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Principles of Shrimp Fishery Management

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Introduction

THERE ARE TWELVE OR MORE SPECIES of shrimp of the family Penaeidae living in the waters of the Gulf of Mexico at depths of forty fathoms or less. The flesh of all of these is edible, but small size and rarity exclude the majority from the commercial catch. Possibly the tastiest shrimp in this area are two species of the genus *Sicyonia,* commonly known as stone shrimp because of their hard shells. They are also rather small and are not very numerous. A night's dragging may yield ten to fifty pounds. They are consumed only by the fishermen themselves and perhaps a gourmet here and there. They have been marketed sporadically and rarely at Brownsville, but we are not concerned with them here.

On the Louisiana coast the "six barbes" of the French fishermen, *Xiphopeneus kroyeri,* or sea bob of the other fishermen is sometimes used on the drying platforms. It is also a very delectable shrimp, but it is just barely large enough to eat, at least for the American taste which is now well accustomed to larger shrimp. Production may be a million pounds a year or even less and in the following remarks we shall not be concerned with them either.

The 200,000,000 pound annual shrimp production of the Gulf of Mexico is based on three species of shrimp. Ranked in order of catch, the first is the brown shrimp, *Penaeus aztecus* Ives, followed by the white shrimp, *Penaeus setiferus* (Linnaeus), and last is the pink shrimp, *Penaeus duorarum* Burkenroad. Roughly, each succeeding shrimp in this short series yields about half as much as the preceding one.

The brown shrimp production is greatest in the western Gulf, especially along the lower half of the Texas coast and Mexico as far south as Obregon, at the very southernmost part of the Gulf of Campeche. Thus, part of brown shrimp grounds lie south of the Campeche pink shrimp area, a fact not commonly appreciated. There is also a small ground for white shrimp lying closer inshore, and farther south, in the same area. It should be noted, however, that the brown shrimp is also becoming increasingly important east of the Mississippi, at least into Alabama waters.

*The writer is indebted for support of certain work in connection with this project to Chief William Red Fox, of the Ogallala Sioux.

The major production of white shrimp has always been in the State of Louisiana where the mighty Mississippi fathers the largest estuarine area on this continent. This was "the shrimp" of the commercial fishery until the Texas fishermen began to produce brown shrimp in 1947 and 1948. The pink shrimp fishery of the Tortugas area began in 1949 and an account has been given by Idyll (1950). The pink shrimp grounds of the Campeche banks were discovered in 1936-37 by the Japanese, who kept quiet about it. They were rediscovered by a Texas fisherman in 1947 and developed by Texas operators in 1950. Very shortly thereafter the Florida fishermen came into the picture.

To summarize briefly, the pink shrimp are caught in two discrete areas in the southern Gulf. The brown shrimp are caught in the northern and western Gulf all the way down to Yucatan. The white shrimp are caught mostly around the mouth of the Mississippi River, with production diminishing east and west, with the limits roughly at Brownsville, Texas and Apalachicola, Florida, also a small pocket at the southern tip of the Gulf next to Yucatan.

These shrimping areas are not continuous as some recent publications and maps would have us believe. They are in fact quite discontinuous, partly because of untrawlable bottom and probably for other reasons that are not understood.

Biological Factors Related to Management

There are some peculiar resemblances and differences between these three species of shrimp. The white shrimp is differentiated from the other two species by the fact that there are no grooves along the sides of the dorsal spine. Furthèrmore, the spermatophores are placed or stuck at the base of the fifth walking legs and there is no receptacle for them. The most closely related species seems to be *Penaeus schmitti* Burkenroad of more southerly waters, which is not fished in the Gulf. In contrast the females of the two grooved shrimp have a small pouch, called the thelycum, for reception of the spermatophore. The ecological relationships of the species do not follow the anatomical patterns.

The adults of these three shrimp also have different depth ranges. About 43 fathoms seems to be the outer limit of the white shrimp, but few are found deeper than 20 fathoms, and most of the catch is taken at 14 fathoms and less. The majority of brown shrimp are caught between 18 and 25 fathoms, but there is a thin population of larger animals extending out to 45 fathoms and possibly beyond. Springer and Bullis (1954) found pink shrimp at depths of 37 fathoms but it is rare at greater depths than 28 fathoms, and most of the commercial catch on the Campeche banks is taken between 20 and 28 fathoms.

The white and brown shrimp are found on mud bottoms. The pink shrimp is found on calcareous sand and to a lesser extent on quartz sand with some mixture of mollusk shells. The young of the white and brown shrimp both invade low salinity estuarine waters and it would appear the white shrimp must invade such areas to grow up for they are found nowhere else under natural conditions. However, some experiments carried on by Mr. Malcolm Johnson indicated that small white shrimp grew well at high salinities and did better than another group at medium salinities. Whether or not it is necessary for the shrimp to have the low estuarine waters for growth of the younger post-larval stages, the bays are utilized as rearing grounds by both species.

The salinity limits are only slightly lower for the white shrimp than for the browns, but the former are considerably the more abundant in the fresher waters. These salinities approach one part per thousand. (For weeks on end I have drunk common tap water of the City of Port Aransas, Texas, which ran 4.9 parts per thousand salt.) In contrast, the young pink shrimp do not often invade low salinity waters, although they have been found by Tulane zoologists at low salinities in Lake Pontchartrain. In fact they avoid such areas, and grow up in shallow, high salinity areas such as Florida Bay, so-called, which is really not a bay but only an area of flats and shallows bordering the open sea. In spite of the fact that young pink shrimp have been found recently in the high salinity bays of the south Texas coast during the recent drouth, the only common feature of the nursery grounds of the three species is the fact that they are all shallow waters. However, they have this in common with the commercial river shrimp of the Mississippi Valley (Gunter, 1937) and, in fact, the young of most marine animals are found in shallower waters than the adults. The point of interest here from the management standpoint is that these growing shrimp can be fished by the little cracker-box boats which cannot compete in the offshore shrimp fishery.

The size ranges of the white shrimp run about 18-20 to a pound. Larger pink shrimp run 15-18 to a pound. The common commercial brown shrimp run about the same size, but at depths of 40-45 fathoms they run 4-6 to a pound. The very largest whites also occasionally run 6 to a pound.

Management and the Prospects of Management

Due to a natural predilection of the human race and to the evident wisdom of protecting the young in certain instances where animals have restricted spawning areas, chiefly in fresh water, we often look first at these matters. We know that shrimp spawn at sea and that their minute larvae drift about in the water, passing through some twelve to fourteen stages which look like quite different organisms. We have an outline of this stage of the life cycle of the white shrimp due to the work of Pearson (1939) and Heegaard (1953), but there are several questionable points. There is less known of the brown shrimp. Pearson says the larvae of this species come in at all times of the year, but the writer has shown (Gunter, 1950) that the post-larval young do not appear in the bays at all times of the year. Furthermore, the life history of this species seems to be just as seasonal and cyclic as any other species. Of the pink shrimp larvae we know nothing except what may be inferred from work on the others. We do know, however, that the larval history and stages are much the same for all the Penaeidae. Madame Heldt in Morocco and Doctor Hudinaga in Japan preceded recent American workers and together these works demonstrated the similarity of all species. This fact creates great difficulty in following the stages of one species in such areas as the Gulf, where twelve species exist in the shallow waters, and their larvae may also be confused with several more that live in deeper water.

Be that as it may, larval shrimp do somehow drift comparatively long distances into shore in quite large numbers. This is an amazing thing, and all we know about it is that it happens. The ripe females spawn offshore and a few weeks later the advanced larvae appear inshore, where they settle to the bottom, acquire color, and from then on live as shrimp.

With management in mind, we may ask what can we do about the larval shrimp? In the first place we do not know what to do and it is difficult to conceive anything within the realm of the remotely possible which we could do about them, if we were going to set out to try. We could determine for purposes of prediction, if there is ever a crop failure, so to speak, of incoming young, but we have no evidence that such a thing has ever occurred. Nevertheless, the point is worth investigating.

The shrimp grow up in the bays or the shallows and then move out to sea. There is where they are fished by the large shrimp boats. The life cycle of the white shrimp is short. A good many live slightly more than a year, but those living to two years are certainly a small percentage of the total, negligible both to the fishery and for management as well. Some years ago Burkenroad (1934, 1939) suggested that there may be an offshore reserve in deeper unexplored waters, but exploration is now complete and no offshore reserve has been found. In fact, the white shrimp is a relatively inshore animal found at the depths stated above. There does seem to be an offshore population of brown shrimp of very large size at depths of 30-45 fathoms and possibly beyond, which is not fished because it is too thinly scattered. They will always serve as a breeding stock even if the inshore population were wiped out. In fact, the white shrimp population does seem to be wiped out every year, or almost completely so, before the next generation is more than well started. In this the life history is similar to that of the Pacific salmon, except the salmon lives four or five years—and there is always a group at sea which will come in to spawn next year. But the white shrimp are a one year stock, to all intents and purposes. Most of the adults are gone by the end of August every year. They may die after spawning, but it is more likely that after spawning they are in a weakened, debilitated condition and then fall prey to the innumerable predators which assail them from every side at all times. A few may survive this critical period by chance and thus live into the second year. It is a general observation of everyone working with shrimp that they are eaten by almost everything that is large enough to eat them, all the time. They are eaten by everything that lives around, in, or above the sea, including the lowly jellyfish. They are not only eaten but they are preferred. Many fishes prefer them, as the author has shown (Gunter, 1945) and it was noted long ago (Gunter, 1941) that when shrimp were washed ashore by hard cold waves the gulls seized them first and only turned to fish when no more shrimp remained.

Larval shrimp fall prey to plankton feeders, but they are protected from larger predators by small size and their colorless condition. In the shallow, lower salinity waters the numbers of species of animals are less than in the open sea, simply because many marine animals cannot withstand lowered salinities. Thus the numbers of predators are less in the shallows, but when the shrimp venture out into the open sea they are faced by a veritable array of fanged and clawed goblins of the deep, and as a matter of fact they do not survive long. Shrimp are not very intelligent animals and it is a good thing, for otherwise they would all soon be scared to death and thus cease to exist. This brings to mind the remarks of Wm. J. Long, who said that God had given the dumb animals two great blessings, no regrets for the past and no fears for the future. Burkenroad has suggested that probably the fishermen get less than half of the shrimp and that is quite likely true.

The picture presented here is quite likely the true situation. What then should be done regarding shrimp in the open sea? There seems to be nothing to do but catch them as fast as possible before something else catches them first. You might ask, catch them all? What about the breeding stock? The answer is: You cannot catch them all, and probably not even a major part of them, and there is always enough breeding stock. In 1940 an extremely hard cold wave struck this country. It killed out practically all the shrimp on the South Atlantic Coast. The Shrimp Investigations personnel of the Fish and Wildlife Service was in the area at the time. They could not find a hatful of shrimp and immediately put out a mimeographed circular exhorting the fishermen not to catch any more shrimp. The fishermen got worried and no one wanted to be low man on the totem pole, so they got out and fished as hard as possible, only to verify the Service's findings. They came home and laid up their boats so long that sparrows built nests in the rigging. There was no spring shrimp fishery, but during the fall the shrimp crop came back as abundantly as ever. The few shrimp remaining after this catastrophe were evidently enough to repopulate the area. This episode afforded me the opportunity to twit my colleagues and I did so, but it is by such happenings that we learn.

The next example comes from an unpublished observation of Mr. Percy A. Viosca, Jr., who often arrives at the right conclusion by uncommon, if not unorthodox, means. Sprague (1950) has described a microsparidian parasite which attacks the gonads of shrimp and in effect castrates them. Mr. Viosca states that one year this disease seemingly castrated 99 per cent of the shrimp in Louisiana waters, but next year the crop was as good as ever.

A little figuring will give some indication of the probable reason for this situation. Five million pounds of shrimp of large size make up 100,000,000 individuals. If each female spawns 500,000 eggs, this will give fifty trillion eggs.

So the indications are that there is nothing to be done about the larval shrimp nor is there anything to be done about the adults in the open sea, except to catch them. Then what about the growing young in the bays and shallows? That may be a different situation. We do not know enough facts about the matter, but here are a few ideas upon which some speculations may be based.

We may look at the problem this way: The young shrimp come into the bays and grow up and then return to the sea. If you have a million pounds of 60 count shrimp in a bay, will you have the same money value of shrimp if you wait until they are 30 count shrimp before catching them, or, will the shrimp die so fast that you would have less in money value? That is the question facing the fishermen. Actually, it devolves upon two questions. How fast do the shrimp grow and how fast do they die? We only have information on the first question, which so to speak, leaves us only one leg to stand on. However, we may be able to set some limits for the other.

Viosca (see Tulian 1919) first recognized that the shrimp have a very fast growth rate, for he said they grow up "in six months or less." This would mean that they increase in length at the rate of about 1 mm (one twenty-fifth of an inch) a day. I found that only such a fast growth rate would fit the other facts of the shrimp life history and independently proposed it (Gunter, 1950) over thirty years later. However, it may not be as independent as it appears for I got the idea from M. D. Burkenroad, as was stated, and although he was honest about it, Burkenroad may have well picked up the idea from Viosca with whom he was associated some twenty-five years ago. Recently Williams (1955) has stated that young white shrimp in North Carolina grow at the rate of about 1.5 mm a day, brown shrimp at nearly 2. mm and young pinks at 2.3 mm. This may well be the case for young shrimp.

Be that as it may, a shrimp which doubles its length increases its weight by about seven times. We do not know the precise figure. If we have a shrimp 50 mm (2 in.) long, in about 50 days it will be about seven times as large by weight, taking the slower growth rate suggested. Thus it would double its weight in a week. Thus even with a fifty per cent mortality of the population every week, the total weight of the shrimp population would be maintained. At this maintained rate of mortality, practically all shrimp would be gone in nine weeks. An average mortality of fifty per cent each month would reduce the population to almost nothing in a year's time and that is more likely. If the average growth rate were maintained, up until the last month or so, then the weight of the population would be increasing all the time up until the last few months.

Actually the mortality is not held on an average. It is probably very high at first, say about 75 to 90 per cent per month and falls rapidly as the shrimp grow, being lowest before they pass out of the bays. In the Gulf it probably increases again, until the onset of cooler weather and rises again in the spring, this holding, of course, only for the northern Gulf.

In any case, if we go back to the example above of 50 per cent mortality a week, which is about 94 per cent mortality a month, the weight of the population will be maintained.

But let us take value alone. Sixty count shrimp are on the bare edge of being marketable. The chances are that 30 count shrimp are worth twice as much to the fishermen or more. Thus we would only have to catch 500,000 pounds of an original million to make as much money. Thus, if our figures and assumptions are anywhere near correct, fishermen could wait one week when the weight per shrimp would have doubled and make just as much money, if 75 per cent of the shrimp had died. At this rate of mortality, 99.6 per cent of the shrimp would be gone in a month. It is highly unlikely that shrimp in the bays die so fast.

This can be shown in a number of ways. If the total spawning stock of female shrimp in the Gulf of Mexico were 25,000,000 pounds it would be approximately a half billion shrimp. Anderson, King and Lindner (1949) say that shrimp spawn 500,000 to 1,000,000 eggs at a time. Not all of these would hatch, but since we now know that some shrimp at least spawn more than once a season, let us take the larger figure and assume that all eggs hatch. This would yield 500 trillion larvae; but at an average mortality rate of 75 per cent a week, or 99.6 per cent a month, in three months time there would be only 32,000,000 shrimp left, or considerably less than the number of parents. But this is unreasonable, for by and large the shrimp stocks maintain themselves. Such a mortality rate would not permit maintenance of the stock, let alone support a shrimp fishery. Yet with such a mortality the shrimp fishermen taking small shrimp in the summer, would not lose money if they waited a week and caught half as many shrimp.

But let us take another example. What would be the case if the mortality were 50 per cent a week and the bay population of growing shrimp only maintained its weight? This is a mortality rate of 92.75 per cent a month. Starting again with the 500,000,000 spawning shrimp and the 500 trillion larvae, we find that in three months time there would still be less shrimp than the original spawning stock. Thus, such a mortality still seems to be unreasonably high. In fact, if the figures about reproductive rates are near correct at all, it takes an average mortality of around 60 per cent per month to reduce the number of young to the original spawning stock in 12 months. This would be about a 40 per cent mortality per week. Since, as we have seen, the mortality of eggs, larvae, and older shrimp in the Gulf are probably higher than growing shrimp in the bays, then it seems that the average weekly mortality of bay shrimp may be even less than 40 per cent. Using this figure we find that a million pounds of shrimp would become two million in a week, during which time the death rate would leave 1,200,000 pounds of better grade shrimp.

In any case it is clear that it takes a terrifically high mortality to offset the fast growth rate of the shrimp. Burkenroad had something like this in mind when he said that all evidence we have shows that less shrimp may be present on the beds at any given time than the total annual production.

The growth rate assumed here is low, probably, for the medium sized or small shrimp and the other assumptions are conservative. Nevertheless, it seems clear that under almost any reasonably valid assumption that can be made, the fast growth rate of bay shrimp more than compensates for mortality. Therefore, it is best to wait on the small shrimp in the bays and not catch them until far into the fall. The bays should be completely closed to shrimping in July, August and September, if not at all times.

The above situation is the only management policy, I can see, that we can apply or need to apply at present. It cannot hurt any one very much. Now you might say that I have labored mightily and brought forth a mouse, but I have tried to show where we stand and in a way it is good that we have to do so little. In any case the proposed inductive approach suggested by Burkenroad (1951), of opening and closing bays on alternate years, with a determination of results, is an unwieldy affair and seems to be obviated by the above suggestions.

But there is one more factor we should hold in mind. The bay and shallow water environment must be preserved at all costs. That is the vulnerable point in the shrimp life history. If the shrimp ages ago adapted themselves to rearing their young in the estuarine waters and shallows, so as to escape the multitudinous goblins of the deep, it will be a bitter cosmic joke for them to run into a worse one who destroys their rearing grounds, now that they have nowhere else to go.

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International Law and the Fisheries

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THE EXPLOITATION OF FISHES in the high seas—the backbone of the world's commercial fishing industries—has become a matter of serious international concern, commanding the attention of the General Assembly of the United Nations.

This was the subject of study at the United Nations International Technical Conference on the Conservation of the Living Resources of the Sea, held at Rome, April 18th to May 10th, 1955.

The 1955 Rome Fisheries Conference had its genesis long before the General Assembly resolution which convoked it. It was made necessary by four things. The first of these is man. From the time man began fishing many eons ago, we have had the rudiments of a fishery conservation problem. It was only a question of time until the forces of nature pitted man's hunger against the capacity of the fish populations to satisfy it. That time has come with respect to a number of species of fish. Last year alone the world's population of over two