted by heat-processing the hake. This report deals with investigation of the nutritional value to the mink of rations containing several forms and quantities of hake.

CONTENTS

INTRODUCTION

In the continuing search for economical food for mink, Pacific hake has considerable potential because it is available in large numbers off the coast of the Pacific Northwest States. Hake might be caught specifically as food for furbearers.

EXPERIMENTS IN FEEDING HAKE

Hake is not unknown to the fur ranchers, who have used, from time to time, the hake that have been caught incidentally with other species. We estimate that the value of the pelts marketed by the mink raising industry in the Pacific Northwest (Washington, Oregon, and Idaho) for the 1968 marketing year was $10,663,000, based on $16.33 average value per pelt.

Our initial experiments involved the feeding of raw hake to mink. As a result of this work, we began experiments on using wet-processed hake in mink rations. Later we tried hake meal.

RAW HAKE

We recognized quite early that when rations containing 20 percent or more of raw hake were fed to mink, the underfur was not pigmented, a condition commonly called "cotton-fur" (Stout, Oldfield, and Adair, 1960a). Our experimental studies later revealed that cotton-fur was part of a syndrome that also included

Published February 1970.

a severe microcytic, hypochromic anemia and marked growth depression (Stout, Oldfield, and Adair, 1960b). The underlying cause of these conditions was a deficiency of available iron induced by the action of an unidentified, organic factor in the raw hake. We demonstrated that the factor concerned in iron interference was heat-labile, and this knowledge provided a practical solution to the problems involved in the feeding of hake to mink (Stout et al., 1960b).

WET-PROCESSED HAKE

We began experiments at the Experimental Fur Farm of the Department of Animal Science at Oregon State University in 1959 (Adair, Stout, and Oldfield, 1960) to test the usefulness of cooked hake as a diet component for young, growing mink. In this preliminary work, the hake was heated to 88° C. and held for 5 minutes at that temperature to inactivate the iron-interfering factor. The resulting product was fed as 20 percent of the wet diet, replacing a like amount of another fish species which was fed in a control ration. Table 1 shows composition of control and hake diets. The growth and fur characteristics of the mink fed the cooked hake diet were similar to those for the control animals.

In the following year we fed to growing mink two additional diets containing hake at levels of 30 and 40 percent by weight on a wet basis (Adair, Stout, and Oldfield, 1961). In this work, the hake, in addition to being cooked as before, was acidified with phosphoric acid to pH 4.5 in an attempt to eliminate the need for freezing the product and holding in cold storage. Mink that were fed the cooked-acidified hake at the 30 percent dietary level had satisfactory growth and fur characteristics. Mink fed at the 40 percent level, however, had poorer growth and fur quality than those fed the control diet without hake or those fed the 30 percent level of processed hake. We observed that feed consumption was lowered when cooked-acidified hake made up 40 percent of the diet. This decrease suggested that the food was less palatable, possibly because of the acid addition rather than the hake itself. Table 2 gives the comparison of performance data from animals fed the various levels of cooked-acidified hake.

Table 1.—Composition of cooked hake and control diets

Item	Processed hake diet	Control diet[1]
	Percent	*Percent*
Processed hake	20	—
Sole	—	20
Rockfish	25	25
Turbot	25	25
Tripe	10	10
Cereal[2]	9	9
Horsemeat	8	8
Beef liver	3	3
Total	100	100

[1] A typical diet fed to mink in the Pacific Northwest during the early 1960's.
[2] The cereal mix contained the following percentages: Wheat germ, 25.0; alfalfa meal, 12.5; skim milk powder, 8.3; meat meal, 16.7; soybean oil meal, 16.7; ground oat groats, 16.6; and brewers' yeast, 4.2.

In 1965 two experimental groups of 26 mink each were fed rations containing 25 percent of hake processed either by heating or by heating and phosphoric acid addition, as previously described (Adair, Stout, and Oldfield, 1966). Both groups performed well and compared favorably in terms of growth and fur characteristics to a control group fed a "typical" Pacific Northwest mink diet (see table 1). Paradoxically, in view of the cotton-fur problem when raw hake was fed, these processed hake products appeared to contribute to a desirable darkening of the fur of standard dark mink. These experiments supported the thesis that hake, if treated so as to inactivate the cotton-fur causative factor, could be a useful, major ingredient in mink diets.

Subsequently, we again fed heated and acidified hake at the 30 percent dietary level with somewhat less satisfactory results, which suggested that the optimum level for the acid-treated material may lie between 25 and 30 percent of the diet, as fed (Adair, Stout, and Oldfield, 1967). In addition, we attempted a more radical approach wherein wet-heated hake was fed as the sole source of protein for 134 days, at a level of 80 percent of the moist diet (Adair et al., 1967). Table 3 gives composition of this latter diet.

As shown in table 3, some adjustment of energy content of the high-hake diet was necessary and we accomplished this by adding lard and sugar (sucrose). The wet-cooked hake, therefore, was the sole source of protein and the major source of minerals and vitamins

Table 2.—Data from mink fed control diet and diets at various levels of cooked, acidified hake

Item	Performance of mink fed					
	No hake (control)[1]		30 percent hake		40 percent hake	
	Males	Females	Males	Females	Males	Females
Final body weight, g.	2,030	1,008	1,850	1,125	1,470	1,074
Weight gain, g.	1,062	348	908	433	511	385
Animal length, cm.	45	37.5	43	37.5	42	37
Fur color[2]	2.2	1.8	1.4	1.9	2.2	2.3
Fur quality[2]	1.6	1.3	1.1	1.0	1.6	1.6
Weight of dried skin, g.	119	64	101	60	90	57
Length of dried skin, cm.	70.5	55.5	67.5	57	63.5	56
"Wet belly" incidence,[3] %	67	0	67	0	11	0
Estimated pelt value,[4] $	14.00	10.00	18.00	10.50	15.00	8.50
Ration cost, % of control[5]	100	100	96	96	97	97

[1] A typical diet fed to mink in the Pacific Northwest during the early 1960's.
[2] Fur color and quality, taken from dried skins, were scored on a scale of 1 (best) to 4 (poorest) by a commercial fur grader.
[3] "Wet belly" is an unprime area of fur surrounding the urinary orifice of the skin. It detracts substantially from the pelt value.
[4] Assigned by commercial fur graders and adjusted for pelt size and occurrence and severity of wet belly.
[5] Costs are estimated because there is no commercial production of processed hake for mink rations.

Table 3.—Composition of a ration using wet-cooked hake as the sole source of protein

Item	Diet (as fed)
	Percent
Wet-cooked hake	85
Lard	4
Sucrose (cane sugar)	11
Total	100

Vitamin E (d-α-tocopheryl acetate) was added as 0.01 percent of the total ration, and 0.5 percent guar gum and 4 percent wheat bran were added to improve consistency of ration.

in this diet. When hake is cooked in the manner described, the resulting product is semisolid. Consequently, when such a high level of hake is included in a diet, the mixture is sloppy and cannot be fed on the wire of the animal cages in the conventional manner. In this experiment, the high-hake diet was fed in earthenware bowls placed on the floor of the cages — a practice that would not be satisfactory on large mink ranches. Notwithstanding the impracticality of this ration, the experiment did establish the suitability of hake protein in support of mink growth and fur production. The problem of physical consistency of the ration can probably be overcome by the addition of nutritionally innocuous binders to the mix.

HAKE MEAL

Like other fish, hake can be reduced to meal; details of the reduction process and the composition of the hake meal have been reported in another section of this Circular. Other fish meals, notably herring, and whitefish have had limited usefulness in some ranch-mink rations.

In 1966 and 1967, we tried hake meal at a 20 percent level in mink rations that have a large amount of dry material. Such rations are currently receiving considerable attention in the fur-farm industry as a possible, economical replacement for diet mixes made from fresh ingredients, which require cold storage. In the first year experiments we used hake meal that was produced in a pilot plant and did not contain the stickwater fraction (Adair et al., 1967). In the second year, we used hake meal that had the stickwater fraction added (Adair, Stout, and Costley, 1968). In each year, the growth of mink on the ration containing hake meal was somewhat less than that of comparable mink on a conventional control diet. This difference might suggest that the nutrient content of the high-dry-matter rations was not optimal; however, we also observed that growth on the hake-meal diet was lower than that on a similar dry diet containing an equivalent amount of herring meal. In view of the satisfactory performance of mink on protein supplied by wet-cooked hake, we may infer that the processing method involved in the production of meal from hake was not optimal (Stout, Adair, and Oldfield, 1968).

The history of the mink industry in this country indicates a succession of changes from one major feed source to another, depending largely on availability and various economic factors. Our experimental work with Pacific hake suggests that this fish, if properly processed, may be a useful addition to this succession and may serve in the future as a major constituent of diets for mink.

ACKNOWLEDGMENT

This research was conducted under contract no. 14-17-007-832 with the Bureau of Commercial Fisheries, under PL-88-309, and the Oregon Fish Commission.

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MS. #1868

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