Constraints on Food Production From Wild Penaeid Shrimp Stocks in the Gulf Of Mexico

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The shallow water shrimp resources of the Gulf of Mexico support two major trawl fisheries. The Northern and Eastern Gulf of Mexico inshore fishery produces small shrimp for canning, drying, salting, bait, and home consumption. The offshore fishery throughout the Gulf produces larger shrimp for sale as food, both fresh and frozen. Part of the harvest of both major trawl fisheries is discarded as undersized shrimp, for legal and/or economic reasons. Recreational harvest is thought to represent a significant part of the inshore catch.

Three major species comprise 99% (by weight) of the reported commercial catch: brown shrimp (*Penaeus aztecus*), white shrimp (*P. setiferus*), and pink shrimp (*P. duararum*). Three minor species of non-*Penaeus* shallow water species are taken in much smaller commercial quantities; seabob (*Xiphopeneus kroyeri*), rock shrimp (*Sicyonia brevirostris*) and sugar shrimp (*Trachypenaeus similis*).

Distribution

Shallow water shrimp are found in all Continental Shelf waters in the U.S. Gulf of Mexico shallower than 60 fm. The greatest portion of the reported offshore catch of brown shrimp is taken in 11-20 fm., that of white shrimp in 5 fm. or less, and that of pink shrimp in 11-15 fm. Highest offshore densities of brown shrimp occur off the Texas coast (Fig. 1), while highest densities of white shrimp occur off the Louisiana coast (Fig. 2), and of pink shrimp off the southwest coast of Florida (Fig. 3).

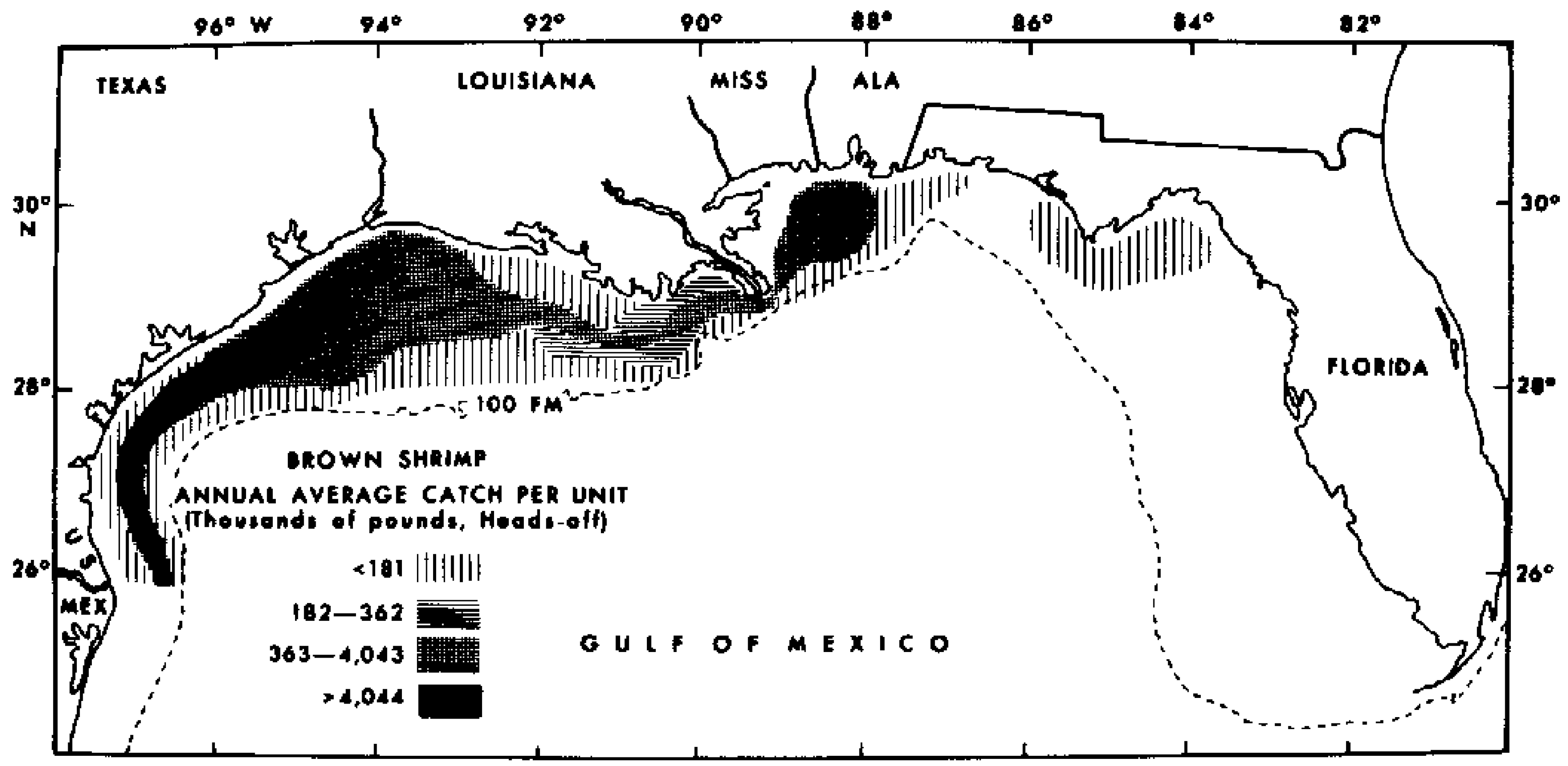

FIGURE 1. The distribution of brown shrimp in the Northern Gulf of Mexico.

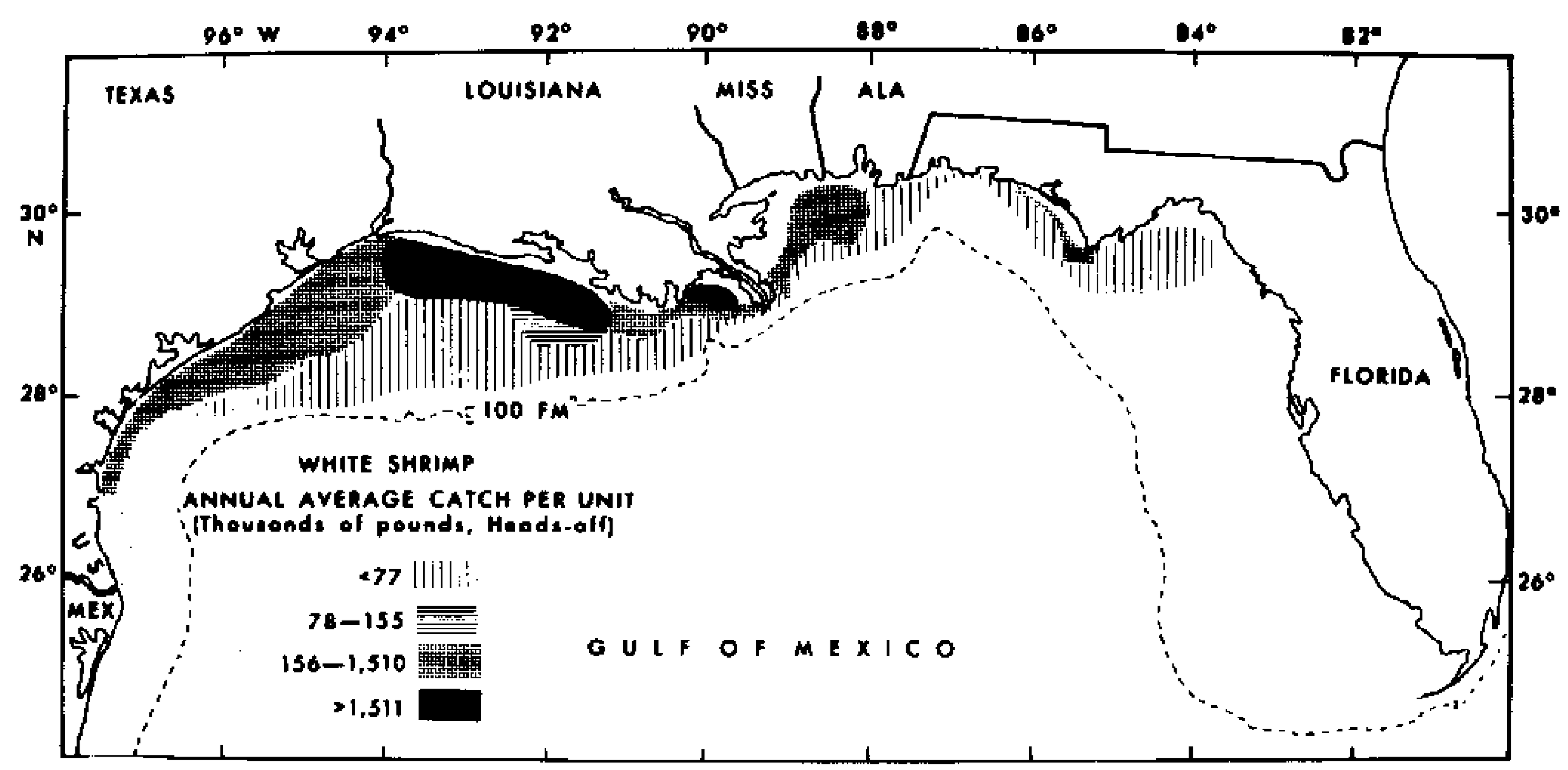

FIGURE 2. The distribution of white shrimp in the Northern Gulf of Mexico.

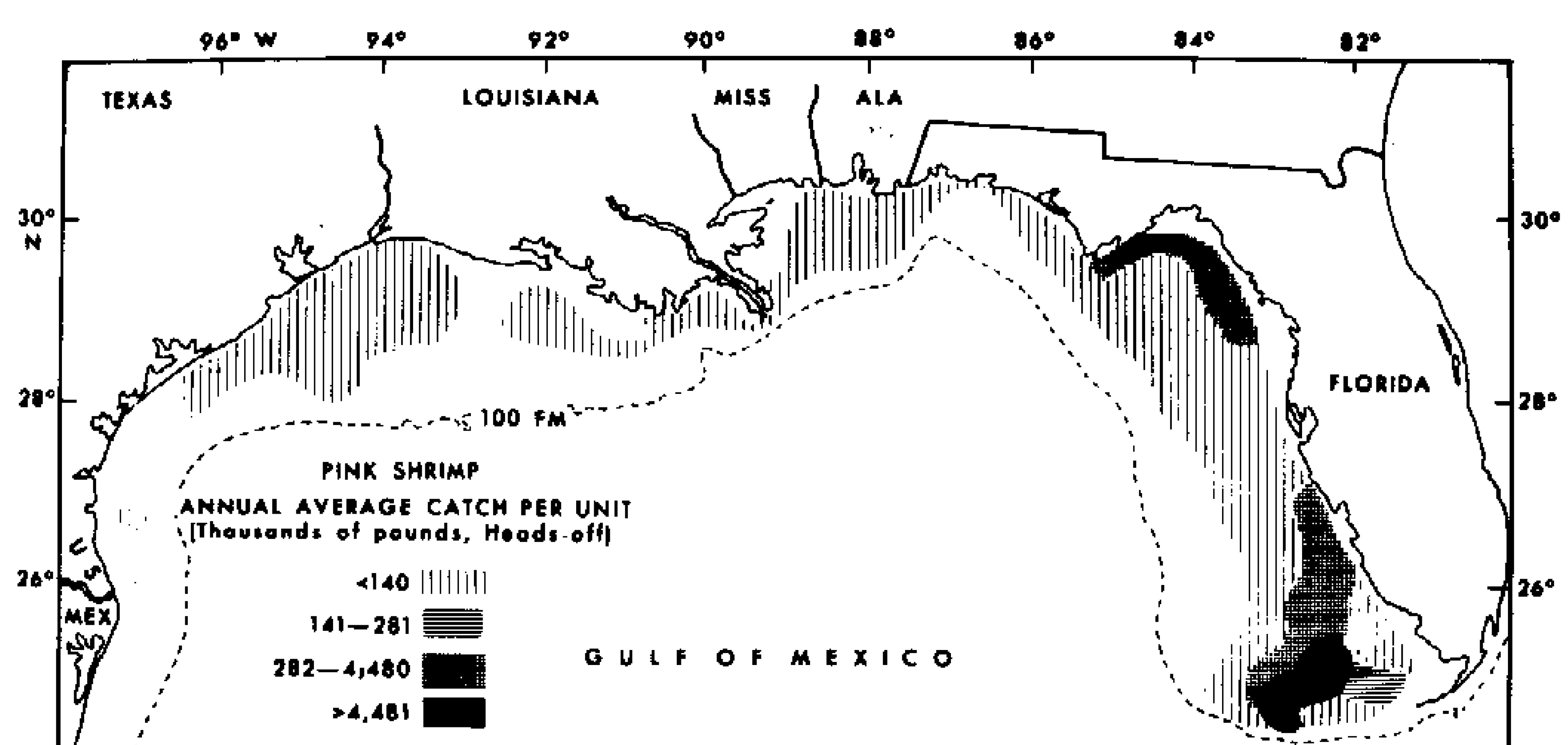

FIGURE 3. The distribution of pink shrimp in the Northern Gulf of Mexico.

The Relationship between Season and Size Caught

Season, shrimp size, and water depth are related. Reported catch records indicate that most small brown shrimp are caught in depths of less than 5 fm. during May. As brown shrimp grow larger, they move into deeper waters so that peak catches of large individuals occur in 11-20 fm. in July or August. Smaller catches of large individuals occur in winter months. Small white shrimp are caught in depths less than 5 fms. during September, and in depths of 6-10 fm. in October. Large white shrimp are caught in depths less than 5 fm. in April and in depths of 6-10 fm. in May. Low catches of white shrimp occur in mid-winter months. The peak reported catch of pink shrimp ususally occurs in January at 11-15 fm.

Effects of Life Cycle

The geographical distribution of shallow water shrimp is related to a large extent to their life cycle (Fig. 4). Adults spawn offshore on the bottom. Eggs hatch in 10-12 hours into planktonic larvae. During the next 12-15 days these larvae metamorphose through additional planktonic stages into postlarvae. These juvenile shrimp then become benthic and

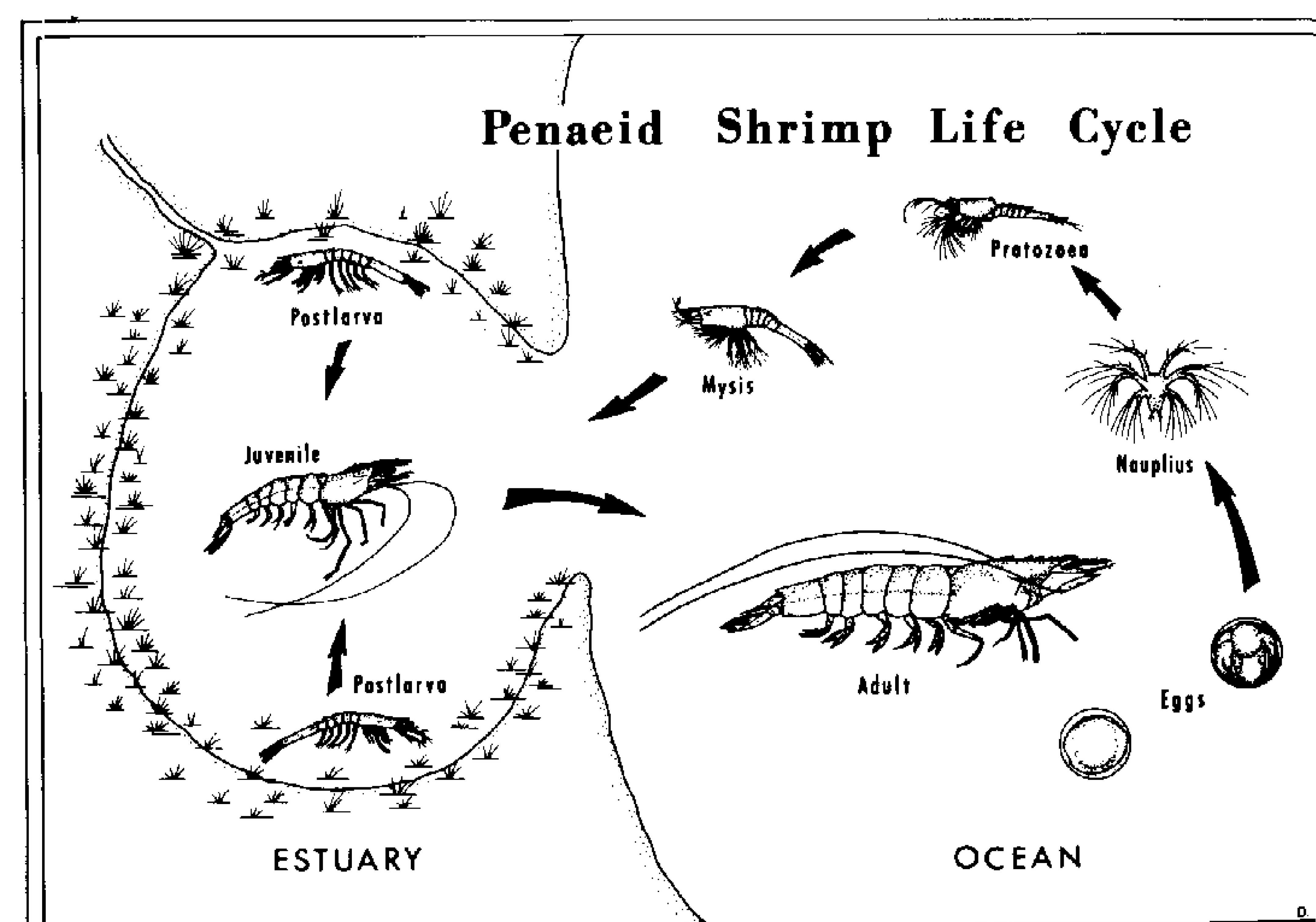

FIGURE 4. The life cycle of shallow water shrimp in the Gulf of Mexico.

enter the estuary. Within the estuary, the juveniles grow rapidly for 1-1½ months before emigrating offshore. During this estuarine phase, the males become sexually mature (contain spermatophores), while the females do not, although they do develop ovaries that contain large numbers of immature eggs. Apparently the females develop ripe eggs only after they leave the estuary.

Effects of Currents

Larvae presumably are carried toward the estuary by wind-driven currents. Juvenile shrimp appear to take advantage of tidal currents to carry them from place to place in the estuary. Likewise, newly adult shrimp take advantage of tidal currents to carry them out of the estuary and beyond. There is evidence that the factor or factors responsible for these movements with currents may be something other than currents themselves (e.g., moon-phase, light vs. dark, temperature, salinity, hydrostatic pressure, and biological rhythms).

Effects of Temperature and Salinity

The effects of temperature and salinity on shrimp distribution are complex; however, shrimp seem to be able to withstand cold temperatures if salinities are moderate to high. Brown and pink shrimp appear to be similar in that they move to deeper, colder more saline waters upon emigrating from the estuary. White shrimp generally move to deeper more saline waters with the onset of cool fall weather.

Effects of Food

Larval stages of shrimp require phytoplankton and zooplankton for food. Major peaks in spawning activity coincide with spring and fall blooms of phytoplankton and zooplankton in the Gulf. Juvenile shrimp ingest large quantities of organic detritus (dead and decaying particulate plant matter) in the estuary. It is thought that they gain nourishment from the microbes and associated microfauna adsorbed on or associated with this detritus. In the northern Gulf, the detritus is produced primarily from marsh grasses, and in the south Florida area, from mangrove leaves. As the shrimp grow larger and leave the estuary, they become omnivorous.

Environmental Effects

Cold spells, floods, droughts, hurricanes, and other climatological extremes or catastrophes are believed to affect distribution and abundance of shrimp, but the relative importance of these factors is not well known or documented.

Man-caused Environment Effects

Man's manipulations and alterations of the coastal environment affect the estuarine substrate, circulation, stream discharge, pattern of distribution, and water quality. The extent to which these changes influence shrimp distribution and abundance is poorly understood, but the loss and degradation of shrimp habitat, especially the estuarine habitat, through man's activities should be a matter of great concern in the management of shrimp fisheries.

Fishing Trends

The average annual shrimp landings from 1965 to 1974 were about 53,000 metric tons. However, these landings have fluctuated from 45,000 to well over 60,000 tons (Fig. 5). Specific information concern-

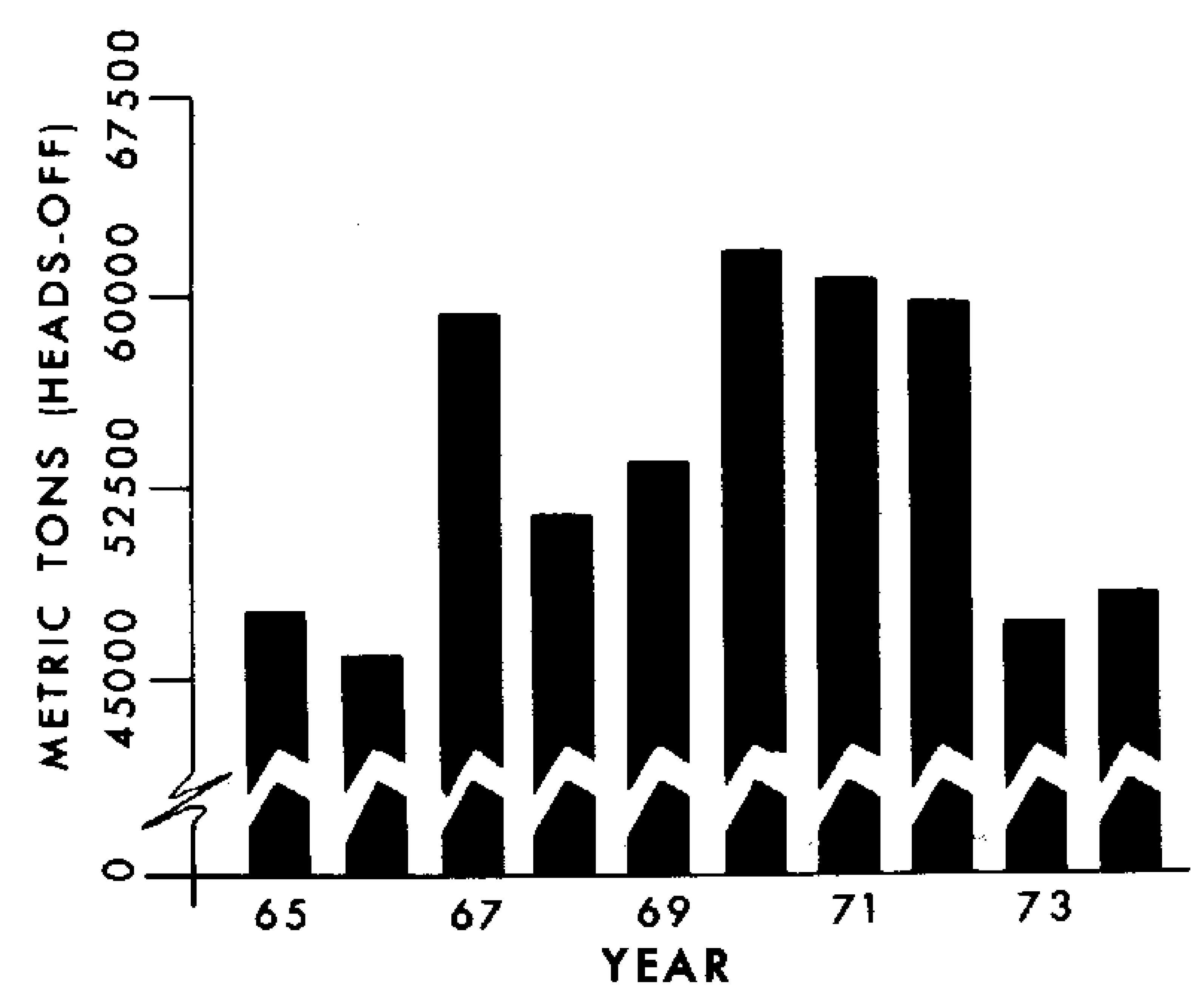

FIGURE 5. The landings of shallow water shrimp in the Northern Gulf of Mexico.

ing the brown, white and pink shrimp fisheries are shown in figures 6, 7, and 8. The brown shrimp landings have averaged about 31,500 metric tons annually; however, landings have fluctuated drastically from 23,000 tons to about 45,000 tons. Fishing effort has increased whereas catch-per-unit effort has decreased. The relationship between annual landings, fishing effort and catch- per-unit effort indicates that the resource is affected by the increase or decrease in fishing pressure, as can be seen in 1969 and 1970. The increased fishing pressure in 1969 was reflected in a significantly decreased catch-per-unit effort and subsequently lower annual landings. The high fishing pressure in 1971 and 1972 may in part account for the lower annual landings in 1973 and 1974.

The white shrimp fishery annual landings have averaged about 15,000 tons and have fluctuated between 10,000 and 19,000 tons. Peak annual landings occurred from 1969 through 1972, with a peak in catch-per-unit effort in 1969. Fishing effort increased from 1969 to a peak in 1973; however, from 1969 to 1973, the corresponding catch-per-unit effort

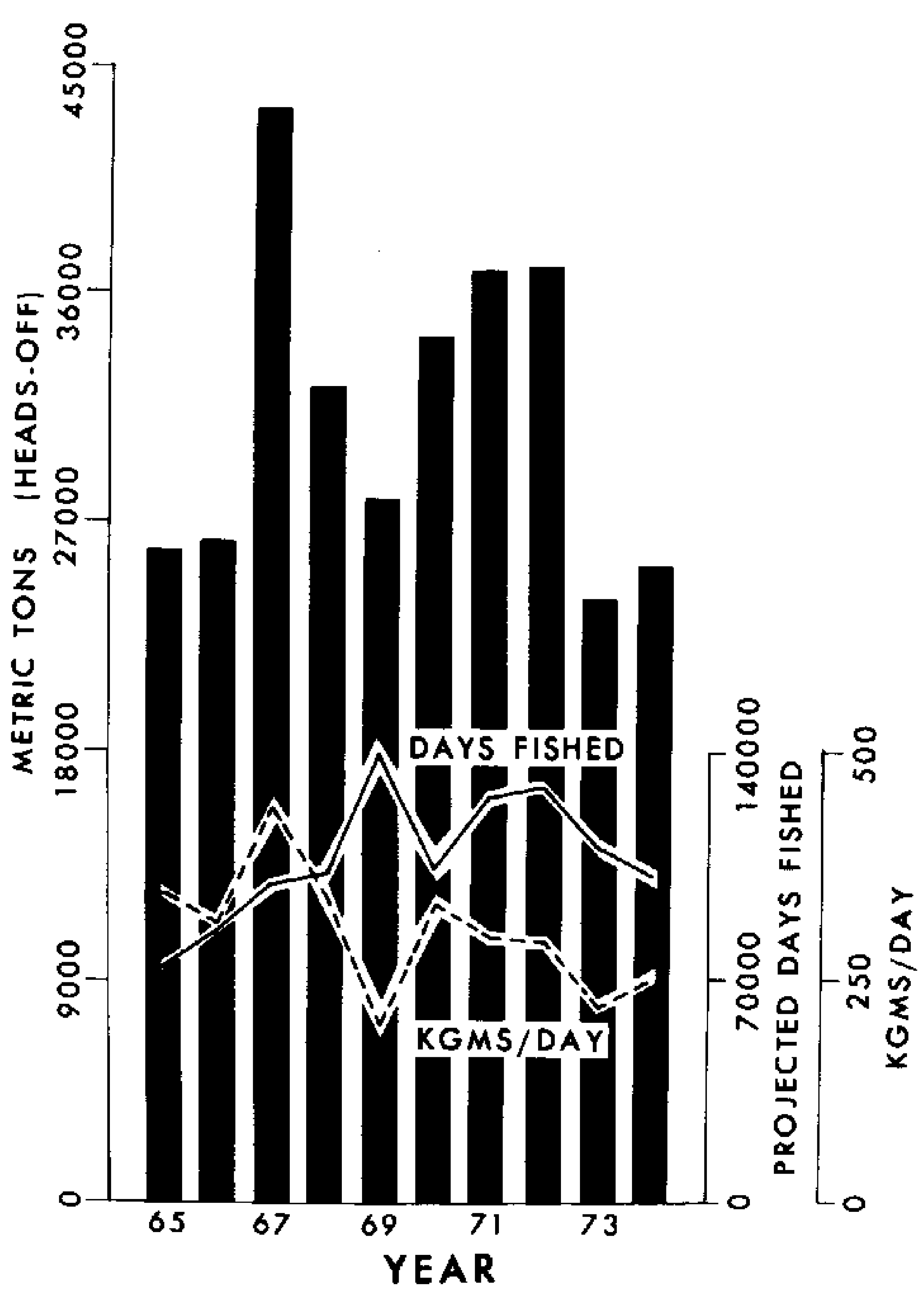

FIGURE 6. Brown shrimp landing in the Northern Gulf of Mexico.

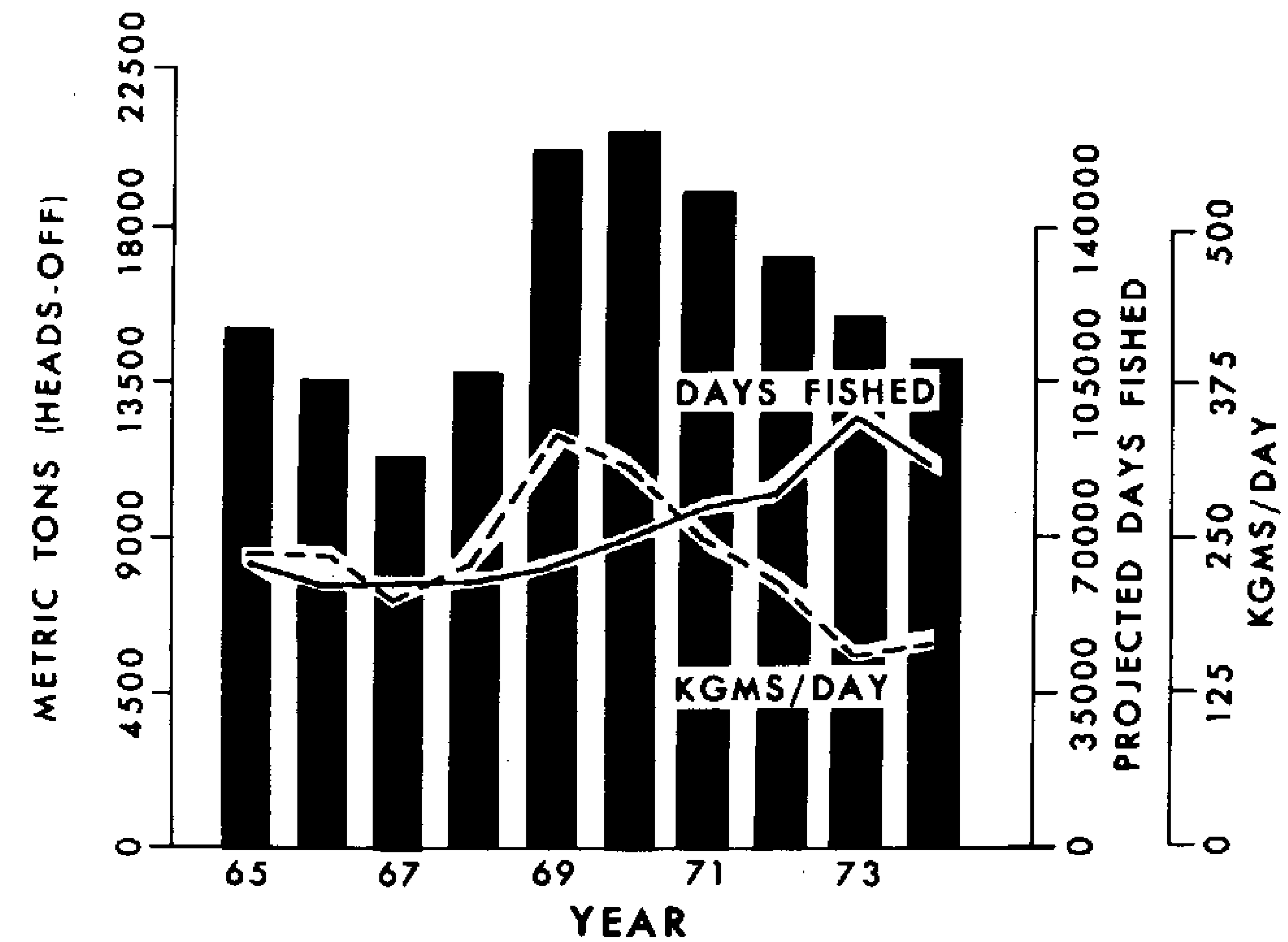

FIGURE 7. White shrimp landing in the Northern Gulf of Mexico.

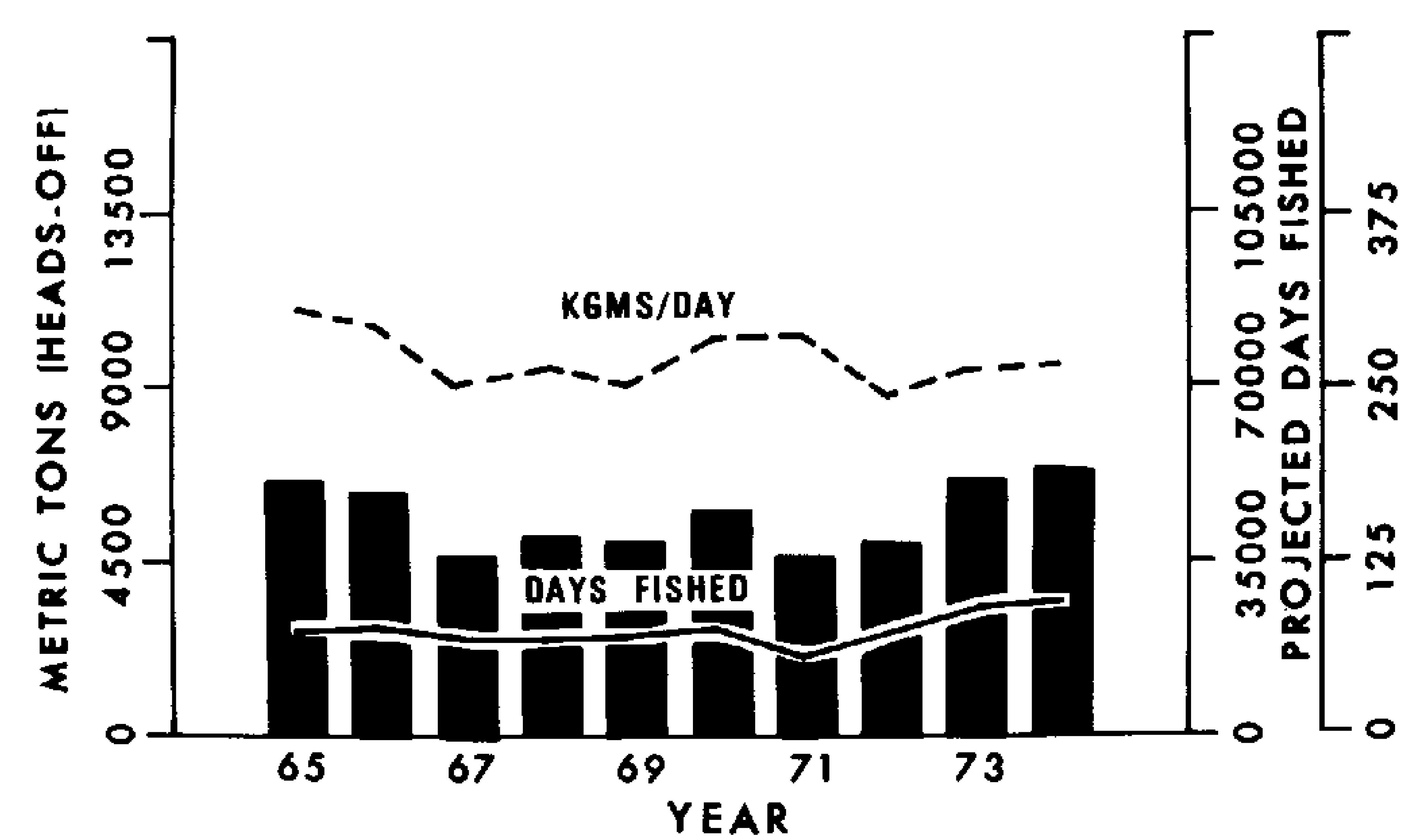

FIGURE 8. Pink shrimp landing in the Northern Gulf of Mexico.

decreased. The increase in white shrimp fishing effort in 1973 is probably due to a shift to the white shrimp fishery from the brown shrimp fishery because of the low brown shrimp abundance. That inter-relation between the brown and white shrimp fisheries is quite evident from figures 6 and 7, especially in the years 1973 and 1974. During that period, brown shrimp catches and fishing effort were low, concurrent with high fishing effort in the white shrimp fishery. The basic trend in the white shrimp fishery has been a decrease in the catch-per-unit effort, coupled with an increase in fishing effort from 1969 to the present. Continuation of this trend will certainly affect the economic conditions in the fishery.

Unlike the white and brown shrimp fisheries which fluctuated widely, the pink shrimp fishery in the south Florida area has been fairly stable through the study period, averaging close to 5,000 tons annually with very little deviation. Fishing effort was relatively stable, as was the catch-per-unit effort.

Maximum Sustainable Yield

The classical approach to determining the production potential for any fisheries resource is to estimate the relationship between catch and fishing effort. The top of the curve representing the relationship is commonly referred to as the maximum sustainable yield (MSY) and has been defined (1) as "the largest average catch or yield that can continuously be taken from a stock under existing environmental conditions". The MSY concept is based upon the assumption that a stock produces its greatest harvestable surplus when it is at an intermediate level of abundance, not at a maximum abundance. Under reasonably stable natural conditions, the growth of an unfished population is balanced by natural deaths. Harvesting individuals from the stock increases production by decreasing competition for the food supply and by decreasing the number of older slower-growing individuals, so that a larger proportion of the stock is composed of young fast-growing individuals. The net effect is that fishing creates a surplus to be harvested. Hence, the fishing or the thinning out of the population creates the production which maintains the harvest operation.

As a first estimation of the total potential, we have examined this relationship and have estimated the MSY for the total U.S. shrimp stocks in the Gulf of Mexico, excluding the Mexican coast. We feel that this is a reasonable approximation of the production limit of the shrimp resource in the U.S. portion of the Gulf of Mexico.

We estimated MSY by Schaefer's method (1957) utilizing annual effort and landings (1956-76) in tail weight for the area from Key West to Brownsville in the Gulf of Mexico. These landings include catches of

brown, white, pink, sugar, and rock shrimp. The measurement of fishing effort was days fished in these areas and we assumed that this effort was directed at the shallow water shrimp resources. It should be pointed out that these annual landings do not account for the shallow water shrimp caught and discarded at sea. At present we do not have a reliable estimate of this portion of the catch. If the magnitude of the discarded shrimp at sea has changed over time, the proposed model is inaccurate. Furthermore, we have not tried to adjust fishing effort data for increases in fishing gear technology. If, in fact, fishing effort has increased in efficiency through time, it will affect the proposed model. Annual data for 1957, 1961, and 1962 were not included in this model. During those years, major hurricane activity occurred and we feel that these years do not reflect a steady state of the fisheries and further, these points fell well outside the bulk of the other data. We have estimated the equilibrium state of the fishery to be quantified by the model $L = F(A + BF)$.

where $A = .45528$, a constant,

$B = .93870396 \times 10^{6}$, a constant,

$F =$ days fished, and

$L =$ landings.

The model predicts a maximum sustainable yield of approximately 55,000 metric tons tail weight (approximately 88,000 metric tons round weight) with 225,000 days fished (Fig. 9). The annual landings and total fishing effort have been fluctuating around that maximum since 1970, indicating that the Gulf of Mexico shallow water shrimp resources have been fully exploited in recent years. Landings in 1976 indicate that this trend is continuing.

Size and Yield Relationship

MSY can be achieved by limiting fishing mortality by controlling either fishing effort or catch. However, if the fishing strategy of the fleet is such that it harvests fish or shrimp before they reach an optimum size, a decrease in the potential yield is very likely. In essence, what must be attained is a balance between the rates of growth and mortality. Animals grow at a very fast rate when young; as they age, that rate decreases. The rate of natural death, however, is usually fairly constant throughout the juvenile and adult life stages. Harvesting very young animals results in a loss of potential weight gain since the growth rate is faster than the loss rate attributed to mortality for young animals. Harvesting animals older

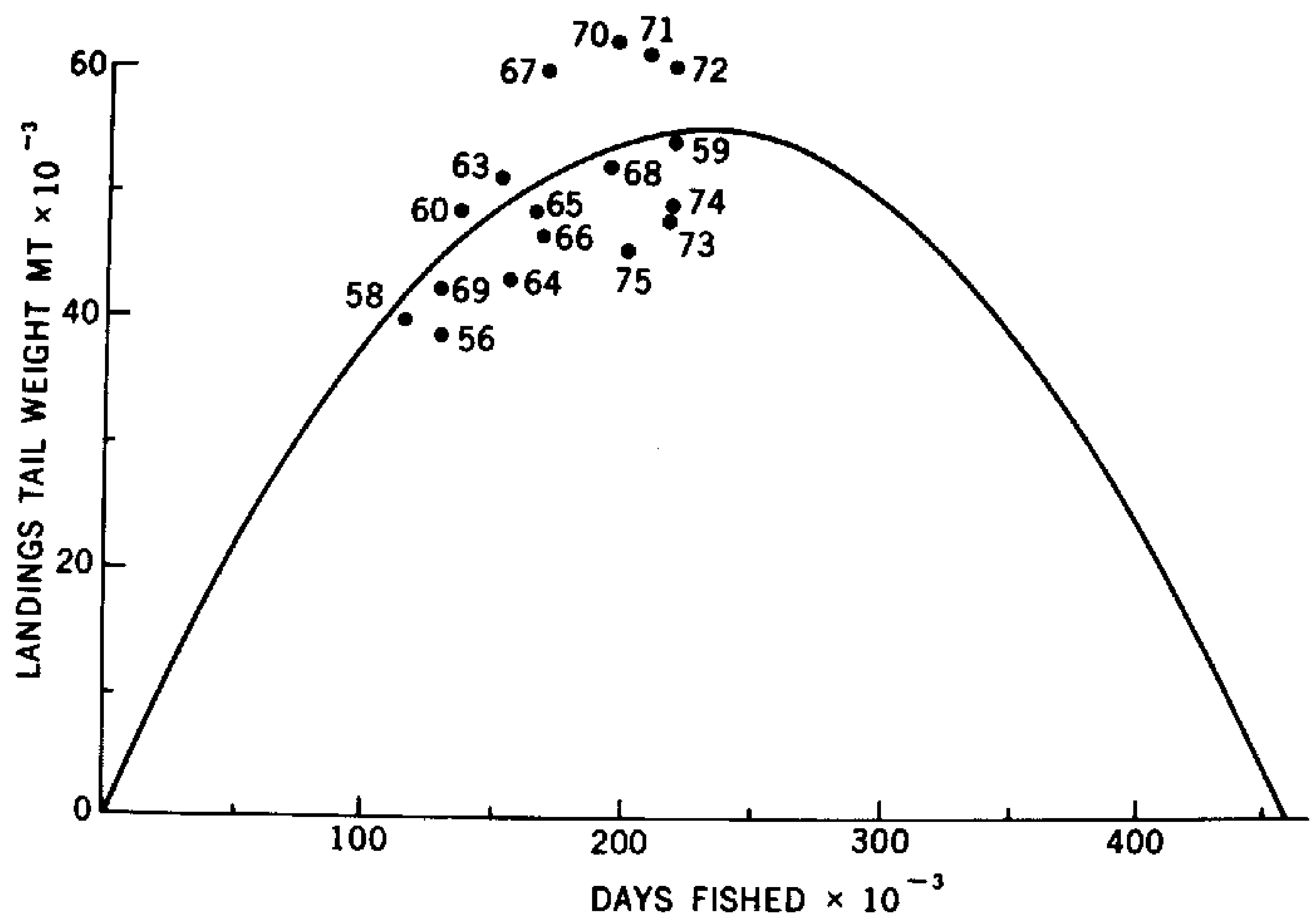

FIGURE 9. The relation between fishing effort and landings of shallow water shrimp in the Northern Gulf of Mexico.

than the age at which the growth and death rates are equal results in weight losses because mortality is removing biomass faster than it is being replaced by growth. Data on hand indicated that these two rates balance at 6-9 months of age or at a size of 20-30 shrimp tails per pound.

Shrimping regulations vary by states along the Gulf coast and, in fact, the harvesting strategy differs significantly between the states of Texas and Louisiana. These two states produce approximately 75 percent of the shrimp landed in the northern Gulf of Mexico. In Texas, the shrimping regulations generally restrict the catch of small shrimp, whereas in Louisiana there are few restrictions on the catching of small shrimp. The overall results of these two diametrically opposed regulatory schemes is that in Texas the bulk of the catch comes from an offshore fishery and consists mostly of large shrimp. In Louisiana there is a substantial inshore fishery which produces a large amount of both small and large brown and white shrimp. The average ex-vessel value per pound for brown shrimp in 1976 dollars was $2.22 per pound in Texas as compared to $1.36 in Louisiana (2). Furthermore, the annual total weight and value of brown shrimp landing has been greater in Texas than in Louisiana (Fig.10).

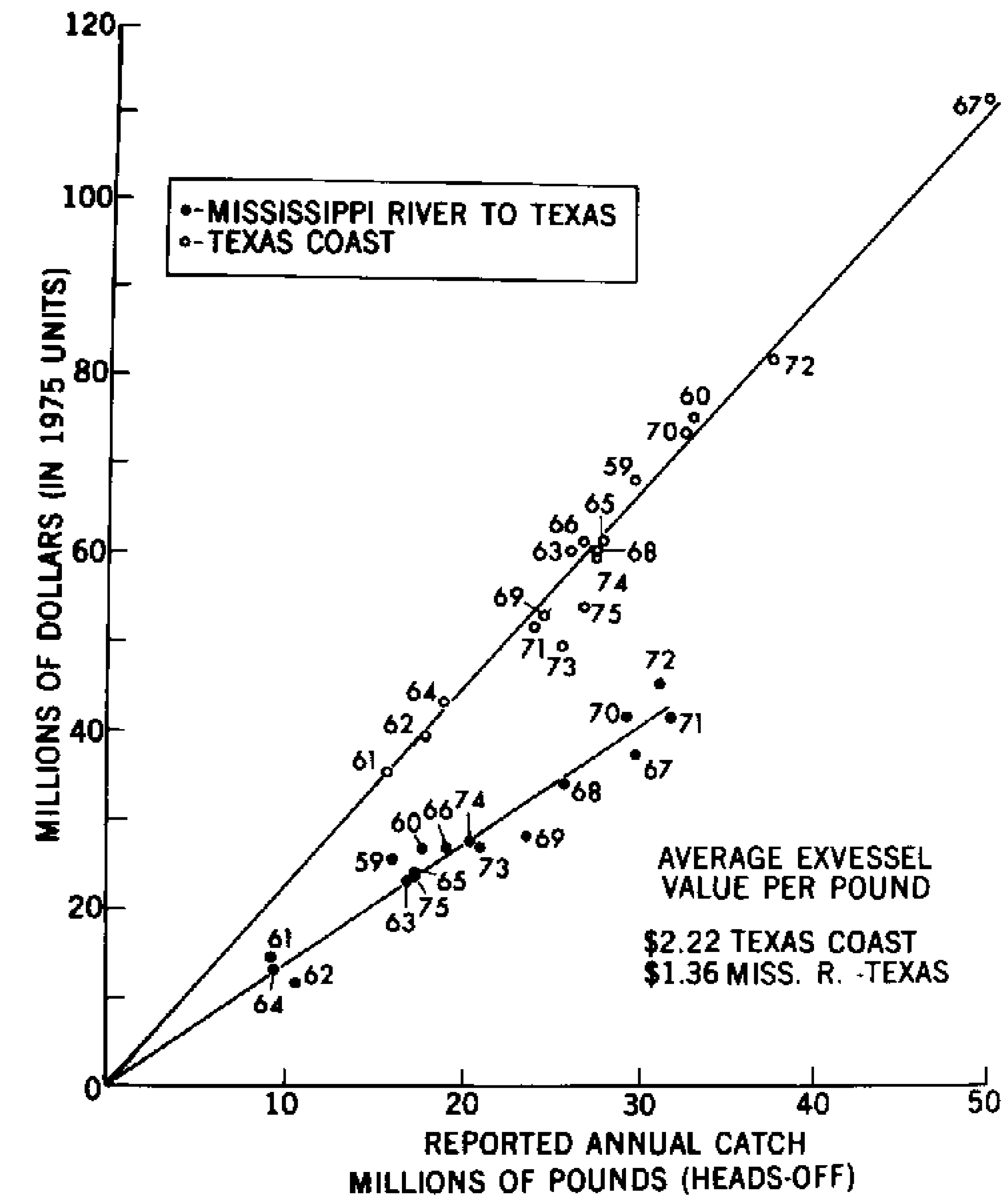

FIGURE 10. The relation between the ex-vessel value of shrimp landings and the annual landings for the Texas coast and the Louisiana coast.

Environmental Management

It is possible that increased productivity of the stocks might be achieved by altering the harvesting management strategy, but the specific ways in which this might be accomplished remain to be determined. Restricting the size at first harvest may increase the yield and the ex-vessel value, but could also eliminate jobs for most of the inshore fishermen. It is also possible that manipulation of the environment (i.e., controlling and directing man's impact on the environment) might be used to some benefit. For example, it is quite possible that alterations in the quantity and distribution of fresh water discharge into the estuaries might be done in such a way as to enhance shrimp productivity. Studies of the relationships among shrimp yield and environmental factors should provide part of the technical information base necessary for such actions.

Laws

Existing laws and regulations have been directed primarily toward limiting the quantity of small shrimp landed. These laws include restrictions on mesh size of the trawl nets, the number of trawls used, minimum legal sizes, and closed areas during certain seasons. While these regulations are effective to some extent, they do not prevent the taking of undersized shrimp (e.g., some are caught and discarded dead offshore and represent a waste of part of the resource).

Economic Factors

The shrimp industry in the Gulf of Mexico underwent a difficult transition period from 1971 to 1975 (3). Low shrimp prices coupled with rapidly escalating prices for fuel and other input items brought about a cost-price squeeze that severely affected vessel owners. Average annual landings were approximately 49,000 pounds. The break-even ex-vessel price for normal production is estimated to be $2.60 per pound. Net profit was calculated to be $0.40 per pound with loan payment and $0.80 without loan payment. Net profit was $1.00 per pound if vessel depreciation and insurance costs were not considered. Since in 1975 production was slightly below normal, and the ex-vessel price of shrimp averaged only $1.66 per pound, vessel owners did not meet their cash expenses. We have reviewed the average price based on the mid-August price in Texas and have estimated the 1977 average price to be approximately $2.26 (Table I). Under this situation then, if 1977 is a normal year, the fleet will,

Table I
Average Price Per Pound of Shrimp Based on Size, Price and Percent by Size

Size (Heads off per pound)	Price (Dollars) Mid-Aug. 77	Percent of 1975 Landings
Under 15	4.09	.02
15-20	3.79	.11
21-25	2.88.8	.16
26-30	2.47	.12
31-40	2.10	.23
41-50	1.74	.14
51-67	1.54	.13
Over 68	1.26	.09

Average price = (size price per pound x % size) = $2.26

be in a much better position than they have been in past years. All preliminary indications are that in 1977 the average price per pound will increase to a figure higher than $2.26 and that shrimp production will be slightly above normal. The prospects for profit appear to be good.

The major economic constraint along the Gulf coast is overcapitalization. A good fishing year followed by another good fishing year produces an increase of the number of vessels being constructed. Since 1976 and 1977 appear to be two good years with high prices, the fleet will expand; hence, in 1978, excess vessel capacity will exist. However, if in 1978 shrimp abundance is low, then severe economic hardship can be anticipated. This sequence is a visible historical trend in shrimp fisheries in the Gulf of Mexico.

Social Factors

The inshore shrimp stocks support very large and increasing numbers of recreational and commercial fishing units and fishermen. The magnitude of the recreational catch is unknown; however, in the last decade the number of boats registered as commercial has increased considerably. It is assumed that the recreational catch of shrimp has also increased significantly in the last decade. The offshore fisheries of Louisiana, Mississippi, and Texas have been expanding, and they represent far fewer fishing units and fishermen than does the inshore fishery. The inshore fishery likewise harvests on an average smaller and less valuable shrimp than that offshore fishery (2). The curtailment or restriction on the inshore fishery with its many small boat and vessel operators can cause severe hardships. Many of these inshore fishermen rely heavily on this income although it may not be their primary source of revenue. The secondary industries likewise are dependent upon these producers. The canning industry of Mississippi and Louisiana depends upon small shrimp landed primarily by inshore boat operators. Management actions which impinge heavily upon this population must be thoroughly analyzed prior to promulgation. However, on the other side of the coin, fishing on the inshore shrimp stocks must be controlled. Continued expansion of this fishery may eventually lead to biological depletion or at the very least, to economic hardship for both the inshore and offshore fisheries. Since unrestricted fishing in the inshore area does affect revenue production by the offshore segment of the fleet, this complex problem needs to be analyzed not only from a biological standpoint but from economic and social aspects as well.

Also of concern is man's effect on that part of the coastal environment which produces the shrimp resources—the estuaries. Continued alteration of the environment by man's activies may result in far greater reduction in productivity than over-fishing. Management of the resource must take into consideration the primary nursery habitats of the shrimp stocks of the Gulf of Mexico. This brings into direct conflict the oil and gas producing areas and the nursery areas in many of the coastal marshes along the entire Gulf coast. Housing development likewise is in direct opposition to the maintenance of estuaries as nurseries. The social conflicts arising from these conflicting uses must be resolved on an equitable and fair basis not only for this generation but for future generations as well. The resources of not only the Gulf but of the world are not just for the use by the present generation, but for future generations as well, and we should look to these resources as providing a safeguard for the future. President Theodore Roosevelt at the turn of the century said, "The Nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased and not impaired in value".

Summary

Total U.S. shrimp production in the Gulf of Mexico from 1964 to 1974 has varied annually from a high of over 60,000 metric tons heads-off in 1970 to a low of about 45,000 tons in 1966. The average potential yield for shallow water shrimp is about 55,000 metric tons heads-off, with annual landings fluctuating close to this maximum since 1970. Size at first harvest is important in terms of the total value and weight of shrimp landed. The optimal size is about 20 to 30 shrimp per pounds heads-off.

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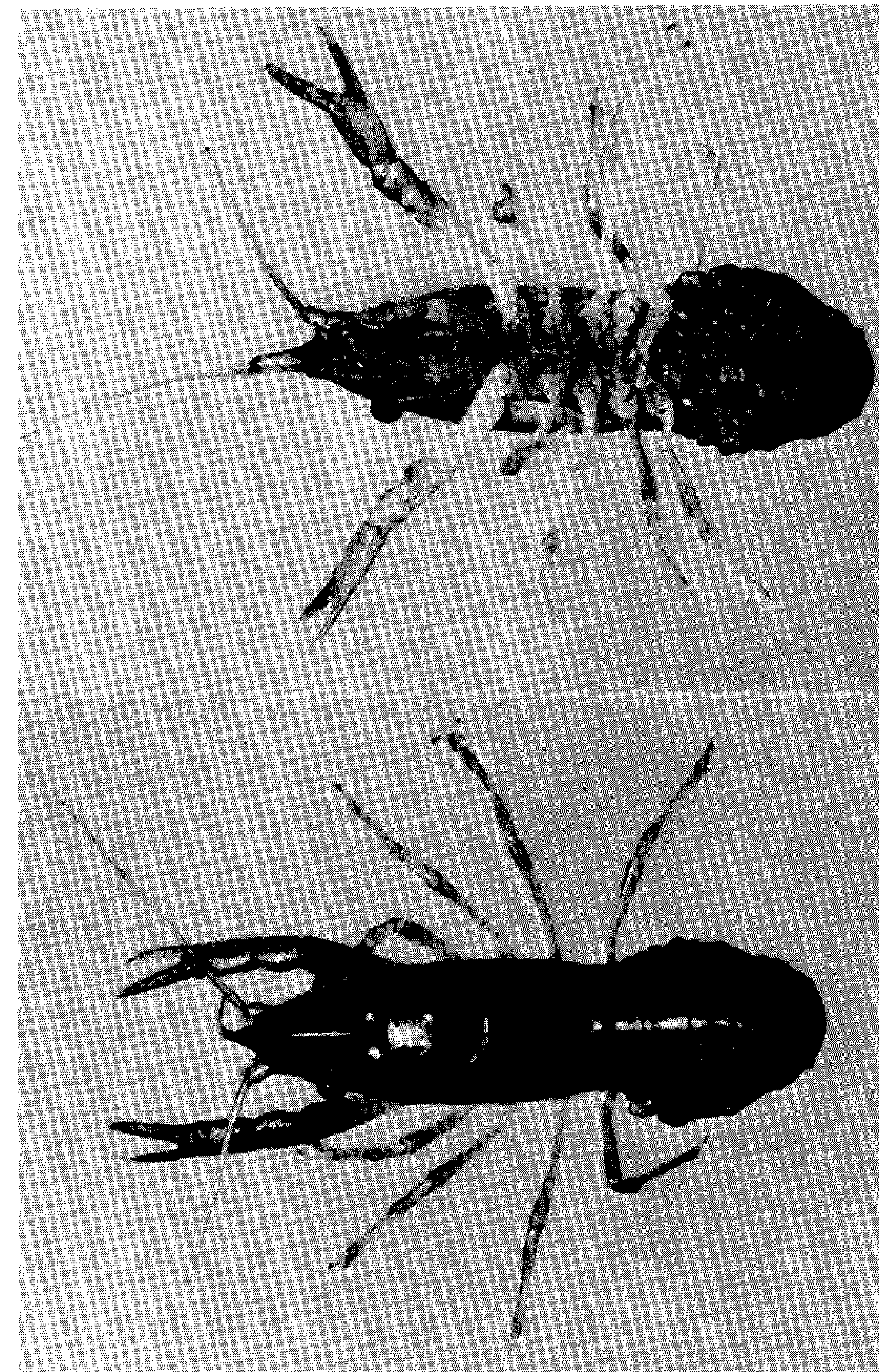

CRAYFISH WITH OFFSPRING. (Photo courtesy of Dr. Alan P. Covich, University of Oklahoma.)