

**Proceedings of the Second Annual Tropical and
Subtropical Fisheries Technological Conference
of the Americas**

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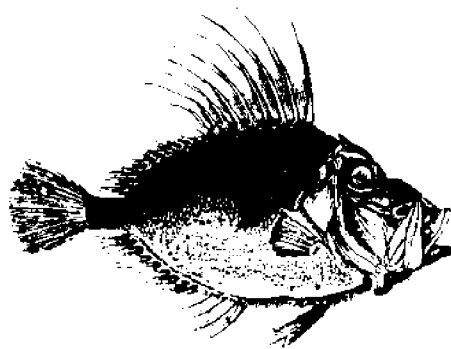
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PROCEEDINGS
of the
SECOND ANNUAL TROPICAL AND SUBTROPICAL
FISHERIES TECHNOLOGICAL CONFERENCE OF THE AMERICAS

October 1977

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Compiled by

Ranzell Nickelson, II

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SCIAENID STOCKS OF THE WESTERN CENTRAL ATLANTIC
BETWEEN CHESAPEAKE BAY, VIRGINIA AND THE AMAZON RIVER, BRAZIL

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The major species of demersal fishes exploited within the western central Atlantic between Cape Hatteras, N. C. and the Amazon River, Brazil are in the family Sciaenidae. They are exploited directly as industrial and food fishes and indirectly as discards of the fish or shrimp fleet. Numerous species of sciaenids are highly prized by sport fishermen (3).

Sciaenids are distributed throughout the entire area from Chesapeake Bay, Va. to off the northeast coast of South America (Fig. 1). Centers of abundance are: the Chesapeake Bay area, around the Mississippi River Delta, and the area off the northeastern coast of South America in association with the Surinam River.

This brief review is concerned with the larger species which are or can be utilized as food or industrial fish. These are: croaker (Micropogon undulatus and M. furnieri), spot (Leiostomus xanthurus), seatrouts (Cynoscion sp.), red drum (Sciaenops ocellata), black drum (Pogonias cromis), Surinam butterfish (Nebris microps), and whiting (Macrodon ancylodon). Many of these species are now utilized extensively, and most of them could sustain additional fishing pressure.

DISTRIBUTIONAL PATTERNS

Sciaenids are continental shelf species found in semitropical and tropical regions. Throughout the western central Atlantic they are primarily estuarine dependent during portions of their life cycle. Species of black bar drums (Pareques) are the only sciaenids which do not use the estuary as a nursery and should be considered insular species.

Continental shelf species inhabit environments which change seasonally and ecologically. These changes are produced by runoff from large rivers and currents generated by tide and wind. These conditions affect movement of water mass, turbidity, and bottom characteristics. Continental shelf species require broad muddy bottom areas, including bays and sounds with a strong estuarine influence on the population. Although sciaenids occur in profusion in the inshore areas of the western central Atlantic area, they are

almost entirely excluded from the islands of the Caribbean and the Bahamas. Centers of abundance for these stocks are associated with major freshwater discharge areas and/or extensive estuarine systems (Fig. 1).

Sciaenids have various life history features which characterize tropical faunas regardless of their geographical location. These are a protracted spawning period, rapid growth, high mortality, and reduced longevity. Stocks in the more northerly latitudes show the greatest divergence from the classic pattern with a compression of spawning period and a somewhat slower growth rate. In addition to these life history features, families of fishes found in the tropics, generally have more genera and species than those found in temperate zones. The family Sciaenidae is represented in the western central Atlantic between Chesapeake Bay, Va. and the Amazon River by 23 genera and 54 species.

GENERALIZED LIFE HISTORY PATTERN

Life histories among sciaenid species differ somewhat, but a similar pattern exists with some differences in timing. The pattern described below is based on that seen for croaker (M. undulatus) and spot from the contiguous waters of the United States (4).

Spawning occurs offshore in the winter with the eggs and larvae or both entering the sounds or bays on wind or tidal currents. Development continues throughout the winter and spring in the estuarine system and in late spring or summer juvenile fish move offshore (Fig. 2). They remain near shore in depths less than 5 fathoms (9 m.) throughout much of the summer. Juvenile croaker move in and out of the bays and sounds at random during this period; however, the overall movement is in the direction of the open Gulf of Mexico. With the onset of cooler temperatures in late fall or winter, croaker and spot move further offshore into depths of 15-40 fathoms (27-73 m.).

Age and growth analysis is complicated by the protracted spawning season and environmental variability. It is known that fishes within the family Sciaenidae are fast growing, short lived, and have an extremely high rate of natural mortality. Gulf of Mexico croaker have a mortality of about 90% their first year. If this is reasonably accurate, population mortality by the end of the third year of life is approximately 97 percent.

DISTRIBUTION OF STOCKS

Mid-Atlantic

Mid-Atlantic sciaenids are primarily exploited for food and consist principally of croaker (M. undulatus), spot, and weakfish (Cynoscion regalis). These stocks, which were quite high and supported a substantial fishery, have declined (6). In the late sixties this decline was arrested and stocks now show a small increase as reflected in the present landings (Fig. 3). No stock estimates for sciaenids in this region are presently available.

South Atlantic

The South Atlantic area extending from Cape Hatteras, N. C. to off Cape Canaveral, Fla. has large quantities of sciaenids (1, 11, 8, 12).

They are generally found in bays, sounds, and immediately offshore in depths less than 10 fathoms (18m)(Fig. 4). In North Carolina sufficient quantities of large croaker (M. undulatus) and trout (C. regalis) are caught to support a foodfish fishery, but the vast majority of sciaenids are caught incidental to foodfish operations and are processed as industrial fish (12). Sciaenid species of major commercial importance in the North Carolina fishery are spot, croaker, and trout, with 100% of the spot, 65% of the croaker, and 43% of the trout utilized as industrial items. The remainder are sold as foodfish.

Other South Atlantic States have large standing stocks of sciaenids, which are principally caught incidentally by shrimp fishermen and discarded at sea or are utilized by sport fishermen. Commercially caught sciaenids, ranked in order of numerical dominance, are: star drum (Stellifer lanceolatus), croaker (M. undulatus), spot, and ground mullet (Menticirrhus sp.); however, when measured by landed weights the order changes to spot, croaker, ground mullet, trout, and star drum.

Overall finfish/heads on shrimp (F/S) discard ratios for North Carolina and Georgia are reported as 5.4:1 and 4.7:1 (12, 8). The similar ratio in each of these two states leads to the assumption that the South Carolina and Florida F/S ratio would be somewhat the same. Shrimp landings in these four states for 1972 amounted to 25 million lbs. (11,333 metric tons); therefore, the magnitude of the finfish discards was about 125 million lbs. (56,664 metric tons). Sciaenids comprise about 75% of the discards; therefore, a minimal estimate of the overall magnitude of the sciaenid discards would amount to about 100 million lbs. (45,331 metric tons). An average discard ratio distorts the actual magnitude of the discards because it masks the time of maximum finfish density (late summer, fall) and over estimates the time of minimum finfish density. Coastal regions of the South Atlantic States (depths out to 10 fathoms) (18 m.) appear to have an abundant supply of demersal fishes that could possibly support an industrial fishery (11).

Gulf of Mexico

Sciaenids are found throughout the Gulf of Mexico, but they are in greatest profusion between Mobile Bay, Ala. and the Atchafalaya Bay in La. (Fig. 5). Densities decreased east of Mobile Bay, Ala. and west of the Atchafalaya Bay, La. with the greatest decrease seen eastward. However, limited pockets of high sciaenid densities exist outside that area in which sciaenids are presently exploited. The industrial and foodfish fisheries in the northern Gulf of Mexico primarily exploit croaker (M. undulatus), spot, and trout (Cynoscion nothus and C. arenarius)(5). Croaker comprise about 50% of the landings (10). Magnitude of the sciaenid stocks within that area fished by the industrial bottomfish fleet amount to about 410,000 metric tons.

Within the Gulf of Mexico, sciaenids are generally distributed in environs similar to those found along the South Atlantic States, except in the northern Gulf of Mexico they have a broader bathymetric range, extending out to about 50 fathoms (92 m.). The central feature of the northern Gulf is the Mississippi River Delta

and its associated soft mud bottom resulting from the deposition of silt from the river. Seasonally high densities of sciaenids are found out to depths of 30 fathoms (55 m.), with commercial concentrations sometimes noted as deep as 50 fathoms (92 m.). Seasonality dictates depth distribution with exploitable sciaenids found offshore in the colder months and inshore during the warmer months.

Total finfish stocks in the Gulf of Mexico are reported at 2,681,000 metric tons (7). Assuming that sciaenids represent about 40% of the total biomass, then sciaenid stocks in the Gulf of Mexico amount to 1,000,000 metric tons. Present utilization of sciaenids including the sport catch account for somewhere near 250,000 metric tons. Sciaenid landings in the Gulf of Mexico presently appear to be about equally divided between sport and commercial interests when the shrimp fleet discards are not considered. The main species exploited by sport and commercial interests are: croaker, sea trout, red and black drum, and spot. Principal sport effort is expended within the bays, sounds, and estuarine areas.

Caribbean

Distribution of sciaenids is more limited throughout the Caribbean than in other geographical regions. Caribbean sciaenids have the greatest potential for exploitation off the northern coasts of Colombia and Venezuela. Little information is available concerning the commercial potential from this region, but Cervigon and Gomez (2) list some density estimates for sea trout and croaker (M. furnieri). A standing stock estimate of finfish for this area is reported as 65,000 metric tons (7). Assuming sciaenids make up 25% of the total finfish stocks, they would only amount to about 15,000 metric tons. Exploitable stocks may be available in restricted area throughout this region but these would probably be utilized for only fresh fish on a local basis.

Northeastern South America

Large quantities of sciaenids are available for exploitation along the northeastern coast of South America (Fig. 5). Presently, sciaenids occurring in the shrimp by-catch are discarded at sea except for the larger, higher priced finfish which can be sold as foodfish. Local fishing could be directed at a foodfish fishery using mainly sciaenids. Catch rates of finfish in lbs/hour have been reported for this area from exploratory cruises conducted by the CALAMAR (9). Marketable finfish catch rates in lbs/hr (kilo./hr.) were as follows: Venezuela (Orinoco Delta), 73 (33); Guyana, 357 (162); Surinam, 504 (229); and French Guiana, 186 (84); with sciaenids generally representing more than 50% of the total catch. Simulated trawl fish production cruises were then conducted by the CALAMAR (July-Oct. 1967 and Aug.-Oct. 1968). These cruises produced 224,730 lbs (102 metric tons) of marketable finfish in 57 days of fishing (daily catch rate of 4,494 lbs. (2 metric tons); (9).

Sciaenid species in this area differ from those along the southeastern United States and the Gulf of Mexico. South American species are represented by several species of sea trout (Cynoscion virescens, C. jamaicensis, C. similus, C. steindachneri, and C. acoupa); croaker, Surinam butterfish; and whiting. An excellent fresh-fish market potential exists throughout this area utilizing these sciaenid species.

SUMMARY

Species of sciaenids are found throughout the western-central Atlantic between Chesapeake Bay, Va. and the Amazon River, Brazil. They are probably the most abundant family of inshore fishes and as such are probably capable of withstanding further exploitation. Dynamics of the sciaenid population appear to be governed as much by environmental conditions as by man's predation. Sciaenid species are capable of withstanding a high rate of exploitation because of high fecundity and fast growth with primary growth completed by the end of the first year of life. Species within the family Sciaenidae generally appear to be capable of reinstating a high population level within a few years after the population has been reduced. It is highly likely that the more abundant species of sciaenids will become increasingly important as food fish items throughout the tropical and semitropical regions of the western central Atlantic in the the future.

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FIGURE LEGENDS

- FIGURE 1.--Distribution of sciaenids from Chesapeake Bay, Va., to the Amazon River, Brazil; heavy shaded area represents centers of abundance.
- FIGURE 2.--Life cycle of croaker (Micropogon undulatus) in the northern Gulf of Mexico.
- FIGURE 3.--Landings of Atlantic croaker, spot, and weakfish from the Chesapeake area for 1930 through 1976.
- FIGURE 4.--Distribution of sciaenids along the southeastern Atlantic between Chesapeake Bay, Va., and Cape Canaveral, Fla.
- FIGURE 5.--Distribution of sciaenids in the Gulf of Mexico.
- FIGURE 6.--Distribution of sciaenids along the northeastern coast of South America between the Orinoco River Delta and the Amazon River, Brazil.

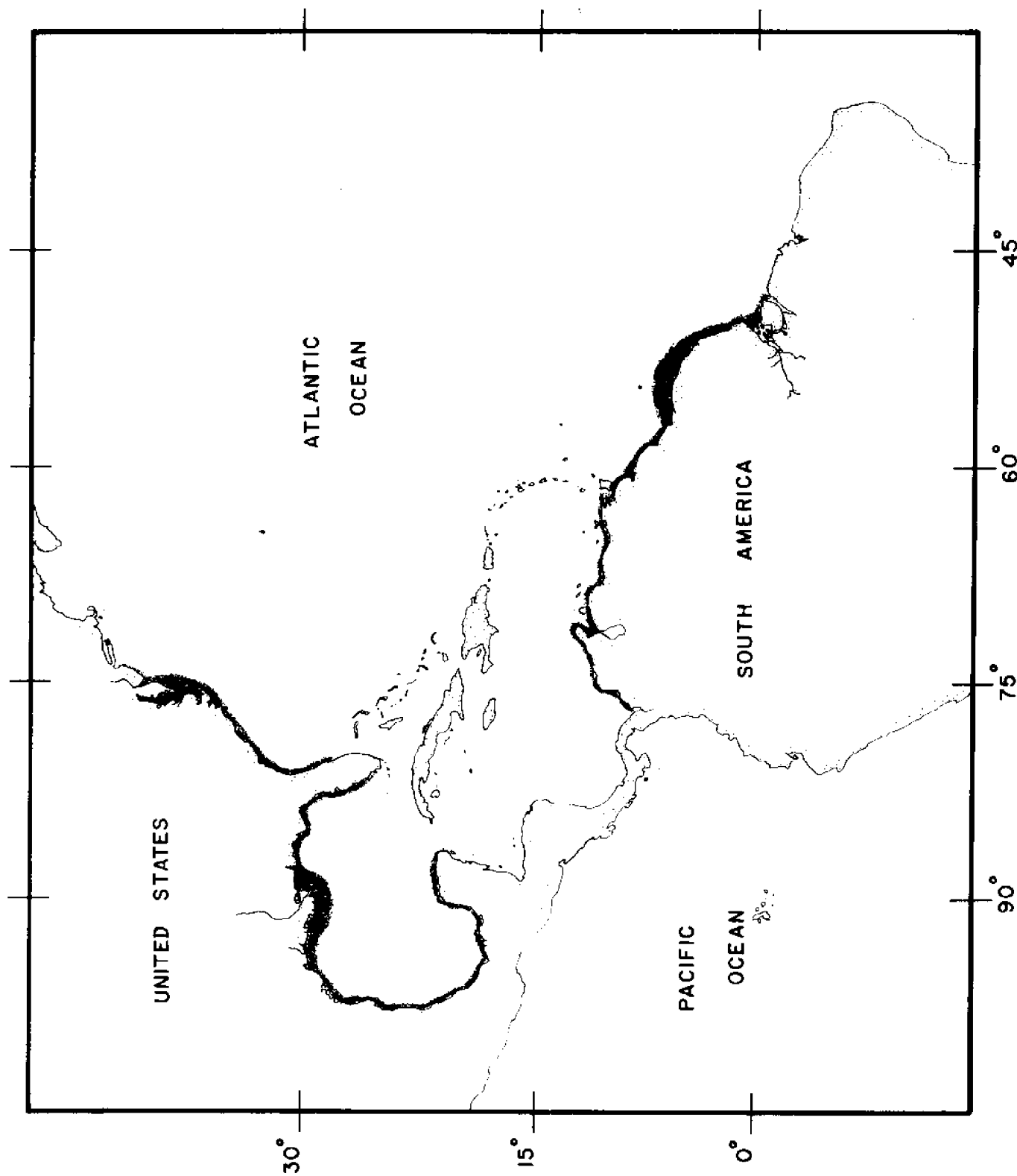


FIGURE 1.--Distribution of sciaenids from Chesapeake Bay, Va. to the Amazon River, Brazil; heavy shaded area represents centers of abundance.

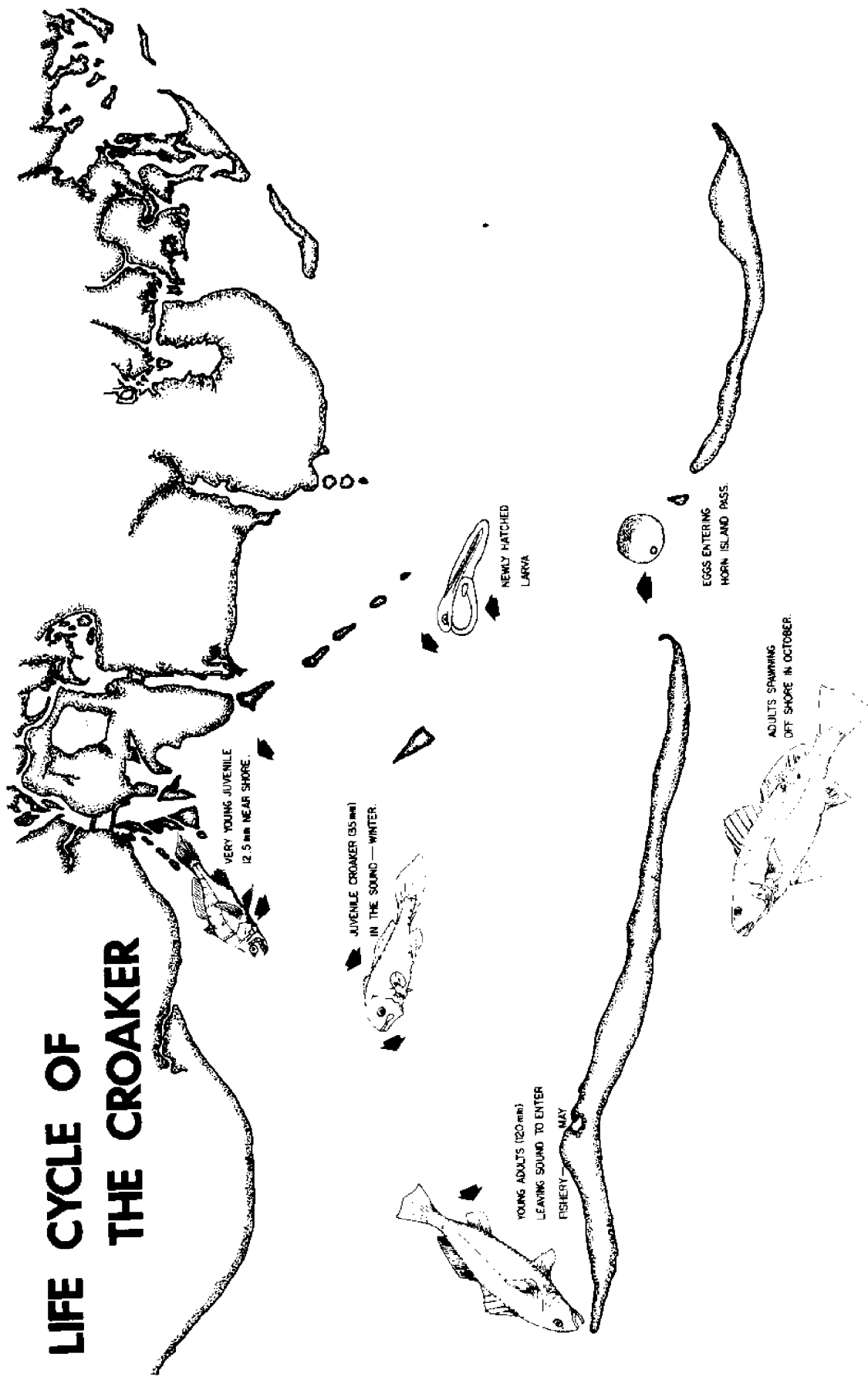


FIGURE 2.—Life cycle of croaker (*Micropogon undulatus*) in the northern Gulf of Mexico.

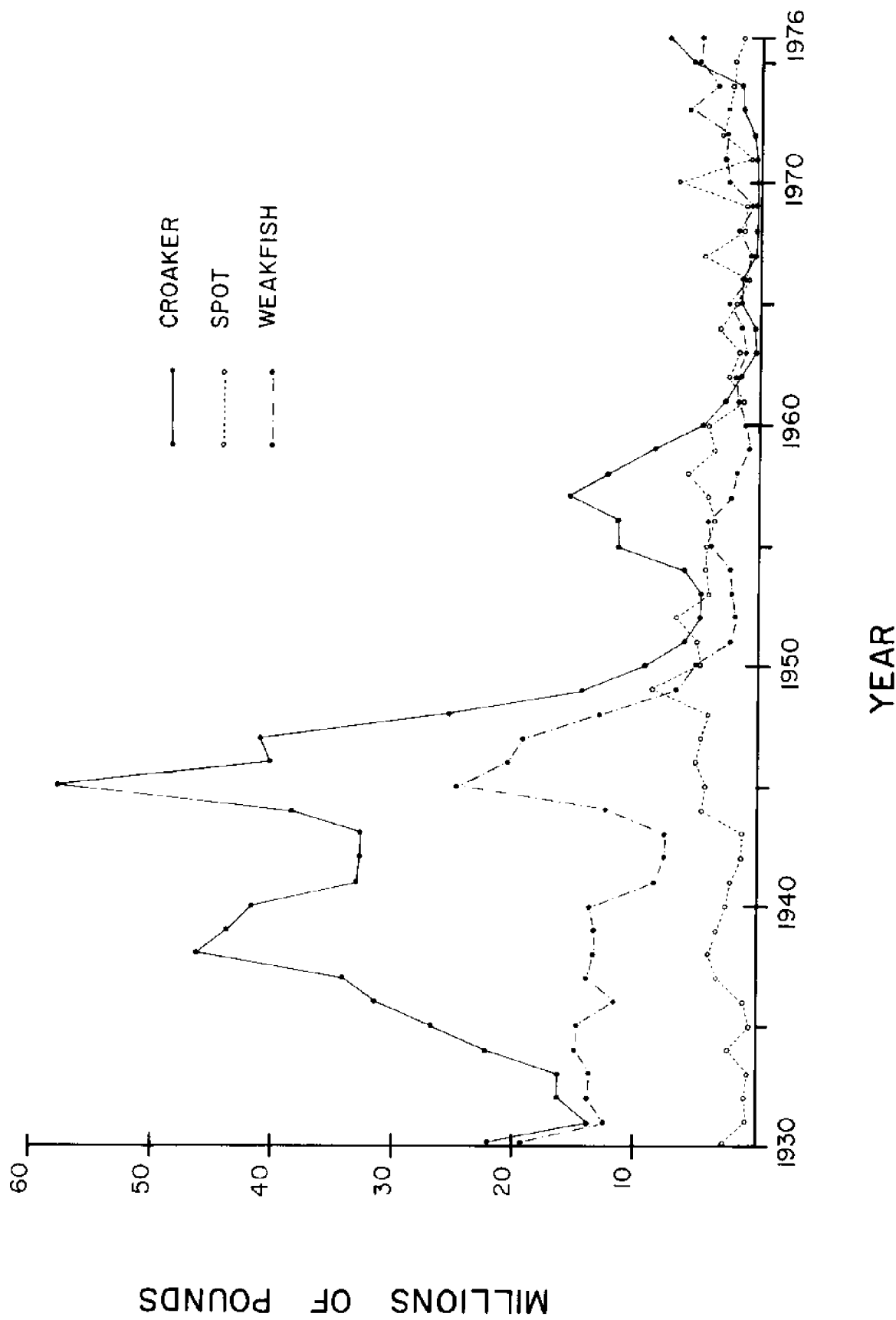


FIGURE 3.--Landings of Atlantic croaker, spot, and weakfish from the Chesapeake area for 1930 through 1976.

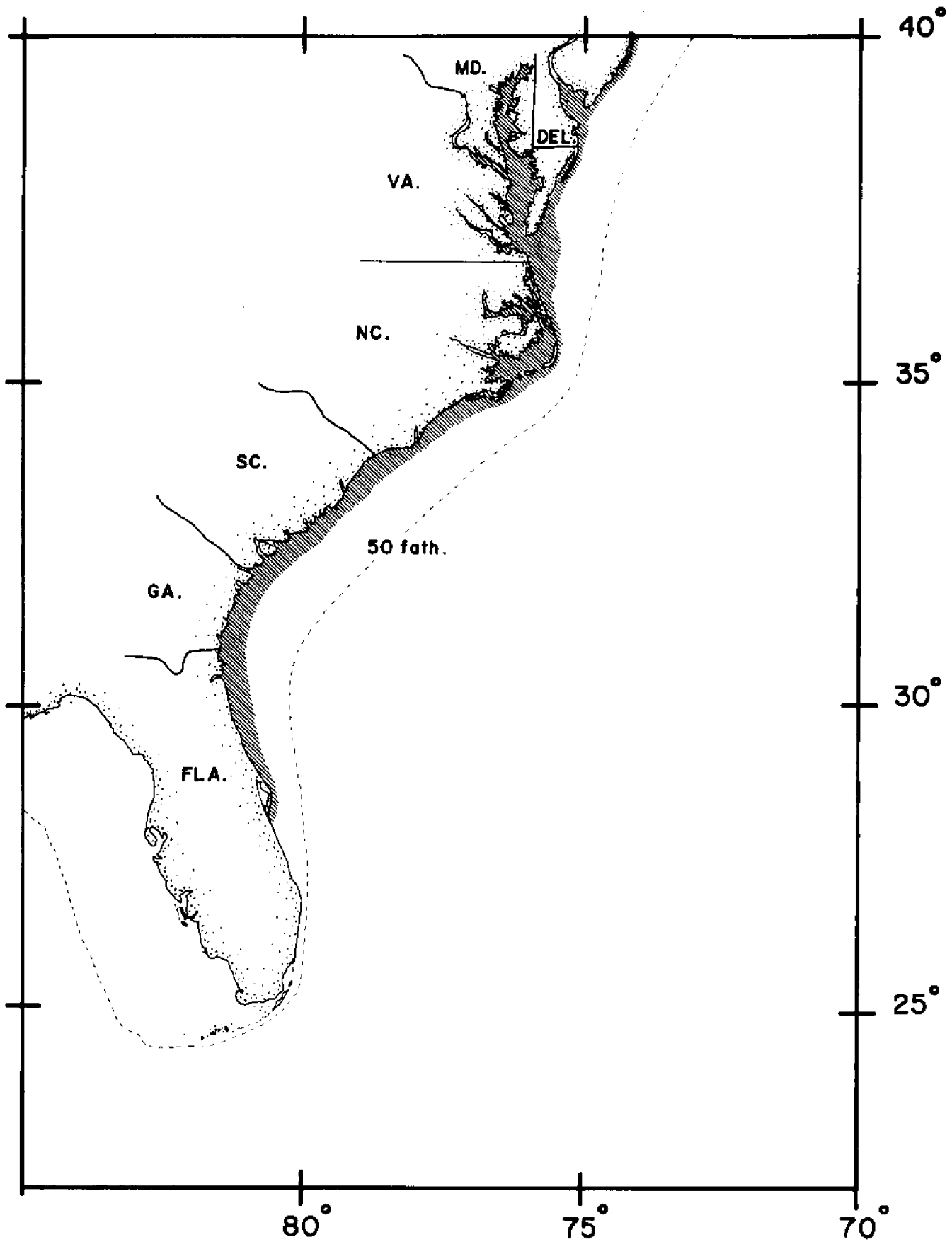


FIGURE 4.--Distribution of sciaenids along the southeastern Atlantic between Chesapeake Bay, Va., and Cape Canaveral, Fla.

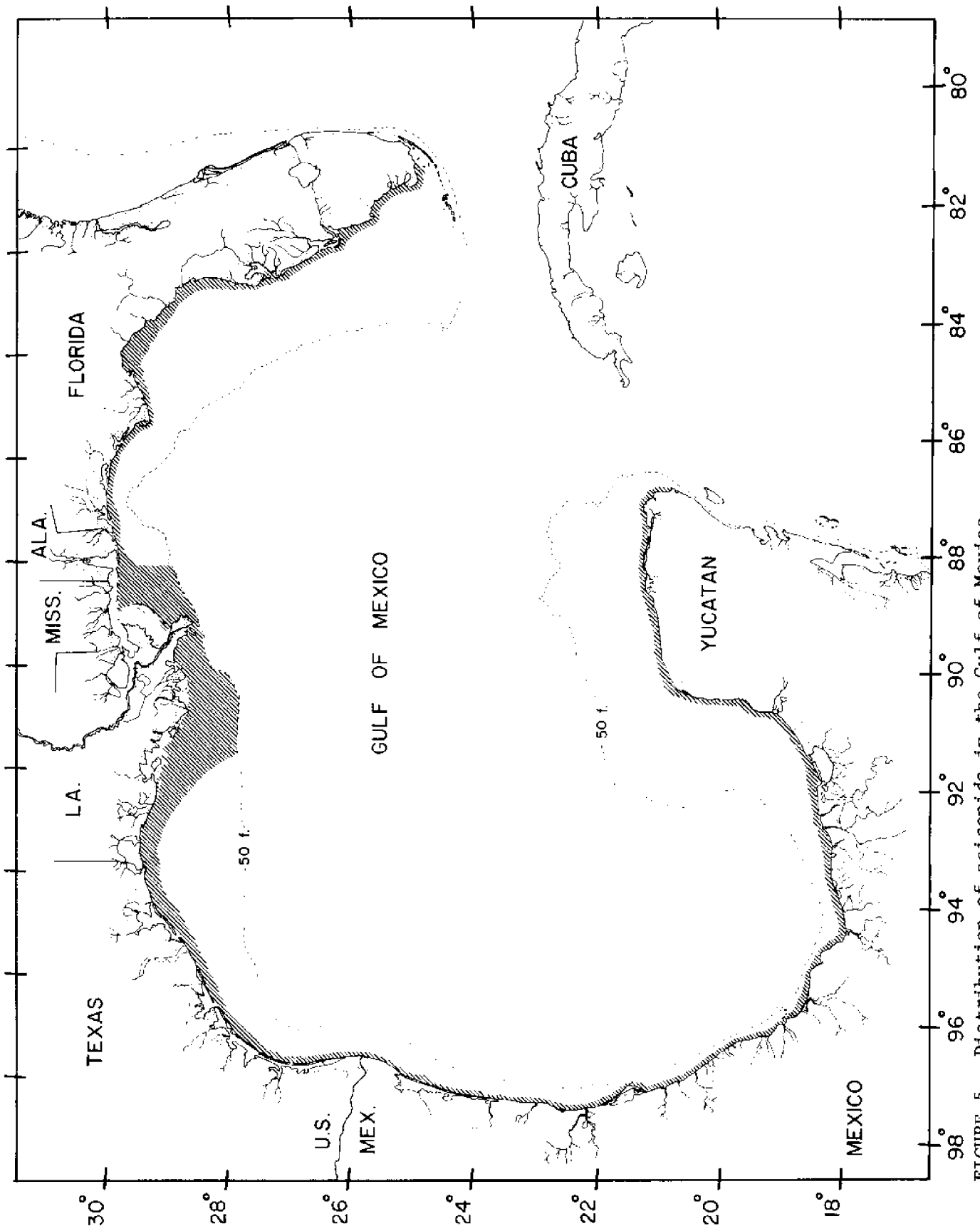


FIGURE 5.--Distribution of sciaenids in the Gulf of Mexico.

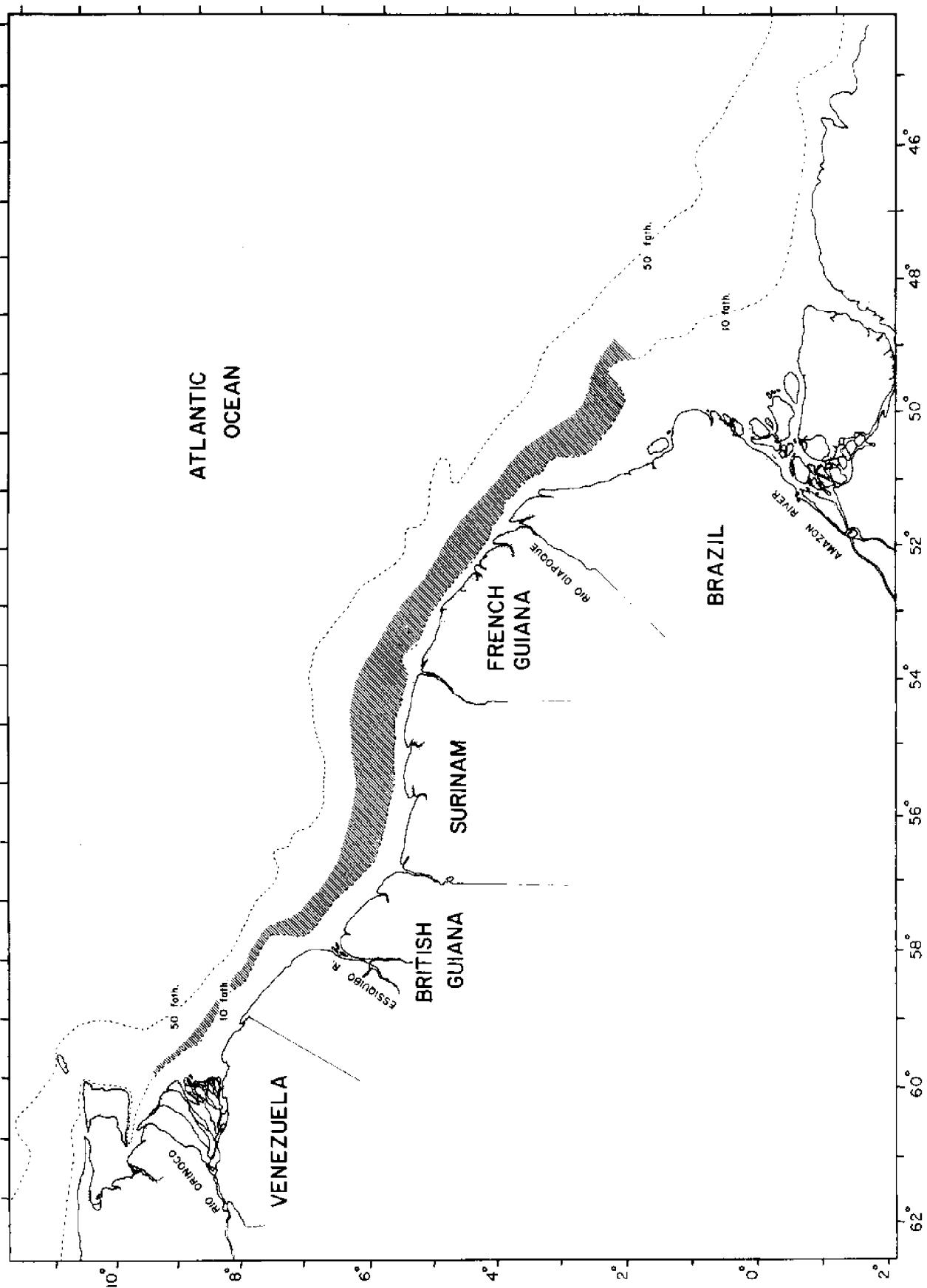


FIGURE 6.—Distribution of sciaenids along the northeastern coast of South America between the Orinoco River Delta and the Amazon River, Brazil.

CATCH PER UNIT OF EFFORT IN THE FLORIDA SPINY LOBSTER FISHERY

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Reliable data on catch-per-unit-effort (CPUE) in the Florida spiny lobster (Panulirus argus) fishery have not been published previously for the same reason that makes them difficult to obtain in the better known northern lobster (Homarus americanus) fishery. Gathering these very essential analytical statistics requires an unusual degree of cooperation on the part of fishermen involved in such studies. Usually this means placing an observer on board recording trap yields, noting the most productive areas, and reporting total production. While the observer may not actually interfere with the work routine, his presence ordinarily is a constraint on common fishing practices that may involve the violation of a variety of conservation laws and tax regulations. Thomas (1973) avoided some of these problems by developing an elaborate stratified probability sampling procedure for his data collection in the Maine lobster fishery. However, Wilson (1977) working in a small sector of the same region has published mixed CPUE data volunteered by fishermen working alone (about 70% of total) with input from project members and claims no significant statistical difference exists.

Examples of CPUE in studies from Florida are essentially limited to the work of Davis (1977) and those of Warner, Coombs, and Gregory (1977). The former discusses results from the totally protected Dry Tortugas National Monument area where all commercial activity has been prohibited for decades. The latter simulated commercial methods during successive four-month closed seasons in the Key West area.

STUDY AREA CONDITIONS

Lobster habitat in Southeastern Florida is atypical of the much more extensive grounds in the Florida Keys where coral reefs and turtle grass (Thalassia) beds predominate. Conditions in the study area have been illustrated and described elsewhere (Craig, 1974) as consisting of lengthy tabular masses of calcarenite (beach rock and water-table rock) covered with epiphytic growths of coral, sponges, and gorgonians. Spiny lobster frequent the dens created by wave erosion and fracturing of these submerged ledges at times when Pleistocene shorelines were much lower than at present.

At the beginning of each fishing season (20 July-1 August) water temperatures are high and lobster feeding activity is at a peak. Strong north-setting currents periodically sweep along this coast as the Florida Current axis unpredictably moves landward. With the approach of the autumnal equinox, the first distinct period of rough seas associated with the passage of a frontal system appears to trigger the mass migratory response documented by Herrnkind, *et al.* (1973). During the winter season the intervals between successive fronts are often only a few days. Water temperatures reach their lowest point when wedges of plankton-rich neritic water are inserted between the coast and the western edge of the Florida Current.

Toward the end of the season (March 31), there is a gradual increase in both temperatures and rhythm of biological activity although seas do not generally subside until the normal summer weather pattern is established in May or June.

METHODS

The present study uses data gathered from a comparatively small (105 Km²) offshore area of 17 m mean depth located between Hillsborough Inlet and Delray Beach in southeastern Florida. All trapping activity was conducted by the investigator so that data gathering was derived from a commercially structured operation identical to realities of the Florida spiny lobster industry.

At the beginning of the 1972-73 season, 250 wooden slat traps of standard top opening design were individually identified and placed at uniform depths and intervals throughout the study area. Each trap was hauled, serviced, and returned to the same location with the appropriate data recorded on board using a trip sheet posted by one of the operators. The data used in this report represent part of the cumulative catch figures acquired in this manner but no special effort was made to establish any preconceived levels of production or effort.

The following season approximately the same number of traps were deployed over the study area in multiple strings of ten each with ground line spacing of 100 m between traps. This method, known as fishing by "trawls," was attempted in order to make some assessment of its efficiency relative to the hauling of single traps. Midway through the season this system was discontinued due to inherent dangers caused by inadequacies in the vessel design. Data for the period October 1973-January 1974 have, unfortunately, not survived intact and were unavailable for analysis in this report.

RESULTS

Figure 1 (A-C) graphically presents average weight of legal catch in kilos, total number of shorts, and a CPUE based on trap hauls in kg/trap over a two-year period.

In Figure 1-A there is an apparent gradual decline in average weight during the season from an initial .50 kg in

August to .47 kg in January but the abrupt rise to .59 kg indicated for November remains unexplained. The decline in numbers of shorts shown in Figure 1-B from an August high of 346 to March low of 54 is believed to accurately reflect cumulative long-term changes in length-frequency of the population. Figure 1-C shows the effects of the last major autumnal mass migration to be noted in the study area. In this case the CPUE curve appears to accurately reflect the young adult population dynamics associated with this phenomena. The August high of .83 kg/trap haul is followed by an abrupt decline to .37 kg for September while the population is less vulnerable to trapping. The October maxima of .88 kg/trap haul probably represents a CPUE ceiling that may not be attained again in view of the deteriorating stock densities.

DISCUSSION

Statistical results obtained from this study have been analyzed by P. Kanciruk (Dept. of Life Sciences, Nova University) who determined by testing that changes shown for average weight of lobsters captured during the 1972-73 season do not have real significance. However, the ratios of short:legal animals did change significantly during this season, varying from 22.6% in August-September to 16.0% for the February-March sample ($\chi^2_1 = 15.08$ - highly significant at the 1% confidence level). The preferred interpretation of these data is that cumulative fishing pressure has removed most of the larger animals from previous year classes and therefore focusses on young adults as they recruit to legal size during the course of each new season.

Of more direct interest are the CPUE data graphically shown in Figure 1-C where there is a significant change from the beginning to the end of the season ($\chi^2_7 = 158$ for the 8-month period). The peak in October is statistically real (χ^2_1 for Oct. vs. Nov. = 254 - highly significant) as is the minimum for September (χ^2_1 for Sept. vs. Oct. = 120). A comparison of CPUE between the August and March samples for 1972-73 results in $\chi^2_1 = 29.1$ and 5.27 significant at the 5% confidence level, for the 1973-74 data.

These findings are consistent with my initial hypothesis that the resource is heavily overfished. This conclusion cannot be rigorously applied to the fishery as a whole because the test area may not be representative and the sampling period is obviously too short. Nevertheless, in the complete absence of contrary data, the implications for conservation management are clear.

Comparison of CPUE between fisheries

The traditional wood slat trap used in northern waters is known to be effective in design - especially since general adoption of knitted twine entranceways and parlors during the 1950s - and has been shown to exert an instantaneous fishing mortality between 90-94.5% (Thomas 1973:56). Comparable

calculations for Florida traps are lacking but we can assume the absence of constricted entrances makes them significantly less effective. However, spiny lobsters are highly social animals attracted to traps already occupied so that these traps have a low coefficient of gear saturation. The result is a tendency toward gear crowding and overfishing.

Spiny lobsters in inshore waters of Florida have distinct increases in stock abundance on a seasonal basis that are not directly related to changes in water temperature. Fishing mortality then becomes proportional to their availability to trapping which is reflected in fluctuations of CPUE not found in the northern lobster fishery.

Static trap fisheries cannot be compared theoretically to other fisheries where on-board gear is shot and recovered. Consequently there is no hypothetical lower limit for CPUE below which fishermen refuse to work (see Cushing 1968:99, Fig. 46) because once the initial placement effort has been made trap tending can be performed on a discretionary basis whenever conditions are judged opportune. This is particularly true in the Florida Keys where fishing strategy involves using unbaited traps. Nevertheless, Table 1 provides an opportunity to make a comparison of two relatively equivalent samples where identical data were collected under carefully controlled circumstances. However, in comparing CPUE between fisheries it is necessary to consider the effect of weather on catch rates. In northern fisheries effort is often curtailed many days by winter storms. This does not necessarily reduce catch rates in traps that remain baited because escapement has been virtually eliminated by knitted parlors. Similar periods of rough seas associated with the passage of polar fronts through Florida result in an initial increase of lobsters entering traps. In the event that hauling is delayed beyond the escapement threshold of approximately 14 days catch rates will sharply decline because lobsters leave these traps when feeding activity is stimulated by lunar periodicity.

The difference in catch rates shown in Table 2 is attributable to several factors in addition to the obvious discrepancy in sample numbers. Data for the Maine fishery (which has no formal closed season) are regional and include an unknown amount of sub-standard production efforts. No equivalent data are available for the entire Florida fishery and the catch rates indicated are significantly higher than the mean for this comparatively uncrowded fishing ground. Monthly fluctuations in Florida catch rates are caused by increases in stock density in August as a result of the four-month closed season. An abrupt decline in September probably reflects the change in lobster behavior reported by Herrnkind, et al. (1973) who describe a gradual build up in numbers of inactive den-bound lobsters during late September prior to the mass migratory phenomenon that normally occurs in October. At the onset of a spiny lobster "walk," young adults become highly active, form chains, move about over the fishing grounds in great numbers and eventually are caught in quantities reflected by a high CPUE for October.

CONCLUSIONS

Declining CPUE is an established indicator of overfishing and unequivocal when data can be demonstrated over a long-term period. Reliable catch figures for the Florida spiny lobster fishery are inherently difficult to obtain, particularly with regard to correlation with effort. Results of this study show an intraseasonal decline in CPUE and interseasonal fluctuations in related factors that are known to be statistically significant.

Although several theoretical explanations for these limited data can be advanced, they most logically fit the classic pattern of an overexploited marine resource at or near a threshold of collapse, assuming progeny for recruitment are derived from autochthonous parents.

Present conservation laws are inadequate to resolve this problem and have remained inflexible in the face of warnings contained in an accumulating corpus of published research by concerned scientists.

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TABLE 1

Comparative CPUE Between Lobster Fisheries of Maine and Florida

	<u>Homarus americanus</u> ¹	<u>Panulirus argus</u> ²
Number of fishermen	15	2
Number of trap hauls	10,733	3,968
Number of lobsters	8,713	4,818
Weight of lobsters in Kg	4,674	2,403
Number/trap haul	.80	1.21
Weight/trap haul in Kg	.43	.60
Weight/lobster in Kg	.54	.50
Number of fishing days	75	94

¹Derived from Wilson (1976; Table 12.1) by combining data from "Controlled" (by fisherman) and "Uncontrolled" areas of the Maine inshore fishery over a single 12 month period.

²Derived from monthly means over a 12 month period comprising two seasons and without weighting proportional to effort.

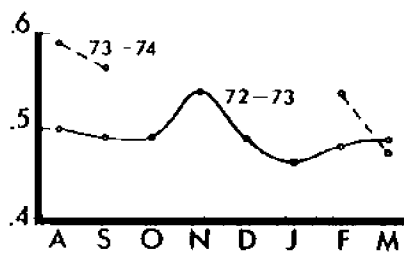
Note: legal carapace length for Maine = 81 mm; Florida = 76.2 mm

TABLE 2

CPUE indicated by number and weight of lobsters per trap-haul
between fisheries by month

	Maine 1968-69*		SE Florida 1972-73	
	(n = 12,065,610)		(n = 3,968)	
	No.	Wt.	No.	Wt.
Aug.	.46 lob./trap haul	.23 Kg	1.70 lob./trap haul	.82 Kg
Sept.	.60	.32	.74	.37
Oct.	.63	.33	1.78	.87
Nov.	.73	.38	1.12	.61
Dec.	---	---	1.17	.62
Jan.	.69	.37	1.15	.55
Feb.	.59	.32	1.19	.46
Mar.	.80	.41	.87	.42

*Adapted from Thomas (1973; Table 4) without adjustment for standard errors; data are representative of the total fishery.



(A)

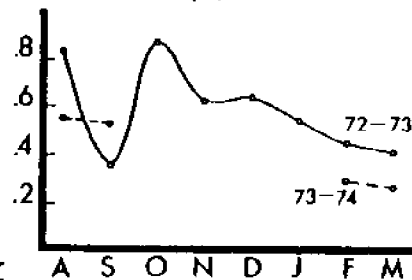


(B)

Fig. 1A Avg. wt. of >76^m/_m lobsters in kg.

1B Total number of shorts.

1C Catch-per-unit-of-effort (kg/haul).



(C)

SEASONAL DISTRIBUTION OF MARKETABLE CROAKER (MICROPOGON UNDULATUS) IN THE GULF OF MEXICO

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INTRODUCTION

During the past decade foodfish croaker (Micropogon undulatus) ranging between 180 to 1800 gm (0.4 to 4.0 lb) have been landed in increasing numbers at northern Gulf of Mexico fishing ports, principally in Louisiana, Mississippi and Alabama. A significant portion of these landings was made in Bayou La Batre, Ala. where current annual landings have averaged about 6.8 million pounds. Since 1972 National Marine Fisheries Service (NMFS) vessels have surveyed the croaker distribution in the northern Gulf of Mexico from Ship Shoal, La. to Mobile Bay, Ala. Seasonal and geographic distribution of the foodfish croaker are discussed based on trawl survey catch records for 1972-76, with notes on port sampling observations of bull croaker averaging 790 to 1000 gm (1.8 to 2.1 lb), taken by snapper boats fishing around oil rigs off the Mississippi Delta.

MATERIALS AND METHODS

Foodfish croakers are landed by numerous trawlers fishing out of Bayou La Batre, Ala. Trawler captains were interviewed from July through September 1972. Data collected on foodfish croaker catch rates were: fishing areas, depths fished, vessel sizes and size of trawls.

Fish processing plants in Bayou La Batre, Ala. were visited in 1972 to gather data on how commercial foodfish croaker landings were graded. Landings of foodfish croaker by commercial snapper boats were sampled during August 1974 and September 1975 to obtain length and weight data on large bull croaker.

Seasonal length frequency and biomass (round weight) estimates of northern Gulf of Mexico croaker population were obtained from NMFS groundfish surveys from November 1973 through November 1974. These data were used for seasonal estimates of the proportion of the croaker population which is of commercial foodfish size (Source: unpublished manuscript of Rohr, Sanders and Reese). Sports fishermen in Pascagoula, Miss. and charter boat captains

in Biloxi, Miss. were interviewed concerning areas they preferred to fish for bull croaker and what size fish were caught.

COMMERCIAL FOODFISH CROAKER LANDINGS

A significant portion of Gulf of Mexico foodfish croaker landings are made in Bayou La Batre, Ala. (C. M. Roithmayr, personal communication). Since 1974, Gulf of Mexico foodfish croaker landings have declined due to changing market conditions brought about by increased landing of foodfish croakers on the Atlantic east coast (E. Moret Smith, personal communication).

Foodfish croaker boats fish for croaker on consignment or land incidental catches while shrimping. Highline foodfish croaker trawlers fishing by consignment may catch up to 65,000 lbs of croaker in 3 days if fish are abundant. Catches of other commercial foodfish, flounder, white sea trout, red snapper are also landed and sold. If a trawler is primarily fishing for shrimp and is only bringing in incidentally caught foodfish croaker the trip time may extend 10 to 12 days.

At sea, foodfish croaker are picked out of the catch along with other edible species of fish, crabs and shrimp. Small "industrial" size croaker are discarded along with other unwanted fishes and invertebrates. Croaker are iced down in the vessel hold and unloaded at dockside by a conveyor system. Inside the processing plant foodfish croaker are hand graded into commercial sizes and packed in ice for shipment in 50 lb. waxed corrugated cartons. Fish over 24 cm (9.5 inches) are sold in three commercial sizes (Table 1).

The primary fishing grounds for foodfish croakers is the Continental Shelf off the Mississippi Delta between 89° to 90° west longitude in depths of 2 to 50 fms. At high river stages foodfish trawlers may fish in depths of 80 to 90 fms directly off the mouth of the Mississippi River (Gary M. Russell, personal communication).

Significantly larger than average size croaker are landed by snapper boats fishing around oil rigs between the "western rigs" in 19-20 fms, 20 miles west of Southwest Pass, Mississippi River and rigs in 5 to 30 fms southeast of Breton Island, La. These croaker are caught by snapper handline reels described by Carpenter (1965). Snapper captains do not ordinarily fish for foodfish croaker because of their low price, but occasionally if snapper fishing is poor, croaker are caught to help pay trip expenses.

Handline caught foodfish croaker catches usually occur in three categories: "small" bull croakers averaging 39 cm and 790 gm (15.4 inches, 1.8 lb); "medium" or average size bull croaker which usually range between 41 to 42 cm and 990 to 1100 gm (16.1 to 16.5 inches, 2.2 to 2.4 lb); and occasional catches of large bull croakers that average about 48 cm and 1800 gm (19.0 inches, 4.0 lb). Snapper boat captains report medium size bull croakers are landed most frequently, small bull croaker catches less commonly, and large bull croaker catches are infrequent. The

length of croakers sampled by NMFS personnel from shapper boat catches ranged from 26 to 48 cm (10.2 to 19.0 inches).

NMFS personnel have undocumented reports of bull croakers averaging 4500 to 5400 gm (10 to 12 lbs) around oil rigs off Grand Isle, La. The largest documented croaker caught in the Gulf of Mexico was reported by Rivas and Roithmayr (1970). It was 67 cm long (26.4 inches), weighed 3632 gm (8.0 lbs) dressed and had an estimated round weight of 3875 gm (8.5 lbs). It was taken by a snapper boat on the 35 fathom lump 57 nautical miles south of Horn Island, Miss.

SEASONAL ABUNDANCE OF CROAKER SIZE CLASSES

Seasonal proportions of different size groups within the croaker population present east of the Mississippi River Delta between 88^o to 89^o west longitude are shown in Table 2. Recruits (young-of-the-year) ranging 7 to 14 cm (2.5 to 5 inches) comprised up to 80 percent of the catch in 2 to 5 fms in June. Medium and large industrial size croaker, 15 to 23 cm (6 to 9 inches), varied between 48.6 to 95.2 percent of the catch in depths of 5 to 50 fms between June and November. The proportion of medium and large industrial croaker is less variable seasonally in depths of 20 to 50 fms, averaging about 78 percent of the population. In 20 to 50 fms, medium foodfish croaker comprise a slightly higher proportion of the population, about 1.1 percent due to the 3.2 percent high in November 1974. Large foodfish, or bull croaker ranged from 0.0 to 1.7 percent of the population inside 20 fms in 1973-4 and fluctuated between 0.4 to 3.5 percent of the population in depths of 20 to 50 fms, averaging 2.3 percent.

SEASONAL RANGE IN ABUNDANCE OF FOODFISH CROAKER

Table 3 shows a summary of the seasonal range in proportion in numbers and weight of croaker foodfish size classes. Generally the numerical fluctuation of different size classes of foodfish croaker is less variable in depths of 20 to 50 fms (37 to 92 m). Note: whereas total numbers of foodfish croaker range from 1 to 40 percent of the population, foodfish croaker may comprise 10 to 50 percent of the weight of the croaker catch.

MAGNITUDE OF THE FOODFISH CROAKER STOCK

Only NMFS trawl catch estimates of the abundance of foodfish croaker are available. In depths of 5 to 19 fms (9 to 35 m) 6 to 7 percent by number of the croaker population were foodfish size whereas they accounted for 21.4 percent of the population in 20 to 50 fms (36 to 92 m). Collectively, perhaps 10 to 15 percent of the population by weight may be small and medium size foodfish. Large bull croakers exceeding 450-900 gm (1 to 2 lbs) are less likely to be caught by trawling because they prefer to frequent reefs, hard bottom areas, and oil rigs. The maximum size of trawl-caught croaker on NMFS vessels ranged between 49 to 52 cm (19.2 to 20.5 inches), averaging 1600 gm (3.5 lbs).

The true population of bull croakers in the Gulf of Mexico is unknown because no data are available on the recreational fishery catch of large croaker; snapper boats may discard croaker smaller than 30 to 35 cm (11.8 to 13.8 inches) and preliminary NMFS bull croaker tagging attempts have been unsuccessful.

Our best estimate is that bull croaker exceeding 33 cm (13.0 inches) account for about 3 percent of the population by number, however, they may comprise as high as 10 percent of the population weight.

STANDING STOCK OF CROAKER

Groundfish survey estimates of the standing stock of croaker have fluctuated between 140,000 to 200,000 short tons in the northern Gulf of Mexico from Mobile, Ala, to Ship Shoal, La. (88° 0' to 91° 5' west longitude) in depths of 2 to 50 fms (Elmer J. Guthertz, personal communication).

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Table 1--Size groups in croaker, Micropogon undulatus, populations in the Gulf of Mexico in depths of 2 to 50 fathoms¹.

SIZE CLASS	LENGTH ²	WEIGHT ³	COMMERCIAL SIZE CLASS
Recruits (Young-of-the-year)	7-14 (2.5-5.0)	4-33 (.01-.07)	Small Industrial Fish
Juveniles and Young Adults	15-23 (6.0-9.1)	34-162 (.08-.36)	Medium and Large Industrial Fish
Adults	24-29 (9.5-11.4)	180-336 (.37-.74)	Small Foodfish
Adults	30-32 (11.8-12.5)	240-453 (.75-.99)	Medium Foodfish
"Bull" Croaker	33+ (13.0+)	454+ (1.00+)	Large Foodfish

¹ Source: Rohr, Sanders and Reese, unpublished manuscript.

² Total length in centimeters, inches in parentheses.

³ Round body weight in grams, pounds in parentheses.

Table 2--Seasonal distribution of length frequency size groups of croaker, *Micropogon undulatus*, east of the Mississippi River Delta (groundfish survey sample area SA1) between November 1973 through November 1974!

DATE/VESSEL	Nov. 1973 FRS OREGON II	June 1974 FRV GEORGE M. BOWERS	June 1974 FRS OREGON II	Aug. 1974 FRS OREGON II	Nov. 1974 FRS OREGON II
Cruise	48	123	51	52	55
Depth Fms:	5-19	2-5	5-19	5-19	5-19
RANGE IN LENGTH (Cm)	PERCENT OF TOTAL POPULATION NUMBER				
7-14	0.1	80.0	50.5	24.4	7.1
15-23	95.2	19.7	48.6	81.7	83.6
24-29	2.6	0.3	0.9	14.7	7.6
30-32	0.4	--	--	0.8	1.0
33+	1.7	--	--	0.4	0.7
TOTAL	100.0	100.0	100.0	100.0	100.0
Depth FMS:	20-50	---	20-50	20-50	20-50
7-14	0.1	--	0.1	1.0	0.0
15-23	81.3	--	84.4	87.7	59.8
24-29	15.3	--	12.5	10.7	33.5
30-32	0.8	--	0.3	0.2	3.2
33+	2.5	--	2.7	0.4	3.5
TOTAL	100.0	---	100.0	100.0	100.0

1 Computed from weighted length frequency of total number of fish per cm total length interval within depth strata given for NMFS groundfish cruises from November 1973 through 1974 (Rohr, Sanders and Reese, unpublished manuscript).

Table 3--Seasonal range in abundance of trawl caught foodfish croaker in the northern Gulf of Mexico from November 1973 through November 1974.

COMMERCIAL SIZE CLASS	DEPTH STRATUM (FMS)	DEPTH STRATUM (FMS)
	2-19	20-50
	Percent Total Population Number	
Small	1-15	11-15
Medium	0.4-0.8	0.2-0.8
Large	0.4-1.7	0.4-2.5
Total Foodfish	1-16	12-40
Percent ²		
Weight of Total Catch When Foodfish Croaker Present	10-50	10-50

¹ Percent of total population numbers within depth strata based on data given in Rohr, Sanders and Reese, unpublished manuscript.

² Off the Mississippi River Delta in depths of 2 to 50 fms foodfish croaker may compose 100 percent of catch in an individual trawl catch (personal observation of author).

POSSIBLE APPROACHES TO THE HANDLING OF UNDER-UTILISED FISH SPECIES

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Introduction

The FAO indicative World Plan of 1970 suggested a potential global production of fish of conventional species in the order of 100,000,000 tonnes. In order to obtain full benefit from this resource it will be necessary to ensure maximum utilisation. At present much fish is wasted and as populations increase the pressure to reduce wastage will increase. The prevention of waste is the theme of this paper and we believe that in the future the time of many fish technologists will be occupied in attempts to fully utilise the fish protein resources available to Man.

The prevention of waste in the developing world is an enormous topic. The work being conducted by the Tropical Products Institute in this field forms the subject of the next paper presented to this Conference and therefore, this paper will be in the nature of a review. An attempt will be made to quantify the losses involved and to indicate possible lines for improvement in traditional processing as well as the development of novel processes. The paper will rely heavily upon information presented in an excellent FAO publication entitled "Expanding the Utilisation of Marine Fishery Resources for Human Consumption" (5) and will also refer to information presented at the 1976 TPI Conference on the Handling, Processing and Marketing of Fish in the Tropics which is to be published shortly. In line with the experience of the authors and the Institute in which they work, the paper will deal primarily with experience in Africa and South-East Asia. The authors have little knowledge of the geographic area being considered by this Conference but much of the information gained in other parts of the world may be relevant here.

The problem

In recent years considerable attention has been directed towards the control of food losses, particularly in developing countries (9). One of the major difficulties is to quantify the extent of the losses. Although it is commonly recognised

that fish wastage occurs on a large scale, the few attempts to quantify the losses have shown wide variations. For the purposes of this paper two broad categories of wastage will be considered.

Firstly, large quantities of fish are discarded on fishing vessels because it is currently uneconomic to preserve and bring them ashore. The best known example is the discarding of the so-called "by-catch" associated with various shrimp fisheries around the world. Based upon a 5:1 ratio of fish to shrimp and a million tonne global shrimp catch the quantity of by-catch wasted annually is somewhere in the region of 5,000,000 tonnes.

Secondly, substantial losses occur from fish which spoil in the high temperatures of the tropics. Substantial spoilage losses also occur in the processing and storage of fish, particularly those using traditional techniques. For example, dried salted fish are subject to microbiological attack, physical damage and insect infestation. Few studies have been conducted but a global figure of 5,000,000 tonnes per year has been suggested (5, James and Krone, 1976, TPI Conference - in press).

Thus, the total losses, although subject to wide error, probably amount to some 10,000,000 tonnes of fish per annum and a high proportion of this wastage occurs in tropical areas. However, this represents only part of the equation since further large quantities of marine resources are wasted in the sense that they are unutilised or under-utilised. Potential fish resources, as seen by FAO (5) include something in the order of 25,000,000 tonnes of small pelagic fish which occur largely in tropical waters but which are as yet not caught. Some of the 17 million tonnes of small pelagic fish currently used for reduction to fish meal could be used for direct human consumption and one might expect the quantity so used to increase.

In addition to the marine fish which are currently unutilised or under-utilised there are other non-conventional resources. These include cephalopods (in the region of 7,000,000 tonnes), small mesopelagic fish and Antarctic Krill. Much has been written about these non-conventional resources (5) and we need not dwell upon their potential as human food material.

The FAO paper referred to above (5) concludes that a potential annual production of conventional fish species (including that used for fish meal) and waste, of the order of 75,000,000 tonnes, is currently available for human consumption. Much of this potential is available in tropical developing areas, particularly small pelagic fish and the wastage of by-catch.

Consumption patterns

In order to determine possible solutions to the problem of unutilised or under-utilised fish it may be of value to consider the changes that have occurred in fish consumption patterns in recent years. Changes in the utilisation of world fish production between 1960 and 1973 are given in Table 1 (James and Krone, 1976, TPI Conference - in press).

Table 1

	1960		1973	
	Million Tonnes	Percentage	Million Tonnes	Percentage
For direct human consumption	31.6	-	47.5	-
Fresh	16.9	53.5	20.2	42.7
Frozen	3.5	11.1	12.0	25.4
Cured	7.5	23.7	8.1	17.1
Canned	3.7	11.7	7.0	14.8
Reduction and other uses	8.6	-	18.5	-

Fresh fish consumption, although declining in percentage terms, is the principle method of fish utilisation. As more sophisticated marketing methods are increasingly used in developed countries (eg frozen fish), so fresh fish consumption will decline. Nevertheless, in developing countries fresh fish will continue to be important. The greatest change in fish consumption patterns since 1960 has been the growth of frozen fish production, from about 10% to 25%. This major increase has occurred largely in the more developed countries although certain developing countries have increased their trade in frozen fish products.

Canned fish production has also shown a steady increase since 1960 despite the increased costs of canning materials. Tropical countries tend to be major importers of canned fish because it may be distributed and stored without refrigeration. Cured fish production on a world-wide basis has remained

relatively stable. However, in developing countries where cured fish is the most important product for the lower socioeconomic groups, cured fish production has continued at a constant level, and has even increased in some situations. Therefore, although the proportion of cured fish has declined from 24% in 1960 to 17% in 1973, this decline has not taken place in tropical countries, it has been almost exclusively in the more developed economies.

Thus, changes in global consumption patterns for fish products must be treated with some caution when one is considering the trends in tropical developing countries. These are related to the constraints imposed by the stage of development in many tropical countries. These changes must be borne in mind when one considers possible changes in fish utilisation patterns.

Constraints to Technological Innovation

The main cause of fish wastage and under-utilisation is that the fish concerned have a low market value. The technological problems involved in utilising such fish are formidable and possible solutions to these problems are often uneconomic. This applies particularly to traditional forms of processing. On the other hand, the nutritional value of these fish is as high as that of the more desirable food species although they may be small, oily, strong flavoured, dark fleshed and have no particularly desirable characteristics.

It may be difficult for some people in developed countries to understand how wastage on such a scale can occur. The reasons are both economic and technical and the extent to which they apply varies with the situation.

The economic problems associated with making unutilised species marketable in traditional forms are considerable. In developing countries the problems are further compounded by the fact that the target group for such traditional products is generally the low income consumer. In fact the major constraint to increasing the availability of fish protein to the most needy in developing countries is their general lack of purchasing power, indeed many people have no purchasing power. In more developed economies the problems may be less formidable in terms of price and yet the production of economically viable products from the range of under-utilised and unutilised fish referred to above is still a major constraint. The only way in which these problems could be overcome in either situation is to apply methodologies which require relatively low cost processing. This often requires that the process be applied on a large scale. This may be possible in industrial fisheries where large quantities are involved but at the other end of the scale (the situation most common in developing countries) this is not the case.

The constraints to the utilisation of these fish are not solely economic. Technical problems arise in the handling of the catch, sorting, grading and processing. These will be discussed later, particularly the handling and processing of by-catch and pelagic species. Further problems arise if it is not possible to process whole fish. As yet there is little or no equipment available which is capable of heading and gutting fish which vary in shape and size. Even where large quantities of standard size fish occur, (eg pelagic species), equipment is not available at a price which allows the process to be economic. This in fact represents one of the more serious constraints to the utilisation of such fish. Hence the problems of acceptability and hygiene associated with the use of whole fish must be resolved before large scale product development is possible.

In the developing country situation there may be further constraints such as the deeply entrenched conservatism of some populations. One must also take into account local preferences, for example the preference in West Africa for strongly flavoured dried fish and the common desire of the housewife throughout the tropics to receive her fish ungutted and head on. It is important to appreciate the effects of local religious attitudes and taboos when marrying technological developments to the formulation of marketing policy. The technologist must also take into account local constraints operating in the marketing system. These include socio-economic factors such as the availability of ice, the role of the middleman, the lack of transport, the availability of cold stores etc. Collectively these factors may limit the practicability of applying the higher and more sophisticated technologies commonly used in developed economies. In such situations the technologist must identify and apply more optimal solutions.

The application of technology

A much used term is the so-called "transference of technology." This is commonly taken to infer a movement of the sophisticated technologies from the industrialised countries to the developing countries. There is also some attempt to publicise the merits of small-scale technological transfer but again usually based largely on Western technology. There is relatively little in the literature about the undoubted merits of many of the indigenous technologies of the tropics or the possibilities for improving their performance (Jones and Disney, 1976, TPI Conference - in press).

In many developing fisheries the transference of technology has been only partially successful. There has been an incomplete appreciation of the socio-economic factors including the capacity of local industries to adapt quickly and evaluate likely potential with any degree of accuracy. There are also a number of indications to suggest that the transference of technology from cold water fisheries to warm water tropical fisheries must be conducted with some caution (2).

Having indicated some of the problems associated with the transference of technology into the developing fishery situation, and suggesting that much can be done to improve traditional methods, it must be recognised that the existing infrastructure and local system cannot possibly cope with the scale of operations needed if complete use is to be made of the under and unutilised fish resources. Large-scale processing will be required involving new, low cost technology. Improvements in the utilisation of fish by traditional methods will largely result from low cost technology which is already known, but requires adaptation and application. However, a new approach will be required where large quantities of material are involved. Low product cost must be achieved by high volume throughput; considerable effort will also be required to identify and develop means of marketing new products.

There are a number of ways in which the development of technological processes, both existing and novel, may be considered. They can be presented in terms of the technology required, on a commodity basis, or along the lines of the different means of processing employed. Each of these approaches has some merit but for the purpose of this paper we will consider firstly the catching and handling problems and then the type of process that may be applied.

Catching and handling

Shrimp by-catch provides a good example of the problems involved. At present discarding the trash fish is the cheapest method of disposal from the shrimp vessel operator's point of view (15). Factors arguing against the landing of shrimp by-catch are the low value of the material, the size and species composition (some 20-50 species may be involved which would require considerable sorting), the lack of suitable refrigerated storage space on board and the possible reduction in shrimping efficiency. Shrimp fisheries exist in many parts of the world and although the vessels vary in type and design, most exhibit the common problem of landing and preserving the fish caught alongside the shrimp. This problem has been considered in a number of reviews (15, Allsopp, 1976, TPI Conference - in press). Attempts have been made to collect the by-catch and bring it ashore in carrier vessels. Also in some countries, eg Guyana and Indonesia steps have been taken to force shrimp vessels to bring ashore at least part of the by-catch as a means of providing locally needed fish supplies. These attempts have failed largely on economic grounds since the value of the catch is insufficient to justify the expenditure of preservation on board a carrier vessel. Nevertheless, it is widely accepted that this wastage cannot continue and attempts are being made to develop methods which are both economically and technically feasible. For example, trials are about to be conducted in Guyana (with Canadian assistance) on

transference at sea of the by-catch from shrimp vessel to a mother vessel. This will handle the by-catch from a considerable part of the fleet, preserve and bring it ashore for local consumption.

Although handling at sea is undoubtedly difficult it is felt that the problems are not insurmountable provided the catch could be preserved, processed and marketed at a profit. The solution to this problem lies in the hands of the technologist.

A further problem associated with the economic utilisation of pelagic fish is the seasonal nature of the fishery. In South-West India for example large stocks of small pelagic fish are known to occur at limited times during the year. The value of these fish is insufficient to justify large-scale capital investment in fishing vessels which for the remainder of the year would be unused. Trials are underway to determine means of capturing such fish in the season with vessels which are suitably equipped to carry out other forms of fishing during the remainder of the year. Such multi-purpose vessels may overcome at least one of the problems associated with utilising this known resource.

Fresh Fish

Improved handling of fresh fish in the tropics probably represents the best method of increasing utilisation. Having made this comment it is also necessary to point out that the existing facilities are far from adequate in most tropical developing countries. Considerable attention must be paid to the provision of ice, cold storage, distribution systems etc.

There is an accumulating amount of evidence to suggest that tropical fish have a longer ice storage life than temperate and cold water species (Shewan, 1976, TPI Conference - in press). Research activities in this field were reviewed at the previous meeting of this group (Disney, 1976, 1st Annual Tropical and Sub-tropical Conference of the Americas - in press). The extended shelf life of tropical fish in ice may in some situations, render it unnecessary to resort to freezing and sophisticated cold storage distribution systems. It may be possible to distribute iced fish over considerable distances and still deliver a high quality product to the main consuming centres. More information is required and papers at this, and other meetings, will hopefully increase our knowledge of this subject.

Frozen Fish

Substantial progress has been made in a number of countries on the increased utilisation of fish through freezing and the distribution of frozen products. The main examples are in West Africa, although a number of other countries (eg India and Peru) have made progress in the establishment of cold storage distribution networks and increasing quantities of frozen fish are being distributed. The economics of such systems are not markedly different from those of iced distribution but the maintenance of adequate cold chain facilities is difficult in many tropical countries.

As a means of reducing fish losses freezing offers a number of advantages in that large quantities of mixed species can be frozen, packaged and distributed together. Also, the marketing requirements in the developing countries are less rigid than those elsewhere (5). Nonetheless, there are as yet relatively few situations where this technology has been applied. The difficulties are not technological but are associated more with the lack of capital and local expertise (4). In India some progress has been made with small pelagic fish (Kuriyan, 1976, TPI Conference - in press).

Canning

Canned fish has important advantages since it is a stable product with a virtually unlimited shelf life and can be marketed through existing trade channels in developing countries. However, it is doubtful if canned fish in its present form can contribute significantly to supplying cheap protein to low income groups in the future. This is due largely to the high cost of canning and cheaper container materials are required. Efforts to develop retortable pouches may prove economically feasible but the technological requirements of the process may limit its application in developing countries. Other alternatives in tropical countries include the packaging of cooked products where some reduction in shelf life may be acceptable, and the introduction of canned minced fish. Examples where canning has been used as an outlet for new supplies of pelagic fish on a limited scale are India and Peru.

Cured Products

The technology involved in these processing methods is well established. The difficulties arise in maintaining minimal cleanliness and providing suitable facilities for processing, storage and distribution. The prevention of wastage in the future will probably rely largely upon increased attention to "good housekeeping," storage and distribution. This will largely be applied through extension work. The application of

mechanical drying may be of benefit in some situations but the high energy cost involved often makes this method uneconomic. Areas where research activity is still required is the use of insecticides to control insect damage and the development of suitable smoking kilns which are efficient in fuel utilisation.

Fish silage

This subject forms the basis of a paper later in this Conference and will not be dwelt upon here. However, this technique has a significant contribution to play in the tropics as a means of utilising waste fish either for human food or animal feed (7). The Tropical Products Institute has worked on this subject for some time (3) and a commercial project is in operation in the Solomon Islands utilising tuna waste to prepare feed for pigs. Further work is planned in Indonesia, Mexico, and the Seychelles.

Fish powders and minces

Much has been written about the use of fish minces, functional protein isolates and hydrolysates as a means of utilising the fish being considered in this paper (13, 14). These subjects cover a whole range of technologies and techniques but they are considered together as the authors consider that this area probably has the greatest potential as a means of reducing fish losses in developing countries.

In the developed countries minced fish has been used primarily for the production of fish fingers, portions, cakes, balls and other convenience-type products. In the future, minced fish is expected to supplement the growing demand for fillet blocks. Apart from these conventional products other uses of the minced fish, particularly from under-utilised species, may be as additives in the preparation of processed meat products. (Steinberg *et al*, 1976, TPI Conference - in press). In the context of developing countries a major area of interest is the use of minced fish for the production of low cost salted and dried products. This process may be particularly suitable for the utilisation of shrimp by-catch and other waste fish. Much of the work has been carried out in developed countries although with the developing country situation in mind. One product of particular interest is the salted fish powder produced in Canada (Bligh, 1976, TPI Conference - in press). Some work has also been conducted in India (Kuriyan 1976, TPI Conference - in press). Work carried out in our own laboratories forms the subject of the following paper and in addition to the experiments carried out in Seychelles and Malawi projects are shortly to commence in Indonesia and Mexico.

The preparation of functional isolates from fish and their use as additives to meat products has already been mentioned. Considerable research efforts undertaken primarily in the US, Canada and Sweden have demonstrated that fish can be processed into stable and acceptable protein concentrates for addition to a variety of foods. This technology is most immediately applicable in developed countries but in developing countries it could be of considerable value in the longer term particularly in situations where large quantities of material is available and where the application of relatively sophisticated technology is found to be economically viable. Non-functional isolates or hydrolysates prepared from fish have also been the subject of considerable research. These products are used primarily as milk replacers in animal feedstuffs and their value in developing countries is questionable but they may be applicable in certain situations.

A further product requiring attention is the preparation of FPC type B. This product has found ready acceptance with consumers whose diet includes dried or salt dried fish either as an ingredient or as a condiment (6). Acceptability trials, using Norse Fish Powder, have been undertaken in various parts of Africa and Asia and the general conclusion has been rather good. Currently this product is on sale in Nigeria and test sales are being conducted in Liberia, Ghana and India. Potential sales are affected by the retail price and considerable efforts will be needed to minimise processing costs particularly as no conventional fish meal plant is suitable for the continuous production of food for human consumption. Nevertheless, this product seems to have a considerable future as a means of utilising waste fish for human consumption particularly in tropical conditions.

If FPC type B seems to have a future in the developing world the same can hardly be said of FPC type A. The latter was, until comparatively recently, considered to be the solution to the protein needs of developing countries. However, due to an imbalance between production research, as opposed to marketing research this potential has not been realised. FPC type A may be used in some situations but costs of production and acceptability problems will limit its use in developing countries (17, Tagle *et al*, 1976, TPI Conference - in press).

Other techniques

Many attempts have been made to develop new technologies as a means of using waste fish material and a number of papers have reviewed this subject (1, 12, 10, 16). Relatively few have been directed towards the simple systems required in the tropics and in the opinion of the authors, such research could prove to be rewarding. The preparation of novel fish products incorporating cereals would seem to the authors to offer considerable potential as a means of producing low-cost products

containing a considerable amount of protein which are acceptable to populations in many developing countries. Some work along these lines is being conducted in Central America (Pedraja - personal communication).

CONCLUSIONS

No single technique or product is likely to meet the requirements of the fishing industries of both the developed and the developing world. Also, a divergence is becoming apparent between those workers intent on providing food from waste fish in developing countries and those directing their efforts towards preparing protein products from fish for use in the more developed economies. Both low level and sophisticated technology is required to solve the problems outlined earlier in the paper and an evaluation of the needs must be made on a case by case basis.

The need to develop specific technologies for tropical fisheries is debatable. It may be possible to select and adapt known technology but the known differences between tropical and temperate species suggests a cautious approach. More research effort is needed, this should ideally be carried out in the developing countries but what is required is closer collaboration between the organisations throughout the world working on these problems. Technological solutions will of necessity be largely financed and discovered from the efforts of developed countries but they will only be applicable if local conditions are taken into account. The workers in the developing countries are best suited to ensure that this is the case.

Reference has been made to the need to consider each situation on its own merit. This should be considered in the context of regional and national preferences. For example, in many countries in South-East Asia waste fish is already utilised to make fish sauce or fish paste. Also in such countries there is a wide variety of fish products which lend themselves to the development of further novel products. Similarly the conservative nature of the consumer tends to be greater in the developing countries than in developed countries. Consequently, the technologist must consider the potential consumer when considering the development of a new product. For instance the work on FPC type B in West Africa (6) showed that the consumption of fish, and the acceptability of the product, varied considerably among different regions within the country and also depended upon socio-economic circumstances. In other parts of the world, possibly Latin America, a more likely approach is to incorporate fish into local cereal products. Work carried out by the Institute in the Seychelles has shown that salt fish cakes, whilst acceptable, are more readily taken by the consumer when potato and fish are prepared together. This work shows promise and is continuing.

Local standards of hygiene should also be considered. The highest standards of microbiological quality are quite rightly, applied to new products. However, it should not be forgotten that the traditional products, which are often consumed alongside the new product, are often heavily contaminated. Some allowance should be made for this, particularly with products made by simple technological means which are to be prepared in the traditional manner prior to consumption. Similarly geographic and religious considerations must be taken into account. In the North-East India for example there are considerable quantities of fish but the bulk of the population is non-fish eating. Consequently fish must be preserved and transported considerable distances before reaching areas of consumption. Traditionally this has been in the form of salted dried fish but more recently, due to the establishment of distribution systems both fresh and frozen fish are now being distributed over considerable distances.

This paper has attempted to outline some possible means of utilising waste fish for human food. We have attempted to stress the interrelationships between socio-economic factors and meaningful technological inputs. This relationship in our experience is of greater importance in developing than in developed situations. Many attempts to solve developmental problems have failed, not because the technology was faulty but because the social or economic climate was not conducive to change.

Finally, this Conference marks a further step forwards in the international exchange of information on tropical fish technology. Only through such meetings can the interchange of information between developing and developed countries be conducted. Further exchange is required as a stimulus for more research in this area. Further research effort is needed on powdered products, bulk freezing and large scale salting and drying, particularly dealing with whole fish.

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DEVELOPMENT OF NOVEL PRODUCTS FROM TROPICAL FISH SPECIES

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In the more developed fisheries around the world there is much discussion concerning the dwindling stocks of certain fish as a result of over fishing. Largely in tropical areas, however, large quantities of fish exist which at present are not fully utilized. These include large stocks of small pelagic species, shrimp by-catch (fish caught incidental to shrimping) and waste fish resulting from processing. For example, it has been estimated that in 1967 more than 600,000 tonnes of fish by-catch were caught and discarded during shrimp trawling operations in the Gulf of Mexico alone (3). A similar resource of small pelagic fish is also known to occur off S.W. India but is largely unexploited (K.K.P. Menon, personal communication).

Much effort has been put into developing methods for utilizing this fish for human food. The approach in developed countries is different from that in less developed countries. In the latter "high technology" resulting in sophisticated, highly priced products is often not applicable. Traditional methods such as salting, sun drying and smoking, while producing low priced acceptable products, are small-scale operations and when a glut of fish occurs the wastage is very high. Often what is required is not new technology but simply to extend the existing processes to allow a greater throughput and to reduce losses.

There are a number of reports of quick salting techniques for fish (5, 6, 8, Bligh, 1976-TPI Conference, in press). In these methods ground fish is mixed with salt, water is removed by pressing or centrifugation and products such as cakes or powders are made. Del Valle (8) found that concentrations of salt up to 100% of the weight of fish were required to destroy the water binding capacity of the flesh of some species. This paper describes some of the work undertaken at the Tropical Products Institute into ways of utilizing waste fish for human consumption. In particular, it examines the effect of different salt concentrations on the physical properties, storage characteristics and organoleptic acceptability of dried fish cakes and powders made from different species of fish.

MATERIALS AND METHODS

Fish Species

Four species of fish were studied. They were chambo (Tilapia lidole), chisawasawa (Lethrinops spp), mackerel (Scomber scombrus) and blue shark (Prionace glauca). Chambo and chisawasawa are tropical fresh water species and were obtained from Malawi. Mackerel and blue shark are UK marine species and are similar to common species of tropical marine fish which represent a source of waste material in developing countries.

Preparation of samples

The fish were prepared for manufacture into cakes by using a Baader 694 meat/bone separator or a Hobart (No 12) electric mincer. Chambo, mackerel and shark were too large to be mechanically de-boned whole. The heads, guts, frames and fillets (or steaks) were therefore separated by hand. For chambo the flesh from the fillets and frames was removed by passing them through the meat/bone separator. On the other hand, mackerel fillets and shark steaks were freed from skin manually and minced electrically.

In the case of chisawasawa both a meat/bone separator and an electric mincer were used. A raw mince was obtained by passing the whole (ungutted) fish through the meat/bone separator. The possibility of using an electric mincer to comminute chisawasawa was also investigated but due to problems of clogging, electrical mincing of the whole raw chisawasawa was not possible. Thus, to facilitate mincing, the fish were first partly cooked by placing them in boiling water for 5 minutes. This gelatinised the connective tissue and partly softened the bones. The minced material from partly cooked whole chisawasawa was too wet for cake formation and was used for the manufacture of salt/fish powders. However, it was found that if the heads and guts were removed, the material obtained after cooking and mincing was suitable for manufacture into cakes.

Manufacture of dried salt/fish cakes

Finely ground salt in the required concentration was mixed into the mince. Portions weighing approximately 100g were then pressed into cakes using a simple hand-operated hamburger press. After pressing, the cakes were laid on wire racks and either sun dried (temperature 25-35°C) or dried in a forced draught oven (Torry mini kiln) at 35°C. Throughout the text the amount of salt added to the minces is expressed as a percentage of the total weight of salt plus minced fish.

De-salting of salt/fish cakes

For de-salting, cakes were soaked in 1 litre of water for half an hour, drained and boiled in a fresh litre of water for 15 minutes.

Preparation of dried salt/fish powders

As for the manufacture of dried salt/fish cakes, finely ground salt in the required concentration was mixed into the mince. The mince was then spread in thin layers on plastic trays and sun dried. The dried material was ground by hand using a pestle and mortar.

Analytical methods

The water content was determined using an oven at 105°C, crude fat by the Soxhlet method using petroleum ether, crude protein (N x 6.25) by the Kjeldahl method and ash using an oven at 500°C. NaCl was measured using the ammonium thiocyanate and silver nitrate method (13). For peroxide values, fat was extracted with chloroform and methanol (2) and the peroxide content determined using potassium iodide and thiosulphate (1). The thiobarbituric acid number (TBA) was measured by the malonaldehyde distillation method of Tarladgis *et al* (14). Methods based on those recommended by the International Committee on Microbiological Specifications for Foods (15) were used for microbiological analyses.

RESULTS AND DISCUSSION

Effect of different salt concentrations on the characteristics of dried salt/fish cakes

Addition of 5, 10, 15 or 20% salt to raw fish minces produced cakes having different appearances and textures. However, addition of the same salt concentration to minces from different species of fish produced cakes with similar physical characteristics. Table I gives the appearance and texture of chambo cakes before and after drying. The largest difference in the cakes was between those made from a mince with 10% added salt and those from a mince with 15% added salt.

Cakes were also made from mackerel minces with 9, 11, 13 and 15% added salt. As expected, as the salt content of the mince increased, the appearance and texture of the dried cakes changed from that described in Table I for 10% salt cakes to that for 15% salt/cakes.

The composition of chambo and mackerel cakes after drying in a kiln at 35°C for 4 days is given in Table 2. It may be seen that after 4 days at 35°C the water content of the cakes made from minces with 9 or 10% added salt was greater than those made from a mince with 5% added salt. However, a further

increase in the salt content of the wet mince caused the water content of the final cake to decrease.

The salt content of dried salt/chambo cakes before and after de-salting and cooking are given in Table 3. The amount of salt remaining in the cakes after de-salting and cooking decreased markedly as the salt concentration in the cake increased.

A chisawasawa mince obtained by passing the whole fish through a meat/bone separator was also used to make salt/fish cakes. Due to the high fat content, this chisawasawa mince was not very gelatinous and was more difficult to press into cakes than the other species used. However, the dry cakes had broadly the same appearance as the chambo cakes described in Table I. Further, the sun drying rates of cakes made from minces to which 5, 10, 15 and 20% salt had been added (Fig. 1) varied in the same way as the final water content of the chambo cakes described above.

From the results it appears that the characteristics of salt/fish cakes during and after drying are determined by whether denaturation of proteins has occurred before pressing. Duerr and Dyer (9) and Fougere (8), found that fish myofibrillar proteins (representing 70-80% of the total proteins) are denatured by salt solutions of above 10% in strength. The findings of this study are similar. In minces containing up to 10% salt the proteins retain their water-holding capacity and in fact salt increases this property. These minces dry slowly and the cakes have an appearance of a shrunken gel. On the other hand, if the salt concentration in the mince is 15% or above, the proteins are denatured and lose their water-holding capacity. The cakes therefore dry more rapidly and the final cake has an open texture. The latter is an advantage, in that it facilitates de-salting. For salt/fish cakes made from raw minces containing 75-80% water, the optimum concentrations of salt is one which will produce a cake which has characteristics somewhere between those found in cakes made from minces having 10 and 15% added salt, ie a coherent cake which will dry rapidly, have a firm but neither tough nor brittle texture and will lose salt easily on soaking and cooking. In practice, it is not possible to ensure that salt is evenly disbursed through the minces and this, combined with the inherent variation in the water content of fish muscle, renders fine control of texture by adjustment of salt concentration impracticable. Routinely therefore, cakes were made by adding 15% salt to the raw minces.

The characteristics of dried salt/fish cakes made from partly cooked minced fish were different from those made from uncooked minces. The appearance, sun drying rate and chemical composition of cakes made from partly cooked chisawasawa mince with 5, 10, 15 and 20% added salt are shown in Table I, Fig. 2 and Table 2 respectively. Cooking partly destroyed the gelling

capacity (ie denatured the proteins) of the wet mince and addition of salt had little effect as far as the physical properties of the proteins were concerned. Salt did, however, have the effect of "holding" water in the cake and as the salt content of the cakes increased so did the drying rate and final water content. All the cakes had a "close" texture and the softness reported in the cakes made from minces with 15 and 20% added salt was due to a high water content rather than to an open texture. Hence with partly cooked fish minces containing approximately 70% water, cakes with the best drying rates and textural characteristics are obtained when between 5 and 10% salt is added.

Changes occurring during storage of salt/fish cakes

The changes occurring in the salt/chambo cakes during drying and subsequent storage for 6 months at ambient temperatures (20-25°C) in containers with loose fitting lids are shown in Table 4. The water content of the cakes changed over the 6 month period. The cakes made from minces with 5 and 10% added salt lost water and those made from minces with 15 and 20% added salt gained water. This again indicates the difference between cakes with high and low salt contents. NaCl is a pro-oxidant (16) and thus the peroxide values of cakes made from minces with 15 and 20% added salt were greater than those made from minces with lower added salt concentrations. Peroxides are primary product of fat oxidation and are themselves broken down as oxidation proceeds (12). This explains the high peroxide values of the cakes after drying compared with those after 6 months of storage. After drying the peroxide values for cakes made from minces with 15 and 20% added salt were very high, as were the TBA values (the TBA value is a measure of malonaldehyde content, an end product of oxidation (4)) after 6 months of storage. Although, there is some evidence to suggest that some of the rancid components are leached out during de-salting and cooking (7), it would seem necessary to reduce the degree of rancidity occurring during storage, possibly by the use of sealed containers and addition of anti-oxidants.

With the exception of the cake with the lowest salt content, the total viable count (TVC) of bacteria did not increase during drying. Further, in all the cakes studied the TVC decreased during storage. This is in agreement with the findings of Del Valle *et al* (7). A more detailed microbiological analysis of the cakes after 6 months of storage showed that there was no *Salmonella* (per 50g), no coagulase positive *Staphylococci* (per 1g), no *Clostridia* spp (per 2g), no *Vibrio* spp (per 25g), the most probable number of coliforms was zero, and salt tolerant bacteria (ie growing on agar containing 5 and 30% salt) were less than 300/g of cake. The bacterial quality of the cakes was therefore extremely good.

Organoleptic acceptability of salt/fish cakes

Acceptability trials were undertaken in the Seychelles and Malawi. Cakes made from raw shark muscle were tested in the Seychelles and cakes from partly cooked chisawasawa muscle in Malawi. The cakes had been made from minces containing 15 and 7.5% salt respectively. The tasters were asked to cook the cakes as they would usually cook dried and/or salted fish and complete a questionnaire. The questions asked and the number of people marking each answer are shown in Table 5. The results, particularly for dried salt/shark cakes, indicate a high acceptability of the cakes.

Dried salt/fish powders

Dried salt/fish powders were made from minced, cooked whole fish. It was found that adding between 2.5 and 20% salt to partly cooked chisawasawa minces had no effect on either the drying rates or the final water contents of the powders. Hence in these dried salt/fish powders made from partly cooked fish, salt serves only to prevent spoilage and not as a means of modifying the physical properties of the product. Low concentrations of salt such as 2.5 or 5% are therefore adequate.

The composition of a dried salt/fish powder made from minced cooked whole chisawasawa with 5% added salt is given in Table 2. Although the fat content of the powder is high and hence rancidity will be a problem, it may be noted that it is no greater than dried whole chisawasawa (see Table 2) which is prepared in large quantities in Malawi. Limited studies in which powders were added to maize or wheat flour and baked into bread and scones, indicated that up to 5% could be added without affecting the acceptability. Similarly, these powders have been added to nsima (maize porridge) and phala (maize gruel) in nutrition clinics in Malawi. The acceptability of these dishes was high, although in certain cases there were complaints regarding grittiness (P. J. Meynell, personal communication).

Another problem likely to be encountered with these powders is high bacterial counts as a result of discharging the gut bacteria through the flesh during the mincing operation. However, a preliminary study of this problem has indicated that the microbiological quality of dried salt chisawasawa/powders is better than that of dried whole chisawasawa prepared locally in Malawi.

The World Food Programme in Malawi has shown an interest in both dried salted powders and cakes and is considering the possibility of using them in nutrition units and hospitals throughout Malawi.

CONCLUSIONS

Dried salt/fish cakes can be made using only very simple equipment. Freshly made cakes have a high acceptability but in cakes with a high fat content, rancidity becomes a problem during storage at ambient temperatures in open containers. Compared with western countries, many rural communities of developing countries have a high organoleptic tolerance for rancid fishery products (11). Thus, further work is necessary to determine what level of rancidity in the cakes is organoleptically acceptable and whether the rancidity can be reduced to this level simply through the addition of antioxidants and the use of sealed containers.

In view of this rancidity problem, the method as it stands is most suitable for making cakes from the flesh of low/medium fat species of fish. The waste from filleting and processing lines often contains a relatively high proportion of such waste and a pilot scheme using filleting waste resulting from the production of smoked Kampango (Bagrus spp) is about to commence in Malawi.

However, the greatest potential for salt/fish cakes and powders is as a means of utilizing small fatty fish. The small size of these fish means that they have to be processed whole and with a minimum of handling, eg using a meat/bone separator. This may mean incorporating the guts into the crude mince and since the guts of these small fish are generally rich in fat and water this will make it difficult to form the mince into coherent cakes. Although the preparation of a salt/fish powder will solve this problem, there will still be the difficulties concerned with rancidity and the possible health risk due to incorporating fish guts into products for human consumption.

Although a number of problems remain, salted/dried fish cakes and powders have a great potential as a means of utilizing waste fish for human consumption and their development will be continued.

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Table I

Appearance and texture of salt/fish cakes

Salt/cake*	After pressing	After drying
(a) <u>Cakes made from uncooked chambo minces</u>		
5% Salt	Gelatinous/fleshy No drip	Dense shrunken gel Leathery texture
10% Salt	Gelatinous/fleshy No drip	Shrunken gel Firm/close texture
15% Salt	Slightly crumbly Some drip	Little shrinkage Firm/open texture
20% Salt	Crumbly Much drip	No shrinkage Brittle/open texture
(b) <u>Cakes made from partly cooked chisawasawa minces</u>		
5% Salt	Thick paste No drip	Slight shrinkage Firm/close texture
10% Salt	Thick paste No drip	No shrinkage Firm/close texture
15% Salt	Thick paste No drip	No shrinkage Soft/close texture
20% Salt	Thick paste No drip	No shrinkage Soft/close texture

* Salt content refers to that added to the mince.

Table 2

Composition of Samples

	Water % (w/w)	Salt % (w/w)	Crude fat % (w/w)	Crude protein % (w/w)	Ash % (w/w)
(a) <u>Uncooked minces and salt/cakes</u>					
<u>Minces</u>					
Chambo	74.4	-	4.0	18.7	1.4
Mackerel	79.3	-	2.6	16.8	1.3
Chisawasawa	75.9	-	8.9	15.3	1.6
<u>Dried salt/ cakes*</u>					
Chambo 5% Salt	19.1	16.3	11.1	48.6	-
Mackerel 9% Salt	27.8	-	-	-	-
Chambo 10% Salt	27.5	20.9	9.9	42.3	-
Mackerel 11% Salt	17.8	-	-	-	-
Mackerel 13% Salt	15.9	-	-	-	-
Chambo 15% Salt	6.2	35.7	11.4	43.1	-
Chambo 20% Salt	3.6	40.9	10.7	41.3	-
(b) <u>Partly cooked chisawasawa mince and salt/cakes</u>					
Mince	71.7	-	3.3	20.4	4.3
<u>Dried salt/ cakes*</u>					
5% Salt	7.0	12.8	-	-	-
10% Salt	6.1	26.9	-	-	-
15% Salt	30.2	21.9	-	-	-
20% Salt	40.7	32.7	-	-	-

---CONTINUED---

Table 2, CONTINUED:

(c) <u>Partly cooked whole chisawasawa mince and salt/powder</u>					
Mince	69.0	-	7.5	15.6	5.2
<u>Dried salt/powder*</u>					
5% Salt	9.4	16.7	17.3	44.3	26.5
(d) <u>Whole chisawasawa</u>					
Sun dried	10.8	-	17.0	53.3	18.8

* Salt content refers to that added to the mince

Table 3

Salt content of salt/chambo cakes before and after de-salting

Dried salt/cake*	Salt (% dry weight)		% salt removed
	Before	After	
5% Salt	17.6	10.6	39.8
10% Salt	30.0	13.5	55.0
15% Salt	36.6	4.5	87.7
20% Salt	43.7	2.9	95.4

* Salt content refers to that added to the mince

Table 4

Changes occurring in salt/chambo cakes during drying
and 6 months of storage at ambient temperatures

Sample	Time of storage (months)	Water (% w/w)	Peroxide value (m equi/kg fat)	TBA (mg/kg)	TVC (/g)
Mince	-	74.4	15.6	-	4.8×10^3
<u>Dried salt/ cakes*</u>					
5% salt		19.1	40.4	-	3.4×10^5
10% salt	0	27.5	40.9	-	1.6×10^3
15% salt		6.2	162.4	-	4.8×10^3
20% salt		3.6	165.4	-	1.5×10^3
5% salt		16.2	11.2	0.06	3.0×10^1
10% salt	6	23.3	16.6	0.16	7.5×10^1
15% salt		6.8	19.4	0.15	6.0×10^1
20% salt		5.6	23.2	0.26	1.0×10^2

* Salt content refers to that added to the mince.

Table 5

Results of organoleptic acceptability trails of salt/fish cakes

Question	Possible answers	Number of people choosing each answer	
		Seychelles trial (Shark cakes) (6 Tasters)	Malawi trial (Chisawasawa cakes) (6 Tasters)
(a) Did you enjoy it?	YES NO	16 0	5 1
(b) Was it than dried fish you have eaten before?	as good not as good better	8 1 7	4 1 1
(c) Would you buy the cakes if available?	YES NO	16 0	4 2

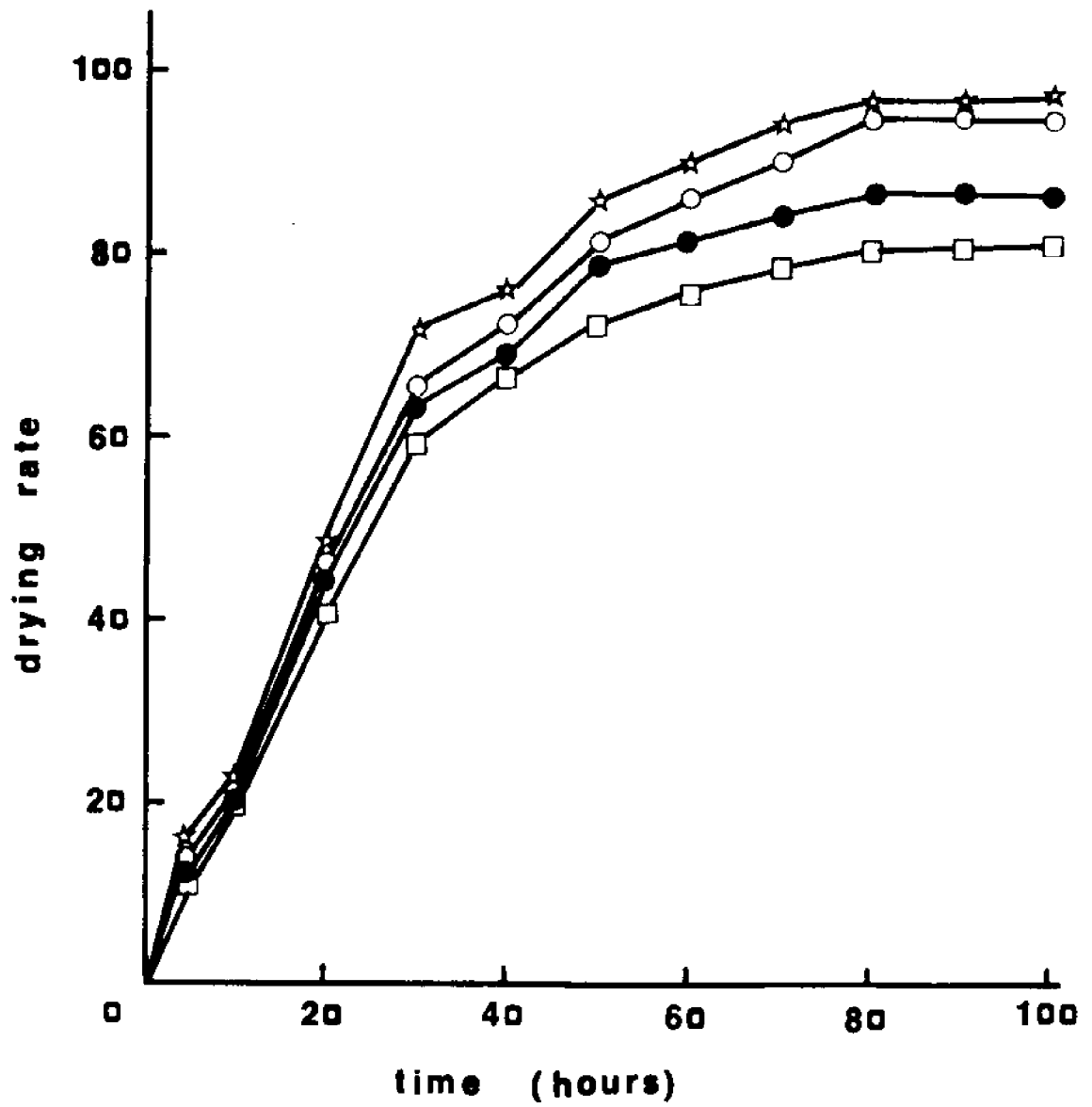


Fig. 1--Sun drying rates of salt/fish cakes made from raw chisawasawa minces containing 5 (●), 10 (□), 15 (○) and 20 (☆) % added salt.

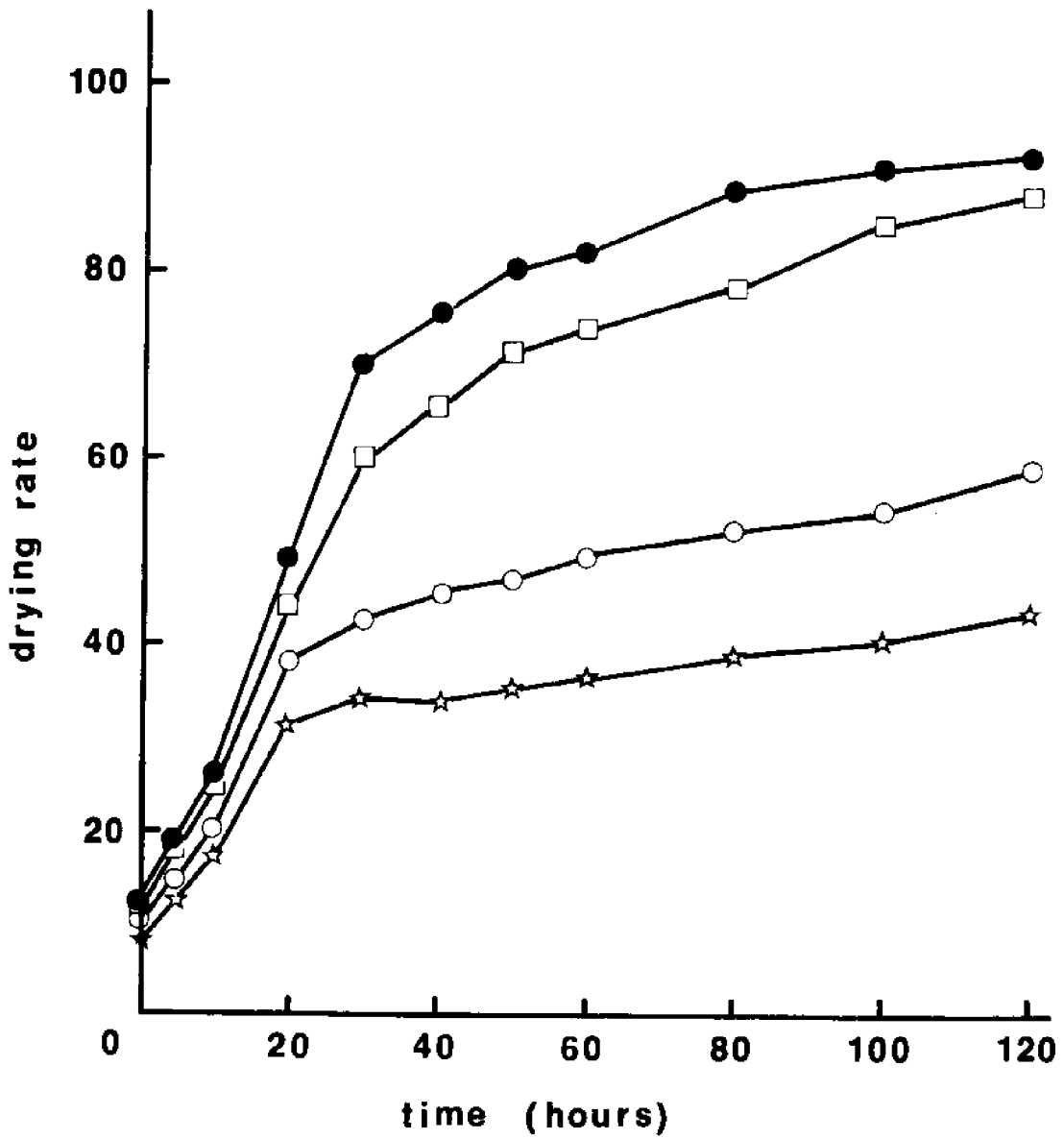


Fig. 2--Sun drying rates of salt/fish cakes made from partly cooked chisawasawa minces containing 5 (●), 10 (□) 15 (○) and 20 (☆) % added salt

SILAGE PRODUCTION IN TROPICAL AND SUBTROPICAL FISHERIES

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Fish silage is a liquid product made by the addition of acid to whole fish or to parts of fish. Liquefaction proceeds by the action of native enzymes in the fish, the acid having both an accelerating effect on the process and a preserving effect on the product. Development work on fish silage dates from the 1920s and the product has become a commercial reality in Denmark and Poland where it is used as feed for pig and mink.

In recent years interest in fish silage has resurged both in the developed and in the developing countries. In the United Kingdom, for example, research and development work (11) culminated in 1976 with a symposium at the Ministry of Agriculture, Fisheries and Food, Torry Research Station on many aspects of fish silage.

In many developing countries, where fisheries typically may be small in scale yet subject to daily or seasonal gluts, ensiling presents a relatively cheap means of utilizing waste. Until recent years the feasibility of producing fish silage had received no attention - a situation recently redressed by studies carried out by staff of the Tropical Products Institute of London in Ghana, Malawi, Brunei and Solomon Islands. In addition, the prospect of a fish silage industry in the Indo-Pacific Fisheries Council (IPFC) region considered by the IPFC Working Party on Fish Technology, Bangkok, November 1975 resulted in the engagement of a consultant to prepare a feasibility study for the region (Sumner, J.L., IPFC Occasional Paper, in press).

Before commercial production of silage can be envisaged in any fishery a number of critical questions must be answered. Among the most pertinent are - "does a raw material source exist and how can the ensiling be best carried out technically?" and "is there an assured outlet for silage and can this outlet be profitably serviced?". The present paper will seek to answer these questions based on an in-depth study of fisheries in the IPFC region though many of the findings are applicable to tropical and subtropical fisheries generally.

METHODS

To collect the information presented in the following, one of us (J.L.S.) made visits during April-May 1976 to the United Kingdom, Italy, Thailand, Malaysia, Singapore, Indonesia and New Zealand. As well, the views of fisheries scientists in Australia, Denmark, India, Philippines, Poland, Solomon Islands and Sri Lanka were canvassed.

RESULTS AND DISCUSSION

Raw material source

A fish silage industry may be established with raw material obtained from several categories: from actual landings of trash fish; from trash fish discarded at sea; from gluts (surpluses) and from fish offal.

In the IPFC region some countries report landings of large quantities of trash fish. In Thailand over 600,000 t/year (2) and in Malaysia 150,000 t/year (1) are utilized mainly by reduction industries which comprise a large number of small plants producing, collectively, fishmeal of variable quality. Clearly, trash fish currently used for reduction cannot be considered as a suitable raw material source for establishing an ensiling industry.

The extent to which the dumping of fish at sea occurs is difficult to estimate accurately; nevertheless the order of magnitude of fish wasted in this way represents a daunting prospect - Thailand 400,000 t/year, India 200,000 t/year (3, 9) and demersal fish, generally, 4-5 million t/year (6). Fish is dumped at sea because the catch comprises small fish of many species and is therefore not marketable; or because fishermen prefer to keep storage space available in case of possible future large catches.

In the IPFC region several instances of dumping at sea were encountered. For example, in artisanal fisheries a huge fleet of small boats makes day trips which, on occasions, extend to 36 hours at which time trash fish are dumped particularly when the boat is fishing for shrimp. Typically, of a catch of 70-100 kg, 40-60 kg will be trash fish and since, in Malaysian fisheries alone, the number of small boats exceeds 15 000 the practice of dumping fish realizes a great waste of resource.

Larger vessels in the region make four-day trips and usually trawl for three days with an average total catch of 1-2 t of which 50 percent is trash fish. If radio communication indicates that shrimp catches are good, trash fish will be dumped to keep space available for shrimp. In the Arafura Sea, where shrimp catches are still good, the pressure to dump trash is high. In this fishery the average trip is 40 days with trash discarded for all but the last two days. The average catch per trip is 10 t of shrimp and, with a shrimp:trash ratio of 1:9, the quantity of trash dumped is 90 t/trip. Each trawler makes

nine trips per year so the average annual waste from each vessel of 800 t, multiplied by the more than 100 trawlers operating in the area, realizes a total loss of resource of around 80,000 t/year.

Acknowledged surpluses are common in fisheries in the developed countries of the region - Australia and New Zealand. In the rest of the region, however, only one glut was detected - from the sardine fishery in the Bali Strait. Due to the introduction of purse-seiners, the catch landed exceeds the capacity of the local canneries resulting in a considerable depression in price of the landed catch. At Muncar, the largest sardine fishery port of Indonesia, the daily surplus was around 150 t for at least a 30-day period so that the total glut was 5,000 t. Conversion of excess landings into silage would effectively maintain sardine prices for canning while also utilizing a resource which has been previously wasted.

Due to efficient utilization of food fish most countries in the region do not waste fish offal; only in Australia and New Zealand is fish offal regularly dumped, usually at a cost to the industry. However, in the Solomon Islands offal from a tuna cannery which was formerly dumped has been converted into silage and fed to pigs. The study carried out by scientists from the Tropical Products Institute has successfully moved from the experimental to the pilot stage.

Technical aspects of ensiling

Silage can be produced both in land-based and shipboard installations - the equipment required is basically the same: a grinder to reduce the fish to around 4-5 mm particles; a mixer to distribute acid evenly throughout the ground fish; a means of metering and safely adding strong acids; and a digestion tank. In the case of silage made from oily fish like sprats and herring it is both desirable and lucrative to reduce the oil content by centrifugation; desirable in order to prevent tainting of pig meat and lucrative because of the current high prices of fish oils.

Ensiling in land-based installations is normally based on fish offal, from seasonal gluts or from trash fish landed from day-trips. The type of equipment relates to the scale of landings but equipment for ensiling is cheaper both to purchase and to operate compared with fishmeal plants of comparable throughput; the overall economies of ensiling also offer the opportunity of better financial returns to the fisherman (10).

Ensiling aboard is practised on some Danish vessels, the raw material comprising trash fish and fish offal. Mixing of ground fish and concentrated sulphuric acid is achieved both by the motion of the vessel and by a monopump which also functions in final pumping-out of silage from the steel digestion tanks coated with glass-reinforced plastic. The acidity of silage is adjusted to pH 2-3 and is checked with pH paper.

A similar system could be implemented in tropical and sub-tropical fisheries aboard both small and large trawlers. Although extra labour is involved in making silage aboard ship, the netting and sorting phases have already been completed. Extra labour merely entails grinding trash fish into a digestion tank rather than dumping this component overboard.

A small fishing boat could expect to ensile up to 0.5 t trash fish during a 24-36 hour trip by utilizing one or more plastic containers of dimension around 1 m³. On larger trawlers it should be possible to convert one or more existing storage rooms, possibly merely by coating with glass fibre.

Paradoxically, an ensiling industry in the IPFC region could effectively improve the quality of and the return from the existing fish reduction industry. For example, in the Gulf of Thailand the poor quality of raw material landed for reduction leads to a product of variable protein content (7). If the large trawlers which fish the Gulf of Thailand in 10-15 day trips were equipped with a silage tank, the trash fish caught in the early part of the trip could be ensiled while that caught later could be retained and iced for reduction to fishmeal. In this way an ensiling and a reduction industry could co-exist in a mutually beneficial way.

The morality of ensiling by-catch aboard ship has been questioned in an editorial in "World Fishing" (March 1976) which stated "...would the principle of returning undersize consumer fish to the sea, though dead, be in question? And what if trawlers install flesh-bone separators?.." The fear that processing and ensiling at sea might lead to depletion of immature stages is a very real one, and stress must be laid on the utilization only of fish stocks which cannot go for human consumption, together with material which would otherwise be discarded.

Potential outlets for silage

Commercially, silage has been used as feed for pig and mink. If pig farms have a piped liquid feeding system silage may be conveniently supplied with only minor alterations to existing liquid feeding systems (8). If farmers use a dry feed system silage, because of its 20 percent solids level, can be incorporated with a cereal base to give a feed which is still sufficiently "dry" for feeding without alteration to the basic system. It has been calculated that a herd of 1,000 pigs requires 0.614 t silage daily (10).

The possibility of incorporating silage with a carbohydrate base such as cassava or maize and then drying to produce a stable feed suitable for poultry has been investigated (6). In the IPFC region a dry silage feed might also be utilized as feed for ducks or fresh-water fish.

The oil content represents a question important both for the producer and utilizer of silage - the former because he must decide whether or not to invest in de-oiling equipment, which will form the

major cost input in establishing a silage plant; and the latter because oily silage will result in tainted carcass meat and, consequently, downgrading at the meat processing plant. While breeding stock can be fed silage irrespective of oil content throughout their life, the intake of oil by pigs and chickens grown for their carcass meat must be controlled either by feeding with low-oil silage (12) or, as in the Polish pig industry, by withdrawing silage over the finishing period (Majewski, J., Central Laboratory, Poland, personal communication).

It should be emphasized that, while the utilization of silage for pig feed has been developed to commercial reality, its employment in poultry feed has received nothing like as much attention and recent studies have shown that difficulties have to be overcome due to low palatability (Disney, J.G., Cole, R.C., Francis, B. and Rice, R. Development of a fish silage/carbohydrate animal feed for use in the tropics. I. Methods of preparation. J.Sci.Fd.Agric. (submitted for publication)), dietary deficiencies (Hoffman, A., Olley, J., Barranco, A. and Clucas, J. Development of a fish silage/carbohydrate animal feed for use in the tropics. II. Animal feeding trials. J.Sci.Fd.Agric. (submitted for publication)) and possible toxicity problems (4).

Economic factors

A trading price for fish silage would reflect the summation of the costs of fish raw material, acids, capital, production and transport. A rational basis for calculating costs of the ensiling and the reduction processes has been recently introduced by Nicholson (10) and is summarized in Table I from which it can be seen, firstly, that silage can be produced more cheaply than meal and, secondly, that the major cost-inputs for silage and meal are, respectively, acids and energy.

The prices of formic acid and concentrated sulphuric acid were, in IPFC countries, around U.S.\$ 750/t and U.S.\$ 50/t, respectively. Following a series of silage production studies in tropical countries, a mixture of concentrated sulphuric acid (3.5 percent by weight) and formic acid (0.5 percent by weight) has been recommended as having acceptable digestive and preservative properties (5).

One tonne of fish raw material therefore requires:

formic acid, 5 kg	U.S.\$ 3.7
sulphuric acid, 35 kg	U.S.\$ 1.8
	<hr/>
Total	U.S.\$ 5.5

If formic acid alone was used at the 3 percent level, the acid cost rises to around U.S.\$ 23/t of raw material ensiled. Since acid is the major production cost item it is clear that streamlining the acidification process might realize significant savings.

The price of trash fish varied in IPFC countries from U.S.\$ 35 to U.S.\$ 60/t dependent mainly on seasonal factors. Using a median price of U.S.\$ 50/t together with the acid costs calculated above an estimate may be made of the cost of producing fish silage (Table II).

Two factors which mitigate against the successful marketing of silage are, firstly, its reputation as a "new", unproven product and, secondly, the high costs of transporting a liquid product. When considering silage as a novel product it must be remembered that it has for a number of years been considered invaluable to the pig raising industries of Poland and Denmark. Regarding transport, Nicholson (10) has calculated that silage can be delivered more cheaply than fishmeal over distances of up to 80 miles so that the siting of an ensiling plant should reflect distances from market outlets.

Probably the major factor which will influence the trading price of silage is the current prices of competing protein meals - meat-meal and fishmeal. In the past two years dry rendered meals have markedly increased in price; and the upward price movements on the New Zealand market presented in Table III make fish silage an attractive market alternative. The fact that energy costs in rendering processes exceed 60 percent of the production costs, coupled with the inevitable price rises in non-renewable energy sources points to a continued upward trend in the prices of feeding meals. Comparatively, because energy costs are less than 10 percent of those incurred in fishmeal production, silage should become even more economically competitive.

Finally, the foregoing calculations have all priced fish raw material nominally at U.S.\$ 50/t but, if trash fish currently discarded is ensiled at sea, the economics become extremely favourable - particularly if fishermen and pig farmers can form some type of joint venture to fix a mutually profitable price for fish silage.

CONCLUSION

Fish silage has proven ability as a protein component of stock feed in Poland and Denmark. A fish silage industry could complement rather than compete with an existing fishmeal industry by utilizing raw materials which are not available to the reduction process, e.g., by ensiling aboard vessels fish currently dumped could be utilized. The decision to de-oil silage to prevent carcass taint is a critical one, but current prices for fish oils are sufficiently high to give a good return on investment in de-oiling equipment. Economically, fish silage is competitive with other dry feeding meals - a competitive advantage which may be expected to be enhanced in the climate of energy price rises because the ensiling process requires less than 10 percent of the energy input of the reduction process.

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	Costs per ton of raw material input U.S.\$	
	meal	silage
<u>Direct Costs</u>		
Fuel oil (0.60 t/t raw material)	8.92	-
Electricity	2.31	0.82
Water	0.02	-
Maintenance	0.98	0.98
Bagging	0.94	-
Labour (3 x 2 man shifts)	3.30	1.27
Acid (formic acid, 3 percent at U.S.\$ 365/t)	-	10.95
	<u>16.47</u>	<u>14.02</u>
<u>Fixed Costs</u>		
Insurance (1 percent of capital cost)	0.369	2.03
Depreciation	3.69	0.16
Interest on capital (at 14.5 percent)	2.95	1.41
	<u>7.01</u>	<u>3.60</u>
Total production cost	23.48	17.62

Production costs based on 10 000 t raw material/year. Both systems have oil extraction equipment.

Table I. Comparative cost statements for reduction and ensiling processes (after Nicholson, 1976)

	Cost/t raw materials (U.S.\$)
<u>Direct Costs</u>	
Electricity	0.20
Labour	0.10
Acid (H ₂ SO ₄ 3.5 percent HCO ₂ H 0.5 percent)	7.00
	<u>7.30</u>
<u>Fixed Costs</u>	
Insurance, administration, fixed costs at 13 percent	0.20
Total Production Costs	7.50
Raw Material Costs	50.00
Total	<u>57.50</u>

Table II. Estimated costs of production of fish silage

Feed Component	Protein Content (%)	Price/t U.S.\$	Price/t Protein U.S.\$
Meatmeal	50	265	530
Bloodmeal	85	450	530
Fishmeal	65	360	550
Silage	15	60	400

Table III. Prices in New Zealand (January 1977) of protein meal component of pig feed

RECOVERY AND APPLICATIONS OF BY-PRODUCTS FROM LOUISIANA SHELLFISH INDUSTRIES

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Significant quantities of potentially valuable proteinaceous "waste" materials are discarded regularly as solid and liquid discharges from Louisiana shrimp and crawfish processors. Within the past several years, environmental and economic constraints have necessitated careful re-evaluation of such practices along with consideration of uses for these by-products for food and feed purposes. Heads-on landings for the Gulf Coast canned and frozen shrimp industry, including both brown and white shrimp, totaled 179.5 million lb in 1976. Figuring a loss of 75.9%, the total potential waste, including materials such as heads, shells, legs, etc., is over 136 million lb. The amount of calculated waste generated in the various processing streams is equally noteworthy. On a basis of approximately 3.3 gal water/lb shrimp processed, as much as 600 million gal are used, comprising a total potential dissolved and suspended microscopic waste load of 4.7 million lb. Approximately 3.3 million lb (dry weight) is from the frozen, peeled tail operations, while the canning portion (raw and blanch wastes) contributes 1.4 million lb (dry weight). On a wet weight basis, tonnages from frozen-peeled shrimp and peeled-canned shrimp processors in 1976 were 16.5 million and 7.0 million lb, respectively.

Three discharge streams of the canning operation have been examined in our investigations, including that from the peeling, separating and deveining phases, from the blanch tanks, and shrimp meat and debris discarded during the several inspections. Primary attention has been given to the blanch portion in terms of recoverable dissolved proteinaceous material from the hot liquor. Other shrimp wastes, analyzed in earlier work, are discussed subsequently, along with presentation of data from relevant investigations of our laboratory.

RELEVANT CRUSTACEAN BY-PRODUCT INVESTIGATIONS

Shrimp meal

Efforts are underway to upgrade the quality of meals from shrimp and other crustaceans, notably in terms of effect of processing conditions on nutritional and pigment value (3, 4). Studies (2, 6) have shown significant extant variability in analyses and potential nutritional composition of shrimp meals, in lipid and

fatty acid composition, as well as in carotenoid pigment level. Such variability, especially in percentages of true protein differentiated from non-protein nitrogen (probably chitin), is seen in Table 1.

TABLE 1. PROTEIN AND CHITIN NITROGEN OF VARIOUS SHRIMP MEAL PREPARATIONS

Preparation	Total Crude Nitrogen (A)	% Crude Protein	Chitin Nitrogen (B)	% Chitin*	Corrected Nitrogen** (CN)	% Corrected Protein***
Dehydrated Meal	5.97	37.3	1.41	20.6	4.56	28.5
Sun-dried Meal	8.27	51.7	0.62	9.0	7.65	47.8
Machine-dried Meal	7.16	44.7	0.83	12.1	6.33	39.5
Shrimp Heads	9.32	58.2	0.76	11.1	8.56	53.5
Shrimp Hulls	7.36	45.9	3.71	54.2	3.65	22.8

*Chitin = 14.6

**CN = A - B

***Corrected protein = Corrected N x 6.25

Information on true protein percentages is necessary when protein levels of final compounded diets must be standardized to evaluate growth response data.

Dissimilarities in percentage of lipids and ratios and concentrations of specific amino acids are extremely important in formulation of shrimp meal-containing diets for economically valuable aquatic animals. Accurate energy levels and essential fatty acids must be considered. Differences in fatty acid composition of two shrimp meals are shown in Table 2. Small amounts of 20:5w3 and 22:6w3, both highly labile fatty acids, in the sun-dried product, along with TLC data on triglyceride hydrolysis, suggested deleterious effects attributed to the particular manufacturing process. These and other data indicate that documentation of the source and type of the crustacean meal is essential for its effective use in aquatic (and other) animal rations.

Shrimp effluents and in-house streams

Analyses of nucleotides and bound and free amino acids in shrimp blanch water from batch tanks (7) have revealed significant amounts of such chemicals (Tables 3 and 4). Concentrations of flavor enhancers such as IMP and flavor-related amino acids, i.e., glutamic acid, glycine and arginine, in blanch liquors are noteworthy. The contribution of glycine to the sweetness of shrimp meat is known, while leucine, glutamic acid, and proline, as well as arginine, also confer a desirable flavor. The flavor-enhancing properties of the 5'-nucleotides are recognized, along with favorable synergistic activities with glutamic acid. Drum-dried

flakes, prepared from blanch water concentrate, have a characteristic strong sweet shrimp-like flavor. Studies noted have relevance to other fisheries industries using blanching procedures, or where discharge streams carry large organic loads with valuable flavor attributes.

TABLE 2. MAJOR FATTY ACIDS OF TWO SHRIMP MEALS (WEIGHT PERCENT COMPOSITION)

Fatty Acids*	Sun-dried (3.5% lipid) (Penaeid)	Vacuum-dried (9.2% lipid) (Pandalid)
14:0	2.5	2.4
16:0	20.8	10.1
18:0	8.7	2.0
20:0	0.7	0.1
22:0	1.4	--
16:1	10.9	9.0
18:1	21.4	17.9
20:1	3.3	13.4
22:1	1.5	18.4
18:2w6	2.9	1.4
20:2w6	1.5	0.3
20:4w6	1.7	0.9
18:3w3	1.3	0.8
18:4w3	0.2	1.1
20:5w3	2.1	7.6
22:6w3	2.2	9.0

*Notation indicates the number of C atoms in the molecule, the number of double bonds and specifies the position of the double bond nearest the terminal methyl group.

TABLE 3. CONCENTRATION OF NUCLEOTIDES IN SHRIMP BLANCH WATER*

Compound	Blanch Water			Shrimp Meat μ moles/g
	μ moles/tank	μ moles/l	g/l	
Hypoxanthine + inosine	$\times 10^6$			
	1.0	778	0.103	0.7
5'-AMP	0.94	707	0.251	0.7
5'-IMP	1.8	1,330	0.462	1.2
ADP	0.17	131	0.050	0.1
ATP	0.012	9	0.004	TR.

*Based on 350 gal batch tank (salt-free)

TABLE 4. MAJOR AMINO ACIDS IN SHRIMP BLANCH WATER*

Amino Acid	g/l	Percent of Protein (N x 6.25)
Lysine	1.39	4.83
Arginine	3.10	11.70
Aspartic acid	1.80	6.59
Glutamic acid	3.02	10.51
Proline	1.21	4.17
Glycine	2.54	9.13
Alanine	1.26	4.49
Leucine	1.33	5.21

*Based on 350 gal batch tank (salt-free)

Evaluation of shrimp protein

Investigations (11, 12) also have included chemical and nutritional evaluation of shrimp waste protein, designated SWP, from cannery effluent. Proximate analyses of the SWP, obtained by isoelectric point precipitation, have shown protein levels of 58.9% with gross energy values of 5170 cal/g. Proximate values of SWP were within ranges reported for various fish meals, containing greater amounts of protein and significantly less ash (6.3%) than commercial shrimp meal from the same facility. SWP contained smaller amounts of calcium, magnesium, and phosphorus compared with quantities of these elements in fish meals.

Further studies have demonstrated the nutritive value of the SWP in that protein quality was improved 74% in a soybean diet when the soybean protein was replaced by 50% of the SWP. Amino acid profile of the shrimp waste protein, compared with casein and soy protein, is shown in Table 5. Use of SWP in canned or processed pet foods, or as an additive to textured vegetable proteins, has been projected.

Pigment levels of crustacean meals

Shrimp meal has long been used in diets by fish nutritionists to lend desired flesh coloration to trout and salmon. Feeding experiments have shown that carotenoids may be transferred from the feed to the flesh of trout and salmon.

Laboratory analyses have indicated noteworthy differences in carotenoid values of various shrimp meals, often reflecting the specific processing techniques used (Table 6). Implications are seen in the overall nutritional quality of the particular meal.

Due to the diverse treatments involved in processing of shrimp meal, carotenoids may be destroyed from excessive heat used as well as from exposure to light and atmospheric oxygen. Thus, pigment may become a limiting factor in the biological value of shrimp meals when used as a dietary ingredient for purposes of favorably affecting pigmentation of the animal in question. Information is needed on the processing technique used to produce the shrimp meal

along with methods for retention of the carotenoid content of the meal during drying and subsequent storage.

TABLE 5. COMPARISON OF AMINO ACID PROFILE OF SHRIMP WASTE PROTEIN (SWP) WITH CASEIN AND ISP

Amino Acid	g/16 g of N		
	ANRC Casein	SWP	ISP*
Essential			
Half-cystine	0.76	1.59	1.2
Isoleucine	6.55	3.26	4.9
Leucine	10.05	7.57	7.7
Lysine	8.01	6.17	6.1
Methionine	3.08	2.84	1.1
Phenylalanine	5.39	4.56	5.4
Threonine	4.28	4.28	3.7
Tryptophan	1.33	1.26	1.4
Valine	7.39	4.42	4.8
Nonessential			
Alanine	3.35	5.29	3.9
Arginine	4.07	6.31	7.8
Aspartic acid	7.39	10.74	11.9
Glutamic acid	23.05	15.46	20.5
Glycine	1.99	4.29	4.0
Histidine	3.02	1.90	2.5
Proline	11.75	3.44	5.3
Serine	6.65	4.53	5.5
Tyrosine	5.82	3.64	3.7

*Isolated Soybean Protein (Promine D)

TABLE 6. CAROTENOID CONTENT OF VARIOUS SHRIMP MEALS

Material	Pigment Concentration micrograms/g
Shrimp meal (from brown shrimp, <i>Penaeus aztecus</i>)*	10
Shrimp meal (from white shrimp, <i>Penaeus setiferus</i>)*	6
Sun-dried shrimp meal**	1-2
Vacuum-dried shrimp meal (<i>Pandalus borealis</i>)***	104

*Southern Shell Fish Company, Harvey, Louisiana

**Blum and Bergeron, Houma, Louisiana

***SeaPro Inc., Rockland, Maine

Other studies concern analyses of pigments in wastes from the rapidly expanding Louisiana crawfish industry. Over 6 million lb of dry crawfish waste are produced yearly, providing a ready source of a usable crustacean meal. Preliminary data on solvent pigment extractions from the large chela (claw) of the crawfish, *Procambarus clarkii*, have revealed concentrations of total carotenoids as high as 196 µg/g dry tissue.

STUDIES OF SHRIMP PROCESSING WASTE STREAMS

Sampling techniques and stream analysis procedure

Samples of effluent streams were taken from three major shrimp canneries in Westwego and Harvey, in the greater New Orleans vicinity. More than 20 such facilities of various sizes are located in the Louisiana-Mississippi Gulf region, the majority of which are found in the New Orleans and Houma, Louisiana area. Logistics of areal plant concentrations are important in any projection of economics of by-product recovery and ultimate use.

Blanch water was taken directly from the blancher overflow valves. While a batch process was used in early stages of the industry, most plants now employ a continuous system in which shrimp are passed through the tank via a screw conveyor and brine water is continually added, with surplus washed from the tank. In blanching or pre-cooking operations (7) shrimp are processed in a boiling brine which extracts moisture and solubles, curls the meat, and develops the characteristic pink to red color of the final product. During this treatment, both particulate and dissolved shrimp protein is concentrated in the liquor which is discarded usually at the end of the daily processing. The three facilities studied all use continuous blanchers in which the greater portion of the water is recirculated within the tank and a lesser amount discarded through an overflow valve. As noted, overflow loss is compensated for by addition of fresh brine, procedures for which vary from plant to plant.

Raw wastewater was collected from effluent streams carrying wastes from the washing, peeling, and deveining operations. All liquid material was collected and stored for transport in 5-gal plastic carboys. Samples of solid waste composed of detritus remaining after initial picking, bits of shell not removed during peeling, and broken pieces of cooked shrimp were also collected. Samples were collected from the discharge chute of the after-blanch air cleaner. All solid samples were packed in plastic bags and stored in ice chests. Subsequently, all material was transported to the LSU Department of Food Science at Baton Rouge and frozen at -5 C until analyzed.

Shrimp blanch water analysis

Blanch water samples were filtered through cheesecloth to remove suspended meat fragments, dried in a microwave oven (Amana Touchmatic Radarange Model #RR-6-W), and the resulting dry weights recorded. Unless otherwise indicated, all dry weight determinations were made in this manner.

The protein liquor obtained after removal of suspended meat was adjusted to pH 4.2 via 12 M reagent-grade (37-38%) HCl, thus

allowing for isoelectric precipitation of dissolved proteins. After precipitation was complete (60-75 min), the supernatant layer (sugar liquor) was removed and the precipitate centrifuged at 10,000 rpm for 10 min. The supernatant was added to the previously-siphoned sugar liquor. Dry weight of dissolved protein removed was determined.

The sugar liquor obtained after removal of dissolved protein was adjusted to pH 9.5 with technical-grade $\text{Ca}(\text{OH})_2$. Adjustment to pH 9.5 in the presence of Ca^{++} ions permitted isoelectric precipitation and salting out of the dissolved sugar. Following this, the supernatant layer (final effluent) was siphoned and the precipitate centrifuged at 10,000 rpm for 10 min. The supernatant was added to the previously-siphoned final effluent. Dissolved sugar removed was dried and weighed.

To determine the amounts of dry solids in the unused blanch water (brine water) and the final effluent, samples of each were vacuum-dried at 85 C/30 in. Hg pressure.

Raw shrimp processing water analysis

Raw shrimp processing water was filtered through cheesecloth to remove suspended meat fragments and shells which were dried and weighed. The remaining liquor obtained was adjusted to pH 4.2 with 12 M HCl, permitting precipitation of dissolved proteins. The supernatant layer was siphoned and discarded, and the precipitate centrifuged at 10,000 rpm for 10 min and dried and weighed.

Shrimp blanch water

Dry weight determination of proteinaceous and other components in shrimp blanch water, representing averages from fifteen collections for the period May through December, 1976, are given in Table 7. Data for both the brown shrimp (*Penaeus aztecus*) and white shrimp (*Penaeus setiferus*) seasons are included. Discounting that noted as "other solids," total suspended and dissolved solids represent 0.55 lb/100 lb raw shrimp processed. On a gallon basis, recoverable dissolved protein comprises 7.5% of the total. In all likelihood, concentrations of suspended meat fragments and dissolved protein are sufficient for economical recovery.

TABLE 7. CHARACTERIZATION OF SHRIMP BLANCH WATER

Component	Average Concentration (dry wt)	
	g/gal H ₂ O	lb/100 lb raw shrimp
Suspended meat fragments	9.5	0.11
Dissolved protein	33.5	0.39
Dissolved sugar	4.6	0.05
Other solids*	194.0	2.27
Total	241.6	2.82

*Includes salts, trace elements, miscellaneous organics.

While the dissolved sugars are not present in large amounts, their removal may be necessary to comply with pending EPA "zero discharge" regulations.

Raw shrimp processing water

Data in Table 8 on the various components in raw shrimp processing water are averages from the same fifteen collections made for the blanch water. The figure of 2.44 lb dissolved protein/100 lb raw shrimp processed compares favorably with previously reported (1) suspended solid loads in raw wastewaters of 3.68 lb/100 lb shrimp processed.

TABLE 8. CHARACTERIZATION OF RAW SHRIMP WASTEWATER*

Component	Average Concentration (dry wt)	
	g/gal H ₂ O	lb/100 lb raw shrimp
Dissolved protein	3.39	2.44
Shells, legs, heads	21.10	15.16
Total	24.49	17.60

*Includes peeling, washing, deveining, and miscellaneous uses.

The g/substrate/gal recovered, less solids, is approximately 50% of that in the blanch water effluent. Possibly, the nutritive value of the extracted raw protein is superior to that of the extracted material from the blanch tanks, since the former has not been subjected to heat treatment, which might cause protein denaturation and destruction of thermolabile amino acids such as lysine.

Waste loads in effluent streams may vary on a daily or even hourly basis. Similarly, waste load variability occurs in effluent blanch streams of the three canneries examined on the same day (Table 9).

TABLE 9. VARIABILITY IN CONCENTRATION OF PROTEINACEOUS MATERIAL IN SHRIMP BLANCHING WATER*

Component	Plant A	Plant B	Plant C
Suspended meat fragments	40.8	0.8	7.4
Dissolved protein	12.5	25.2	25.0
Total	53.3	26.0	32.4

*Expressed as g (dry wt)/gal blanching water.

Dissimilarities exist not only in amounts of total dissolved and suspended wastes, but also in the relative amounts of the different components comprising the effluent loads. Variability may be due

to size of shrimp, whether they have been deveined, blanch period, temperature, and salinity. Nevertheless, plant-to-plant and day-to-day dissimilarities, depending on the tonnage being processed, ultimately can be calculated to give an average amount of potential waste product recovery.

Another source of valuable shrimp meat is that from the discharge section of the forced-air apparatus used to remove debris (i.e., small meat pieces and shell fragments) originating from the turbulence of the blanching portion of the operation. In some plants, this material is separated by hand. In both instances, the debris, including the food-grade shrimp meat pieces, is traditionally treated as waste and either included in the meal or discarded entirely. Laboratory hand-separation of meat particles and shells revealed the presence of as much as 82% edible food-grade meat. Based on a discard solid shrimp load weight of 500-1000 lb/8 hr, it is apparent that as much as 410-820 lb of valuable shrimp meat are discarded daily.

In addition, it is estimated that the peeling, separating, and deveining streams contribute as much as 900-1100 lb recoverable protein/8-hr day while blanch streams have proteinaceous loads as great as 200-260 lb/8-hr day. These figures do not include the multi-tons per day of solid waste incorporated into meal. Extrapolation of recovery amounts to numerous localized plant operations over a concentrated processing season, often with peak load days as long as 16-20 hr, further indicates the significant magnitude of resource available for application.

APPLICATIONS OF SHRIMP BY-PRODUCTS

The diversity of applications of by-products from the shrimp processing operation (5) is noted in Table 10. These include use in aquaculture diets, pet foods, concentrated flavor sources, additives to textured vegetable proteins for fabrication of shrimp products, and as a pigment source in broiler diets. Proposed usages for chitin and its derivative chitosan are further markets for exoskeleton waste.

TABLE 10. APPLICATION OF SHRIMP BY-PRODUCTS

Livestock Feed Ingredient	Source of:
Tropical Fish/Bird Diets	- Shrimp Protein Concentrates
Aquaculture Diets	- Flavor Concentrates
Pet Food Supplement	- Carotenoid Pigments
	- Chitin/Chitosan
Use in Fabricated Shrimp Products	

Use of shrimp meals in poultry feed formulations has been well demonstrated, especially for purposes of imparting desirable pigmentation to meat, skin or egg yolk. In this regard, there is a need for higher quality meals, in terms of pigment and protein percentages and low ash content, which are available in large tonnage

amounts to satisfy the demands of this industry.

With increased cultivation of economically valuable freshwater and marine animals, greater attention is being given to diets and dietary ingredients that can impart desirable coloration in the meat and/or external surfaces of the cultured species. This continued interest in applications of fishery wastes, notably by-products of the shrimp processing industry, has focused attention on the pigment quality of crustacean meals. Thus, shrimp meals and pigment-fortified marine substrates are receiving increasing attention as skin/flesh coloration agents in salmon and trout diets.

Shrimp-based flake diets developed at LSU (8) have been used in nutrition of various fishes, especially freshwater and marine tropicals, specialty diets to enhance pigmentation, breeding, etc., and supplementation and ultimate replacement of currently used live food in aquatic animal culture. The tropical fish market is by no means insignificant, for in analyses of sales of aquarium-related products in 1973-74 foods of various types increased from 57 to 67 million dollars.

Analyses and quality evaluations of shrimp by-products and development of shrimp meal-fortified diets are needed for production of nutritionally-sound formulations in aquatic animal husbandry. Experimental data have shown repeatedly the value of shrimp meal in crustacean diets (9) and as a component of larval flake diets designed as a supplement and/or replacement for brine shrimp (*Artemia*). The latter, commonly used as a live food in larval stages of aquatic animal growth, are in extremely short supply and efforts are being made to develop artificial larval diets. Overall, the monetary worth of aquaculture is increasing yearly, with projections to nearly \$400 million by 1982.

Water-soluble proteins from autolyzed shrimp wastes have been evaluated as microbiological growth media (10). Data showed that a peptone derived from such wastes compared favorably with five commercially available peptones in supporting growth of several microorganisms.

Considerable interest is being shown in recovery of chitin and chitosan, a polyglucosamine substance from chitin, from shellfish processing wastes. Commercial use of materials from the shrimp exoskeleton is being proposed in paper-making, pharmaceutical, food-processing, agricultural, waste treatment and monitoring, and adhesive industries. For instance, chitosan has been found to be an effective coagulating agent for poultry processing wastes wherein treatment reduced suspended solids in the composite effluents by as much as 74-94%.

Shrimp meat fragments can be readily used in development of flavor concentrates, reconstituted shrimp and for use with textured soy protein in fabricated shrimp products. Lyophilized cooked shrimp protein concentrate has a strong shrimp flavor and a pinkish-orange color, along with a salty taste from the brine used. Both aspects can be adjusted via rehydration and comminution with vegetable protein extenders. A product such as this could be used as a mock shrimp for human consumption, requiring only formation of the shrimp-TSP mixture into a shape of a fantail or butterfly shrimp. The shelf life of minced fish can be extended by comminution with shrimp meat, a process in which rehydrated shrimp protein concen-

trate conceivably could be used. Interest is being shown by national food flavor industries in the potential of natural concentrated shrimp flavors in seafood products. The shrimp industry as a whole is looking into processes and products that will "extend" shrimp, using procedures that combine shrimp meat and flavor with vegetable proteins and fillers such as soy or rice.

It is clear that Gulf shellfish processing industries can provide a broad spectrum of nutritionally valuable proteinaceous by-products for use in the food and feed sectors of our economy. Systems need to be designed for economically sound product recovery, thus minimizing discharge wastes by conversion of such materials into valuable items of commerce.

ACKNOWLEDGMENTS

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ESTIMATED YIELDS OF EDIBLE ARKHELLS
(ANADARA SPP) IN MANGROVE AREAS

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Arkshells of the genus Anadara (Fig. 1) appear to be associated with mangroves in various parts of the world (1, 2, 3, 4). Some are found in watery mud in the shade of mangroves (A. tuberculosa, A. similis, and A. multicostata), while other species are found on tidal flats (A. (Grandiarca) grandis) or in shallow water (A. subcrenata in Fiji) not far from mangrove forests.

These species have heavy porcellanous shells, the contents contributing only 18-35% to the total weight. The shell is covered with a thick periostracum which may be worn away near the umbo with the shell showing corrosion, presumably from the acidic mangrove soils. The arkshell is typically strong-ribbed with a straight hinge and flattened area near the hinge which has growth marks or fine ridges. The shells attach by byssus threads to mangrove roots submerged in mud. They may also be found on the surface of the mud no longer attached, especially in areas where they are collected, the byssus threads having been broken. These occasionally can be seen actively feeding as they lie partly open on the surface during low tide. They are making use of organisms associated with the organic materials of the substrate.

Fauna of wet mangroves of Colombia include quite a varied assemblage of species such as several species of snapping shrimps (Alpheidae), crabs (one species of which climbs the mangrove trees: Goniopsis gaudichaudi), gastropods, small or juvenile fishes of several species and larvae and juveniles of penaeid shrimps.

THE FISHERY

The fishery for the various species of Anadara is done by hand collection mostly by women and children. The shells can be located through experience in knowing where they attach and feeling for them with the hands or feet in the mud. In Fiji where A. subcrenata is in shallow water out from the mangroves, the women stand in water sometimes up to their necks and pick up the shells with their toes and transfer them to their hands for inspection before putting in a bag slung from the shoulder. In Colombia the fishermen go by dugout canoe into the mangrove creeks when the tide is out and walk barefoot in the deep mud among the trees. The shells are collected by hand and put in baskets. The time for

collecting is limited by the 3-4 m tides, amounting to not more than four hours. Returning to the villages the shells are put in an intertidal shelter made from coconut fronds where they are kept until needed for cooking or taking to market. The species has ability for only limited movement but escape is prevented by a ridge of mud around the shelter.

METHODS

Fishermen were contracted or coopted by the head of the village to collect in the fishing area selected. The fishing area was measured with a surveyor's chain (3) or estimated (4) while fishing was in progress. Observations (Table 1) were made on individual rates of collecting (4). The total catch was weighed and counted at the end of the fishing period. In addition transect counts and metre ring counts were made (3) of shells across and throughout the area in Fiji. From these data weights per m^2 were estimated. Total area of distribution was estimated from field visits through the area and from an aerial photograph map showing mangroves (4).

An experiment on growth over an 18 month period was done by holding small and medium-sized *A. tuberculosa* in a plastic mesh iron tray buried among the mangroves where the species was common.

Also samples were collected monthly from the field and from the market for measurements of size and weight (4). Daily records were kept of quantities in the market.

RESULTS AND DISCUSSION

The area of distribution of *A. tuberculosa* on the Colombian coast (Fig. 2) was estimated at 30 km^2 and average number of specimens one per square metre (average weight 50 g (Fig. 3)). From these data the total available stock was estimated to be about 1500 tons of which 500 tons could be harvested annually. The amounts appearing in markets, etc. indicated commercial use of about 150 tons annually of which about 45 tons were exported unprocessed. With the amount used for subsistence the total exploitation rate would possibly be about 300 tons a year (4).

In Fiji the quantity of arkshells (*A. subcrenata*) in a near-shore area of 0.06 km^2 was estimated to be 11 tons (7 shells per m^2 and individual weights averaging 25 g). Harvesting rate suggested was 3 tons per year from this bed of arkshells (3). The species appears frequently in urban markets in Fiji and there is frequent use of it as barter for agricultural produce between inland and coastal fishing villages. Also for subsistence the quantity required for a meal can be obtained quickly and easily at the shore.

Anadara was sold alive in the markets but in Colombia was also sold cooked and strung on slivers of bamboo. A few experiments showed that it could be kept out of water at average temperatures of 28C for at least 7 days without showing signs of spoilage but usually it was kept more than three days during marketing. The flavour was somewhat similar but milder than in the soft-shelled clam. Tenderizing or chopping finely for chowders was required.

GROWTH AND MATURITY

Measurements of monthly samples from fishing and from the market indicated that growth was most probably slow, not exceeding one mm per month. (Fig. 4). This was corroborated by the experiment with tray-grown specimens in a mangrove area (Fig. 5). From the smallest size seen (30 mm long) a period of 26 months would be required to reach average commercial size (56 mm). Since growth may be faster at smaller sizes it is possible that growth of juveniles to 30 mm did not require more than one year or two years at the most.

Sexes were separate and gonad development apparent at small sizes: 32 mm long in females and 36 mm in males. Variation in numbers mature and spawning each month occurred (Fig. 6) but not less than 20% in any month (Feb. 1971) and as high as 90% (June, 1970) (4).

CONCLUSIONS

Where they are exploited mainly for subsistence such as in Colombia and Fiji, it would seem inadvisable to increase commercialization of species of Anadara. However, there must be areas of the world where exploitation could be initiated or increased for the various species. Since they are slow-growing and low-priced in most markets they would hardly be useful for aquaculture apart from holding them in enclosures. Experiments on growth rates under enriched conditions would be useful. Methods of depuration would also require evaluation where the enrichment was from sewage.

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Table 1. Collecting rates of arkshells by individual fishermen from an area of about 4000m² on the Pacific coast of Colombia in 1972.

Date	Total Collected	Hours Collecting	Total Weight KG	Rate KG/Hour
15 May	74	1	3	3
16 May	192	2	8	4
"	312	4	18	5
"	264	4	16	4
"	204	4	13	3
"	1,308	4	69	17
"	1,080	4	65	16
27 June	65	1/4	3	12
"	137	1/2	6	12
"	61	1/2	2	4
TOTALS	3,697	24 1/4	203	8

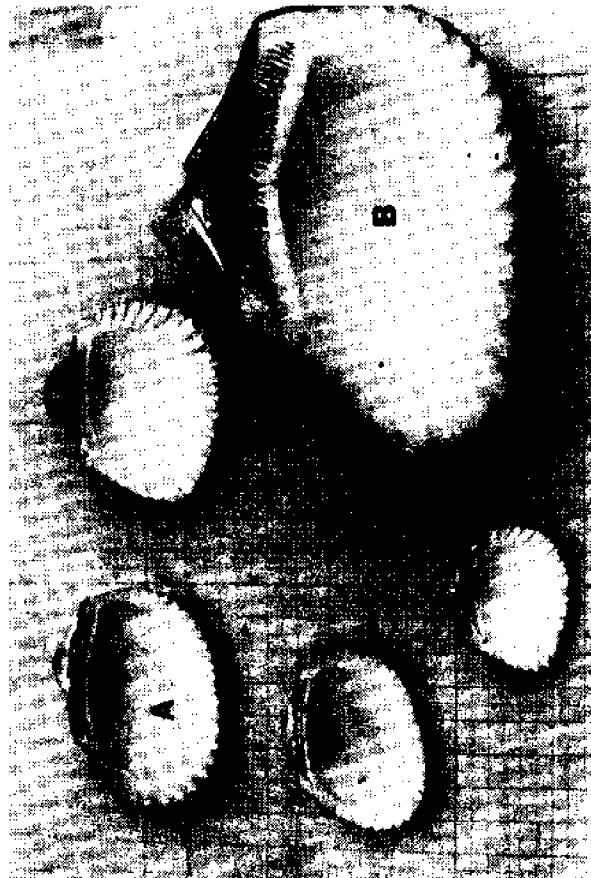


Fig. 1. Arkshells from the Pacific coast of Colombia. A = Anadara tuberculosa, B = A. (Grandiarca) grandis.

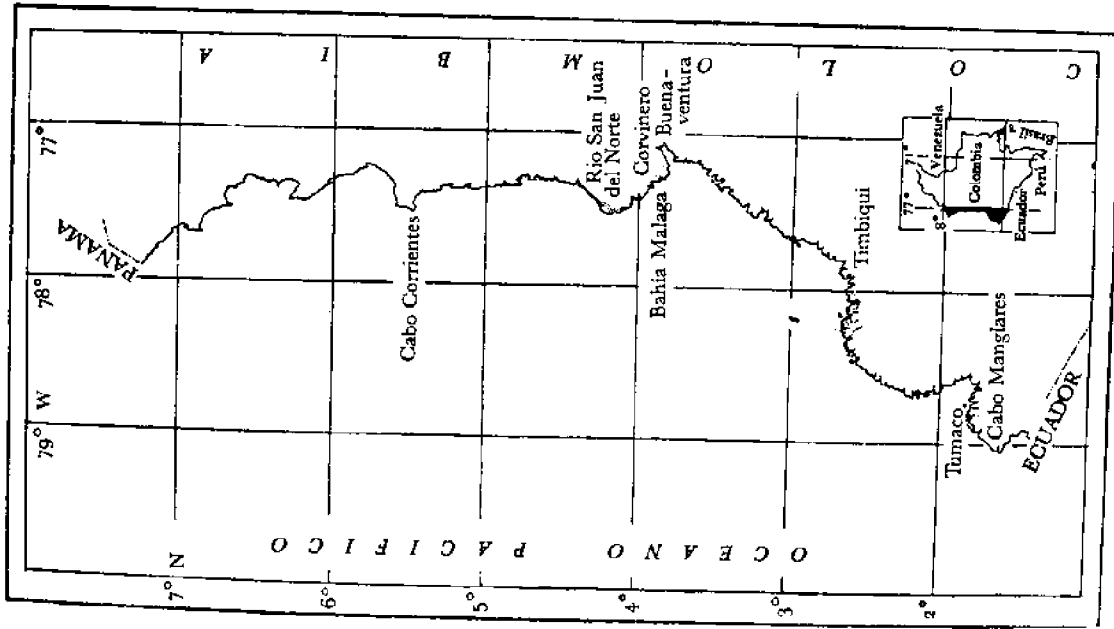


Fig. 2. Map of the Pacific coast of Colombia.

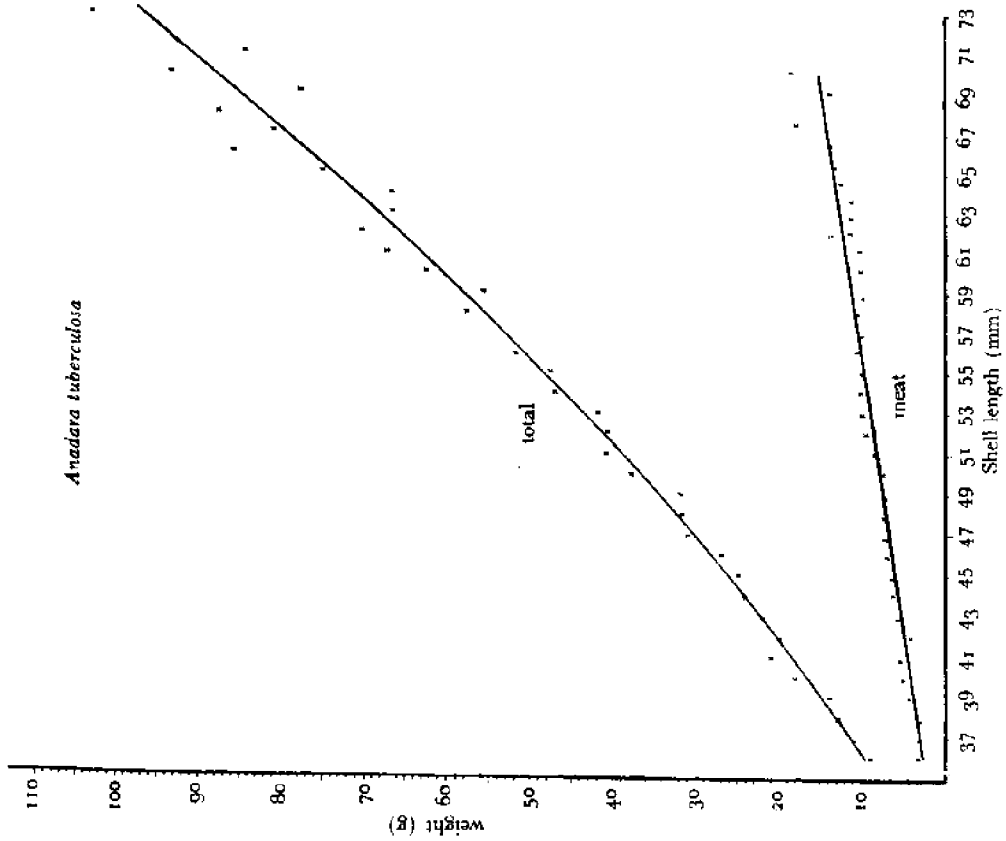


Fig. 3. Total and meat weights of *Anadara tuberculosa* (948 specimens) (4)

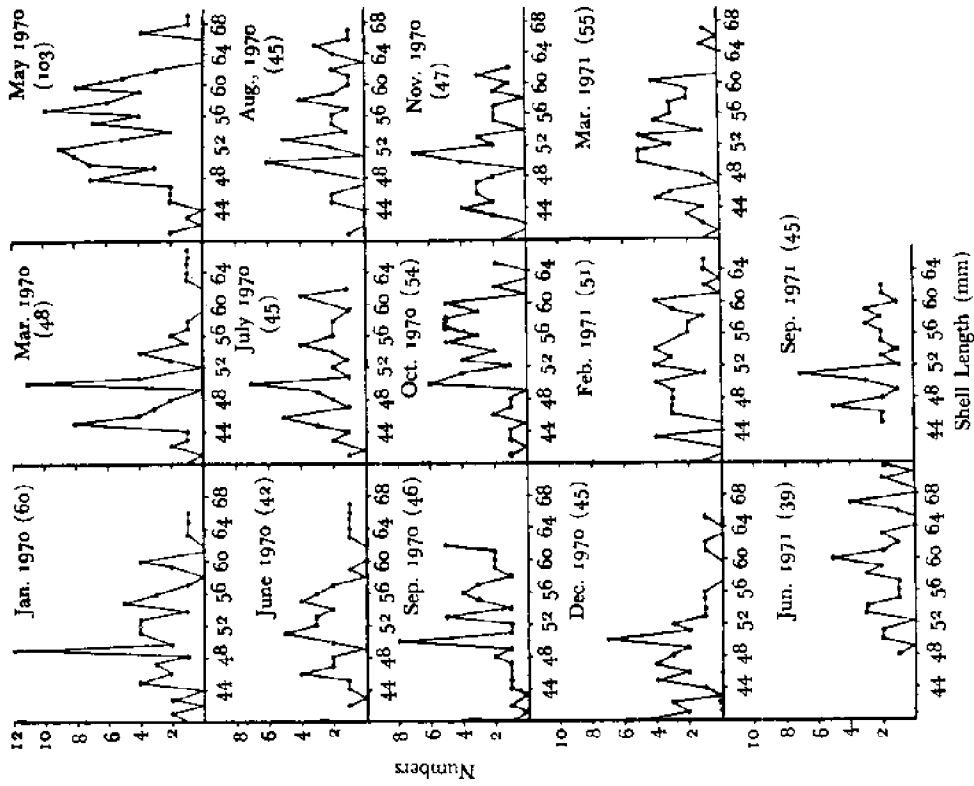


Fig. 4. Monthly shell length frequencies of *Anadara tuberculosa* from market samples at Buenaventura (4)

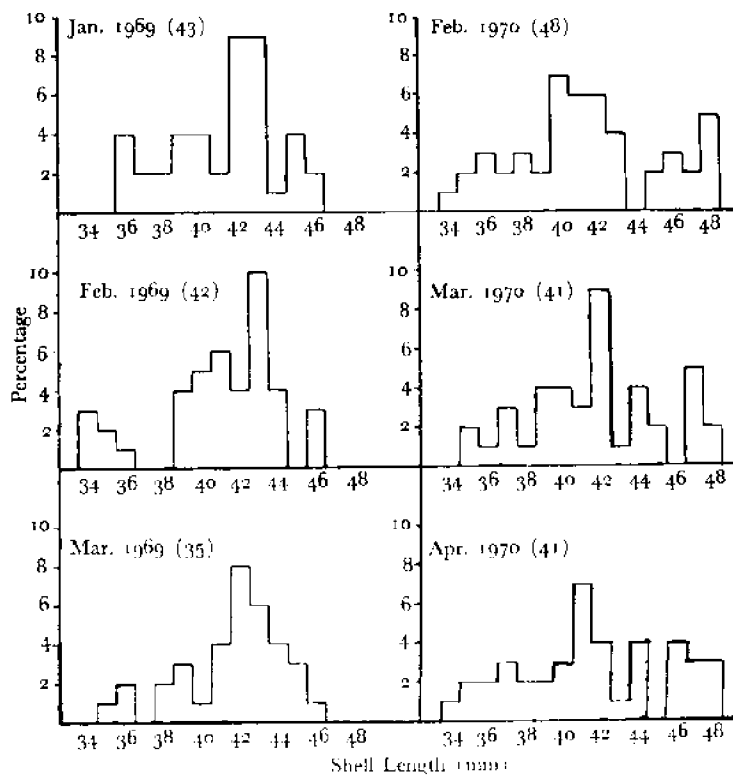


Fig. 5. Monthly shell length histograms of *A. tuberculosa* held in growth experiment in mangroves (4).

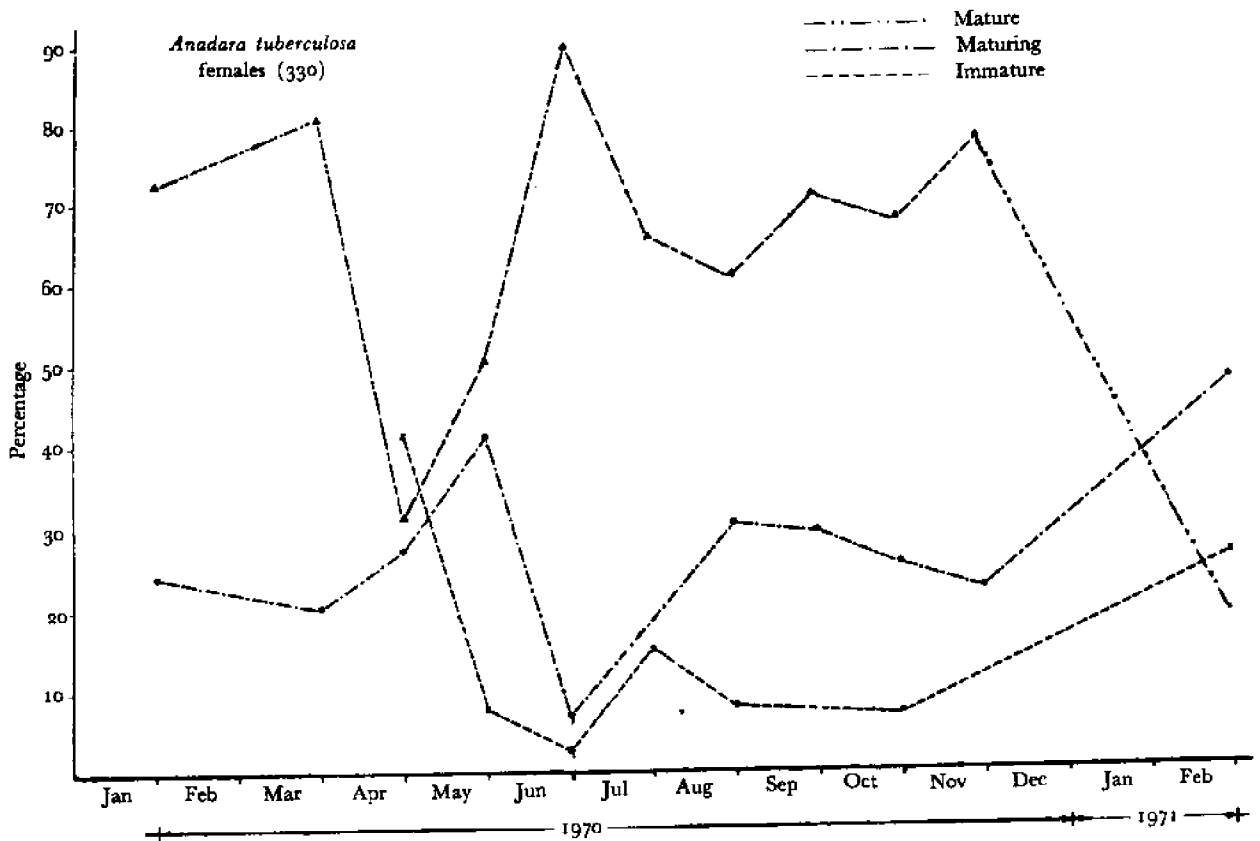


Fig. 6. Percentages of immature, maturing and mature Anadara tuberculosa in monthly samples, 1970 and 1971 (4).

DEVELOPMENT OF A SQUID PROTEIN CONCENTRATE
FROM ILLEX ILLECEBROSUS

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Squid, a member of the Cephalopodia, comprise one of the largest and relatively unutilized resources in the sea. In 1969, squid harvest accounted for under 1% of the world total marine catch (1). Less than 10% of the ocean's area is fished for cephalopods, although it has been postulated that the annual potential catch of oceanic squid is from 100-300 million tons (19). In analyses of cephalopod resources, Voss noted landings in the Caribbean Sea of 900 tons with an estimated potential of >100,000 tons (18, 19). Squid is valued as a delicacy in Asian and Mediterranean countries, but is utilized primarily for fish bait in the United States (9). Various procedures for processing squid for food have been reported (3, 16) along with attempts to establish the marketability of the product (6). In addition to its abundance and widespread distribution, other desirable qualities of squid, i.e., high fecundity, lack of scale and bone, high nutritive value, suggest that this resource can be an important source of raw material for manufacture of a wholesome marine animal protein concentrate as well as a marine food product (14).

Concepts in development of marine protein concentrates are based on a need to more effectively utilize the finite supply of world fishery resources. In this regard, increasing attention is being given to previously unexploited marine animals and to various species traditionally discarded as waste. Current marine protein concentrates, prepared by a variety of solvent extraction procedures, have been proposed for a range of food uses, especially in fortification of cereal-based products. While solvent extraction processes result in nutritionally valuable protein concentrates with acceptable organoleptic properties, functional properties are absent. Functionality, i.e., solubility, water binding ability and emulsion formation are valued in food preparations, including beverages, and in such semi-solid foods as sausages and luncheon meat formulations. Without such features, proteins are largely reduced to the role of a food supplement. A market survey in 1970 (4) concluded that functional properties constitute a crucial factor in determination of the market potential of animal protein

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concentrates.

Investigations reported here were undertaken to establish optimum procedures for manufacture of squid protein concentrate from Gulf of Mexico squid for ultimate human consumption. Major attention has been given to examination of functional properties of aqueous-derived squid protein concentrate along with factors affecting protein extraction, digestibility and amino acid profile, and organoleptic quality of the final product.

MATERIAL AND METHODS

Source and sample preparation. Squid used was the species Illex illecebrosus, commonly known as "arrow squid," collected in the Gulf of Mexico. Two hundred pounds of squid in frozen block was obtained from the National Marine Fisheries Service Southeast Fisheries Center, Pascagoula, Mississippi. Upon receipt in the Department of Food Science, Louisiana State University, frozen samples were sorted into separate lots, each containing 10 random sizes, and maintained at -20 C until used in various phases of the study.

Frozen samples were thawed in a 1:2 ratio of water and squid, and stirred continuously for 30 min at 50 C (17), allowing rupture of viscera and resultant autolytic enzymatic digestion of the skin material. The deskinned, eviscerated squid was washed thoroughly in tap water and comminuted in a Waring Blendor for 1 min, producing a puree-like product used for preparation of both solvent-extracted protein concentrate and the protein isolates obtained by isoelectric point precipitation.

Analyses of protein solubility and functionality. The effect of salt, temperature and pH on protein solubility was determined. Sufficient quantities of NaCl were added to make 100 ml of extracting media with 0.1, 0.25, 0.5 and 1.0 N NaCl content. Slurries of these salt contents, along with those without added salt, were used for extraction at pH levels of 3, 5, 6.8, 8, and 11. The extraction and centrifuging procedures were conducted at 5, 25 and 55 C at each of three pH's indicated. To examine ratio of squid to extracting medium on protein solubility, 5, 10 and 20 g of squid per 100 ml of extracting medium were extracted at three pH levels.

The pH for maximal protein precipitation was determined by titrating aliquots of the extracts, obtained by extraction, at pH 3, 6.8, and 11, followed by centrifugation at 8,000 rpm and 10 C. Nitrogen content of the supernatant was analyzed using the macro-Kjeldahl method.

Analyses of protein functionality. Procedures for evaluation of squid concentrates for functionality (including solubility, emulsion stability, and swelling and wetting in water), pepsin digestibility, and proximate composition are summarized as follows:

Solubility: A 1 g sample of protein was mixed in 100 ml of distilled water and pH adjusted to 8. The solution was stirred for 1 hr at 25 C, and the resulting dispersion centrifuged (Sorvall RC 2-B) for 30 min at 5,000 rpm. The extractable Kjeldahl nitrogen was determined and the percent soluble protein calculated as (g protein in filtrate/g protein in sample) x 100.

Emulsion Stability: The testing procedure followed recommendations of the General Mills Protein Technology Center. A 1 g sample of protein, 75 ml of 0.1M, pH 7.0 citrate-phosphate buffer, and 25 ml of Wesson Oil were blended in a Waring Blendor at maximal speed for 2 min and the emulsion immediately transferred into a graduated cylinder and allowed to stand at room temperature. The interval between emulsion formation and breakdown, indicated by a phase separation, was recorded. The emulsion stability of sodium caseinate was determined for comparative purposes.

Swelling and Wetting in Water: A 10% suspension of protein in 0.1M, pH 7.0 citrate-phosphate buffer was prepared in a graduated cylinder, covered, inverted gently three times, and allowed to settle at room temperature for 60 min. Results were expressed in terms of swelled volume (ml)/wt insoluble protein (g), where weight of insoluble protein (g) = wt original material - wt soluble protein.

For determination of wettability, a 10% suspension of protein in 0.1M, pH 7.0 citrate-phosphate buffer was centrifuged at 10,000 rpm for 30 min. The precipitate was weighed to determine the amount of water being held and results expressed in terms of wt water bound (g)/wt insoluble protein (g).

Pepsin Digestibility: Pepsin digestibility was determined according to the AOAC procedure (2).

Proximate Analysis: The macro-Kjeldahl procedure was used for nitrogen determination. Moisture, lipids, and ash determinations were carried out according to standard AOAC procedures (2). Amino acid analyses were run on a Beckman 116 Amino Acid Auto-analyzer. Duplicate samples of 200 to 300 mg were hydrolyzed with 200 ml 6 N HCl for 22 hr. The acid was removed at reduced pressure in a rotary evaporator at 50 C and the residue dissolved in 0.2 N sodium citrate buffer, pH 2.2. Amino acids were determined in the hydrolysate, except for tryptophan which was analyzed colorimetrically (8).

Isolation of isoelectric protein. A 10 g sample of squid was ground in a Waring Blendor for one minute and slurried in 100 ml of aqueous extracting medium. Total volume of extracting medium consisted of the water contained in the squid, volume of acid (HCl) or base (NaOH) used to obtain the desired slurry pH, and water to adjust the final volume to 100 ml. The slurry was stirred at room temperature for 30 min and centrifuged for 30 min at 8,000 rpm at 10 C. The supernatant was decanted from the residue solids and the pH of extraction prepared by addition of 1 N NaOH or 1 N HCl. A 20 ml aliquot of the extract was taken for nitrogen determination.

Preparation of solvent-extracted protein concentrate. A solvent-extracted protein concentrate was prepared using a two-solvent system of azeotropic isopropanol and 95% ethanol, with a solvent/squid ratio of 2:1. Four successive stages of extraction were performed, three with isopropanol, the fourth with ethanol. In the first stage extraction, squid slurry was mixed with azeotropic isopropanol at 25 C with a ratio of solvent to squid of 2:1 by weight. After mechanical agitation for 1 hr, the solid fraction was separated from the solvent-fat-moisture portion by forced

vacuum filtration. Extraction procedures for the second and third stages were similar to those of the first, except that an extraction temperature of 70 C was used. The fourth stage extraction involved use of 95% ethanol at 60 C. Final solids from the fourth stage were desolventized in a vacuum oven at 60 C for 22 hr to obtain the deodorized squid protein concentrate.

Deodorization of protein. Ground squid was extracted at pH 11 at room temperature in accordance with previously described procedures. Aliquots of the extract were acidified with 1 N HCl for precipitation at pH 5, followed by centrifugation to obtain protein isolates in the form of wet curd.

Deodorization tests included those using acid-activated clays in addition to hydrogen peroxide, ethanol, and a combination of both. Four types of acid-activated clays were compared for their ability to deodorize protein extracts with minimal adverse effect on protein recovery. One of these, Impact 150, was chosen as the most efficient deodorizer and was used throughout the study.

For deodorization with acid-activated clay, aliquots were taken from the pH 11 extract and mixed with 5% (weight ratio) clay. The mixture was stirred for 10 min at room temperature, followed by centrifugation for 30 min at 5,000 rpm. The supernatant, at pH 8.5, due to the acidity of the clay, was separated from the residue solids and precipitated at pH 5 and again centrifuged.

For deodorization with hydrogen peroxide, the protein isolate was stirred in four volumes of 5% H₂O₂ for 30 min, followed by 30 min centrifugation at 5,000 rpm and 25 C. To remove residual H₂O₂ from the solids, the latter were washed in five volumes of distilled water and centrifuged twice. For deodorization with 95% ethanol, the protein isolate obtained from precipitation at pH 5 was stirred in three volumes of 95% ethanol for 30 min at room temperature. The mixture was centrifuged at 5,000 rpm for 30 min, the supernatant discarded, and the centrifuge residue washed with five volumes of distilled water followed by two successive centrifugations. For deodorization with both acid-activated clay and 5% H₂O₂, or both acid-activated clay and 95% ethanol, deodorization with acid-activated clay preceded either 5% H₂O₂ or 95% ethanol deodorization.

RESULTS AND DISCUSSION

Protein extraction in aqueous medium

Effect of pH and salt on protein solubility: Protein solubility at 25 C with a 1:10 (by weight ratio of squid to extracting medium) is shown in Figure 1. Minimum solubility occurred at the isoelectric point of pH 5, at which 18% of the proteins remain in solution. Solubility increases on both acidic and basic sides of the isoelectric point, with maximal solubility of 53% at pH 11. In the acidic range, solubility reaches a maximum of only 50% at pH 3.

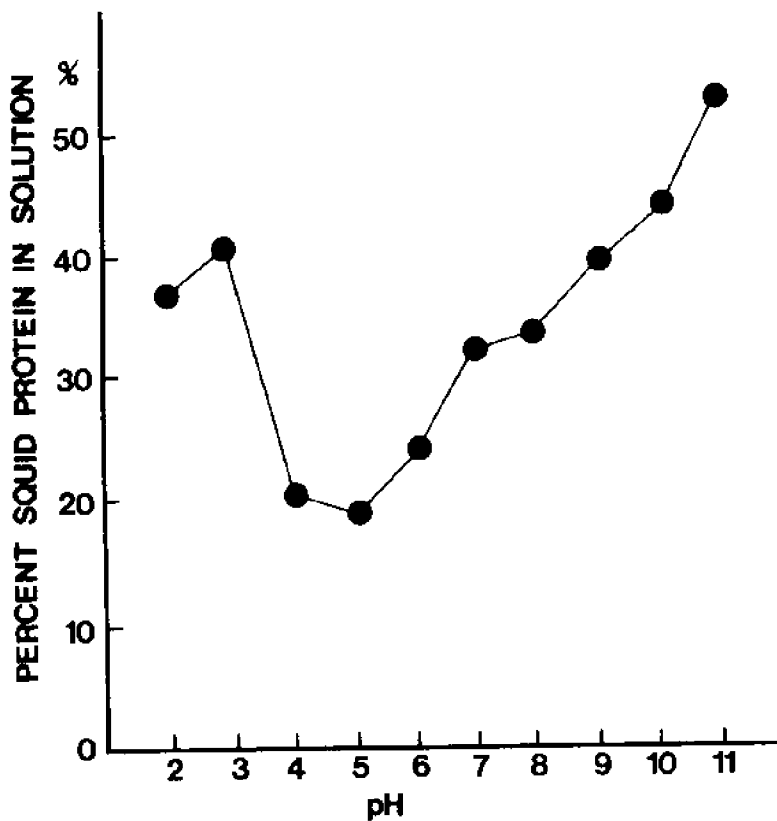


Figure 1. Solubility of squid protein as a function of pH at 25 C

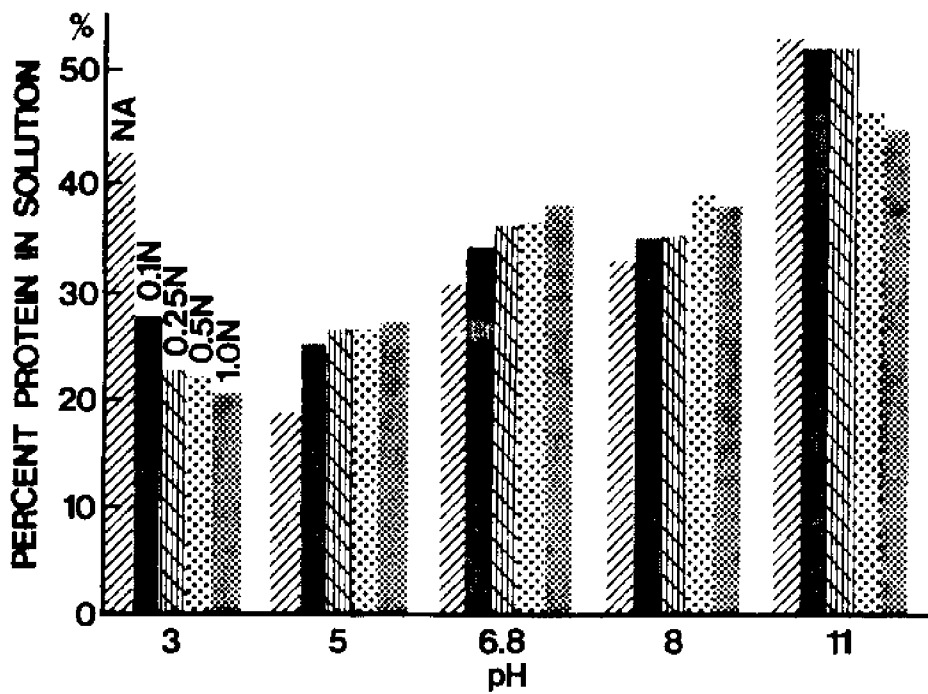
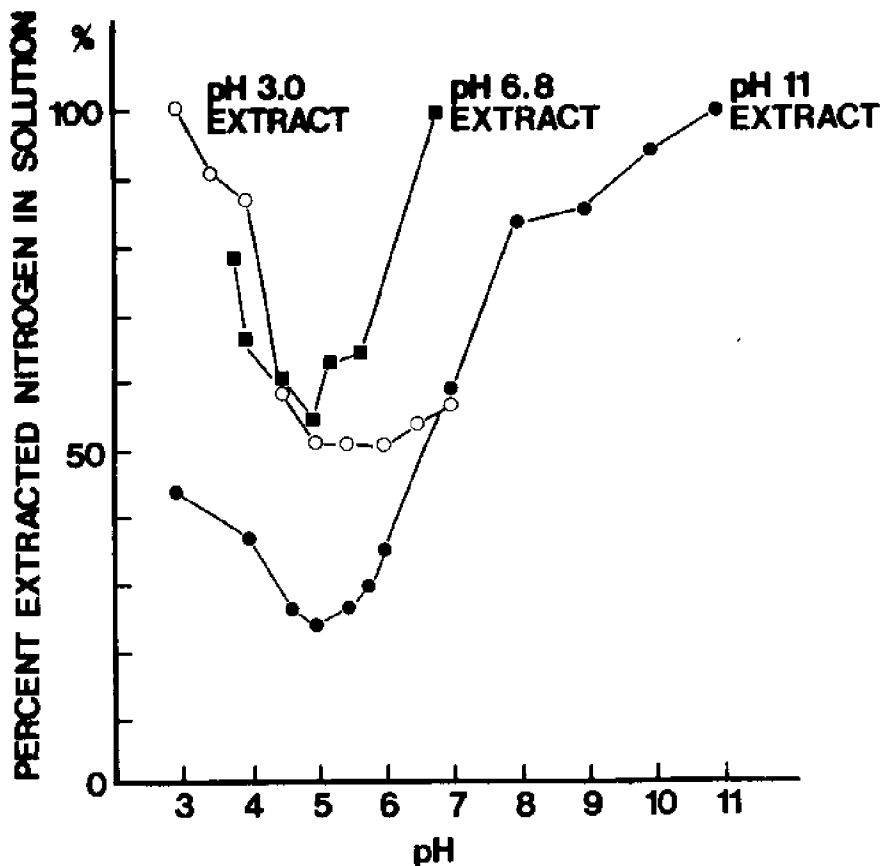


Figure 2. Effect of salt concentration (NaCl)/pH on squid protein solubility

Solubilities of squid protein at different salt concentrations (1 N, 0.5 N, 0.25 N, 0.1 N and no added salt) in the extractant at room temperature are graphed in Figure 2. The ratio of raw material to extracting medium was 1:10. Near the isoelectric point of pH 5, solubility shows a slight increase with salt concentration. In contrast, in both acidic and basic ranges, addition of salt to the extractant results in progressively decreased solubility. A 1 N NaCl solution at pH 3 inhibited extraction of squid proteins to the extent that the solubility of 21% is lower than the 27% value obtained at pH 5. The yield of squid protein precipitated at the isoelectric point from extracts obtained at other pH levels decreases directly with amount of salt present.

Effects of pH on nitrogen precipitation from extracts obtained at various pH's. Means of estimation of the amount of precipitable proteins from extracts is given in Figure 3. For example, in the extract prepared at pH 11, the amount of soluble protein decreased with increased acidification, reaching minimal solubility at pH 5. At this pH, approximately 24% of the proteins of the extract are in solution, the remaining 76% being precipitable.



EFFECT OF pH ON NITROGEN PRECIPITATION FROM EXTRACTS OBTAINED AT pH 3, 6.8 AND 11

Figure 3. Effect of pH on nitrogen precipitation from extracts obtained at pH 3, 6.8 and 11

Effects of ratio of raw material to extracting medium on solubility: At all levels of extraction pH, both the volume of recovered extract and its protein content decreased with increased amount of squid in the solution (Table 1). As noted, the recovered

TABLE 1. EFFECT OF RAW MATERIAL AND EXTRACTION MEDIUM RATIO ON PROTEIN EXTRACTION

pH	Squid/Medium Ratio ^a (g/100 ml medium)	Protein Extract	
		Volume ^b (ml)	Percent protein ^c
3	5	86	52.0
	10	77	40.3
	20	76	33.8
6.8	5	92	39.4
	10	88	31.1
	20	74	23.5
11	5	94	83.5
	10	73	53.2
	20	79	49.5

^aFrozen squid per 100 ml of extracting medium at 25 C.

^bVolume of extract recovered by centrifugation.

^cPercent of protein in volume of recovered extract.

volume by centrifugation was from 86-94 ml of the 100 ml solution containing 5 g squid. With increase in amount of squid used to 20 g, only 74-79 ml were recovered. Greater amounts of squid increased viscosity of the solution as well as the tendency for gelation. These factors contribute to recovery of progressively diminished volumes of extracts when the concentration of raw material is increased in the solution. As noted in Table 1, 84% of the protein in solution was recovered in the extract at pH 11 when 5 g of squid was used, while with 20 g of squid, the protein recovery decreased 50%. Comparable situations were noted in protein recovery at extraction pH's of 3 and 6.8.

TABLE 2. TEMPERATURE AND pH EFFECTS ON SOLUBILITY OF SQUID PROTEIN^a

Extraction Temperature (C)	Percent Protein Extracted					
	Single Extraction			Triple Extraction		
	pH			pH		
	3	6.8	11	3	6.8	11
5	41.8	31.0	65.8	57.4	76.9	82.4
25	40.3	31.1	53.2	59.6	71.7	83.6
55	46.2	28.7	72.3	63.4	72.5	84.0

^aMaterial/Medium Ratio: 10 g squid/100 ml extracting medium.

Extraction temperature and protein extraction: With an increase in temperature from 25 to 55 C, the amount of extracted squid protein increased at pH 3 and 11, but decreased at pH 6.8 (Table 2). Conversely, as the temperature was reduced from 25 to 5 C, the protein extraction again increased at pH 3 and 11, but decreased at pH 6.8. Maximum extraction of 72% was obtained at pH 11 and 55 C. Protein extraction is more strongly dependent upon pH than upon temperature. Data on the protein extraction after three successive extraction procedures is shown in Table 2. Extraction after the third cycle was negligible. These repeated extractions resulted in a gain of extracted proteins of about 50% at pH 3 and 11 and by as much as 130% at pH 6.8 over amounts from single extractions. Maximal proteins extracted increased to 85%, at pH 11 at both 25 and 55 C. These data, based on repeated extractions, show the greater dependence of protein extraction on pH rather than on temperature.

Deodorization of protein. Data on fat reduction and deodorization of the variously treated isolated squid protein preparations are given in Table 3. All of the deodorizing agents used were

TABLE 3. EFFECTS OF VARIOUS TREATMENTS ON FAT REDUCTION AND ODOR

Products and Treatments	Percent Fat	Odor	
		Fresh	After Storage for 2 Months (room temp.)
Undeodorized protein isolate	4.1		
Isolates deodorized with:			
Acid-activated clay Impact 150	3.2	No ^a	Strong
5% H ₂ O ₂	3.3	No ^a	Strong
95% Ethanol	1.8	No ^b	Strong
Acid-activated clay + 95% Ethanol	1.1	No	No
5% H ₂ O ₂ + 95% Ethanol	1.6	No	No
Acid-activated clay + 5% H ₂ O ₂	2.9	No ^a	Faint
Solvent-extracted concentrate	0.1	No	No

^aFishy odor detectable after 3 days.

^bFishy odor detectable after 1 month.

effective, especially 95% ethanol in combination with other materials. The lowest fat level (1.1%) was achieved in the sample treated with acid-activated clay plus 95% ethanol, followed by the sample treated with 5% H₂O₂ plus 95% ethanol (fat content, 1.6%). These two samples were practically odorless and organoleptically most stable, although their fat contents still were considerably high. As with fish protein concentrates, the odor of the squid protein concentrate is not associated with fat alone, but also with other substances that can be adsorbed to clay particles or are susceptible to oxidation with H₂O₂. Yamanish et al. (20) identified a soluble substance produced from oxidation of piperidine as well as piperidine itself as responsible for a foul fishy odor.

Three of the deodorized protein samples in Table 3, each treated with acid-activated clay Impact 150, 5% H₂O₂, or 95% ethanol, did not exhibit a detectable odor when freshly prepared. However, a fishy odor was noted in samples treated with 5% H₂O₂ or acid-activated clay individually after 3 days of preparation, and in the ethanol-treated sample after 1 month. Samples deodorized with 5% H₂O₂, acid-activated clay or 95% ethanol all developed an offensive odor after storage for 2 months at room temperature. The odor was least pronounced in the sample treated with 95% ethanol, but was stronger in samples treated with 5% H₂O₂ or acid-activated clay.

The remaining three samples, deodorized with combinations of each two agents, were more satisfactory with respect to organoleptic characteristics. In particular, two samples treated with 5% H₂O₂ plus 95% ethanol and with acid-activated clay plus 95% ethanol, respectively, were essentially odorless and remained so after storage for six months at room temperature. The sample treated with acid-activated clay plus 5% H₂O₂, however, exhibited no detectable odor when freshly prepared, but after one month at room temperature developed a faint fishy odor. The odor intensity of this sample after six months at room temperature appeared essentially unchanged.

A complete removal of odor could not be accomplished through solvent-extraction using isopropanol alone. Even after three successive cycles of extraction using azeotropic isopropanol, a detectable fishy odor persisted in the squid protein product although the treatment reduced the fat content to less than 0.01% (Table 4).

TABLE 4. FAT CONTENT OF SOLVENT-EXTRACTED SQUID PROTEIN CONCENTRATE

Treatments	Percent Fat
Eviscerated, deskinned squid	6.5
1st Extraction with azeotropic isopropanol	4.3
2nd Extraction with azeotropic isopropanol	1.0
3rd Extraction with azeotropic isopropanol	0.1 ^a
4th Extraction with 95% ethanol	0.1 ^b

^aFaint fishy odor.

^bNo detectable odor.

Introduction of 95% ethanol, either cold or hot, following the three stages of isopropanol extraction was necessary to accomplish satisfactory deodorization. The resulting product had the least amount of fat content (<0.1%) of all the squid protein products prepared. The odor characteristics of this product were essentially equivalent to the products treated with acid-activated clay plus 95% ethanol or with 5% H₂O₂ plus 95% ethanol, which contained a much larger amount of fat than the solvent-extracted product.

Evaluation of protein concentrates

Solubility: Solubility data on the various squid protein concentrates is given in Table 5. Protein concentrates deodorized

with acid-activated clay, 5% H₂O₂, 95% ethanol or their paired combinations showed solubilities of from 37-60%. These were noticeably higher than that of the solvent-extracted squid protein concentrate (ca 3%) as well as that of solvent-extracted fish protein concentrates.

TABLE 5. SOLUBILITY OF VARIOUS PROTEIN CONCENTRATES AT pH 8

Products and Treatments	Percent Soluble Protein	Percent Solubility Reduction
Undeodorized protein isolate	63.9	0.0
Isolates deodorized with:		
Acid-activated clay Impact 150	60.1	5.9
5% H ₂ O ₂	59.9	6.2
95% Ethanol	41.5	35.0
Acid-activated clay + 95% ethanol	37.2	41.7
5% H ₂ O ₂ + 95% ethanol	37.2	41.7
Acid-activated clay + 5% H ₂ O ₂	47.9	25.0
Solvent-extracted concentrate	3.1	95.2

Of the variously deodorized squid protein concentrates, those treated with 95% ethanol, either singly or in combination with other agents, exhibited consistently lower solubilities (37-41%) than did products not exposed to 95% ethanol (47-60%). Deodorization with 95% ethanol reduces the solubility by as much as 35-41%. However, this reduction is less than that associated with azeotropic isopropanol treatment noted elsewhere. Spinelli et al. (15) reported a solubility reduction of as much as 80% from fat extraction with 60% isopropanol at 20 C followed by vacuum drying at 60 C. Both acid-activated clay and 5% H₂O₂ accounted for a similar solubility reduction (6%) when used individually. However, when deodorized successively with acid-activated clay and 5% H₂O₂, a solubility reduction as high as 25% was achieved.

Emulsion stability, swelling and water binding characteristics: Emulsion stability of three deodorized products were essentially of equal magnitude (from 50-55 min) and was markedly superior to that of Na caseinate (25 min). Emulsion stability of the solvent-extracted squid protein concentrate was virtually nonexistent. Spontaneous uptake of water from surrounding fluid can be expressed in terms of either volume, "swelling," or weight, "wetting" (Table 6). The deodorized aqueous isolates exhibited a swelling capability nearly equal to that of undeodorized protein isolate. The wetting property of the aqueous protein isolates was little affected by deodorization. The solvent-extracted squid protein concentrate showed neither swelling or wetting properties.

Proximate analysis and pepsin digestibility: Proximate analysis for seven squid protein products is shown in Table 7. These products satisfy both FAO and FDA standards with respect to crude protein and moisture contents, although the lipid levels are somewhat higher (1-3%) than that recommended by FAO and FDA (0.5-0.75%). However, these products were essentially free of fishy odor with

an appreciable level of organoleptic stability. As expected, the solvent-extracted squid protein concentrate exhibited the lowest lipid content (<0.1%) of all the products prepared. Meinke et al. (11) reported a lipid content of 7-17% in an undeodorized protein isolate of golden croaker, considerably higher than the 4% level noted for the undeodorized squid protein. All of these products exhibited excellent pepsin digestibility.

TABLE 6. EMULSION STABILITY, SWELLING, AND WATER BINDING CHARACTERISTICS OF VARIOUS SQUID PROTEIN CONCENTRATES

Products and Treatments	Emulsion stability (in min)	Water uptake (swell volume ml/g insoluble protein)	Wetting in (weight water bound g/weight insoluble protein/g)
Undeodorized protein isolate	90	10.2	7.2
Isolates deodorized with:			
Acid-activated clay			
Impact 150 + 95% ethanol	50	8.5	5.8
5% H ₂ O ₂ + 95% ethanol	50	8.5	5.8
Acid-activated clay + 5% H ₂ O ₂	55	9.9	6.8
Solvent-extracted concentrate	2	0.9	0.5
Na Caseinate	25		

TABLE 7. PROXIMATE ANALYSIS AND PEPSIN DIGESTIBILITY OF VARIOUS SQUID PROTEIN CONCENTRATES

Products and Treatments	Crude Protein (N x 6.25)	Lipids	Moisture	Ash	Pepsin Digestibility
Whole squid	78.6	9.5	9.0	6.4	95.1
Eviscerated squid	86.9	6.5	9.1	3.8	96.0
Undeodorized isolate	89.1	4.1	6.8	2.1	99.2
Isolates deodorized with:					
Acid-activated clay					
Impact 150 + 5% H ₂ O ₂	89.8	2.9	6.7	2.2	99.9
5% H ₂ O ₂ + 95% ethanol	91.6	1.6	6.9	2.1	99.9
Acid-activated clay + 95% ethanol	91.0	1.1	6.2	2.2	99.9
Solvent-extracted concentrate	95.8	0.1	2.2	2.8	98.8

The amino acid analyses of the various types of squid protein concentrate prepared are given in Table 8, along with that of the Astra fish protein concentrate for comparative purposes. Compari-

son of the various squid products reveals little difference with respect to amino acid profiles. The ratio of essential to total amino acids ranged between 42.03 (isopropanol-extracted concentrate) to 44.31% (aqueous isolate deodorized with 95% ethanol). All of the squid protein concentrates exhibited higher ratios of essential amino acids to total amino acids than the whole or eviscerated squid. The isopropanol-extracted nonfunctional concentrate had a slightly lower essential to total amino acid ratio than the aqueous isolates. Comparison with Astra fish protein concentrate shows that the essential to total amino acid ratios of the squid protein concentrates are of comparable magnitude. Both the aqueous isolates and the solvent-extracted squid protein concentrates contained greater amounts of essential amino acids, with the exception of tryptophan, than FAO recommended standards.

TABLE 8. AMINO ACID ANALYSES OF SQUID PROTEIN CONCENTRATES

Amino Acid	Whole Squid	Undeodorized Isolate	Deodorized with Clay Impact 150	Solvent-Extracted	Astra Fish Protein Concentrate
Essential					
Lysine -----	7.29%	11.41%	9.12%	8.95%	9.38%
Threonine -----	4.60	5.73	5.64	4.90	4.45
Valine -----	5.05	5.66	5.37	5.14	5.95
Methionine ----	4.03	2.82	3.94	2.97	3.55
Isoleucine ----	5.56	6.40	6.33	7.00	4.68
Leucine -----	8.17	10.24	9.27	8.97	8.27
Phenylalanine -	4.98	4.83	4.11	4.44	4.24
Tryptophan ----	1.23	1.24	1.26	1.20	1.65
Total -----	40.91	48.33	45.04	43.57	42.17
Non-Essential					
Histidine -----	2.93%	2.86%	2.99%	2.67%	2.60%
Arginine -----	6.15	6.47	7.30	6.73	6.39
Aspartic -----	10.54	11.60	12.61	11.39	9.84
Serine -----	4.10	5.17	4.61	4.92	4.19
Glutamic -----	16.63	17.73	17.58	17.74	14.60
Proline -----	4.45	3.52	3.53	3.80	3.66
Glycine -----	5.83	4.18	4.00	5.16	4.08
Alanine -----	4.68	4.41	4.12	4.22	5.97
Tyrosine -----	2.75	3.93	4.11	3.45	3.66
Total -----	58.06	59.87	61.85	60.08	54.99
Essential					
Total %	41.34	44.67	42.14	42.04	43.40

SUMMARY AND CONCLUSIONS

These studies have demonstrated that a functional protein concentrate with a range of desirable properties, i.e., organoleptic stability, solubility, emulsifying ability, water uptake ability, digestibility and high essential amino acid contents, can be prepared from squid (*Illex illecebrosus*) through an aqueous isolation procedure. Recent investigations (5) on development of a squid protein isolate (from a species of *Loligo*) have noted effects of processing conditions on yields, including extraction time and temperature, solvent-to-squid ratio, extractant and recovery procedure. Over 80% of the squid protein was extractable in alkaline

medium or salt solution. Extraction included solubility and oil binding capacity in an oil-in-water emulsion. The squid protein exhibited excellent rehydration properties along with a 67% salt-soluble protein, indicating a high oil-binding capacity. Earlier, Matsumoto (10) reported on the high proportion of water-soluble protein (ca 77-85% of total protein content) of squid. The solubility of squid protein and its use in fish sausages has been noted (13). In Japan, squid is commonly used in making fish sausages, although concentrations used do not exceed 25% to avoid deleterious effects on elasticity of the product. Elsewhere (7), properties of spray-dried squid protein have been examined with attention given to yield, nutritional value of the protein concentrate and its functional properties. An isolated protein was obtained from extracts by isoelectric precipitation or by direct dehydration after salt removal. The amino acid profile of the squid powder compared favorably with fish protein concentrate, meeting the essential amino acid requirements of FAO reference protein.

In the current investigation, extraction of squid protein in the aqueous medium is influenced dominantly by pH, and to a lesser extent by salt content, ratio of raw material to extracting medium, and temperature. The solubility profile of frozen squid meat is generally comparable to that of fish, but with an isoelectric point located near pH 5, whereas that of fish usually is between pH 5 and 7. Maximum solubility of frozen squid meat is at pH 11. The yield of squid protein isolates, precipitated at the isoelectric point from extracts obtained at other pH levels, diminished in proportion to the increasing amount of salt in the medium. At all levels of extracting pH, both the volume of recovered extracts at the isoelectric point and their protein content decreased with the increasing concentration of squid in the solution. Protein extraction was more strongly dependent upon pH than upon temperature, both in single and successive extraction procedures. For all practical purposes, extraction at room temperature is adequate. The extract of squid protein obtained at pH 11 gave the largest yield of the protein isolate.

Protein isolates obtained in the aqueous medium and deodorized with acid-activated clay, 5% H₂O₂, 95% ethanol or their paired combinations, exhibited a solubility between 37-60%, distinctly higher than the 3% solubility of the solvent-extracted squid protein concentrate. The former isolates exhibited distinctly higher emulsion stability (from 50 to 55 min) than that of Na caseinate (25 min). Emulsion stability of the denatured solvent-extracted squid protein concentrate was negligible. Deodorization using acid-activated clay, 5% H₂O₂, 95% ethanol, or their paired combinations, had no deleterious effect on the swelling and wetting ability of the aqueous squid protein isolates. The solvent-extracted squid protein concentrate exhibited neither swelling nor wetting properties.

Squid protein, deodorized with combinations of acid-activated clay, 5% H₂O₂ and 95% ethanol, exhibited less odor than solvent-extracted fish protein concentrate. None of the deodorizing agents tested, i.e., 5% H₂O₂, acid-activated clay and 95% ethanol, alone accomplished complete deodorization of the protein isolate. The use of paired combinations of these deodorizing agents, especially those of 5% H₂O₂ plus 95% ethanol, was most effective in removing

odor as well as fat. The application of acid-activated clay and hydrogen peroxide for deodorization of squid protein isolate is of particular interest. In the vegetable oil and other edible oil industries, clay has been used to purify the color of the product and remove undesirable organic impurities by selective adsorption. Hydrogen peroxide has also been used to bleach FPC-fortified wafers (12). However, the potential use of these materials as deodorizing agents has received little attention. The present research suggests that clay and hydrogen peroxide, in combination with ethanol, has possible application in deodorization of other food products, including fish protein concentrate.

The aqueous squid protein isolates, both deodorized and undeodorized, as well as the solvent-extracted squid protein concentrate, showed excellent pepsin digestibility with a protein content approaching that of the commercially produced solvent-extracted fish protein concentrate using eviscerated, deboned fish or fillets. The solvent-extracted squid protein concentrate exhibited a lipid content of less than 0.1%.

Further studies are needed to evaluate the nutritional value of the squid protein concentrate. Economics of squid utilization will, in the main, be dictated by the price of the raw product and ultimate cost of the deodorization process. Animal feeding studies are necessary to establish the protein efficiency ratio (PER) and other accepted nutritional standards for the aqueous extracted squid protein concentrate. However, based on investigations of squid protein from other workers, there is no reason to question the potential food value of this unutilized fishery resource.

ACKNOWLEDGMENTS

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THE EFFECT OF FROZEN STORAGE ON THE FUNCTIONAL AND
ORGANOLEPTIC PROPERTIES OF MINCED FISH MADE FROM SEVERAL
UNDERUTILIZED SPECIES HARVESTED FROM THE GULF OF MEXICO

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In 1976, about 63 percent of the fishery products consumed in the United States were imported from other countries (6). Whitaker (9) projected that our domestic needs for fishery products would total 3.7 billion pounds by 1985, up 1.0 billion pounds from present consumption. If the United States fishing industry is to remain viable, and our markets less dependent on imports, new domestic sources of fishery products must be developed that are equal in every respect to those supplied by foreign countries.

In southeastern waters of the United States, there are several species of food fish that have already been accepted by the consumer. The commercial production of these species, however, has not reached its full potential. Product form and storage stability may account in part for underutilization of these species. Fish blocks prepared from minced flesh, from which a variety of fishery products could be made, would be one way to utilize the available resource. Foreign supplies of traditional fillet blocks are becoming less available; minced blocks made from underutilized species of fish, if they met certain quality criteria, could help alleviate this shortage. The quality of minced fish blocks is known to be affected by a combination of factors, such as physiological state of the fish, processing and storage conditions, and type of packaging used (3,5). Further, some species are more sensitive to a particular variable than others. The objective of this study was to investigate the storage stability of minced fish blocks prepared from several underutilized species harvested from the Gulf of Mexico that show a reasonable resource potential and consumer acceptability in other product forms.

MATERIAL AND METHODS

Preparation of minced fish blocks

Minced fish blocks were prepared from two different catches: (i) mullet (Mugil cephalus), croaker (Micropogon undulatus), spot (Leiostomus xanthurus), and whiting (Menticirrhus littoralis), harvested in September, 1975; (ii) mullet, sand trout (Cynoscion

arenarius) and cutlassfish (Trichiurus lepturus), harvested in December, 1975.

Minced speckled trout (Cynoscion nebulosus), which has a good frozen storage stability and organoleptic acceptability, was used as the standard in the organoleptic tests. The standard was vacuum packed and stored at -40°C.

Fish were packed in ice upon harvesting and shipped to the Texas A&M processing laboratory at Corpus Christi, Texas. Fish were processed soon after catch. They were scaled, headed, and gutted, and then minced through a Bibun^{1/} meat separator at near maximum belt tension with a drum having 5-mm openings. The minced fish flesh was packed in wax-coated cardboard boxes of one pound capacity and frozen at -40°C on a plate freezer. Subsequently, boxes were overwrapped with a polyethylene film and stored at -10°C for up to 12 months. The samples were evaluated after 0, 1, 2, 3, 6, 9, and 12 months of storage.

Chemical Analysis

Samples were analyzed for protein, ash and moisture using AOAC Methods 2.051(1). Fat content was determined by the SAK Method (7). The pH was measured by placing an electrode assembly directly into the thawed minced fish sample. The thiobarbituric acid (TBA) test was used as a measure of oxidative rancidity by applying Vyncke's Method (8).

Functionality Measurement

Texture: The texture of the raw and cooked minced fish was measured using a Kramer shear press (4). For each test, 170 grams of raw sample and 140 grams of cooked sample were used. The shear values were determined using a 3,000 pound ring and a standard shear cell.

Cooking loss: A 170 gram sample of minced fish was placed in a glass cup, overwrapped with aluminum foil, and then baked in an oven at 230°C for 30 minutes. After cooking, the sample was cooled and drained over a screen for 5 minutes, then reweighed to determine cooking loss.

Water Holding Capacity: Water released during the texture test was passed through a screen (Tyler, 425 Micron) placed under the shear cell and collected in a stainless steel pan. Water holding capacity was calculated as the percentage of moisture remaining in the sample after shearing based on the moisture content of the sample before shearing.

^{1/} The use of trade names does not imply endorsement by the Department of Commerce.

Color: A 120 gram sample was placed in a clear plastic cup and set on a piece of glass over a Hunter Color Difference Meter, Model D25. The sample was covered with a black cover and the values for "L", "a" and "b" were observed. The color meter was standardized with a tile reading, L=92.8, a=-0.8 and b=-0.7.

Sensory Evaluation

Frozen minced fish blocks were cut into sticks one half inch thick, battered and deep fat fried for 2 minutes at 190°C. The sticks were cooled, wrapped and refrozen. For sensory evaluation, the fish sticks were reheated in an oven at 205°C for 20 minutes and served to a panel of 10 judges. Panelists evaluated the sticks for flavor, texture and appearance. Evaluations were performed using a 5-point scale. A score of 3 was assumed to be "equal" to the standard. A score of 5 represented a value "much better" than the standard and a score of 1 represented a value "much worse" than the standard.

Microbiological Evaluation

Total plate counts were carried out according to the Manual of Products and Laboratory Procedures outlined by Baltimore Biological Laboratory (BBL) (2).

RESULTS AND DISCUSSION

The results of proximate composition, pH measurement and yields of minced fish for the 6 species are given in Table 1. Values for the separate lots of mullet caught in September and December are listed separately.

For species caught in September, protein ranged from 18.3% for whiting to 18.7% for mullet. Croaker, spot, and whiting had moderately high fat content (average, approximately 3%), while mullet was somewhat higher (4.5%). The mullet caught in December had a lower fat content (2.8%). The cutlassfish had the highest fat content (5.2%) and the sand trout was the leanest of all species (1.8%). All species had an ash content of about one percent. Moisture contents ranged from 75.2% for cutlassfish to 79.3% for whiting.

The pH values differed between species. They varied from 5.8 for mullet caught in December to 6.7 for spot. The pH of mullet caught in September (6.5), however, was higher than that of the mullet caught in December (5.8), which may be a seasonal variation.

The highest yield was obtained for cutlassfish (51.6%) and the lowest for croaker (33.3%). Both catches of mullet gave relatively high yields (42-45%). Variations could be attributed to differences in species, as well as to seasonal, size and physiological differences.

The results of functionality measurements and sensory evaluations of the 6 species of minced fish caught in September and December are given in Figures 1-12. There was a gradual increase in the shear force values for raw and cooked samples from the September catch (Fig. 1). The shear values for all species reached their maximum after 9 months of storage. Mullet showed the highest shear value, followed by croaker, spot and whiting. These changes were less significant for the raw samples. Similar results (Fig. 2) were obtained for species caught in December. Again, mullet showed the highest shear value, followed by cutlassfish and sand trout.

After 6 months of storage, the amount of cooking loss decreased and then increased after 9 and 12 months of storage for species caught in September (Fig. 3). Of the December catch (Fig. 4), mullet had the highest cooking loss after 6 months and cutlassfish and sand trout the lowest.

Both raw and cooked samples from the September catch (Fig. 5) reached the maximum loss of water holding capacity (W.H.C.) after the first and second month of storage. Cooked samples had 10-20% less water holding capacity than raw samples. All four species from the September catch showed similar patterns of water holding capacity. Of the December catch (Fig. 6), cooked sand trout possessed about 8% higher water holding capacity than cutlassfish and mullet.

As to the degree of lightness "L" (measured by the Hunter C Color Meter) for the species caught in September (Fig. 7), all species except mullet became slightly lighter in color after 3 to 6 months of storage. The color of mullet changed from pink to brownish gray after one or two months of storage. Of the species caught in December (Fig. 8), cutlassfish and sand trout show similar patterns of "L" values during storage. Mullet exhibited a darker color for both cooked and raw samples.

The initial TBA numbers for croaker, spot and whiting of the September catch (Fig. 9) were similar; they ranged from 3 to 5 mg/kg. The TBA numbers did not change appreciably during storage. For mullet, the TBA number increased sharply after the first month of storage. The TBA numbers for cutlassfish and mullet caught in December (Fig. 10) show higher values than for sand trout. For raw cutlassfish, the initial TBA number was about 7 mg/kg, and for mullet, about 2 mg/kg. The sharpest change for both mullet and cutlassfish occurred after 6 months of storage.

The initial flavor scores for croaker, cutlassfish, whiting, sand trout and spot tended to be lower than or equal to the standard (Fig. 11). No organoleptic tests were performed on mullet because of the presence of parasites. Cutlassfish initially had flavor scores close to the standard, but its acceptability gradually decreased during storage. Initially, texture scores for croaker and whiting were lower than for the standard

(Fig. 12), whereas sand trout and spot were scored almost equal to standard. At 2 to 3 months of storage, the texture scores for croaker, spot, cutlassfish and whiting increased and the scores for sand trout decreased. At 6 months of storage, the texture scores for all species except sand trout were much higher than the standard. No appearance data are included due to the absence of significant differences in the evaluation of the different species, as served to the panel.

The initial microbial counts for all species ranged from 15,000 to 18,000 per gram. After 12 months of storage, the microbial counts were slightly lowered and averaged 12,000 per gram.

CONCLUSIONS

The following conclusions were reached as to the frozen storage (10°C) characteristics of minced fish made from several underutilized species harvested from the Gulf of Mexico:

1. The texture became tougher after two or three months of storage; mullet exhibited the toughest texture, followed by croaker, cutlassfish, whiting, spot and sand trout.
2. Cooking loss increased for all species after 6 months of storage; the highest cooking loss was for mullet, followed by spot, whiting, cutlassfish and sand trout.
3. Water holding capacity gradually decreased after 3 months of storage. The greatest change occurred for mullet and spot; whiting and cutlassfish had similar water holding capacities. Raw and cooked sand trout had the highest water holding capacity.
4. The initial TBA numbers for croaker, spot and whiting were similar and did not change appreciably during 9 months of frozen storage. The fatter species, mullet and cutlassfish, became rancid after one and four months, respectively.
5. Except for mullet, the color of minced fish did not change significantly. Most species became slightly lighter in color after 4 months of storage.
6. Croaker was most organoleptically acceptable and retained its quality through 9 months of frozen storage. Whiting had good acceptability up to 6 months of frozen storage.

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SEPTEMBER	SPECIES	PROTEIN	MOISTURE	ASH	SAK FAT	pH	AV. YIELD
	CROAKER	18.5	77.9	1.14	3.18	6.6	33.3
	SPOT	18.5	78.4	1.06	2.96	6.7	34.6
	WHITING	18.3	79.3	1.01	2.70	6.6	39.1
	MULLET (I)	18.7	76.6	0.93	4.50	6.5	42.3

DECEMBER	CUTLASS FISH	17.1	75.2	1.11	5.20	5.9	51.6
	SAND TROUT	17.4	78.9	0.98	1.80	6.4	37.7
	MULLET (II)	17.4	76.3	1.05	2.80	5.8	43.0

Table (1): Proximate Composition, pH and yields of minced fish species harvested from the Gulf of Mexico in September and December of 1975

TEXTURE

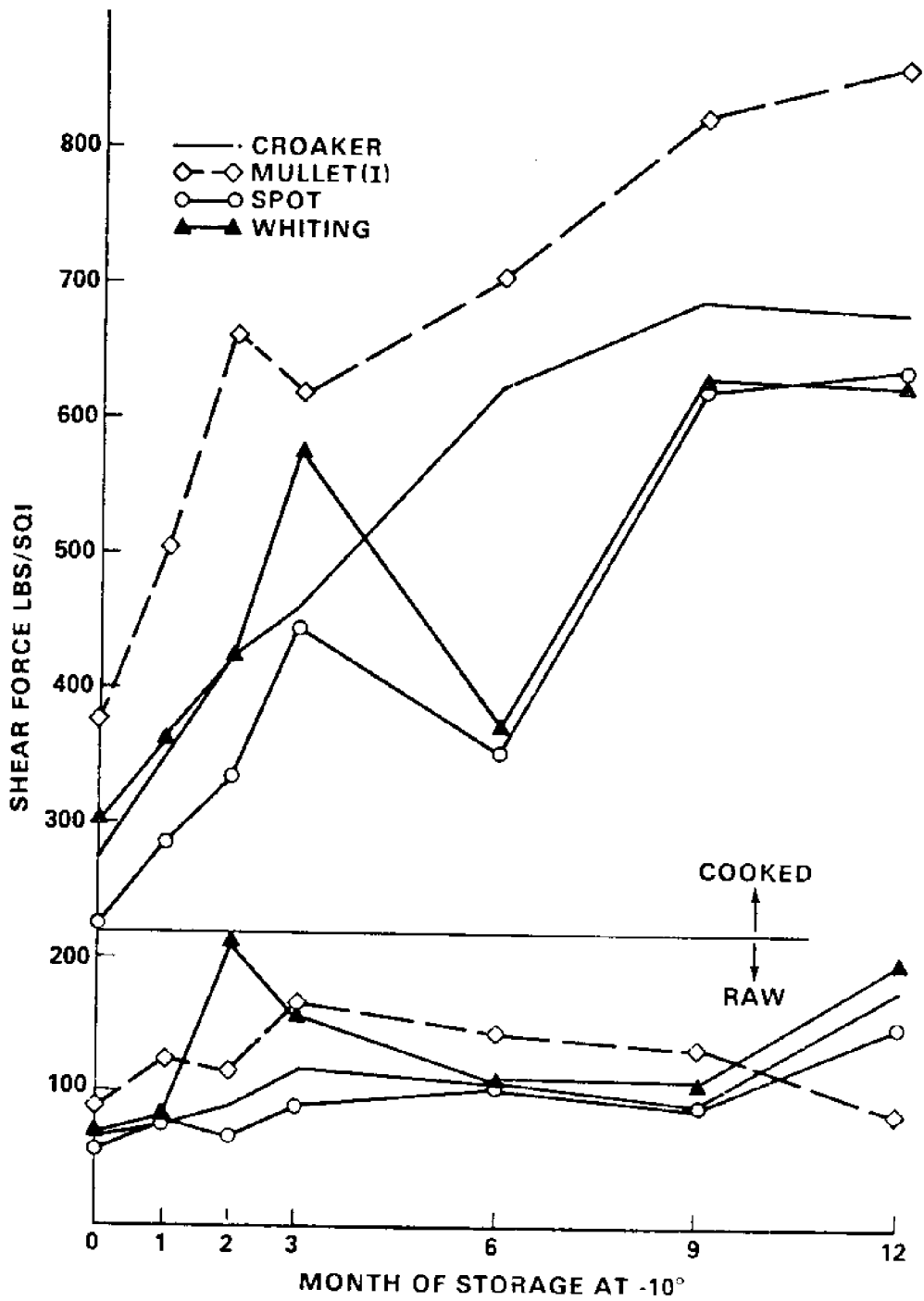


Figure (1): The effect of storage on the shear values of cooked and raw species of minced fish caught in September 1975

TEXTURE

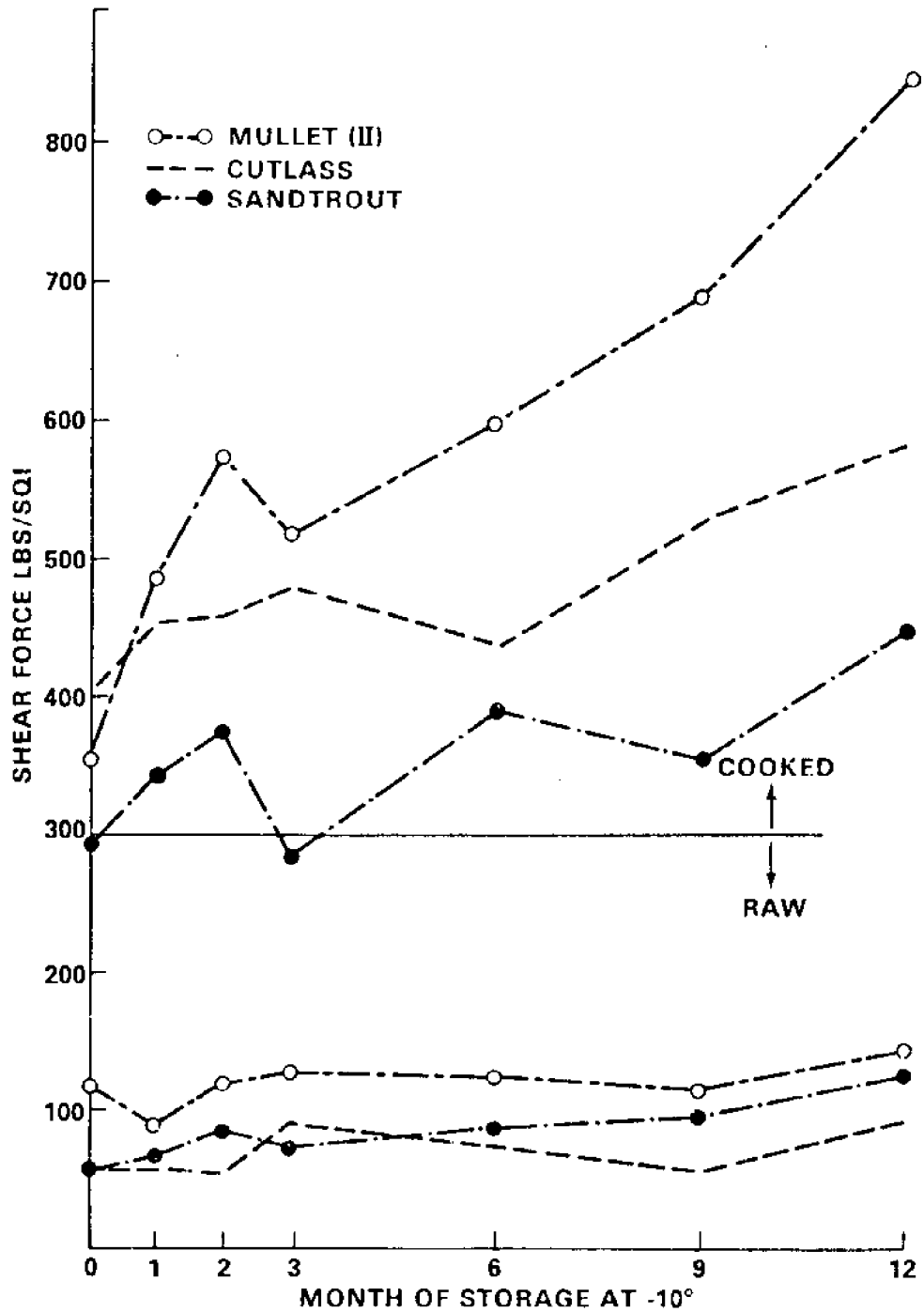


Figure (2): The effect of storage on the shear values of cooked and raw species of minced fish caught in December 1975

COOKING LOSS

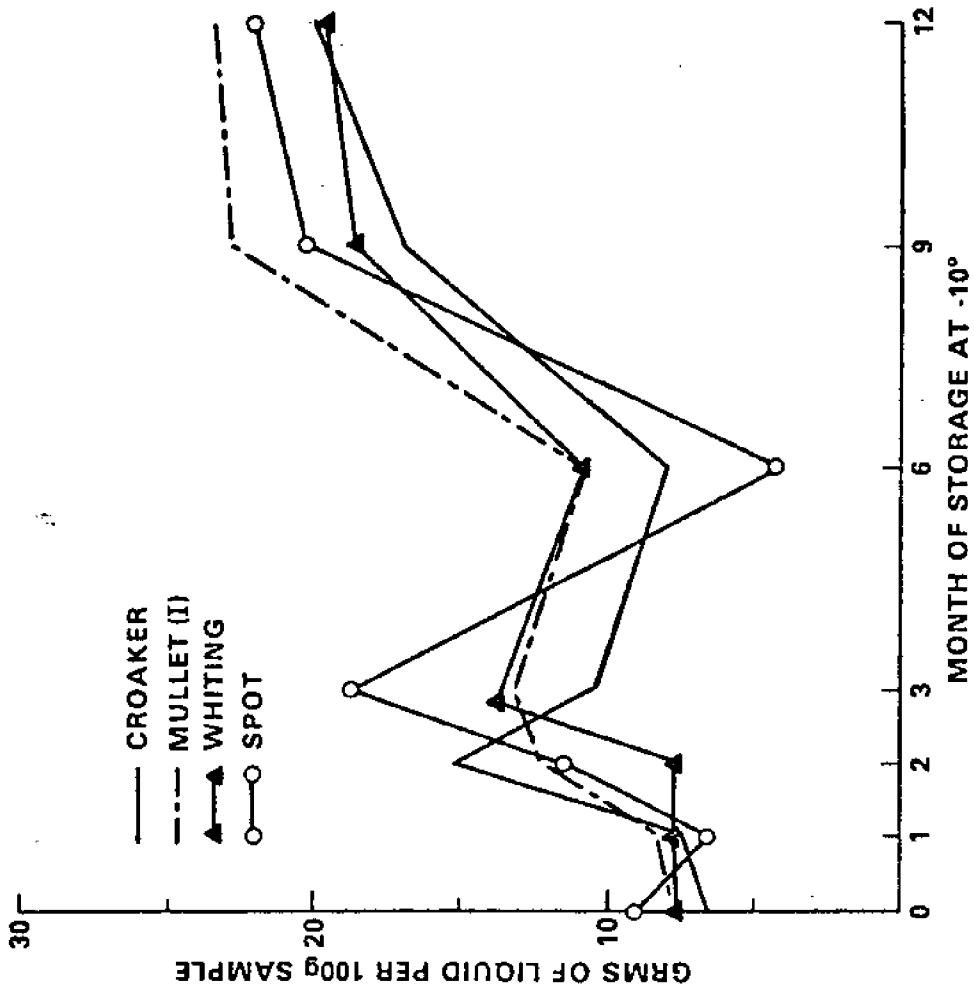


Figure (3): The effect of storage in the cooking loss of minced fish species caught in September 1975

COOKING LOSS

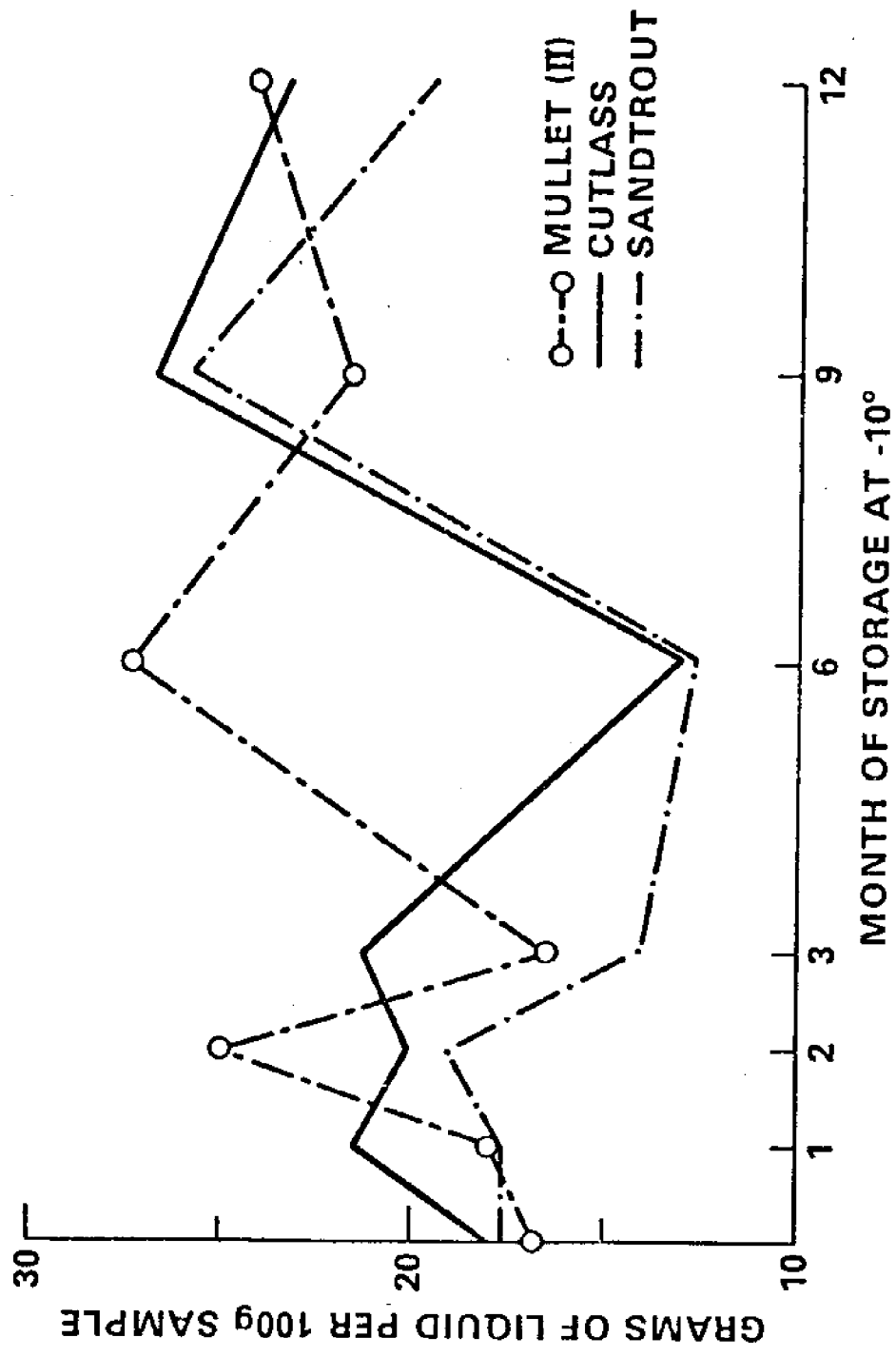


Figure (4): The effect of storage on the cooking loss of minced fish species caught in December 1975

W.H.C.

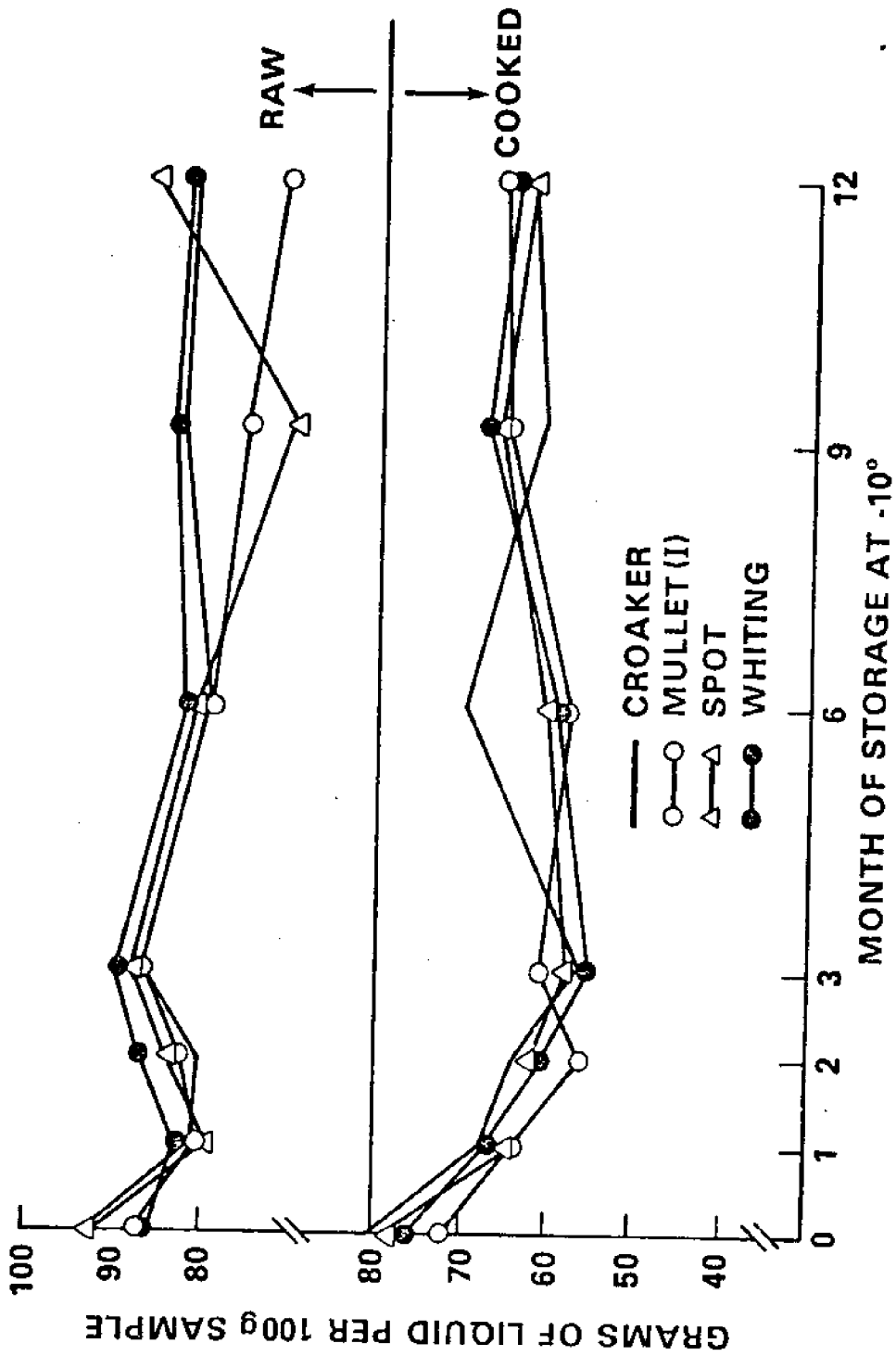


Figure (5): The effect of storage on the water holding capacity of minced fish species caught in September 1975

W.H.C.

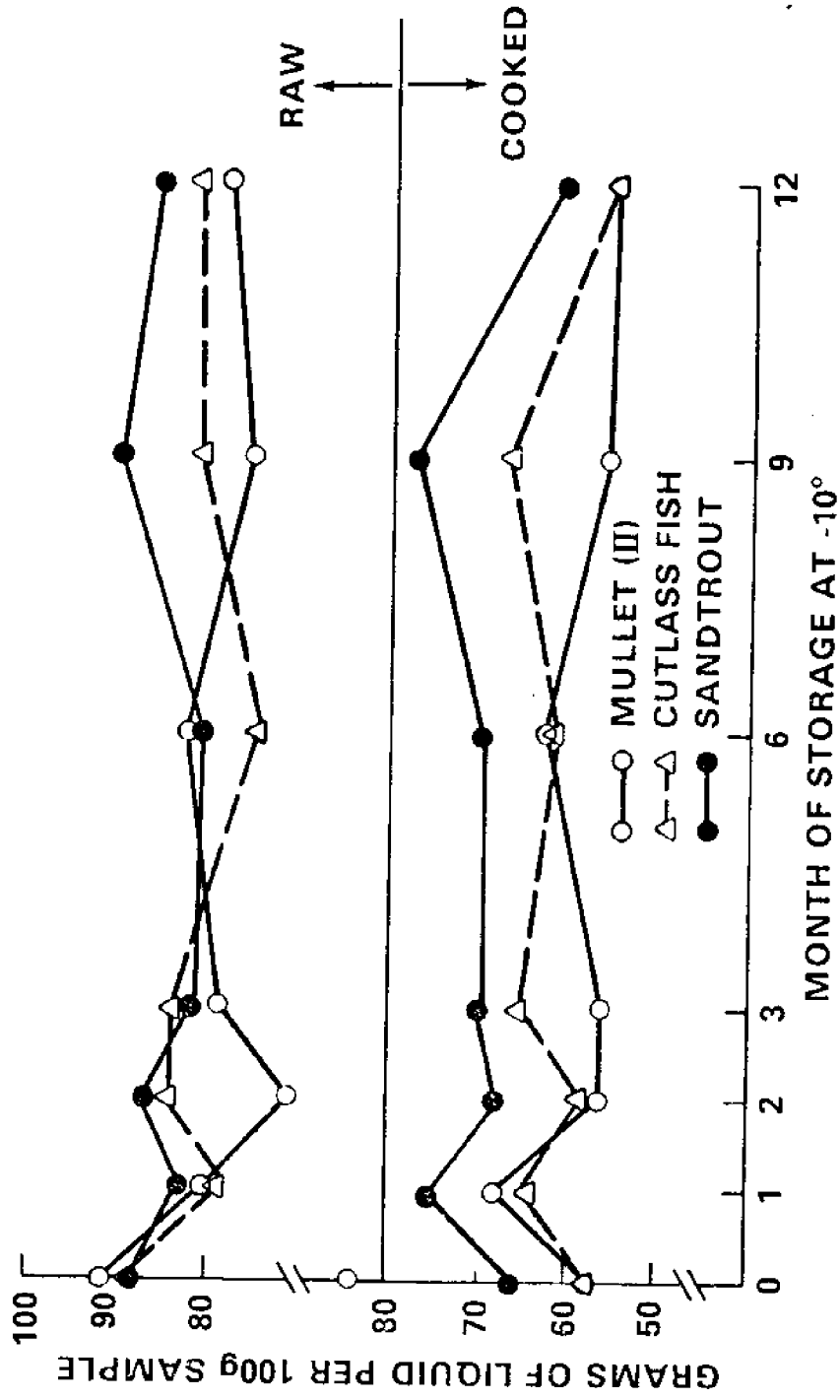


Figure (6): The effect of storage on the water holding capacity of minced fish species caught in December 1975

COLOR

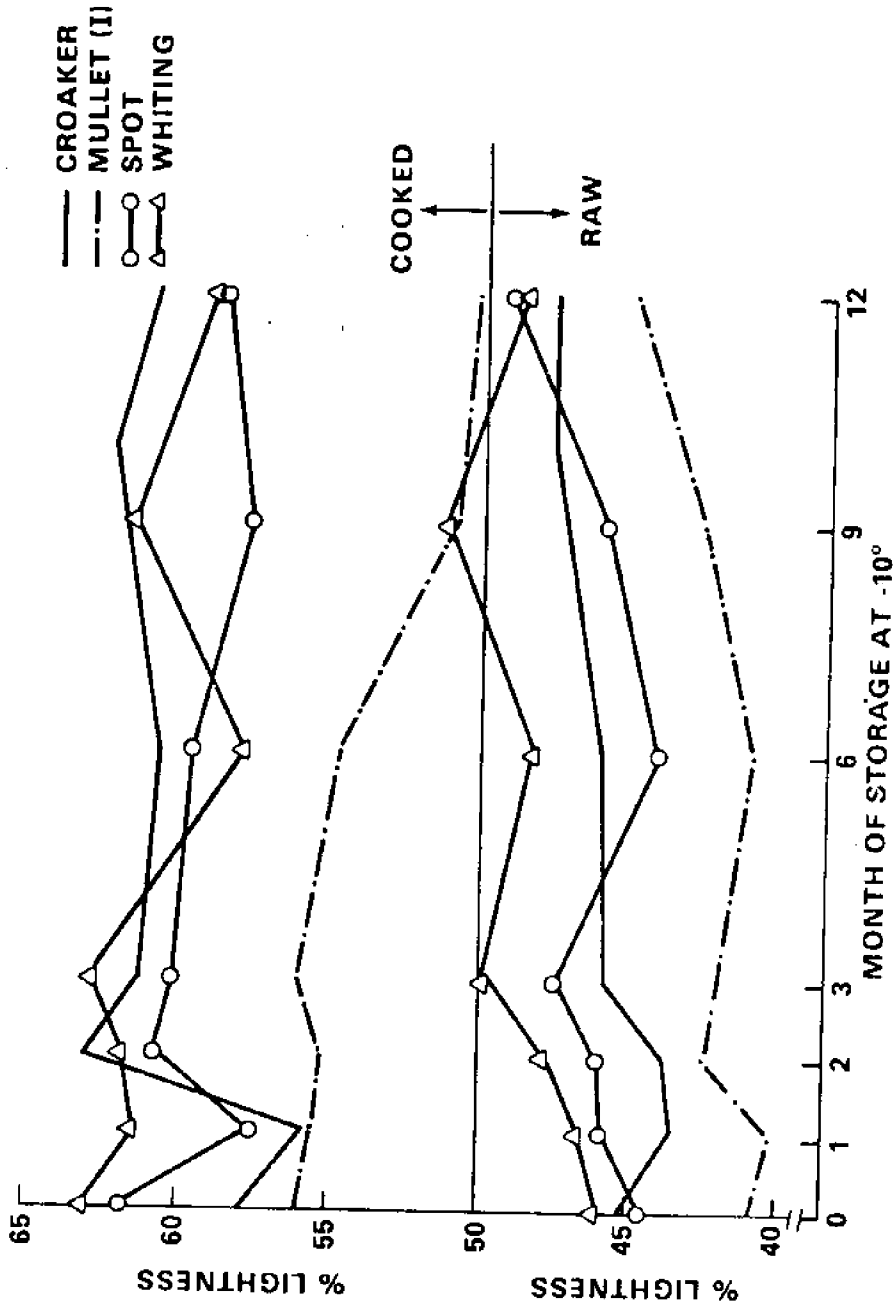


Figure (7): The effect of storage on the % lightness of minced fish species caught in September 1975

COLOR

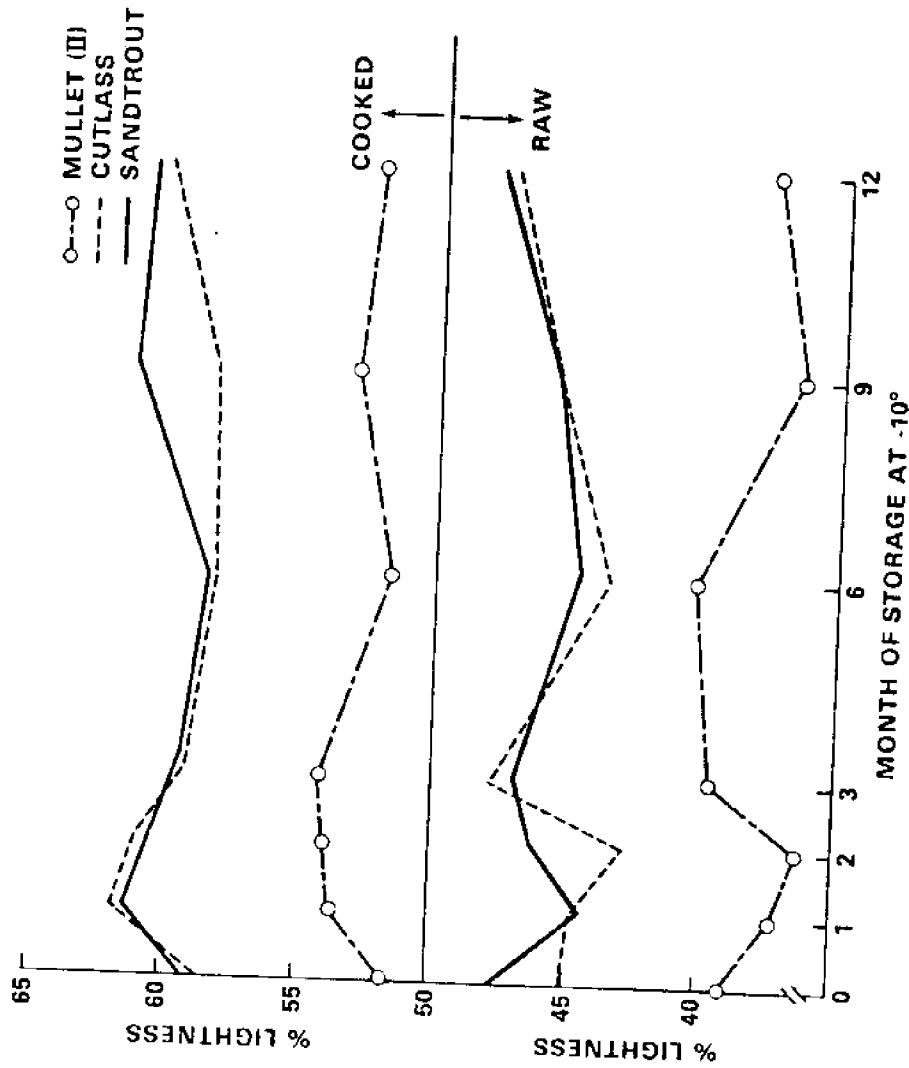


Figure (8): The effect of storage on the % lightness of minced fish species caught in December 1975

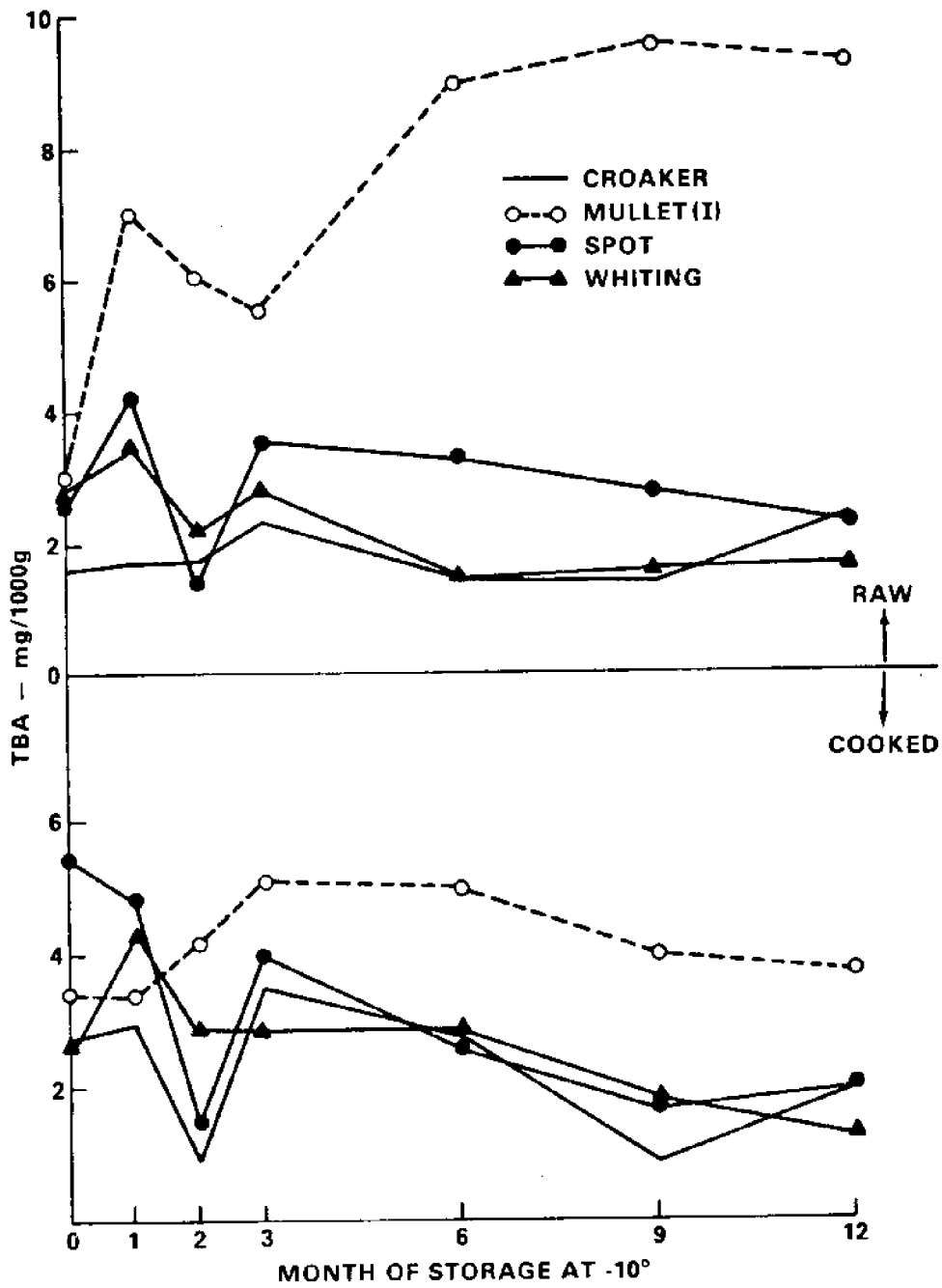


Figure (9): The effect of storage on the TBA number of minced fish species caught in September 1975

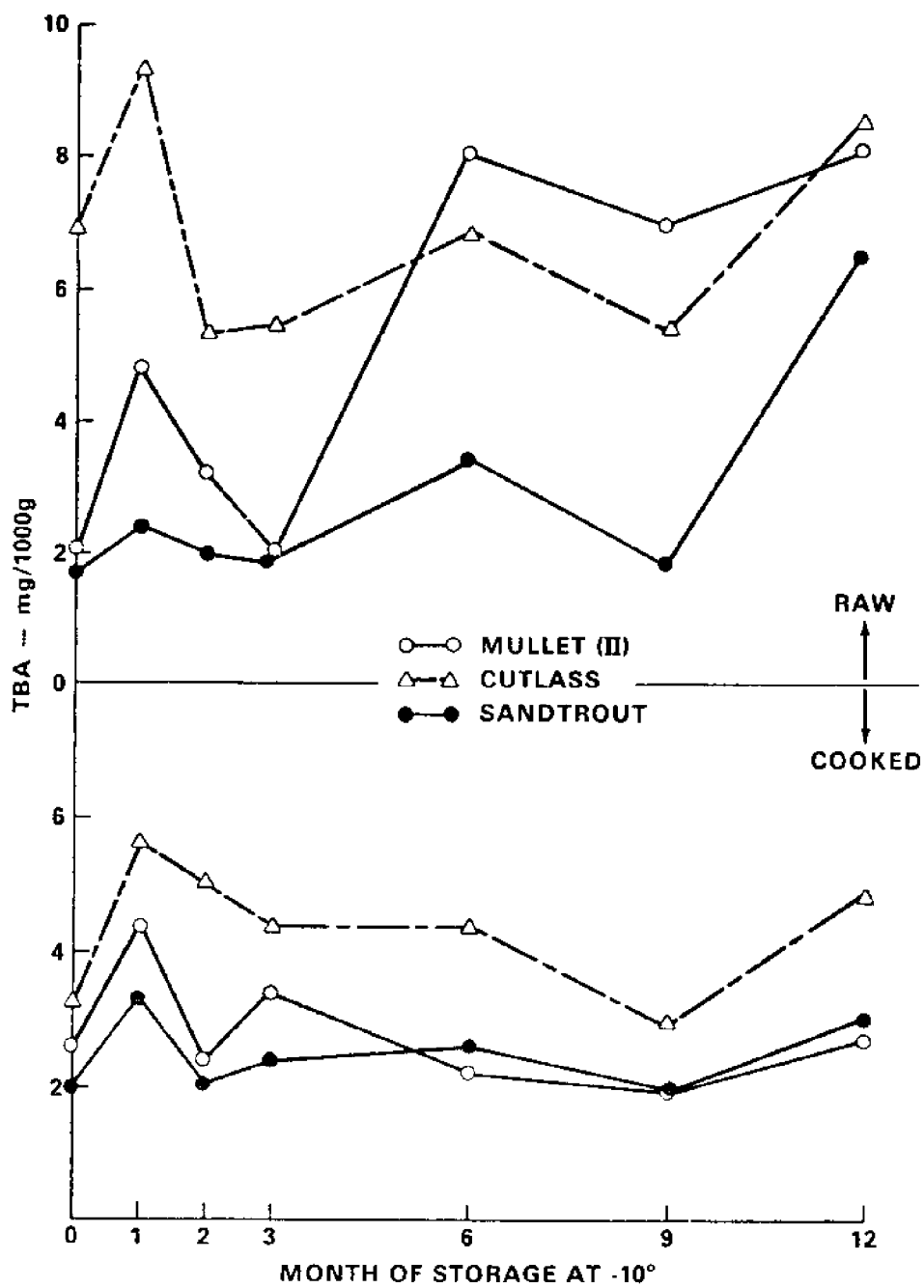


Figure (10): The effect of storage on the TBA number of minced fish species caught in December 1975

FLAVOR

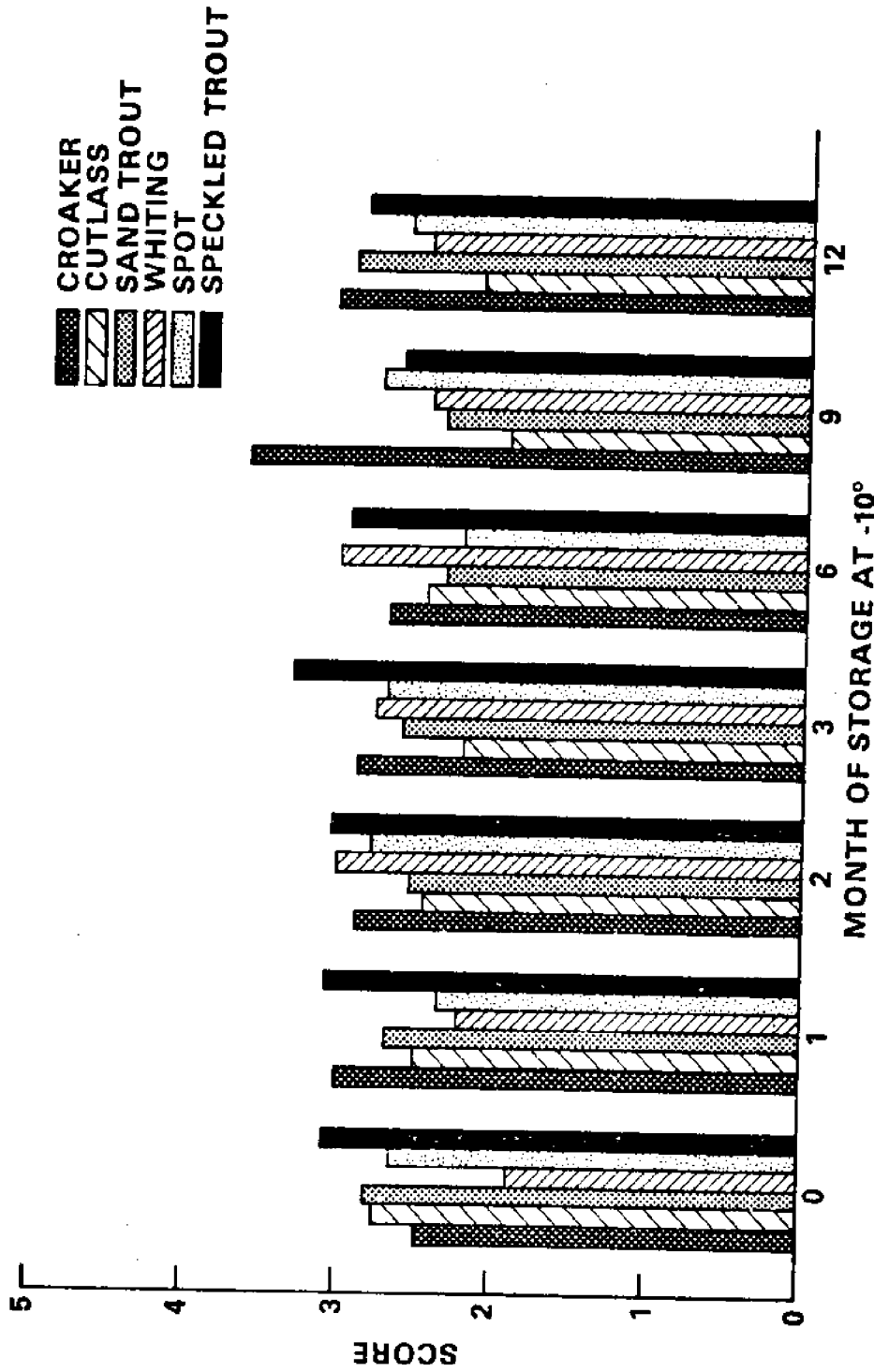


Figure (11): The effect of storage on the flavor scores of minced fish species caught in 1975

TEXTURE

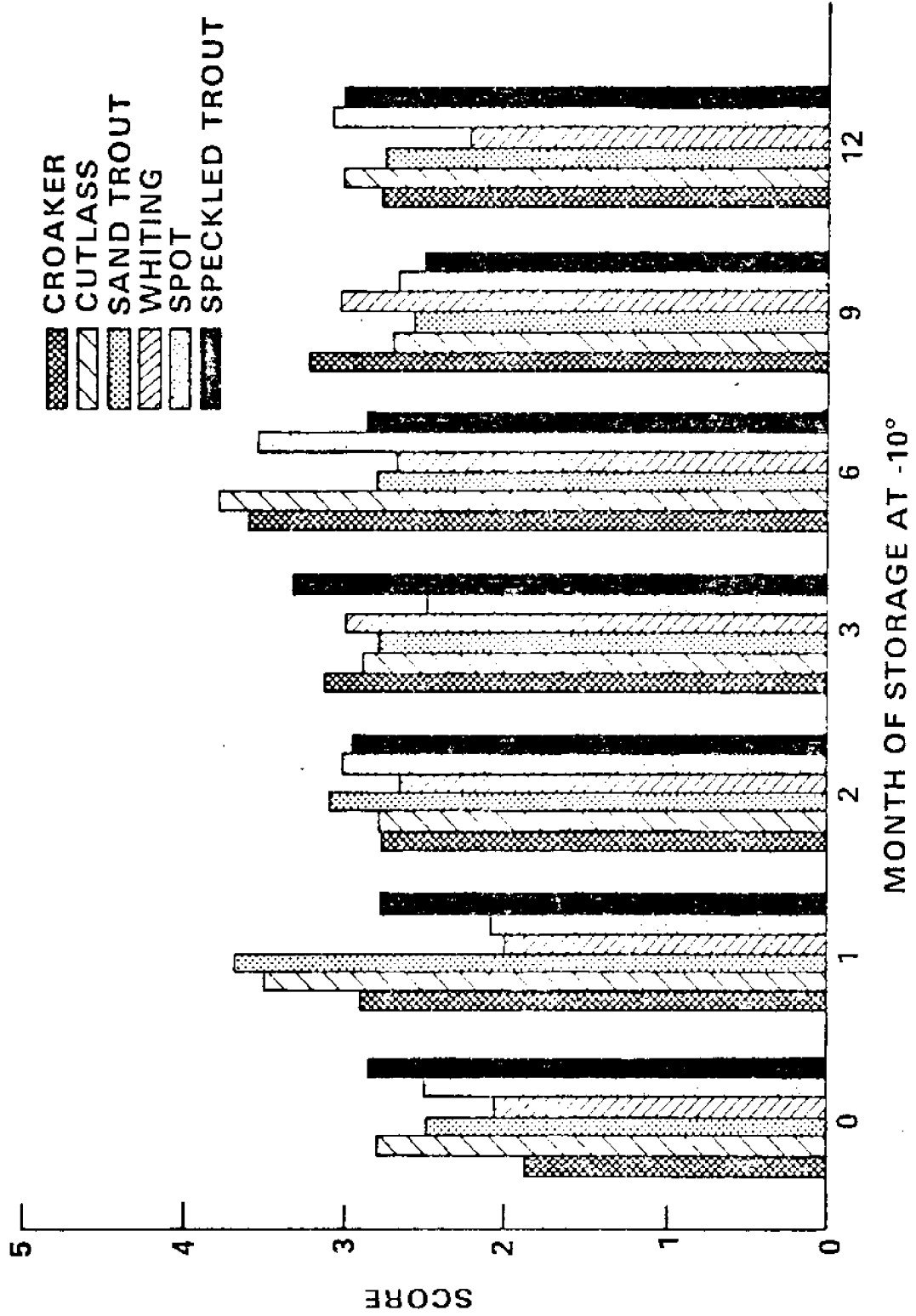


Figure (12): The effect of storage on the texture scores of minced fish species caught in 1975

CONSUMER ACCEPTANCE OF CUTLASSFISH RELATIVE TO COD AND POLLOCK IN FISH STICK FORM

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INTRODUCTION

The direct result of decreased landings in recent years of cod, in the face of increasing demand for frozen sticks and portions, has been a shift to underutilized species in the seafood stick and portion industry. This is how the Pacific pollock came into use. As a matter of fact, it is now so widely used that, in 1973, the Pacific pollock became the world's largest single species fishery. However, according to the National Marine Fisheries Service, the pollock yield peaked in 1971 and fish stocks in that area may have declined by as much as 75 percent since 1971 (3). Consequently, additional species are being examined as possible substitutes for cod and pollock, one of which is the cutlassfish, Trichiurus lepturus. Its textural properties have been evaluated in comparison with cod by Suter and Hart (5).

In the process of product development an assessment of acceptability to consumers is an important phase. The purpose of this study was to obtain an estimate of consumer acceptance of fish sticks prepared from cutlassfish at an early state in the development process. In this study the cutlassfish product is evaluated in comparison with cod and pollock products. The use of a representative sample of consumers in the evaluation process, while inefficient for screening large numbers of products, is a necessary phase in the research program when alternatives can be narrowed to a manageable number.

RESEARCH DESIGN AND PROCEDURE

Questionnaire Formulation

The questionnaire was divided into two parts; a demographic and an evaluation section. The former was made up of six questions, selected on the basis of their possible association with ratings of the fish stick products. The latter included four 7-point verbal hedonic rating scales, one scale each for texture, internal color, flavor, and overall satisfaction. In addition, a space for respondent comments was reserved beside each characteristic evaluation.

The Sample

The sample consisted of a consumer taste panel of 236 individuals in Dallas, Texas. Dallas was selected as a test city because a large sample was easily obtainable and test kitchens were available for the study. Two criteria for selection were used; first, that potential panelists be consumers of seafood and second, that they be 15 years of age or older.

Processing, Preparation and Serving

The cod and pollock used in this study were obtained in block form from an established processor in the northeastern United States. The cutlassfish was caught in Galveston Bay and processed into blocks at the Texas A&M University Research and Extension Center at Corpus Christi, Texas.

Minced blocks of flesh from the carcass were used for all three species. This is considered an acceptable product for fish sticks by reputable industry processors.

Each block was hand-processed into stick form using commercial dimensions. Since commercially processed fish sticks are heavily breaded, taste differences among fish flesh in some cases are eliminated. The hand-processed sticks were not as heavily breaded so that an evaluation of the flesh, not the breading, would be assured.

All samples were kept frozen until just before serving. The sticks were prepared in microwave ovens with cooking times of 30 seconds and were served directly to the panelists in bite-sized, unseasoned portions.

Measuring Procedure

While the demographic data was being filled out, the first sample was prepared. The respondents were then given the first evaluation form and the rating procedure explained.

The methodology utilized in the measuring procedure was a side-by-side test, modified slightly. That is, rather than serve the products simultaneously, each species was served individually, evaluated by the respondent and the rating form picked up before the next sample was presented. Also, water was made available between servings.

As discussed previously, the measurement instrument chosen for this test was a 7-point verbal, hedonic scale. To ensure that the evaluation would be as accurate as possible, each panelist was separated by curtains to discourage communication during this procedure. Also, individuals were asked to abstain from smoking. Finally, in order to eliminate order bias, the sequence of presentation of products was changed at given intervals.

RESULTS

The analysis of the data was conducted by performing chi-square tests of significance on the distributions for the ratings of fish sticks processed from cod, pollock and cutlassfish in terms of texture, color, flavor, and overall satisfaction. Additional tests were conducted on the distributions for ratings of the three species in terms of overall satisfaction compared to the demographic characteristics. The seven verbal levels on the scale were assigned numerical values with "dislike extremely" equal to one and "like extremely" equal to 7 for the purpose of calculating mean and median ratings.

Characteristic Ratings

Texture. In spite of the fact that all three species had been minced and processed according to the same method, the respondents detected differences in texture among the three products.

The calculated chi-square value of 113.017 for 12 d.f. shows a high degree of disparity among the three species for this characteristic. However, the frequency distributions for cod and cutlassfish in terms of texture are very close (Table 1). Pollock was rated far lower than the other two, thus the reason for the large chi-square value. The means and medians reflect the same distinctions.

Internal Color. The respondents rated cod as clearly superior to the other two products for this category. Also, cutlassfish was rated as more acceptable than pollock in terms of flesh color (Table 2).

The distribution for cod, in comparison with pollock and cutlassfish, is lower at the unacceptable and higher at the acceptable ratings. Seventy-five percent of the panelists rated cod five or higher. While fifty-four and forty-three percent judged cutlassfish and pollock, respectively, at five or better (Table 2).

It is believed that the main reason why cod was rated so high in terms of color, as compared to cutlassfish and pollock, was due to its light color. Most of the unfavorable comments received for internal color were concerning the darker color of the flesh and, conversely, the majority of favorable comments were in reference to the lighter product.

Flavor. The differences in distributions for the three species in terms of flavor were highly significant (Table 3). The frequency tables indicate that the ratings for cod and cutlassfish are almost identical and are clearly superior to pollock. The means and frequency distributions verify the observation that pollock is indeed inferior in this category. The means are 4.75, 4.61 and 3.82 for cod, cutlassfish and pollock, respectively. One would infer from

Table 1. Distributions, means and medians, and chi-square value on ratings of 3 products for texture.

Rating Term	SPECIES					
	Cod		Pollock		Cutlassfish	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Dislike Extremely	17	7.20	53	22.46	14	5.93
Dislike Moderately	18	7.63	44	18.64	13	5.51
Dislike Slightly	28	11.86	54	22.88	32	13.56
Neither Like nor Dislike	19	8.05	16	6.78	25	10.59
Like Slightly	42	17.80	29	12.29	48	20.34
Like Moderately	70	29.66	30	12.71	75	31.78
Like Extremely	42	17.80	10	4.24	29	12.29
	236	100.00	236	100.00	236	100.00
MEAN	4.82		3.23		4.78	
MEDIAN	4.86		2.89		4.71	

Chi-Square Value (Table) @ .01 level = 26.2170

Chi-Square Value (Calculated) = 113.017** with 12 d.f.

Source: Completed questionnaires, Dallas, May 1976.

Table 2. Distributions, means and medians, and chi-square value on ratings of 3 products for internal color.

Rating Term	SPECIES					
	Cod		Pollock		Cutlassfish	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Dislike Extremely	6	2.58	15	6.41	9	3.83
Dislike Moderately	2	.86	22	9.40	12	5.11
Dislike Slightly	11	4.72	46	19.66	36	15.32
Neither Like nor Dislike	38	16.31	51	21.79	50	21.28
Like Slightly	35	15.02	40	17.09	36	15.32
Like Moderately	77	33.05	46	19.66	73	31.06
Like Extremely	64	27.27	14	5.98	19	8.09
	233	100.00	234	100.00	235	100.00
MEAN	5.49		4.17		4.65	
MEDIAN	5.34		3.68		4.31	

Chi-Square Value (Table)@ .01 level = 26.2170

Chi-Square Value (Calculated) = 100.289** with 12 d.f.

Source: Completed questionnaires, Dallas, May 1976.

these statistics that cod was, again, superior to the other two species for flavor. However, a closer look at the distribution of ratings for flavor reveals that cod and cutlassfish are rated at five or above (better than neutral rating) by the same proportion of respondents (62 percent). Thus, from this viewpoint the flavor of cutlassfish is as acceptable as the flavor of cod, and the flavor of pollock is clearly inferior to the other two species.

Overall Satisfaction. As would be expected, cod is given the highest rating for this category, cutlassfish is a close second and pollock is rated a relatively distant third (Table 4). The high degree of significance and the mean and median values support this conclusion.

The frequency distributions for the three species, in terms of overall satisfaction reflect the same pattern noted in the ratings for texture, flavor and color (Table 4). That is, the distributions for cod and cutlassfish are very much alike in that they are low in the unacceptable portion and high in the acceptable region. More respondents, however, rated pollock in the unfavorable range. Thus, these results appear to be a good summary of the observations for the three individual evaluation factors.

Related Factors

The only demographic characteristics affecting the ratings of the three products were frequency of breaded seafood products consumption and sex of the respondent. Rotation order appears also to have influenced the ranking of some species.

Since overall satisfaction appears to be an adequate representation of the ratings for texture, color and flavor, all further tests of significance are conducted relative to this characteristic.

Frequency of consumption of breaded seafood products. The distributions for the consumption of fish sticks and the ratings of overall satisfaction were compared to each other by species in order to determine whether the former affected the scoring of the latter. The ratings were aggregated into three levels for parts of this analysis; dislike (1-3), neutral (4), like (5-7). This was necessary because of the large numbers of cells in the comparison.

The chi-square value for cod indicates that the ratings for this product were not affected by the consumption levels of breaded seafood products. However, a highly significant difference in distributions was found for pollock and cutlassfish. This indicates that the evaluation of the latter two species were influenced by this variable (Table 5).

The frequency tables for the ratings of pollock and cutlassfish were examined to determine which levels of frequency of consumption

Table 3. Distributions, means and medians, and chi-square value on ratings of 3 products for flavor.

Rating Term	SPECIES					
	Cod		Pollock		Cutlassfish	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Dislike Extremely	13	5.58	33	14.10	18	7.73
Dislike Moderately	20	8.58	27	11.54	23	9.87
Dislike Slightly	29	12.45	53	22.65	29	12.45
Neither Like nor Dislike	25	10.73	22	9.40	17	7.30
Like Slightly	47	20.17	48	20.51	53	22.75
Like Moderately	61	26.18	37	15.81	61	26.18
Like Extremely	<u>38</u>	<u>16.31</u>	<u>14</u>	<u>5.98</u>	<u>32</u>	<u>13.73</u>
	233	100.00	234	100.00	233	100.00
MEAN	4.75		3.82		4.61	
MEDIAN	4.66		4.23		4.58	

Chi-Square Value (Table) @ .01 level = 26.2170

Chi-Square Value (Calculated) = 41.877** with 12 d.f.

Source: Completed questionnaires, Dallas, May 1976.

Table 4. Distributions, means and medians, and chi-square value on ratings of 3 products for overall satisfaction.

Rating Term	SPECIES					
	Cod		Pollock		Cutlassfish	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Dislike Extremely	13	5.60	36	15.38	18	7.73
Dislike Moderately	17	7.33	41	17.52	21	9.01
Dislike Slightly	24	10.34	48	20.51	28	12.02
Neither Like nor Dislike	26	11.21	26	11.11	22	9.44
Like Slightly	45	19.40	43	18.38	51	21.89
Like Moderately	74	31.90	27	11.54	68	29.18
Like Extremely	<u>33</u>	<u>14.22</u>	<u>13</u>	<u>5.56</u>	<u>28</u>	<u>10.73</u>
	232	100.00	234	100.00	233	100.00
MEAN	4.84		3.56		4.59	
MEDIAN	4.85		2.85		4.57	

Chi-Square Value (Table) @ .01 level = 26.2170

Chi-Square Value (Calculated) = 68.445** with 12 d.f

Source: Completed questionnaires, Dallas, May 1976.

Table 5. Frequency distributions and chi-square values for overall satisfaction relative to frequency of consumption of fish sticks.

Consumption (fish sticks)	Dislike (1 - 3)			Neither Like Nor Dislike (4)			Like (5 - 7)		
	Cod	Pollock	Cutlass	Cod	Pollock	Cutlass	Cod	Pollock	Cutlass
Once a Week	14	43	25	9	7	7	75	50	66
More Than Once a Month	27	59	23	14	4	11	63	42	69
Once a Month	22	55	35	13	16	9	65	29	56
Once Every Three Months	24	53	27	10	10	6	61	37	67
Once a Year	26	61	17	13	17	22	61	22	61
Never Eat Them	40	67	67	7	20	7	53	13	27

-----percent^a-----

Chi-Square Value (Table) @ .05 level = 43.767

Species

- Cod Chi-Square Value (Calculated) = 31.502 with 30 d.f.
- Pollock Chi-Square Value (Calculated) = 46.961* with 30 d.f.
- Cutlassfish Chi-Square Value (Calculated) = 47.136* with 30 d.f.

^aPercentages may not total to 100 due to rounding.

Source: Completed questionnaires, Dallas, May 1976.

Table 6. Frequency distributions and chi-square values for overall satisfaction relative to sex of the respondent.

Rating Term	Species					
	Cod		Pollock		Cutlassfish	
	Male	Female	Male	Female	Male	Female
Dislike Extremely	4	9	12	24	3	15
Dislike Moderately	7	10	17	24	7	14
Dislike Slightly	11	13	25	23	12	16
Neither Like Nor Dislike	19	7	13	13	13	9
Like Slightly	20	25	24	19	28	23
Like Moderately	39	35	17	10	41	27
Like Extremely	<u>15</u>	<u>18</u>	<u>8</u>	<u>5</u>	<u>10</u>	<u>15</u>
	114	119	116	118	115	117

Chi-Square Value (Table) @ .05 level = 12.571

Species

Cod Chi-Square Value (Calculated) = 9.186 with 6 d.f.

Pollock Chi-Square Value (Calculated) = 8.350 with 6 d.f.

Cutlassfish Chi-Square Value (Calculated) = 15.905* with 6 d.f.

Source: Completed questionnaires, Dallas, May 1976.

affected the ratings for the two products in terms of overall satisfaction (Table 5). The less frequent consumers of breaded seafood products tended to downgrade pollock and cutlassfish more than frequent users of these products.

Sex. The chi-square value for the overall satisfaction ratings of the three species versus sex of the respondent was significant at the 95% confidence level. The individual frequency distributions reveal that male and female ratings for cod and pollock were essentially the same, whereas the same comparisons for cutlassfish show an obvious difference in distributions (Table 6). Females tended to rate the cutlassfish lower than males.

Rotation Order. Chi-square tests were performed on the distributions of the ratings for each species in terms of overall satisfaction relative to rotation order. The chi-square value for cod was not significant at the 90 percent confidence level, implying that the sequence of presentation had no effect on this product (Table 7).

Tests of significance on the ratings for overall satisfaction of pollock and cutlassfish relative to rotation order show that rankings were affected by this variable. Pollock was rated higher when it was served first.

The distribution for cutlassfish, as indicated by the chi-square value, also varied considerably as the sequence of presentation was changed. Ratings were higher when the cutlassfish was first or followed pollock. They were lower when following cod. The fact that some order bias occurred confirms the logic of using a procedure which protects against this in presenting the products.

Respondent Comments

Comments were extremely varied, making it difficult to establish a definite pattern between those who like products and those who disliked them. However, some comments were mentioned more frequently for each species relative to the other two.

Texture. Respondents used the terms "tough" or "rubbery" quite frequently for all species. The number of remarks using these adjectives was far greater for pollock than for cod and cutlassfish.

On the positive side, cod was described as being "flaky" while the term "tender" was used for cutlassfish by a number of panelists. There were few positive comments in any one category about the texture of pollock.

Internal Color. The descriptor terms most often used for this factor were "light" or "dark." Generally, the term "dark" was used when rating the cutlassfish and pollock. As previously discussed,

Table 7. Frequency distributions and chi-square values for overall satisfaction relative to rotation order.

Rotation Order ^a	Dislike (1 - 3)		Neither Like Nor Dislike (4)		Like (5 - 7)				
	Cod	Pollock	Cutlass	Cod	Pollock	Cutlass	Cod	Pollock	Cutlass
(1) P, C, C.F.	19	31	13	16	9	0	66	38	59
(2) C, C.F., P	25	53	48	13	25	13	63	23	40
(3) C.F., P, C	35	59	11	8	14	19	57	27	70
(4) P, C.F., C	18	45	20	16	7	14	66	48	66
(5) C, P, C.F.	24	63	30	11	7	4	65	30	66
(6) C.F., C, P	18	65	24	3	6	6	79	29	71

-----percent-----

Chi-Square Value (Table) @ .05 level = 43.767

Species

Cod Chi-Square Value (Calculated) = 38.965 with 30 d.f.

Pollock Chi-Square Value (Calculated) = 45.399* with 30 d.f.

Cutlassfish Chi-Square Value (Calculated) = 48.513* with 30 d.f.

ap = Pollock, C = Cod, C.F. = Cutlassfish

Source: Completed questionnaires, Dallas, May 1976.

these two were inferior to cod for this characteristic. The adjective most frequently used for cod was "light."

Flavor. In general, cutlassfish was described as "fishy" by the panelists, while cod and pollock were termed "bland." These comments do not imply positive or negative evaluation since direct comparisons of the ratings for each species would be required to determine the effect of the descriptor terms on the evaluation. This was not possible due to the high number of varied responses.

CONCLUSIONS

The cutlassfish, in relation to both the cod and pollock appears to be almost as well accepted as the former and clearly superior to the latter. In light of these results, the cutlassfish appears to have a potential in the fish stick market as an effective substitute for cod and pollock.

Since this has been the first formal taste panel test for cutlassfish in the form of fish sticks, further studies of a similar nature should be organized under different conditions. For example, additional taste tests panels could be conducted to determine the acceptance of cutlassfish using commercially breaded products, filleted fish sticks, or different treatments of the flesh to improve its color. Also, in future tests the source of the fish used in manufacturing the product could be better identified and perhaps controlled as a test variable. Research studies to identify economically viable harvesting, processing and marketing systems for the cutlassfish could also be undertaken.

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THE ROLE OF INSPECTION IN FISHERIES DEVELOPMENT

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As attempts are made to develop certain fisheries to commercial economic importance, significant problems, constraints and barriers will be encountered by the industry. These elements, as they arise and are identified, must be studied, and methods for resolving them must be found. We do not know specifically at this stage what all of these elements will be. However, we do know that in order for a fishery to become viable, it is necessary that the resource be available in sufficient quantities, that harvesting be economically and technically feasible for the fishermen, that the raw material used be suitable for processing, that methods for processing be safe, efficient and economically and commercially feasible, and that the end product which is produced be safe, wholesome and of an acceptable quality. Before any large sums of money are invested into the development of a fishery, we must be certain that before the product gets into the market place, it meets all of the pertinent requirements of the state and federal governments regarding product contamination, adulteration, safety, composition, labeling and nomenclature. Because of existing safety and product compliance constraints and the likelihood of additional regulations and constraints in the future, there is a need for the development and use of a methodology to determine whether or not specific species of fish and shellfish used as raw materials, ingredients used in products, sanitation of the processing facilities, processing and manufacturing methods, handling procedures, storage, distribution, and marketing operations are in compliance with all federal and state regulations. The United States Department of Commerce, Seafood Quality and Inspection Division, can provide one methodology to assist the seafood industry in pursuing fisheries development projects.

MATERIALS AND METHODS

Screening and review of raw materials and ingredients

USDC inspection methods provide a screening and review system for all raw materials and ingredients to ascertain their safety and acceptability before deciding on their fitness for use in manufacturing final product. This screening procedure consists of determining if there be any known risks of contaminants exceeding

established guidelines and tolerances which may be present in the proposed raw materials. This could involve investigation of the specific species of fish or seafood to be used to see if there be any existing potential for a health hazard due to the presence of microconstituents exceeding amounts prohibited by law, in order to determine whether or not raw materials are suitable for further processing. Certain restrictive factors, such as size of the fish, geographical location of the source, and susceptibility of the species for deteriorative quality changes would be evaluated. Results of such screening could be used to make decisions as to whether or not the raw materials are safe and therefore feasible for use.

Ingredients contemplated for use would also be screened chemically and microbiologically for safety compliance; then reviewed as to their acceptability under existing regulations, considering permissible concentrations in the end product.

Evaluation of plant facilities

USDC methods provide for inspectors to consult with industry on plant design, plant layout, product flow plans, and the performance of sanitary compliance surveys of existing facilities in order to rate the plant's capability to produce wholesome products under approved sanitary conditions. Inspectors trained in this area sit down with the processor, and together they come up with recommendations for needed corrective action and for improvements or changes in order to meet federal and state requirements.

Assessment of processing and production methods

Techniques such as hazards analyses and critical control points assessments are employed by USDC through examining in detail individually each step in the production operation employed in the manufacture of the product. A detailed written quality control plan, identifying control points and locations where line inspection stations are needed, plus a schematic product flow chart and control system, are developed to make certain that each processing step is being monitored and controlled. Time and temperature parameters and other controls where needed are developed to specifically fit the requirements of the product and the operation. Types of controls are custom developed and depend on the type of end product produced, the characteristics of the species, quality factors which are determined to be important to the saleability of the product, and their applicability and meaningfulness in meeting the objective of providing a safe, wholesome product, acceptable to the consumer.

Care is taken to prevent use of overly sophisticated controls which are not needed in each and every operation. Simplified versions of the controls given above are used wherever the size or degree of complexity of production operations warrant.

End product evaluation

Product specifications, designed around the particular product being manufactured, are developed by USDC. This is accomplished by study of the quality factors associated with and which are characteristic of the product as well as by the ability of the processor to

meet such quality criteria. Development of quality specifications help the processor to decide what is important to him and to his customers and to provide standardization and uniformity for his product. Such specifications have cutoff points where the product is identified as being acceptable or unacceptable, and results of product evaluation by use of product specifications can be used as a feedback mechanism to indicate where improvements are needed. Revisions on the specifications can be made at any time to take care of changes or necessary adjustments in the nature or character of the product being produced.

USDC inspection methods help the processor to develop product specifications that can be given official USDC approval, and used to certify his products to bear the USDC federal inspection marks.

Labeling and packaging review

The USDC inspection program methods provide for services to review product name labels and labeling statements for fishery products in order to insure compliance with current laws such as the Fair Packaging and Labeling Act. This is a critical area for new products inasmuch as the cost of printing incorrect labels, which cannot legally be used, is an expensive waste. Methods used by USDC can be immensely beneficial to those preparing new product labels.

Analytical services

The USDC inspection laboratory in Pascagoula has the capability to assist fishery development in performing chemical and microbiological analyses on raw material or final product to determine acceptability. Methods consist of using the results to compare with known parameters of safety and with legal tolerances. Reports are furnished to applicant for use in making decisions about their products and procedures. Any question anyone in the seafood industry may have on the suitability of his raw material or product can be answered by having analyses made by USDC.

Marketing assistance

In order to help gain wide consumer acceptance of fishery products, the U. S. Department of Commerce provides inspection and certification services which permits the processor to use the "Packed Under Federal Inspection" mark. This is particularly desirable when introducing new products, where the new product is generally unknown and where there may be doubt or reluctance on the part of consumers to try out something different, as for example squid or shark meat. Having the assurances of the U. S. government that the product is safe, wholesome, and of good quality, and that it has been packed under sanitary conditions, can go a long way to assuage consumer fears.

RESULTS AND DISCUSSION

Many new business endeavors have failed in the past for not recognizing the importance of establishing consumer confidence in

the dependability and uniform quality and integrity of the product offered for sale. USDC seafood inspection was started nineteen years ago because of the poor quality of two new fishery products in the market place. These products were breaded fish sticks and breaded shrimp. The seafood industry approached the federal government and asked that this chaotic situation be remedied by the promulgation of grade standards and the implementation of an objective, unbiased federal inspection system to restore consumer confidence in breaded fish sticks and breaded shrimp, which should have had wide appeal as a convenience food. As a result of restoring quality and consumer confidence to the products through inspection, these two products became widely accepted throughout the United States and today constitute a large part of the fishery products consumed by the public and institutional trade.

In developing new fisheries and products made from unutilized and underutilized species, it is extremely important to avoid starting off with adverse publicity and consumer opposition, lest adverse reaction and consumer attitudes create a resistance to these products which will retard fisheries development on these now unused resources for a long time to come. USDC inspection is willing to share its methods with all those interested in providing safe, high quality seafood to the American consumer.

CONCLUSION

Through a careful step by step approach to problem solving in developing new products, giving proper consideration to the health, safety and quality factors involved, there is absolutely no reason why viable commercial fisheries cannot be developed with great potential benefits for the seafood industry and the American public.

One method which has been presented here and which can be utilized in protecting the industry from making disastrous mistakes, by avoiding the pitfall of not giving sufficient consideration and attention to the safety and quality aspects of the development of their products, is through use of the consultative, analytical and inspection methods of the United States Department of Commerce Seafood Quality and Inspection Program. It is recommended that these methods and the assistance of USDC inspection be used to the fullest extent.

BACTERIOLOGICAL PROFILES - PROCESSED
FRESHWATER CATFISH - NORMAL FLORA AND SALMONELLA

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INTRODUCTION

The importing of catfish from Mexico has been a problem for several Texas fish processors. The presence of salmonellae on catfish prohibits its entry into the United States because the U.S. Food and Drug Administration (FDA) considers Salmonella to be a harmful and deleterious substance under the Federal Food Drug and Comestic Act. No reports of salmonellae in live catfish could be found in the literature. The presence of E. coli antibodies in brown bullhead catfish (12) and enteric pathogens in carp (6) indicated that the environment of catfish could contribute to the presence of salmonellae. Margolis (8) suggested that the intestinal flora of fish is dependent on its food source, and that a non-feeding fish does not harbor a specific microbial flora, if any, in its intestinal tract. Lewis et al. (7), however, found that salmonellae could be recovered from the intestine of catfish at least 30 days after initial contamination through feeding.

An FDA survey of 48 catfish processors in 9 states indicated that there was a very low incidence of the human enteric pathogens, Salmonella and Edwardsiella (1). While only 9 of the 48 fresh catfish processors had samples positive for salmonellae, the contamination levels ranged from 5% to 80% in the samples examined. Although the processing procedure described in this paper was developed to aid a processor of imported catfish, the principles involved can be applied to domestic catfish processing plants.

The initial results of an investigation to determine the source of salmonellae in farm-raised and commercial catfish are also presented.

MATERIALS AND METHODS

A.O.A.C. procedures (2) were used for the enumeration of coliforms and Escherichia coli. Aerobic plate counts (APC) were conducted by the spread plate method on Trypticase Soy Agar (TSA) incubated at 25C for 48 hours. All samples, except water, were initially diluted in 0.5% Lactose broth with additional

dilutions in 0.1% peptone broth. This initial dilution in lactose broth allowed pre-enrichment of all samples for Salmonella. Pre-enrichment was followed by the selective enrichment of 1 ml portions of the lactose broth in 10 ml Tetrathionate broth and 10 ml Selenite-Cystine broth for salmonellae, and 10 ml GN broth and 10 ml double strength SS broth (DSSS) with 0.5% dextrose for Edwardsiella. The agar was removed from SS agar by filtration through a Whatman No. 1 filter under suction. Brilliant Green agar with sulfadiazine, Bismuth Sulfite agar and SS agar with 1% sucrose and 0.65% agar added as recommended by Sperber and Deibel (11) were streaked from Tetrathionate and Selenite-Cystine broth. SS agar and XLD agar were streaked from GN and DSSS broth. Suspect colonies from each plate were picked to Triple Sugar Iron agar (TSI) slants and Motility-Indol-Lysine (MIL) deeps. MIL is a modification of Ederer and Clark's (4) Motility-Indol-Ornithine (MIO) medium with lysine substituted for ornithine. This allows for the rapid biochemical differentiation of indole positive Edwardsiella. The media was prepared by adding 1.0% trypticase and 0.2% agar to Falkow Lysine broth. Incubation was at 35C for 24 hours at each step in the isolation procedure. Serological confirmation of Salmonella was performed with Poly-O antisera. All media used was BBI with the exception of SS agar which was Difco.

Samples were collected as follows: Water was collected from a 1 foot depth approximately 3 feet from the bank of the pond using a sterile 750 ml Erlenmeyer flask attached to a hand vacuum pump and sterile rubber tubing. The Most Probable Number (MPN) for Salmonella was determined using 100 ml, 10 ml and 1 ml of water in a 1:9 ratio with lactose broth.

Live fish were taken immediately from the seine and placed in a 48 quart insulated ice chest that had been previously cleaned, sanitized and partially filled with pond water. The fish were removed and rendered unconscious with quinaldine. A rectangular piece of skin was excised with a sterile scalpel then removed with sterile skinning pliers. The exposed area was later measured to determine the area of the skin. A 1-3 g portion of the intestinal tract was removed and weighed in a sterile petri dish. The samples were placed in lactose broth in milk dilution bottles with glass beads and shaken vigorously.

Dressed fish were selected during processing, placed in separate plastic bags, stored on ice and returned to the laboratory. A 50 g sample was removed from the belly flap and fillet area and blended in 450 ml of lactose broth within 3 hours of processing.

Retail samples of fresh water catfish were purchased from retail markets located within a 200 mile radius of the laboratory. Samples were purchased in steak, fillet or dressed form and transported on ice to the laboratory. The samples were identified by storage condition, country of origin and farm-raised vs. wild status. A 50 g sample was taken from the belly flap-fillet area and blended in 450 ml of lactose broth.

Dressed and retail market fish to be examined for salmonellae and *Edwardsiella* only were placed in sterile 1 qt. mason jars with 500 ml of lactose broth. In the case of fish too large for the jars, the anterior portion, including the visceral cavity, was used.

A total of 20 colonies were picked from countable plates. Colonies were selected on their relative abundance to similar colony types. Identification of bacterial isolates was based on major characteristics of bacterial genera commonly found on foods as described in Bergey's Manual for Determinative Bacteriology (3). The characteristics included morphology, glucose fermentation, oxidase, catalase, motility, spore production and heat sensitivity.

RESULTS AND DISCUSSION

Catfish were received at the processing plant dressed, eviscerated or in-the-round. Salmonellae was isolated from the dressed carcasses, the visceral cavity of the eviscerated fish and on the skin and in the viscera of fish in-the-round. The muscle tissue of the salmonellae-positive fish was found to be negative for salmonellae. These results indicated that the salmonellae contamination of dressed fish was from contamination during processing. Figure 1 depicts the processing procedure that was used for eviscerated fish and fish in-the-round.

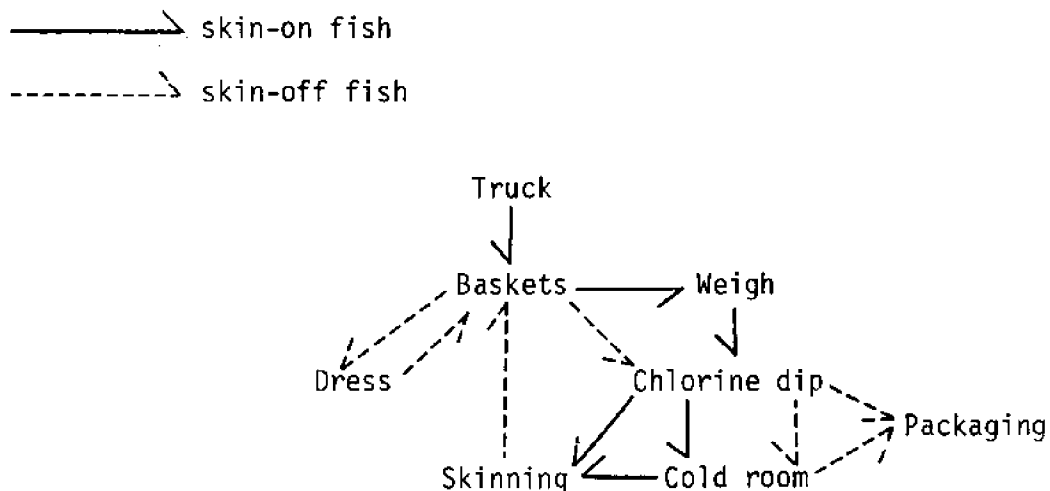


Figure 1. Steps in original processing procedure.

The results in Table 1 show that 48.6% of the samples processed by this procedure were salmonellae-positive. The absence of *E. coli* in several salmonellae-positive samples, the almost identical APC's of salmonellae-positive and negative samples and the high value of the range in coliforms was evidence that cross-contamination occurred in this processing procedure.

Table 1. Salmonellae in dressed fish (old process)

37 samples 48.6% Salmonellae positive						
	Log APC		Coliforms		<i>E. coli</i>	
	+	-	+	-	+	-
Range	4.0-6.8	4.4-6.8	13-24,000	23-9300	0-2100	0-360
Mean	6.1	6.1	---	---	---	---
Median	5.9	5.6	>1100	23	>1100	<240
Mode	5.7	---	>1100	<240	>1100	<240

To eliminate cross-contamination and reduce salmonellae contamination the process was streamlined and the procedural changes are shown in Figure 2. The fish were washed and eviscerated. Individual spray nozzles and iodine hand dips (25 ppm) were at each eviscerator's station. The knives used for evisceration were kept in the hand dips facilitating the sanitation of the eviscerators hands and equipment. The belly cavity was opened and the viscera removed without rupturing the intestinal tract. The visceral cavity, equipment, working area and hands were washed prior to receiving the next fish. The eviscerated fish was then moved to the skinning area. The fish was placed on a metal hook and skinned with skinning pliers maintained in the iodine hand dip. Care was taken during skinning not to touch the exposed flesh. The fish was then deheaded with an electric band saw. A final trim, inspection and wash was performed and the fish were placed on ice and packaged. A primary provision of the new process was for thorough and scheduled (every 2 hours) cleaning and sanitizing which included the changing of chlorine and iodine hand dips. Garbage and debris were continuously removed during processing. Figure 2 shows the primary steps in the processing scheme.

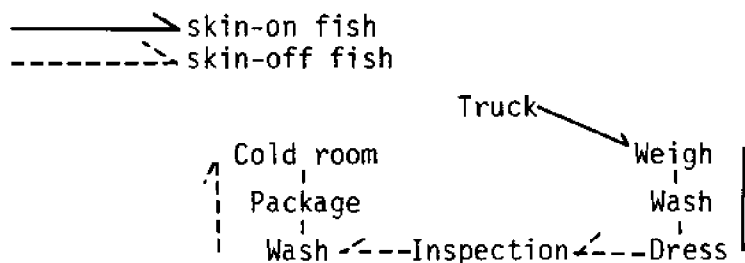


Figure 2. Steps in new processing procedure.

Table 2 shows the results of the changes made in the processing procedure. There was a reduction in the APC, coliforms and *E. coli*. No salmonellae-positive samples of dressed fish were found. This was true for fish that were shown to be salmonellae-positive prior to processing. FDA inspection results were included in the data because an injunction prohibited the plant from processing severely limiting the number of samples that could be obtained for this purpose.

Table 2. Salmonellae in dressed fish (new process)

	17 samples 0.0% Salmonellae positive		
	Log APC	Coliforms	<i>E. coli</i>
Range	2.7-5.6	0-93	0-15
Mean	4.8	--	--
Median	3.8	3.6	0
Mode	---	0	0

A bacteriological laboratory was established so the quality of incoming and outgoing fish could be monitored. The laboratory has the capacity to perform plate counts by the spread plate method on Standard Methods agar, coliforms using Violet Red Bile agar pour plates, *Staphylococcus aureus* by direct-plating on Baird-Parker agar and salmonellae isolation by the procedure previously described. This laboratory, the cleaning and sanitizing regime and innovative processing procedure give this plant dimensions that cannot be equalled by any comparable hand-processing plant in the southern U. S.

The initial data from the bacteriological analysis of 3 catfish ponds is shown in Tables 3, 4 and 5. The major flora of the dressed fish corresponds to that found on the skin and the pond water. No salmonellae were found in the pond water, viscera or skin of live fish from ponds 1 and 3. The skin of 2, viscera of 3 and 4 of 5 dressed fish from pond 2 were positive for salmonellae. The water in pond 2 had a salmonellae MPN of 1.1/ml.

These initial results indicate that the bacterial flora of the fish is representative of the bacterial flora of its aquatic environment. The presence of salmonellae on the skin and viscera is a result of its presence in the pond. Its presence on live fish can result in contamination of dressed fish if good processing procedures are not followed. An effective processing procedure was developed that eliminated or greatly reduced this contamination.

Table 3. Bacterial Flora - Pond #1

Temperature 25.6C(78F)

<u>DRESSED FISH (5)</u>		<u>WATER</u>	
1.1 x 10 ⁵		3.9 x 10 ³	
<u>Aeromonas</u>			<u>Coryneforms</u>
<u>Coryneforms</u>	67%	54%	<u>Moraxella</u>
<u>Moraxella</u>			<u>Aeromonas</u>

Table 4. Bacterial Flora - Pond #2

Temperature 29.4C(85F)

<u>DRESSED FISH (5)</u>		<u>WATER</u>	
1.1 x 10 ⁷		3.2 x 10 ³	
<u>Lactobacillus</u>			<u>Lactobacillus</u>
<u>Aeromonas</u>	99.7%	100%	<u>Coryneforms</u>
<u>Coryneforms</u>			<u>Aeromonas</u>

Table 5. Bacterial Flora - Pond #3

Temperature 15.6C(60F)

<u>DRESSED FISH (3)</u>		<u>WATER</u>	
6.4 x 10 ⁴		5.9 x 10 ³	
<u>Coryneforms</u>			<u>Aeromonas</u>
<u>Moraxella</u>	81%	91%	<u>Moraxella</u>
<u>Flavobacterium</u>			<u>Pseudomonas</u>
<u>Pseudomonas</u>			
<u>Aeromonas</u>			

The FDA survey of retail catfish referred to the isolation of the human enteric pathogen, Edwardsiella, on 2 samples of fish (1). Edwardsiella has been implicated in the catfish disease, emphysematous putrefactive disease of catfish (9). In the survey FDA found Edwardsiella by using salmonellae isolation techniques. This procedure has only been 40% effective as the Edwardsiella isolation procedure used in this laboratory. Table 6 shows the relative occurrence of Edwardsiella in pond water and mud, catfish skin and viscera and on dressed fish. Edwardsiella has been found in turtles (personal experience), frogs (10) and snakes (5) which can account for its presence in catfish ponds. The significance of Edwardsiella in fish and ponds and its public health significance is not clear at this time.

Table 6. Occurrence of Edwardsiella

<u>EDWARDSIELLA</u>	
Ponds(26 of 32)	81.3%
Skin(8 of 16)	50.0%
Viscera(11 of 16)	68.8%
Dressed Fish	
Domestic(46 of 63)	73.0%
Imported(5 of 22)	22.7%

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THE EFFECTS OF ANTIBACTERIAL AGENTS AND WASHING
PROCEDURES ON THE BACTERIOLOGICAL QUALITY OF GULF FISH

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INTRODUCTION

Most of the marine fish landed in Texas are either marketed as fresh fish on ice or stored and shipped on ice prior to further processing. Processing methods used by fish processors in handling fresh fish are not very advanced compared to methods used by poultry and red meat processors. This lack of technology contributes to the loss of fish due to spoilage.

Fish spoils as a result of microbial, autolytic and chemical processes. Normally, microbial decomposition is the primary problem except with fatty fish (11). In an attempt to delay spoilage by reducing the microbial levels on fish, some fish processors have used chlorine dips. Research data is not available on the value of this type of treatment for fish.

A considerable amount of research has been conducted to test chlorine treatments with poultry. Patterson (14) tested treatments similar to those used by fish processors. Chicken carcasses were submerged for 4 hours in chilled water with either 200 or 400 ppm chlorine, added as sodium hypochlorite. Initial reduction in bacterial numbers and a 20-25% increase in shelf-life was reported with the treated carcasses, as compared to the untreated carcasses. McVicker et al. (7) tested a similar treatment with 20 ppm chlorine and reported some initial lowering of bacterial counts but no increase in storage life. Dawson et al. (4) reported that treatments with 140 ppm chlorine increased the shelf-life of fryers 5 days.

The use of chlorination in poultry processing plants has been reported to result in a better product. Chlorine is added to the entire plant water supply, to the final washers or to the spin-chillers. Mead et al. (10) reported that 20 ppm chlorine in the water supply of a turkey processing plant resulted in a 10-fold reduction in the number of bacteria on the carcasses. Sanders and Blackshear (15) found 40-50 ppm chlorine in the final washers of a chicken processing line to be the optimum concentration for reducing bacterial levels. They reported $\frac{1}{2} \log_{10}$ reductions and concluded that varying the pH from 5.9 - 9.0 did not affect the results. Mead and Thomas (8) found that 45-50 ppm chlorine in conjunction

with 5 liters/carcass of water exchange in a spin-chiller reduced the bacterial levels on chickens by 2 log₁₀. They concluded that the effect of chlorination in the spin-chiller was to destroy bacteria which were removed by the physical action of the water, preventing recontamination and cross contamination (9).

Chlorine treatments have also been applied with red meats. Kelly (5) found that lamb carcasses rinsed for 2 minutes with 80°C water containing 450 ppm chlorine had bacterial levels 2 log₁₀ lower than carcasses rinsed with similar non-chlorinated rinses. However, after 10 days of storage there were no differences in bacterial counts and the day of spoilage was the same for all carcasses. Smith et al. (16) reported that 200 ppm chlorine affected a 2 log₁₀ reduction in bacterial counts on lamb carcasses when compared to untreated carcasses. Bailey (3) and Kotula et al. (6) have reported similar reductions with lamb and beef carcasses treated with chlorine. Swift and Company, Inc., Chicago, Ill. has developed a process called Chlor-Chill for use with lamb, pork and beef. In this process an automatic spraying system is used to spray the carcasses at predetermined intervals with a mild chlorine solution throughout the chilling period. They report that the process results in almost bacteria-free carcasses at the meat packing plant and markedly reduces tissue shrink (2).

Research with chlorine treatments with poultry and red meat carcasses indicates that these treatments are effective for reducing bacterial levels but the reductions in bacterial numbers do not always result in an increased storage life. Fresh fish presents a different situation because of the scales and slime layer and might not respond to chlorine treatments like poultry and red meat carcasses.

In chlorination processes, consideration must be given to the amount of "free available chlorine" present, the pH, the type of chlorine compound used and the temperature (12,13). Natural waters contain impurities which combine with chlorine, forming compounds which have vastly inferior bactericidal activity when compared to free chlorine. Tests can be conducted to determine how much of the added chlorine is combined and how much is free (free available chlorine). According to Palin, the pH of a solution determines what form the chlorine added to that solution takes (Fig. 1). Between pH 1 and 5 a transition from 100% molecular chlorine (Cl₂) to 100% hypochlorous acid (HOCl) occurs and from pH 5 to 10 the HOCl completely dissociates to form hypochlorite ion (OCl⁻). Hypochlorous acid has 80 times more bactericidal activity than hypochlorite ion. The type of compound used for preparing a chlorine solution is important because this influences the pH. When chlorine gas is dissolved in water, no significant change occurs in the pH, but sodium hypochlorite solutions are highly basic. A 200 ppm chlorine solution prepared with sodium hypochlorite has a pH of 10. Temperature is important because a 10°C increase in temperature has been reported to increase the bactericidal activity of a chlorine solution by 50%. Consideration is given to each of these factors in the chlorine treatments with fish.

MATERIALS AND METHODS

Species and source of fish

Spotted sea trout (Cynoscion nebulosus) and Southern flounder (Paralichthys lethostigma) obtained from commercial and non-commercial sources in the Corpus Christi Bay and Upper Laguna Madre area were used for the investigations. Only fish caught less than 1 day before the trials were used. The fish were iced and transported to the Corpus Christi laboratory where the fish were gilled and eviscerated.

Chemical

The DPD Ferrous Titrimetric Procedure (1) was used to determine the chlorine content of solutions. The procedure of Triebold (17) was used to standardize the ferrous ammonium sulfate used as the titrant. The DPD procedure differentiates between free and combined chlorine. Chlorine concentrations are expressed as ppm free available chlorine. Household bleach (5.25% sodium hypochlorite) was the chlorine source. When the pH was altered, reagent grade glacial acetic acid was added in the quantity necessary to attain the desired pH.

Chlorine treatments

Chlorine treatments consisted of submerging the fish in 12 x 40 x 60 cm vats containing 20 liters of solution. The combination of chlorine concentration, submersion time, pH value and solution temperature used in each test is specified in the list.

- i) 200 ppm Cl - 5 min. - pH 10 - 25°C
- ii) 200 ppm Cl - 5 min. - pH 5.5 - 25°C
- iii) 200 ppm Cl - 5 min. - pH 10 - 55°C
- iv) 200 ppm Cl - 5 min. - pH 5.5 - 55°C
- v) 40 ppm Cl - 60 min. - pH 9 - 30°C
- vi) 157 ppm Cl - 60 min. - pH 10 - 30°C

Four fish were used for each test and tests were duplicated when enough fish were available. When available, both flounder and trout were used in the tests. Along with each test 4 fish were retained as untreated controls or submerged in vats of non-chlorinated water for comparison.

Washing treatments

Four fresh caught trout and 4 trout about 5-7 days old were sprayed with a forceful stream of tap water for 1 minute. Equal numbers of trout were left untreated as controls.

Six trout and 6 flounder were obtained from a fish market. Three fish of each species were left untreated (swim bladder, kidneys, gonads and lower intestinal tract not removed) and 3 fish of each species had all abdominal contents removed and the abdominal cavity was rinsed with water.

Handling after treatment

The 4 fish from each treatment were stored in separate ice chests after treatment. The effects of the washing and chlorine treatments were evaluated as specified in the bacteriological sampling and organoleptic evaluation sections.

Bacteriological sampling

One skin sample was taken from each fish for total aerobic plate counts before treatment and every few days after treatment

until the fish was spoiled. The skin samples were obtained by removing a portion of skin with a sterile sharpened stainless steel tube (inside area - 4.15 cm²), a sterile scalpel and sterile tweezers. The portion of skin was placed in a 100 ml dilution bottle containing 10 ml of sterile 0.1% peptone and 15 grams of sterile glass beads (2mm diameter). The bottle was closed tightly and shaken rapidly up and down in a 40 cm arc 50 times. Appropriate decimal dilutions were prepared in sterile 0.1% peptone. Plates were prepared by the spread plate technique on Trypticase Soy Agar (BBL) with plate incubation for 48 hours at 25°C.

Organoleptic evaluation

The odor and appearance of the fish were noted periodically throughout each test. Special attention was given to the day of spoilage of the treated fish relative to the controls and to any adverse changes resulting from the treatments.

RESULTS AND DISCUSSION

Chlorine treatments

The results are expressed in terms of changes in bacterial level and storage life of the chlorine treated fish relative to the water treated fish. This method of evaluation distinguishes between changes resulting from the washing action of the dip and changes due to the bactericidal activity of the chlorine. Each column in the graphs represents a value obtained by averaging 4 samples from 4 different fish.

Treatment (i) (200 ppm Cl, 5 min., pH 10, 25°C) did not effect the bacterial levels on the flounder tested (Fig. 2 and 3) but reduced the bacterial levels on the trout (Fig. 4). The storage life was not affected with either species. Treatment (ii) (200 ppm CL, 5 min., pH 5.5, 25°C) did not affect the bacterial levels on the flounder (Fig. 3) but like treatment (i) reduced the levels on the trout (Fig. 4). No change in the storage life resulted from this treatment. The pH 5.5 solutions caused whitening of the fish's skin. Treatment (iii) (200 ppm Cl, 5 min., pH 10, 55°C) reduced the bacterial levels on one group of trout (Fig. 5) but did not affect the levels on another group (Fig. 6). The storage life was not affected in either case. This treatment had some adverse effects on the appearance of the fish. Treatment (iv) (200 ppm Cl, 5 min., pH 5.5, 55°C) did not affect the bacterial levels (Fig.7) or the storage life of the trout tested. The appearance was adversely affected by the treatment. Treatment (v) (40 ppm Cl, 60 min., pH 9, 3°C) did not reduce the bacterial levels on the trout tested (Fig. 8) nor extend the storage life. Treatment (vi) (157 ppm Cl, 60 min., pH 10, 3°C) reduced the bacterial levels on the trout tested (Fig.8) but did not increase the storage life.

In some cases the bacterial levels on the chlorine treated fish were reduced compared to the water treated fish, but no consistent pattern is evident as to which treatments are effective. Greater reductions were not evident with the low pH and high temperature treatments. The storage life of the chlorine treated fish were in some cases greater than the storage life of the water treated fish. Evidently the reductions in bacterial numbers were not great

enough to affect the storage life.

Washing treatments

The spraying treatments tested with trout reduced the bacterial levels by 1-2 \log_{10} and extended the storage life 2 days relative to untreated fish. In conjunction with this test a group of trout were treated as in chlorine treatment i. These fish showed the same reductions in bacterial levels and extensions of storage life as the sprayed fish (Fig. 9). Note that these chlorine treated fish are compared to untreated fish not water treated fish as before.

The trout and flounder which were stored as obtained commercially spoiled 1-2 days before the completely eviscerated fish and had bacterial counts $\frac{1}{2} \log_{10}$ higher.

These 2 tests show that more thorough eviscerating and washing of fresh fish extends the storage life and reduces bacterial levels as compared to untreated fish as much or more than a chlorine dip.

CONCLUSION

The types of chlorine dips tested can not be recommended for use with fresh fish because more thorough washing and eviscerating was more effective in reducing bacterial levels and extending storage life. Other types of chlorine treatments not tested might be effective with fish. A system utilizing a process similar to the spin-chilling process used with poultry would possibly be effective with fish.

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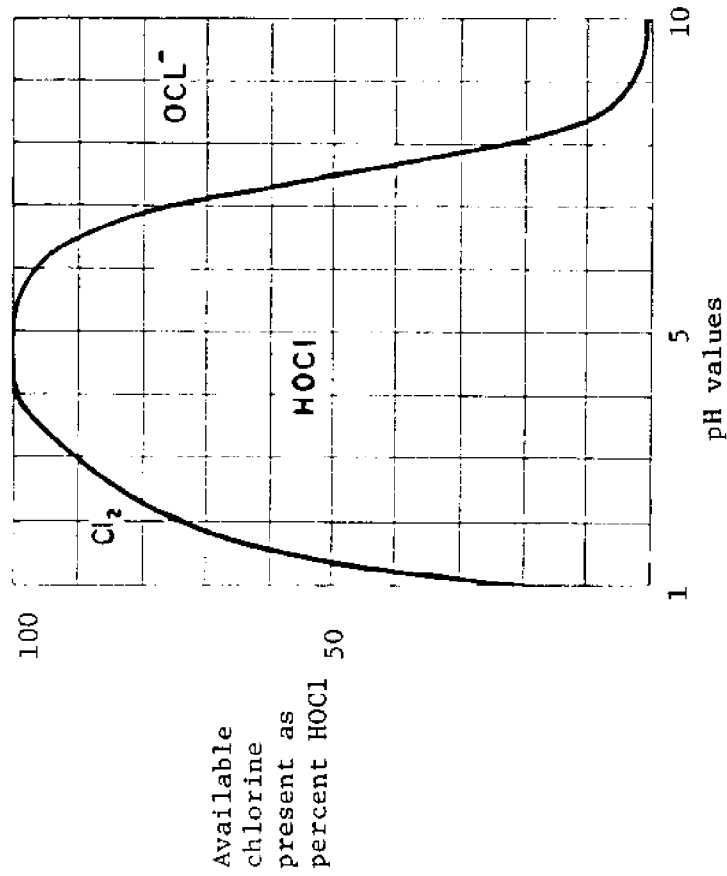


Fig.1 - Relationship between pH and form of available chlorine.

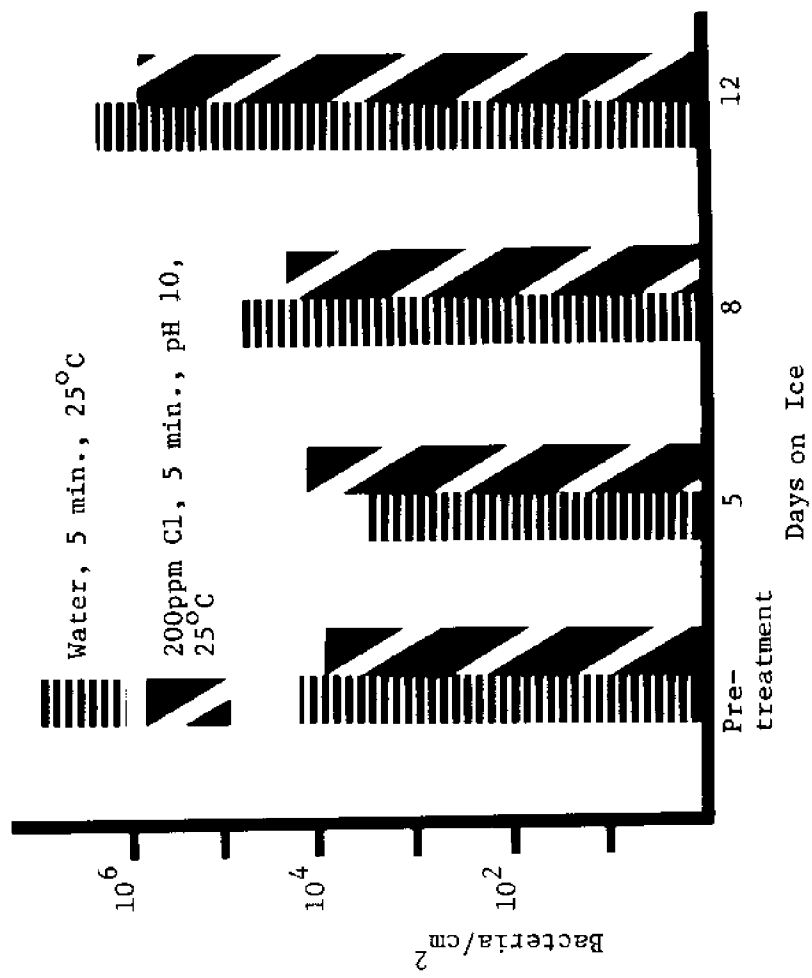


Fig.2 - Treatment (i), flounder

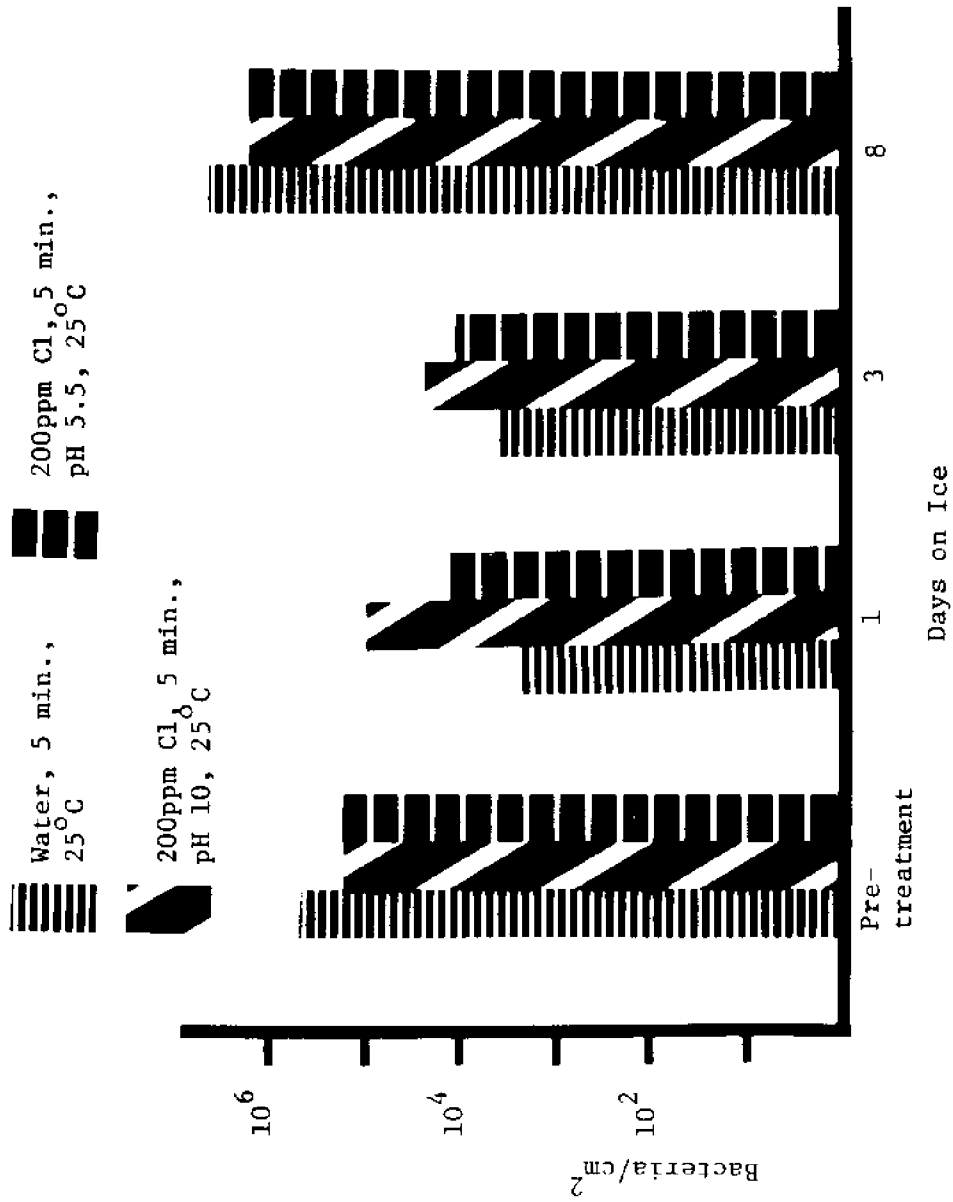


Fig.3 - Treatments (i) and (ii), flounder

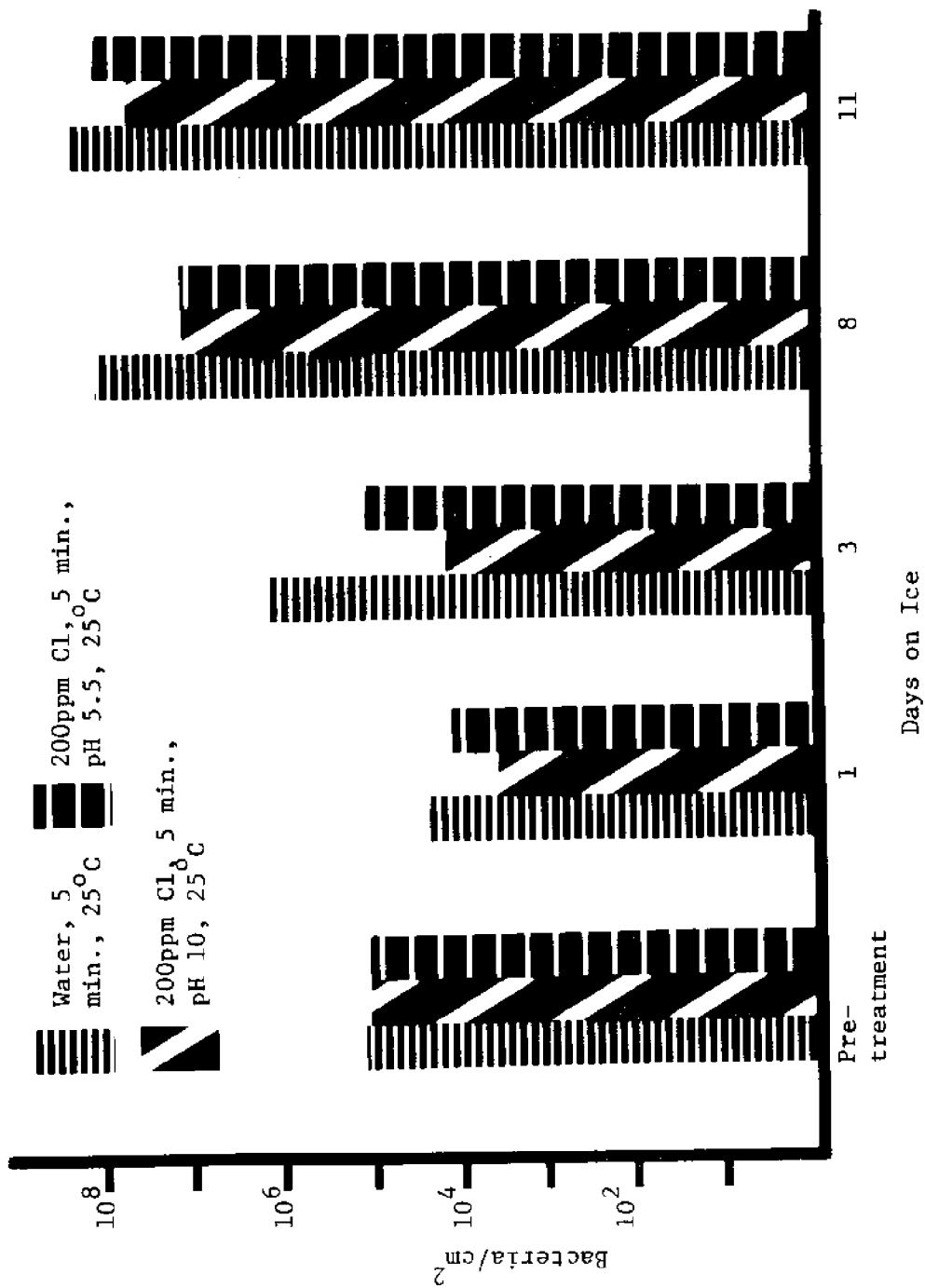


Fig.4 - Treatments (i) and (ii), trout

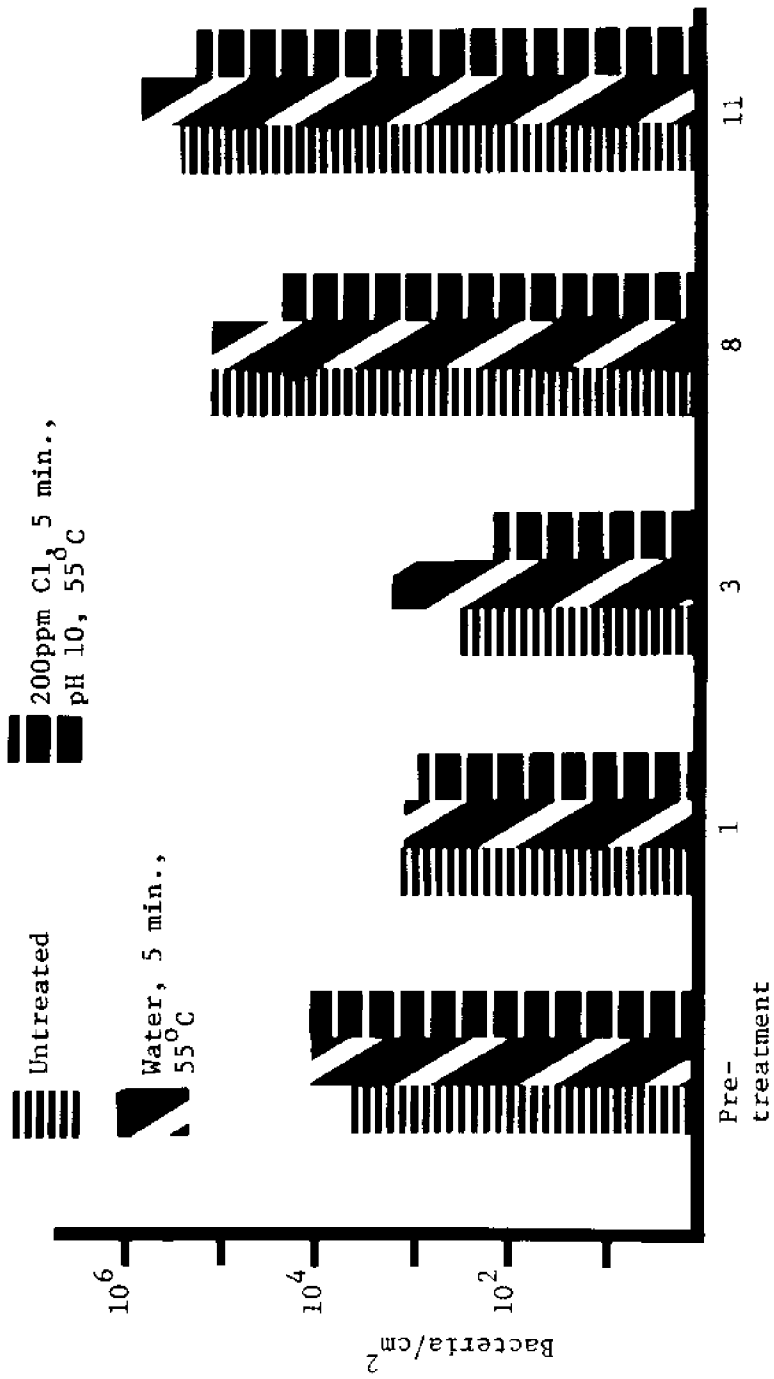


Fig.5 - Treatment (iii), trout

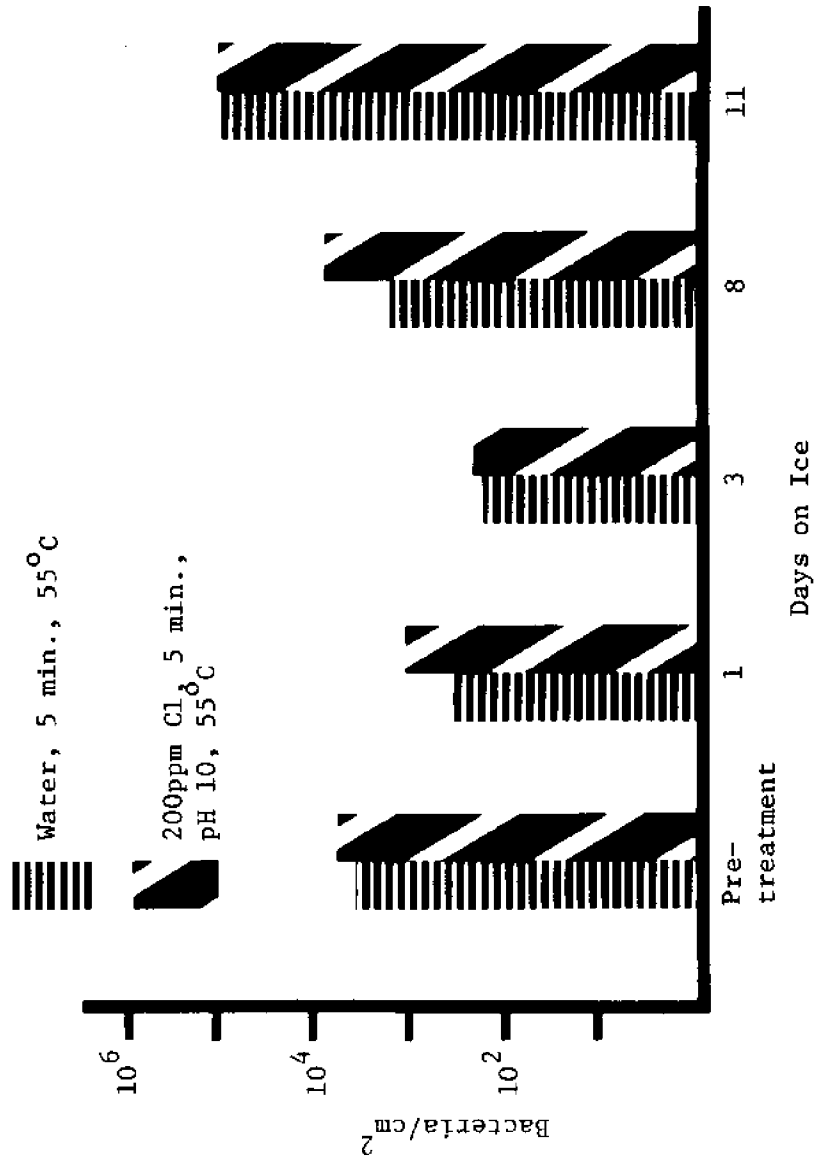


Fig.6 - Treatment (iii), trout

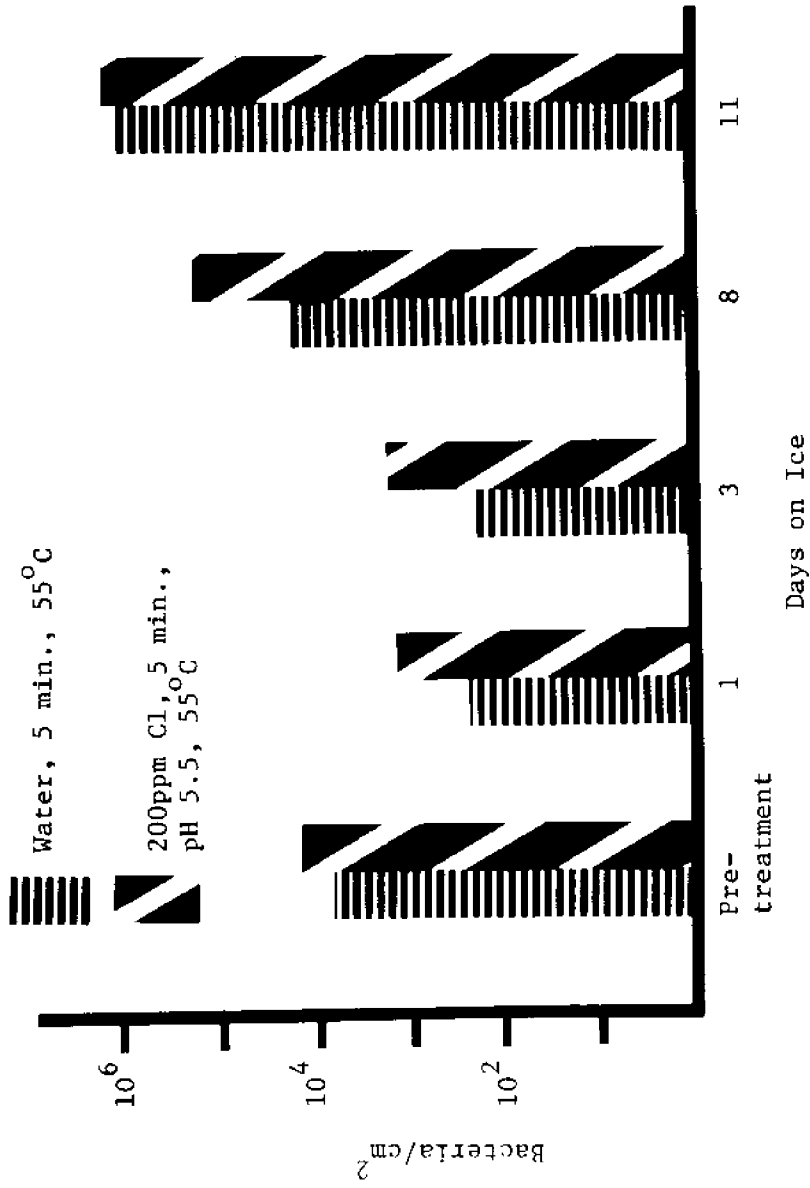


Fig.7 - Treatment (iv), trout

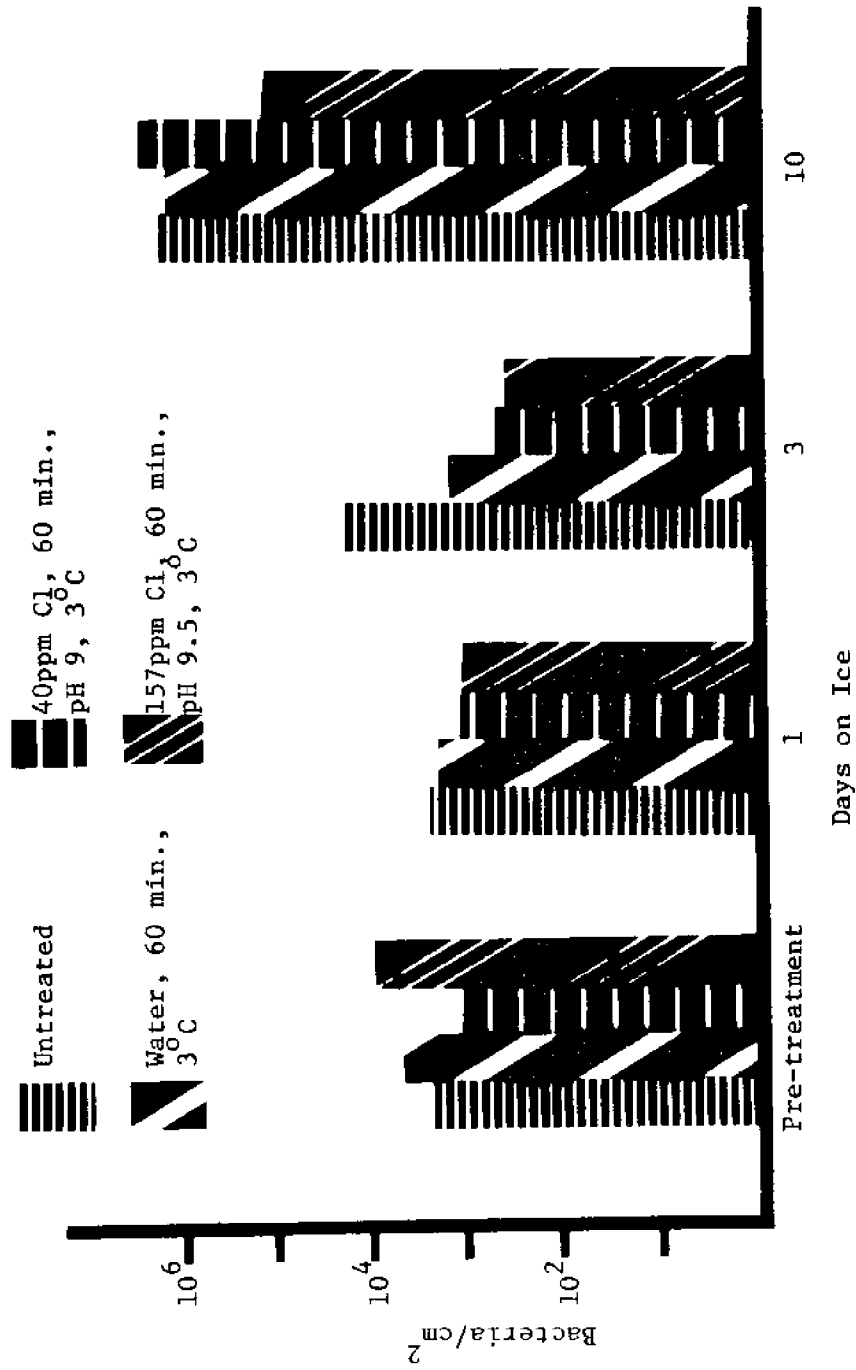


Fig.8 - Treatments (v) and (vi), trout

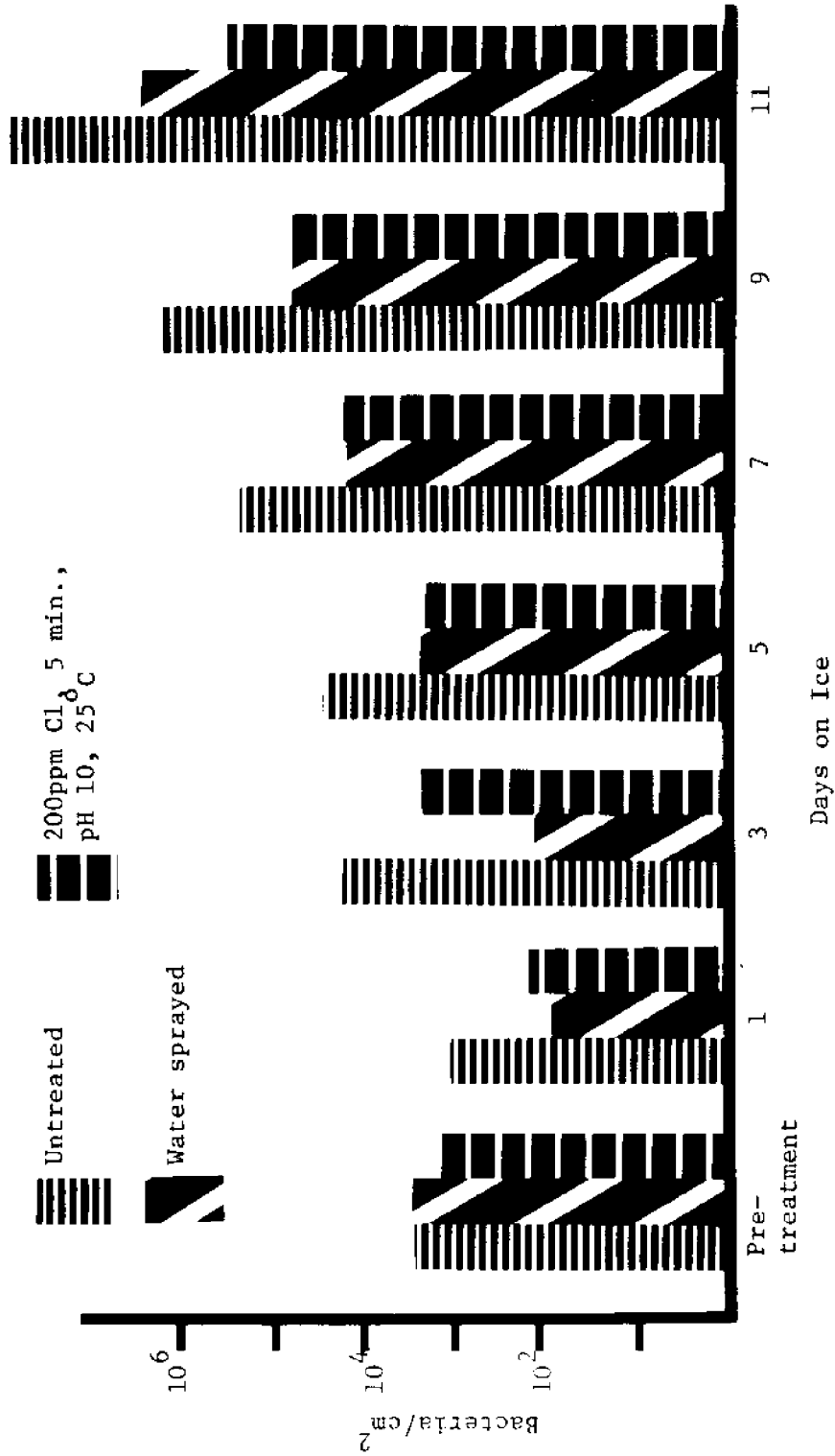


Fig.9 - Water spraying and treatment (i)

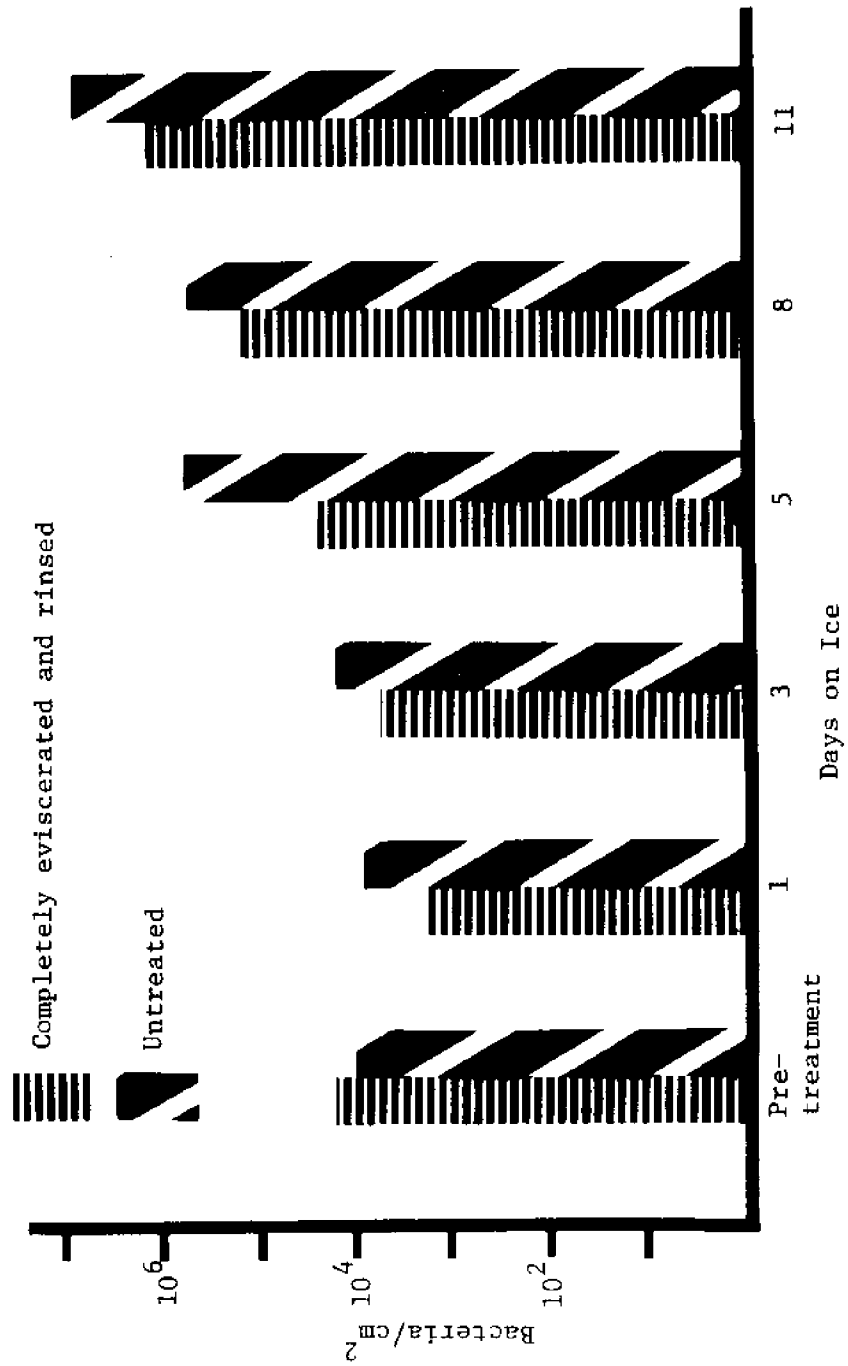


Fig.10 - Evisceration tests, trout

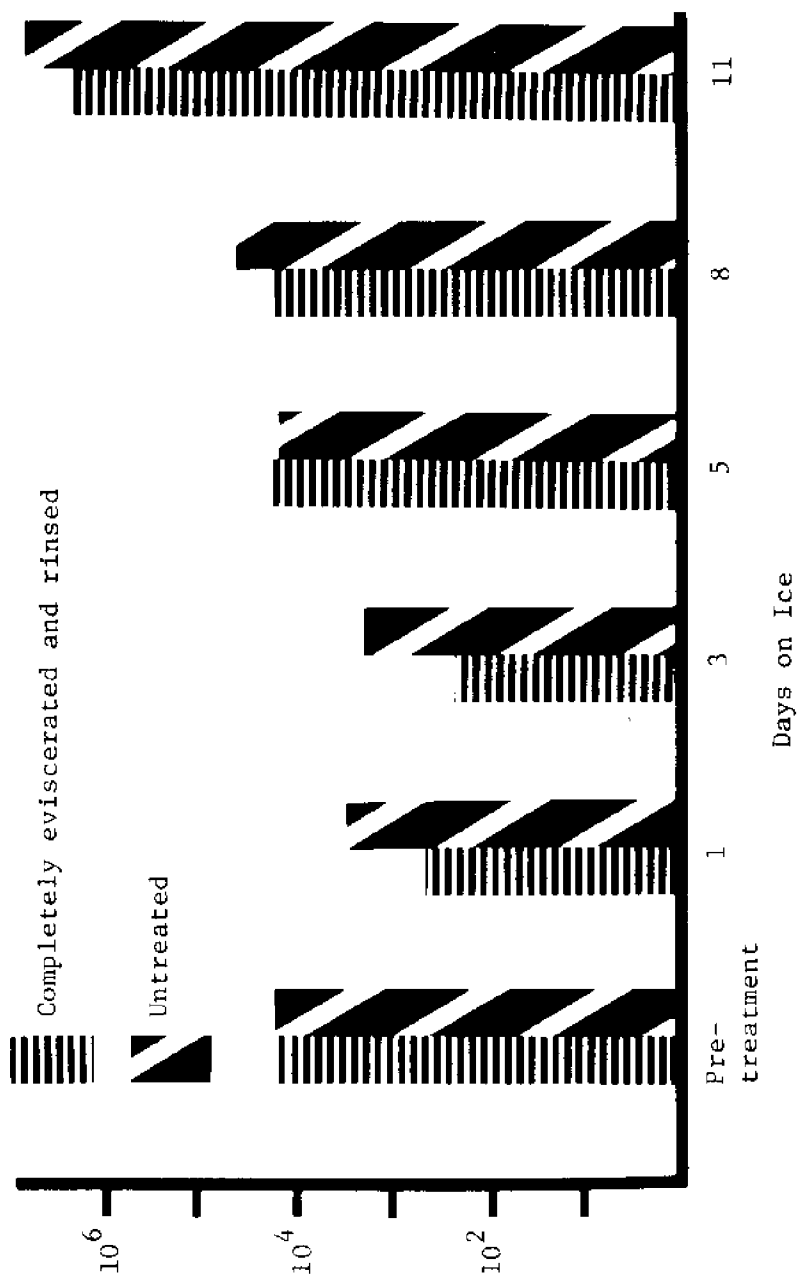


Fig.11 - Evisceration tests, flounder

MICROBIOLOGY OF THE SMOKED MULLET PROCESS

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Little is known of the microbiology of the smoked mullet process (10). This may be somewhat surprising since it is estimated that about 2 million pounds of mullet are smoked each year in Florida (3). Most reports in the literature regarding smoked fish discuss the microbial flora of species produced in countries other than the U. S. Shewan (9) devoted most of his discussion of smoked fish to the cold smoked process with only a limited discussion of the hot smoked process. Graikiski (6) in a brief summary of the hot smoked process reported that spore-forming bacteria were the predominant surviving microorganisms on freshly smoked fish. There is some disagreement as to the destructive effect of cold smoking on the flora normally present on fish (4, 9). This may be due to the many different procedures used in the process. In a previous report from this laboratory (7) on the quality of commercially hot smoked mullet, it was found that high total aerobic plate counts were not uncommon on the retail product. Experimentally prepared hot smoked fish, however, were produced with a low count which persisted through 13 days of storage at 40°F.

In order to gain some insight into the microbial changes that take place during smoking, both hot and cold smoked mullet were prepared and the qualitative and quantitative changes in the flora were followed during each phase of processing.

MATERIALS AND METHODS

Fresh mullet were obtained from Cedar Key, Florida, during June and August of 1976. The fish were packed in plastic bags and frozen at -20°F until used.

The fish (1-2 lbs.) were removed from the freezer and thawed in flowing water. They were headed, butterflied and gutted and placed in ice overnight. They were then brined in a 20% sodium chloride solution for 30 minutes using 1 lb of brine for each lb of fish, rinsed in tap water and drained for 30 minutes. The fish were placed skin side down on racks and smoked in a Koch Grandprize smokehouse using hickory sawdust as the source of smoke (8).

Cold smoked fish were smoked at 120°F for 5 hours. The hot smoked fish were smoked at 150°F for 3 hours, then the temperature was raised to 225°F until the loin muscle internal temperature reached either 165 or 180°F and held there for 30 minutes. An additional 2-3 hours was usually required for this step to be completed. The fish were cooled and packed in Whirlpak bags and stored at 41°F for up to 20 days. Two hot and two cold smoked experiments were conducted. Total aerobic plate counts (incubated at 68°F for 5 days) and coliform counts were conducted using standard procedures (1). The plate count agar contained an added 0.5% sodium chloride to enhance recovery. Duplicate samples for each treatment were analyzed at each test period and the results averaged. For identification of the flora, a number of isolates equal to the square root of the number of colonies on the countable plates were obtained. Identification of the isolates was by standard procedures (5), employing the descriptions in Bergey's 8th edition (2).

RESULTS AND DISCUSSION

The data in Table 1 summarize the microbial analyses conducted during the preparation of both hot and cold smoked mullet. The hot smoked fish heated to either 165 or 180°F did not show any major degree of microbial survival. The fish heated to 180°F exhibited lower counts than the fish heated to 165°F. For the fish heated to 165°F, there appeared to be a die off of surviving organisms during storage; however, the counts were so low as to make interpretation difficult. No coliforms were recovered from the fish after smoking or during storage. These data would indicate that the excessively high counts observed on retail samples (7) were indeed due to either insufficient heating or recontamination after processing.

A large surviving population was expected on the cold smoked fish in light of Shewan's study (9), which reported that smoking at 96°F could be expected to destroy only 25-70% of the flora. The temperature of 120°F, while high for a cold smoked product, is apparently too low to produce a major antimicrobial effect. This would indicate that other factors are aiding in the reduction of microorganisms, such as the phenolic compounds in the smoke (9). The surviving flora in our study was capable of extensive multiplication during storage at 41°F. By 7 days the counts had increased from initial levels of 15,000 organisms per gram to over 400,000 organisms per gram on the cold smoked fish, a level believed to be beyond acceptable limits (8).

The flora of the raw fish was representative of what one would expect from an estuarine species (Table 2). It was quite diverse, mainly gram negative organisms with a few gram positive species. The fish after brining, while not exhibiting a major shift in population, appeared to contain more gram positive organisms than

the raw fish. As there was a noticeable reduction in total numbers after brining, there logically would be expected to be an increase in the more resistant gram positive species. The flora remaining after hot smoking was quite restricted and represented those species resistant to heat, mainly Bacillus and other gram positive organisms. In the two studies of the cold smoked fish in which identification of the surviving flora was made, two different patterns of survival were exhibited. In the first study, after 14 days of storage, there were gram positive organisms surviving: Micrococcus, Staphylococcus and Bacillus. Following storage in the second study, gram negative organisms were much more in evidence. Seven genera were isolated, four of which were gram negative (Table 2). Conditions for smoking each batch were kept as constant as possible. However, uncontrollable variables such as ambient temperature, wind velocity, smoke density and humidity may have influenced the results. Regardless of the reason for the trends observed, it seems certain that special care must be exercised in the handling of cold smoked fish.

From our results, it appears that hot smoked mullet does not present any unusual spoilage or health problems if handled properly after smoking. This seems to be the case whether the fish is heated to an internal temperature of 165 or 180^oF. However, cold smoked fish undergoes rapid microbial development as noted. Therefore, it would be best if this product was stored frozen and if not, refrigerated storage should be limited to less than one week.

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Table 1. Changes in the microbiology of mullet during smoke processing

	Hot smoked (165° + 180°F)			
	<u>Aerobic plate count/g</u>		<u>Coliforms/g</u>	
	<u>165°F</u>	<u>180°F</u>	<u>165°F</u>	<u>180°F</u>
Raw fish	135,000	225,000	200	60
Brine	<10	470	<1	<1
Fish after brine	21,000	16,000	180	30
Smoked 0 day	32	2	0	0
Stored 5 days	22	0	0	0
" 10 days	20	5	0	0
" 15 days	10	0	0	0
" 20 days	8	0	0	0

	Cold smoked (120°F)	
	<u>Aerobic plate count/g</u> *	<u>Coliforms/g</u> *
Raw fish	108,000	12
Brine	<10	<1
Fish after brine	86,000	4
Smoked 0 day	15,000	19
Stored 7 days	420,000	440
" 14 days	3,600,000	7600

*Averages of two studies

Table 2. Microbial Species and the Number of Times Isolated During
Smoke Processing of Mullet.

	Raw (4) [*]	Butterfly (4)	Brine (2)	Brine after fish (4)	Fish after brine (4)	Cold smoked 0 day (2)	Cold smoked 7 days (2)	Cold smoked 14 days (2)	Hot smoked 0 day (2)	Hot smoked 5 days (2)	Hot smoked 10 days (2)	Hot smoked 15 days (2)	Hot smoked 20 days (2)
<u>Streptococcus faecalis</u>			1										
<u>Micrococcus luteus</u>		2	1	4	9	8	17	17				1	
<u>M. roseus</u>		1											
<u>Staphylococcus epidermidis</u>	2	11		5	16	6	1	1				1	
<u>S. saprophyticus</u>		1		2	1	8		1					
<u>Lactobacillus casei</u>	1												
<u>Corynebacterium pseudodiphtheriticum</u>	2			1		1							
<u>C. sepedonicum</u>						1							
<u>C. michiganense</u>	2	1	1		5				1				
<u>C. fascians</u>	1	1											
<u>Arthrobacter globiformis</u>	1			2	1								
<u>A. citreus</u>	2				2								
<u>A. tumescens</u>	1				4		1						
<u>Bacillus firmus</u>							1	3					
<u>B. circulans</u>	3	2	1	4									
<u>B. coagulans</u>		2		1	1				4	3	3	1	2
<u>B. brevis</u>		1											
<u>B. badius</u>	1	1			2				2	1			1
<u>B. sphaericus</u>											2		
<u>B. fastidiosus</u>				1									
<u>Yersinia sp.</u>	1												
<u>Yeast</u>		3			3			1					

Table 2 (continued)

	Raw (4) [*]	Butterfly (4)	Brine (2)	Brine after fish (4)	Fish after brine (4)	Cold smoked 0 day (2)	Cold smoked 7 days (2)	Cold smoked 14 days (2)	Hot smoked 0 day (2)	Hot smoked 5 days (2)	Hot smoked 10 days (2)	Hot smoked 15 days (2)	Hot smoked 20 days (2)
<u>Alcaligenes</u>													
<u>aquamarinus</u>	2												
<u>A. faecalis</u>					1								
<u>Flavobacterium</u>													
<u>F. aquatile</u>	3	1			4								
<u>F. ferrugineum</u>		3		2	1								
<u>F. rigense</u>	2		4										
<u>F. devorans</u>	1	1											
<u>F. indoltheticum</u>	19	6	4	4	7								
<u>Acinetobacter</u>													
<u>calcoaceticus</u>	1	9		11	3		1	2					
<u>Moraxella</u>													
<u>M. nonliquefaciens</u>	3	3		1	5		1	2					
<u>M. osloensis</u>	7	7		2	4								
<u>M. bovis</u>							1						
<u>Aeromonas</u>													
<u>hydrophila</u>	1												
<u>Pseudomonas</u>													
<u>P. fluorescens</u>	3	4			1								
<u>P. putida</u>	1	1		2									
<u>P. marginata</u>	1	2			1								
<u>P. stutzeri</u>	1				2								
<u>P. pseudomallei</u>			2		1								
<u>P. caryophylli</u>	2	1											
<u>P. alcaligenes</u>	2	1					2						
<u>P. acidovorans</u>			2										
<u>P. mendocina</u>							1						
<u>Erwinia</u>													
<u>herbicola</u>	1	2		5	1		3	4					
<u>Escherichia</u>													
<u>coli</u>		1		1									

Table 2 (continued)

	Raw (4) [*]	Butterfly (4)	Brine (2)	Brine after fish (4)	Fish after brine (4)	Cold smoked 0 day (2)	Cold smoked 7 days (2)	Cold smoked 14 days (2)	Hot smoked 0 day (2)	Hot smoked 5 days (2)	Hot smoked 10 days (2)	Hot smoked 15 days (2)	Hot smoked 20 days (2)
<u>Enterobacter cloacae</u>				2		1	1	2					
<u>aerogenes</u>						1							
<u>Citrobacter freundii</u>						1							
<u>intermedius</u>							1						
<u>Proteus mirabilis</u>						1							
<u>inconstans</u>	1												
<u>Klebsiella pneumoniae</u>							2						

* () number of samples run

GLYCOGEN AND CHOLESTEROL CONTENT OF MARYLAND, ALABAMA AND LOUISIANA OYSTERS DURING A CONSECUTIVE TWELVE MONTH PERIOD

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The cholesterol contents of oysters vary in the literature to such a great extent that it is extremely difficult to make an assessment of the dietary cholesterol content. The cholesterol values range from 50 mg/100 grams to as high as 250 mg/100 grams of oyster meat.

This high cholesterol content reported associated with oysters has led many doctors to advise and design special low cholesterol diets and recommend the complete deletion of oysters from the diet, thereby adversely affecting the entire oyster industry.

The glycogen content of oysters is another area which has been neglected and very little information is to be found.

Thus, a comparative study of the glycogen and cholesterol content of Maryland, Alabama and Louisiana oysters during a consecutive 12 month period was undertaken to provide this data.

MATERIALS AND METHODS

Sampling

Oyster samples were collected by personnel in Technological Laboratories from Maryland and Alabama and in the Food Science Department from Louisiana. The sources of the oysters represented Chesapeake Bay, Mobile Bay and Barataria Bay in Maryland, Alabama and Louisiana, respectively.

The samples from Maryland and Alabama were shucked, packed unwashed in pint plastic containers and frozen. They were then packed in dry ice and shipped to the Food Science Department at LSU by the most rapid means of transportation - air or bus. The samples of Louisiana oysters were shipped by refrigerated truck from Barataria Bay to a New Orleans Wholesaler, shucked and placed unwashed in pint jars, and picked up and transported on ice to the Food Science Department within 6 hours of collection. At LSU, they were packed in plastic containers and as the other oyster samples, frozen and immediately stored in the freezer at - 25 C for subsequent analyses of glycogen and cholesterol. All samples were run in duplicate.

Glycogen Determination

Fifteen grams of thawed oyster meat from each sample are homogenized for 3 minutes with 100 ml of 5% trichloroacetic acid (TCA). The homogenates are then transferred to large plastic centrifuge vials and centrifuged for 15 minutes at 5,000 rpm in a Sorvall Super-Speed RC2-B Centrifuge. The supernatant is filtered through Whatman's No. 42 (acid washed) filter paper. The process is repeated and the filtrates are combined for each sample and measured volumetrically and diluted up to 990 ml total volume with 5% TCA and thoroughly mixed. Duplicate samples of the filtrates, containing 1 ml each, are pipetted into 15 ml Pyrex centrifuge tubes and 5 ml of 95% ethanol are added to each. The tubes are capped and placed in a water bath for 3 hours at 37 - 40°C after which they are centrifuged in a Sorvall GLC-1 for 18 minutes at 3,000 rpm. The supernatant is gently decanted and the tubes are allowed to drain in an inverted position for 10 minutes. The precipitated glycogen is dissolved in 2 ml of distilled water and the glycogen is determined by the Anthrone Method of Carroll et al. The optical density of the glucose produced is determined spectrophotometrically of a B & L Spectronic 20 Colorimeter at 620 nm and the following formula used to calculate the glycogen content:

$$\frac{\text{Optical density of unknown}}{\text{Optical density of standard}} \times 0.1 \times \frac{\text{Volume of extract}}{\text{Sample weight}} \times 0.9 \times 100 = \text{Mg of glycogen per 100 g of sample}$$

Cholesterol Determination

Oyster samples were removed from the freezer, thawed and weighed. Due to variation in the size of individual oysters, the sample size varied from 20 to 40 grams. After weighing samples, the oysters were chunked and placed in 25 x 80 mm cellulose thimbles for extraction of total lipid in the Soxhlet Unit for 24 hrs with 200 ml of reagent grade absolute methanol. After 24 hrs refluxing, the alcohol extract was collected and measured volumetrically. The difference between the measured alcoholic extract and 200 ml of absolute methyl alcohol was utilized to rinse out the boiling flask and added to the original alcohol extract, thereby maintaining the 200 ml volume. The oyster sample was now refluxed for 24 hours with 400 ml of chloroform and treated similarly to maintain the 400 ml volume. Both extracts are combined, mixed and stored in a suitable flask under nitrogen at refrigeration temperature overnight to facilitate the precipitation of suspended tissue particles in the extracts.

Upon removal from refrigeration, the 1:2 methyl alcohol-chloroform mixture is allowed to equilibrate with room temperature and filtered through a coarse grade Buchner filter until clarified and transferred to a 1 liter separatory funnel. Potassium Chloride (0.88%) is now added and thoroughly mixed with the 1:2 methyl alcohol-chloroform mixture to insure thorough washing. The separatory funnel mixture is stored in the refrigerator and allowed to settle and separate. The upper phase layer is removed by

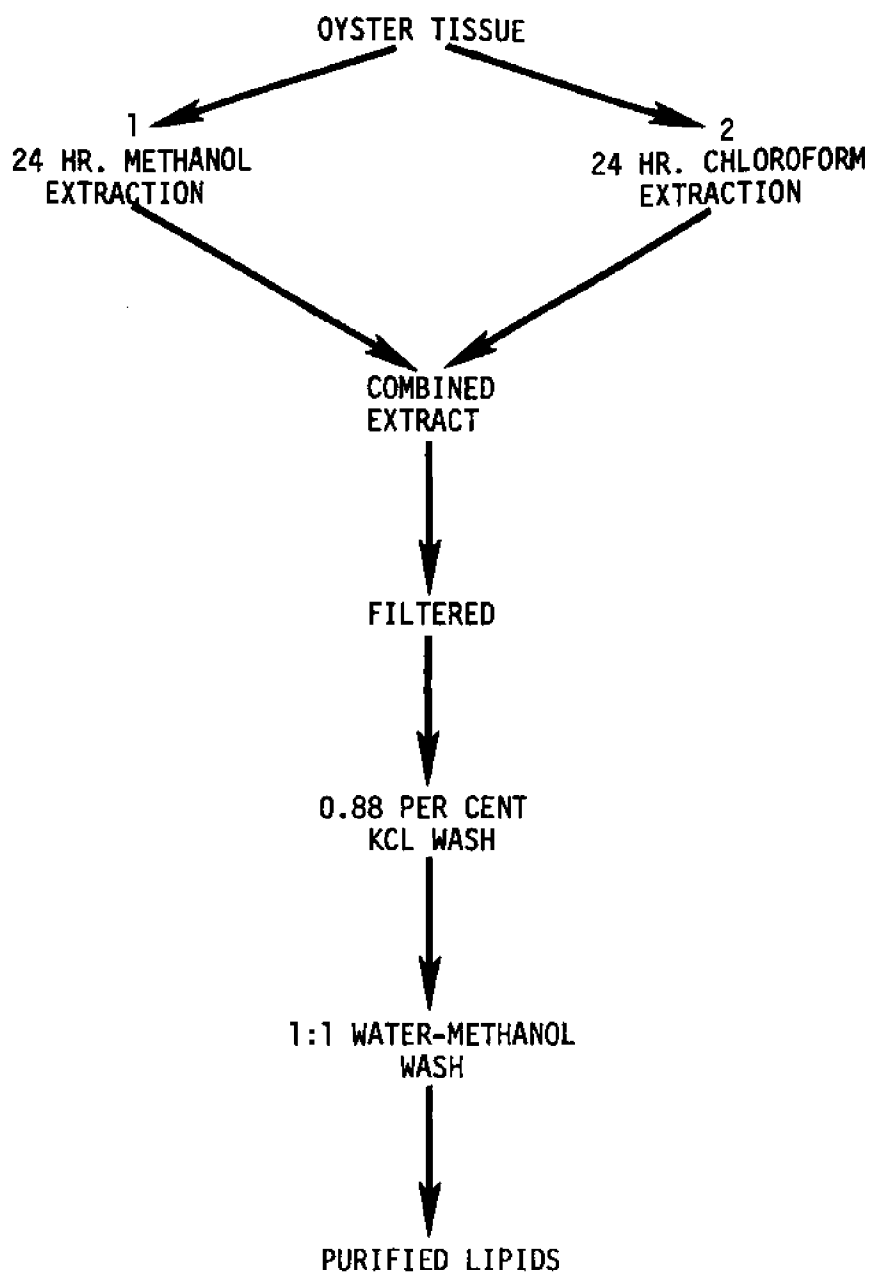


FIGURE 1. TOTAL LIPID EXTRACTION

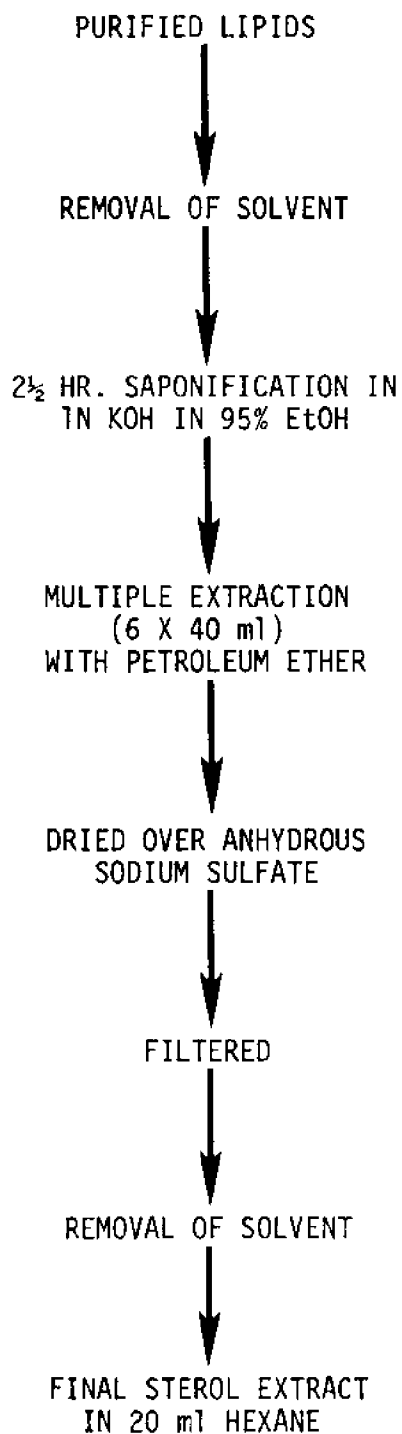


FIGURE 2. EXTRACTION OF STEROLS

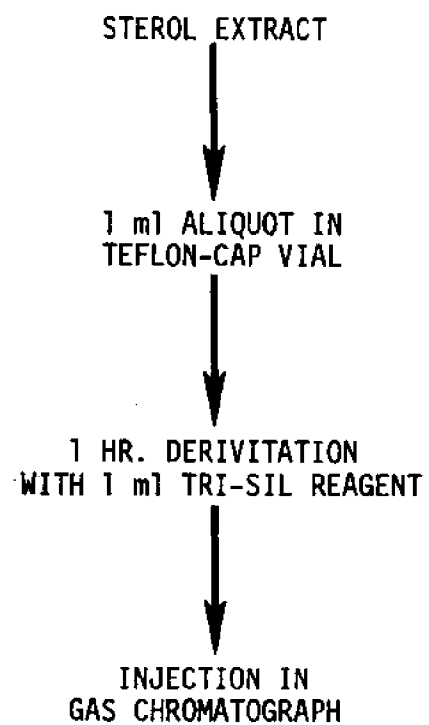


FIGURE 3. PREPARATION FOR CHROMATOGRAPHIC ANALYSIS

ITEM	CONDITION
COLUMN	
LIQUID PHASE	10 PER CENT OU-30
SUPPORT	CHROMASORB W AW-OMCS
MESH	80/100
LENGTH, O.D.	20", 1/8"
CARRIER GAS	HELIUM
FLOW RATE	35 ml/MINUTE
CHROMATOGRAPH	
OPERATING TEMPERATURE	260°C
DETECTOR	FLAME IONIZATION
INJECTION TEMPERATURE	300°C
DETECTOR TEMPERATURE	300°C
INTEGRATOR	
ATTENUATION	4-8
CHART SPEED	5 MINUTES/INCH
OUTPUT	0.03 mv/MINUTE

FIGURE 4. CONDITIONS FOR GAS CHROMATOGRAPH ANALYSIS FOR CHOLESTEROL WITH A HEWLETT PACKARD 5720A GAS CHROMATOGRAPH

aspiration, while the lower phase layer is retained for further washing with 110 ml of a 1:1 water-methanol mixture. The separatory funnel content is again thoroughly mixed and stored overnight in the refrigerator and results in the separation of the purified lipid in the lower phase layer. This part of the procedure is illustrated in Figure 1.

The lower layer containing purified lipid is drained into a 1 liter boiling flask and the solvent is removed utilizing a rotary evaporator under vacuum at 42°C. The residual lipid material is dissolved in chloroform and transferred to a 50 ml flat bottomed boiling flask. The chloroform solvent is removed utilizing a rotary evaporator as before. The lipid residue is dissolved in 24 ml of 1NKOH in 95% ethanol and refluxed for 2½ hrs and allowed to cool to room temperature. To the extract, 48 ml of distilled water is added and the tissue sterols are extracted from the resulting solution by the addition of 40 ml petroleum ether with mixing. After settling, the desired tissue sterols are found in the top layer. The bottom layer is drained off and subsequently extracted six additional times and the resulting ether extracts are pooled. The pooled ether extracts are washed several times with 60 ml of distilled water and dried over anhydrous Na₂SO₄ under nitrogen and stored. The dried ether extract is filtered over anhydrous Na₂SO₄ and the solvent removed in a rotary evaporator. The residual sterol material is transferred to a small volumetric flask and dissolved in 20 ml of high purity hexane and stored under nitrogen at -25°C for future analysis. This is illustrated diagrammatically in Figure 2.

In preparation for chromatographic analysis, the sterol extract was warmed to room temperature and 1 ml was pipetted into teflon capped vials for derivitization by the addition of 1 ml of Tri-Sil Reagent (silylation). The reaction is complete in one hour and microliter samples of the derivitized extracts were then injected into a Hewlett Packard 5720A Gas Chromatograph with a Hewlett Packard 3380A Integrator. This is diagramed in Figure 3. The operating conditions for gas chromatograph analysis for cholesterol with a Hewlett Packard 5720 A Gas Chromatograph is shown in Figure 4.

RESULTS AND DISCUSSION

Glycogen

The average glycogen values for the period of October 1975, through September 1976, are listed in Table 1. This data is graphically presented in Figure 5. Note the broken line in the plot of Maryland glycogen values as samples were not received for these months, but the data was estimated.

The glycogen values for oyster samples from Alabama and Maryland follow the same general trends, relatively low, August through December, and rising to a peak in May. In contrast, Louisiana oysters apparently demonstrate a bimodal plot with peaks in February and May, but generally lower glycogen values throughout the year in comparison to glycogen values for Alabama and Maryland oysters.

The glycogen values for Louisiana oysters are in agreement with the studies of Pollard (14) and Feiger et al. (5). Pollard (14) found an inverse relationship of glycogen and oyster set, wherein peak periods of oyster set were bimodal, May and June, and August. Feiger et al. (5) showed that glycogen content begins to decrease during the latter part of May and early June, reaches a minimum in September, and with advent of cooler weather in October and November sharply increases. The cyclic nature of glycogen in oysters from Alabama and Maryland agree with the investigations of Galtsoff et al. (8) with lows starting in July and highs in the Spring.

Glycogen is the reserve material of the oyster. During rapid proliferation of sex cells, this glycogen reserve is utilized and at the conclusion of the reproductive cycle, spawning, the glycogen content is at a minimum. Immediately after spawning, the oyster begins to form and store glycogen. This seasonal fluctuation of glycogen are common to all species of oysters, but the pattern of changes varies in different localities and in different species depending upon local conditions, especially temperature, salinity, abundance and type of food available, and intensity of feeding, Galtsoff (7). Pekelharıng (13) first reported that the quantity of glycogen stored in connective tissue gradually decreases as the gonads of the oyster increase in bulk and this finding was confirmed by Bargeton (2), Bierry et al. (3), and Gaarder and Alvsaker (6).

It has been generally concluded by investigators that the most important environmental factors are temperature and salinity.

High temperatures affects oysters' gonads formation and spawning, thus glycogen content, as well as respiration and feeding. Temperatures of 26°C appear ideal for the mollusk as Pollard (14) reported in Louisiana peak spawning and spatfall, minimum glycogen values, between 26° and 34°C. Ingle (9) reported that Florida maximums between 27° to 28°C and minimum of 26°C for peak spawning and spatfall and therefore, minimum glycogen values.

Perhaps the most important environmental factor for the oyster is salinity. The ideal salinity for growth and development of *C. virginica* in Gulf waters appears to be from about 15 to 22.5 ‰ although it ranges from almost 40 ‰ in the sheltered bayous of the Gulf Coast to less than 3 ‰ at the upper reaches of bays after heavy rainfalls as found in Chesapeake Bay and Mobile Bay, Pollard (14). Thus, changes in salinity, especially low salinities which reduce the reproductive capabilities of the oyster will also affect the glycogen content.

Cholesterol

The average cholesterol values for the period of October 1975, through September 1976, are listed in Table 2. This data is graphically presented in Figure 6. Note the broken line in the plot of Maryland cholesterol values as samples were not received for these months, but the data was estimated.

The cholesterol values for oyster samples from Alabama and Maryland follow the same general trends, with Maryland lagging about a month behind. Low cholesterol values were found in November,

<u>Month</u>	<u>Year</u>	<u>Mg/100 g of Oyster</u>		
		<u>Alabama</u>	<u>Louisiana</u>	<u>Maryland</u>
October	1975	603	876	2510
November	1975	1322	467	1929
December	1975	1925	1374	1919
January	1976	2211	1827	*
February	1976	2117	2349	*
March	1976	4069	1597	3346
April	1976	4155	1333	4973
May	1976	6797	2960	6920
June	1976	3731	968	4098
July	1976	953	836	3135
August	1976	916	606	3017
September	1976	1143	715	*

*Sample Missing.

Table 1. Monthly Concentration of Glycogen in Alabama, Louisiana and Maryland Oysters.

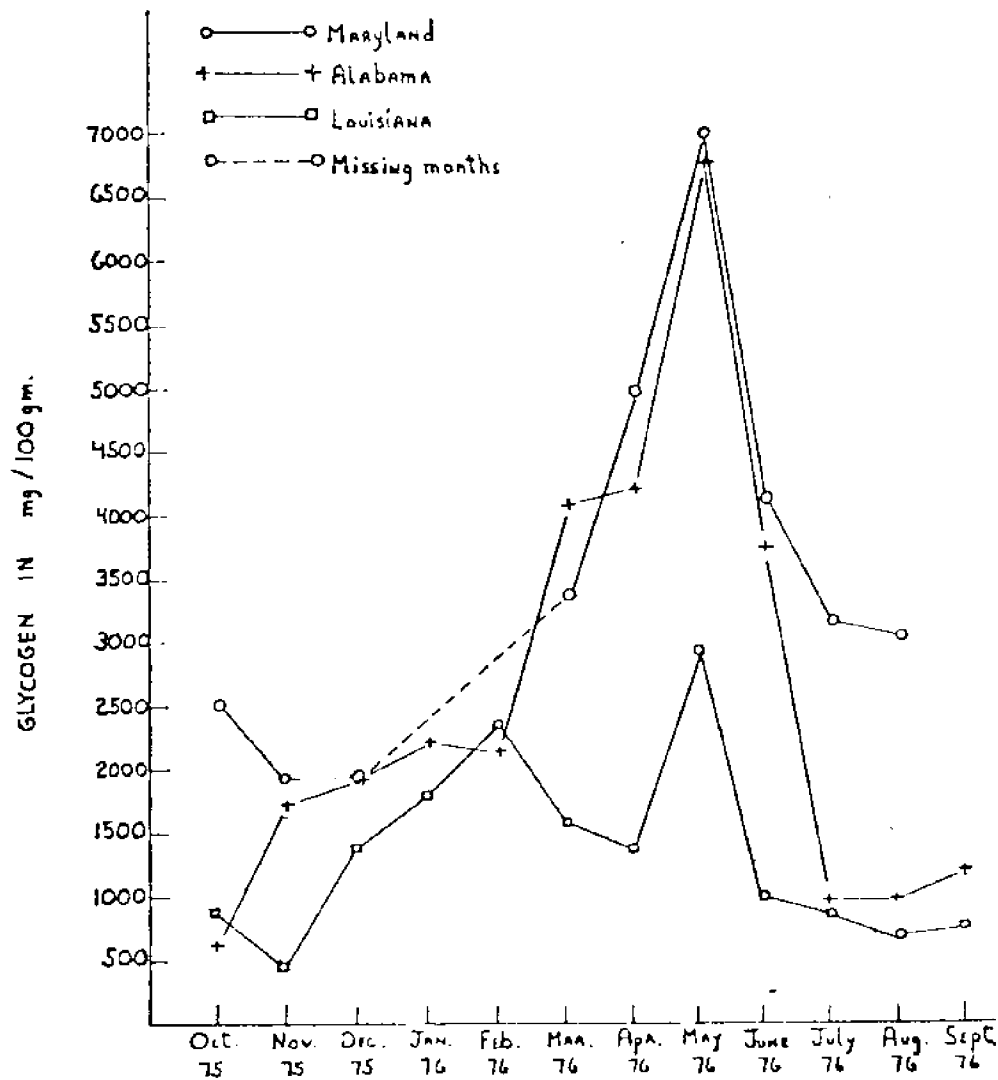


FIGURE 5 Variation of Glycogen Content from Oct. 1975 to Sept. 1976

<u>Month</u>	<u>Year</u>	<u>Mg/100 g of Oyster Tissue</u>		
		<u>Alabama</u>	<u>Louisiana</u>	<u>Maryland</u>
October	1975	108	103	106
November	1975	109	142	77
December	1975	116	109	124
January	1976	157	129	*
February	1976	76	164	*
March	1976	140	117	105
April	1976	148	107	94
May	1976	124	106	123
June	1976	109	98	91
July	1976	77	218	37
August	1976	57	97	69
September	1976	65	108	*

*Sample Missing

Table 2. Monthly Concentration of Cholesterol in Alabama, Louisiana and Maryland Oysters.

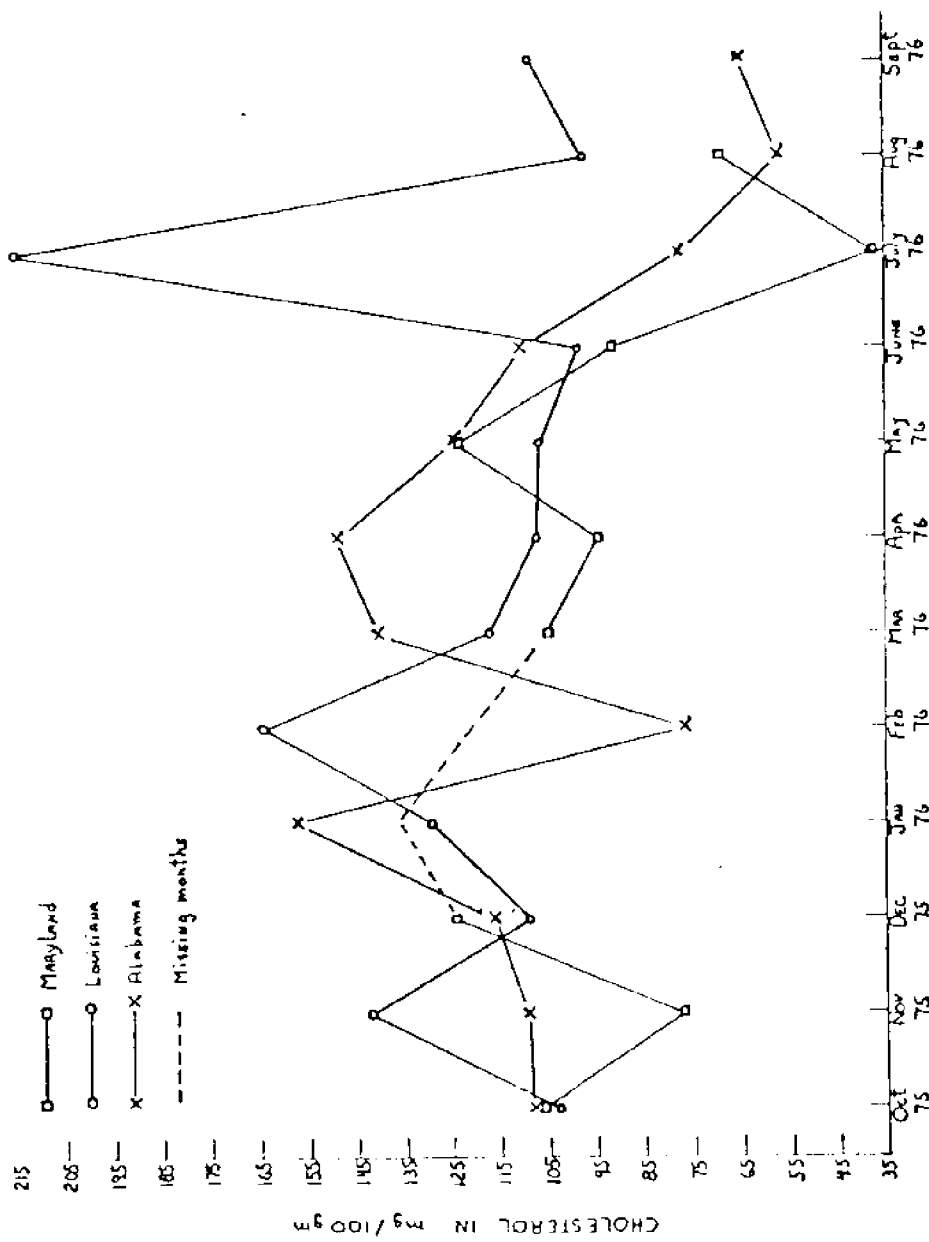


FIGURE 6 Variation of Cholesterol Content from Oct 1975 to Sept 1976

February, April and July with highs in January, April and May. In contrast, cholesterol values for Louisiana oysters appear to be completely out of phase with Alabama and Maryland cholesterol values with lows in December, June and August, and highs in November, February and July, and generally higher cholesterol values overall than found in Alabama and Maryland oysters.

The values reported in the available literature by Kritchevsky et al. (11) Kritchevsky and Tepper (10), Okey (12), Achard et al. (1), Thompson (16), and Sidwell et al. (15) for the cholesterol content of shellfish, specifically oysters, vary considerably which is confirmed by this study. The relatively low and high values reported by Sidwell (15) and Kritchevsky et al. (11) are confirmed by these results if collections from certain areas are sampled during a specific month of the year. These results are more in line with the value reported by Kritchevsky et al. (11). The variations in the cholesterol content of oysters from Alabama, Louisiana, and Maryland are apparently due to the seasonal variation in temperature, salinity, etc. due to geographical location.

The wide variations of cholesterol values noted in the literature can very easily be attributed to the methodology utilized in extraction of the cholesterol, the method utilized to detect the cholesterol and the specific collection month and the location of the oyster sampled.

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EFFECT OF RIGOR MORTIS, POSTMORTEM pH, AND STORAGE
TEMPERATURE ON WARNER-BRATZLER SHEAR STRESS VALUES
FOR WHITE SHRIMP (Penaeus setiferus)

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Texture of animal products (including fish and crustaceans) is described by tenderness or toughness. Objective evaluation of tenderness of meat is generally expressed in terms of maximum shear force which may be obtained by means of a Warner-Bratzler shear apparatus (10, 13, 14, 16, 20, 21).

The literature describing textural measurements of shellfish muscle is very limited. Dagbjartsson and Solberg (10) showed for lobster a trend toward slightly increasing toughness with prolonged cooking time but this tendency was not statistically significant when measured in chew counts or in Warner-Bratzler shear force values. Cocktail shrimp toughness has been attributed to cooking time up to ten minutes, sauce pH, length and condition of frozen storage (1) and processing techniques (23), the additives such as polyphosphate decreased the toughness (2).

The occurrence of rigor in shrimp muscle has not been conclusively demonstrated. Flick and Lovell (11) indicated that shrimp stored in ice for 10 days did not exhibit any of the characteristics commonly associated with rigor. However, Lightner (17) indicated that rigor was evident in shrimp at temperatures ranging from 10-30°C.

Postmortem pH in penaeid shrimp has been studied by several investigators (4, 11, 22). Generally pH increased from about 7.2-7.3 to 8.0-8.2 during ice storage. More recent investigations using several different lots of shrimp have indicated that shrimp tissue pH may be lower than 7.2 in some lots (8). Tissue pH and textural scores of fish have been shown to be correlated (15, 18). The relationship between tissue pH and texture of shrimp has not been established.

A number of investigators have determined the effect of postmortem changes on the texture of fish and mammals. Very little is known about the effect of postmortem changes on shrimp texture. It was the purpose of this investigation to determine the variation of shrimp texture with rigor-mortis and postmortem pH development.

MATERIALS AND METHODS

Rigor-Mortis Determination

Shrimp (*Penaeus setiferus*) for rigor-mortis determinations were kept and fed in 30 gal aquariums for at least a week prior to slaughter. Antemortem struggle was minimized to prevent depletion of glycogen and ATP. Shrimp were sacrificed by deheading with a sharp knife. The tail (abdomen) was wrapped in polyvinyl chloride film to prevent dehydration and immediately hooked to an isometric transducer with the anterior end attached to the transducer and the posterior end attached to a fixed bar (Fig. 1). Signals from the transducer were fed into an X-Y recorder. Rigor development was followed until there was no apparent change in the slope of the recorded curve. The period of time between the onset of tension and the beginning of tension loss was considered as the duration of rigor. Three shrimp were used for isometric tension measurement at each of $23 \pm 1^\circ\text{C}$ and $3 \pm 1^\circ\text{C}$ temperature condition.

pH and Textural Measurement

Shrimp for pH and textural measurements were obtained live from commercial sources and transported to the laboratory. The shrimp were sacrificed by deheading, then separated into two groups. Group One was placed in an ice chest as described by Cobb *et al.* (6). Group Two was placed in a 1000 ml glass jar at room temperature (23°C). Shrimp were sampled as described in Table 1. pH determinations were made with a combination electrode on homogenates of shrimp (1 part shrimp to 2 parts water).

Shrimp were cooked in a large volume of water for 4 min and were immediately cooled by dropping them into 500 ml tap water (22°C) and held for 5 minutes. Cross-sectional dimensions were measured and textural measurements were performed by using a Warner-Bratzler shear apparatus connected to a constant loading rate (50 mm/min) testing machine. Six shrimp tails were sheared in the middle of the segments 1, 3, and 5 which correspond to place 1, 2, 3, respectively, in this paper.

Textural properties of shrimp were evaluated in terms of shear stress which was defined as the maximum shear force per unit cross-sectional area (N/cm^2) required to shear the muscle tissue. The cross-sectional area of shrimp was assumed to be ellipsoid. Data were analyzed using the analysis of covariance.

RESULTS AND DISCUSSION

Duration of Rigor-Mortis

Isometric tension development of white shrimp (*Penaeus setiferus*) tails during postmortem storage at 23-24°C and 0°C, respectively, is shown in Fig. 2 and 3. Each curve was obtained from one shrimp tail. At room temperature (23-24°C), the shrimp tail began rigor-mortis approximately 20 min after death. Rigor development continued for about 2 hr and 40 min. At ice temperature storage (0°C), the shrimp developed a similar but more pronounced tension curve than that of shrimp stored at room temperature. Rigor began approximately 7 hr postmortem and development continued for about 3 hr and 40 min.

Rigor-mortis definitely develops in penaeid shrimp and is temperature dependent, occurring more rapidly at higher temperatures. The effect on texture of freezing shrimp during rigor has not been established but may explain why freezer-boat shrimp are frequently reported to be tough or dry. The rapid onset of rigor at higher temperatures, characteristic of subtropical and tropical areas where much of the shrimp catch is made, indicates that a substantial portion of shrimp frozen at sea may be in rigor when frozen.

The duration of rigor in shrimp used in this study was relatively short, less than 6 hr. This is contrasted with the observations of Lightner (17) who found that the onset of rigor (stiffening of the abdominal musculature) in *P. aztecus* was evident at 4 hr (20°C) and did not disappear until 48 hr later. The above differences could be due to the different methods used to follow rigor-mortis development or to other factors, such as differences in species or physiological condition of the shrimp.

Postmortem pH

The relation between tissue pH in shrimp tails and postmortem storage time at room (23-24°C) and ice (0°C) conditions was studied. Fig. 4 shows postmortem pH of shrimp tails kept at room temperature (23-24°C). Fig. 5 illustrates postmortem pH of shrimp tails kept on ice. Analyses were performed on four lots (A, B, C, D) of shrimp tails. The initial pH in the four lots varied from 6.77 to 7.05. At room temperature, only lot A had a postmortem pH drop, then pH increased until spoilage occurred. pH increased with postmortem time in lots B, C and D. pH values in each lot of shrimp changed at different rates. In ice-stored shrimp, a drop of pH occurred in lots A, B and D but not in lot C. The minimum pH was measured at 7 hr (pH = 6.7), 2.5 hr (pH = 6.8) and 4 hr (pH = 6.55) after death in lots A, B and D, respectively. The final postmortem pH in each lot of shrimp was influenced mainly by the magnitude of the initial drop as the rate of pH increase in each lot was approximately the same.

Tissue pH of freshly killed shrimp varied considerably and was lower than that reported for penaeid shrimp by other investigators (5, 11, 19). The cause of the initial variation was not evident. Physiological stress effects probably were not responsible for the low initial pH as the group with the lowest pH (group D) had the least chance to be stressed prior to pH measurement. The initial pH drop in ice-stored shrimp was probably due to lactic acid formation. Bailey *et al.* (4) and Flick and Lovell (11) have shown considerable lactic acid formation in post-mortem shrimp. The increase of pH after the initial drop was probably due to postmortem ammonia production (7). Variation in both the initial pH and subsequent drop (Fig. 5 and 6) caused the post-mortem pH to vary, suggesting that pH is a poor shrimp quality indicator. This is in contrast to the report of Bailey *et al.* (4).

Shear Stress Measurement

Preliminary work conducted in this study showed that the best cooking time for shrimp of tail length 4-7 cm is 4 min. The shrimp is still partially cooked using cooking time less than 4 min. Additional cooking beyond the minimum 4 min did not have a significant effect on stress values of shrimp. Size of shrimp should be uniform, place of shear cut along the shrimp tail should be in the same area to minimize the variability of the shear stress values.

Variation of shear stress value with postmortem time is shown in Fig. 6 and 7. Increasing of shear values were evident at 4 hr in the shrimp stored at 23-24°C and at 8 hr in the shrimp stored at 0°C. Decreasing of shear values followed the time of 4 hr and 8 hr in shrimp stored at 23-24°C and 0°C, respectively. The analysis of covariance also showed the significant effects ($P < 0.01$) of storage temperature, pH, postmortem time, place (position of shear), and temperature and place interaction, on shear stress values when considered the whole period from fresh till spoilage occurred. The effect of postmortem pH and post-mortem time on stress values is in agreement with other research reported on fish and warm-blooded animals (9, 12, 15).

The increasing of shear values in the time period of 4 hr at room temperature storage is corresponding to the high isometric tension value in Fig. 2 and low pH value in Fig. 4. The low pH (6.5-7.2) is closed to pI of actomyosin protein, therefore high potential of protein aggregate. Formation of actomyosin bonds during rigor development also cause aggregation of protein. Therefore, the high shear values were obtained in this time period of shrimp at room temperature storage. The same phenomenon also occurred in shrimp stored at 0°C with the only difference in time.

Shrimp from lots A, B and C were obtained at different times of the year. Therefore, age and probably stage of molting were different for all three lots. The above sampling differences could have contributed to the large variation of stress values as shown at some points in Fig. 6 and 7. Variation in shear by the position of the shear along the shrimp tail (place) may be associated with the amount of exercise of the muscle, the crosslink of the muscle fiber (3), and/or collagen content.

CONCLUSION

A myograph with an isometric transducer was used to follow rigor-mortis development in shrimp tails. Full rigor development in shrimp occurred within 12 hr, depending on storage temperature. Rigor development at 23-24°C began 20 min after death and continued for 2 hr and 40 min. Rigor at 0°C began 7 hr postmortem and continued for 3 hr and 40 min.

Shrimp tissue homogenates (two ml distilled water per g shrimp tissue) were used for pH measurement. pH of the fresh shrimp (Penaeus setiferus) tails varied from 6.77 to 7.05. The pH dropped during the first 10 hr of postmortem aging at ice storage temperature in three of the four sampling lots, then increased. This initial pH drop affected subsequent postmortem pH values. The rate of postmortem pH increase during room temperature storage was faster than for ice temperature storage.

Texture (shear stress in Newton/cm²) of shrimp was measured with a Warner-Bratzler shear apparatus. Shear values increased with post-mortem time until 4 hr and 8 hr in shrimp stored at 23-24°C and 0°C, respectively, then slightly decreased. Post-mortem time and pH had a significant effect ($P < 0.01$) on stress when the entire period of storage was considered.

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Table 1. Experimental design of sampling time for textural and pH measurement for lots A, B and C.

Lot	Receipt Date	Sampling Time (hr) for Textural and pH Measurement	
		Room Temperature Storage	Iced Storage
A	1/25/75	0 ^a , 7, 8, 12, 36	0, 7, 8, 12, 24, 48, 120, 168, 216, 276, 336, 408
B	10/10/75	0, 2.5, 8, 12, 21	0, 2.5, 8, 12, 24, 120, 168, 288, 336, 384
C	11/21/75	0, 2, 4, 6, 8, 10, 12	0, 2, 4, 6, 8, 10, 12

^aSix shrimp were used at each sampling time for textural measurement and four to five shrimp for pH measurement.

Table 2. Covariance analysis of shear stress in shrimp tails maintained at room (23-24°C) and ice storage (0°C) temperatures until spoilage occurred.

Source	df	ss	F value
Regression	19	33.9856	19.45**

Source	df	Partial ss	Partial F value
pH ^a	1	2.6015	28.29**
Time ^b	1	0.9966	10.84**
Place ^c	2	18.1310	98.58**
ST ^d	5	11.0120	23.95**
Place x ST ^e	10	2.7193	2.96**

$$\text{Model: STRESS} = B_0 + B_1 (\text{pH}) + B_2 (\text{Postmortem Time}) + (\text{Place}) + (\text{Storage Temperature}) + (\text{Place} \times \text{Temperature})$$

* (P<0.05)

** (P<0.01)

^apH = pH of shrimp tails measured at the same postmortem time as texture

^bTime = Postmortem time

^cPlace = Position of shear according to Fig. 2

^dST = Storage temperature

^ePlace x ST = Place and temperature interaction

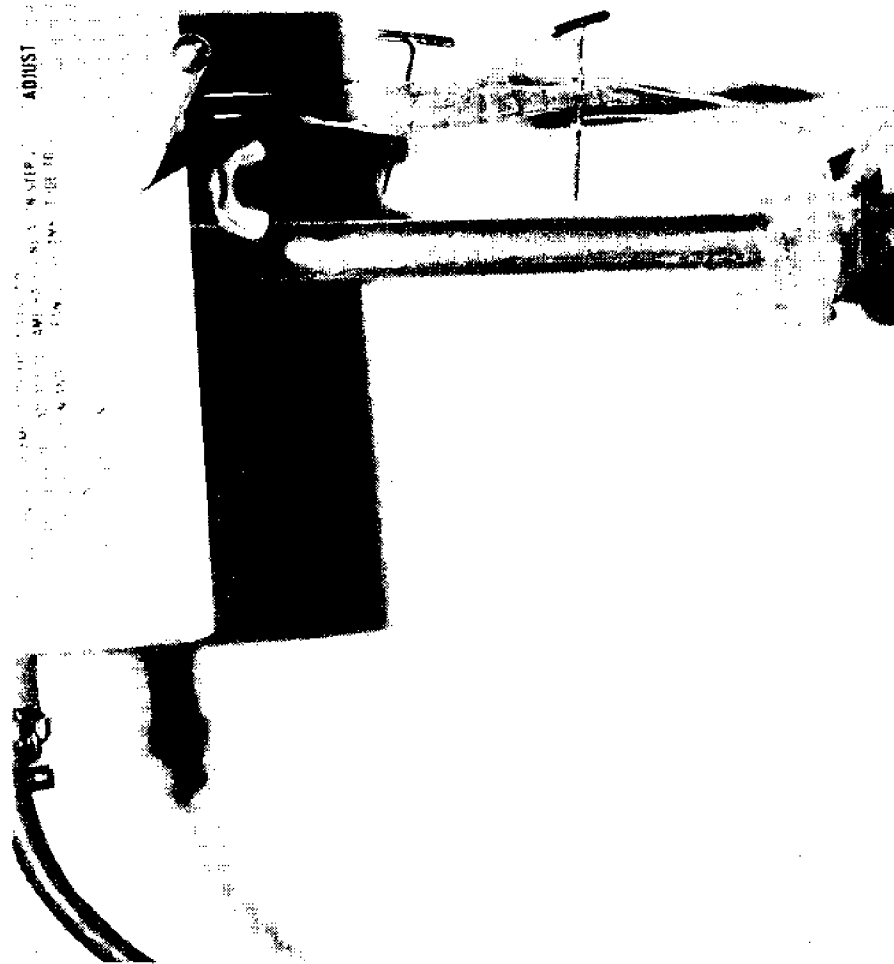
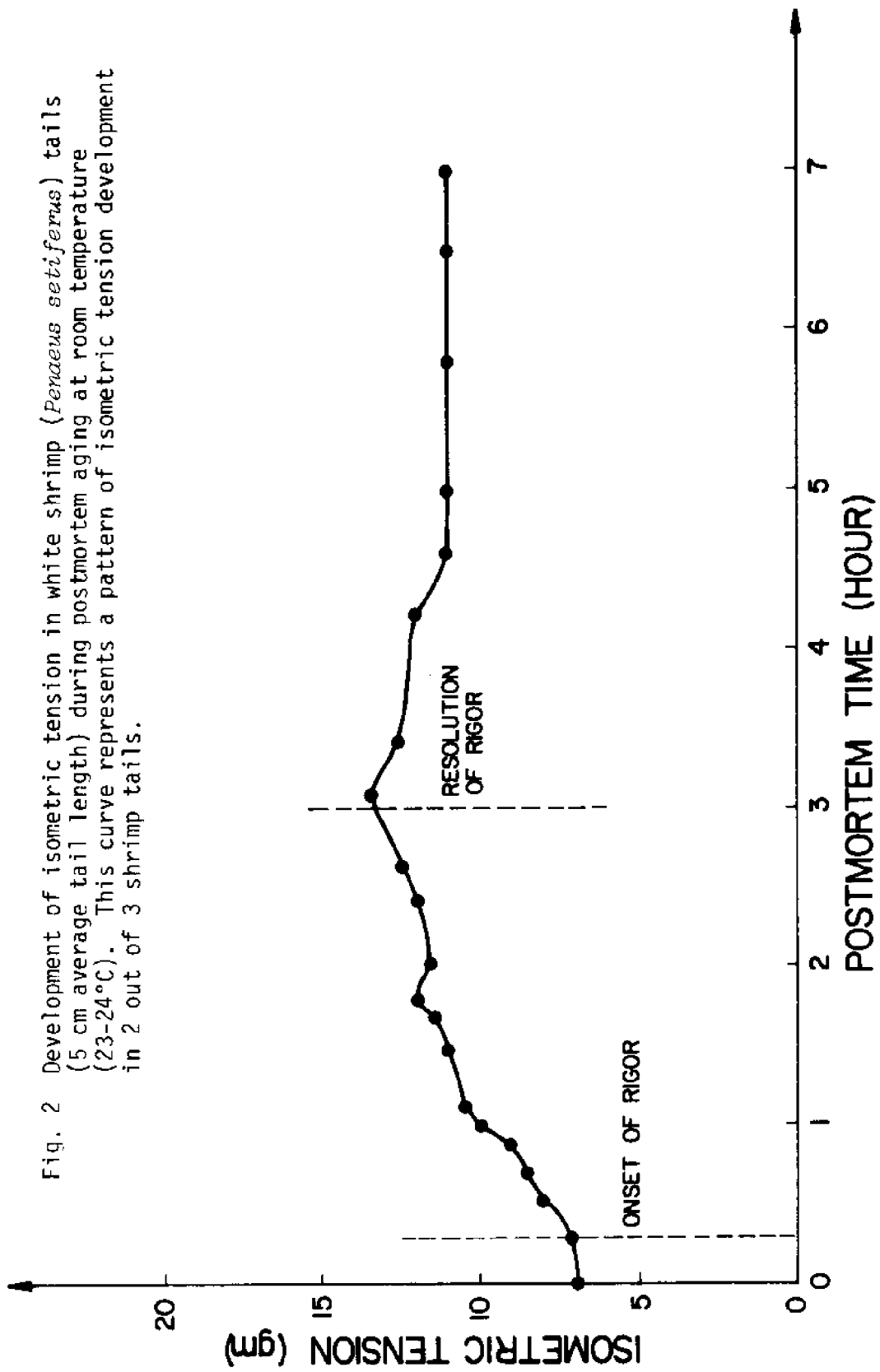


Fig. 1. Position of shrimp during the duration time of rigor-mortis determination.

Fig. 2 Development of isometric tension in white shrimp (*Penaeus setiferus*) tails (5 cm average tail length) during postmortem aging at room temperature (23-24°C). This curve represents a pattern of isometric tension development in 2 out of 3 shrimp tails.



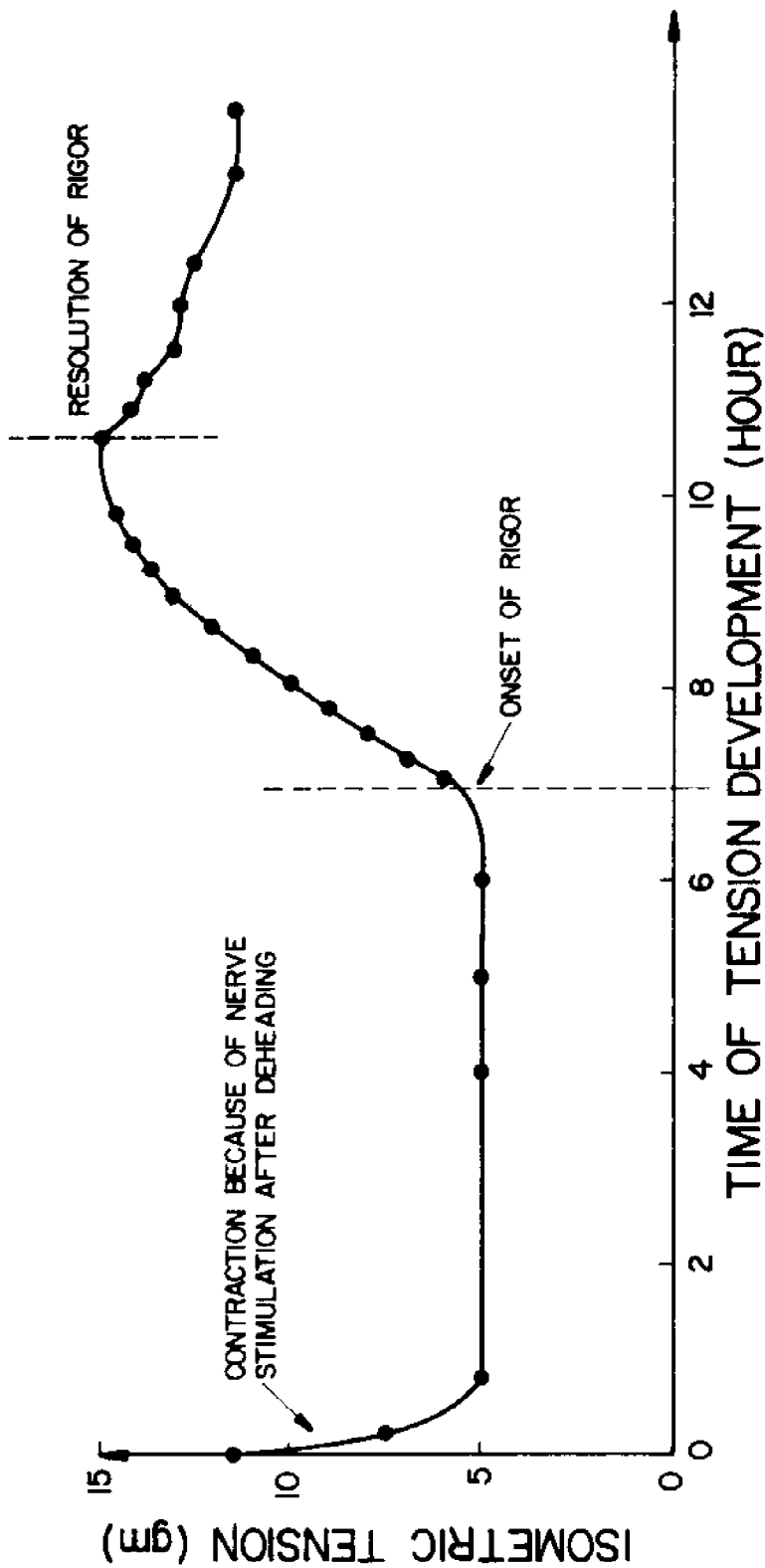


Fig. 3 Development of isometric tension in white shrimp (*Penaeus setiferus*) tails (5 cm average tail length) during postmortem aging at zero degree centigrade. This curve represents a pattern of tension development in 2 out of 3 shrimp tails.

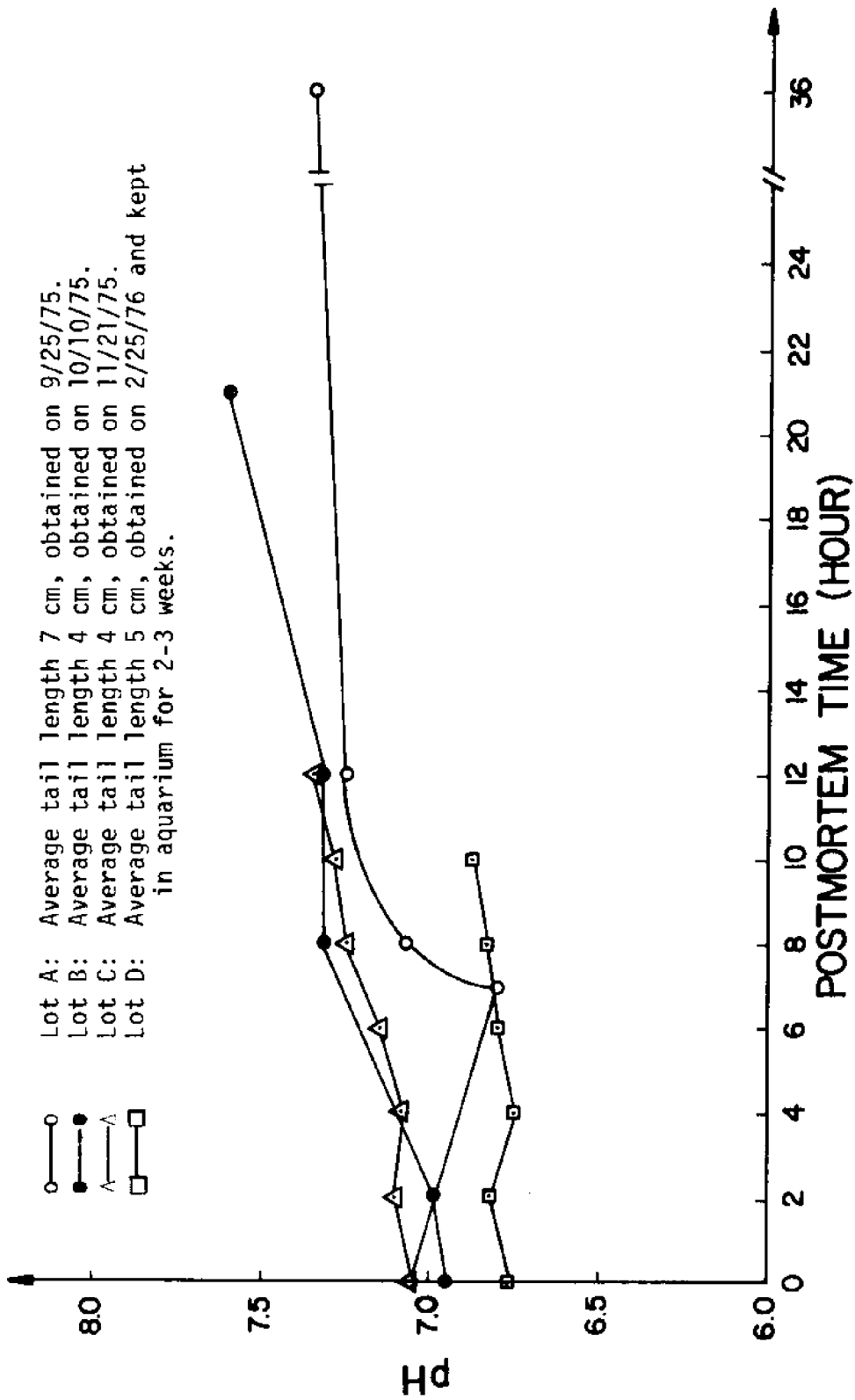


Fig. 4 Effect of postmortem aging at room temperature (23-24°C) on the pH of the shrimp tail tissue.

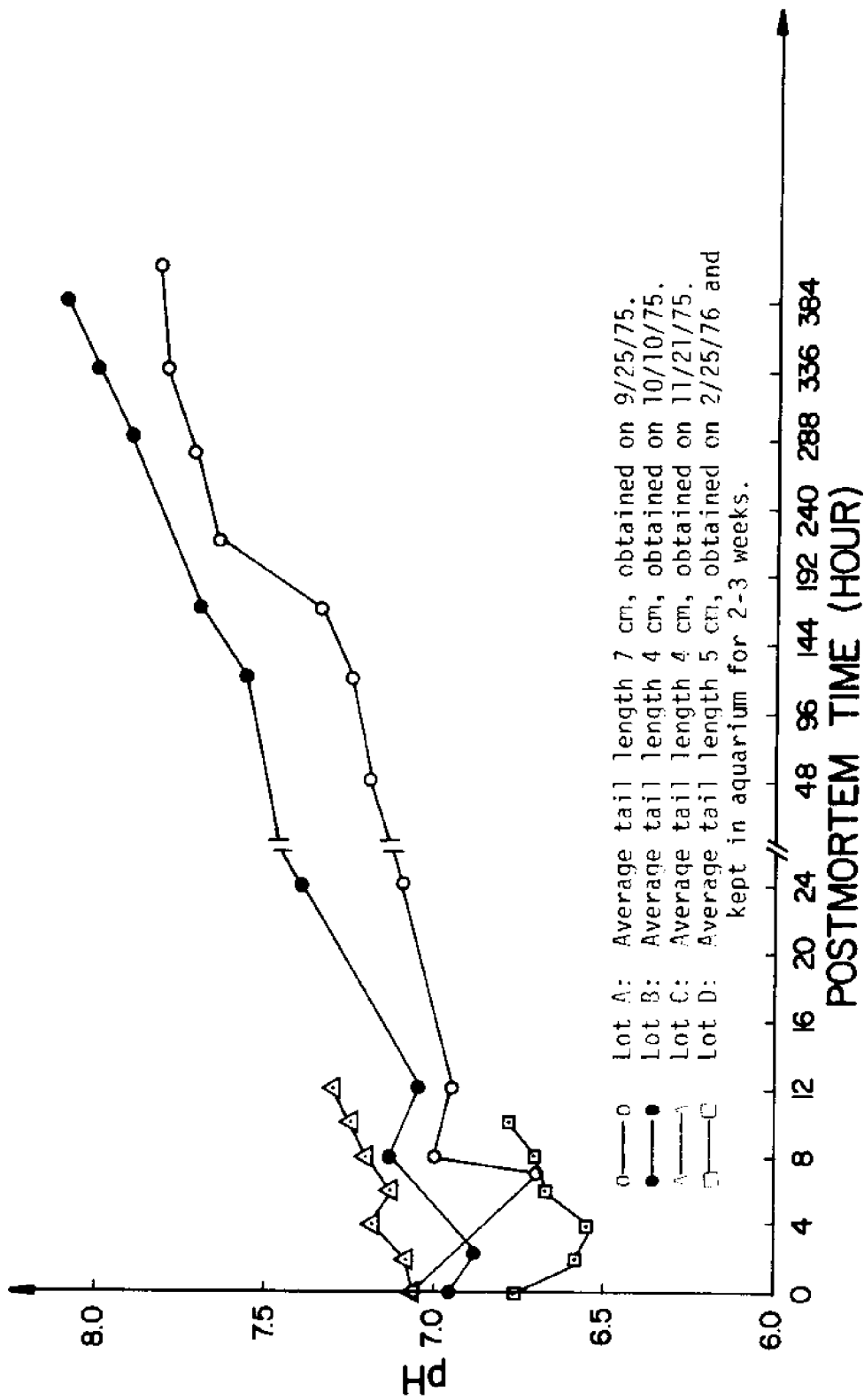


Fig. 5 Effect of postmortem aging at 0°C on the pH of shrimp tail tissue (sample designation as in Fig. 4).

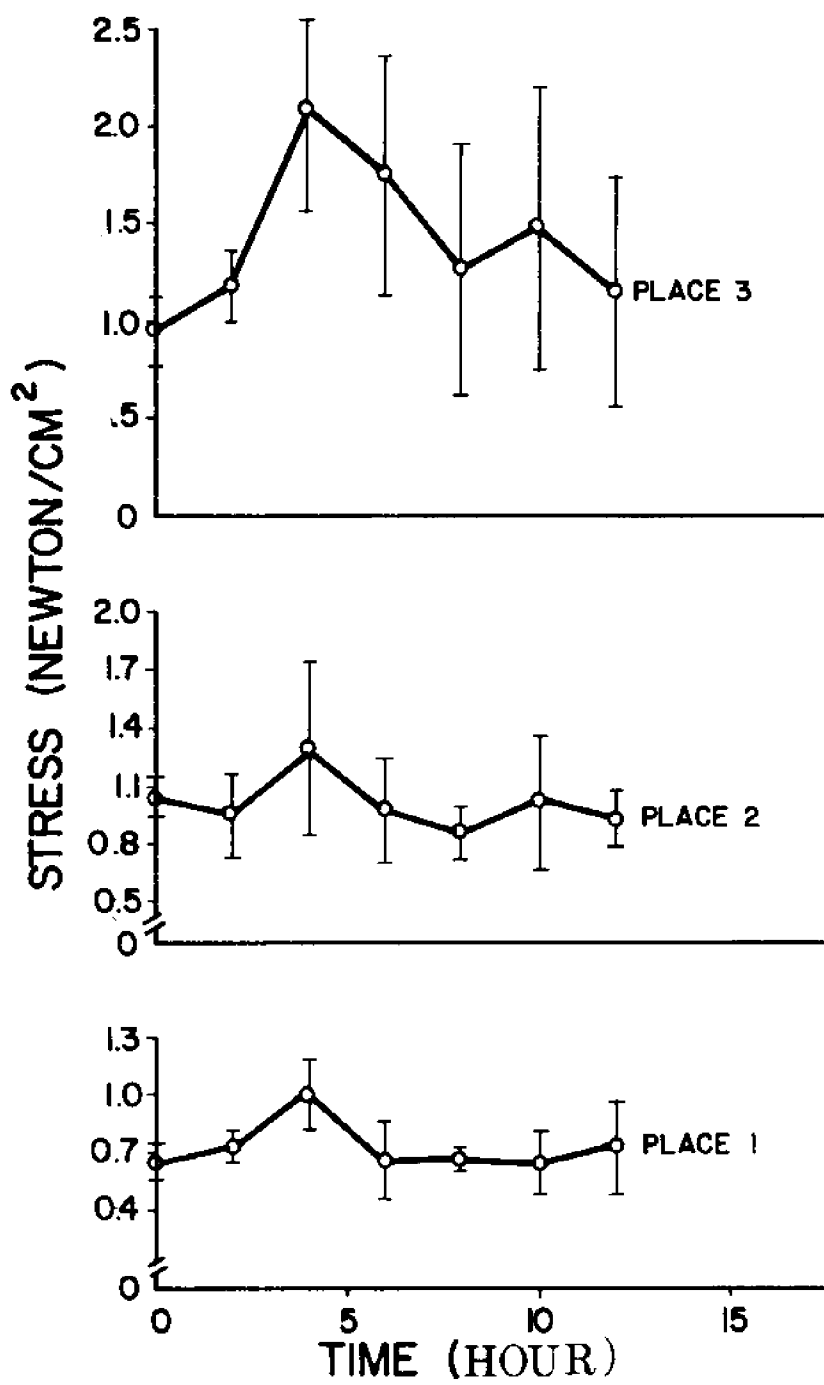
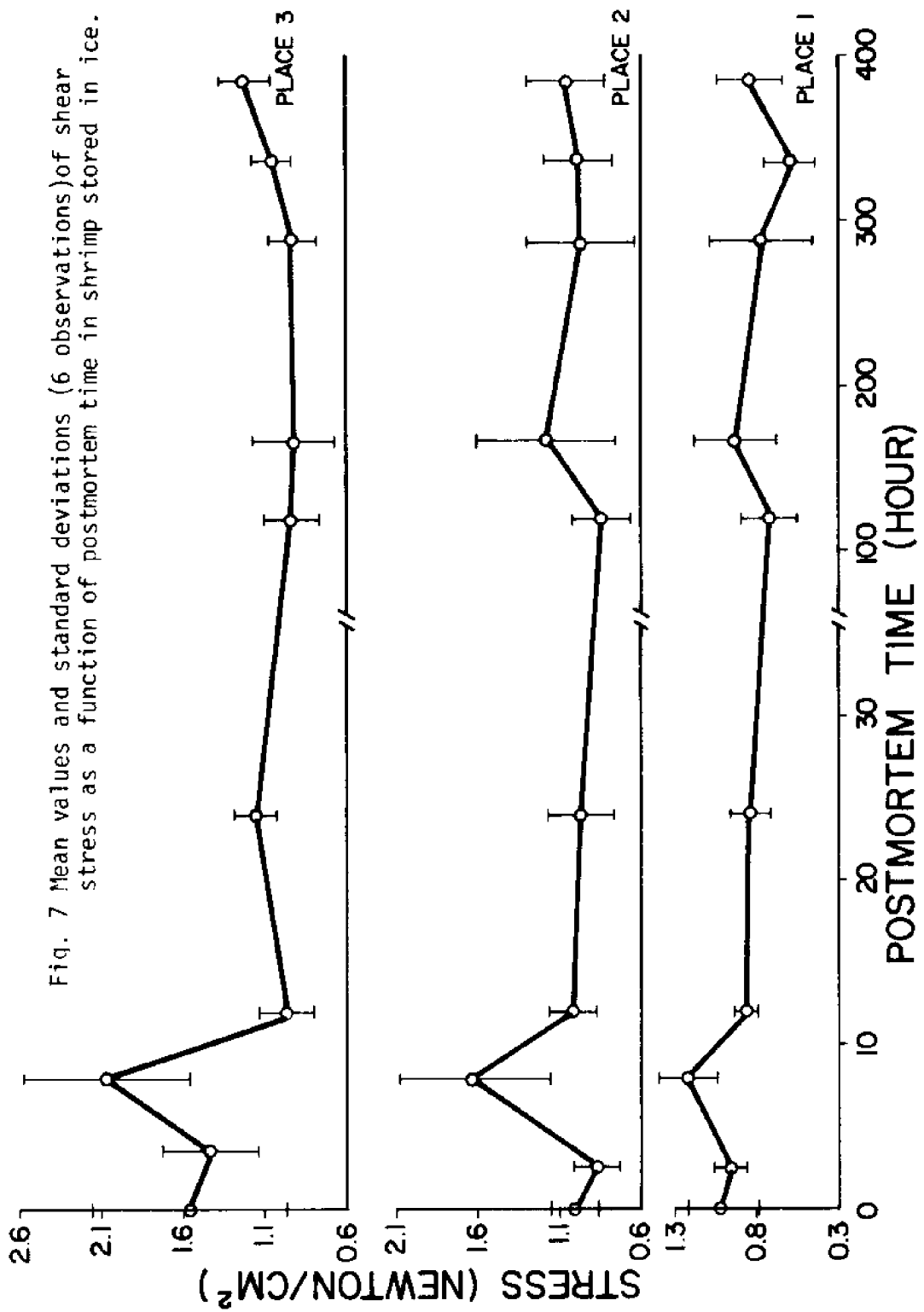


Fig. 6 Mean value and standard deviation (6 observations) of shear stress as a function of postmortem time in shrimp stored at 23-24°C.

Fig. 7 Mean values and standard deviations (6 observations) of shear stress as a function of postmortem time in shrimp stored in ice.



AMMONIA-PRODUCING ENZYMES IN PENAEID SHRIMP

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INTRODUCTION

Ammonia is a major by-product of bacterial and autolytic shrimp muscle decomposition during postmortem storage. The production of ammonia leads to undesirable odors and flavors. No information is available concerning the ammonia-producing enzymes in shrimp. Identification of the types of enzymes present in shrimp muscle may help in understanding quality deterioration during postmortem storage.

Ammonia could be produced through the oxidation of amino acids, deamination of arginine in the ornithine cycle and/or the degradation of nucleotides. Arginine oxidase, alanine oxidase, serine oxidase, proline oxidase, glycine oxidase, arinase, urease, adenase, guanase, adenosine deaminase and adeny] monophosphate (AMP) deaminase were evaluated.

MATERIALS AND METHODS

Shrimp

Fresh white shrimp (Penaeus setiferus) were obtained directly from fishing boats at Galveston bay, then packed in ice and shipped to the laboratory. The shrimp were deheaded, deveined, thoroughly washed in distilled water, then used immediately or held at -24 C until use (maximum of 3-4 days for repeat analysis).

Chemical Analyses

Protein determination was based on Kjeldahl nitrogen content x 6.25 (4) or the biuret procedure (3). Ammonia determination was based on the microdiffusion method with saturated Na_3PO_4 as the releasing agent as described by Cobb et al. (9) or the colorimetric method described by McCullough (19).

Enzyme Assays

Arginase activity

Shrimp muscle was homogenized in 3 vol of 0.1% hexadecyltrimethylammonia bromide (CTB, Eastman) in a blender for 30 sec.

The homogenate was centrifuged at 16,500 x G for 20 min. The supernatant was used for the determination of arginase activity.

Arginase activity was determined by a modification of the method of Andrews and Reid (2) employing L-(+)-arginine as a substrate and pure urease to convert urea to ammonia. The assay system contained 0.5 ml of 0.24 M L-arginine, pH 9.6; 2 ml of 0.01 M glycine buffer, pH 9.6; 0.5 ml of 3.5 mM magnesium sulfate; 1.0 ml of urease solution (1.0 g of urease and 15 g of sodium chloride brought to 50 ml with distilled water, stirred for 30 min, allowed to stand at room temperature for 3 hr, filtered through Whatman No. 41 filter paper and adjusted to pH 7.0); and 2.5 ml of enzyme extract. After incubating 30 min, this reaction was stopped by the addition of 0.5 ml of 20% trichloroacetic acid (TCA). Ammonia was determined by the microdiffusion method.

Urease activity

The same extraction procedure as described for the arginase assay was used to prepare the crude enzyme extract for urease. Urease activity was measured by determining the amount of ammonia produced from urea. Ammonia was assayed using the microdiffusion method. To 5 ml of crude enzyme extract, 4 ml of 0.02 M phosphate buffer (pH 7.0), 1.0 ml of 0.2 M urea (in 0.2 M phosphate buffer, pH 7.0) and 0.05 ml Procaine penicillin G in dihydrostreptomycin sulfate solution (Diamond) were added. The assay system was incubated at room temperature and stopped after various incubation times (up to 3 days) by the addition of 1.0 ml of 20% TCA.

Adenase, adenosine deaminase, AMP deaminase and guanase

Shrimp were homogenized with 11 vol of prechilled distilled water in a blender for 30 sec. The homogenates were stirred at 1 C for 1.0 hr, and then centrifuged at 14,000 x G for 25 min. The supernatant was used for nucleotide deaminase determination.

Enzyme activities were measured by a modification of the method of Stone (25). The assay system consisted of 3.6 ml of substrate and 0.4 ml of shrimp muscle extract. The substrates were: (i) 9.0 mM adenine in 0.05 M phosphate buffer, pH 7.0; (ii) 9.0 mM adenosine in 0.1 M barbital buffer, pH 8.6; (iii) 9.0 mM AMP in 0.1 M citrate buffer, pH 6.5; and (iv) 10 mM guanine in 0.1 M tris, pH 8.0. The reaction was carried out at 37 C for 30 min. Adenase, adenosine deaminase and AMP deaminase activities were measured by the decrease in absorbance at 265 nm (25). Guanase activity was measured by the decrease in absorbance at 290 nm (24). Ammonia formed was determined by the colorimetric method of McCullough (19) or by the microdiffusion method of Cobb et al. (9).

Amino acid oxidase activity

Shrimp were homogenized with 1.0 vol of prechilled distilled water in a blender for 30 sec. The homogenate was centrifuged at 4,500 x G for 30 min. One ml of Procaine penicillin G in dihydrostreptomycin sulfate solution was added to 100 ml of supernatant and this mixture was used for the amino acid oxidase determination.

Amino acid oxidases were assayed by a modification of the method of Curti et al. (12). To 4.0 ml of shrimp extract, 1.0 ml of 0.2 M tris buffer (pH 7.8) containing 2.5 $\mu\text{g/ml}$ catalase and 1.0 ml of 0.05 M substrate in 0.2 M of tris buffer (pH 8.0) were added. Substrates included arginine, proline, glycine, alanine and serine. Reaction time was varied from 1.0 to 24 hr. The ammonia content was determined in the samples at the beginning and end of the reaction and in a control (no substrate added).

Enzyme Stability during Storage

Shrimp for stability experiments were prepared as previously described and dipped in Procaine penicillin G in dihydrostreptomycin sulfate solution (1%) to retard bacterial growth. For bag storage, shrimp were placed in zip-loc plastic bags and placed in insulated ice chests in a monolayer with 15 cm of crushed ice beneath the bag and 10 cm above the bag. Shrimp for ice storage experiments were stored in the same manner but without bags. The same extraction procedures as described under enzyme assays were used for preparation of homogenates. Homogenates were put into Erlenmeyer flasks containing 1% Procaine penicillin G in dihydrostreptomycin sulfate solution with screw caps and placed in the ice chest. Ice chests were placed in a cold room (5-8 C) and ice was replaced as needed. Shrimp samples were analyzed every 3-4 days for 13 days.

RESULTS AND DISCUSSION

Alanine oxidase, arginine oxidase, glycine oxidase, proline oxidase, serine oxidase, adenase, guanase and urease could not be detected in shrimp muscle extract, even after prolonged periods of incubation. Only arginase, adenosine deaminase and AMP deaminase were detected. Although ammonia is not formed directly by arginase, the urea produced by arginase during post-mortem storage could be hydrolyzed by bacterial ureases.

Effects of pH on the enzyme activities

The pH optimum of arginase was 9.6 (Fig. 1), which is in agreement with the data for arginase reported by previous workers.

The maximum adenosine deaminase activity was obtained around pH 8.5 (Fig. 2). This pH value is different than reported from other sources. The adenosine deaminases from the rabbit and other vertebrates were most effective near the neutral state, and were comparatively active over a wide range of pH (7, 11, 17, 22). The adenosine deaminases in ammonium sulphate fraction of the lobster hepatopancreas (21) and in the aqueous extract of the lobster tail muscle (13) had pH optima of 7.0. The optimal pH of clam adenosine deaminase was 5.0 (1).

During postmortem ice storage, pH value increases from about 7 to 8 in shrimp muscle (5, 6, 15, 26). This could offer an optimal pH for the reaction of adenosine deaminase and cause an increased production of ammonia.

Shrimp AMP deaminase in both citrate and succinate buffer

(0.1 M) showed an optimal pH at 6.5, which is quite similar to the enzymes from various species of fish and shellfish. The enzyme had a higher activity in citrate buffer (Fig. 3).

Effects of temperature on the enzyme activities

The optimal temperature of shrimp muscle arginase and AMP deaminase after 30 min incubation was 37 C (Fig. 4 and 5). Above 37 C the activities decreased rapidly. The maximum activity of adenosine deaminase was at 48 C (Fig. 6).

Enzyme stabilities

Shrimp arginase and AMP deaminase lost their activities while adenosine deaminase was stable in frozen storage. The stabilities of shrimp arginase, adenosine deaminase and AMP deaminase during ice storage are listed in Tables 1, 2 and 3, respectively. Because of the similarity in the ice-stored shrimp, bag-stored shrimp (no leaching) and homogenates, the activities of enzymes were not affected by the leaching of melting ice. Since the pattern of changes of enzyme activities in homogenates was analogous to that in ice storage and bag storage, homogenates can be used as a representative of whole shrimp to explain the real changes in shrimp during ice storage. This would reduce individual variation.

Shrimp arginase was labile during ice storage, and more than half of the activity was lost in 9 days at 0 C. The loss of specific activity with a concomitant loss of tissue activity was highly suggestive that the decreased activity was due to inactivation and not a general proteolysis. This was further confirmed by the consistency in total protein contents over the storage periods. The inactivation of shrimp arginase could be caused by the accumulation of ornithine, a competitive inhibitor of arginase (8, 10, 16), and/or the instability of arginase during storage.

Table 1. Stability of shrimp arginase activity at 0-3 C.

Storage Time (days)	Homogenates	Ice Storage	Bag Storage
	Tissue Activity	Tissue Activity	Tissue Activity
0	100	100	100
3	73	76	109
6	55	64	92
9	36	40	32
13	16	12	30

Adenosine deaminase in shrimp muscle extract increased in activity during storage. Aikawa (1) reported that aqueous solutions of purified clam adenosine deaminase remained intact at 0 C for one month. The increase in activity of adenosine deaminase during

storage may be due to the accumulation of its activators, decomposition of its inhibitors and/or the shift of pH to near its optimum.

Table 2. Stability of shrimp adenosine deaminase activity at 0-3 C.

Storage Time (days)	Intact Shrimp		
	Homogenates	Ice Storage	Bag Storage
	Tissue Activity	Tissue Activity	Tissue Activity
-----%			
0	100	100	100
2	123	134	116
5	127	132	109
8	136	120	155
12	111	95	116

AMP deaminase in shrimp was quite labile and lost about half of its activity after 2 days storage. Dingles and Hines (13) reported that the AMP deaminase activity of a crude cod muscle extract in 0.02 M succinate decayed to about 50% of its initial value during storage for 3 days at 0 C. Nikiforuk and Colowick (20) and Makarewicz (18) reported that phosphate inhibited the reaction of AMP deaminase. In fish and rabbit muscle, inorganic phosphate increased in the muscle with the dephosphorylation of sugar phosphates and nucleotides. The accumulation of inorganic phosphate and loss of ATP (15), an activator of AMP deaminase (18, 23), during storage at 0 C may contribute to the loss of activity of A,P deaminase.

Table 3. Stability of shrimp AMP deaminase activity at 0-3 C.

Storage Time (days)	Intact Shrimp		
	Homogenates	Ice Storage	Bag Storage
	Tissue Activity	Tissue Activity	Tissue Activity
-----%			
0	100	100	100
2	52	78	95
5	35	60	45
8	32	43	58
12	9	3	31

Comparison of activities of enzymes in three species of penaeid shrimp

Arginase, adenosine deaminase and AMP deaminase levels for three species of penaeid shrimp are listed in Table 4. By statistical analysis, there was no significant difference in adenosine deaminase

levels between species, but differences were found in arginase and AMP deaminase. Brown shrimp had the lowest level of arginase and pink shrimp had the highest activity in AMP deaminase. The higher levels of arginase and AMP deaminase in pink shrimp could contribute to the fact that pink shrimp are reported to spoil more rapidly than brown and white shrimp.

Table 4. Enzyme activities in three species of penaeid shrimp

Species	Arginase activity	Adenosine deaminase activity	AMP deaminase activity
	----- $\mu\text{mol/g/min}$ -----		
Brown shrimp (<i>P. aztecus</i>)	0.49 ^a	0.37 ^a	0.71 ^a
Pink shrimp (<i>P. duorarum</i>)	1.62 ^b	0.39 ^a	1.38 ^b
White shrimp (<i>P. setiferus</i>)	1.33 ^b	0.49 ^a	0.67 ^a

a,b In the same enzyme any means subscribed with the same letter are not significantly different, and any means subscribed with different letters are significantly different at 1% level.

CONCLUSION

The major ammonia-producing enzymes in shrimp muscle were adenosine deaminase, AMP deaminase and arginase. Arginase, adenosine deaminase and AMP deaminase had optimal temperatures of about 37 C, 48 C and 37 C, respectively, and optimal pH values of about 9.6, 8.6 and 6.5 respectively. During ice storage, the activities of arginase and AMP deaminase decreased and adenosine deaminase remained stable. Brown shrimp had the lowest level in arginase and pink shrimp had high activity of AMP deaminase and arginase.

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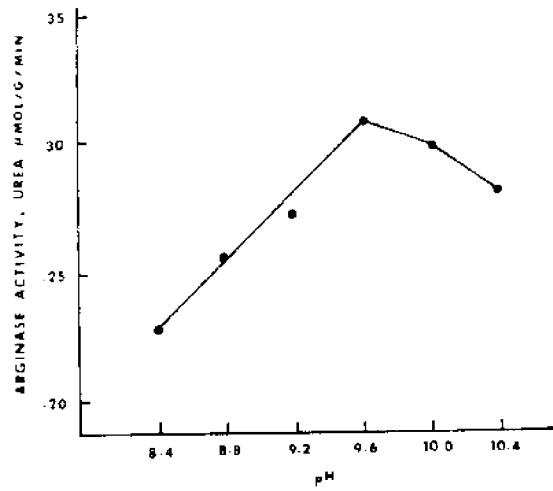


Fig. 1 - Effect of pH on arginase activity. (0.1 M Sørensen's glycine buffer, 20 mM arginine, 37°C).

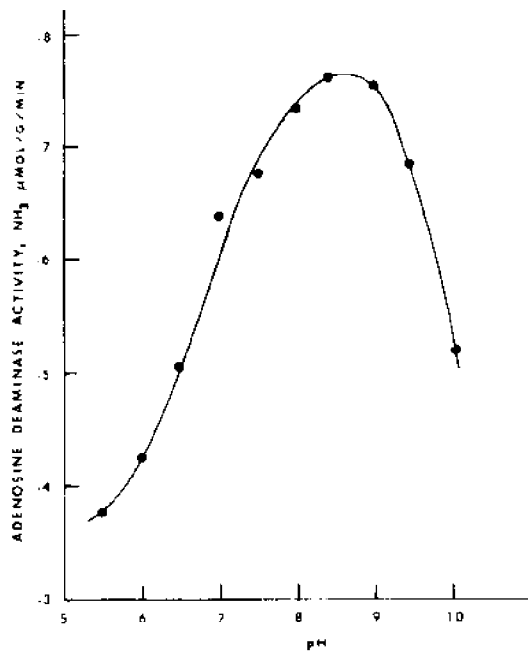


Fig. 2 - Effect of pH on adenosine deaminase activity. (0.1 M barbital buffer, 9.0 mM adenosine, 37°C).

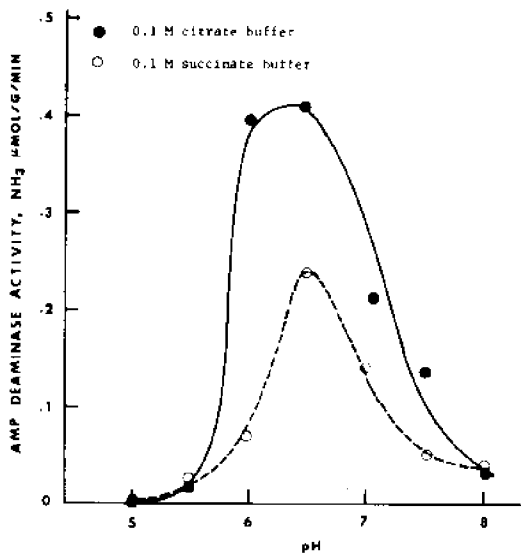


Fig. 3 - Effect of pH on AMP deaminase activity. (0.1 M buffer, 9.0 mM AMP, 37°C).

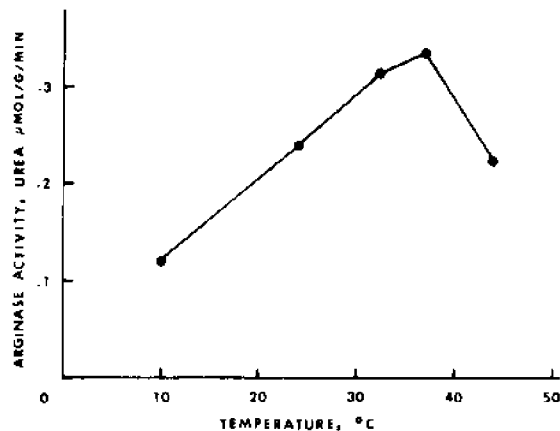


Fig. 4 - Effect of temperature on arginase activity.

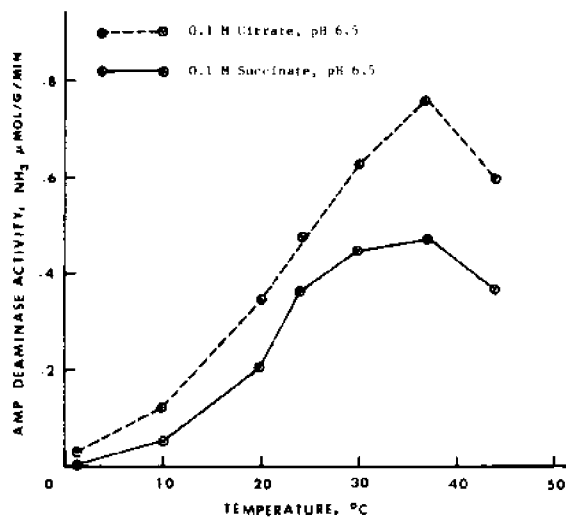


Fig. 5 - Effect of temperature on AMP deaminase activity.

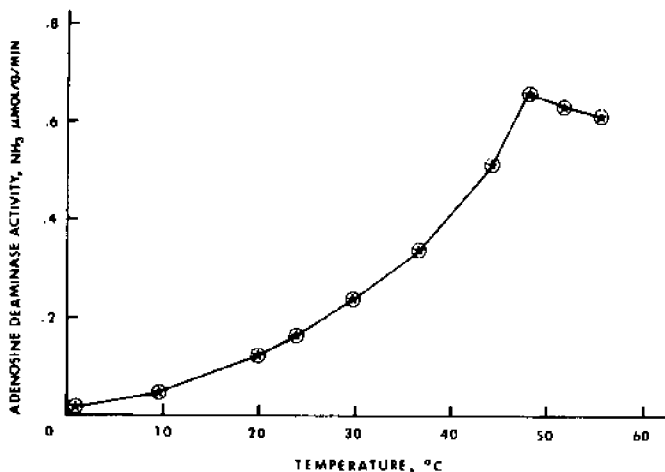


Fig. 6 - Effect of temperature on adenosine deaminase activity.

EFFECT OF ICE STORAGE ON THE TOTAL WEIGHT, PROXIMATE
COMPOSITION AND MINERAL CONTENT OF SHRIMP

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In 1975, U.S. trawlers brought home more than 344,000,000 pounds of shrimp (1). To maintain quality, shrimp should be frozen immediately after being caught. Since few shrimpers have freezing equipment aboard, most shrimp reaches port either chilled on ice or at ambient temperatures. Several researchers have noted rapid organoleptic and quality changes in shrimp stored on ice and have attempted to use these changes as indicators of spoilage (3, 9). Shrimp have previously been shown to be highly nutritious, containing protein of excellent quality and many essential minerals (7, 10). Although protein and other solids appear to diminish during ice storage (4), little information is available on additional nutritional changes in shrimp during ice storage. The purpose of the present study was to determine what effect ice storage has on the total weight, proximate composition, and mineral content of shrimp.

MATERIALS AND METHODS

Sampling

Medium size fresh brown shrimp (*Peneaus setiferus*) were obtained from Apalachicola Bay, Florida. The freshly caught shrimp were placed in plastic bags at the wharf, covered with ice, and immediately transported to the laboratory in Gainesville where they were washed, headed and divided into 1 kg samples. The "zero day" samples were immediately stored at -30°F while the other samples were stored in ice for 7 and 14 days. Before ice storage, the weighed, bagged samples were emptied into separate 26 x 41 x 28 cm styrofoam chests, half-filled with ice and were then covered in ice which was replenished as needed. A hole in the bottom of the ice chest allowed melted water to drain and be collected for analysis. After storage, the shrimp were rebagged, reweighed and stored at -30°F until analyzed.

Moisture analysis

Peeled shrimp were analyzed in triplicate for moisture content according to AOAC (2). Approximately 10 grams of ground shrimp were added to two grams of asbestos fiber and 5 ml of distilled water in 50 mm x 40 mm aluminum pans and dried overnight at 100°C in a forced air oven.

Crude fat analysis

Crude fat was determined by a modification of the AOAC method (2). Approximately two grams of dried shrimp were placed in a 100 ml Mojonnier flask and solubilized by heating with 8 ml concentrated HCl on a steam bath for 60 minutes. After cooling, 10 ml of 95% ethanol and 25 ml of ethyl ether were added. After shaking, 25 ml of petroleum ether was added, the flask was shaken and then centrifuged at 600 rpm for 10 minutes. The fat layer was decanted into a beaker and the portion remaining in the Mojonnier flask was extracted twice again with 15 ml of ethyl ether and 15 ml of petroleum ether which was added to the beaker. The sample was then evaporated to dryness and further dried at 100°C for 90 minutes.

Protein analysis

Dried shrimp were analyzed for protein by the standard AOAC micro-Kjeldahl method (2). The factor 6.061 was used to convert nitrogen to protein since it is more appropriate for fish flesh than the common factor 6.25 (8).

Ash analysis

Ash was determined by heating approximately three grams of dried shrimp overnight in a muffle furnace slowly brought to 550°C.

Mineral analysis

Ash was dispersed with two ml deionized water and heated at 100°C for 1½ hours and then reashed as described above. Approximately 200 mg of ash was then dissolved in 50 ml of 0.2N HCl. Calcium, cobalt, copper, chromium, iron, magnesium, manganese, nickel, strontium and zinc were analyzed by atomic absorption spectroscopy. Potassium and sodium were determined by flame emission spectroscopy and phosphorus was determined colorimetrically (6).

Statistical analysis

The data were subjected to analysis of variance and Duncan's multiple range test (5).

RESULTS AND DISCUSSION

Shrimp stored on ice gained weight during the first week of storage but lost some of the weight gained during the second week of storage (Table 1). The same shrimp, however, increased in moisture content over the entire 14 day storage period (Table 2). If water uptake was the only factor involved in weight change, the shrimp should have gained weight over the entire storage period. The increased water uptake was obviously counteracted by loss of other components. In fact, protein and ash did decrease in shrimp stored on ice (Table 2). By calculating percent moisture back to the initial zero day value of 77.6%, it can be seen that the water taken up by the shrimp does replace protein and ash (Table 3). The actual protein loss, confirmed by Kjeldahl analysis of the ice meltwater and calculated from the initial protein present, was 8.8% after 7 days and 17.8% after 14 days ice storage. The apparent protein loss (reduction in percent protein in a specific "as purchased" weight of shrimp calculated from Table 2) was 16% after seven days and 25% after 14 days.

Phosphorus, sodium, potassium, magnesium and copper decreased in shrimp stored on ice (Table 4). Iron, zinc, manganese and chromium were unchanged while calcium and strontium increased. Phosphorus, sodium, potassium and copper decreased more than 50% after 14 days storage on ice (Table 5). Mineral losses were probably due to leaching out by the ice meltwater. The increase in calcium and strontium could be due to a binding phenomena within the shrimp or to high levels of these minerals in the ice. If calcium and strontium were bound intracellularly to water-insoluble substances, the water soluble components would be lost much more rapidly from the shrimp flesh and would account for their apparent increase.

The data indicate that the loss of protein and minerals represent a nutritional disadvantage to the consumer of shrimp stored on ice. The only apparent solution to this loss of nutrients would be to freeze the shrimp rapidly following harvest. As this is not possible under existing conditions of harvest, this loss will have to be tolerated until freezing aboard ship becomes more common.

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Table 1-Weight change of shrimp during ice storage

<u>Days Storage</u>	<u>Sample</u>			<u>Mean</u>
	1	2	3	
	Percent			
0	-	-	-	-
7	+7.6	+8.2	+7.9	+7.9
14	+5.6	+5.5	+4.8	+5.3

Table 2-Effect of ice storage on proximate composition
of shrimp^{1,2}

	0 day	7 day	14 day
	Percent		
Moisture	77.6 ± 0.1a	81.3 ± 0.1b	83.5 ± 0.1c
Protein (NX6.061)	19.6 ± 0.5a	16.5 ± 0.3b	14.7 ± 0.3c
Fat	0.9 ± 0.1a	0.8 ± 0.1a	0.8 ± 0.1a
Ash	1.8 ± 0.1a	1.4 ± 0.1b	1.0 ± 0.1c

¹Wet basis

²Mean ± standard deviation

Values followed by the same letter are not statistically significant at the P < 0.05 level.

Table 3-Proximate composition of ice stored shrimp calculated back to 77.6% moisture content

	<u>0 day</u>	<u>7 day</u>	<u>14 day</u>
	Percent		
Moisture	77.6	77.6	77.6
Protein	19.6	17.3	15.8
Fat	0.9	0.8	0.9
Ash	1.8	1.5	1.1

Table 4-Effect of ice storage on mineral composition of shrimp^{1,2}

	0 day	7 day	14 day
	(mg/100 gm)		
Phosphorus	269 ± 11a	177 ± 9b	134 ± 10c
Sodium	238 ± 41a	161 ± 11b	95 ± 22c
Potassium	167 ± 49a	105 ± 29b	77 ± 20b
Calcium	94 ± 9a	128 ± 14b	132 ± 9b
Magnesium	46 ± 3a	38 ± 3b	34 ± 3c
Iron	2.2 ± 0.4a	1.9 ± 0.4a	1.5 ± 0.3a
Zinc	1.3 ± 0.2a	1.1 ± 0.2a	1.1 ± 0.3a
Strontium	0.32 ± 0.5a	0.46 ± .08b	0.55 ± .10c
Copper	0.33 ± .03a	0.19 ± .03b	0.11 ± .01c
Manganese	0.08 ± .01a	0.07 ± .01a	0.06 ± .01a
Chromium	0.04 ± .03a	0.04 ± .02a	0.02 ± .02a
Nickel	0.01 ± .02a	0.00 ± .00a	0.00 ± .00a
Cobalt	0.00 ± .00a	0.00 ± .00a	0.00 ± .00a

¹Wet basis

²Mean ± standard deviation

Values followed by same letter are not statistically significant at the P < 0.05 level.

Table 5-Change in mineral content during ice storage

	7 days	14 days
	Percent change	
Phosphorus	-34.2	-50.2
Sodium	-32.4	-60.1
Potassium	-37.1	-53.9
Magnesium	-16.7	-26.1
Copper	-42.4	-40.4
Strontium	+43.6	+71.9
Calcium	+36.2	+40.4

EFFECT OF VARIOUS PROCESSING FORM, PACKAGING MATERIAL,
STORAGE TEMPERATURE, AND ICE STORAGE TIME ON THE
SHELFLIFE OF FRESH GULF FISH

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Shelflife becomes much more critical when fresh fish are overwrapped using polyester films than with the more traditional method of icing (4). The action of melting ice in maintaining temperature near 0°C and removal of bacteria and their metabolites is lost. Only when rancidity is the limiting factor has the prepackaging of fresh fish not shown to decrease shelflife compared with icing of fresh fish (2,9). Murry et. al. (10) report length of shelflife of prepackaged fish to be from seven to 14 days. Contradictory results exist relating to temperature and packaging materials that have been used with no information existing concerning fish from the Gulf of Mexico.

A market survey was conducted in five metropolitan areas of Texas to determine existing conditions of overwrapped fresh fish (Phillips, Cobb; unpublished data). Results of chemical analyses and sensory evaluations indicated that 58% of the packaged fish was of unacceptable quality. A high incidence of isolates of E. coli and coagulase positive staphylococcus above levels suggested for fresh fishery products (8, 12), indicated problems in sanitation. To provide information for control of sales of overwrapped fresh fish, it was necessary to evaluate the parameters involved in packaging in relation to shelflife. These being, (i) the different processed form in which the product was presented, (ii) different packaging materials used, (iii) storage temperatures, and (iv) days on ice prior to packaging.

MATERIALS AND METHODS

Collection of fish

Three species of fish were used in all sections of the study: (i) speckled sea trout (Cynoscion nebulosus), red fish (Sciaenops ocellata), and (iii) red snapper (Lutjanus campechanus). Fresh fish were obtained from wholesale houses along the coast or directly from the Gulf of Mexico. Upon harvest, all fish were gilled, eviscerated, and placed on ice for transportation to the laboratory.

Handling and Preparation of Samples

All fish were transported to the laboratory within 12 hours of capture. Upon arrival, fish were washed with normal tap water to remove slime and external debris and stored in ice until initiation of testing. Handling and preparation was conducted to simulated practices that might be used in commercial fish processing houses. Testing of treatments was begun within 24 hours of capture.

Processing Form Treatments

Fish were obtained from ice storage and washed with normal tap water. Individuals from each species were prepared as gilled eviscerated with heads-on, (H), gilled eviscerated with heads-off, (H-O), and fillets. Samples of each treatment were placed on polystyrene trays and overwrapped with PVC film. Overwrapped packages were placed in low temperature incubators and held at $2^{\circ} \pm 0.2^{\circ}\text{C}$. Three packages of each species and treatment were removed from refrigerated storage every two days for chemical and microbial analysis until sensory evaluations indicated the product was no longer acceptable. Three ice stored fish of each species were analyzed on the day of packaging and every two days until unacceptable, as a comparison.

Packaging Treatments

Fillets from speckled sea trout, red fish, and red snapper were prepared from ice stored fish and packaged in the same manner as those in the Processing Form section. Treatments for packaging included 3 different commercial wraps: (i) Avisco MC PVC "E-Z Stretch", (ii) Dow polyethylene (PE) "Handy Wrap"; (iii) Dow "Saran Cutter Box". Specifications of each wrap are listed in Table 1.

Table 1. Physical properties of material used in packaging treatments

Packaging Material	Thickness (mil)	Oxygen Transmission Rate cc/100sq.in/24hr/atm	Water Vapor Transmission Rate gm/100sq.in/24hr/atm
AVISCO PVC	0.6	1200	24
DOW PE	0.6	840	2.4
DOW SARAN	0.5	2	0.2

Overwrapped packages were placed in low temperature incubators and stored at $2 \pm 0.2^{\circ}\text{C}$. Chemical, microbiological and sensory evaluations were conducted in the same manner as those analyzed in the Processing Form section.

Storage Treatments

To determine the effects of storage temperature and days on ice prior to packaging, samples of the three species of fish were removed from ice storage on alternate days beginning 24 hours after capture and filleted. Fillets were packaged using the same methods and material followed in the section for Processing Form. Over-wrapped packages were placed in two temperature incubators and stored at 0°, 2°, and 5° ± 0.2°C. Packages of each treatment and species were removed every two days and examined chemically and microbiologically as previously stated.

Bacteriological Analysis

All samples were analyzed for (i) aerobic plate counts (APC), (ii) coliform organisms, (iii) *E. coli*, and (iv) coagulase positive staphylococcus. Gilled, eviscerated head-on and head-off fish were swabbed using appropriate areas of side, gill region, and body cavity to arrive at a representative surface area. Approximately 50 grams of fillet was blended in 450 ml of phosphate buffer using Waring blenders and transferred to appropriate dilutions of phosphate buffered water. APC's were determined with the spread plate method by placing 0.1 ml from the appropriate dilutions on to Standard Methods Agar (SMA-BBL) and incubating at 20°C for 72 hours. Coliform organisms, *E. coli*, and coagulase positive staphylococcus were determined as described in the Official Methods of Analysis (1) substituting 5 tube for 3 tube MPN method.

Chemical Analysis

For chemical analyses, 50 g of fish was placed in a Waring blender with 100 ml (1-2 ratio) of 7% trichloroacetic acid solution and blended for three minutes. The mixture was filtered through No. 1 Whatman filter paper to remove the protein precipitate.

Total volatile nitrogen (TVN) and trimethylamine nitrogen (TMN) analyses employed the modified Conway microdiffusion dish (11). The procedure involved $\text{Na}_3\text{PO}_4\text{KOH}$ as a releasing agent using the method of Cobb et. al., (3). For TMN, 0.5 ml of 40% HCHO was added to the sample prior to mixing with the releasing agent. Diffusion time was 1.5 hours for TVN and 3.5 hours for TMN before titrating with 0.02 N H_2SO_4 using a Metrohm Herisau Dosimat (Brinkman Instruments). TVN and TMN analyses were expressed as mg nitrogen/100 g fish (mgN/100g fish).

Sensory Evaluation

Sensory evaluations were made using a trained laboratory panel to determine at what time the packaged fish became unacceptable. This was accomplished by having each member observe and record visual and odor observations of freshly opened overwrapped packages of fish. Observations were either acceptable or unacceptable.

Analysis of Data

Analyses of data were conducted by three by five by three

factorial analysis of variance for (i) species, days, process form; (ii) species, days, packaging material; and (iii) species, days, storage temperature.

RESULTS AND DISCUSSION

The present study involves technological implications of packaging fresh Gulf fish with polyester film in relation to shelf-life. The investigation was divided into three sections: (i) Processing Form; (ii) Packaging Material; (iii) Storage Temperature and Days on Ice Prior to Packaging.

Processing Form

The three species of fish whether prepared and packaged as head-on (H), headoff (H-O) or fillet were judged unacceptable on the ninth day of refrigerated storage at 2°C. Figure 1 shows total volatile nitrogen (TVN) values recorded on alternate days from the initial day of packaging to the ninth day. The astrix line represents 30 mg TVN/100g fish which is the reported level of maximum acceptability (13). This level is shown to fall within the period of time when the packaged fish were acceptable at day 7 and unacceptable on day 9. In Figure 2 trimethylamine (TMN) values are shown for the same product over the same period of time. Astrix are superimposed on the graph corresponding to the time from Figure 1 at 30 mg TVN/100 g fish. TMN values at the astrix are between 10 and 15 mg TMN/100 g fish which is reported as the maximum levels of acceptance (5, 12). Results of aerobic plate counts (APC) shown in Figure 3 indicate levels between 10^7 and 10^8 on day 9 and also at the 30 mg TVN astrix. This agrees with reports in the literature that are expected at spoilage (14).

Statistical analysis using measured values of TVN are shown for red snapper in Table 2. Species, days, and form varied significantly. Interactions of species*form and species*days*form were not significant at the 0.05 level. The interaction relationship of species*form for red fish, red snapper and trout at day 9 is shown in Figure 4. Red fish had higher values of TVN than red snapper or trout. H-O fish in all species were higher than H or fillet.

Packaging Material

As in the section on Processing Form, all product was unacceptable on the ninth day from packaging. Figure 5 shows the results of TVN analysis of red snapper fillets packaged with polyvinylchloride (PVC), polyethylene (PE), and polyvinylacetate (SARAN) films. TVN levels of 30 mg/100 g are again between day 7 and day 9. In Figure 6, TMN values are near 15 mg/100 g fish as in the previous section. Aerobic plate counts shown in Figure 7 indicate increasing levels with increasing oxygen and water vapor transmission rates shown in Table 1. Bacteria numbers were again between 10^7 and 10^8 /g.

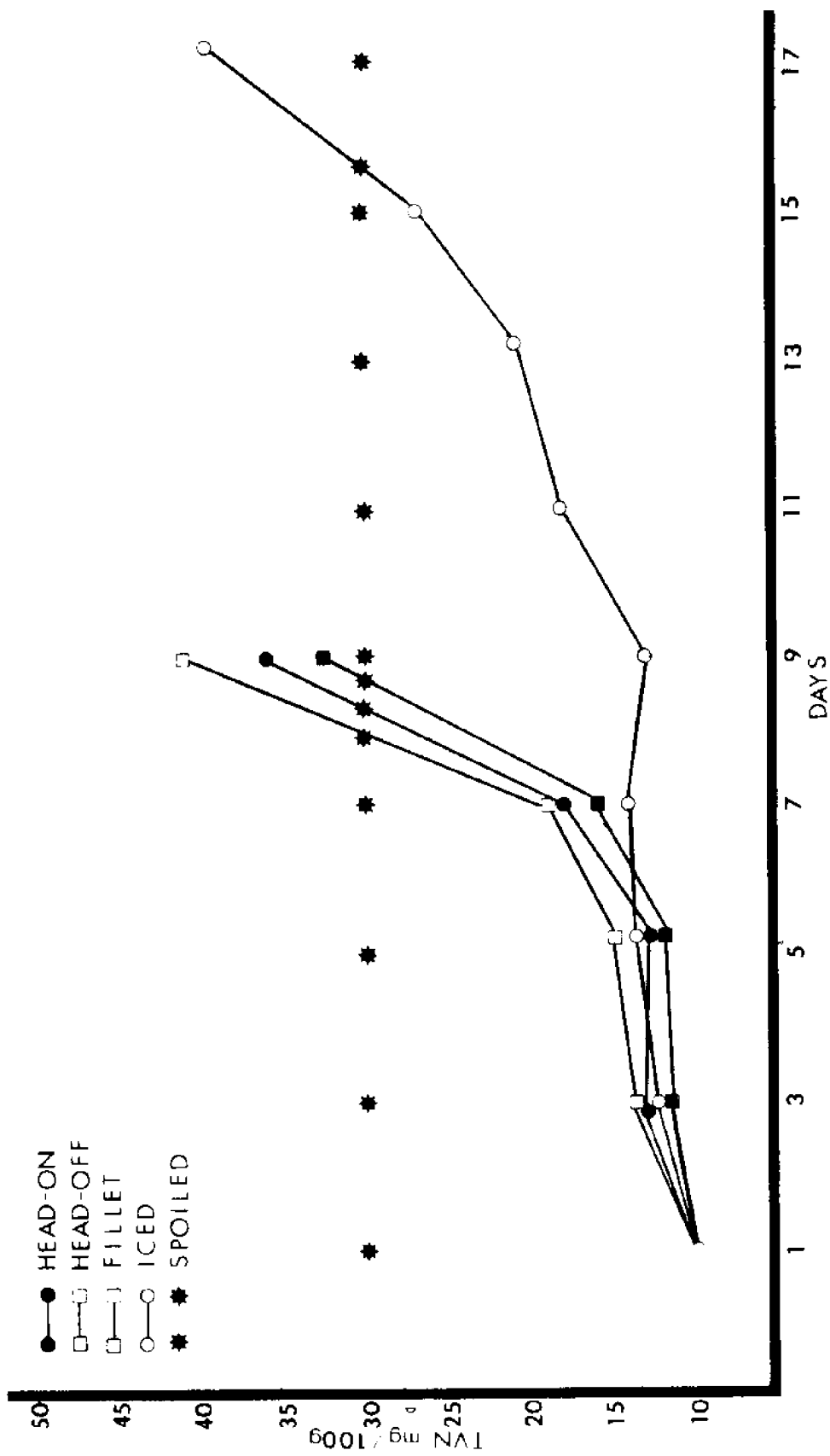


Figure 1. Effect of processing form on total volatile nitrogen (TVN) analysis of Red Snapper overwrapped with PVC stored at 2°C.

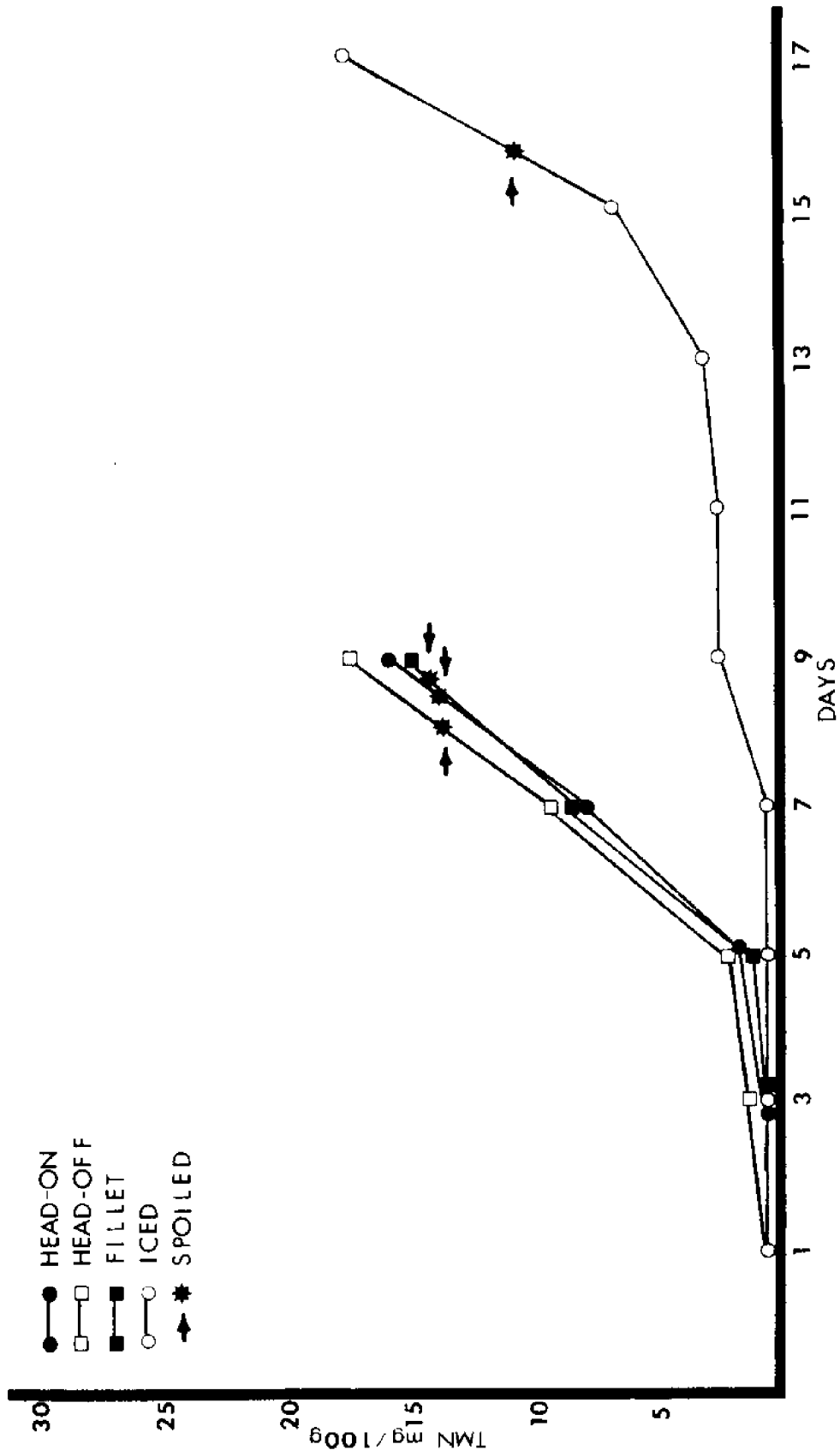


Figure 2. Effect of processing form on trimethylamine (TMN) analysis of Red Snapper overwrapped with PVC stored at 2°C.

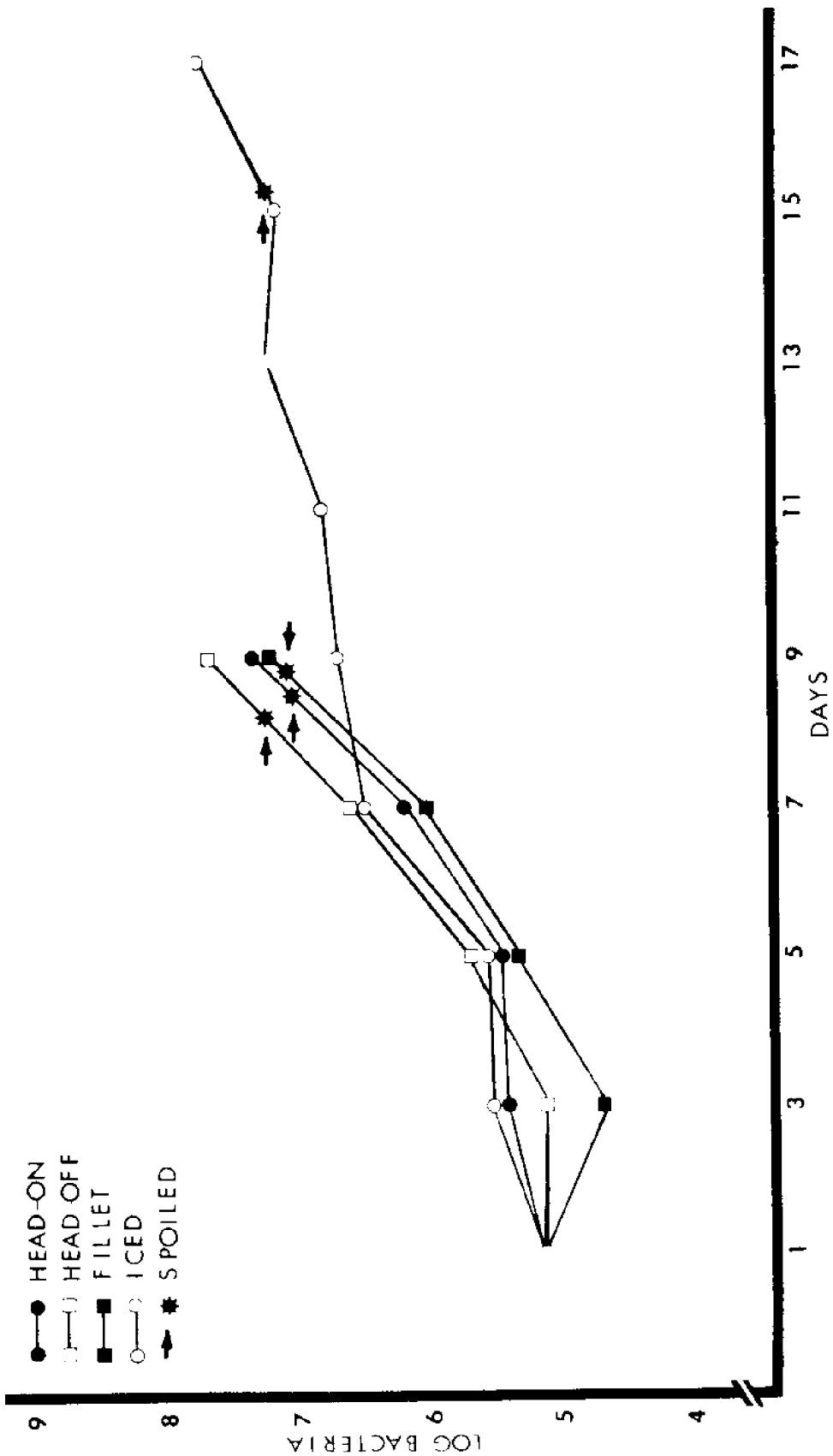


Figure 3. Effect of process form on aerobic plate counts of Red Snapper overwrapped with PVC and stored at 20°C.

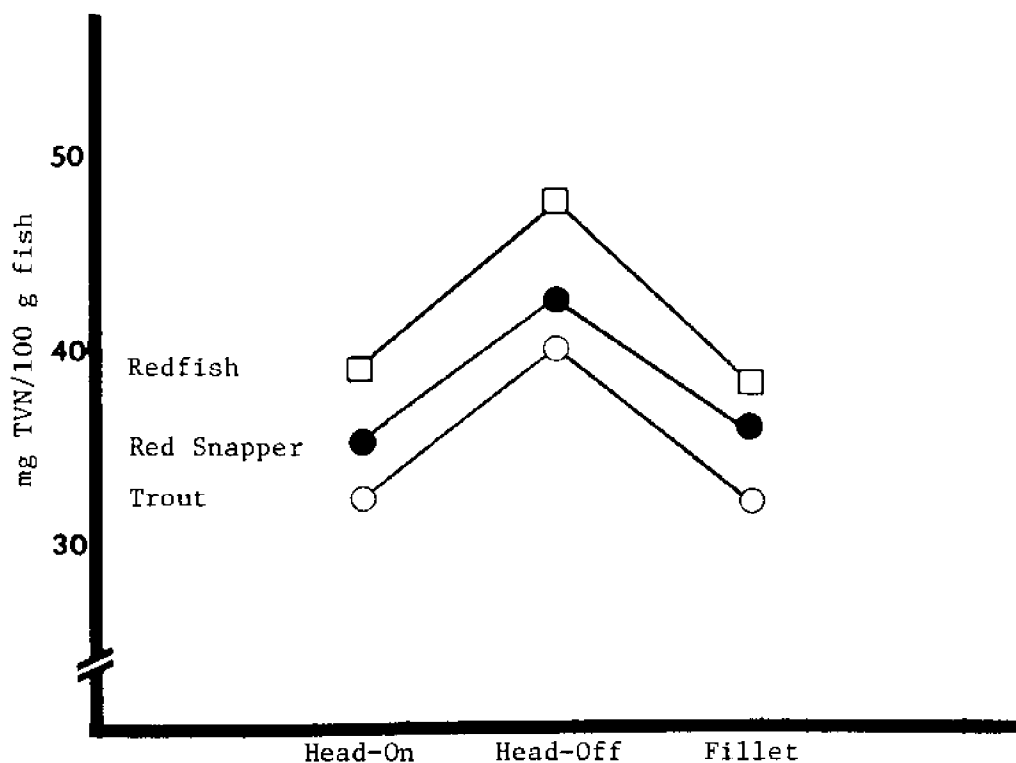


Figure 4. Species*form interaction for Redfish, Red Snapper, and Trout at day nine.

Table 2. Analysis of variance of data from Process Form treatments using heads-on, heads-off, and fillets from speckled sea trout (*Cynoscion nebulosus*), red fish (*Sciaenops ocellata*), and red snapper (*Lutjanus campechanus*).

Source	DF	SS	MS	F Value	Prob>F
Species	2	120.6310	60.3155	32.5824	0.0001
Days	4	27501.8834	6875.4709	3714.1282	0.0001
Form	2	294.9996	147.4998	79.6794	0.0001
Species*Days	8	254.3120	31.7890	17.1724	0.0001
Species*Form	4	10.0201	2.5050	1.3532	0.2501
Days*Form	8	401.8704	50.2338	27.1363	0.0001
Species*Days*Form	16	39.1350	2.4459	1.3213	0.1851
Error	225	418.5125	1.8512		

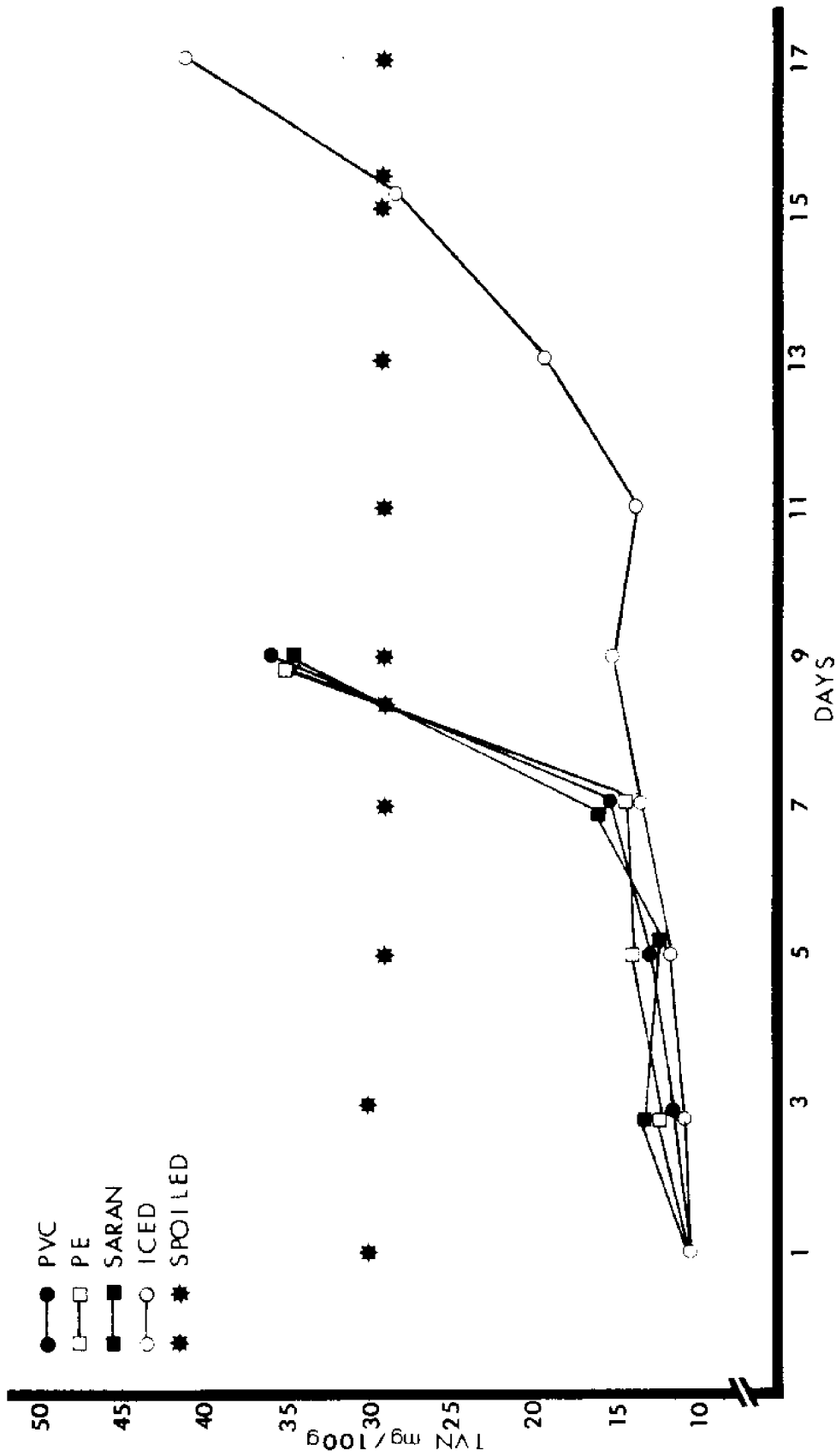


Figure 5. Effect of packaging material on total volatile nitrogen (TVN) analysis of Red Snapper fillets stored at 2°C.

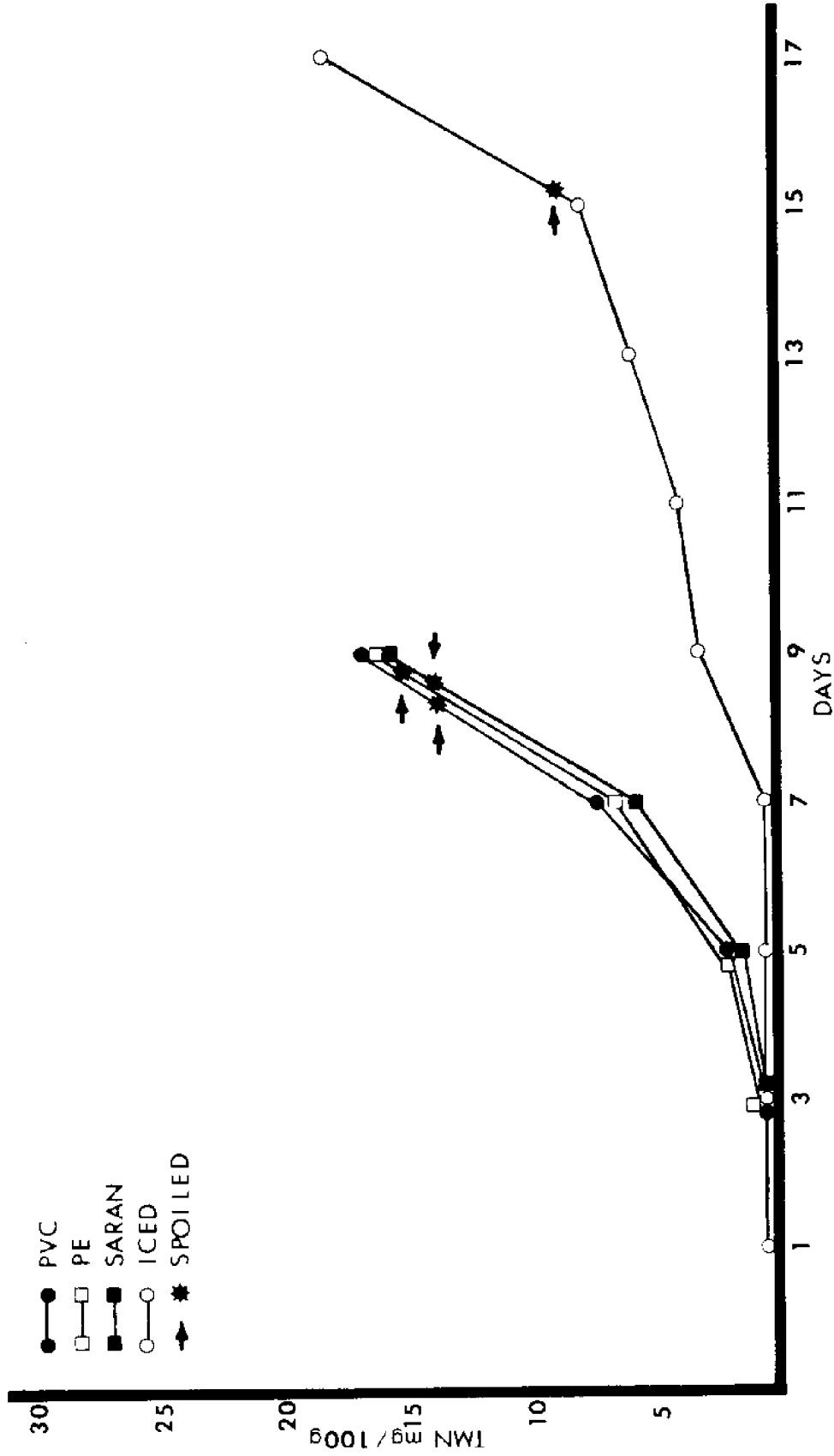


Figure 6. Effect of packaging material on trimethylamine (TMN) analysis of Red Snapper fillets stored at 2°C.

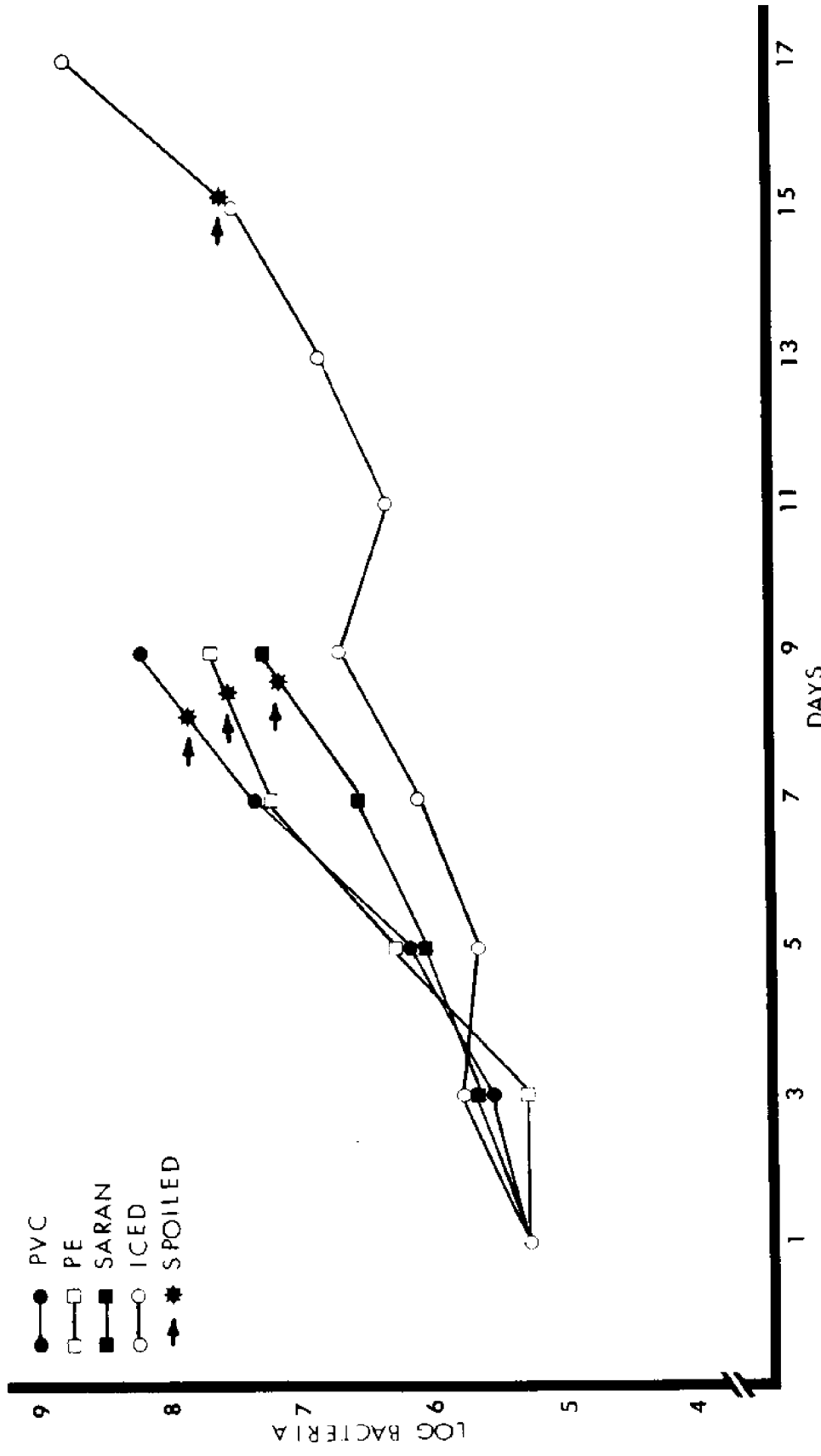


Figure 7. Effect of packaging material on aerobic plate counts of Red Snapper fillets stored at 2°C.

Results of statistical analysis shown in Table 3 indicates significant differences for species but non-significance for wrap, species*wrap, and species*days*wrap. Figure 8 represents interaction effect of species*wrap at day 9 for the three species. As in the Processing Form section, red fish had consistently higher levels of TVN than red snapper or trout. The type of film used in overwrapping showed little effect with respect to TVN values, being constant for each species.

Storage Treatments

The results of packaging fish on alternate days of ice storage and holding at temperatures of 0^o, 2^o, and 5^o C are shown for red snapper fillets in Figure 9. At refrigeration storage of 0^o C, for every two days fish were held on ice, two days at refrigeration storage were lost through day seven. Fish packaged on day nine and stored at 0^o C did not lose two days of refrigeration storage when compared to day seven, this being due to the maximum of 15 days ice storage of the fresh fish. Fish stored at 2^o and 5^o C show approximately one day shelflife differences. Between days one and three, one day of shelflife was lost with two days being lost between days three and five. At days seven and nine the same effect is seen as at day nine and 0^o C. TMN measurement corresponding to 30 mg TVN/100 g fish are shown in Figure 10 and indicate between 10 and 15 mg/100 g fish with the exception of day five where levels were above 15 mg. APC levels shown in Figure 11 exceed 10⁷/g as in the prior two sections.

Statistical analyses shown in Table 4 indicate non-significant differences for species and species*temperature. All others were significant at the 0.05 level.

CONCLUSION

As stated by Davis (4) packaging is not a means of preservation of fresh fish but a method of presentation. Results of this study indicate that the major factor contributing to shelflife of over-wrapped fish is the refrigerated storage temperature and the period of time from harvest prior to packaging. Though significant differences existed for species in the Processing Form and Packaging Material sections in relation to actual measured levels of TVN, all products became unacceptable between days seven and nine.

Removal of the head from fish appears to limit shelflife approximately one day when compared to fish with heads-on and fillets. Under conditions imposed during the study, the added exposure of surface area to bacteria in fillets appeared to be nullified by washing of the surfaces.

Oxygen and water vapor transmission rates had no significant effect on shelflife though increasing APC levels were noted with increasing transmission rates. No significance in shelflife is a result of the relatively short period of time for which fish remain in packages prior to spoilage.

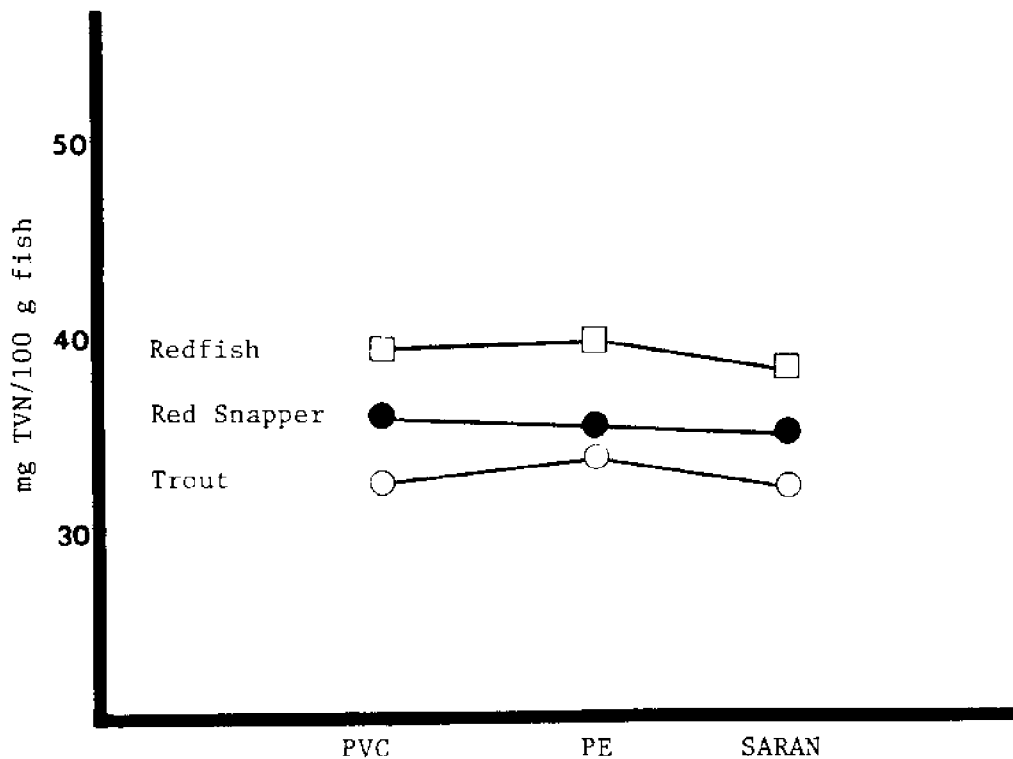


Figure 8. Species*packaging material interaction for Redfish, Red Snapper and Trout at day nine.

Table 3. Analysis of variance of data from Packaging Material treatments using polyvinylchloride (PVC), polyethylene (PE), and saran wraps on fillets from Speckled Sea Trout (*Cynoscion nebulosus*), Red Fish (*Sciaenops ocellata*), and Red Snapper (*Lutjanus campechanus*).

Source	DF	SS	MS	F Value	Prob>F
Species	2	138.6814	69.3407	75.2611	0.0001
Days	4	23184.9944	5796.2486	291.1374	0.0001
Wrap	2	2.8532	1.4266	1.5484	0.2131
Species*Days	8	222.2310	27.7800	30.1519	0.0001
Species*Wrap	4	4.3377	1.0840	1.1771	0.3212
Days*Wrap	8	17.5005	2.1876	2.3743	0.0178
Species*Days*Wrap	16	17.7897	1.1106	1.2054	0.2644
Error	225	207.3005	0.9213		

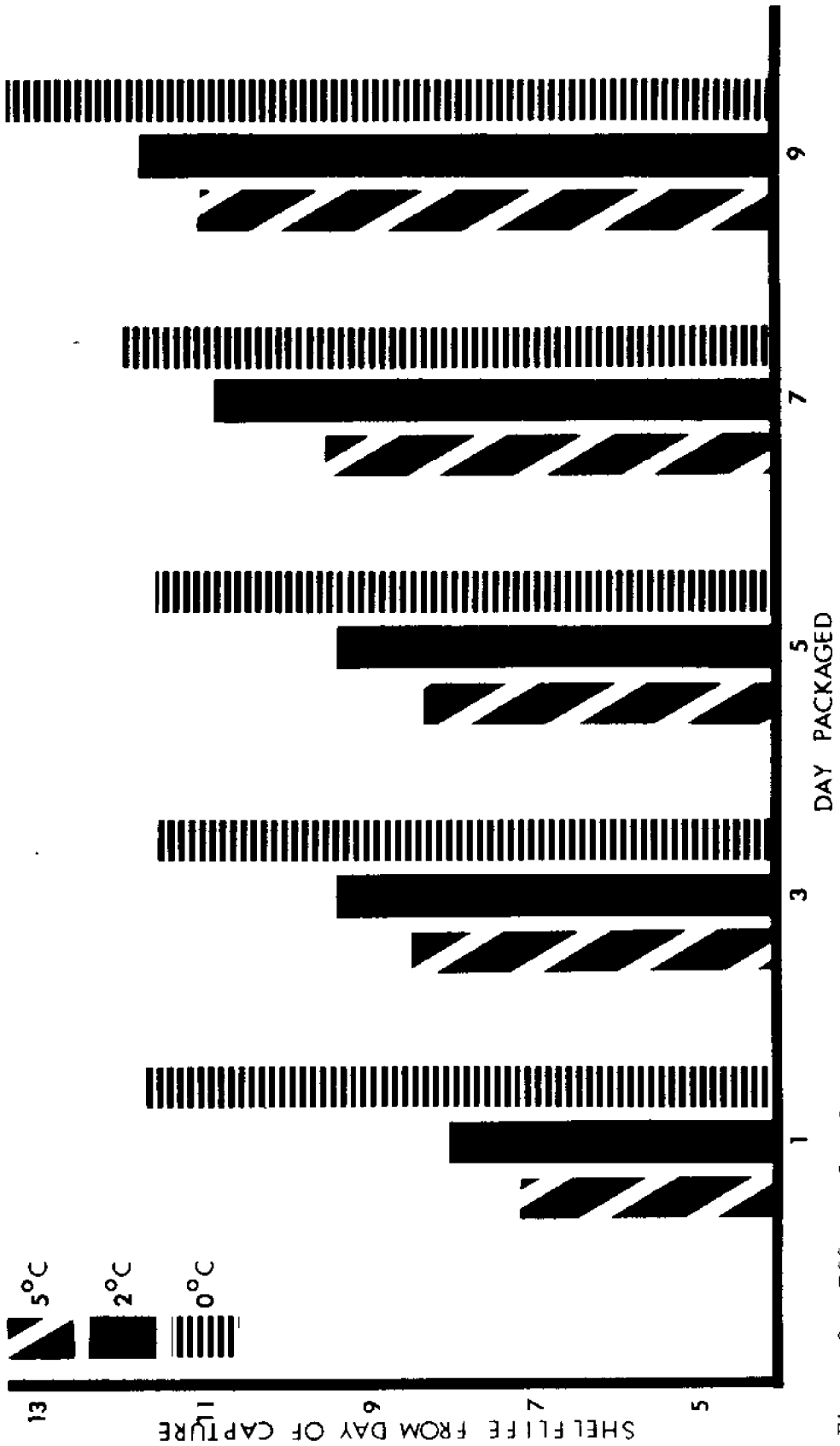


Figure 9. Effect of refrigerated temperature storage and days on ice prior to packaging on shelflife of Red Snapper fillets.

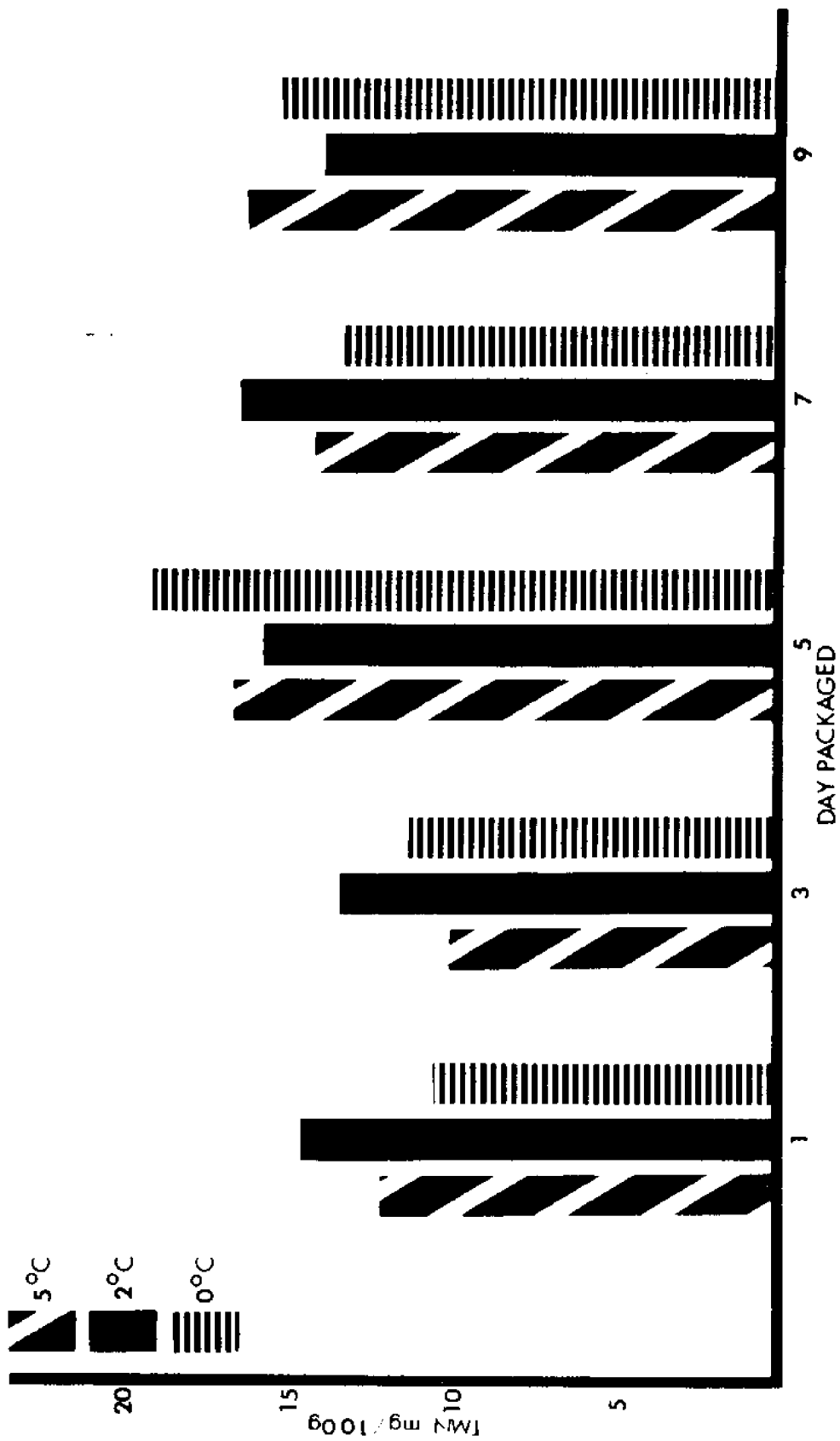


Figure 10. Effect of refrigerated storage temperature and days on ice prior to packaging on trimethylamine (TMN) levels of Red Snapper fillets.

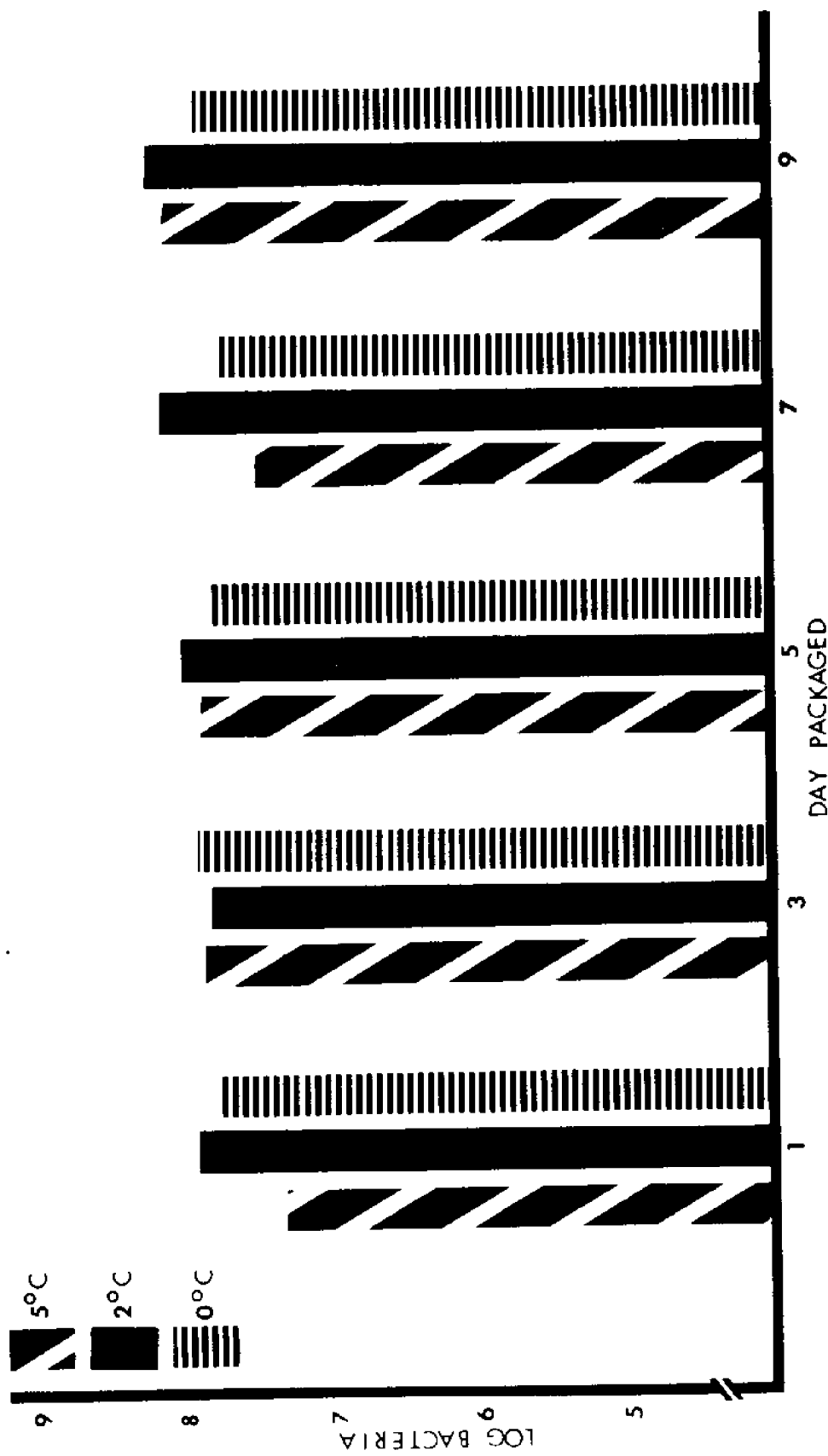


Figure 11. Effect of refrigerated storage temperature and days on ice prior to packaging on Aerobic Plate Counts of Red Snapper fillets.

Table 4. Analysis of variance of data from Storage Temperature Treatments of 0^o, 2^o, and 5^o ± 0.2^oC using fillets from Speckled Sea Trout (Cynoscion nebulosus), Red Fish (Sciaenops ocellata), and Red Snapper (Lutjanus campechanus) packaged on days 1, 3, 5, 7, and 9.

Source	DF	SS	MS	F Value	Prob>F
Species	2	0.2271	0.1135	0.1135	0.1963
Days	4	105.0538	26.2634	388.6083	0.0001
Temperature	2	126.8594	63.4297	938.5495	0.0001
Species*Days	8	2.6349	0.3294	4.8734	0.0004
Species*Temp	4	0.4641	0.1160	1.7168	0.1620
Days*Temp	8	14.0476	1.7559	25.9819	0.0001
Species*Days*Temp	16	3.1487	0.1969	2.9129	0.0027
Error	45	3.0412	0.0676		

To enable a minimum of three days shelflife in the package, results shown in Figure 9 indicate that at refrigerated storage temperature of 5°C fish must be packaged within four days of harvest, at 2°C packaging must take place within six days of harvest; and at 0°C fish must be packaged within 10 days of harvest.

At no time during the study did coliform organisms exceed 120/g. Only three isolates of IMViC++-- E. coli were identified and all from one shipment of red fish. Two coagulase positive staphylococci isolates were identified and both from the above shipment of red fish. This indicates that contamination of fresh fish found in the market survey takes place from the processing house to the market.

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ANALYSIS OF SOYBEAN PROTEIN ADDITIVES IN FISHERIES PRODUCTS

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Because of the growing demand and rising prices for meat and meat products as well as the emerging awareness of both producers and consumers of the food value and general potential of soybean protein for human consumption, the use of soybean protein as both meat extenders and meat analogues is now common. While the processing technology has been developed to the extent that such plant protein is now used in a variety of food products, little attention has been given to techniques which could be used by processors in their quality control programs to assure the uniform consistency of their supplemental food products.

The purpose of the present investigation was to evaluate a number of techniques which could quickly, easily, and inexpensively quantitate the amount of soy protein in a variety of fisheries products. The method which best meets these criteria in an accurate, reproducible manner is the technique commonly referred to as rocket-immunoelectrophoresis. In this technique, an aliquot of a protein homogenate is subjected to electrophoretic migration in a gel containing antibodies to the protein to be analyzed. Since the distance of migration of the protein to be analyzed is directly proportion to the concentration of protein, and since no other proteins in the sample form an immuno-precipitate product, quantitation is readily achieved by measuring the distance of migration of the (rocket height) sample to be analyzed. It is the purpose of this report to describe our initial findings on the use of rocket-immunoelectrophoresis for the quantitation of soy protein in fisheries products.

MATERIALS AND METHODS

Production of Antiserum

The soy protein isolate, Promine D (Central Soya), was homogenized in 0.05 M. Tris-Glycine buffer (pH 8.0), centrifuged and the supernatant placed on a Sephadex G-75 gel filtration column, from which two major peaks were obtained. The first peak was dialyzed against normal saline and diluted to a concentration of 2 mg/ml. On day 0, 14, 28, and 42 a rabbit weighing 4 kg was given injections of a mixture containing 50 μ l antigen (100 μ g) and 50 μ l, Freund's incomplete adjuvant (water in oil emulsion) (1). The injections were given in the thicker part of the skin above the scapula, and the injection was given as superficially in the skin as possible. After eight weeks, blood was drawn by direct cardiac puncture, allowed to clot at ambient temperature for one hour, refrigerated, and cen-

trifuged. After centrifugation, the serum was drawn off, filtered through cheesecloth to remove insoluble lipids, and stored in aliquots at -20°C .

Standard Preparation

Standard was prepared from soy protein isolate (Promine D) by homogenizing 28 mg in 7 ml of 0.02 M veronal buffer (pH 8.6) in a glass tissue homogenizer. Following centrifugation at $1000 \times g$ for 15 minutes serial dilutions were made to form a series of standard solutions of varying concentrations. All standards were stored at -20°C until used.

Sample Preparation

The individual fishery products to be supplemented with soy protein were dehydrated by lyophilization. The dry soy protein isolate Promine D was added to the fishery product (w/w) to the desired soy protein concentration. These soy protein supplemented fishery products were then homogenized, centrifuged and diluted according to the procedure described for standard preparation.

Rocket-Immunoelectrophoresis

Rocket-immunoelectrophoresis (RIE) was performed on 0.5% agarose gel slabs. Agarose gel slabs were prepared by adding powdered agarose (Bio-Rad) to 0.02M barbital buffer, pH 8.6 (w/w), boiled until the agarose dissolved and stored at 4°C in aliquots corresponding to the volume of 1 gel. For use, one of the solidified aliquots was placed in boiling water until the agarose was liquified and then placed in a thermostated water bath where it was allowed to cool to 50°C (2). Antiserum was then added to the liquified agarose in an amount corresponding to $20 \mu\text{l}/\text{cm}^2$ and gently mixed.

The liquified agarose containing antibodies was then poured between two glass plates where it was allowed to cool and solidify into a gel slab 1.5 mm thick x 12 cm high x varying widths depending on the number of samples. One of the glass plates was removed and sample wells were cut 5 mm apart in the gel parallel to and 3 cm from one end using a specially designed vacuum gel puncher 3 mm in diameter (Bio-Rad). The gel was then placed on the cooling stage of a Model 1400 electrophoresis cell (Bio-Rad) such that the sample cells were at the cathode end and maintained at a constant temperature of 12°C contact between the gel and the buffer vessels was made by 1.5% agarose gel wicks.

Five μl of the standards and samples were applied to the wells while under a potential of 2 V/cm to avoid diffusion rings around the applications (3). Five μl of a 1% bromophenol blue solution was also applied to one well as a tracking dye to aid in determining completion of the run. After all of the samples were applied, a potential of 10 V/cm was applied, and electrophoresis continued for 90 minutes. The gel was then removed from the apparatus and partially dehydrated by pressing under weighted filter paper for 5-10 minutes. The gel was then washed twice in 0.1 M NaCl solution for 15 minutes to remove the non-precipitated proteins and one final wash in distilled H_2O for 15 minutes to remove the NaCl. The gel was then air dried under a warm air blower to a thin dry film on a clear plastic backing and then stained for one minute in 0.5% Coomassie Brilliant Blue R-250. Excess stain was removed by placing the gel in acetic

acid, ethanol, and water (10:45:45), washed for one minute in H₂O and blown dried. Quantitation was by plotting a standard curve, measuring the peak height of each of the samples from the top of the well and determining their concentrations from the standard curve (4). The concentration obtained for each sample was multiplied by the dilution factor, this product divided by the undiluted concentration of the standard and this quotient multiplied by 100 to obtain percent concentration. A flow diagram outlining the steps for sample work-up can be found in Figure 1.

RESULTS AND DISCUSSION

As can be seen in Figure 2, four distinct antigen-antibody precipitates (rockets) were observed using the antiserum prepared in this study. Of these 4 rockets, one was easily distinguished from the others by its form, shape, ability to take up stain and its demarcation on either side of the precipitant zone. It was this rocket (the heavily stained rocket) which was used for all quantitative studies throughout the remainder of the study.

As shown in Figure 3 and Table I, when haddock, and commercial, fish sticks (pollock) were supplemented with 20% Promine D, experimentally determined soy concentrations were in close agreement to the 20% Promine D concentrations added. This same figure and table (Figure 3 and Table I) also illustrate how this technique can be used to quantitate soy protein concentrations in other meat products as well, as both ground beef and weiners gave comparable quantitative results as the fisheries products.

That this technique can be used at soy protein concentrations as high as 50% is illustrated in Figure 4 and Table II. In this experiment, the cod, haddock and fish sticks were all determined within 1% to be supplemental with 50% soy protein.

The sensitivity of the technique to detect soy protein supplements as low as 1% is illustrated in Figure 5 and Table III. In this experiment, haddock supplemented with soy protein amounts ranging from 1% to 20% was analyzed. As can be seen from the table, experimental results agreed closely with the theoretical values, even at the 1% concentration end. However, in order to keep the peak heights in the range of least error (1-4 cm), lower antibody concentrations must be incorporated into the gel, resulting is less densely stained rockets. In addition, various enhancement techniques to increase the sensitivity (5) must also be employed. Since these techniques essentially involve longer staining and incubation times, analysis of samples containing these lower soy protein concentrations require a longer analysis time.

CONCLUSIONS

The use of rocket-immunoelectrophoresis appears to be a feasible way to quantitate soy protein additives in a variety of fishery products. The method is sensitive enough for analysis over the range of concentrations of soy protein frequently encountered. In addition, the technique does not involve complicated chemical procedures and is rapid enough that one technician could easily carry out over 100 analyses per day. In addition, since no expensive equipment is utilized, an initial equipment cost of about \$500 is all that is

required in addition to the 5-15¢ cost per sample needed for reagents on a routine basis.

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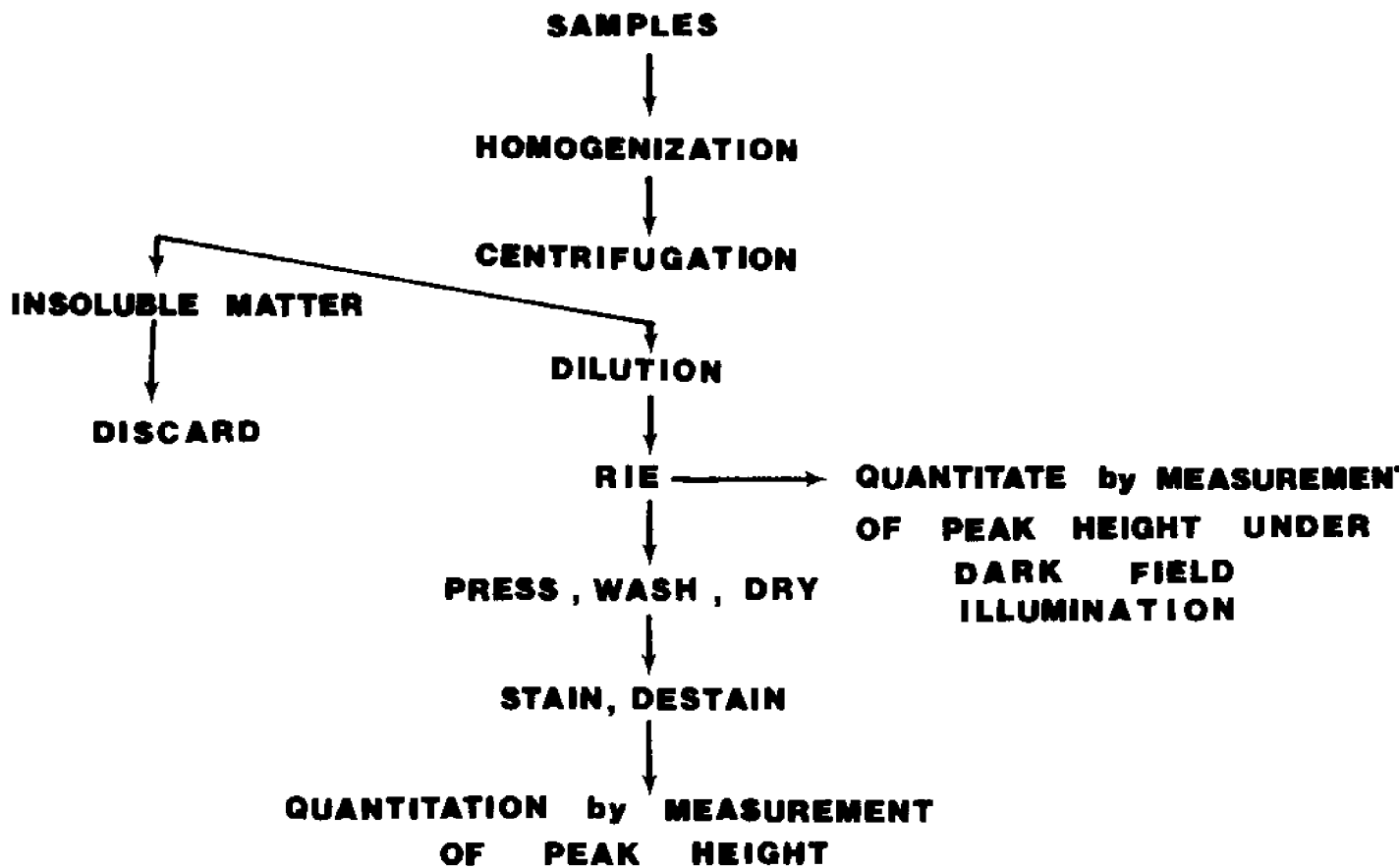


Figure 1. Flow diagram for preparation of fishery product for analysis of soybean additives.

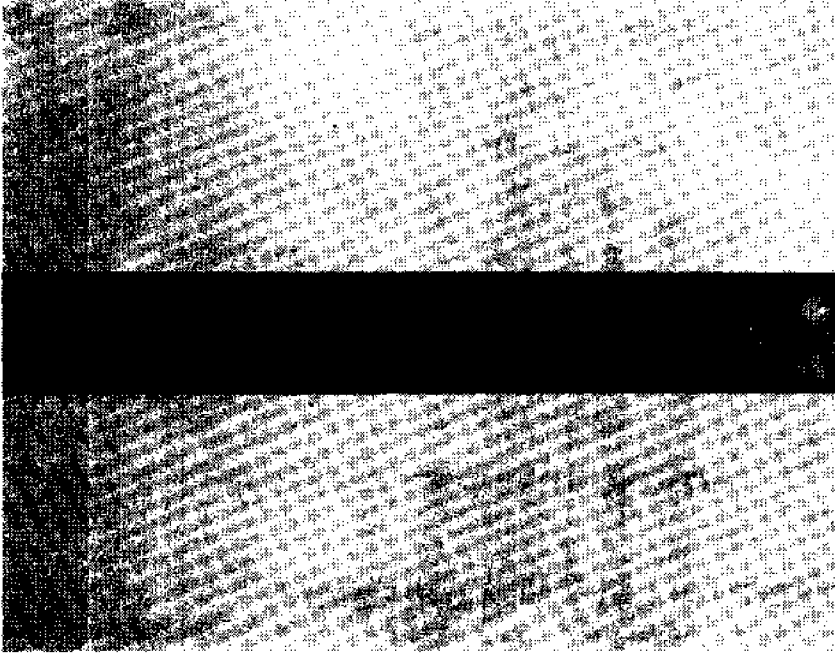


Figure 2. Typical rocket obtained with soybean protein.

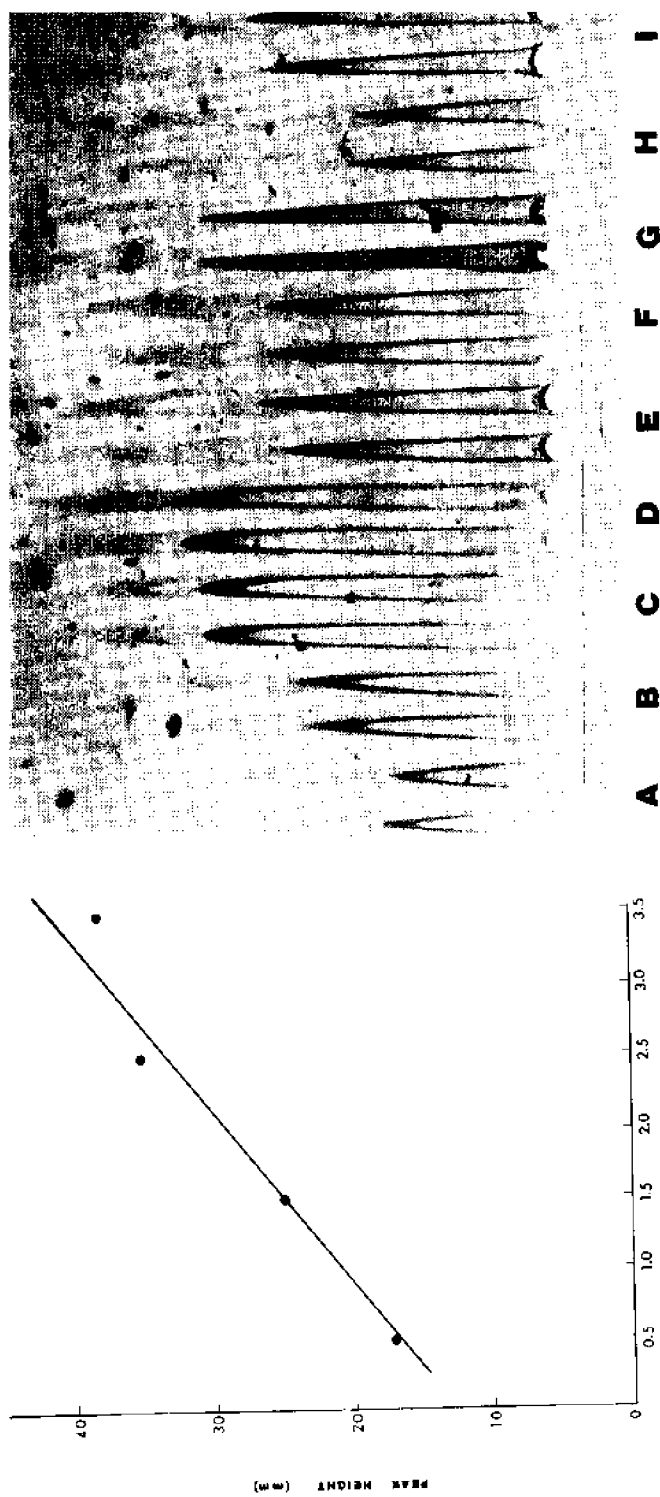


Figure 3. Rocket immunoelectrophoresis of products containing 20% soybean protein additives.

- (A) 0.5 g/l standard (B) 1.5 g/l standard (C) 2.5 g/l standard
- (D) 3.5 g/l standard (E) Ground beef (F) Weiners
- (G) Haddock (H) Crab (I) Fish Stick

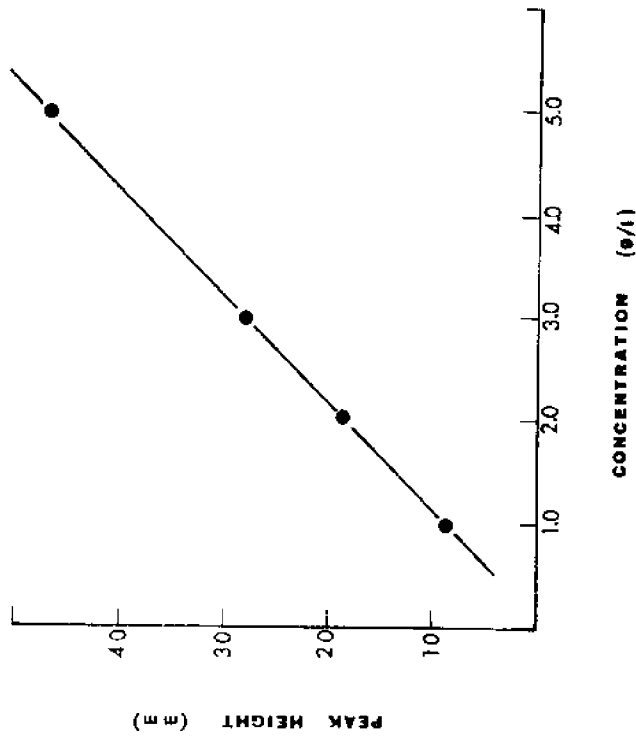
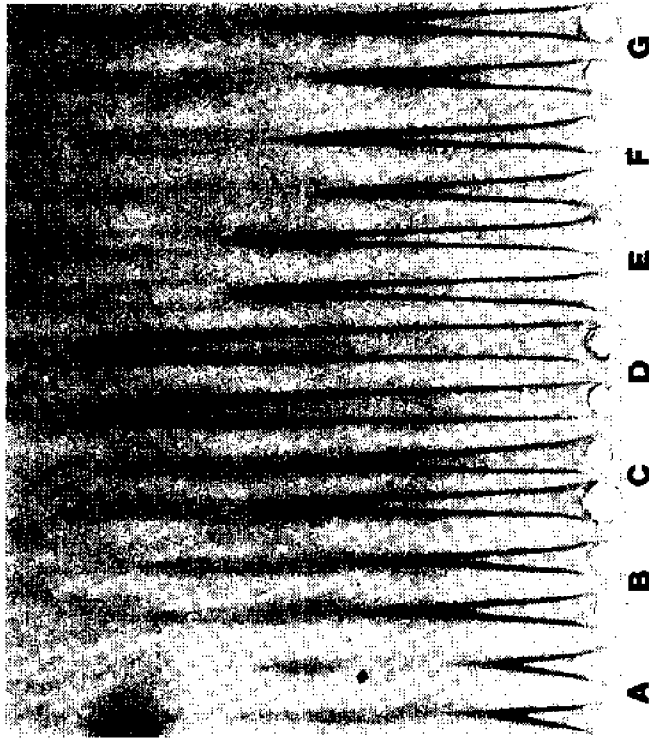


Figure 4. Rocket immunoelectrophoresis of products containing 50% soybean protein additives.

- (A) 1 g/l standard
- (B) 2.0 g/l standard
- (C) 2.0 g/l standard
- (D) 5.0 g/l standard
- (E) Cod
- (F) Haddock
- (G) Fish Stick

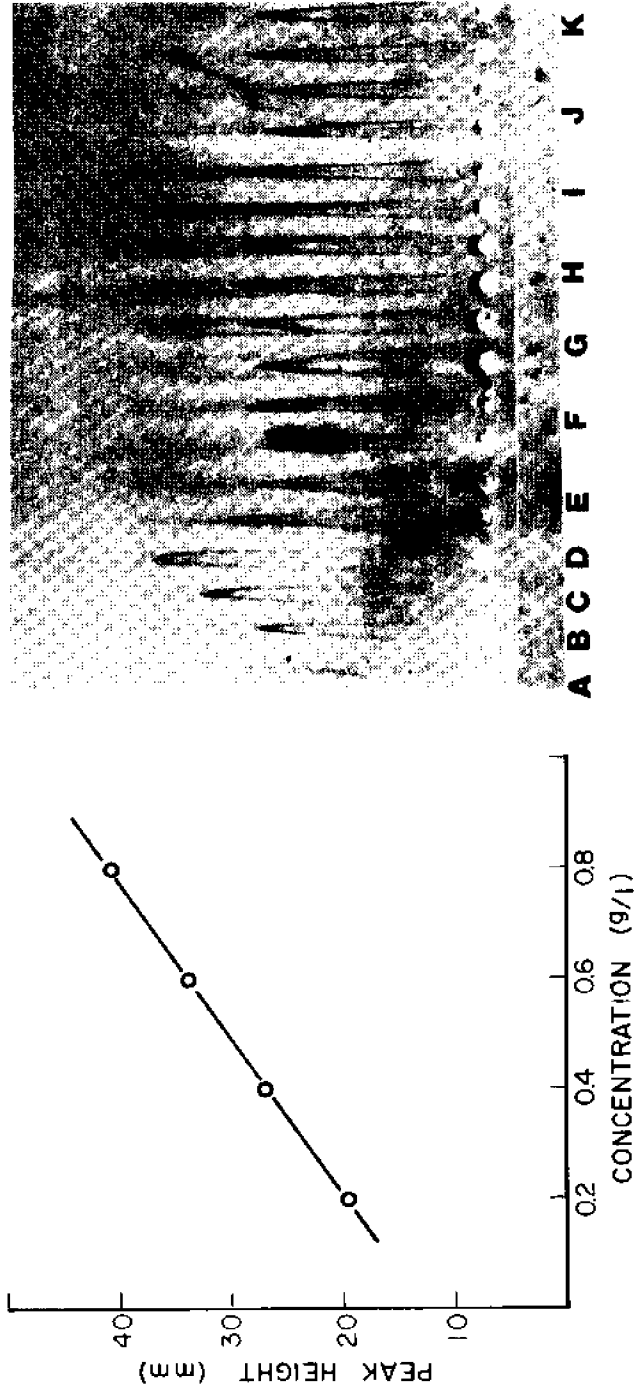


Figure 5. Rocket immunoelectrophoresis of Haddock containing varying amounts of soybean protein additives.

- | | | | | | |
|-----|------------------|-----|------------------|-----|------------------|
| (A) | 0.2 g/l standard | (B) | 0.4 g/l standard | (C) | 0.6 g/l standard |
| (D) | 0.8 g/l standard | (E) | 1% additive | (F) | 2% additive |
| (G) | 3% additive | (H) | 4% additive | (I) | 5% additive |
| (J) | 10% additive | (K) | 20% additive | | |

TABLE I

20% Soy Protein Supplement

Sample	Rocket height (mm)	Soy concentration (g/l) added to gel	Total sample concentration (g/l) added to gel	Percent soy protein in sample (calculated)
std.	17.0	0.5	0.5	100
std.	24.9	1.5	1.5	100
std.	35.2	2.5	2.5	100
std.	38.0	3.5	3.5	100
Ground beef	27.8	1.9	10.0	19
Weiners	28.2	1.9	10.0	19
Haddock	35.0	2.7	15.0	18
Crab	19.0	0.8	5.0	16
Fish stick	28.7	2.0	10.0	20

TABLE II

50% Soy Protein Supplement

Sample	Rocket height (mm)	Soy concentration (g/l) added to gel	Total sample concentration (g/l) added to gel	Percent soy protein in sample (calculated)
std.	8.5	1.00	1.0	100
std.	18.9	2.00	2.0	100
std.	27.8	3.00	3.0	100
std.	46.8	5.00	5.0	100
Cod	32.1	3.42	7.0	49
Haddock	23.6	2.53	5.0	51
Fish stick	23.1	2.48	5.0	50

TABLE III

Haddock supplement with various
amounts of soy protein

Actual % soy in Haddock	Rocket height (mm)	Soy concentration (g/l) added to gel	Sample concentration (g/l) added to gel	Percent/Soy protein in sample (Calculated)
std.	19.5	0.200	0.2	100.0
std.	27.0	0.400	0.4	100.0
std.	33.8	0.600	0.6	100.0
std.	40.6	0.800	0.8	100.0
1%	26.6	0.395	50.0	0.8
2%	27.8	0.435	25.0	1.7
3%	28.2	0.445	16.7	2.7
4%	28.5	0.450	12.5	3.6
5%	29.3	0.470	10.0	4.7
10%	25.8	0.375	5.0	7.5
20%	27.4	0.420	2.5	16.8

PRELIMINARY OBSERVATIONS ON THE FROZEN STORAGE STABILITY
OF THE FRESHWATER PRAWN, MACROBRACHIUM ROSENBERGII

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INTRODUCTION

We have witnessed in the last decade the rapid emergence of the freshwater prawn culture industry (3). I suppose the term industry at present is a misnomer since much of the production at least in the United States has come from government subsidized entities. Increasingly government and industry are participating toward the goal of commercial cultivation of freshwater prawns. To date, much of the research effort has been directed toward intensive culture programs of rearing the various members of the genus Macrobrachium. We have now reached a stage in time where we in the technological field must be prepared to deal with increasingly larger volumes of prawns to prepare, preserve and market.

All of the latter three are closely allied since it is consumer acceptance which taken first governs preparation which, in turn, governs preservation. The alternatives at present are twofold; the first being the traditional tails only where in the case of the freshwater prawns only 40% of the gross weight may be recoverable as salable product whereas the second alternative, that is, heads-on, although utilizing the entire animal, may present major technological problems.

A study was thus launched to determine methods of preparation and preservation. This report presents the preliminary analysis of that study.

MATERIALS AND METHODS

Pond-reared freshwater prawns (Macrobrachium rosenbergii) were obtained from the Brownsville facility of Aquaprawns, Inc. All samples were placed on ice immediately after capture and transported to the Corpus Christi Seafood Technology Laboratory of Texas A&M University where they were separated randomly and assigned into units of ten utilizing the following scheme:

1. Glaze frozen controls (tails only), code FC

2. Glaze frozen heads-on with hepatopancreas removed , code FPG
3. Glaze frozen heads-on, code FUG
4. Vacuum frozen controls (tails only), code VC
5. Vacuum frozen heads-on with hepatopancrease removed, code VPG
6. Vacuum frozen heads-on, code VUG

The treatments described as "hepatopancreas removed" entailed an incision into the cephalothorax with subsequent removal of the hepatopancreas and associated digestive, reproductive and circulatory organs. These samples were then thoroughly rinsed with potable water prior to freezing. All samples were preserved at -20 C.

Monthly samples were drawn for biochemical and microbial tests. The biochemical examination included tests to determine total volatile nitrogen (TVN), ammonia and trimethylamine nitrogen (TMN). All of the latter were determined by microConway distillation of extracts (1). A 7% TCA solution was used to homogenize the shrimp tissue (2 ml:1g, respectively). Na₃PO₄ saturated with KOH was used as the releasing agent for TVN and TMN tests whereas Na₃PO₄ served as the releasing agent for ammonia determinations. Formalin was added to the extract (0.5:1v/v, respectively) for the TMN determinations (1). The latter served to inhibit distillation of primary and secondary amines and ammonia. Furthermore, amino acid nitrogen (AA-N) was determined by the cuperic phosphate suspension method (1).

The microbial test consisted of standard plate counts using the streak plate technique with five days of incubation at 37 C.

Taste panel tests were informally conducted at Texas A&M University. These tests were conducted in three month intervals against a pond-reared white shrimp (Penaeus setiferus) standard.

All data were examined by ADVA with a 2-way classification scheme (4). The treatment means were subsequently compared by the Student-Newman-Keul test for multiple comparisons with $\alpha = 0.05$. In addition all data were plotted by linear regression.

RESULTS

All tests, excluding TMN, were able to detect significant differences over time. However, only the TVN and ammonia values were significantly different among treatments. Fig. 1-5 depict the data for each test and treatment as presented by linear regression.

The results of the TVN analyses revealed that in the standard frozen treatment (glazed), the frozen controls differed significantly from the heads-on samples. The TVN values of vacuum frozen samples showed significant differences between the hepatopancreas removed (VPG) from the remainder

After six months of storage, the taste and moisture scores of the organoleptic test showed significant decreases. Texture, however, remained relatively unchanged. The only detectable difference among the treatments and penaeid control was a significant lower taste score of the heads-on preparation.

DISCUSSION

It is difficult to assess in detail the results of this experiment since data concerning the technological aspects of freshwater prawns is nearly nonexistent. Initially we had anticipated conducting an ice storage test in conjunction with the frozen storage study but the results of our preliminary examination showed that at least superficially, the heads-on samples would not last more than a few days prior to the onset of spoilage. This phenomena in freshwater prawns has been substantiated in the literature (3) as well as by personal conversations with commercial aquaculturists. One may still relate the results of ice storage experiments with penaeid shrimp to the present study. One must, however, keep in mind that ice storage has the benefit of "washing action" whereas frozen storage results in less "drip" loss. These factors in conjunction with the variability of environment creates difficulties in interpretation and comparison.

Superficially the major visual difference between vacuum sealed and standard glaze is the effect of dehydration on the latter. As long as the polyethylene unit is intact, very little, if any, dehydration will take place. In time however, the vacuum will be lost primarily due to handling of the frozen product.

The low levels of TMN found in this study appears to be related to the low salinity/pseudo-freshwater in which the prawns were reared (5). The salinity of the pond water in Brownsville average 3-4%. When one extrapolates the data reported in the literature (5) to this salinity, it becomes very evident that the levels found in this study (2.20-5.81 mg N/100 g) are not only realistic but characteristic of crustaceans reared in freshwaters. In consideration of the very low TMN levels and the inherent error in measuring such levels, we discount this variable in the quality assessment of freshwater prawns.

As expected, the levels of microorganisms decreased over the frozen storage period. The levels (Fig. 5) decreased in the order of one log magnitude and are a result of frozen storage period rather than treatment.

The TVN values reported in this study were substantially higher than that reported for penaeids (1). This levels (17.81-39.00 mg N/100 g) in fact correspond to penaeids held on ice for 15 days and are characteristic of the onset of spoilage in the latter. However, only 30-50% of the TVN found in the freshwater prawns could be attributed to ammonia whereas the latter comprises much of the TVN found in penaeids (1). Thus, the source for the TVN found in this study will have to be verified in future studies.

The informal taste panel comparison among the various treatments showed that up to six months at least, the freshwater prawns compare favorably with penaeids. However, after this period a significant decrease in scores were noted on the heads-on product.

This report has presented the preliminary data and analysis of the frozen storage stability of freshwater prawns under several different treatments. As in most studies the answers obtained are

somewhat overshadowed by the new questions arising. These questions include the role of catheptic enzymes in spoilage on ice prior to frozen storage and the source of the high TVN values. We have demonstrated that the method of preparation does affect the desirability of the product after storage but that the difference was determined organoleptically and not detected by biochemical or microbial tests.

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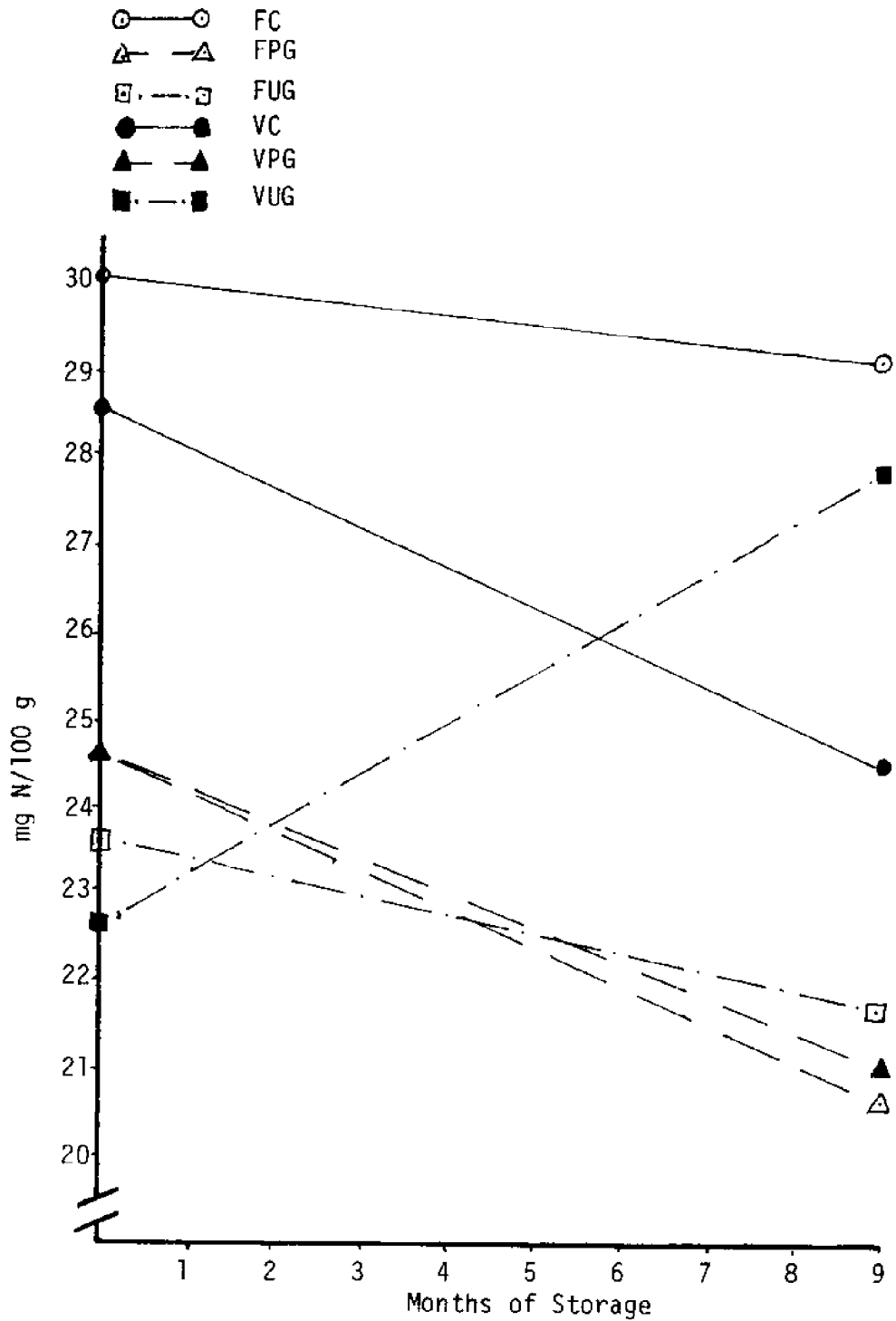


Fig. 1 - The linear relationship as expressed by changes in total volatile nitrogen content for the treatments: glaze frozen controls (FC), glaze frozen heads-on with hepatopancreas removed (FPG), glaze frozen heads-on (FUG), vacuum frozen controls (VC), vacuum frozen heads-on with hepatopancreas removed (VPG), and vacuum frozen heads-on (VUG).

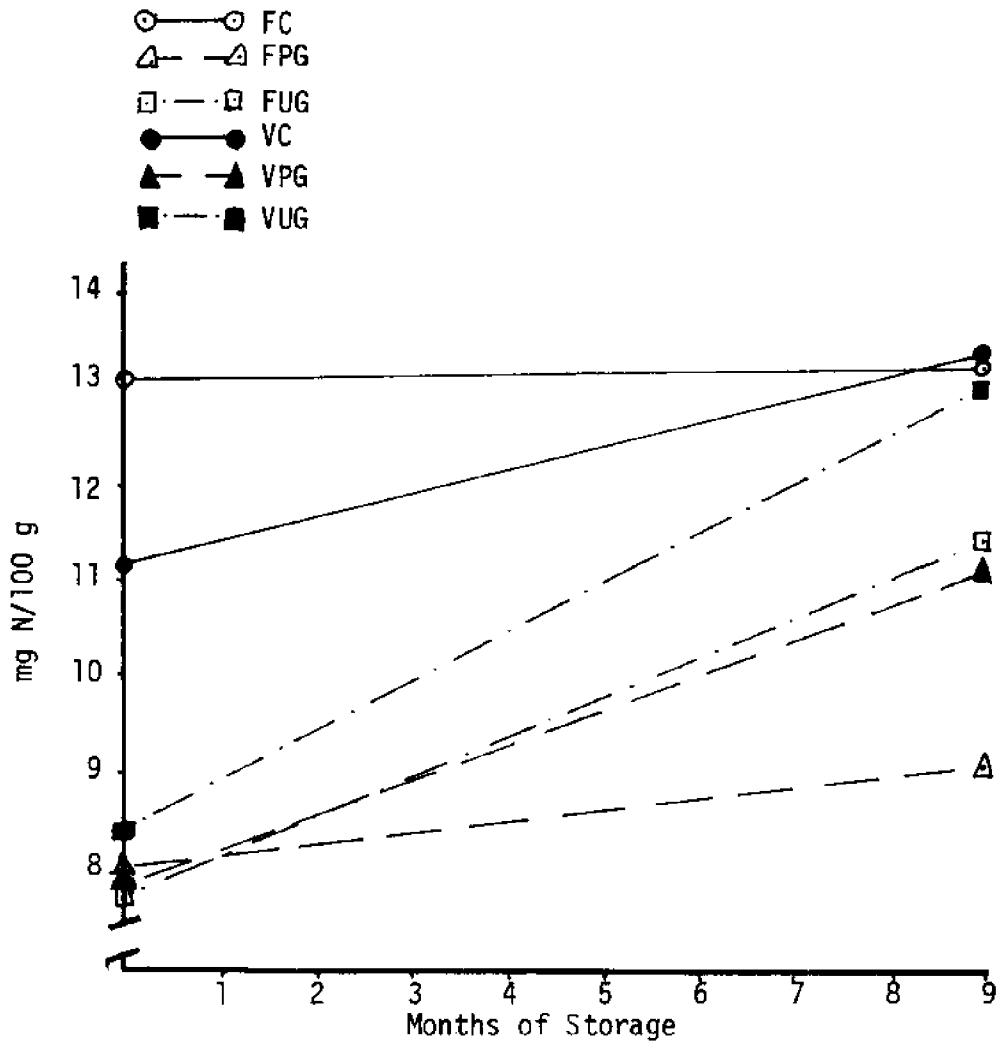


Fig. 2 - The linear relationship as expressed by changes in ammonia content for the treatments: glaze frozen controls (FC), glaze frozen heads-on with hepatopancreas removed (FPG), glaze frozen heads-on (FUG), vacuum frozen controls (VC), vacuum frozen heads-on with hepatopancreas removed (VPG), and vacuum frozen heads-on (VUG).

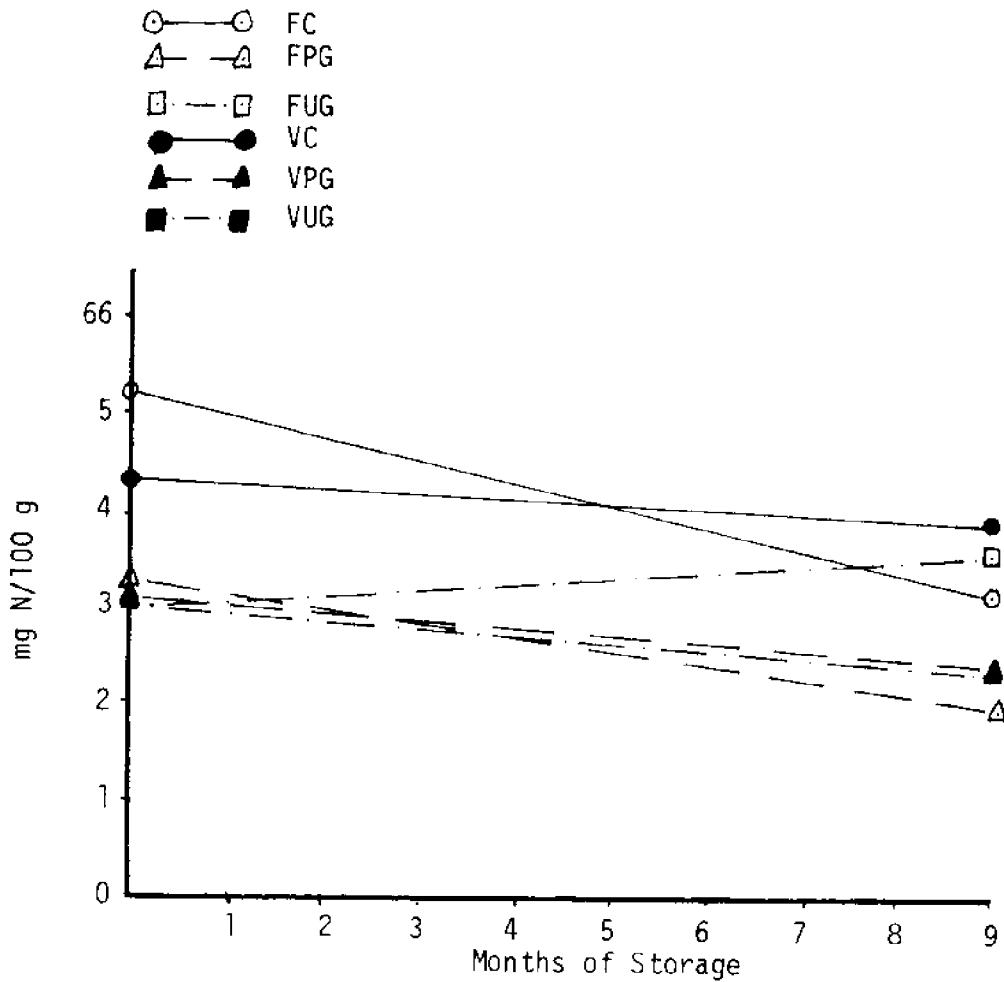


Fig. 3 - The linear relationship as expressed by changes in trimethylamine content for the treatments: glaze frozen controls (FC), glaze frozen heads-on with hepatopancreas removed (FPG), glaze frozen heads-on (FUG), vacuum frozen controls (VC), vacuum frozen heads-on with hepatopancreas removed (VPG) and vacuum frozen heads-on (VUG).

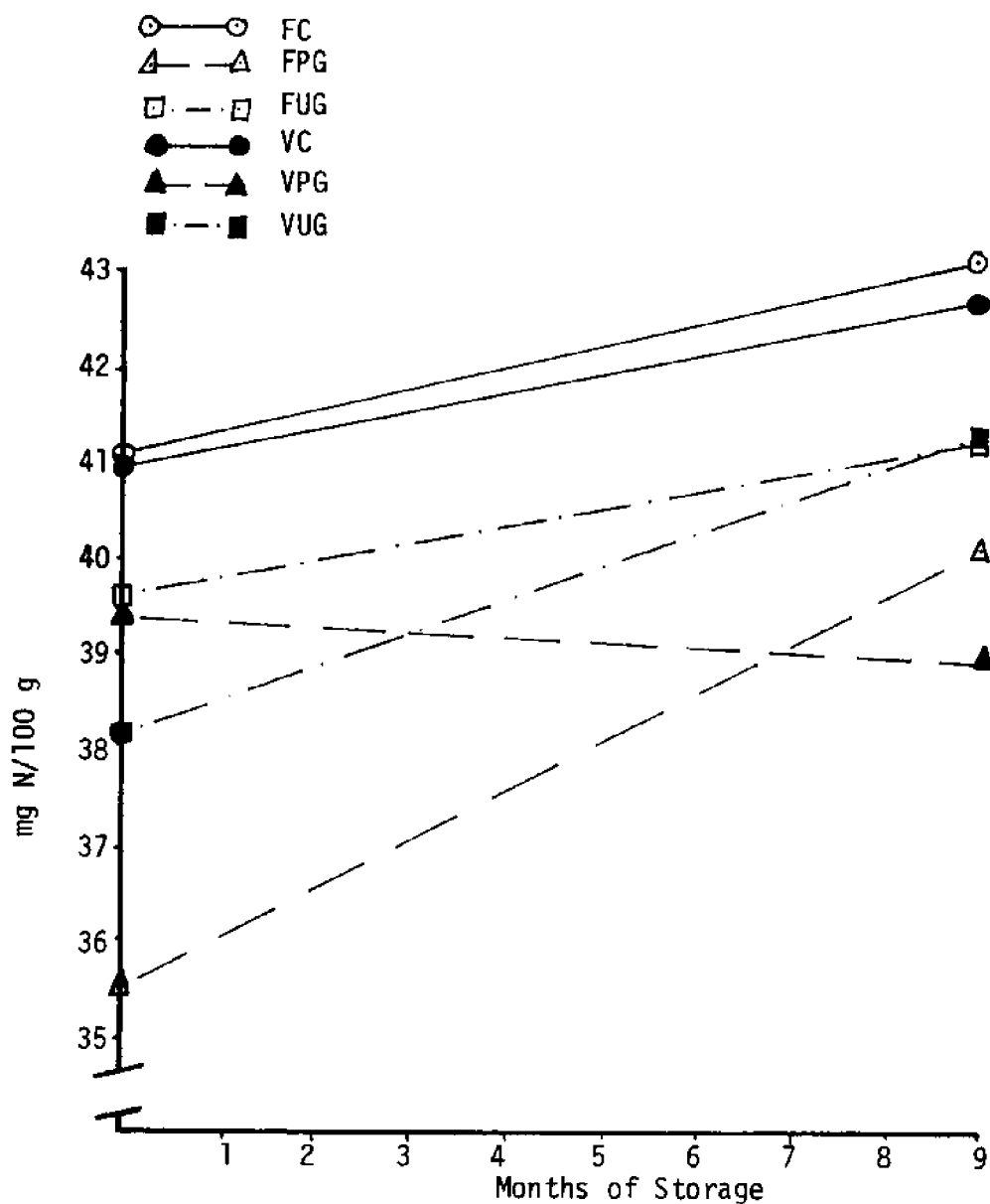


Fig. 4 - The linear relationship as expressed by changes in amino acid nitrogen content for the treatments: glaze frozen controls (FC), glaze frozen heads-on with hepatopancreas removed (FPG), glaze frozen heads-on (FUG), vacuum frozen controls (VC), vacuum frozen heads-on with hepatopancreas removed (VPG) and vacuum frozen heads-on (VUG).

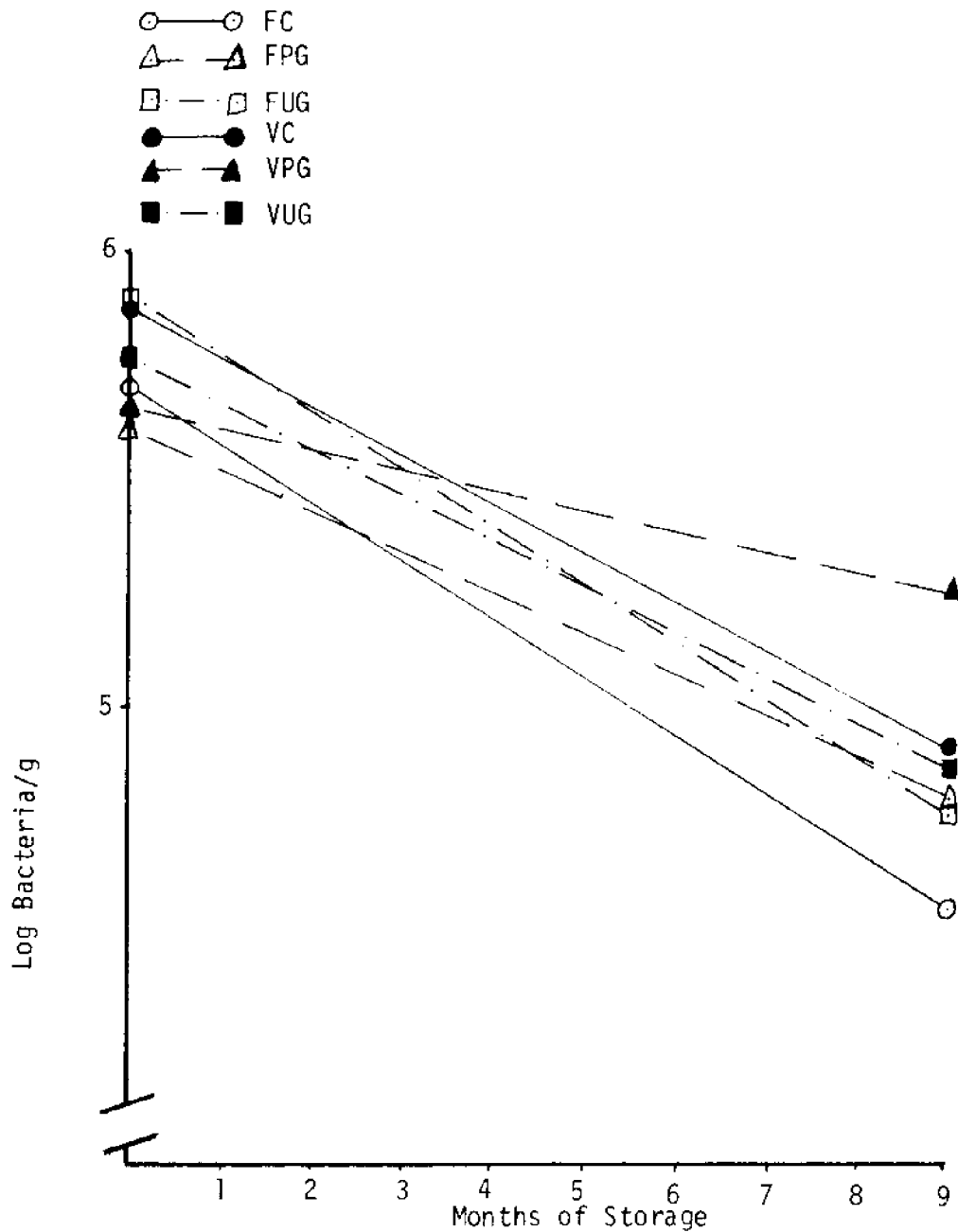


Fig. 5 - The linear relationship as expressed by changes in standard plate count for the treatments: glaze frozen controls (FC), glaze frozen heads-on with hepatopancreas removed (FPG), glaze frozen heads-on (FUG), vacuum frozen controls (VC), vacuum frozen heads-on with hepatopancreas removed (VPG) and vacuum frozen heads-on (VUG).

ECONOMIC POTENTIAL FOR PRODUCING AND MARKETING
UNDERUTILIZED FISH: LAKE OKEECHOBEE SCALE AND ROUGH FISH

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A current major interest in commercial fisheries concerns the development and use of underutilized fish stocks. Making any stock of fish available to commercial harvest requires both biological consideration of the harvest effects on the biomass and consideration of the economic feasibility of producing and marketing the fish. Prohibitive economic barriers in either the harvesting, marketing, or consumer acceptability of a new fish product would render an entire fish management and utilization program ineffective.

The primary objective of this paper is to present the applied economics methods used and results of a study designed to determine the economic feasibility of a fish management and utilization program prior to the initiation of the program.¹ The Florida Game and Fresh Water Fish Commission recommended that Lake Okeechobee in South Florida be opened to commercial fishing subject to certain limitations. Biological recommendations were such that the lake was overpopulated and that annual harvest of one-half the standing stock in the lake would make the lake a more successful fishery from both a sport and commercial viewpoint. Fish proposed for harvest included all fresh water fish except bass and chain and redbfin pickerel. Fishing devices proposed included the traps and trotlines currently legal in Lake Okeechobee and the use of haul seines and trawls subject to certain limitations. All bream and crappie harvested would be tagged before marketing because they are considered gamefish and not commercially legal in other parts of Florida.

The study was designed to indicate prices acceptable to consumers of both scale and rough fish and to determine if these prices would allow adequate economic incentives for fishermen, wholesalers, and retailers involved in the production and marketing of the fish.

¹This paper represents a brief condensation of a detailed report done for the Florida Game and Fresh Water Fish Commission during the first three months of 1976.

Specific commercial outlets for the food fish, the market potential for the rough fish and the number of fishing permits that could be issued to support an economically and biologically successful fishery were determined. Additionally, the study provided a cost analysis of the proposed tagging program.

DATA SOURCES

The analysis presented in this report was based primarily on data gathered through surveys. A total of 88 questionnaires were completed. Information from thirty-one market surveys covering retailing and/or wholesaling activities provided the basis for the expected prices, margins and sales volumes. Cost of production analyses of haul seiners and trawlers was based upon information from nineteen Florida operators and seven out-of-state interviews. The utilization potential of rough fish was developed from surveys conducted with an additional thirty-one firms or individuals.

ECONOMIC HARVEST POTENTIAL AND REQUIRED FISHING EFFORT

Cost and return data for haul seines and trawls were developed to answer two questions. First, expected net returns at two different fish price levels were estimated to indicate the economic feasibility of both haul seine and trawl fishing. Second, the numbers of haul seine and trawl units needed to achieve the biologically recommended minimum harvest were determined for economically feasible catch rates.

Harvest Rates

Production data on haul seines were based on an average catch of two pounds per yard of net per haul from an earlier study of Lake Okeechobee. Total production of 499,200 pounds per year was estimated given an anticipated 156 days of fishing effort per year. Species composition of the haul seine catch was 82,680, 60,216, 39,000, and 317,304 pounds, respectively for catfish, bream, crappie and rough fish. The low number of fishing days was used because fishing would be allowed only during weekdays by program design. Further limitations due to down time and weather led to the estimate of fishing days. Harvest data for a 30 foot trawl was based on estimates from 23, 31, and 34 foot trawls experimentally fished by the Game and Fresh Water Fish Commission during winter months for biological surveys. A weighting scheme was used to adjust the normally higher winter catch rates to develop a daily catch rate for lake trawling. Based on 156 days of fishing effort total annual production for a trawling unit was estimated to be 113,100 pounds made up of 12,480 pounds of catfish, 17,004 pounds of bream, 28,236 pounds of crappie, and 55,380 pounds of rough fish.

Annual revenue generated with these harvest rates was based on round-weight prices of 31 cents per pound for catfish, both 30 and 25 cents for crappie and bream (30 cents used for this paper) and three cents for rough fish. Catfish prices were based on market prices and the remaining prices were based on the marketing surveys.

Annual total revenue estimated for a haul seiner was \$63,511 and \$19,102 for a trawling unit.

Costs of Production

Cost schedules were developed for fishing units. Variable costs for gas and oil, ice, repair and maintenance, crewshares and miscellaneous cost items represented 84 percent of total costs of haul seining and 50 percent of total costs of trawling. The main difference was due to crewshares since a haul seine unit requires four men while the small trawling units require only one operator. Depreciation, licenses, and permits constituted fixed costs. Total cost annually was estimated at \$50,178 for haul seining and \$7,122 for trawling.

Net Returns

Comparison of anticipated costs and returns left a net return to the owner of a haul seine unit of \$13,333 and \$11,980 to a trawl unit operator. Total investment required for a haul seine unit was \$22,600 while only \$9,900 was required for a trawl unit. Total net returns per day of fishing effort in haul seining was \$85.47 compared to \$71.72 to the owner of a trawling unit.

Economic Potential

With these anticipated prices and estimated harvest rates it was concluded that fishermen would be encouraged to enter the fishery because of the projected net returns. This return favorably compared with those from other small scale low capital investment fisheries in which fishermen were currently engaged in other areas of Florida.

Number of Fishing Units

Current harvest from Lake Okeechobee of catfish, bream crappie and rough fish at the time of the study was 2,264,868 pounds from trotlining, trapping and sport fishing (Table 1). Biological minimum recommended harvest was estimated at 21,532,421 pounds annually, which left an available minimum harvest of 19,267,553 pounds to reach biological control standards for the biomass in the lake. Based on the annual catch rates for trawls and haul seines it was determined that 39 haul seines or 170 trawls would be necessary to reach this minimum recommended harvest if only one method or the other was allowed (Table 1). Various combinations of haul seine units and trawl units to reach the minimum recommended harvest were also determined for the total catch and for the individual species (Figure 1). Because the population of some species were more limited than others the minimum harvest would be reached with fewer days of fishing effort for these species. Linear equations were provided to determine the number of haul seines and fishing units for various combinations of fishing units and desired

Table 1. Estimated haul seine and trawl operating units needed to maintain the minimum recommended harvest in Lake Okeechobee by type of fish and total pounds of fish

Type	Present ¹ Harvest	Minimum Recommended Harvest	Necessary Harvest to Maintain Minimum	Haul Seines Needed to Maintain Minimum ²	Trawls Needed to Maintain Minimum ³
Catfish	1,947,462	3,565,300	1,617,838	20	130
Bream	103,935	2,598,369	2,494,434	41	147
Crappie	212,471	1,687,339	1,474,868	38	52
Rough Fish	1,000	13,681,413	13,680,413	43	247
Total	2,264,868	21,532,421	19,267,553	39	170

¹ Game and Fresh Water Fish Commission. "Okeechobee Fishery Utilization Proposal."

² Based on annual harvest rate per haul seine of 499,200 pounds and no trawls operating.

³ Based on harvest rate per trawl of 113,100 pounds and no haul seines operating.

⁴ Determined by dividing the necessary harvest to maintain minimum for each type by the catch per operating unit for each type.

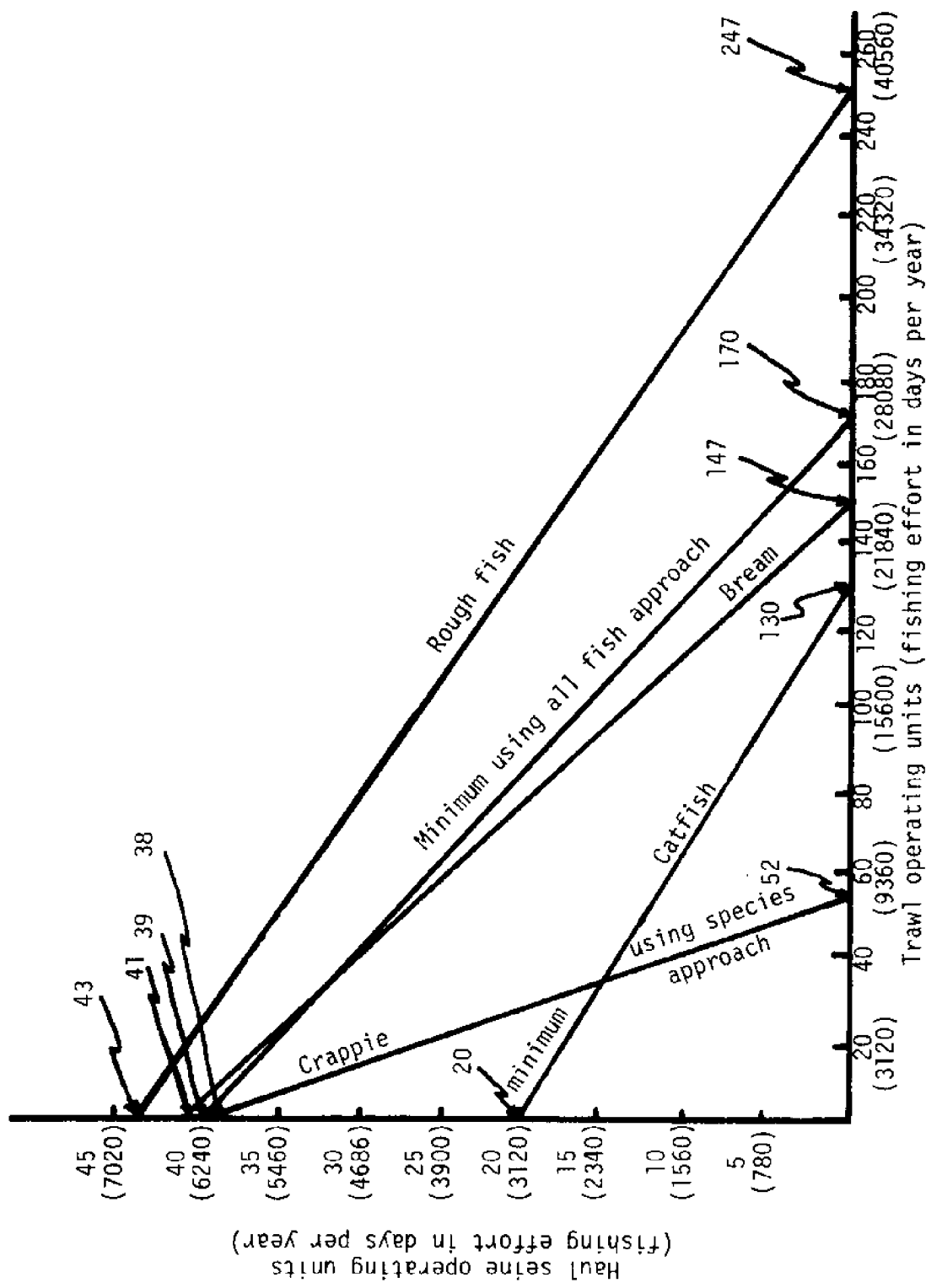


Figure 1.--Various combinations of trawls and haul seine units and days of fishing effort needed to maintain minimum recommended harvest

days of fishing effort.² These equations for the total population and individual species can be used to determine annual numbers of fishing units allowed to reach recommended harvest as annual catch rates vary. Equations were also provided to determine various combinations of full-time fishing units to reach recommended harvest.

MARKET POTENTIAL FOR BREAM AND CRAPPIE

The market potential for these two species, not previously legal commercially in Florida, was assessed by determining the expected prices and margins at both the retail and wholesale market levels. These margins were then related to prices necessary to cover fish production costs and program administration costs. Price relations were examined to determine if all parties involved in the market and production system would receive adequate returns to encourage participation in the market. A final consideration was to determine the market effect on species with which bream and crappie might compete in the market.

Retail Fish Marketing

Retail surveys were obtained from sixteen retail fish markets located throughout the state of Florida. Average anticipated sales per retail fish market in Florida was 11,101 pounds of crappie and 11,046 pounds of bream annually for a total of 22,047 pounds. Approximately 225 retail markets out of the 5,000 retail seafood licensed firms in Florida could handle the entire minimum recommended harvest of bream and crappie from Lake Okeechobee. North and Central Florida retailers' estimates of sales were over twice the estimate in South Florida. Seventy percent of the retailers interviewed believed the legalization of sales of bream and crappie would bring new customers to their establishments.

Crappie was expected to be slightly preferred to bream, bringing an average price of \$.82 per pound while bream was expected to sell for approximately \$.75 per pound. Retailers expressed a willingness to pay suppliers an average of \$.42 per pound for crappie and \$.39 per pound for bream. Both the selling price and the purchase price varied considerably by location and region. One factor

$$^2M = ah + bt$$

where:

- M = minimum recommended harvest
- a = annual haul seine catch rate
- h = number of haul seine units
- b = annual trawl catch rate
- t = number of trawl units

For a given h or t the equation can be solved for the other variable to determine various combinations of haul seines and trawls to reach recommended harvest.

causing the variation in estimated price was the expected size of the fish landed. Most retailers expressed a preference for individual fish of eight ounces and above, but it was recognized that initially a large part of the catch would be less than eight ounces.

Individual estimates of margins necessary to cover all expenses, including profits, were more consistent than estimates of market prices. The weighted average estimated margin for crappie was \$.40 per pound and \$.35 per pound of bream. Those estimating larger sales tended to operate on smaller margins which is consistent with normal business practices.

As was noted earlier, most retailers (70 percent) expected new customers if bream and crappie became legal in Florida seafood markets. However, bream and crappie would also be substituted for some existing species in the market. Tilapia was most frequently suggested as a substitute species at the retail level. Sheepshead, drum and sand perch were also frequently mentioned and catfish less often. Several retailers suggested that there would be no price effect on tilapia since it is considerably lower in value (price) compared to that anticipated for bream and crappie. Furthermore, a substantial unfulfilled demand presently for tilapia was noted in the Central Florida area. Introduction of bream and crappie into these markets may simply reallocate the present supply of tilapia to deficit fish supply areas rather than depress its market. Specific price effects on other fish is discussed in a later section of the paper.

Wholesale Fish Marketing

Twelve potential bream and crappie wholesalers who marketed catfish from Lake Okeechobee (and other areas) were interviewed. The average wholesaling firm expected to sell approximately 13 percent of total volume to Florida buyers and the remaining 87 percent out-of-state. Total annual projected sales of bream and crappie could reach nearly one million pounds in-state and 6.6 million pounds out-of-state for a total of approximately 7.6 million pounds annually. Eleven wholesalers projected out-of-state sales to be 165 percent of the available recommended harvest (4 million pounds) from the lake. In addition, the additional one million pounds to Florida buyers would only meet the projected demand of approximately 45 retail outlets in Florida. If projected demand is nearly twice the projected supply, prices will be considerably higher than presently anticipated and this would insure the economic success of the program.

Marketing Margins

Added costs to the fish as they moved through the wholesale market sector was calculated using two methods. First, wholesalers were asked about expected prices in Florida, all Southern states, the Midwest, and Northern states. The expected price in Florida was 48 cents while 57 cents per pound was anticipated in other states. An imputed wholesale marketing margin was then calculated between these prices and the prices wholesalers

expected to pay fishermen.

The second method involved estimating actual expected operating costs as a check in determining the wholesale marketing margin. Assembly costs, boxes, ice, labor, and delivery costs to designated market locations were determined as well as costs of overhead and returns to management. These individual estimates allowed estimates of the marketing margin for each of three sales areas. These margins ranged from 16.68 to 22.28 cents per pound.

Program Administration Fee

Another added marketing cost would be the tagging of bream and crappie introduced into the market. This is necessary since harvest is not legal in any other part of Florida. This cost was estimated to include a fee to cover the cost of the tag, its application, and provide enough revenue to cover the state's cost of administering the entire utilization and management program. The cost estimate depends on the number of fish per pound, tag cost, level of total catch, labor wage rate, and level of administrative funds to be generated. A range of costs were presented for consideration. Three levels of administrative cost, four levels of total catch of bream and crappie and two fish sizes were considered. Within each of these classifications, tagging fees per pound and per tag were calculated and added into the marketing margin as a cost at the wholesale level.

Estimated Prices and Total Margins

Bream and Crappie Prices

The process of determining the market feasibility of catching and marketing bream and crappie involved adding fishing and marketing costs at each level and comparing these to expected or "reasonable" prices. The costs of production analysis showed that 30 cents per pound would yield fishermen an acceptable level of returns and encourage fishing activity. The tagging fee used was 5.61 cents per pound or 1.87 cents per tag. Addition of production costs, tagging costs, and marketing margins at the wholesale and retail levels gave an estimated retail price of 92.5 cents per pound in Florida (Table 2). This price was consistent with those currently charged for tilapia and catfish in Florida. Consideration of other market outlets also presented a favorable economic potential. Bream and crappie could be delivered to most Southern states at an average 56.50 cents per pound with an anticipated market wholesale price of 57.0 cents. Delivery cost to Northern and Midwestern states was 60.5 cents and average expected wholesale price was 71.0 cents (Table 2).

Favorable results of the analysis of out-of-state markets was especially important considering wholesalers' estimates are that these markets would absorb more than one and one-half times the minimum recommended harvest from the lake. This means that anticipated Florida prices would be driven up to obtain any of the available supply and because of the shortage in the out-of-

Table 2. Estimated costs, margins and prices for bream and crappie by types of market and sales area

Item	Cents per pound
Fisherman price	30.00
Program management cost:	
Tagging labor	2.21
Tag and administration	5.61
Florida analysis:	
Margin to Florida wholedeale dealers	<u>16.68</u>
Total cost to Florida retailers	54.50
Retail margin for crappie	<u>38.00</u>
Computed Florida retail price	92.50
Southern states analysis:	
Margin to Florida wholesale dealers	18.68
Total cost to deliver to Southern states	56.50
Expected price to Florida wholesalers	57.00
North and Midwest analysis:	
Margin to Florida wholesale dealers	22.68
Total cost to deliver to North and Midwest states	60.50
Expected prices to Florida wholesalers	71.00

state markets. There appeared to be sufficient demand to absorb the total catch with adequate returns to all involved in the production, marketing and administration of the bream and crappie segment of the lake fishery.

Effect on Existing Fisheries

The effect of the proposed program on prices in the markets for existing fisheries was the last major consideration. Tilapia, the most frequently mentioned substitute for bream and crappie had only been a commercial fish for three years and sufficient data were not available for analysis of the effect of bream and crappie on tilapia prices. In addition, crappie and bream had not been on the commercial market making the analysis indirect rather than through direct statistical estimation.

The anticipated effect on tilapia prices was estimated to be minimal for several reasons. First, anticipated prices for bream

and crappie on the market were considerably higher than tilapia prices. Second, there is some potential of present tilapia fishermen shifting to crappie and bream fishing with nets in Lake Okeechobee and this would reduce the tilapia supply which should raise prices to at least offset any detrimental effects. Third, both wholesalers and retailers stated that currently, a considerable demand for tilapia goes unsatisfied. Fourth, the potential for out-of-state shipments of bream and crappie means that most of the competition would be with species other than tilapia.

In almost all cases, both retailers and wholesalers stated catfish prices would not be affected by the introduction of bream and crappie. This leaves small saltwater ground fish as available substitutes. A review of over forty estimated demand equations showed the demand for individual species and the aggregate of species at the wholesale level to be highly elastic. This meant that a relatively large percent change in quantity would result in a relatively small change in price. The introduction of four million pounds of bream and crappie into the Florida market would result in a decrease of 1.37 percent in average prices. This translates into a projected decrease of one-third of one cent per pound for all Florida finfish.

ROUGH FISH UTILIZATION

Rough fish such as gizzard shad and gar make up a large portion of the biomass in Lake Okeechobee. Markets for these fish provided the largest hurdle for program success. Potential markets analyzed for rough fish included animal consumption (fish bait, crab bait, reptile and mammal feed, fish meal, and pet food), human consumption (roe), and other uses (fertilizer and oil).

Animal Consumption

Fish Bait

Chumming of haul seine areas is to insure reasonable catches. It was estimated that each haul seine unit would utilize about 50,000 pounds annually (primarily gizzard shad). These fish would be provided by each haul seiner for their own use. Utilization of lake rough fish for chum in other fisheries such as ocean going party boats did not appear to present any market potential.

Crab Bait

With one exception all crab bait dealers indicated a supply situation during 1975 that left some demand unfilled. Generally, about 35 percent of the crab bait market in Florida went unfilled. This represented a potential annual need for 1.8 million pounds of rough fish in the crab bait market. This market currently existed at no development cost. Expected delivered prices in the crab bait market were between five and six cents per pound. Freezing and bait delivery costs would have left between two and three cents per pound return to fishermen for rough fish.

Demand for crab bait is seasonal. About 40 percent of annual demand occurs during the summer months with consumption during the fall, spring, and winter consisting of about 30, 20, and 10 percent of annual demand. Developing a successful crab bait market for initial rough fish coming from the lake depended on the time of program implementation. The lead time and capital requirements for the development of this market were fairly minimal.

Reptile and Mammal Feed

Marine mammal attractions indicated a general unwillingness to use freshwater fish because they wished to maintain the diet of their mammals as close as possible to that consumed in their normal habitat. Reptile attractions were not interested in Lake Okeechobee rough fish because of the high percentage of gizzard shad and the potential odor problem near tourist attractions.

Fish Meal

In general, when fish meal is in the range of 1 1/2 to 2 1/2 times the price of other protein feeds such as soybean meal, it is combined with grain, alfalfa, silage, etc., and becomes a part of feed for poultry and swine. The demand and price of fish meal is highly correlated with that of soybean meal. At the time of this study soybean meal was about \$135 per ton at Midwestern localities and fish meal was currently quoted at about \$260 per ton at Gulf and Southeastern locations.

Processing all 14 million pounds of potential harvest into fish meal would have increased total U. S. supply about 1,500 tons. U. S. supplies averaged about 260,000 tons the last three years. This increased supply would have negligible effect on fish meal prices.

Rough fish from Lake Okeechobee make a very oily raw product. Simple processing of the fish into a meal that could be easily sold was not possible. The two feasible possibilities were shipping the raw fish to a processor capable of further processing or developing a processing facility on Lake Okeechobee.

Holding facilities would be required to assemble fish in the vicinity of Lake Okeechobee for two weeks at expected harvest rates before economical shipping costs could be achieved. Even at full boat load rates for a 400 ton vessel, shipping and storage costs would exceed the price the nearest processor could afford to pay for the raw rough fish product. At normal shipping costs and if fishermen were to receive a minimum of two cents per pound, the world price of fish meal would have to rise to about \$475 per ton. Prices this high are not probable currently. This use of rough fish did not appear economically feasible.

The estimated cost of establishing a processing facility on Lake Okeechobee would require an estimated capital outlay of

\$700,000. The facility would process about 50 tons of raw material per 24 hours. One ton of raw material would yield 450 pounds of high protein meal and about 310 pounds of oil. These two products at 1976 price would have yielded a market value of \$105 per ton of raw product.

This raw product yield would have returned fishermen less than one cent per pound. At these prices rough fish would first go into the bait market with the residual going to meal. Average total cost from processing would equal average returns at about 4,000 tons of raw material processed annually or slightly more than one-half the available raw product in the lake. These cost and price factors make either kind of rough fish utilization for meal economically unfeasible.

Pet Food

Because of the composition of the rough fish and low raw supply volumes pet food manufacturers were not interested in rough fish utilization.

Human Consumption and Other Uses

Gizzard shad roe is consumed locally and represents the only possible use for human consumption. Mullet roe during 1975 commanded a wholesale price of \$2.00 per pound. A similar market for shad roe would have yielded 2.5 cents per pound for the whole shad to the fisherman. The remaining parts of the shad could still be marketed in any of the other methods. Little commercial interest was found for this use of shad.

The process used to manufacture fertilizer from fish is precisely the same as for fish meal. In recent years the price for fish meal has been more attractive than fertilizer prices and for that reason few fish have ended up as fertilizer. Oil is produced as a by-product of fish meal and its production would depend on the feasibility of fish meal production.

ECONOMIC IMPACT

The six counties surrounding Lake Okeechobee represented an area which would benefit substantially from the proposed program. Employment generated in the immediate Lake Okeechobee area by the full scale operation of the Utilization Plan based on an operation of five haul seine and 45 trawl units would number approximately 79 people. An additional 148 jobs would be created throughout the economy of Florida and the U. S. from processing through final consumption. These estimates then total 227 jobs created by the program at full operation. Even if all the fish were consumed out-of-state, approximately 70 percent of the jobs, 159, would still be created in Florida.

Based on the operation of five haul seine and 45 trawl units, a total of \$784,520 in returns to owners and crewshares would be generated on an annual basis. An initial capital investment of

\$558,500 would be made for equipment and another \$190,685 would be spent annually in the Lake Okeechobee area for gas, oil and other expenses of operation. Total annual sales by fishermen would be \$1.2 million. The addition of bream and crappie to the Florida seafood production and marketing industry would generate a wholesale sales value of fresh water fish of between \$2.9 and \$4.9 million. Exact value would depend on the amount sold outside Florida. These estimates assumed approximately four million pounds of bream, crappie and an additional 1.6 million pounds of catfish would be sold.

SUMMARY AND EVALUATION

Using price levels and catch rates thought to represent actual conditions that would exist in the proposed Lake Okeechobee haul seine and trawl fishery it appeared that both types of fishing operations would be economically feasible. An adequate number of permits to trawl and haul seine could be issued to insure public support of the program. A substantial demand for bream and crappie was evident. Less than 200 retail outlets in Florida could market the entire catch. In addition, out-of-state demand expressed a potential of 150 percent for the projected catch. Expected prices appeared to be more than adequate to cover all costs of production, processing, and marketing and for administration of the utilization program. Adverse market effects on other Florida foodfish producers would be nominal for a few species and non-existent for most species.

It was apparent that there was a partial market for "rough" fish or fish other than bream and crappie. The data suggested that rough fish could start generating income to fishermen amounting to about \$70,000 annually. The cited markets are easy to develop, the capital requirements are moderate and the time to activate the necessary facilities is relatively short. Allowing for at least two haul seiners and 50 trawls, it could be expected that 3.04 million pounds of rough fish are likely to be harvested based upon available markets. There will be about 700,000 pounds of rough fish that will not have a ready, reasonably priced market. Publicly supported marketing efforts will likely be required to develop a market for the excess rough fish.

The Lake Okeechobee Fish Management and Utilization Plan was initiated on October 15, 1976. In the five months ending on March 4, 1977, a total of five haul seine permits and 200 trawl permits were issued. All haul seine units and about 150 trawl units were fishing full-time. The total harvest during this period in which weather was a limiting factor amounted to 432,816 pounds of catfish, 1,689,698 pounds of bream and crappie, 637,991 pounds of rough fish and a small amount of turtles.

Fish buyers were paying 35 to 50 cents per pound for untagged bream and crappie to the fishermen. Dealers or tagging stations are sold tags for 2 1/2 cents each and could charge up to six cents for tagging. Bream and crappie were selling tagged at the wholesale level for 50 to 75 cents per pound and up to \$1.19 per pound in the in-state retail market. Rough fish prices at the

fisherman level ranged from between seven to 12 cents per pound.

All prices estimated in the initial report were slightly lower than those actually occurring in the market at all levels after initiation of the program. It was pointed out that there would be insufficient supply to meet projected demand for bream and crappie and that higher prices than used in the report might occur. Lack of supply to satisfy demand has apparently led to the higher than anticipated price. Lack of markets for the rough fish has also materialized as was pointed out, although prices are higher than anticipated. Catches of rough fish are also lower than anticipated. This apparently stems from the desire of the fishermen to catch the higher valued species and the abnormal winter conditions during the initial program months which restricted effective operation of the haul seine units.

This paper has shown the methods and application of applied economics in its use to analyze an anticipated fishery management program. Answers are necessary in all these areas before the success of any management and utilization program can be judged before its implementation.

ECONOMETRIC FORECASTS FOR THE UNITED STATES TUNA INDUSTRY*

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I. INTRODUCTION

Industry modeling has currently reached a stage of development where it is recognized as an effective tool for marketing and planning decisions. Although past modeling efforts have been directed towards large industries, little has been done for the smaller and more volatile industries. These industries are more difficult to model because of cyclical benefits, especially with regard to greater stability in economic cycles.

The purpose of this paper is to forecast the future market conditions in the tuna industry, which is small and specialized. The methodology chosen is econometric because the greater flexibility of the techniques allows the best use of limited data. Although landings are forecasted, the orientation of the model is primarily economic; specifically the consumer, producer and price structures of the industry.

The model is used in two types of forecasting exercises. The first is what is known as a "control" or "baseline" forecast. This assumes that the structure of the industry remains basically the same and that there are "normal" changes in national and international conditions (the national and international trends are predicted by an independent source). The model would then predict how the industry will adapt to these future conditions. A control forecast of this type is presented in Section III.

The second use of the forecast model is an "alternate" forecast which examines the effects of effective legislative restrictions on purse seine harvesting of yellowfin tuna that school with porpoise. The purpose of the restrictions is to limit incidental porpoise mortality, and preliminary tests

*This paper in no way reflects the official views of the United States Department of Commerce.

indicate that the model could help identify some of the economic impacts the industry would face from such a restriction.

The paper is divided into three remaining sections. The first section describes the estimation of the economic model based on characteristics peculiar to the tuna industry. The second section provides the "baseline" forecast which is used for comparison with the alternate forecasts. The third section discusses the "alternate" forecast on future market conditions resulting from legislative restrictions on purse seine harvesting.

MODEL ESTIMATION

In this section we discuss the variables and interrelationships that make up the tuna model. The main types of endogenous variables are landings and imports of raw tuna, canned supplies, consumption, and prices. Exogenous are U. S. consumption and prices, the Inter-American Tropical Tuna Commission (IATTC) quota, and fleet capacity (gross tonnage). A list of the variables' symbols is provided in the appendix.

Equation Estimation

Catch per vessel-ton-tropical tuna

In the model, catch per vessel-ton (PVTT) is used as an index of vessel productivity. It is an estimation based upon past industry performance and incentives to increase production. The explanatory variables are lagged polynomials of the dependent variable and the deflated exvessel price of yellowfin (PXTS). Because the catch is regulated in important areas, the allowable number of fishing days (QT) is also included in the estimation.

The Wholesale Price Index (WPI) is used as the price deflator. The variables D1, D2, and D3 are seasonal dummies for the first, second, and third quarters, respectively. The variables DT1, DT2, DT3 are the seasonal dummies multiplied by a time trend to reflect any changing seasonal patterns.

As vessel productivity increased in past quarters (the dependent variable lagged), the current period's productivity (in 1,000 lb./vessel-ton) increased but at a decreasing rate. Thus, diminishing returns in the tropical tuna fishery are illustrated as past effort influences present catch rate. The real exvessel price of yellowfin, reflects production costs and has a net positive relationship to catch per vessel-ton over the whole cycle of the lag. Notably, the current period shows a negative sign, which is probably due to short-run adjustments by harvesters in the use of existing vessel tonnage.

Finally, for every day added to the IATTC quota, the quarterly catch per vessel-ton increases. Explicit seasonal

variables are also added to account for changing industry harvesting patterns. That these changes have taken place primarily between the second and third quarters is probably because of the increasingly stringent IATTC quotas. (T-tests values in parentheses)

EQUATION 2.1

$$\begin{aligned}
 PVTT = & 0.0041069 QT + 0.096395 D1 + 0.58022 D2 + 1.66351 D3 \\
 & (1.963) \quad (0.149) \quad (0.802) \quad (2.198) \\
 & - 0.0029882 DT1 + 0.00048774 DT2 - 0.013891 DT3 \\
 & (-0.426) \quad (-0.066) \quad (-1.710) \\
 & + \sum_{i=1}^5 a_i PVTT_{t-i} + \sum_{j=0}^4 b_j \frac{PXTS}{WPI} t-j
 \end{aligned}$$

\underline{i}	\underline{a}_i	\underline{T}	\underline{j}	\underline{b}_j	\underline{T}
1	0.0162	0.013	0	-10.15	-2.747
2	0.2249	3.012	1	2.195	1.262
3	0.2798	3.398	2	7.357	0.451
4	0.1663	2.023	3	5.335	3.237
5	0.1156	-0.872	4	-3.871	-1.034
SUM	0.8028		SUM	0.866	

Regression:

-2
R = 0.7356
SE = 0.3176
DW = 1.7499
PERIOD = 1963.1 to 1975.4

CONSTANT IS SUPPRESSED
CONSTRAINTS: NONE
DEG. POLYNOMIAL: 2

Catch per vessel-ton-albacore tuna

Estimated similarly to tropical tuna, vessel productivity for albacore (PVTA) is most influenced by seasonal factors, which reflect the availability of this tuna, and by the previous catch rate. The deflated price (PIA) has a positive relationship with catch per vessel-ton; however, the statistical significance is low.

EQUATION 2.2

$$\begin{aligned}
 PVTA = & 0.016170 \frac{PIA}{WPI} - 0.39403 D1 - 0.51591 D2 + 0.98721 D3 \\
 & (1.582) \quad (-1.605) \quad (-2.055) \quad (3.068) \\
 & + 0.0019377 DT1 + 0.0029362 DT2 - 0.0075639 DT3 + \sum_{i=1}^4 a_i PVTA_{t-i} \\
 & (0.7066) \quad (1.0921) \quad (2.5399)
 \end{aligned}$$

Equation 2.2 (con.)

<u>i</u>	<u>a_i</u>	<u>T</u>
1	0.1353	1.609
2	0.1781	3.605
3	0.2209	3.409
4	0.2637	2.373
SUM	0.7980	

Regression: -2

R =0.8045

SE=0.1445

DW=1.8446

PERIOD=1962.1 to 1975.4
CONSTANT IS SUPPRESSED

CONSTRAINTS: NONE

DEG. POLYNOMIAL: 2

Landings:

Landings have two categories: (1) tropical tuna, which include yellowfin, skipjack, and bluefin and are primarily harvested by purse seines; and (2) albacore tuna, which are primarily caught by bait or jig boats. In the model, landings of tropical tuna and albacore (LT and LA) are calculated as an identity equal to the landings per vessel-ton in the fishery (PVTT and PVTA) times the number of vessel-tons (NVTT and NVTA). The number of vessel-tons is exogenous to the model.

$$LT = PVTT * NVTT \quad 2.3$$

$$LA = PVTA * NVTA \quad 2.4$$

Total landings (L) are the sum of landings of tropical tuna and albacore landings.

$$L = LA + LT \quad 2.5$$

Domestic canned pack

Explaining the domestic pack (DCPS) is best done using a technology relationship based upon the supply of inputs and modified by short-term trend factors. The supply of raw tuna (SRWS) is the major technology constraint here due to the absolute dependence on the one input and the high cost of storage. A time trend (TIME) variable indicates an increasing intensity of the raw material utilization. Finally, the dependent variable lagged one quarter gives an indication of the reluctance of the industry to markedly change production levels during short-run cycles. This is a common phenomenon in most manufacturing industries because producers are usually unable to hire skilled labor on a very short-term basis and are correspondingly reluctant to lay off workers during short downturns.

EQUATION 2.6

$$\text{DCPS} = -9.0609 + 0.33443 \text{ SRWS} + 0.16468 \text{ DCPS}_{t-1} + 0.30501 \text{ TIME}$$

(10.775) (2.216) (2.079)

Regression:

-2

R = 0.9073

SE = 10.0976

DW = 1.9073

PERIOD = 1962.1 to 1975.4

Foreign imports

Raw (noncanned) tuna

Raw tuna is imported into the United States (FSRWS) largely to fill the gap between the domestic canning capacity and the amount provided by the domestic harvesting sector. Because we have incomplete knowledge of the capacity of canners, we use instead the behavioral indices of what would cause canners to adjust inputs relative to domestic supplies. These include short-term changes in level of production (%DCPS) and a (1-year moving average) trend in consumption (CS). The lagged dependent variable mainly accounts for (1) shipping delay when importing and (2) the increasing trend toward a higher use of imported versus domestic raw tuna.

EQUATION 2.7

$$\text{FSRWS} = -15.7913 + 0.44309 \% \text{ DCPS} + 0.53861 \text{ FSRWS}_{t-1} + 0.59375 \text{ CS}$$

(2.037) (4.188) (2.236)

Regression:

-2

R = 0.6308

SE = 31.4271

DW = 1.7543

PERIOD = 1962.1 to 1975.4

Imported canned tuna

Estimating the level of canned imports (FCPS) is made difficult because of the canners' ties to the harvesting sector and because canners have higher profits from domestic production than from importing canned tuna. The only relationship that proved significant in accounting for this was a distributed lag of the Wholesale Price Index for tuna (PWCPS). Its negative coefficient over the sum of periods indicates the processors' practice of relying on the domestic production instead of imported canned tuna as wholesale price (and thus profits) increase. A time trend is also used to denote a slow increase in imports of canned tuna.

EQUATION 2.8

$$FCPS = 42.0816 + 0.14165 \text{ TIME} + \sum_{i=0}^6 a_i \frac{PWCPS}{WPI} t-i$$

(2.147)

i	a _i	T
0	8.683	1.069
1	-1.714	-0.604
2	-8.708	-2.072
3	-12.300	-2.324
4	-12.490	-2.940
5	-9.276	-2.646
6	-2.661	-0.296

-2

R = 0.25
SE = 3.863
DW = 1.964

SUM = -38.464
CONSTRAINTS: NONE
DEG. POLYNOMIAL: 3

PERIOD = 1962.1 to
1975.4

Total canned pack

Because most tuna in the United States is canned before being sold to retail outlets, the total canned pack (CPKS) is the amount of tuna generally available to domestic consumers. In the model it is an identity equal to the sum of domestic canned pack plus the imported canned tuna.

$$CPKS = DCPS + FCPS$$

2.9

Prices

There are seven stochastic equations estimated in this section covering exvessel, wholesale, retail, and meal prices. Equations are based primarily upon the technology and market factors that affect industry prices; however, usually at least one behavioral estimator reflects the peculiarities of the industry.

Exvessel price of yellowfin

Possibly more than any of the other price equations, the California exvessel price of yellowfin (PXTS) attempts to integrate the technology and behavioral inputs. First the Wholesale Price Index (WPI) has a positive effect on yellowfin price, signaling increases in the cost of production and, hence, exvessel prices negotiated by vessel owners. Foreign imports of uncanned raw materials also have a positive effect on exvessel price, reflecting the generally higher costs for importing and the preference of U. S. canners to use tuna caught by domestic harvesters. The dependent variable lagged one quarter reflects the slow price response to short-run economic cycles.

EQUATION 2.10

$$PXTS = -0.3809 + 0.013254 \text{ FSRWS} + 0.76372 \text{ PXTS}_{t-1} + 0.028143 \text{ WPI}$$

(3.141) (7.931) (1.660)

EQUATION 2.10 (CON.)

Regression:

-2
 R =0.9552
 SE=1.0970
 DW=1.7410
 PERIOD=1962.1 to 1975.4

Albacore prices

There are two price equations for unprocessed albacore. The first, import prices (f.o.b. Japan to American Samoa) is the contract price for this raw material which accounts for the majority of albacore packed by domestic canners. The second, exvessel prices (California) are contract prices usually negotiated for the entire fishing season.

Import Prices (PIA): This equation uses the same format as yellowfin exvessel prices except that the domestic consumption trend replaces the wholesale price index. Because albacore meat is a higher quality item and has a smaller portion of the market than other tunas, one can expect a larger price fluctuation as demand changes. This is reflected in the strong coefficient for domestic consumption.

$$PIA = -196.215 + 0.38373 FSRWS + 0.55735 PIA_{t-1} + 3.2813 CS \quad EQ. 2.11$$

(1.736) (4.673) (3.265)

Regression:

-2
 R = 0.9404
 SE=55.7107
 DW= 1.355
 PERIOD=1962.1 to 1975.4

Exvessel prices (PXAS): This is largely a linking equation where the current exvessel price contract is determined by the current import price level coupled with the previous quarter's contract price.

$$PXAS = 0.70928 + 0.011487 PIA + 0.71087 PXAS_{t-1} \quad EQ. 2.12$$

(5.016) (12.023)

Regression:

-2
 R =0.9793
 SE=1.2658
 DW=1.9305
 PERIOD=1962.1 to 1975.4

Wholesale price of canned tuna

Wholesale price of canned tuna (PWCPS) is best explained by variables relating to the cost of inputs and changes in short-run demand. The price of yellowfin has the greatest per unit

effect on wholesale price, with the Wholesale Price Index also having a positive relationship, reflecting the costs of other inputs such as labor, metal for cans, and utilities. Short-term changes in demand are demonstrated by two variables. First, the domestic canned pack in the previous quarter reflects the market influences in the industry where a strong demand in the previous quarter will positively affect prices in the current period. Second, the dependent variable lagged one quarter is used in a manner similar to other price variables and shows stability factors. Finally, a time trend variable explains some of the positive trend unaccounted for by either input prices or cyclic variations.

$$\begin{aligned}
 \text{PWPCS} = & -7.7858 + 1.8724 \text{ PXTS} + 0.09570 \text{ WPI} + 0.1669 \text{ TIME} \\
 & \quad (6.812) \quad (1.601) \quad (2.856) \\
 & + 0.5334 \text{ PWPCS}_{t-1} + 0.04578 \text{ DCPS}_{t-1} \quad \text{EQ. 2.13} \\
 & \quad (7.051) \quad (2.036)
 \end{aligned}$$

Regression:

-2

R = 0.9931

SE = 2.7957

DW = 1.8271

PERIOD = 1962.1 to 1975.4

Wholesale price of tuna meal

Tuna (and mackerel) meal comprises 10 to 15 percent of fish meal supplies. Over the estimation period, there were two main sources of supply: Peruvian fish meal and domestic production of menhaden meal. Peruvian meal was available in such large quantities in and out of the United States that it had the price leadership. Therefore, like the exvessel price of albacore, the price of tuna meal (PMS) is best explained by the movement in the price of the competing imports (PPAM). The dependent variable lagged one quarter again reflects the price stability factors, particularly the delayed responses in price adjustments.

$$\begin{aligned}
 \text{PMS} = & 20.033 + 0.658 \text{ PPAM} + 0.146 \text{ PMS}_{t-1} \quad \text{EQ. 2.14} \\
 & \quad (10.176) \quad (1.777)
 \end{aligned}$$

Regression:

-2

R = 0.945

SE = 18.011

DW = 1.752

PERIOD = 1962.1 to 1975.4

Retail prices

Light tuna: Variations in the retail price of the 6 1/2-oz can of light tuna (PRTS) were well explained by variables relating to the cost of inputs. Both the price of yellowfin and

the Wholesale Price Index affect the retail price response as the price of the raw material and other input factors, respectively, rise. As with the wholesale price equation, a time trend variable had good explanatory power and reflects price movements not attributable to changes in factor input prices.

$$\text{PRTS} = -36.3391 + 1.0398 \text{PXTS}_{t-1} + 0.992 \text{TIME} + 0.383 \text{WPI} \quad \text{EQ. 2.15}$$

(5.344) (3.531) (3.536)

Regression: Cochrane-Orcutt Estimation

-2
R = 0.996
SE = 1.845
DW = 1.521

PERIOD = 1960.2 to 1975.4

White tuna (albacore): Variations in retail price of the 7-oz can of white solid tuna (PRAS) are explained by variables reflecting the cost of inputs and by variables reflecting changes in domestic and foreign canned supplies. The exvessel price of albacore and the Wholesale Price Index are intended to reflect changes in raw material price and other inputs. As with light tuna, increases in these variables account for most of the increases in retail white tuna prices. The domestic canned pack, a proxy for supply, is negatively related to retail price. Imports of canned tuna reflect a demand orientation where an increase in imports signals an increase in demand, and hence, an increase in price.

$$\text{PRAS} = -75.7187 - 0.00038 \text{DCPS} + 0.0774 \text{FCPS} + 0.022 \text{PIA}_{t-1} \quad \text{EQ. 2.16}$$

(-1.714) (1.489) (8.781)

+ 1.014 \text{TIME} + 0.1281 \text{WPI}

(7.869) (3.823)

Regression:

-2
R = 0.995
SE = 1.006
DW = 2.055

PERIOD = 1970.1 to 1975.4

Per capita tuna consumption

Per capita U. S. tuna consumption (PC) is estimated on an annual basis. It is a standard demand equation, reflecting population (POPUS), the level of total U.S. consumption (CON), and the price of tuna related to its close substitutes (red meat and poultry = CPIMPF). Total U.S. personal consumption expenditures, divided by U. S. population, is the primary demand factor.

The deflated retail price of light tuna denotes product substitution due to price differentials and has a negative coefficient. There is also the dependent variable lagged, which would reflect a long-term trend in consumption habits towards increased tuna purchases and stability in consumer food buying patterns.

$$PC = 0.62624 \frac{CON}{POPUS} + 0.55660 PC_{t-1} - 0.25732 \frac{PRTS}{CPIMPF} \quad \text{EQ. 2.17}$$

(3.079) (3.857) (-1.676)

Regression:

-2
R = 0.9482
SE = 0.1256
DW = 2.1438
PERIOD = 1953 to 1975
CONSTANT IS SUPPRESSED

Total consumption

Total consumption (C) is calculated in the model as an identify equal to the per capita consumption times the level of the U.S. population.

$$C = PC * POPUS \quad 2.18$$

Value identities

In many instances we have estimated variables for both price and quantity produced. It is possible to calculate the value of the commodity. These value identities are shown in equations 2.19 through 2.24. Note that the value given can only be approximate because prices vary considerably depending on quality and species.

Canned pack identities

$$DCPS\$ = DCPS * PWCPS \quad 2.19$$

$$FCPS\$ = FCPS * PWCPS \quad 2.20$$

$$CPKS\$ = DCPS\$ + FCP\$ \quad 2.21$$

Landing identities

$$LA\$ = LA * PXAS \quad 2.22$$

$$LR\$ = LT * PXTS \quad 2.23$$

$$L\$ = LA\$ + LT\$ \quad 2.24$$

Other identities

$$SRWS = L + FSRWS \quad 2.25$$

BASELINE FORECAST

This section has the results of a forecast for all model variables through 1981. This particular forecast is called a "control" or "baseline" forecast and assumes that there will be no major changes in industry structure other than those caused by economic forces. It is made under the premise that there will be no major government interference (either laws or court decisions) which would prohibit the harvesting of yellowfin tuna.

Landings

The model forecasts indicate a moderate downward trend in landings through 1981 for both albacore and tropical tunas. For albacore, 1977 is expected to be an improvement over 1976. It is notable, however, that even with a record exvessel price, the 1976 landings have been low. This has been due in part to biological factors (affecting the albacore migration patterns), but possibly also to an abnormally good season in the dungeness crab fishery which competes for the effort of the jigboat craft used to catch albacore. For the tropical species, the model shows a steady and gradual decline in the fishery following the record 1976 catch. Factors behind this decline include the limited growth projected in the domestic fleet capacity coupled with increased competition from other nations' tuna fleets. In addition, there is expected to be an increased pressure on the yellowfin resources in the high-yield CYRA areas, causing a gradual decline in the catch rate.

Consumption

After a decline in 1977, the total consumption of canned tuna is expected to increase at a fairly steady rate of 3 to 4 percent (2 to 3 percent per capita) through 1981. This is somewhat lower than the nearly 5 percent annual growth rate in total consumption exhibited during the past decade. For the 5-year forecast period, the most significant factor affecting the growth in tuna consumption will be the growth in total U. S. Personal Consumption Expenditures, which is projected to be very strong (3 to 5 percent annual growth rate). The growth rate in tuna consumption is dampened in 1976-77 by consumer resistance to the increased price of tuna relative to other food items.

Imports

In line with past trends, the model has predicted a growing gap between domestic landings and consumption. This can only be made up from an increasing share of imports, which will enter the country primarily in the raw material form. The ratio of canned to raw imports is not expected to increase significantly because the tariff structure encourages the domestic pack of (imported) raw tuna, which is duty-free, while it discourages the importation of canned tuna with an ad valorem duty ranging

from 6 to 35 percent (Table 1).

Prices

Two developments are discernable from the forecasts of all tuna prices. The first is that the record high prices for landed albacore and for tuna meal will be abated by external economic pressures. These pressures will mainly take the form of price or market competition as the price of white tuna becomes high relative to red meat and poultry, and soybean meal price declines. The second development is that after the increases in 1977, the wholesale and retail prices for canned tuna will increase at a very moderate rate averaging about 3 to 4 percent per year. This is due to the diminishing increases or decreases in raw material prices coupled with an expected slow increase in the cost of production of about 4 percent annually (Table 2).

Processing

The pack of tuna in the United States is oriented almost entirely to domestic markets; thus, production is expected to change roughly in line with the increases in consumption, noted above. Except for increases in 1976-77, imported canned tuna is not expected to significantly increase its current 5 to 10 percent share of the market.

ALTERNATE FORECAST

The alternate forecast examines the effects of government regulations upon the incidental catch of porpoise by the purse seine tuna fleet.

The purpose of this alternate forecast is to show the implications of a possible, but currently unplanned set of exogenous events, and give the planner a range of options in assessing growth patterns of an industry. In regard to government actions, an alternate forecast may also become an input into an environmental impact statement (EIS) that would assess the economic impacts caused by the new regulations.

In this section, we examine a situation where the federal government places restrictions upon the purse seine harvesting of yellowfin tuna to reduce the incidental porpoise mortality associated with this type of fishing. Because the regulations will directly affect the catch rates and landings, this analysis is concerned primarily with the impacts upon prices and imports.

Background for formulating assumptions

As of January, 1977, the U.S. purse seine fleet faces a set of restrictions that could limit but not eliminate its operation.

Table 1 -- Baseline forecast

VARIABLE	ACTUAL	ANNUAL FORECASTS				
	1976	1977	1978	1979	1980	1981
UNPROCESSED: QUANTITY	-----Million Pounds-----					
TOTAL TO BE PROCESSED	1296.4	1278.0	1386.2	1383.0	1368.2	1363.2
DOMESTIC CATCH	663.2	565.9	619.3	576.3	533.1	497.1
ALBACORE	34.3	38.6	37.4	34.2	32.1	30.6
TROPICAL	628.9	527.3	581.9	542.1	501.0	466.5
IMPORTED RAW	633.3	712.1	766.9	806.7	835.1	866.1
*						
PROCESSED: QUANTITY						
TOTAL CAN PACK	693.1	714.4	750.8	757.9	758.3	762.2
DOMESTIC	634.2	656.4	692.7	699.9	700.4	704.2
IMPORTED	58.9	58.0	58.1	58.0	57.9	57.9
*						
UNPROCESSED: VALUE	-----Million Dollars-----					
DOMESTIC CATCH	202.8	185.0	205.1	196.9	189.0	184.5
ALBACORE	15.9	20.8	18.3	14.8	13.6	14.5
TROPICAL	187.0	164.3	186.8	182.1	175.4	169.9
*						
PROCESSED: VALUE (AT WHOLESALE LEVEL)						
TOTAL CAN PACK	897.3	985.5	1064.2	1119.9	1165.2	1216.2
DOMESTIC	820.8	905.6	981.9	1034.2	1076.2	1123.7
IMPORTED	76.6	80.0	82.3	85.7	89.0	92.5

Table 2 -- Baseline forecast

VARIABLE	ACTUAL 1976	ANNUAL FORECASTS				
		1977	1978	1979	1980	1981
* CONSUMPTION: QUANTITY						
TOTAL (MIL LB)	715.0	706.9	724.5	748.2	769.0	795.3
1 YR. MOVING AVERAGE	692.0	705.5	716.6	739.7	760.5	785.5
PER CAPITA (LB)	3.32	3.26	3.31	3.39	3.45	3.53
* CATCH RATE (1000 LBS/ VES TON)						
ALBACORE	0.75	0.85	0.81	0.74	0.69	0.66
TROPICAL	4.68	3.87	4.27	3.98	3.70	3.50
* PRICES: ACTUAL						
MEAL (\$/TON)	274.3	351.3	294.2	273.8	271.1	281.3
EXVESSEL (¢/LB)						
ALBACORE	42.7	52.1	49.1	43.5	41.4	45.4
YELLOWFIN	29.8	31.2	32.1	33.6	35.0	36.4
IMP. ALBACORE (\$/TON)	1103.3	1296.5	1092.2	948.4	990.4	1158.5
RETAIL CANNED (¢/CAN)						
ALBACORE (WHITE)	92.0	100.3	101.8	103.3	107.9	116.8
* PRICES: INDEX (1967=100.)						
WHOLESALE CANNED	195.0	207.6	213.3	222.4	231.3	240.2
RETAIL CANNED TROPICAL (LIGHT)	186.2	196.0	200.2	208.2	216.8	225.5

The following primary or direct effects can be expected from the restrictions:

1. A shift in fishing effort to species other than yellowfin tuna. Because tuna purse seines are very specialized vessels, most of this shift would be to the skipjack fishery.

2. A shift in fishing effort to grounds where there is little or no incidental porpoise catch.

3. A decline in the number of vessels. This would depend on the economic severity caused by the regulations. This could either be by scraping the less efficient vessels or by transferring their flags (to other nations).

These three direct effects can be expected, in turn, to induce other changes. The more important indirect changes are listed below:

1. A decrease in operating efficiency. This would be caused by the change in fishing effort away from the more easily caught yellowfin tuna to grounds where harvesting yellowfin tuna cause no incidental porpoise catch.

2. A corresponding shift of foreign effort away from the grounds more intensely fished by the U.S. fleet. This would tend to somewhat alleviate the decline in the U.S. catch rate. Ironically, it would also tend to increase the incidental porpoise catch by foreign purse seine vessels because the high yield grounds would be those where tuna school with porpoise.

3. No anticipated shortage of tuna products. Because of the high volume of tuna traded in foreign markets, there should not be any shortage of tuna products in retail markets. Any decrease in domestically harvested tuna could easily be offset by equal increases in tuna imports. If problems resulted from the regulations prohibiting the importation of yellowfin tuna caught on porpoise, there would probably be a shift to the importation of skipjack tuna.

Technical assumptions

Based upon the background assumptions discussed in the previous pages and on certain technological relationships formulated by the National Marine Fisheries Service (NMFS), the following are incorporated into the alternate forecast:

1. It is assumed that the regulatory action will be implemented over the full 5-year forecast period, from 1977 to 1981. The assumptions on the porpoise quotas are shown in Table 3.

2. It is assumed that as the size of the quota is reduced, fishermen will make a greater effort to reduce the incidental

Table 3 -- Assumptions on allowable porpoise catch by U.S. purse seine vessels*

Year	Allowable incidental porpoise catch		
	Run A	Run B	Run C
	- - - - 1,000 porpoise caught - - - - - - - - -		
1977	96	60	60
1978	96	60	55
1979	96	60	50
1980	96	60	45
1981	96	60	40

*As of April 1, 1977, the quota was set at 59,050

Run A is a rounded version of the 96,100 quota which was set by the Administrative Law Judge in Jan. 77, but later revised by NMFS.

Run B is a rounded version of this 59,050 quota.

Run C is entirely hypothetical, based upon one interpretation of the Marine Mammal Protection Act of 1974 that may require the quota to be eventually reduced to a near-zero level.

Sources: (1) NMFS-(1977)

(2) NMFS-EMRD(1975)

porpoise catch. The reduction in porpoise mortality rates would come about through shifts to fishing grounds where porpoise do not school with yellowfin tuna. Table 4 lists the estimated relationship between the incidental porpoise mortality rate and the size of the quota (the correspondence is the same for all three runs).

3. As the size of the quota decreases, a shift in effort away from yellowfin tuna, (mostly caught on porpoise), to skipjack (not caught on porpoise) is expected. The relationship between the quota and the yellowfin/skipjack catch has been estimated and shown in Table 5. This assumption separates yellowfin tuna caught on porpoise from that not caught on porpoise.

4. To achieve the regulatory effect in the model, we apply the quota restrictions to influence the catch rate. The catch rate is left unaffected until the quota is reached. After the quota is reached, we assume that purse seine fishing will continue only for skipjack.

5. There is no provision made in the alternate forecast for a reduction in the number of vessels in the purse seine fishing fleet. Because we are working with an absolute quota, any change in fleet size would be offset by an equal change in the catch rate.

6. In the absence of any regulations or porpoise quota, NMFS has estimated a porpoise catch of 120,000. This figure is used, where necessary, to align the alternate with the baseline forecasts.

7. We assume that there will be no change in the albacore fishery or tuna fisheries using lines, other than those caused by economic (price) incentives.

8. We assume that there will be no shortage in the supply of tuna to retail consumers.

9. As with the baseline forecast, the supply of tuna to consumers (domestic canned pack plus canned imports) does not exactly equal domestic consumption. In the alternate forecasts, the changes in demand (consumption) of tuna has a proportional effect upon the supply of tuna (production).

10. Differences between domestic production needs and the availability of domestically harvested tuna are accounted for by an increase in imports. The increase is in both unprocessed and canned imported tuna, where each type of import changes in proportion to its share of the total in the baseline forecast.

Table 4 -- Relationship between the incidental porpoise mortality rate and size of quota.

Quota size	Incidental mortality rate	Percent yellowfin caught on porpoise*
1,000 porpoise caught	porpoise mortality rate per 1,000 lb yellowfin caught	percent of fishing grounds
120	0.55	67
110	0.54	65
100	0.53	62
90	0.52	60
80	0.51	58
70	0.51	55
60	0.50	53
50	0.49	51
40	0.49	48

*Percent of total eastern tropical Pacific yellowfin tuna.

Table 5 -- Relationship between the porpoise quota and the catch of yellowfin, skipjack, and bluefin tunas.*

<u>Catch of all tropical tuna other than ETP* yellowfin</u>		
<u>Porpoise quota</u>	<u>Ratio to total tropical tuna</u>	<u>Ratio to ETP yellowfin</u>
1,000 caught	- - - - - percent - - - - -	
120	30	43
110	32	47
100	35	54
90	37	59
80	39	64
70	42	72
60	44	79
50	46	85
40	49	96

*ETP = Eastern Tropical Pacific

Results

Given the technical assumptions and possible quota restrictions, three runs of the model were made. The results are shown in Tables 6 through 8, and discussed below. The percentages noted in the text are calculated based on the maximum impact for each run as compared to the baseline forecast.

Landings and domestic processing

The greatest economic effect of the porpoise quotas is upon the U.S. purse seine fleet and domestic landings. In the three runs, tropical tuna landings are reduced between 11 and 24 percent. Because of the increase in albacore exvessel price, the model also shows a small increase in albacore landings. Although the 11-to-24-percent decline is not drastic compared to similar swings that have occurred in other industries, one must recognize that the impact upon the tuna industry will be great. In the 5-year interval preceeding the tuna-porpoise controversy (1970-75), the fleet had exhibited a total growth in landing of over 20 percent and a growth of nearly 75 percent in the value of these landings. A dramatic sudden decline in an industry prepared for rapid expansion will undoubtedly cause economic hardships.

The processing sectors show a decrease between 3 and 4 percent in total domestic canned pack. This is mainly caused by an increase in competition from imported canned tuna, not from a reduction in domestic consumption.

Imports

To meet the demands of domestic processors and consumers, any reduction in domestic catch will require a nearly equal increase in imports. Increases in raw (unprocessed) imports range between 3 and 9 percent. Increases in canned imports range between 7 and 15 percent.

Prices and Consumption

The impact of the quota restrictions upon prices should be significant although not extreme. As expected, the impact on yellowfin prices is the greatest, ranging from 1 to 4 percent. Exvessel albacore prices also increase but at the somewhat slower rate of 0.5 to 3 percent. At the retail level, the effect of the quota restrictions becomes proportionately smaller, generally averaging about a one cent per can increase. Given the small change in retail prices, the consumption of tuna remains almost the same in all cases.

CONCLUSIONS

Any analysis using computer models is always subject to criticism based upon the limitations of the models and the validity of the assumptions that drive it. No model is ever so perfect that it does not need further refinement, and no set of assumptions is ever so perfect that it does not necessitate further research to yield more accurate results. The question, however, of

Table 6 -- Effects of porpoise quotas on domestic landing and processing of tuna.

	Actual		Forecast			
	1976	1977	1978	1979	1980	1981
			-----million pounds-----			
Baseline						
Catch - Tropical tuna	628.9	527.3	581.9	542.1	501.0	466.5
Albacore tuna	34.3	38.6	37.4	34.2	32.1	30.6
Domestic canned pack	634.2	656.4	692.7	699.9	700.4	704.2
Run A - 96,000 Quota						
Catch - Tropical tuna	-	520.3	520.3	520.3	501.1	466.5
Albacore tuna	-	38.7	37.5	34.3	32.1	30.6
Domestic canned pack	-	653.9	672.9	698.8	700.4	704.1
Run B - 60,000 Quota						
Catch - Tropical tuna	-	459.1	459.1	459.1	459.1	459.1
Albacore tuna	-	38.8	37.6	34.5	32.3	30.7
Domestic canned pack	-	636.5	671.1	685.8	693.2	705.0
Run C - 60/40,000 Quota						
Catch - Tropical tuna	-	459.1	443.2	424.8	403.5	379.0
Albacore tuna	-	38.8	37.6	34.5	32.4	30.9
Domestic canned pack	-	636.5	668.2	679.6	683.7	688.9

Table 7 -- Effects of porpoise quotas on tuna imports

	Actual		Forecast				
	1976		1977	1978	1979	1980	1981
			-----million pounds*-----				
Baseline							
Imported - unprocessed	633.3		712.1	766.9	806.7	835.1	866.1
canned	58.9		58.0	58.1	58.0	57.9	57.9
Run A - 96,000 Quota							
Imported - unprocessed	-		712.2	774.7	828.4	847.1	865.8
canned	-		58.5	62.1	59.3	57.9	57.9
Run B - 60,000 Quota							
Imported - unprocessed	-		724.6	828.8	845.8	854.7	876.2
canned	-		63.0	66.1	63.1	60.4	58.3
Run C - 60/40,000 Quota							
Imported - unprocessed	-		724.6	836.7	862.6	882.1	907.1
canned	-		63.0	67.1	65.3	63.8	63.0

* The approximate conversion factor from raw (unprocessed) tuna to canned tuna is 2.0.

Table 8 -- Effects of porpoise quotas on tuna prices and consumption

	Actual		Forecast			
	1976	1977	1978	1979	1980	1981
			-----Prices: cents/pound-----			
Baseline						
Exvessel - Yellowfin	29.8	31.2	32.1	33.6	35.0	36.4
Albacore	42.7	52.1	49.1	43.5	41.4	45.4
Retail* - light	157.2	165.5	169.0	175.8	183.0	190.4
white	210.2	229.2	232.7	236.1	246.6	267.0
Run A - 96,000 Quota						
Exvessel - Yellowfin	-	31.2	32.4	34.0	35.2	36.5
Albacore	-	52.1	49.2	43.7	41.5	45.5
Retail* - light	-	165.5	169.1	176.2	183.3	190.5
white	-	229.3	233.1	236.6	246.9	267.0
Run B - 60,000 Quota						
Exvessel - Yellowfin	-	31.4	33.0	34.7	35.8	36.9
Albacore	-	52.2	49.6	44.1	41.9	45.7
Retail* - light	-	165.6	169.7	176.8	183.9	190.9
white	-	229.5	233.8	237.0	247.1	267.2
Run C - 60/40,000 Quota						
Exvessel - Yellowfin	-	31.4	33.2	34.9	36.3	37.6
Albacore	-	52.2	49.7	44.3	42.2	46.1
Retail* - light	-	165.6	169.7	177.0	184.2	191.5
white	-	229.5	233.8	237.5	247.5	267.9
	1976	1977	1978	1979	1980	1981
			-----Consumption: million pounds-----			
Baseline						
Run A - 96,000 Quota	715.0	706.9	724.5	748.2	769.0	795.3
Run B - 60,000 Quota	-	706.9	724.5	748.0	768.8	795.2
Run C - 60/40,000 Quota	-	706.9	724.2	747.7	768.4	794.9
	-	706.9	724.2	747.6	768.2	794.6

*Light is pack from tropical tuna; white is pack from albacore tuna

whether model forecasts and analysis can be used as an input into planning decisions is now a well-researched topic and validated beyond debate. This paper is a positive example of how months of prior modeling research can be effectively applied to analyze current policy decisions.

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APPENDIX

Endogenous Variables:

- C. Total domestic consumption of tuna.
- CPKS: Total canned supplies, domestic and foreign.
- CPKS\$: Dollar value of total canned supplies domestic and foreign.
- CS: Total domestic consumption of tuna, moving average over four quarters.
- DCPS: Domestic canned pack tuna.
- DCPS\$: Dollar value of domestic canned pack tuna at wholesale level.
- FCPS: Foreign canned tuna imported to the United States, seasonally adjusted.
- FCPS\$: Dollar value of foreign canned pack tuna imported to the U.S. wholesale level.
- FSRWS: Foreign supply of tuna (loins & disks) and fresh and frozen imported to the United States. Raw weight.
- L: Total domestic landings of tuna.
- L\$: Dollar value of total domestic landings of tuna at dockside.
- LA: Total domestic landings of albacore.
- LA\$: Dollar value of total domestic landings of albacore at dockside.
- LT: Total domestic landings of tropical tuna.
- LT\$: Dollar value of total domestic landings of tropical tuna at dockside.
- PC: Per capita domestic consumption of tuna.
- PIA: Wholesale price of imported albacore, f.o.b. Japan to American Samoa.
- PMS: Wholesale price of tuna and mackerel meal, California, seasonally adjusted.
- PRAS: Retail price of solid, white tuna, 7-oz. can.

- PRTS: Retail price index of chunk, light tuna, 6 1/2-oz. can (1967 = 100).
- PVTA: Productivity in the Pacific albacore fleets, landings per vessel-ton.
- PVTT: Productivity in the tropical tuna fleet, landings per vessel-ton.
- PWCPS: Wholesale price index of chunk, light tuna, 6 1/2-oz. can (1967 = 100).
- PXAS: Exvessel price of albacore, California.
- PXTS: Exvessel price of yellowfin tuna, California.
- SRWS: Total supplies of tuna, raw weight.

Exogenous Variables

- 1 - CON: Personal Consumption Expenditures, all items, constant 1958 dollars.
- 2 - CPIMPF: Consumer Price Index, Meats, Poultry, Fish (1967 = 100).
- 3 - D1: Dummy variable, first quarter.
- 4 - D2: Dummy variable, second quarter.
- 5 - D3: Dummy variable, third quarter.
- 6 - D6870: Dummy variable, for 1968 through 1970.
- 7 - DT1: Moving trend dummy variable, first quarter.
- 8 - DT2: Moving trend dummy variable, second quarter.
- 9 - DT3: Moving trend dummy variable, third quarter.
- 10 - NVTA: Number of vessel - tons, Pacific albacore fleet.
- 11 - NVTT: Number of vessel - tons, tropical tuna fleet.
- 12 - POPUS: U.S. population, excluding armed forces.
- 13 - PPAM: Wholesale price of Peruvian anchovy meal, East Coast.
- 14 - QT: Fishing quota, in days, for the C.Y.R.A.
- 15 - TIME: Time trend, linear.
- 16 - WPI: Wholesale Price Index, all items (1967=100).

FEASIBILITY ANALYSIS OF STATE-OWNED EXPERIMENTAL POND FARMS

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The purpose of this paper is to provide a framework for assessing the viability of establishing state-owned experimental pond farm stations. Although the proposed analysis can be easily generalized the emphasis is on the culture of the giant Malaysian prawn (Macrobrachium rosenbergii). This study has been spurred by the current situation in Hawaii in which a major bottleneck to industry progress appears to be an inherent conflict between the long-range objectives of scientists and the short-term needs of commercial growers.

Prawn farmers in Hawaii are currently being somewhat subsidized in that they are provided technical assistance and juveniles for stocking in their ponds without charge under a 3 year period of assistance. In return, the farmers are required to provide the Division of Fish and Game with data (construction cost, operating cost, production and sales data, income statements) and the use of ponds to test new pond management techniques and devices. Without evaluating the completeness of the data supplied by the farmers and the extent of usability of these ponds in the conduct of scientific experiments, it is imperative that alternative facilities be investigated because the 3-year period of assistance will soon be drawing to a close for most of these ponds. Even if these assistance arrangements are renewed, it is appropriate to evaluate alternatives because the use of commercial ponds for scientific research has been a frustrating experience for both the farmers and the scientists. One alternative which appears to be particularly viable, but which needs evaluation to determine feasibility, is the establishment of a state-owned experimental pond farming station which contains, e.g., 32 1/10 acre ponds (3.2 acres of ponds) which would be suitable for field experimentation leading to accelerated improvement in production management techniques and greater profits for the prawn farmer.

The following are statements made by leading aquaculturists on the need for facilities for the scientific study of pond farming under controlled field conditions:

"Success in prawn culture to date has been based largely on 'green thumb' methods which, while eminently practical and productive,

are not designed to produce some of the detailed information necessary to optimization of culture practices. To obtain precise data on utilization of feeds, the contribution of natural pond productivity, population counts in a pond at key intervals, and other factors vital to optimizing production, requires pilot-scale operations specifically designed for fully controlled experiments."(1)

"A difficulty in interpreting food research data is that the experiments were not conducted according to an agreed standard. The variation in animal size, environmental parameters, and types of growing systems make it nearly impossible to relate one kind of data to another."(1)

"We do not know why growth of shrimp in the PAC [Pacific Aquaculture Corporation] pond was slower than in Ota's ponds. It is unlikely that environmental differences between years (1970 and 1973-74) were large enough to account for the discrepancy. Feeding and other management practices applied to Ota's ponds and the PAC pond appear to have been very similar and do not provide the answer either. It is exactly such discrepancies as this that emphasize the need for a better understanding of the shrimp pond ecosystem... We are in a difficult position with regard to recommending management procedures for pond rearing of *Macrobrachium* because we do not know what conditions to encourage."(2)

"Under a State [of Hawaii] subsidy, farmers' ponds were stocked with juvenile prawns. The farmer is not charged for the supply and may keep all the commercial profits. There is no research control over the ponds..."(6)

"Kato's operation [21-acre prawn pond farm in Laie, Oahu], which also produces catfish and carp on Maui, has been successful while others have failed: "'We are pragmatists,' he said. 'Our job is to produce fish and we do. We make no pretense to doing scientific research... Some people may call our methods cautious but we know what works; we produce a crop and we make money. And that's why we're here.'"(3)

METHODS

The following tasks need to be undertaken in order to assess the feasibility of a state-owned experimental pond farming station:

1. Estimation of type of facility required. Tentatively, it is expected that 32 1/10 acre ponds (a total of 3.2 acres in ponds) would be sufficient. Additional land would be required for access roads and any buildings required. The Department of Land and Natural Resources has already studied some prospective sites as to suitability for prawn farms; another study has already been funded for an evaluation of existing fish ponds in Hawaii; and the Department of Planning and Economic Development will be completing (by February 1977) a survey of all islands to determine possible aquaculture sites and to

take steps to preserve them for future use. In addition to estimating the cost of site acquisition (which might be nil if stated-owned land is found suitable), it will be necessary to determine that the land is not of marginal quality, that sufficient water is available, and that run-off water can be drained in an environmentally satisfactory way. It will also be necessary to estimate the costs of land clearing and excavation, pond construction, and number and probable depth of wells if needed.

2. Estimation of type of buildings and equipment required along with estimated cost of each item. These items would include workshop/storage/house/laboratory-office, fencing, pumps for wells, 1-2 trucks, and basic scientific equipment needed for measuring water quality and other parameters of the pond ecosystem.

3. Estimation of operating costs in terms of labor, nets, raw materials, electricity, water, maintenance, and professional staff on the assumption that all ponds are being utilized. It may be that items (1) and (2) above can be treated as capital costs and amortized over the expected economic life of the assets; in this event, it may be possible to charge the project only the amount of annual depreciation plus interest.

4. Estimation of probable revenue from the experimental station: (a) revenue from sale of prawns or other species under culture; (b) revenue from rent (of land, labor, and equipment) charged the user of the facilities. The user would likely be a scientist under a federally funded or foundation funded research grant.

5. Estimation of the degree of utilization of the 32 ponds-- who would be using the ponds, how many of the ponds would they need and for how long a period, what species would be under study and what are some of the likely areas of research, in what way and to what extent would this research aid existing and/or prospective pond farmers and the State of Hawaii aquacultural industry, what is the relative demand for fresh-water vs. brackish water ponds, can multipurpose experiments be designed (e.g., dual crop aquaculture, polyculture, algae/taro/lotus root/watercress and/or fish culture), what are the employment and income generating aspects of the funded research projects (over and above the rent paid for use of the experiment station facilities)?

6. Evaluation of and recommendations for organizational structure of the proposed experimental station. Input would be obtained from interested parties as to whose jurisdiction the proposed experimental station should fall under, or, alternatively, whether it should be autonomous; and what its internal organizational structure should look like in terms of a policy governing group and an operating governing group.

7. In combination with the tasks outlined above, inquiry will be made of comparable experimental stations located elsewhere in order

to determine their origins in terms of feasibility studies and enabling legislation, their operating costs and revenues as well as organizational structure, physical layout, and the types of and benefits from the research undertaken at their facilities.

RESULTS AND DISCUSSION

Although the basic objective of the proposed study is to establish the feasibility (monetary costs vs. revenues) of a state-owned experimental pond farming station, an important aspect of this feasibility which must also be considered is the worthwhileness of the scientific research results that might be obtained. Some of the scientific experimentation which could be undertaken at such a facility include the following:

1. Evaluation of a wide continuum of stocking densities with stocking of identically sized juveniles and a constant grow-out period. Data would be kept on survival rate, feeding rate, water quality, average size (length, weight) at harvest, total ponds harvested, total pounds of feed.

2. Evaluation of stocking the ponds with juveniles of varying beginning weight, e.g., 0.2g vs. 1.0g vs. 2.0g.

3. Evaluation of ponds fitted with draped netting or other substrates so as to increase the total surface area for prawn habitat.

4. Evaluation of 2-3 crops/year with perhaps increased feeding rates and/or fertilization vs. 1 crop/year.

5. Evaluation of dual crop aquaculture-schemes (e.g., *Macrobrachium* in the warm months and another species in the cool months) or polyculture schemes--two or more species in the same pond (e.g., *Macrobrachium* along with mullet, carp, or catfish).

6. Evaluation of feeding rates (e.g., 5 percent of biomass per day) based on continuously monitored survival/growth rates and water quality parameters.

7. Evaluation of initial stocking density on female/male survival rates and hence on average weight at time of harvest. Since growth rate during the early stages of growth is not influenced by initial stocking density, this type of experiment should perhaps treat the length of grow-out season as a variable parameter.

8. Evaluation of prawn grow-out in ponds in which optimum growing temperatures (about 28-30°C) are continuously maintained. The higher cost of such a system would have to be more than offset by 2-3 crops per year of marketable prawns.

9. Evaluation of alternative feeding regimes, e.g., feeding of pond twice daily--half in the morning and half in the later after-

noon vs. feeding once a day vs. feeding 3-4 times a day.

10. Determination of optimal flow of water into the pond from among several alternative management schemes, e.g., 0.01 gpm for each 1 lb. of prawn vs. 0.02 gpm.

11. Evaluation of alternative feeds, e.g., chicken feed (broiler starter) vs. Ralston Purina Shrimp Ration #20.

12. Pond grow-out of alternative species of *Macrobrachium*, e.g., *M. carolinus*, *M. acanthurus*, *M. ohione*, *M. americanum*, *M. tenellum*.

13. Evaluation of a male-only pond grow-out with initial stocking of juveniles which have been sex-sorted.

14. Evaluation of a multiple pond system in which each pond is harvested (by draining instead of by seining) once--at the end of the grow-out period--and then putting nonmarket-size and soft-shell prawns in the next-pond-to-be-harvested.

15. Evaluation of marked feed trials in pond surroundings. The percentage of the stomach contents consisting of this feed could indicate its importance in the diet of the prawn.

16. Evaluation of methods of supplemental oxygenation of the pond, e.g., bubbling of atmospheric air, injection of liquid oxygen.

There have been attempts to conduct many of the above evaluations in laboratory studies, on the one hand, and clusters of small ponds have been utilized for demonstration projects under field conditions, on the other. Examples of the latter are the (1) use of 25 quarter-acre fishponds at the Cedar Bayou (Texas) plant of Houston Lighting & Power Company to study the effect of warm water on the growing season of shrimp, redfish, speckled trout, spadefish, pompano, croaker, mullet, black drum, flounder and spot (5); (2) use of 18 thermal effluent marine shrimp mariculture ponds at the Barney M. Davis Station of Central Power and Light Company at Corpus Christi, Texas (5); and (3) use of 20 half-acre ponds at Angleton (Brazoria County, Texas) for the growout of brown shrimp (4). The Corpus Christi and Angleton projects, under the direction of Drs. Jack C. Parker and Fred Conte, have been cooperative ventures assisted by the Texas Agricultural Extension Service, Texas A&M University Sea Grant College, National Marine Fisheries Service, a Brazoria County governmental agency and several private sector corporations--Ralston Purina, Dow Chemical, Texaco, Par Tex Construction Company, and Central Power and Light.

It should be mentioned that there is often a world of difference between laboratory studies and field operations. The former type of study is concerned primarily with obtaining results which are statistically significant. Economic significance is not usually

examined and, indeed, great expense is undertaken to keep conditions at the experimental design levels. Even so, extrapolation of laboratory results to field conditions is itself a risky business for any commercial grower.

It is useful to distinguish between several categories of projects:

- (1) Experimental (laboratory)
- (2) Demonstration (field)
- (3) Pilot-Scale Commercial
- (4) Full-Scale Commercial

There is no doubt that pilot-scale and full-scale commercial projects produce highly valuable data needed for pond management technology, but such projects are usually undertaken as major investments by private business firms and the results obtained are viewed by them, and quite properly so, as proprietary in nature. The experimental and field demonstration projects have often been funded, at least in part, by governmental agencies and the results obtained have been freely disseminated. The author's subjective assessment is that 80 percent of the non-commercial projects have dealt with laboratory experiments or conceptual feasibility studies. The relatively few demonstration projects have been of limited usefulness because of an inadequate experimental design--one or two ponds were used when even a small 2x2 factorial design with 2 replications would have required 8 ponds.

CONCLUSION

The proposal for state-owned experimental pond farm stations will enable the transference of laboratory experimental designs, with suitable quantities of replication, to field conditions. It will not, however, be a panacea for there is an ever-present danger that such stations can become the bailiwick of a particular interest group, quite likely the scientist or governmental planner. Control of such a station should be equitably divided up between members of the academic, governmental and business communities.

Once such stations are established, there is a need to continuously monitor the results obtained to make sure that the station is not being monopolized by scientists with long-range projects of marginal near-term value or by advocates of a particular species to the exclusion of all others.

On a more global basis, the authors would like to propose the establishment of an experimental pond farm industry which can serve as the launching pad for freely disseminated information of great potential value to all commercial growers seeking to improve their

production management techniques. It is perhaps not too visionary to suggest that eventually there could be an international consortium of experimental pond farm stations sharing their information on demonstration projects with a worldwide data bank and collaborating with synergy on species of common interest.

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RATIONAL APPROACHES TO IMPROVING LABOR PRODUCTIVITY

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INTRODUCTION

Labor productivity in the U.S. is going down. On February 28, the Wall Street Journal reported that productivity fell at a revised annual rate of 1 percent in the fourth quarter of 1976. A National Commission on Productivity has been established as a federal effort to curb our decreasing productivity. Nationwide, over half of business costs are wages and salaries. As productivity falls, cost per unit output increases. As cost increases, so must prices and so goes the economists inflationary wage-price spiral. Productivity gains can be made in two ways, increased capital investment for plant modernization and increased worker efficiency. This paper discusses the manager's role in increasing productivity. An analysis of measuring, increasing, and continuing worker productivity will aid managers in their struggle to decrease operating costs.

MEASURING PRODUCTIVITY

Need for precise measurement

All businesses need some form of productivity measurements which accurately reflect labor productivity. These measures might be cases/man-hour, tons/man-hour, sales/square foot or other appropriate parameters. These productivity measures must accurately reflect controllable labor input. Once these productivity measurements are developed, the productivity data must be systematically recorded. Your trade association should then be given this individual firm data for summary and analysis. Table 1 shows the trends for 83 wholesale grocery operations since 1971 compiled by the North American Wholesale Grocer's Association. Wholesale grocers use tons per man hour for their productivity measurement. A table such as this allows an individual manager to compare his operations with industry averages and pinpoint productivity problem areas. However it is little consolation to a manager if his declining productivity is simply part of a declining industry average that is decreasing profits or increasing inflation. What is desperately needed is some method of releasing the potential within each person and motivating a desire to increase his own daily productivity.

	1976			1975			TONS PER MAN HOUR			
	SMALL	MEDIUM	LARGE	SMALL	MEDIUM	LARGE	1974	1973	1972	1971
	Total Dept. (A+B+C+D)	0.98	1.08	1.09	0.89	1.08	1.24	0.98	1.17	1.03
A-Direct Labor	1.56	1.84	1.79	1.45	1.74	1.84	1.59	1.79	1.62	1.44
1 Receiving	1.87	2.38	2.55	1.76	2.41	2.90	2.18	2.59	2.28	1.91
Car Unload Unitized	9.25	4.19	5.46	13.50	4.75	6.85	4.71	6.57	8.03	6.22
Car Unload Manual	2.32	2.25	1.96	2.21	2.41	2.45	1.91	2.39	2.11	1.91
Carrier Unloading	24.31	28.84	34.65	40.92	53.53	26.73	40.51	34.36	48.71	23.07
Backhaul Unloading	5.50	4.07	8.65	2.70	5.86	8.83	6.83	7.15	6.71	5.53
Move Inbound Stock	2.43	3.48	3.59	2.48	3.37	4.34	3.10	3.67	3.12	2.75
2 Shipping	1.35	1.49	1.39	1.24	1.35	1.33	1.25	1.36	1.26	1.16
Order Selection	1.79	1.88	1.85	1.67	1.74	1.80	1.65	1.79	1.73	1.56
Truck Loading	5.41	7.10	5.63	4.72	6.00	5.12	5.12	5.69	4.61	4.49
Selection (Pieces/Hr)	119	132	128	116	126	127	119	126	128	109
B-Repack Labor	0.34	0.43	0.44	0.20	0.38	0.58	0.45	0.34	0.17	0.30
C-Indirect Labor	4.13	4.41	4.54	4.29	4.78	6.07	4.20	5.75	4.98	4.66
1 Supervision	13.85	15.97	13.89	12.29	15.92	21.80	12.77	18.87	15.84	17.71
2 Record Handling	26.54	24.41	22.82	27.45	32.73	31.14	26.58	36.26	27.96	28.54
3 Inbound Checking	12.74	15.14	17.86	16.50	14.25	22.94	15.45	18.72	17.93	16.76
4 Outbound Checking	14.60	19.57	23.36	13.56	30.93	34.75	16.02	19.52	18.31	11.34
5 Stock Control	55.11	60.30	93.45	72.14	102.09	107.71	84.92	126.34	73.66	82.71
6 Housekeeping	24.49	20.96	22.49	29.36	18.39	24.25	22.47	30.34	30.15	27.00
D-Support Labor	19.43	14.76	17.25	19.06	14.14	18.54	13.85	17.75	15.71	14.67
1 Re Coopering	70.42	59.04	70.28	54.30	67.44	79.29	61.82	86.94	65.43	53.05
2 Maintenance	73.48	33.66	34.67	52.60	36.01	41.26	27.76	41.04	37.55	40.56
3 Other Work	42.25	47.38	67.16	66.45	35.55	57.57	53.60	48.85	46.00	40.56

FACTORS FROM NAWGA'S WAREHOUSE OPERATION SEMINARS FOR 1971-1976

TABLE 1

INCREASING PRODUCTIVITY

Why do people work?

At first glance, it may seem silly to ask this question at all, since the answer appears self evident. People work for money. Although the obvious answer is far from complete, it should not be ignored. While modern students of work motivation often appear to be arguing that work behavior is influenced by many motives in addition to monetary reward, it would take a very wild variety of special pleading to maintain that these other motives will operate effectively in the total absence of monetary compensation. For economic reasons, the other motives for work may be of greater interest to employers of labor than the strictly monetary motive. An industrialist will be pleased indeed to learn how he can secure increased output without increasing the wage bill. Nevertheless, the monetary reward consequent upon work constitutes one of the primary motives regarding the work behavior of the employee. In the modern industrial society, whether capitalist or communist, money is the essential medium of exchange and the prerequisite for material existence. While the love of money may be the root of all evil, money is also the chief means by which people estimate the quality and quantity of their work.(4)

Again, why do we work? In the simplest terms: to eat, to exchange our skills and efforts for the things and services we can obtain only by earning the money paid for work. When a professor considers changing to a new university, unquestionably the salary of the new job is a key determinant. While some changes are made for prestige and improved facilities at work, few changes are made with reductions in pay. The question of work load for academicians is frequently a sore point between them and their administrators. At one college, the professors refused to take on extra teaching loads. But when extra pay was offered, not one professor refused to take on an extra load.

There are serious problems between management and workers that stifle motivation. Managers generally believe that the major problem to be solved in order to raise productivity is workers' lack of a will to work and their opposition to productivity improvements. However, I believe that work is as natural as play or recreation. But this problem remains unsolved because managers have been looking at the symptoms. Workers' lack of will to work and their opposition to productivity improvement are not problems to be solved but symptoms of the problem. The true problem is that management and workers are not motivated in the same direction; they have different goals, aspirations, and needs.

What do management and workers each want?

Management strives for increased productivity, higher profits, an improved competitive position in the marketplace, strengthened finances, and a more effective organization. While labor's interests

are also served by these objectives, in daily relations between management and labor in the plant, the short-term interests of the workers come to the fore and control their relations with management. Workers primarily want wage increases, greater security, shortened working hours, and improved fringe benefits. Though reduced productivity and increased cost actually erode their security, the effect of these factors is too indirect to enter significantly into their considerations. Workers voice concern for the welfare of their employer and his ability to stay in business; but when confronted by daily issues, they fall back on their subjective interests. Many managers know from bitter experience that demonstrating with hard facts to their employees that competitors are way out in front usually brings no improvement in productivity. Pleas of poverty when negotiating renewal of a labor agreement often fall on deaf ears at the bargaining table.

Let's look at the executives, administrators, professionals, and company salesmen. Have you ever heard of a manager who worked himself out of a job by superior performance? Have you ever heard of a salesman whose security was threatened because he sold too much, or of an engineer who caused the layoff of other engineers because he was too creative? These employees can usually anticipate rewards for their creativity and effectiveness.

When workers excel and raise productivity, the company benefits and management is pleased, but the workers do not benefit. To the contrary, in the short term their economic interests are threatened; some suffer loss of income. When exempt employees are more effective, they cover themselves with glory; their economic security is enhanced, not threatened. Ironically, the relationship between workers and management actually provides workers with the incentive not to cooperate in productivity improvement.

When managers state that workers oppose productivity improvement on the plant floor, they are correct. But when managers claim that this attitude of the workers is their problem, they are not correct. Workers' attitude is not the problem, but a symptom of the problem. The problem is that management and workers are not motivated in the same direction; they have different goals, aspirations, and needs. The closer the goals of each can be brought to the other, the more effectively will the organization serve the needs of both.

What are the goals of workers?

It is my contention that the primary concern of the average blue-collar worker is not pay but job security. Furthermore, job security is an essential first which must be guaranteed in order to increase the desire to work. In Japan, where each worker has a guaranteed job for life, it is interesting to note that their productivity per man hour is much higher than the United States. By itself, guaranteed job security will not motivate a worker to increase his output; however, it is a necessary condition which must be met to remove the fear that a worker has of working himself out of a job. Management generally vigorously opposes the concept of guaranteed job security because it smacks of a guaranteed minimum annual wage. However, the auto industry has somewhat painlessly solved this problem through the use of the supplemental unemployment benefits (SUB) plan.

During the past twenty years SUB has proven to be the most effective way of assuring income for workers. The SUB is a private plan of employment benefits whose eligibility or benefit requirements are linked directly to the public program of unemployment insurance. Essentially the SUB guarantees that a worker on layoff will receive payments in addition to his unemployment insurance of amounts that can approach his regular take-home pay. The SUB is extremely low cost to management. The plans range in the rubber, steel, and auto industry in cost from 5¢ to 10¢ per man hour (1). At pennies per man hour, management can create a plant environment in which the fears of layoffs are greatly reduced. The SUB plan effectively protects employees from the seasonality considerations and layoffs in the auto industry. However, SUB does not go far enough. We all know that the auto industry has many problems and does not guarantee worker satisfaction. As discussed previously, guaranteed job security is a necessary but not a sufficient condition to raising the employee's motivation to work. Once security is established, motivational plans must be established in order to effectively increase productivity.

As further evidence of the necessity for job security, consider the following quotation from Mr. James F. Lincoln, founder of Lincoln Electric Company (3).

The greatest fear of the worker, which is the same as the greatest fear of the industrialist in operating a company, is lack of income. The policy of industrial management is controlled by a program that will in the opinion of management assure continuous profit. All industrial plants are controlled by this need. The wage earner has the same necessity and a more personal one than has the industrialist. That necessity also controls his actions. The industrial manager is very conscious of his company's need of uninterrupted income. He is completely oblivious, evidently, of the fact that the worker has exactly the same need. The worker's fear of no income is far more intense than the industrialist, since his daily bread and that of his family depends on his job. The industrialist would not miss a meal if his company should run at a loss for a length of time equal to that for which the worker was laid off because of lack of orders.

In spite of these facts, the industrialist will fire the worker at any time that he feels that he can get along without him. The worker has no control over the future.

His need of continuous income is far more urgent than that of management, yet he has no recourse. Only management is responsible for the loss of the worker's job. Only management can follow and develop a program that will bring in orders. The worker can't. Management, which is responsible, keeps its job. The man who had no responsibility is thrown out. Management failed in its job and had no punishment. The wage earner did not fail in his job but was fired. No man will go along with such injustice, nor should he. This is still true, in spite of custom which completely sanctions such procedure.

It is management's duty to make the worker secure in his job. Only so can the worker feel that he can develop his skill and apply his imagination that will do his job more efficiently, without fear of unemployment from the progress he makes. If a man is threatened with a loss of his job by a better way of producing, which eliminates the need for his services, he can not do his best.

This attitude that the unprotected worker has toward progress will limit his usefulness to the company. There may even be no conscious effort on the part of the worker to hold back progress. However in his subconscious mind there is the fear of the consequences that come from job elimination unless there is assurance that if the job he is doing is eliminated for any reason there will be another one equally attractive waiting him. Only so can any man cooperate to the full both by mind and body in the progress so necessary in a free economy.

Only management can protect the worker in matters of this kind. The fact that the usual management will fire the worker when he runs out of work has had more to do with production limitation than any other circumstances. No man will willingly work to throw himself out of his job, nor should he.

Lincoln practices what he preaches. At Lincoln Electric every employee who has at least two years service is guaranteed 52 pay checks a year equal to at least 30 hours pay. Job security is only part of the story at Lincoln. Since 1934 when management at Lincoln Electric took its first step towards increasing productivity, they have incorporated wage incentive and profit sharing plans which are unrivaled anywhere. The work pace at Lincoln Electric is probably faster than any place in the world. Lincoln Electric's products are competitive on a world market basis, and they have not increased prices substantially since 1934. The obvious question now is why has not Lincoln's incentive plans, practices, and principles been adopted on a wider basis.

A recent article which appeared in Business Week (2) may shed some light on managerial attitudinal problems which tend to stifle work productivity.

In the early 1970's, when everyone was talking about blue-collar blues and worker alienation, General Foods Corporation opened a dog-food plant in Topeka, Kansas, designed to be run with a minimum of supervision. Many functions normally the prerogative of management would be performed by the workers themselves. Workers would make job assignments, schedule coffee breaks, interview prospective employees, and even decide pay raises.

The plant was widely heralded as a model for the future, and General Foods claims that it still is. 'Very successful' is the way J. W. Bevans Jr., manager of organizational development for GF describes the experiment. In fact, GF has applied a similar system at a second dog-food plant in Topeka and at a coffee plant in New Jersey.

And it says it may eventually do the same at two plants in Mexico and among white-collar workers at its White Plains headquarters.

But management analysts and former employees tell a different story. And General Foods, which once encouraged publicity about the Topeka plant, now refuses to let reporters inside. Critics say that after the initial euphoria, the system, faced with indifference and outright hostility from some GF managers, has been eroding steadily.

'The system went to hell. It didn't work,' says one former manager. Adds another ex-employee: 'It was a mixed bag. Economically it was a success, but it became a power struggle. It was too threatening to too many people.' He predicts that the plant will eventually switch to a traditional factory system. In fact, he says, the transition has already begun.

The problem has not been so much that the workers could not manage their own affairs as that some management and staff personnel saw their own positions threatened because the workers performed almost too well. One former employee says the system--built around a team concept--came squarely up against the company's bureaucracy. Lawyers, fearing reaction from the National Labor Relations Board, opposed the idea of allowing team members to vote on pay raises. Personnel managers objected because team members made hiring decisions. Engineers resented workers doing engineering work. . . .

A former employee at the Topeka plant sees it this way. 'Creating a system is different from maintaining it,' he says. 'There were pressures almost from the inception, and not because the system didn't work. The basic reason was power. We flew in the face of corporate policy. People like stable states. This system has to be changing or it will die.' . . .

There is no question that the company has met many of its goals. Unit costs are 5% less than under a traditional factory system. . . . This . . . should amount to a saving of \$1 million a year. Turnover is only 8%, and the plant went three years and eight months before its first lost-time accident. . . . Says one employee who left after two years: 'There was too much competition because of jealousy between teams and team leaders.' . . .

More important, employees believe they ought to share financially in the system's success, an idea that has been backed by managers, though GF's headquarters is noncommittal.

Both General Foods' experience and Lincoln Electric's experience were successful. However, General Foods' success appears to be deteriorating, and the reason probably is because General Foods has not been sharing any of the financial savings with the employees. Lincoln Electric gives employees bonuses and benefits which are greater than stockholder dividends, and they have done so since

they incorporated their incentive plans in 1934. At General Foods the article seems to imply that managers began to feel threatened by employees making decisions which affected their productivity. This is not atypical. Managerial attitudes toward employees traditionally have been very paternalistic and presumptuous. Most managers feel that they know what is right for employees and do not want employees making decisions. Employees react to this type of treatment in the traditional ways and tend to slow down work or not bother to worry about their productivity. It is only when employees know that they are going to receive a piece of the action (just like managers) with incentives and bonuses will they tend to have a desire to increase their productivity. First though they must have guaranteed job security. We have seen that this can be done using the concept of the auto industry of supplemental unemployment benefits, and this can be incorporated into the general pay schedule of the employees at little or no cost to the company. Managerial attitudes must be changed if we are to expect employees to change their attitudes.

CONTINUING PRODUCTIVITY

Dodging the ruts

Most successful businesses develop work methods which give reasonable performance. As time progresses, these business practices become habits. When I walk into a processing plant and begin to question these work practices, I invariably get the answer, "We've always done it this way" or "I don't know, I guess I've never thought about why we do it this way." Habits can be good or bad. Work methods and managerial practices are often developed with too little thought. Managers should periodically tour their workplace and see what is really happening. Often poor work practices go unnoticed simply because managers are "too busy." In today's competitive marketplace, the edge rests on management's ability to continually review and update their operating methods.

Searching for the "one best way"

As indicated earlier, most of the labor motivational problems rest on antiquated and unenlightened managerial attitudes. Successful managers are never satisfied with their current approach. They are always looking for a better way to increase their worker productivity. The standard work simplification method developed by A. H. Mogensen consists of four steps:

1. Eliminate - Is the operation necessary, or can it be eliminated?
2. Combine - Can it be combined with some other operation or action?
3. Change sequence, place, or person - Can these be changed or rearranged?
4. Simplify the necessary operations - Can the method be improved?

Applying these four fundamental steps often causes dramatic changes which result in tremendous cost savings.

CONCLUSIONS

Each business type must develop their own indices of productivity. These indices need to be reviewed and compared with industry averages. Workers are motivated by monetary gain and use pay as a chief means of estimating the quality of their work. Managers must recognize the workers' goals of security. Motivational efforts only succeed when workers can directly relate their productivity gains with their salary gains. Managerial attitudes toward workers must change if we are to expect employees to change their attitudes. Managers must be continually searching for the "one best way."

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PRELIMINARY ESTIMATES OF THE
FISH PROCESSING INDUSTRY'S CAPACITY

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Research into industrial market structure has usually included capacity utilization among the criteria for measuring market performance. Capacity utilization can also gauge an industry's ability to absorb increased production without adding fixed resources. This is especially useful in extraordinary situations such as war or, in the case of fisheries, the extension of economic jurisdiction to 200 miles. Of particular importance for the research is matching an appropriate method of estimating capacity utilization with one of several definitions of capacity.

In this paper, several definitions of capacity are discussed relative to the fish processing industry. These definitions are then correlated with appropriate methods of estimating capacity. Finally, the results, obtained from available data and the proper methodology-definition mix, are used in a policy framework for evaluating the industry. The fish processing industry itself is divided into several groups of product categories between which substitutability of products is not perfect. The groups discussed in this paper are canned tuna, canned shrimp, fresh and frozen shrimp, groundfish fillets, fish sticks and portions, and fish meal. While the analysis is national in scope, regional conditions also can be estimated from the data or by induction.

DEFINING PROCESSING CAPACITY^{1/}

A review of the economic literature on capacity reveals several interpretations of the term (5). Among most users capacity is defined as "the maximum amount of output that can be produced during

a given time period with existing plant and equipment." The phrase "can be produced," however, leads to two interpretations of capacity which will be discussed herewith (2, p. 47).

Engineering capacity

This refers specifically to the physical capabilities of the system given a constant level of capital, labor, and technology. The only constraint on the amount that can be produced is the physical capacity of the existing plant and equipment as it operates around the clock, 7 days a week. There is no reference to the economic incentive to produce nor to the relevant issues of capital/labor substitution and the proportion of available time to which each of the factors are applied. The definition is thus more applicable to an "extraordinary demand" or stress situations and appears less relevant for the fish processing industry because of its operating characteristics during the year and within seasons.

Economic capacity - microeconomic approach

This refers to a program of production in which the profit-optimizing objective underlies the firm's decisionmaking process. Thus, under traditional microeconomic theory, maximum capacity will be the point at which all firms operate where marginal cost equals marginal revenue. (This makes the standard assumption that short-run average cost is less than or equal to marginal revenue.) In practice, firms try to minimize short-run average costs, thus maximizing or approaching maximum profit.

The economic theory for this measurement is irrefutable. The major limitation in this approach lies in its application to an imperfect world where other factors beside short-run profit maximization may affect decisionmaking factors which are not normally included in the total cost and total revenue functions. If we consider cases of imperfect information, for instance, which results in a sub-optimal production level, then at a given marginal revenue price the system will be operating at under 100% capacity ($MR > MC$). On the other hand, if we consider factors such as firms' reluctance to turn away customers in the desire for long run profit maximization, then the system can operate at over 100% capacity ($MC > MR$). By definition, this economic capacity would always be below the engineering capacity. Despite its economic bias, this approach would have limited applicability because it overlooks the institutional response of producers during exceptional situations (such as the imposition of the 200-mile limit).

Economic capacity - macroeconomic approach

This is defined as "the maximum sustainable level of output (which) the industry can attain within a very short time if the demand for its product were not a constraining factor, when the industry is operating its existing stock of capital at its customary level of intensity" (3, p. 2). Taken on a macroeconomic level, the capacity utilization concept reduces down to an empirical observation of how much producers have been willing to operate. There is not explicit reference to profit maximization or prices or acceptable patterns of producer behavior, which also raises the question whether this approach is really an engineering one. However, profit maximization to some degree is implied here because it is surely one of the major factors used by the industry in determining maximum output.^{2/}

This approach becomes effective largely in cases where there are many non-economic factors such as special producer/supplier relationships, affecting the production process. A large number of institutional factors thus make the classic microeconomic approach (profit maximization) less relevant for defining the maximum output that would be expected.

MEASURING PROCESSING CAPACITY

Measuring capacity is commonly done using one of two approaches, each associated with the microeconomic and macroeconomic approaches of the economic interpretation. The first method surveys an industry or a sample thereof with a questionnaire, assuming that respondents have this estimate readily at hand or can easily generate it. If the questionnaire is properly worded, this method is consistent with the microeconomic approach. The second method, exemplified by the Wharton School of Finance, infers capacity using already published secondary data (3). This method would well suit the macroeconomic approach.

Survey method

This is currently used by several agencies including the Bureau of Economic Analysis (B.E.A.) which estimates capacity utilization for the durable and nondurable goods industries. "Food including beverage" is one such category in the latter industry; however, the fish products are a negligible part of this statistic.^{3/} As mentioned, this approach assumes that the respondents have at their disposal the statistic on actual output and an idea of their maximum capacity. It would seem reasonable to expect that respondents know their actual output because it is requested by several State and Federal agencies.

In designing a questionnaire, both B.E.A. and McGraw-Hill have found sharply reduced responses if capacity is defined on the questionnaire itself; however, they have found "that responses to undefined terms...correspond very well to what (they) meant by these terms," i.e., an economic interpretation. B.E.A.'s questionnaire asks each firm (1) their present capacity utilization (% terms) and (2) their preferred capacity (% terms). Dividing the response from (1) by the response from (2) results in a usable estimate of utilization rate.

Inferential method

This can be either graphical or econometric. In the graphical analysis, quarterly production figures for an industry are plotted over time and a trend line indicates the industry's capacity. The trend line is derived by connecting peak quarters, defined a priori as a quarter in which the industry achieves maximum sustainable output in the short run, or 100% capacity. If there is little a priori information to identify peak quarters of an industry they may then be defined as quarters that had production higher than in the preceding and following quarters. Percent capacity in any quarter is the ratio of actual output divided by the accompanying value from the trend line (Figure 1).

Advantages with the graphical method include its low cost and ease in calculating an estimate of capacity. Its disadvantages include (1) it could assume an engineering interpretation of capacity depending on one's reading into the macroeconomic approach, (2) it is useful primarily in historical constructs, and (3) without a priori knowledge, to define a peak quarter as 100% may be doubtful. Available data on processed products would make analyses possible for the United States as a whole, by defined regions, by general product categories (fresh, frozen, etc.), and by species.

The econometric analysis estimates a production function for the industry's output. Capacity utilization for any quarter or year is the ratio of actual to estimated output. A production function can be estimated using a number of specifications, although a Cobb-Douglas function is most common. It is the type:

$$Q_t = AL_t^b K_t^c V_t$$

where Q_t = output in period t
 A = constant term
 L_t^b = employed labor in period t

K_t^C = utilized capital in period t
 V_t = proxy for technology in year t

Like the graphical analysis, its advantages include low cost and ease of estimating a capacity utilization rate. Its disadvantage lies in the scarcity of data on the above labor and capital variables; there are only enough data available to permit a cross-sectional analysis, by state, to estimate a national production function for two product groupings--canned and cured, and fresh and frozen products.

Based on available resources, the macroeconomic interpretation of capacity and the inferential method of measurement were used to estimate capacity utilization.

FINDINGS

The estimated capacity utilization in selected fish processing industries is shown in Table 1, which indicates considerable differences in the average capacity utilization between industries. The processors of sticks and portions appear to have very little excess capacity, whereas fish meal processors have capacity utilization that averages only about 50 percent.

The determining factor of the level of capacity utilization is the fluctuation in the output. In fish processing industries the seasonal fluctuation is closely associated with the availability of raw material. In industries where use of frozen or imported raw material is not economically feasible and where landings are highly seasonal, capacity utilization is low. The processors tend to build capacity to take care of the peak landings; consequently, the plant is idle or works at a fraction of capacity during the off-season. The fish meal industry is typical in this respect.

Industries that can use raw material holdings or imported raw material or that do not have seasonal landings tend to have relatively high capacity utilization. Canned tuna and sticks and portions industries are examples in this case (Table 1).

In view of a possible expansion of domestic landings under the extended jurisdiction, it appears that the average capacity utilization may decline rather than increase, if industries become more dependent on seasonally fluctuating sources of raw material. The importance of low-cost cold storage for raw material and availability of freezing facilities is evident.

Table 2 shows capacity utilization of selected industries in different regions. The variations reflect the differences in regional conditions as far as availability of raw materials is concerned. For example, processors of fillets and steaks and of sticks and portions on the Pacific Coast have somewhat lower capacity utilization than processors in New England.

The decline in capacity utilization in some fish processing industries in recent years suggests that these industries could operate closer to capacity if landings increase, even if the increase coincides with the peak of the season. Thus Pacific and Gulf fillet and steak industries, Pacific fish meal, and Gulf shrimp and fish meal industries could absorb higher supplies in the short run.

It should be emphasized, however, that economical storing of raw material is probably the most crucial factor in improvement of capacity utilization in most fish processing industries. As suggested by the average capacity utilization figures, many domestic fish processing industries could handle considerable more raw material with the present capacity.

EXPANSION POTENTIAL

The results from the inferential method of estimating capacity utilization, combined with the possible increase in fish products from extended jurisdiction, should yield information on the adequacy of existing facilities. Our procedure was to add the increased production in each product category to respective actual 1975 production.^{4/} This sum was divided by the total capacity in each product category at the national and regional levels, indicating a new capacity utilization (Table 3).

The information provided in Table 3 suggests that, of the three major fishing regions, the Gulf of Mexico could absorb increased production the most easily and that fish meal facilities are more than adequate. The increased production from extended jurisdiction comes from a minimum level of added investment by the fish harvesting industry, resulting in increased landings. There are also two higher levels of investment, each resulting in successfully larger landings.^{5/} Even at this minimum level of increased investment, most facilities would not be able to absorb more production. This is particularly evident for facilities to process fresh and frozen steaks and fillets in New England and the Pacific, and fish meal in New England.

Much of the increased landings (over 60%) come from now underutilized groundfish and pelagic species--pollock, mullet, croaker, mackerel, and hake. These can be processed into fillets or steaks, or could be canned. However, the probability of using canning facilities is remote. Salmon canning operates only on a seasonal basis and, considering the high variable costs, the canned product must be of high value. Sardine canneries in New England have the same problem. Gulf shrimp canneries lack filleting lines or machinery for these finfish. Only tuna and mackerel canneries offer a realistic possibility for canning the underutilized fish.

At higher levels of investment, capacity utilization exceeds 100% for those regions and products operating below capacity as indicated in Table 3. At the second (or moderate) level of investment, facilities for fish meal in the Pacific and for fillets and steaks in the Gulf would operate at 100% capacity. At the maximum level of investment, though, fish meal facilities in the Gulf would operate at only 67% capacity.

SUMMARY AND CONCLUSIONS

In this paper several definitions and methods of calculating capacity were developed and discussed. For the researcher, it is important to make a proper match of a definition and estimation technique. Here, we found that for the fishing industry the economic definition was better suited rather than the engineering definition. Further the microeconomic approach and the survey method was identified as one proper match, and the macroeconomic approach and the inferential method was another proper match. Both matches have a unique set of advantages and disadvantages. The capacity utilization rates derived herein followed the macroeconomic-inferential procedure.

It was found that large differences existed in capacity utilization between groups of fish processors. This can be explained as primarily due to fluctuating output, which in turn is caused by availability of raw material. In industries where raw material storage and import schemes are uneconomical and landings are very seasonal, the utilization rate is low. This is the case for the fish meal industry. The raw material situation for the canned tuna and sticks and portion industries is just the opposite, and the utilization rate is substantially higher. Capacity utilization was also estimated for the three main processing regions - New England, the Pacific, and the Gulf of Mexico using either available data or induction (the Pacific

has almost all the tuna canneries). Differences in utilization rates between and among these regions were similar to those on the national level.

The adequacy of existing plant and equipment was tested in the event there would be more fish to process as a result of the new 200-mile jurisdiction. Our results indicated that a minimum level of additional investment by the harvesting sector, the increase in landings would seriously strain most processing facilities in all three regions. The only exception to this was fish meal facilities in the Gulf and in the Pacific, and fillet and steak facilities in the Gulf.

FOOTNOTES

1/ Largely taken from "Defining and Measuring Capacity for the Fish Industry," Ballard, Bass, and Blomo, National Marine Fisheries Service, manuscript, November 5, 1975.

2/ In fact, capacity defined in the microeconomic end approach could be expanded to include non-traditional objectives consistent with industry practices as well as profit maximization. However, use of this defined capacity would be preferred since it would be more compatible with the empirical observations.

3/ In addition, there are no further breakdowns of the above category, "Food including beverage."

4/ Increased production derived from landings reported in Noetzel and Vondruska (4, pp. 13, 17 and 19) and appropriate conversion rates.

5/ Ibid.

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Table 1. Estimated utilization capacity of selected fish processing industries, 1971-1975.

Year	Canned tuna	Canned shrimp (canned oyster) ^{1/}	Fresh & froz. shrimp	Fresh & froz. fillets ^{2/}	Fish meal	Sticks & portions
1971	76	51	84	78	50	82
1972	88	68	78	75	48	89
1973	86	62	77	81	49	95
1974	89	62	70	75	51	84
1975	70	36	68	75	49	85
Mean	81.8	55.8	75.4	76.8	49.4	87.0
Mean devi- ^{3/} ation	7.04	9.84	5.12	2.16	0.88	4.0

^{1/} Part of the shrimp canning capacity is used for oyster canning.

^{2/} Cod, cusk, flounders, haddock, hake, ocean perch and pollock species.

^{3/} Mean deviation = $\frac{\sum(\bar{x} - x)}{n}$

\bar{x} = arithmetic mean of x values

n = number of items to be averaged.

Table 2. Estimated capacity utilization of selected fish processing industries by region, 1971-1975.

Year	New England		Pacific			Gulf					
	Filletts and steaks ^{1/}	Sticks and portions	Filletts and steaks ^{2/}	Sticks and portions	Canned tuna	Fish meal	Filletts and steaks ^{3/}	Sticks and portions	Fresh and frozen shrimp	Canned shrimp and oysters	Fish meal
1971	82	82	76	50	76	65	93	87	84	51	45
1972	73	89	85	76	88	81	73	88	78	68	39
1973	88	93	65	79	86	74	67	98	77	62	35
1974	84	86	70	66	89	64	69	66	70	62	41
1975	NA	83	NA	76	70	66	NA	76	68	36	40
Mean	81.8	86.6	74.0	69.4	81.8	70.0	75.5	83.0	75.4	55.8	40.6

^{1/} Cod, haddock, flounder, ocean perch and whiting species.

^{2/} Halibut, flatfish, ocean perch, cod, hake, salmon, rockfish and sablefish species.

^{3/} Mullet, croaker, mackerel, and snapper species.

Table 3. Capacity utilization for fish processing industry segments with minimum level of fishing effort.

Region	Product		
	Fresh & frozen steaks and fillets ^{1/}	Canned ^{2/} seafood	Fish meal
-----percent-----			
New England	144-184	--	--- ^{3/}
Pacific	188-207	99	81
Gulf	76	--	40
National ^{4/}	136-164	99	56

^{1/}The range in percent is due to the additional processing of non-groundfish species.

^{2/}Tuna canning facilities.

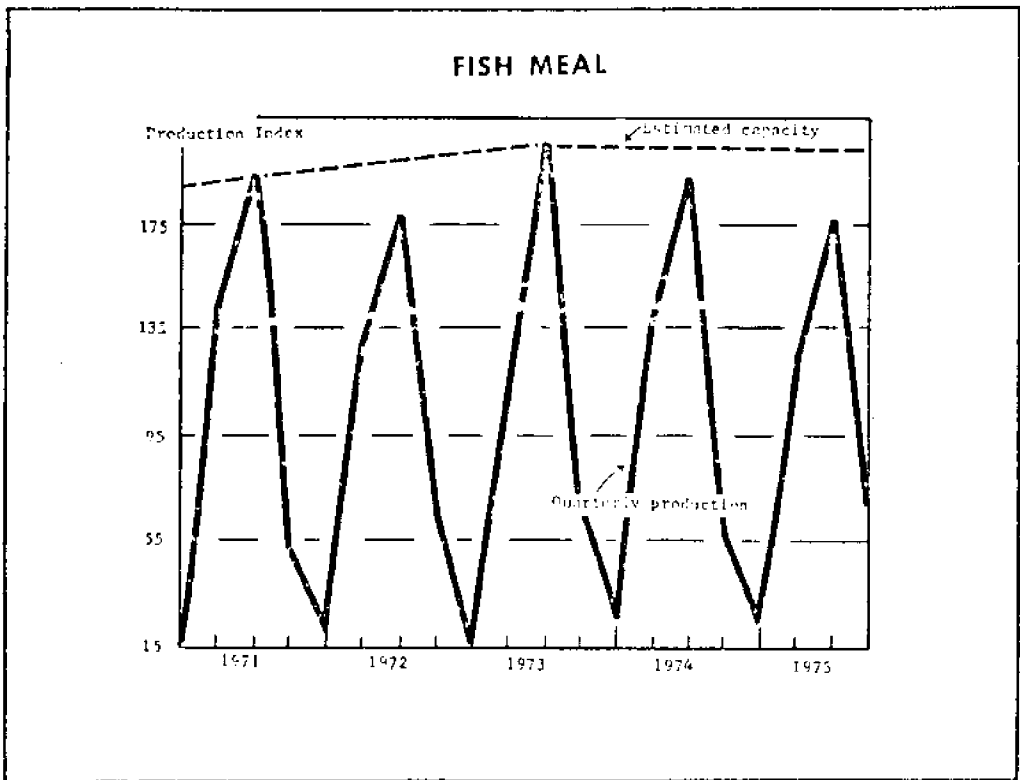
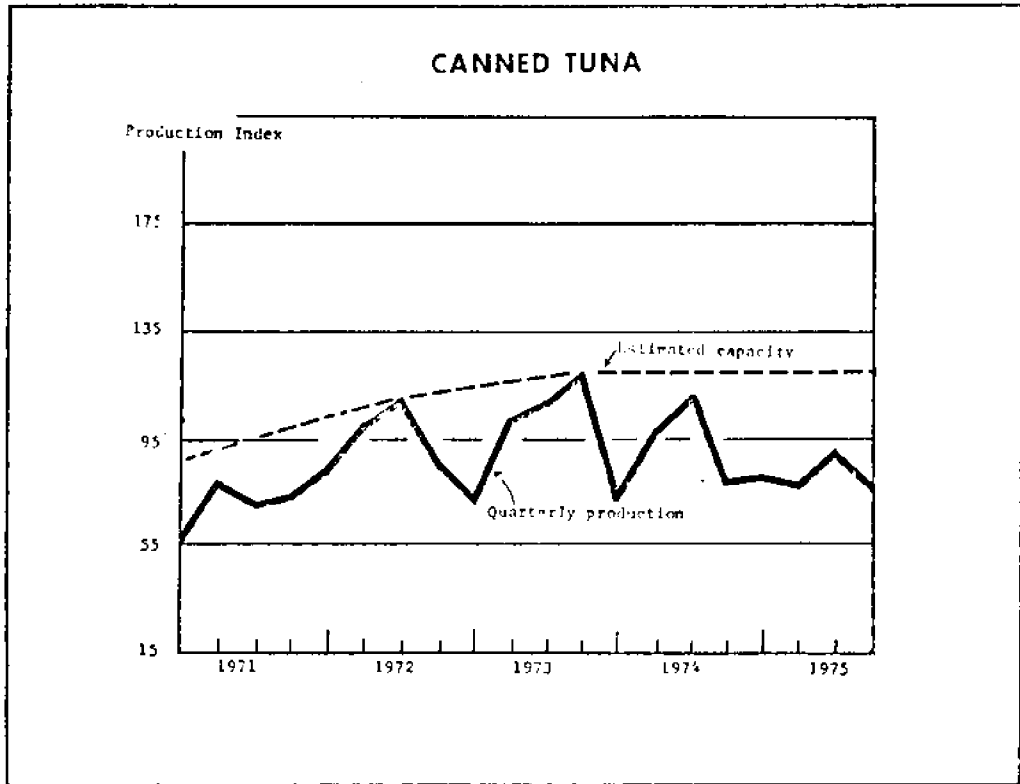
^{3/}Exceeds 300%.

^{4/}Summation of regional production and potential expansion.

Note: Minimum level of fishing effort is defined as additional inputs invested by the fish harvesting industry resulting in increased catches over those expected from present trends.

Source: Tables 1 and 2, Noetzel and Vondruska, op. cit.

CAPACITY UTILIZATION



Production Index is calculated around the average quarterly production.

Figure 1: Production and trend-through-peaks.

POTENTIAL FOR EXPORTING MISSISSIPPI FISH TO NIGERIA

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Background

Nigeria offers a potentially large market for the exportation of fish from the Gulf coast. Nigeria, located on the west coast of Africa, is a relatively large country with an estimated population of 60 to 70 million. It has a relatively high population density (179 persons per square mile) with a proportionally large urban component (26 percent). Nigeria has a large number of cities with relatively high population levels. Lagos has more than a million; Ibadan, over 700,000; and there are at least 23 other cities with populations of more than 100,000 and 21 cities with from 50,000 to 100,000 residents.

With recent discoveries of oil, Nigeria has become one of the world's leading exporters of petroleum. In addition to the large sums of foreign exchange generated from petroleum exports, Nigeria is one of the world's leading producers and exporters of palm oil. Because of the large volume of exports, national income is relatively high compared to other developing countries. Consequently, there is a large and growing demand for imported items, including fish.

Because of its geography, Nigeria is a deficit country in high protein foods. The northern part of the country is largely desert, arid land while the southern and eastern-most parts of the country are rain forests. A relatively narrow plateau stretches from west to east and is suitable for the production of crops and livestock. The demand for high protein foods is met largely through imports. Importation of fish is necessary because Nigeria's continental shelf is relatively small and will not sustain heavy fishing. Nigerians import approximately 80,000 metric tons of fish each year. Fish are imported either frozen, smoked, dried, or canned.

Native fish in the Nigerian waters are very similar to some of the fish in the Gulf of Mexico. Consequently, there is little problem with consumer acceptability.

Previous Fish Exports to Nigeria

A U.S. fish company shipped some whole frozen gulf coast fish to Nigeria early in 1976. The fish were taken in Mississippi, Alabama, and Florida waters. The initial shipment consisted of mixed Mississippi taken fish, primarily croaker and mullet, mixed

gulf fish taken and processed in Alabama, and thread herring, mullet, and saltwater buffalo taken and processed in Florida. The fish taken from Mississippi waters were about 60-80 percent croaker with some sand trout and saltwater catfish. A potential export volume of 1,000 tons per month is anticipated. This demand can be met with readily available underutilized species of fish.

Transportation

The extremely high transportation cost was the primary problem encountered in the initial shipment of frozen fish to Nigeria. The shipment was lifted by conference carrier steamship line at a rate of \$.27 per pound. Because of anticipated unloading problems in Nigerian ports, the carrier added an additional 60 percent port detention surcharge to the basic conference rate. This resulted in total transportation costs of \$.43 per pound.

Estimated total costs consisted of \$.08 per pound for the fish, \$.10 per pound for processing, and \$.43 per pound for transportation for a total of \$.61 per pound. The fish was sold at retail in Nigeria for about \$.40 per pound; thus the company lost at least \$.20 per pound on fish sold. They were willing to absorb this loss in order to determine whether or not frozen Gulf coast fish would be acceptable in the Nigerian market. The company met with great success in marketing the fish in Nigeria.

Distribution

Upon arrival in Nigeria, the frozen fish was transported from the reefer ship to the dock by small lighters, which lifted the cargo from the reefer ships in Sapele harbor and transported it to the warehouses on the shore. Since no freezer facilities were available, the fish had to be sold immediately. Even though a system of supermarket-type grocery stores exist in Nigerian cities, it was not utilized to market the frozen fish. The traditional Nigerian marketing system was used, which includes selling fish in open markets directly to consumers and in relatively small quantities. This will place limitations on the volume of frozen fish which may be imported and absorbed by the traditional Nigerian market. Marketing through grocery stores may provide an expanded market potential for both frozen and canned fish.

The fish began to thaw immediately upon unloading and were either purchased and cooked by the consumer during the first day or were smoked and held by the distributor or consumer for future consumption.

POTENTIAL FOR EXPORTING CANNED GULF COAST FISH TO NIGERIA

In addition to frozen fish there appears to be a potential market in Nigeria for canned gulf fish.

Cost Components

Fish

Mullet. Mullet is available, FOB the canning plant for about \$.10 per pound. After dressing, approximately 50 percent of the fish remains and is suitable for canning. This raises the cost

of mullet required to pack a 1-lb. can to \$.20. Mullet is readily available from gulf waters in the quantity required for export to Nigeria.

Croaker. Croaker can be purchased for about \$.20 per pound. Processed yield would be about 50 percent raising the cost per pound to about \$.40.

Ribbon Fish. The cost of the ribbon fish is the lowest at about \$.15 per pound on a cleaned basis. Much of the processing work remains to be done on this species. Enough of this species has been canned to indicate that it has a definite commercial potential.

There is also a potential for establishing a gulf coast fishery for some of the small species of fish for the Nigerian market.

Cans, Cartons, and Labels

The cans and cartons are available at a cost of approximately \$.08 per can. Labels cost about \$4.00 per thousand.

Processing

Processing costs for each species are approximately the same. The processing method for mullet has been previously tested. The research and development work for mullet has been completed. Much of the work has been done for canning both croaker and ribbon fish. Additional testing will be done to assure a safe, sanitary product, and one which will be as desirable as possible to the consumer.

Transportation to the Port

Cost of transporting the fish from the canning plant to the port is estimated to be \$.03 per case, including handling, transportation, and the port charge.

Stevedore Charges

Stevedore charges for moving canned fish from the wharf to the hold of the ship amounts to \$3.25 per ton with individual case handling for cases weighing 63 pounds or less. This was the basis used for estimating the cost in table 1. However, if the load is palletized, stevedore charges would be reduced by 50 percent. With forklifts and pallets readily available, it should be relatively easy to palletize the cases of fish, to load them on the truck in pallets, then off-load on the dock and load onto the vessel still palletized, thus, securing the lower stevedore charge.

Freight

Freight charges vary considerably depending upon the port of destination in Nigeria. As shown in table 2, three Nigerian ports were considered, Port Harcourt, Warri, and Sapele. Sapele is considered to be the most desirable of the three ports. It is assumed that a Nigerian company would be the receiver-wholesaler for shipments of fish going into Nigeria.

The basic freight charges are \$144 per 2,240 pounds or per forty cubic feet. This rate applies to Port Harcourt and Warri.

<u>Cost Components</u>	<u>Mullet</u>	<u>Croaker</u>	<u>Ribbon Fish</u>
	dollars per 303 can (1 lb.)		
Fish	.20	.40	.15
Cans & Cartons	.08	.08	.08
Labels	.004	.004	.004
Processing	.25	.25	.25
Transportation to Port	.0012	.0012	.0012
Stevedore Charge	.0021	.0021	.0021
Freight	<u>.1369</u>	<u>.1369</u>	<u>.1369</u>
Sub Total	<u>.6742</u>	<u>.8742</u>	<u>.6242</u>
Exporter's Commission	<u>.0337</u>	<u>.0532</u>	<u>.0262</u>
TOTAL	<u>.7079</u>	<u>.9274</u>	<u>.6504</u>
Unloading and Handling	<u>.003</u>	<u>.003</u>	<u>.003</u>
	<u>.7109</u>	<u>.9304</u>	<u>.6534</u>
Estimated Marketing Costs			
Distribution (5 percent of total delivered price)	.0355	.0560	.0277
Retail (25 percent of total delivered price)	<u>.1777</u>	<u>.2780</u>	<u>.1384</u>
	<u>.9241</u>	<u>1.2644</u>	<u>.8195</u>

TABLE 1

COSTS OF PROCESSING AND EXPORTING CANNED FISH TO NIGERIA

The rate at Sapele is \$21 per 2,240 pounds or per forty cubic feet more than for the other two ports. In addition to the basic freight rate, there is an additional charge for port detention. This is applied by the steamship lines because of delays in off-loading ships at these ports. The port detention charge at Port Harcourt is 100 percent over the basic rate; at Warri and Sapele, 60 percent over the basic rate. In addition to the port detention charges, harbor dues are imposed by the Nigerian government. At Port Harcourt and Warri, harbor dues are \$1.07 per 1,000 kilograms (2,204.6 lbs.) or cubic meter. At Sapele, the rates are somewhat higher. For lighterage and harbor duties, the rate is \$3.85 and \$.54, respectively, for a total of \$4.19 per 1,000 kilograms or cubic meter.

The costs in table 1 are based on a shipment of 500 tons (one million pounds) which at 31 pounds per case would amount to 32,258 cases. The rate for the noncontainerized cargo bound for the port at Sapele is \$106,000 or \$.1362 per can of fish.

Exporter's Commission

The exporter's commission is estimated to be 5 percent of the total value handled (including transportation) for each can of fish. There is a possibility that the shipper could act as his own export agent, thus avoiding the commission charge.

Unloading and Handling

Unloading and handling charges at the Nigerian ports are estimated to be \$.003 per can. This slightly exceeds the stevedore and handling charge at the U.S. port.

Estimated Total Delivered Costs

The cost of a can of fish delivered to Nigerian port, including unloading and handling, varies from a low of \$.82 for ribbon fish to \$1.26 for croaker. It is anticipated that these prices would be competitive with canned fish of equal quality imported to Nigeria from other countries.

Estimated Marketing Costs

The usual wholesale and retail margins in the Nigerian marketing system are not known precisely but were estimated at 5 percent of the total delivered cost and retail add-on margin at 25 percent. These are estimates only to be used as a basis for estimating a possible retail price for the canned fish in the Nigerian marketplace. As shown in table 1, each can of mullet would retail for approximately \$.92; croaker, for \$1.26; and ribbon fish, for \$.82.

Comparing the relative prices of the three varieties of canned fish with frozen fish, which was delivered to Nigeria earlier, shows the mullet and ribbon fish to be relatively competitive with the frozen fish. Assuming that frozen fish would be sold in Nigeria for about \$.65 per pound and with a 50 percent waste factor, the cost to the consumer would be \$1.30 per pound. Each species of canned fish would cost the consumer slightly less than the frozen fish. In addition, there are advantages of canned

	<u>Port Harcourt</u>	<u>Warri</u>	<u>Sapele</u>
Basic Rate (including port detention charges)	\$ 5,140.80	\$ 4,112.64	\$ 4,112.64
Harbor Dues	19.41	19.41	105.19
Total	5,160.21	4,132.05	4,217.83
Cost Per 1-lb. Can	.1667	.1335	.1362

Basis--39,990 lbs. or 1290 Cases or 829.77 Cu. Ft.

TABLE 2
TRANSPORTATION COSTS FOR CANNED FISH
FROM GULFPORT, MISSISSIPPI TO SELECTED NIGERIAN PORTS
AS OF JULY, 1976

fish over frozen fish, such as ease of transportation, storage, and extended shelflife.

CONCLUSIONS AND IMPLICATIONS

The information in this paper indicates that there is a potential market for Mississippi fish in Nigeria. There are sufficient quantities of fish in gulf coast waters of the species demanded by Nigerians to support an export fishery.

While major obstacles to establishing such a fishery exist, none are insurmountable. Fishermen are not accustomed to fishing for these species, and some changes in fishing practices will be necessary. However, the possibility of increased income for fishermen should overcome this obstacle.

Transportation costs appear to be the most formidable obstacle. Conference steamship lines add on to the basic rate an additional charge because of anticipated delays in securing a berth and unloading the cargo.

The opportunity for fish exportation exists and only awaits for the resolution of the details. A Mississippi export fishery would greatly enhance the incomes of Mississippi fishermen and processors, the port of Gulfport, and the economy of the Mississippi gulf coast.

