THE GULF OF MEXICO RESEARCH AND FISHERY ON PENAEID PRAWNS[1]

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ABSTRACT

A review of recent biological research on the Gulf of Mexico penaeid prawn stocks is presented. The status of population dynamics research on these stocks is discussed as well as management procedures being used by various States in the United States.

The general history of this fishery is reviewed with emphasis on recent trends, changes in fishing methods and regulations, and the biological and economic consequences.

INTRODUCTION

Since the topic of this talk is very broad, I am not going to discuss all aspects of the fishery. Instead I will emphasise recent research developments in relation to the major subject areas of this Seminar: Descriptive Biology, Population Dynamics, Commercial Fishery and Management.

DESCRIPTIVE BIOLOGY

During the last 20 years annual shrimp landings from the United States fishery in the Gulf of Mexico have ranged from 60 million kg to 108 million kg heads-on. About 98% of the catch consists of the brown shrimp, *Penaeus aztecus*, the white shrimp, *Penaeus setiferus*, and the pink shrimp, *Penaeus duorarum*. The remaining 2% of the landings are seabob shrimp, *Xiphopenaeus kroyeri*, royal red shrimp *Hymenopenaeus robustus*, Brasilian shrimp, *Penaeus brasiliensis*, and rock shrimp, *Sicyonia brevirostris*. Descriptive information on the fishery, the distribution of catches and the seasonal changes in landings is presented by Osborn, Maghan and Drummond (1969).

Although our knowledge of the basic biology of the three major species in the Gulf of Mexico is incomplete, recent research has added to our understanding of these species. Research work on diseases of shrimp has blossomed in recent years because of interest in shrimp culture. Because of the lack of basic research in this field, much of the recent work has been descriptive histology and histopathology. The most harmful pathogen observed in the larval stages is a fungus of the genus *Lagenidium* which has caused mortalities of 100% in shrimp hatcheries. In the juvenile and adult stages microsporidians, *Nosema, Pleistophora* and *Thelohania*, and bacteria, *Vibrio alginoliticus* and *V. parahaemoliticus* are common disease organisms. The role of a protozoan parasite, *Zoothamnium* sp. is illustrative of the importance of stress in shrimp diseases. *Zoothamnium* frequently occurs attached to the gills with little if any adverse effect. However, when shrimp infected with *Zoothamnium* are subjected to environmental stresses such as low oxygen or unusually low salinity the parasite has a harmful effect. Synergistic effects of disease organisms and environmental stresses seem to be extremely important with shrimp. With captive shrimp deaths attributed to disease are frequently associated with poor environmental conditions. Overstreet (1973) has presented a good discussion of shrimp diseases in the Gulf of Mexico region.

In the field of behavior we have a longstanding puzzle concerning how postlarvae get into the estuaries and how juveniles get back out to sea. Hughes who worked first in South Africa and later in the United States on this problem has provided some partial explanations for the migrations (Hughes, 1967; 1969a; 1969b). In summary he observed that postlarvae were active in the water column after acclimation to a given salinity. If the salinity decreased, the postlarvae settled to the bottom until the salinity increased again. Juveniles exhibited changing rheotactic responses in a rhythm corresponding to tidal cycles. This biological rhythm was maintained after the shrimp were removed from the natural environment. Juveniles also swam into the current or maintained their position on the bottom except when salinity was reduced, at which time they swam with the current.

Recent shrimp experiments conducted at the

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Galveston Laboratory utilising improved tagging methods have been surprising in that a substantial number of shrimp were recovered after long periods at large. We have concluded from these experiments that shrimp live longer than previously thought (some for more than 3 years) and that mortality rates in the offshore environment are lower than we had estimated.

Some interesting observations have been made relating to the differences in environmental requirements between the estaurine and oceanic stages in the life cycle of shrimp. From laboratory experiments we have evidence that juveniles benefit from a high organic content in the water. Nevertheless, there are apparent drastic changes in the environmental requirements of shrimp corresponding to their immigration from the estuaries. We are just beginning to understand the requirements of sub-adults and adults, which is probably the reason these stages grow poorly in captivity and fail to develop normal ovaries. Two factors which seem to be very important in this respect are light intensity and dissolved organics.

Because of recent interest in pollution in the United States, a vast amount of data are being accumulated on the tolerance of shrimp to pesticides, herbicides and other pollutants. While most of this information has not been published, it should be appearing in the literature soon.

POPULATION DYNAMICS

Although biologists at the Galveston Laboratory have worked with the population dynamics of Gulf of Mexico stocks for a number of years, we don't have any simple solutions to the unusually difficult problems encountered with penaeids. There are no simple formulas for learning how to manage penaeid populations correctly. We can learn much, however, by examining those approaches which have been used and by asking ourselves which are most valuable.

Numerous studies of spawner-recruit relations have been conducted in search for answers to the question 'How heavily can we fish a stock of shrimp without reducing its reproductive potential?' Although the results of these studies are not clear-cut, some general assumptions have emerged. The assumptions, which are illustrated by the spawner-recruit curve in Fig. 1, are as follows:

(a) Because of the high fecundity of shrimp, a relatively small population of spawners is required to maintain stock levels.

(b) The fishery is operating at levels of spawner abundance somewhere on the flat part of the curve so that environmental fluctuations rather than changes in spawner abundance are the primary cause of stock fluctuations.

(c) Overfishing is unlikely because fishing becomes unprofitable at levels of abundance which are still on the flat part of the curve.

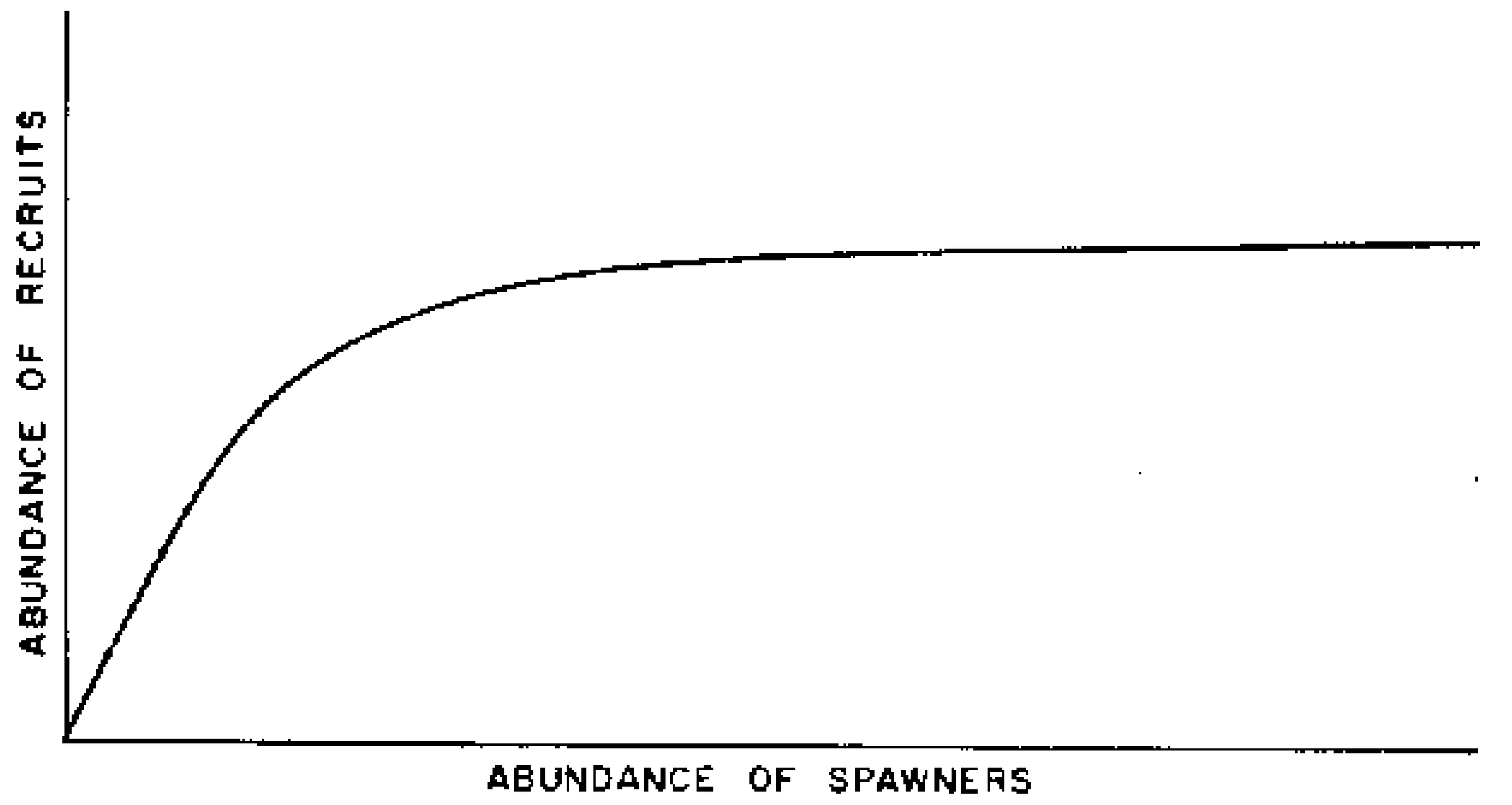

Figure 1. A hypothetical spawner-recruit relationship for penaeid shrimp.

I want next to discuss spawner-recruit relations for two separate fisheries in the Gulf of Mexico.

The first is the situation with brown and pink shrimp. These species are fairly typical 'grooved' penaeids which Kutkuhn (1966) placed near the 'deep-water, marine' end of the environmental spectrum for penaeid shrimp. In most cases there are spawning reserves of these animals in deep water that are not fished. Trawling usually is discontinued when catches drop below about 70 kg of tails per day. We have worked with all kinds of indices of abundance for these species using good data collected over a 15-year period, but have found no correlations between numbers of spawners and numbers of recruits to the fishery produced by these spawners. One of two things is happening; either the spawner-recruit relationship is very flat over the range of stock sizes encountered, or environmentally induced variation is masking underlying spawner-recruit relationships.

Personnel in our Population Dynamics Investigation at the Galveston Laboratory have looked for the same kind of relationships in their prediction work with brown shrimp, except they have examined shorter portions of the life cycle. For example our biologists have been interested in correlations such as those between abundance of postlarvae and juveniles, postlarvae and adults, and larvae and adults. Sampling has been conducted to measure abundance at all stages in the life history of the shrimp and landing statistics from both offshore and estuarine fisheries have been used. Relationships can be summarised as follows:

(a) No correlations were found between abundance of adults and abundance of larvae or postlarvae which were off-spring of these adults.

(b) No correlations were found between abundance of larvae and abundance of later stages.

(c) Positive correlations were found between abundance of postlarvae and abundance of both juveniles and adults (Baxter, 1962; Berry and Baxter, MS.; Baxter and Renfro, 1966; and Berry and Baxter, 1969).

(d) Positive correlations were found between abundance of juveniles and adults (Berry and Baxter, 1969).

It is apparent from this work that the variability in the system is greatest between the adult and postlarvae stages. Failure to discover spawner-recruit relationships is probably due to environmentally induced variability during this portion of the life cycle.

Other evidence that the reproductive capacity of brown shrimp has not been reduced by fishing is the stability of the catch over the last 15 years.

The second shrimp fishery I want to discuss is the white shrimp fishery. The white shrimp is much closer to the estuarine end of Kutkuhn's environmental spectrum (Kutkuhn, 1966) and is seldom found in water deeper than 20 m. Some adults apparently move back into the estuaries. The stocks of white shrimp are fished very heavily and are all readily accessible to the fishermen. There are no 'spawning reserves' in deep water as there are with brown shrimp.

In searching for relationships between the abundance of spawners and the abundance of recruits we have found, as we did with browns, an absence of any clear-cut relationship.

The major difference between browns and whites can be seen by examining landings of white shrimp for the period that records exist. In contrast to landings of brown shrimp, white shrimp landings have declined over a period of years. White shrimp landings are portrayed in Figs. 2 and 3. Caution must be used in the interpretation of these figures since statistics are incomplete prior to 1955 and since only white shrimp were harvested until the late 1940s. The shaded portions of the landings curves (Figs. 2 and 3) represent white shrimp landings. For both the Georgia-Florida area and the Louisiana area a marked decline in white shrimp landings has occurred. For Louisiana I have also presented a measure of effort (number of trawl licences sold) which indicates effort has increased and, therefore, catch-per-unit-of-effort has declined more rapidly than landings. Although we don't have

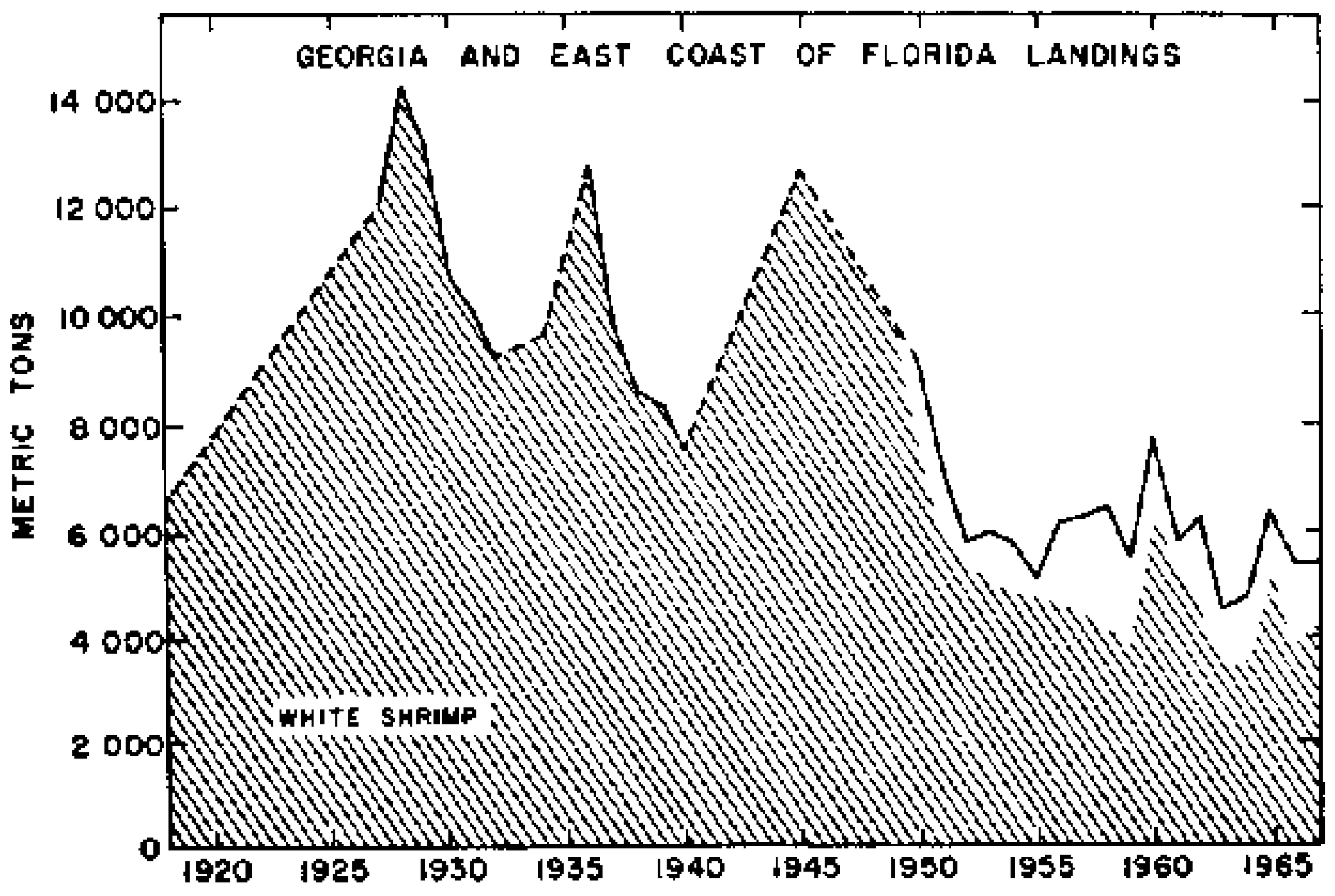

Figure 2. Landings of all shrimp and landings of white shrimp (shaded), Georgia and east coast of Florida.

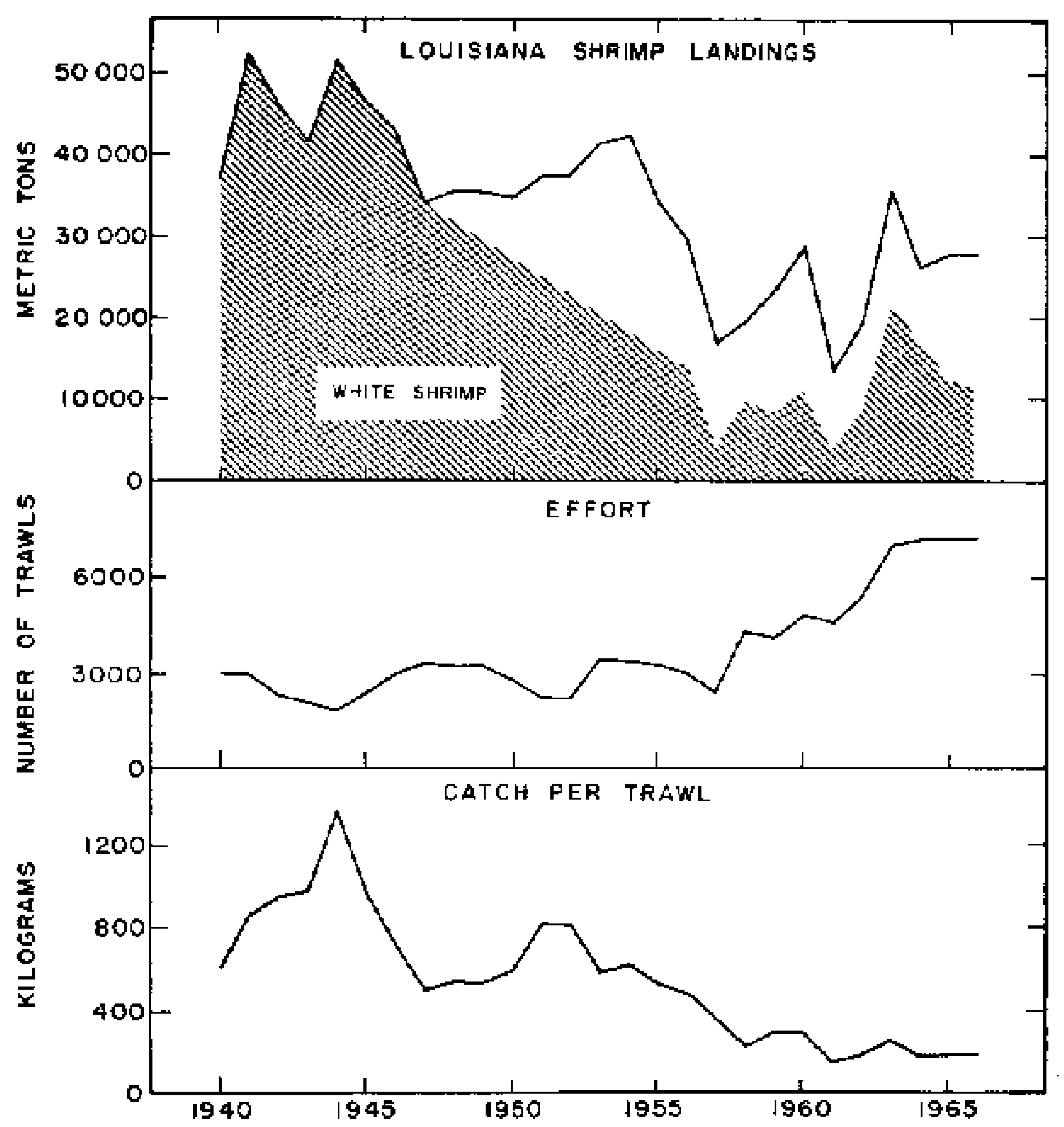

Figure 3. Landings of all shrimp and of white shrimp, number of trawl licences sold and catch per trawl, Louisiana.

firm evidence, there may be situations where the reproductive capacity of penaeid shrimp stocks has been reduced.

Beverton and Holt models have frequently been used to determine the optimum time to begin fishing a shrimp population. Results have been applied to situations where a closed season exists to protect small shrimp in the estuaries and a decision must be made concerning when to begin harvesting as the year-class increases in average size. Growth and mortality rates have been estimated using mark-recapture experiments. The central problem has been separating fishing mortality from natural mortality. The model is sensitive to small changes in these parameters, i.e. small differences in the proportion of the total mortality assigned to fishing or to natural causes make relatively large differences in the optimum size at first harvest.

The reasons we have had trouble separating natural from fishing mortality are as follows:

(a) Fishing effort is constantly shifting so that it is nearly impossible to estimate effort being applied to a given stock over a long period of time.

(b) During the period when growth and mortality rates are critical, shrimp are very small and difficult to mark.

(c) Population size in numbers is so great it is difficult to mark sufficient numbers of shrimp.

(d) We have never obtained a satisfactory estimate of the mortality caused by marking.

Although this approach has been used frequently in the United States, the results have not been very satisfying. It is, nevertheless, useful because it provides at least ballpark estimates where none are otherwise available. Berry (1967) has developed a model for the pink shrimp population of the Florida Tortugas grounds. This study probably represents the most successful use of Beverton and Holt's model with penaeids. Several aspects of this fishery, such as the discrete nature of the population, relatively constant effort and localised landings made this study a model of considerable value for comparative purposes.

Although shrimp prices have been used with the Beverton and Holt model, models for shrimp fisheries have never been developed to truly economic models including harvesting costs.

Are there alternative approaches to the size at harvest problem? There are no well-tested techniques that I can recommend; however, there are some other possible approaches utilising landing statistics.

The first approach is that of comparing the value of the harvest in different years in which the average size at harvest has been different. In Texas (Neal, 1967) the value of 1,000 shrimp harvested has varied from $18 to $22 with no change in regulations. This comparison is of special interest for years with the same initial crop size.

A second aproach is that of comparing the value of harvests from different fisheries in which management or fishing pressure differs.

A third possible approach is that of manipulation of regulations for purposes of evaluation. If conducted over a long period on a scientific basis this approach offers some interesting opportunities.

Each of these approaches requires a solid statistical base for a period of years. A problem which frequently arises in the interpretation of catch and effort statistics for the fisheries in the Gulf of Mexico is that fishing methods change. Changes in the gear type or size of nets and vessels require an adjustment to standardise the units of effort. Three separate groups of vessels in the Gulf of Mexico shrimp fishery have been examined to determine the relative fishing power of vessels with different characteristics. Characteristics considered were those which have changed over the last 15 years such as vessel weight, horsepower, vessel length, and total width of the nets used.

Although the results have not been published, the results of the three studies were similar. In all three cases the best vessel characteristic was vessel length. The relationship between relative fishing power and vessel length was represented by the equation:

Fishing Power $= a + b$ (Vessel Length) where a ranged from -0.424 to 0.630 and b ranged from 0.022 to 0.036 when vessel length was expressed in feet.

COMMERCIAL FISHERY

The Gulf of Mexico fishery is a particularly complex one involving a large number of vessels with rapid changes in effort from one species to another or one location to another. Total United States landings (Fig. 4) increased until the early 1950s and have been relatively constant since that time. Numbers of vessels have increased since 1962 (Fig. 5) as have numbers of fishermen. Both statistics are apparently related to the price of shrimp. The results of increasing fishing pressure on these

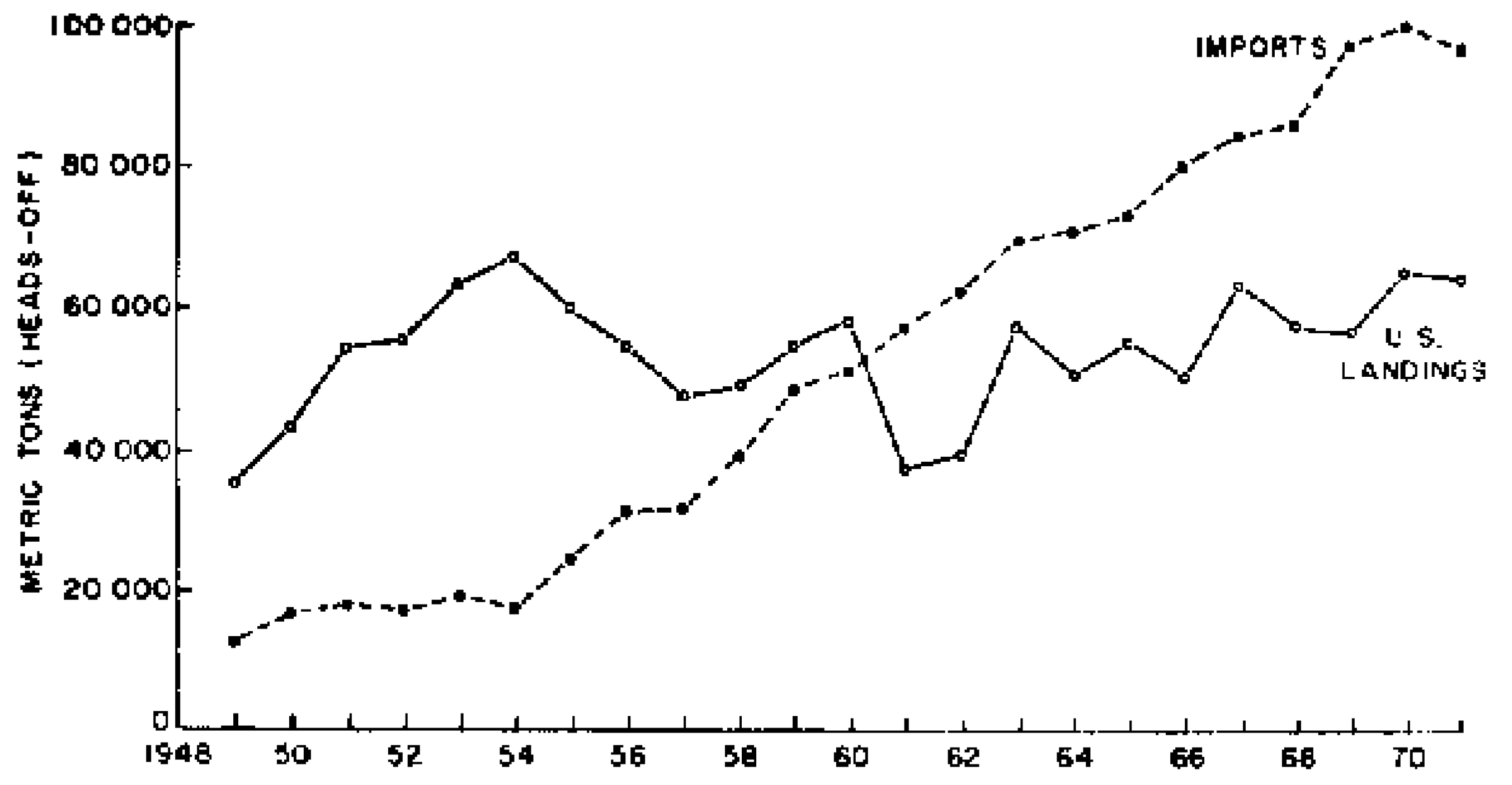

Figure 4. Total United States landings of shrimp from the Gulf of Mexico and total United States imports of shrimp.

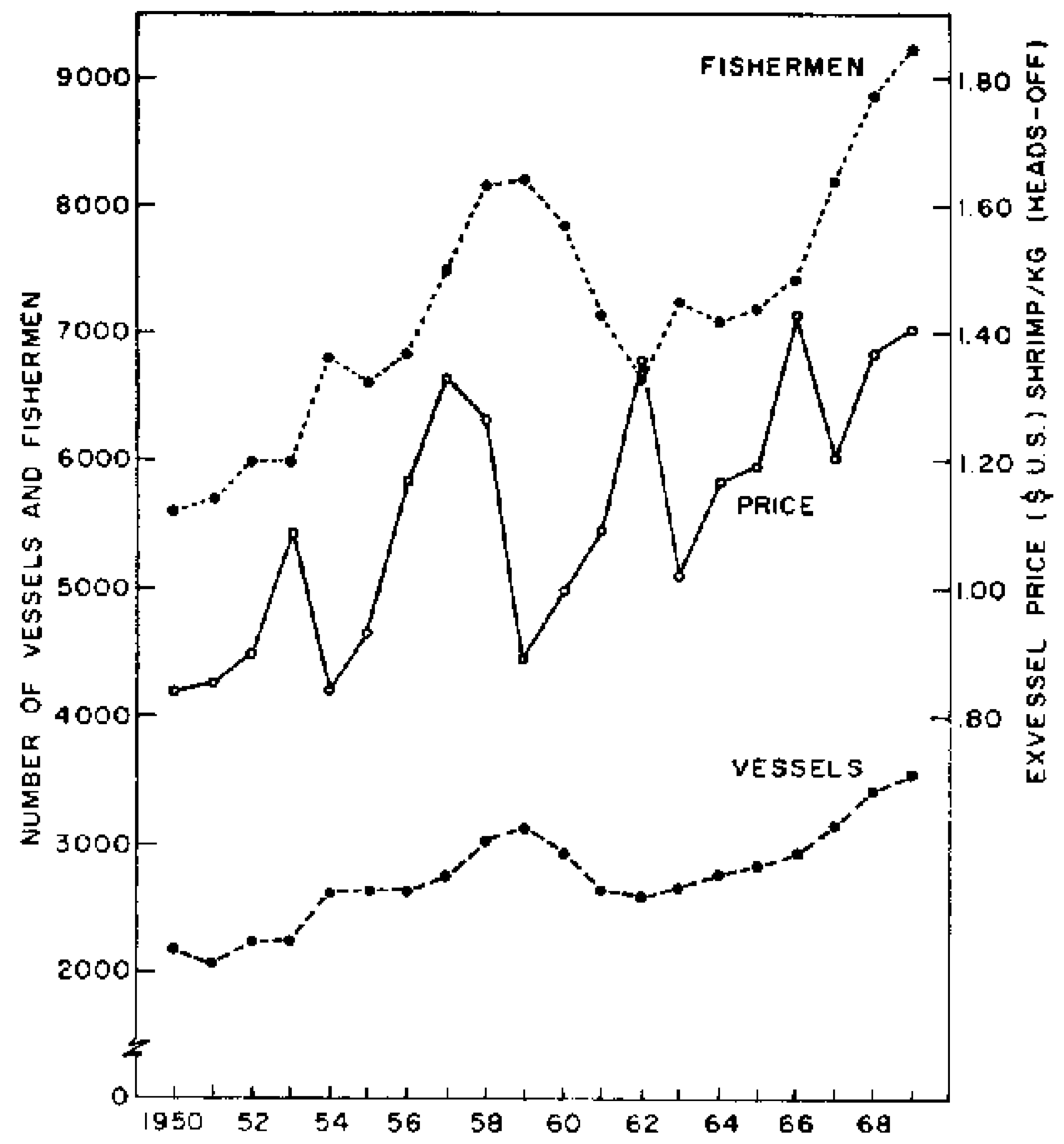

Figure 5. Number of vessels (over 5 tonnes) and numbers of fishermen working on these vessels in the Gulf of Mexico shrimp fishery, along with average ex-vessel price of shrimp.

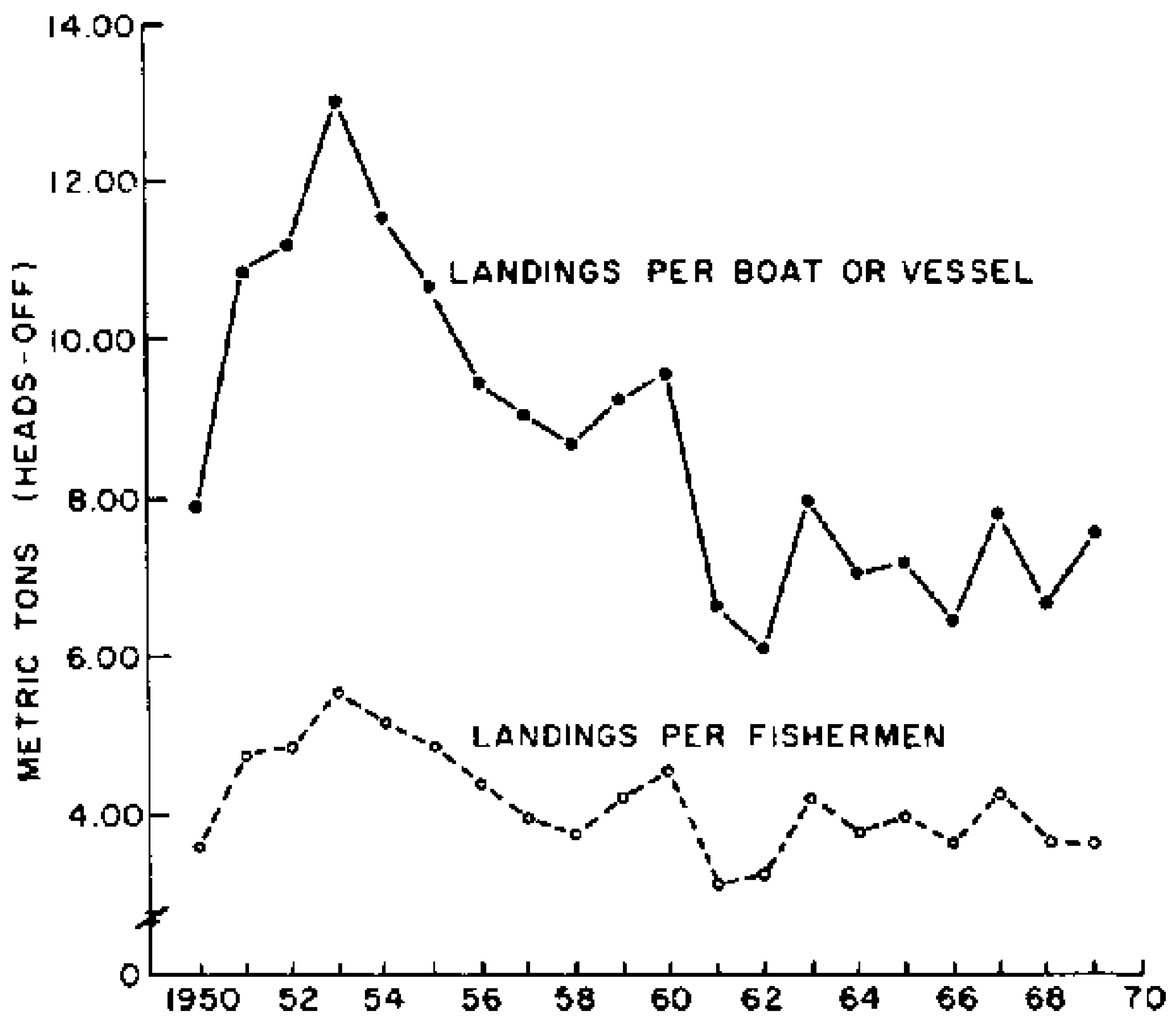

Figure 6. Landings per boat or vessel and landings per fisherman for the Gulf of Mexico shrimp fishery.

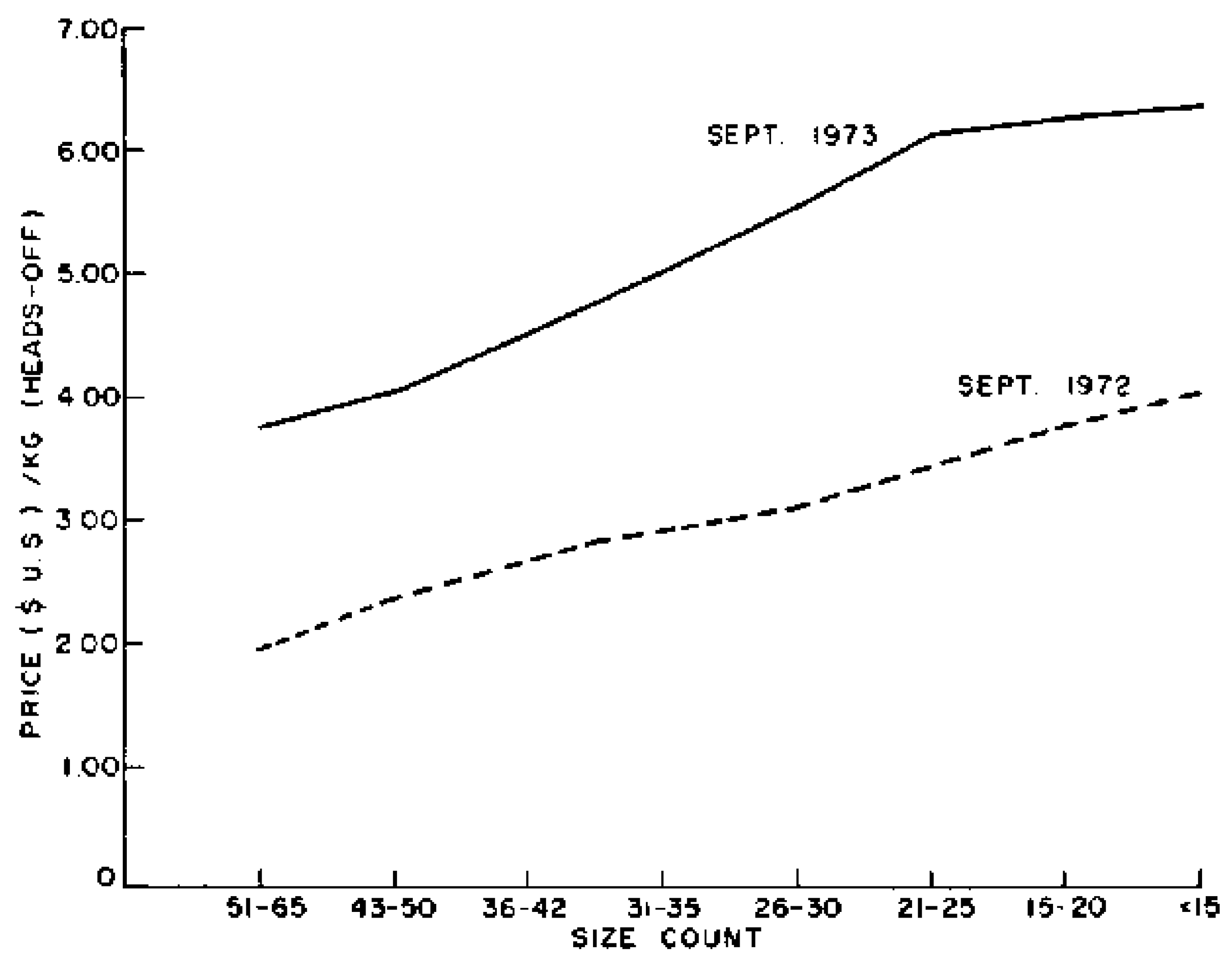

Figure 7. Dockside prices for brown shrimp, heads-off, on the Texas coast, September 1972 and September 1973.

populations are illustrated in Fig. 6. Landings per vessel have definitely declined, and landings per fisherman are lower than they have been during at least two periods in the past.

The usual method of holding shrimp on the boats is with ice. Trips of up to 12-14 days are common. Boats with freezers have been used occasionally, but mechanical problems with the freezers and a lack of qualified maintenance people have caused most of the boat owners to shift back to the use of ice. A sodium bisulphate dip is used by some fishermen to prevent black spot, but more frequently fishermen simply mix the chemical with the shrimp as they are being iced on the boat.

Problems with the quality of the product reaching the consumer have resulted in the initiation of a voluntary inspection program. The inspection is conducted by the federal Government at the request of and at the expense of the individual processor. The response to the program has been very good and at present 45 large shrimp processing plants take part in the voluntary inspection plan. The advantage to the processor is that he can advertise his products as government inspected, and the Government publishes lists of firms taking part in the inspection.

A major increase has occurred in the *per capita* consumption of shrimp in the United States (Table 1) in spite of the price increases. At least part of the increase in demand has been generated by active market promotion programs. These programs have been funded largely by industry contributions. Our economists have projected a demand picture for the United States market through the year 2000. Based upon projected *per capita* consumption of 1.15 kg by 1980 and 1.17 kg by 2000, and expected increases in the U.S. population, consumption will be 269,438 tonnes (heads-off) by 1980 and 359,251 tonnes (heads-off) by 2000. World consumption is expected to reach 747,718 tonnes (heads-off) by the year 1980.

Prices during the last year (Fig. 7) reflect the increasing demand combined with a fixed supply from the Gulf of Mexico. Of major interest is the fact that the price for 51-65 count shrimp increased 98% during the 12-month period, while the price for 15-count shrimp increased 58%.

Table 1.
Consumption of Shrimp in the United States (Heads-off weights)

Year	*Total consumption (Tonnes)*	*Per capita consumption (Kilograms)*
1947	45,128	0.31
1948	45,945	0.31
1949	48,124	0.32
1950	49,531	0.33
1951	58,975	0.38
1952	63,469	0.40
1953	64,241	0.40
1954	66,874	0.41
1955	71,187	0.43
1956	68,736	0.41
1957	62,970	0.37
1958	69,099	0.39
1959	84,489	0.48
1960	88,939	0.49
1961	87,304	0.48
1962	88,212	0.66
1963	98,927	0.52
1964	102,513	0.54
1965	111,366	0.57
1966	111,003	0.57
1967	121,218	0.61
1968	129,617	0.65
1969	127,892	0.64
1970	146,233	0.72
1971	141,103	0.69

MANAGEMENT

A particularly awkward situation exists with respect to management of the Gulf of Mexico shrimp fishery. It is complicated from the political standpoint as well as the biological standpoint. Most of the management oriented research has been conducted by the federal Government, yet the federal Government has no management authority. The States each regulate their own fisheries even though vessels move freely from State to State. A substantial portion of the fishing is done in international waters where no regulations are applied. Vessels from five Gulf coast States, Mexico and Cuba, take part in the fishery.

The regulations applied by the various States differ considerably. Generally there is at least partial protection of the small shrimp during the estuarine portion of their life cycle. Some States also have short closed seasons to protect the shimp immediately after they leave the estuaries. Most States regulate the mesh size used in their waters as well as the net size used in estaurine waters. There is essentially no regulation offshore in waters outside the jurisdiction of the various States. The width of the fishery jurisdiction of the States varies from 3 to 10 miles depending upon the State.

With increasing international fishing pressure on the stocks and rapidly increasing prices, the United States must demonstrate that the shrimp stocks are being managed wisely if it hopes to protect its fishing interests. The present system of conflicting State laws does not help the United States position. As a possible solution to this predicament a State-Federal Management Program has been implemented. Under this program federal money is being used to implement management programs under the direction of State Governments. Close cooperation between the State and federal authorities is being encouraged to insure that State management policies support federal interests.

A controversial issue with respect to management of the shrimp fishery is that of limited entry. The United States prawn fishery is a classic example of overcapitalisation or economic overfishing. The harvesting costs are higher than necessary because unnecessarily large numbers of boats and men are involved in harvesting. As a result real income per fisherman is declining even though the total catch is static. The concept of limited entry is very unpopular with State regulatory agencies.

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