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By-Catch: Over the Side Discards, an Assessment and an Alternative

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By

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ABSTRACT

The Incidental capture and resultant mortality of numerous fin-fish and other species of marine organisms by non-selective types of fishing gear constitute a major waste of the various fishery resources. The magnitude of the discarded by-catch and its effects upon the major fisheries is examined. Specific gear types contributing to the problem will be identified. The Gulf of Mexico shrimp fishery of the U.S., which annually catches over a billion pounds of unwanted fin-fish or "trash-fish" will be examined and an evaluation of the continuing development of selective shrimp trawling gear specifically designed to reduce the incidental capture of sea turtles, fin-fish, jellyfish, and other marine organisms will be conducted. Information is also presented on other possible gear modifications and operational alternatives both domestic and foreign, directed at minimizing the impacts of this neglected but critical facet of fishery science - truly, an international fishery management problem. It should be noted that all observations and recommendations within this paper are those of the author and should not be mistaken for those of the United States Federal Government or any Department thereof.

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INTRODUCTION

Since the earliest days of mankind, the various marine fishery resources have been utilized as a primary food source. Important aspects of fisheries have since expanded to incorporate not only a source of food, but income, employment, and recreation. Man is finally coming to perceive the true importance of these limited resources, limited in the sense of fragility and vulnerability to damage or destruction by man, yet renewable if properly utilized and not over-exploited. Fishing is recognized as the oldest use of ocean space, thus one of the world's oldest industries.

Man has progressed immensely since early encounters with abundant natural resources of fish. Once, man's only concern was how to effectively capture this resource; now modern man finds himself harnessed to the task of assuring future generations with abundant living resources through well planned and implemented fishery[1] development programs.

Increased knowledge of the marine environment and technological advances through new gear, more efficient vessels, greater mechanical power, new fish locating devices, and increased overall demand have placed an ever-increasing amount of pressure on these sensitive fishery resources. Most of these dramatic changes attributing to significant growth in the world fish catch have occurred within the last three decades. The world fish catch increased from 20 to 65 million tons between 1950 and 1965. This expansion coincided with a concomitant growth in the world economy in part due to the economic output of many developing countries which had only recently gained independence. This dramatic harvest growth was directly related to the introduction of synthetic fibres in the manufacture of nets, accompanied by the mechanization of net hauling which in turn, made possible the use of large purse seines and trawl net fishing.

Much of the expansion in the developing world has been due to the transfer of modern technology, e.g., the introduction of trawling in southeast Asia and Africa which led to a rapid increase in catches during the Sixties and subsequently, in several instances, to over-exploitation. Expansion of world fisheries has since been constrained by the productive capacity of several fish stocks. Rates of growth in world landings slowed significantly from approximately 6 percent per year to approximately 1 percent at times. The 1981 total world commercial fishery landings, the most recent for which data are available at this writing, were a record 74.8 million metric tons.[2] This is an increase of 2.4 million metric tons or 3 percent compared with 1980. The United States was the fourth leading nation in total catch with approximately 5 percent.

As more stocks become, at first, fully exploited and then, over-exploited, international interest in management problems grow. Further complicating the issues are the recent significant changes in the legal regime of the oceans. More than 100 coastal states have extended their national jurisdiction over living and non-living resources within the waters up to 200 nautical miles from their coastline. This culminated in the signing of a new Convention on the Law of the Sea in December, 1982 by a large number of member states of the United Nations, making the principle of Exclusive Economic Zones (EEZ's) a reality. While granting the coastal states greater opportunities to utilize the benefits of the fishery resources in the waters under their jurisdiction, they must also take responsibility for the conservation and management of these renewable resources.

One of the most significant challenges facing the world community is the expected growth in the demand for fish and the need to ensure that this demand can be satisfied at reasonable prices. It is anticipated that world demand for edible fish will grow to 100 million tons by the year 2000 in order to feed an estimated worldwide population of 6 billion people. Therefore, it is reasonable to assume that this demand will not be met by conventional harvesting means as we now know them. Aquaculture has been a promising new area of fishery development, however, many barriers continue to plague its evolution. Caveats to aquaculture development include, but are not limited to, environmental pollution, site location and degradation, poor dissemination of technical and economic information, need for specialized personnel, high capital costs, economic production of high value species only, and most importantly - constraints of political and administrative nature rather than scientific and technological.

Thus, the only viable alternative appears to be the increased utilization of marine organisms now being discarded over the side of harvesting vessels at sea. These marine organisms incidentally captured in the direct exploitation of target species usually associated with commercial fishing are most often referred to as "by-catch". By-catch often include various species of amphibians, fish, invertebrates, mammals and reptiles. Although some of the by-catch may be of commercial value, only a very small portion is utilized, usually only as a source of food for the vessel's crew. That part of the gross catch not used in any manner whatsoever is usually shoveled over the side and referred to as "trash fish", discards, or discarded catch. The primary discard is fin-fish for which there is presently no ready or economically feasible market. These fin-fish are usually discarded dead because the vessels lack storage capacity and/or the market demands remain poor.

Environmentalists, governments, scientists, and industrial interests have sought to either dramatize or minimize the issue of by-catch and over the side discards. The overall impact of incidental captures and their eventual destruction is still poorly understood. The measurable effects of the by-catch problem on the marine ecosystems, human populations (socially and economically), tourist related development, commercial processing, and ultimately the fishery resource itself, have been less important than the political utility of the issue in motivating and coalescing public, as well as governmental response.

I. FISHING GEAR SIGNIFICANTLY CONTRIBUTING TO BY-CATCH

Gear used commercially for fishing which contributes significantly to by-catch and the resultant discard waste are non-selective types of harvesting gear. This non-selectivity stems primarily from the lack of knowledge necessary to capture only the target species. Another contributing factor is that once a means of increasing a gear's selectivity is proven, the gear modification itself requires a substantial increase in initial acquisition costs, handlin costs, repair costs, and possibly decreases the target specie's harvest. These nonselective types of fishing gear include purse seines, long lines, gillnets, assorted pots, and otter trawls.

A. Purse-seine Gear

Purse-seining is a commercial fishing method of particular importance for the capture of species (menhaden and herring) utilized in bulk reduction processes, such as fish meal for oils and animal feeds. It is also used extensively in the catching of high individual value species of food fish such as tuna. The operational procedure involves the setting out of a long net to form a wall of webbing around a school of fish to be taken. The top of the net usually remains on the surface, aided by cork floats attached to the webbing by means of a corkline. A leadline runs along the net bottom to sink the webbing, thus forming a "wall". When the net has encircled the fish, its bottom is pulled together so that an artificial pond of webbing captures the catch. This pond is then hauled in by a hydraulic block until the fish are gathered alongside the vessel and may be hauled aboard.

Most often, the method is utilized in harvesting pelagic species swimming from the surface to a depth of perhaps 70 fathoms. Other fisheries utilize the purse seine to catch demersal species, such as cod, swimming near the seabed. In such cases, the wall of netting is sunk to the bottom of the seabed with a reduced corkline holding the wall upright, yet below the surface. A number of different methods of utilizing this specialized encircling gear are in common use. The operation is very effective upon schooling fish stocks. In fact, this type of harvesting gear is, to a major extent, responsible for the successes in both the menhaden and the tuna fisheries.

Menhaden landings in 1982 of 1.3 million metric tons set a record and accounted for 43 percent of the commercial fishery landings in the United States, placing it first in quantity. Menhaden were fifth in value. Wet reduction of menhaden yields three products: fish meal, fish oil and condensed fish solubles. Menhaden meal is a valuable ingredient for animal feeds. It contains a minimum of 60 percent protein with a well-balanced amino acid profile. The broiler and swine industries are heavily dependent on fish meal as a feed ingredient. Aquaculture is demonstrating ever-increasing demands for menhaden meal in formulated feeds for catfish, salmon, trout, and shrimp. Menhaden oil has been used for years as cooking oil and margarine in Europe, however, the U.S. Food and Drug Administration (F.D.A.) are not presently allowing such uses in the U.S. It is, however, used in the U.S. as components of marine lubricants and greases.

Although information pertaining to associated menhaden fishery by-catch is minimal, it is thought to be relatively insignificant. In fact, most of the incidentally captured fin-fish are simply processed along with the target species - menhaden. The significance of the menhaden fishery, however, lies in its various possibilities for expansion of the world catch figures and the further utilization of the species. The stock appears capable of further exploitation. Methods of gaining F.D.A. approval for expanded human consumption of the fish oil and oil products are being tested. A new development involves the processing of a menhaden-derived fish product (suremi) for direct human consumption at a very competitive price.

Tuna landings in the United States in 1982 were the fourth most important commercial fishery in terms of value landed, and fifth in quantity. Three basic forms of fishing account for nearly all the commercial catch of the principal market species. On a global basis, bait fishing is presently the most important method, followed closely by longlining and purse seining. Purse seining is much more effective in terms of catch per unit of effort expended, thus, in part, explaining the U.S. preference for this method of harvesting tuna.

Purse seining is an example of a multispecies management problem which involves various species of porpoise becoming incidentally captured in association with tuna and thus constituting by-catch. Considerable porpoise mortality has caused widespread concern over the effects of this resultant mortality on porpoise stocks. These marine mammals apparently attract certain tuna, allowing fishermen to encircle a school of easily sighted porpoise and likely capture tuna associated with the porpoise. The porpoise that are caught have no market value, so they must be either released alive or, if killed, discarded at sea. Fishermen derive several benefits from releasing them alive. Aside from humanitarian reasons, the porpoise, once released, will presumably associate with tuna in the future, thus further enabling capture of more tuna. If the porpoise are killed in the nets, considerable amounts of valuable fishing time is lost in removing them.

Attempts to reduce porpoise mortality resulted in the development of two effective approaches.[4] A backing down procedure was developed by United States tuna fishermen around 1960. After the seine has been pursed, and from one-half to two-thirds of the net encircling the tuna and porpoise has been hauled aboard, the vessel commences backing down. It is critical that the porpoise are near the far side of the net, away from the vessel, and the tuna are headed toward the vessel. At this time, the vessel's engine is shifted to reverse and power applied, thus moving the vessel backwards.

Water pressure forces the far end of the net's corkline to submerge a few feet below the surface, allowing the porpoise to escape.

Despite these efforts to separate and save the porpoise, many animals still become entangled and die. In an effort to eliminate the entanglement mortality during backdown, fishermen began replacing the uppermost strip of usual 4 1/2 inch mesh webbing in the release area with a 120 fathom strip of 2 inch mesh webbing approximately 6 fathoms deep. This safety panel or Medina strip (after Captain Harold Medina) resulted in fewer porpoise entangling their flippers and snouts in its smaller meshes during backdown, thus reducing mortality.[5] The advantages of the Medina panel gained acceptance among United States tuna vessels. The incorporation of the safety panels into the seines of United States vessels was further stimulated by enactment of the Marine Mammals Protection Act (MMPA) on October 21, 1972. The adoption of safety panels by many U.S. vessels represented a significant step in reducing the hazard to porpoise caught with tuna. Mortality estimates for the international tuna fleet from 1959 to 1977 are given in table 1.[6] These estimates are based on National Marine Fishery Service (NMFS) marine mammal observer data and the Inter-American Tropical Tuna Commission logbook data.

Other management efforts continue to be examined in an effort to eliminate this fishery caveat entirely. Several international organizations have addressed the issue by setting quotas of porpoise kills. Fishing-induced porpoise mortality could be eliminated entirely by prohibiting the use of purse-seine gear in fishing for yellowfin tuna associated with porpoise. Obviously this would be difficult as well as an economic loss in the sense that purse seining is presently the only economically efficient means of harvesting tuna in the offshore portions of the eastern Pacific. Therefore, more research is needed and must be directed toward development of new types of porpoise saving gear and fishing techniques. Hopefully, such research will lead to more efficient techniques which captains and vessel owners will logically want to adopt. Such a gear developmental breakthrough will obviously require a long-term gear research and development program that would have to be substantive, broad ranging, imaginative, and well funded to have any chance of success. NMFS has played an important role in developing release methods and has and is continuing to experiment with a number of fishing techniques and gear modifications designed to reduce porpoise mortality. Unfortunately, a continued onslaught of pervasive budget cuts are making it increasingly difficult for any federal agencies to ameliorate the situation.

The United States fishermen along with the industry in general have by virtue of their vast experience in fishing with purse-seine gear been instrumental in past gear adaptations and developments. Their skill, knowledge, practical experience, intuition, and now hopefully their funds, will continue to play an important role in improving fishing techniques.

B. Longline Gear

Whereas purse seining and otter trawling are "active" fishing methods - the vessel works the gear in order to capture the fishery stock, the effectiveness of "static" methods depends on the fish moving to the gear which is set out in a particular manner by the vessel and left for a period of time in one place; the vessel returning later to retrieve the gear and the catch. The most common types of static gear are: longlines, gillnets and assorted pots. Again the propensity for concomitant capture of non-targeted species exists.

Longlining may be applied to the capture of demersal or pelagic fish, the gear being rigged to favor the species being sought and the area being fished. Longlines are of particular importance in harvesting high individual value fish such as swordfish, halibut, and tuna. It is also used for other species including cod.

The operation involves setting out a long length of line, usually several miles, to which short lengths of line carrying baited hooks are attached approximately 2-6 feet apart. The fish are attracted by the bait, hooked, and held by the mouth until they are brought aboard the operating vessel which periodically hauls the gear. A typical arrangement for subsurface or pelagic longlining is shown in Figure 2. There are wide variations in the dimensions, operations, and rigging of the long-line gear depending on the area, species, and local tradition.

The multispecies management problem here involves primarily billfish which are often exploited together with tuna in longline fisheries. The key problem is that there are two distinct groups of harvesters, commercial fishermen and sport fishermen, who hold conficting views concerning the proper objectives of management. The issue is further complicated by the subsequent incidental capture of various non or underutilized species including numerous fin-fish, shark, moray eels, sea snakes, and sea turtles. Reports from NMFS foreign fishery vessel observers confirm the occasional catch of several endangered species of sea turtles including the leatherback (Dermochelys ceriacea).

The Japanese tuna fleet off U.S. shores is contributing significantly to incidental captures of various species, many of which the foreign fleet is not permitted to harvest and although of value both to the U.S. fishermen and foreigners, it must be released. The non-target species, often are billfish which are severely stressed, or dead and simply sink into the abyss. Approximately 500,000 to 1 million pounds of swordfish per year are discarded as a result of foreign longline fisheries in the U.S. EEZ. Various members of the billfish family including blue and white marlin are showing a size decline indicating a detrimental effect to the populations of these stocks.

Various fishery management methods have been imposed but with little success thus far. They include gear restrictions, fish size limits, variable season closures, and quota systems. Mortality reduction can be attained by a conscious effort on the part of the foreign fleet fishermen to avoid hauling the by-catch species out of the water by gaff or mouth hook, and cutting of the line close to the mouth. Approximately 50% of the incidentally captured billfish appear to survive according to NMFS observers when this technique is utilized. Larger size hooks also are being tested as a possible succor to the enigma. Still other management methods include the fining of foreign vessels for each billfish capture (actively being considered) or possibly more feasible would be the processing of such catch which would then be surrendered to the U.S. Coast Guard or other government agency (possibly NMFS) to be auctioned. All proceeds could be placed into a fishery development fund for research purposes (such as the Saltonstall-Kennedy fund). All legitimate interests must be recognized, alternative courses of action considered, and some solution, possibly a compromise, agreed upon if the resources involved are to be successfully managed.

C. Gillnets

The gillnet is a large wall of netting which can be set just above the sea bed when fishing for demersal species, or anywhere from mid-water to the surface when pelagic species are sought. In relatively shallow water nearshore, the nets are usually set and anchored in position, but an alternative is the drift net which is free to move according to tide and wind conditions (Figure 3) .

The gear itself is a net of twine in which the fish are trapped by their gills as they try to swim through, or several sheets of various sizes of mesh in which they become entangled. Rigging of the gear varies widely. The top of the net is seized to a float or corkline and the bottom is attached to a headline. The combined action of the floats and weights maintains the vertical stretch of the net.

Vessels of almost any size can undertake gillnetting or drift netting and the majority of the fleet is artisinal in that they usually return daily to land their catch. This usually results in a greater utilization of the various by-catch spscies and results in fewer overall discards. Little overall catch information is available from the gillnet fishery due to its great diversity. However, Florida gill netters alone reportedly took 46,500 pounds of sea turtles incidental to other species in 1970 (latest NMFS statistics). It is however, becoming an increasingly utilized method of harvest, presumably due to certain economical advantages over other energy intensive methods such as trawling (primarily due to increases in fuel costs). The primary management techniques in such a fishery would include mesh size regulations, and area and season closures. Little good would be derived from size limits because of the almost total mortality of the captured species.

D. Pots

This method is particularly well suited for the capture of crustaceans, such as lobster and crab, whose principal habitat at the harvesting stage is benthic, however some demersal fish traps do exist (Figure 4).

Pots of various sizes and configurations are set out and attract various species being fished by means of bait, usually cut up fish. The pot is constructed in such a manner that once the marine animal enters through a specifically designed entrance, it is unable to exit again and becomes trapped; it is then removed periodically when the operating vessel retrieves the pot.

Certain non-target species are known to fall prey to pots as well as undersized or egg-bearing target species which by law must be returned to the sea. Although these undersized organisms are released over the side alive, most have undergone a terrific change in environmental surroundings, going from depths up to 600 meters to sea surface and temperature changes of up to 20°C in only a matter of minutes. These overwhelming changes certainly have some disorienting effects upon the organisms at the least. The trip from the surface back to the ocean floor is not without hazards of various predators when the organism is in a most vulnerable state. If the discarded catch survives these sources of trauma it still has the problem of re-establishing itself on the sea-floor, possibly in an area miles from its original capture, in a totally foreign habitat.

Management techniques concerning this type of fishery have been primarily focused on seasonal and area closures, trap number limits, and size restrictions. Many traps are being equipped with escape hatches or vents which allow undersized species a means of avoiding capture as illustrated in figure 5.

E. Otter Trawls

World wide, the most commercially used method of harvesting fish for human consumption is trawling. The bottom fisheries of the continental shelf areas provide species such as haddock, cod, and shrimp. Trawling is used in the mid water region as well, for herring which are primarily used for reduction purposes.

The trawl net is basically a large bag made of webbing which is towed along the sea bed to scoop up fish and/or shrimp on or near the bottom. Depending on the gears construction and rigging, its operating characteristics may be altered to permit use on a number of different types of bottom and for many different species of marine organisms (primarily fish and shrimp). Figure 6 illustrates a typical otter trawl in some detail. It appears as a large bag shaped net, wide at the open end or mouth leading to the body of the net and tapering to the closed end where the marine organisms are collected and trapped in the "cod-end) or "bag".

The mouth of the trawl forms somewhat of an oval shape when viewed from the front, and two wings stretch out in front on either side to increase the area swept and to guide the catch in the net's path down to the cod-end. Holding the upper edge of the mouth upward is the "headrope" to which are fixed a number of floats. The bottom of the mouth is attached to the fastrope or leadline which is weighted. The combined effect of the floats and weights, as well as water pressure during the tow, keep the mouth open vertically.

As indicated in figure 6, the headrope and the top of the mouth usually overhang the footrope and aids to ensure that the organisms disturbed by the groundrope do not swim upward and over the trawl, but are forced down towards the cod-end by the overhanging webbing.

The otter trawl itself, gets its name from the flat wooden doors used to spread the net. First introduced in 1894 in Granton, Scotland by a Mr. Scott, it consisted of a bracketed, flat, wooden trawl door which was used as a spreading device to replace the awkward and restrictive beam on a beam trawl. The horizontal spread of the trawl's mouth is attained by these "otter boards" or "doors" towed ahead of the net and set at an angle of attack to the towing direction which provides an outward spreading force necessary to spread the wings to which they are fastened. Actual arrangement of the connections between the doors and the trawl wings varies depending on the handling arrangements aboard the operating vessel as well as the species targeted for harvesting.

Advent of the otter trawl is most likely the most significant single harvesting development in the fishing industry. An indication of its significance can be seen upon examination of Thailand's remarkable marine landing increase of 760 percent between 1958 and 1976.[7] This can directly be attributed to trawl fishing which was first introduced as a result of a Thai-German project in 1961. The use of otter trawls grew so rapidly that demersal species now comprise four-fifths of their total catch. This introduction of effective gear that could be used on indigenous boats, the availability of venture capital, and the sea-going traditions of the Thai people made this bilateral project one of the most successful ever undertaken. A tremendous proliferation of fish species in Southeast Asia often yields trawl hauls of approximately two hundred species.

The Thai experience in exploiting multiple species is of great relevance to other developing countries as well as most developed countries. The target species of shrimp and other acceptable species are sorted out from the mixed catch. The "trash fish", for which most states have no ready market, constitute approximately one third of the catch. They are not discarded dead at sea, but are used for catfish food, duck food, or for reduction to fishmeal. The overcapitalization and subsequent overfishing in the Gulf of Thailand that resulted from a failure to limit entry of new vessels into the Gulf should serve as an example for other developing countries that may be developing ambitious plans to modernize their fishing industry. Management techniques affecting trawling will be discussed in detail later.

Obviously, more information and research is needed to ascertain the complete impacts of by-catch and subsequent over-the-side discards of these aforementioned fishery harvesting techniques. Volumes of by-catch differ significantly from region to region, season to season, as well as between gear types and even individual crew methods of sorting and handling. Its propensity for waste has become an increasing concern to fishery biologists.

II. OVERALL VOLUMES OF BY-CATCH

A. World Wide

It should come as no surprise that estimates of world wide quantities of by-catch vary widely. Only recently, after many years of intense effort, have world statistics of annual fishery landings or, for that matter, United States landings become anything more than educated guesses. Wide seasonal, geographic, gear related and annual fluctuations in abundance have caused considerable fluctuations in the volumes of by-catch discards further complicating efforts at estimating the overall amounts. Even with this phalanx of variables, it appears self-evident that "over the side discards" are a significant idiosyncrasy of the world fisheries.

Though most discard volume estimates are limited to a particular fishery method, further complicating procedures for ascertaining a percentage for the world fishery, a conservative estimate is 10 percent. In 1981, the world commercial fishery landings were approximately 75 million metric tons. The generally accepted 10 percent by-catch figure would then approximate 7.5 million metric tons or more which could be at least partially utilized. This annual quantity of discards at sea has the potential for lessening the overall shortage of animal protein for mankind if properly utilized.

Further analysis on a world wide basis can only be attempted after a more systematic data base is established, including more precise information on the species of discards, their sizes, weights, numbers, etc. Certainly the need exists for consistent field survey procedures for specific sampling and estimation methods applicable to the discard problem. Though not the subject of this paper, such statistical procedures have been adequately addressed recently and will certainly be of use to fishery scientists (Saila, 1983).

B. United States

On a national level, the United States landed approximately 3.8 million metric tons of commercial fishery species. Using the conservative estimate of only 10 percent of the total catch constituting by-catch, a figure of approximately 422,000 metric tons could be estimated. However, documentation of the shrimp fishery in U.S. waters of the Gulf of Mexico alone, produced a figure of 511,000 metric tons annually, with a fish to shrimp mean ratio of 9.1 to 1 averaged across areas, seasons, years, and depths (Pellegrin, et al, 1983). Another study (Juhl, et al, 1976) determined that incidental fin-fish capture during shrimping operations resulted in a discard ratio of 3 to 20 pounds for each pound of shrimp. On the findings of these reports, a more realistic overall U.S. by-catch estimate of 50 percent of total catch produced an annual by-catch volume nearing 2 million metric tons. Again, it must be stressed that until more acceptable methods of recording and/or estimating the overall volumes of by-catch and resultant discards are utilized, the overall seriousness of the situation cannot be ascertained.

III. POTENTIAL PROGLEMS ASSOCIATED WITH BY-CATCH DISCARDS

The overall volume of discards depends, as stated earlier, on many elements, including the type of fishery. The problems arising from the over-the-side dumping of potentially large volumes of incidentally captured species have seldom been addressed.

The most obvious, and often, the only problem addressed regarding discards is that of the waste incurred when potentially good animal protein is shoveled over the side of the harvesting vessel. Reasons behind such actions include lack of vessel holding capacity for anything other than the high value target species, conversion of the many different organisms into a saleable product, the reluctance of the consumer to try new products, and even the social behavior of some fishermen reluctant to change their age old habits of dumping all but the target species.

Another problem involves the biological aspects of killing actual target species which are just too small. These undersized specimens which are often destroyed by various fishery methods, are often next year's crop. Many reports of annual average size reductions of catch have been reported and can certainly, in part, be attributed to the kill of juvenile species the previous seasons.

An area of concern primarily due to lack of information is in regard to the incidental capture and removal of certain species that are predators or competitors with the primary target species of commercial value. Care must be taken in the implementation of certain management practices to avoid harmful effects upon the primary species of interest.

A final proposed area of concern involves a very sensitive and controversial issue which has not been previously addressed. This issue concerns the effects upon the environment in which the discarded incidental catches are dumped. The general public is aware of some of the hazards involved with beach washups of occasionally large volumes of fin-fish. In areas of high fleet or vessel concentration (primarily trawlers and purse seiners) occasional washups of these discards present not only problems of aesthetics, but possible health hazards as well. Such "fish kills" have at times, been mislabeled to be the result of "red tides" or plankton blooms. These beach washups are reported to cause negative economic impacts upon coastal beach communities dependent upon tourists and their expenditures for their survival.

A much less noticeable, yet possibly the most damaging aspect of the by-catch dumping and subsequent bottom accumulation, would be in regards to biochemical oxygen demand (B.O.D.). The most widely used parameter of organic pollution applied to both wastewater and surface waters is the 5-day BOD test. This test involves the measurement of dissolved oxygen used by micro-organisms in the biochemical oxidation of the organic matter, in our case, fin-fish. The BOD measurement is significant in sewage treatment and water-quality management due to its ability to determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present. The concern here is that the volume or concentration of dead and decaying discards, the location of this concentration, and the subsequent current and flow conditions of the water column could combine to cause a condition of znoxia in the surrounding waters. Such conditions could prove fatal to a number of different marine organisms, furthering the overall impact. BOD measurements are frequently utilized by EPA in measuring similar effluents from fish processing plants, however no BOD determinations of by-catch accumulations have been made.

A "waste product" has been defined as a damaged, or defective throw away, a superfluous material produced by a manufacturing process, and refuse, or trash.[9] Marine pollution has been defined in two ways: 1) a harmful condition arising from the amounts, concentration, distribution, and physical or chemical behavior of natural or synthetic materials introduced into the environment; or 2) in a more general sense, as the introduction by man of substances or energy into the marine environment, causing harm to living resources, human health, and/or economic activities.[10]

A United States National Academy of Sciences report estimated the total petroleum hydrocarbon input in the ocean annually to be 6.1 million metric tons. The conservative 10 percent by-catch figure of 7.5 million metric tons world wide begins to promulgate the seriousness of such dumping methods when it exceeds the mean estimate of marine pollution by oil. Certainly this is not to say by-catch accumulations should be regarded in the same context as oil pollution, however, certain caveats do exist and must be recognized.

There are certain aspects of by-catch discards which could conceivably be considered beneficial. Recreational fishermen will attest to the advantages derived from fishing near vessels that are shoveling the "trash fish" over the side. They have long recognized the value of these discards as a food source to scavengers, predators, and other oceanic fishes. Many of these predators depend heavily upon such dumping activities. It also serves as a reintroduction to the life cycle of nutrients into the water column. More recently, studies are indicating a direct dependence upon shrimp-vessel discards in the Gulf of Mexico by sea gulls.

IV. A REGIONALIZED INVESTIGATION OF BY-CATCH AND SUBSEQUENT DISCARDS

To further assess the significance of the discarding at sea of marine organisms, it is necessary to examine in detail a specific regional fishery. Incidental captures and resultant mortalities of a large variety of species by Gulf of Mexico and South Atlantic shrimp fleets have received increased attention recently. Although the problem of discarded by-catch and its biological, economical and socialistic aspects are not unique to the shrimp fisheries, the magnitude of discards among the Gulf and south Atlantic fleets are significant.

A. The Gulf of Mexico Shrimp Fishery

The shrimp industry is generally recognized as one of the most important fisheries in the United States. In 1982, shrimp was first in value of commercial fishery landings and the fourth most important in quantity in the United States.[11] U. S. landings of shrimp were approximately 142 tons valued at $590.1 million. This was a decrease of 35 tons in quantity, but an increase of $45.7 million (10 percent) in value compared with 1981. Shrimp landings, interestingly enough, increased in the New England region by 49 percent and 55 percent in the south Atlantic region. However, the Gulf region suffered a 22 percent reduction in shrimp landings and the Pacific Coast had a 34 percent reduction compared to 1981 figures.

The Gulf region landings were approximately 105 tons. Mississippi was the only state to show an increase. Louisiana led all states with approximately 45 tons. The average vessel price per pound in the Gulf region was $2.03 in 1982 compared to $1.50 in 1981.

Thus, it should be clear that the penaeid shrimp fishing industry is one of the most valuable fisheries in the southeastern United States. A large trawler fleet consisting of various designs and sizes operates in the Gulf of Mexico and off the southeastern coastal states from Texas to North Carolina (Captiva, 1966). The majority of the trawlers tow at least two trawls, one from each side of the vessel, and are called double-rig trawlers.[12] Most smaller vessels tow a single trawl from the stern and primarily fish the bays and sounds where the size and number of nets used is restricted by law. The larger commercial vessels usually fish offshore and are not restricted to net size or number of nets. The primary gear utilized is the demersal otter trawl, a nonselective bottom net that incidentally catches numerous fish and other invertebrates. Its primary components were discussed earlier and are further described by Marinovich and Whiteleather (1968).

The three major species that make up the Penaeid fishery are the brown shrimp, Penaeus aztecus; the white shrimp, Penaeus setiferus; and the pink shrimp, Penaeus duorarum. Because these primary target species vary in abundance seasonally and geographically, the shrimp fleet is migratory and intensively searching the Gulf waters.

B. The Scope of Discards

This concentrated effort by an unlimited entry fleet produces an enormous by-catch of fin-fish, undersized shrimp, other invertebrates, and occasionally sea turtles.

The annual estimate of total fish by-catch for the Gulf region of the U.S. fishery has been reported to be more than 15 times that of the south Atlantic region.[13] This was suggested to be a result of the vast estuarine complex of the Gulf of Mexico centered on the Mississippi River delta, one of the largest and most productive estuarine regions of the world. Ninety percent of the commercial harvest and seventy percent of the recreational catch of the Gulf region is estuarine dependent. The primary fin-fish by-catch was composed of Atlantic croaker (Micropogon undulatus), and spot (Leiostomus xanthurus) according to a NMFS shrimp fleet by-catch program (Pellegrin, et al, in preparation). Other by-catch species are listed in table 2.

Therefore, it can be surmised that demersal fish constitute a large portion of the presently unutilized by-catch of the shrimp industry, some of which are juveniles of commercially exploited species. Directed commercial fin fisheries and recreational fin fisheries in the Gulf region harvest approximately 2,000 to 4,000 tons annually.[14]

C. Alternatives

The Gulf shrimp fishery and its resultant by-catch discards provide the fishery scientist and fishery manager with a perplexing issue. Some of these fishery specialists would view the situation as a nightmare of interrelating variables and unknowns. Others may see the <u>problem</u> - as an opportunity to assess and evaluate new management techniques, and the <u>Gulf</u> - as an unlimited laboratory.

The complexity of the issue is a result of the interaction between species. The competition-interaction problem must be carefully reviewed from a cogitation of dynamics and stability among ecological systems. Care must be exercised in developing and implementing various alternatives for the shrimp fishery with due consideration for the biological and economic utility to the entire ecosystem.

Numerous alternatives, however, do exist. Certain minimum trawl mesh size restrictions are utilized within selected bays and estuaries. Such measures, although sound in principle, are only partially effective in allowing smaller fish and shrimp to escape the trawls and certain death.

Similar in nature was the development of trawls which incorporated fish separator panels. Based upon behavioral observations of shrimp and fish in operating trawls by diver scientists, a "U" type vertical separator panel was developed by NMFS personnel to separate shrimp from fish (Watson and McVea, 1977). Problems included shrimp loss, clogging and gilling of fish in the separator chute.

Another NMFS study centered around the use of an electrical shrimp trawl. The trawl was primarily developed to study shrimp responses to a large range of voltage and exposure times for various substrate types in an effort to develop predictive models for use within a large range of environmental conditions. The trawl was capable of sampling populations of shrimp for fisheries management applications as well as determining the efficiency of conventional shrimp trawls. Through actual underwater observations, it was found that under certain voltages, some fin-fish appeared to sense and avoid the mouth of the trawl and its electrical current to a certain degree. The drawbacks to this gear, however, are its initial expense and operating costs, the dangers involved with the electrical currents aboard ship, and the general unreliability of the system under varying circumstances. For more detail see Watson, 1976.

A more conventional alternative would be to consider, under certain circumstances, proposing seasonal or area closures. The Fishery Conservation Zone off the Texas coast was closed to shrimp trawling from 22 May to 15 July 1981 to provide shrimp with an extended growing period. It was anticipated that the shrimp would grow larger prior to harvest and thus bring a better market price.

Watts and Pellegrin (1982), to evaluate impacts of the Texas closure period, conducted a series of investigations ranging from shrimp population dynamics to shrimp economics. The analyses supported a hypothesis of increased shrimp catches due to the closure. Fin-fish catch rates and compositions were not, however, shown to change as a result of the closure.

Many variables including climatic changes, river run-off and subsequent flooding, storms and/or hurricanes could render such efforts a total loss overnight. Many feel, for these reasons, the need to harvest the catch "as is" in order to avoid risk. Hopefully, more subsequent data in such cases, as well as seasonally overlaps such as the case of shrimping near sea turtle nesting beaches during their migrations, will prove the value of such actions.

An alternative with some promise which needs further research involves the use of underwater sound. Certain underwater sounds may induce escape reactions in fish, but leave shrimp vulnerable to capture (Sternin and Allsop, 1982). Other sounds simulating feeding, etc., could be used to congregate fish as well. A literature search by this author several years ago to determine if there were any sounds capable of being transmitted in association with shrimp trawls to drive away sea turtles proved futile.

Reduction of the length of trawl towing times, while not directly effective in reducing fin-fish by-catch, has been utilized effectively in areas of incidental capture and resultant mortality of sea turtles. A study conducted by NMFS observers on various Gulf and South Atlantic cooperative shrimp vessels, indicates that the percentage of captured turtles which are brought on deck in a comatose state, increase rapidly with increases in towing time. Thirty-three percent of turtles captured during tows of 60 minutes were comatose, fifty percent in tows of 90 minutes, and up to 88.9 percent at tows of 270 minutes in length (Seidel, in preparation). Coinciding with this study were efforts at establishing the best techniques for revival of comatose turtles which, if thrown over the side of the vessel in this state would certainly prove fatal.

Two more possibilities proposed by this author for consideration, would each appear to be readily sensed by the lateral lines of most fin-fish which are used to detect approaching objects by pressure changes in the surrounding medium.

A simple false tickler chain or bottom sweep stretched across the trawl's path from the otter doors or preferably farther up the warps would stir up most all organisms. The fish would be alerted to the trawl's approach and would be more apt to swim out of its path. The shrimp would simply rise off the bottom into the trawl's path.

The second technique would involve the attachment of a perforated hose across the footrope or ahead of it. A top side compressor could pump compressed air through the hose, thus forming a bubble screen barrier for visual, as well as pressure sensitive stimuli to organisms in the trawl's path. Both techniques share the possible hazard of being snagged, broken and rendered useless during a tow, but could possibly be refined through further observations and testing.

Caddy (1982) recommends several additional areas of by-catch considerations in the management of shrimp fisheries in the Western Central Atlantic Fishery Commission region.

They include further utilization of existing by-catch and a better understanding of by-catch population dynamics, mesh selection studies for optimem yields, and the improvement of selector trawls.

V. A SUCCESS STORY - THE TRAWLING EFFICIENCY DEVICE

Worldwide, sea turtles are being taken incidentally to commercial fishing operations directed for other species. In the United States, incidental catch occurs primarily along the Southeastern and Gulf coasts. The shrimp trawls (demersal otter trawls) are the most frequently involved type of gear. Turtles can not swim fast enough to escape and often drown because the trawls may be kept under water for several hours at a time.

Trawlers have been reported to catch up to 25 yearling or adult turtles per day during the period of May to August, in certain areas primarily off the Georgia coast. Incidental turtle captures have also been reported throughout the Gulf of Mexico. The U. S. commercial shrimp fishery concentrates fishing effort during the opening weeks of the shrimp season which apparently coincides with peak sea turtle nestings of the loggerhead sea turtle (Caretta caretta). The turtles captured are not all nesting loggerheads, however, there is an overall abundance of loggerheads during this period.

The next most frequently caught turtles according to Chavez (1969), are the Atlantic ridleys (Lepidochelys Kempii); the green (Chelonia mydas); and the leatherback (Dermochelys coriacea) sea turtles. The Atlantic ridley, the leatherback, and the hawksbill (Euretumechelys imbricata) have been placed on the endangered species list while the green, loggerhead, and Pacific ridley (Lepidochelys ollivacea) have been placed on the threatened species list.

Recent investigations by NMFS during the 1978-80 fishing seasons on the U.S. east coast determined that the sea turtle catch rate per 100 feet of trawl headrope was 0.045 per towing hour, and the mortality rate for an average 150-minute tow was 19 percent.

The Southeast Fisheries Center (SEFC) of the NMFS initiated a gear development project to attempt to significantly reduce capture and resultant mortality of sea turtles in shrimp trawls in an effort to mediate the problem, insure the viability of shrimp industry activities and protect these threatened and endangered sea turtles. The SEFC's Harvesting Technology Branch of the Mississippi Laboratories in Pascagoula, Mississippi, was assigned the task of developing a shrimp trawl for the commercial shrimp industry that would reduce sea turtle captures with a minimal amount of shrimp loss.

Scuba diver scientists used techniques similar to those described by Wickham and Watson (1976) to evaluate towing characteristics of over 100 different trawling configurations to select a trawl capable of being adapted for the purpose of excluding turtles. After numerous designs were evaluated, a product referred to initially as the "turtle excluder device"

(TED) was developed. The device is a 4 X 3 X 3 foot frame constructed of 3/8 inch galvanized conduit-like pipe with bars slanting at approximately 45°, spaced 3 to 6 inches apart, with a 3 foot square door or escape hatch. The TED is placed inside the trawl at the intersection of the trawl body and the codend or bag (figure 7). As a turtle or other large object enters the device, it strikes the slanted bars and exits through the hinged door.

The device originally called the Turtle excluder device has been renamed the "trawling efficiency device" due to resultant modifications rendering benefits to shrimping beyond sea turtle conservation. Modifications included a webbing funnel inserted just ahead of the TED to accelerate water flow through the device, thus preventing shrimp loss through the door or hatch. Another change was the elimination of some webbing on the device forward of the funnel, thus allowing fin-fish to swim out and excape.

Testing of the TED was conducted on cooperative and chartered commercial shrimp vessels. The major objectives of the tests were to determine the effectiveness of the TED in 1) reducing turtle capture, 2) maintaining equal shrimp catch rates compared to standard shrimp trawls towed simultaneously, and 3) determine the effectiveness of TED in reducing by-catch. Tests have proven the TED valuable in improving trawling efficiency and in cutting down the by-catch level of many marine organisms including cannonball jellyfish, turtles, sharks, skates, rays, horseshoe crabs, loggerhead sponges and assorted fin-fish.

The TED benefits from such exclusions by not having to be emptied as frequently, allowing longer tows with reduced drag, decreasing sorting time by crew of potentially hazardous marine organisms, and a possible fuel savings as well. Test data indicate a possible increase of shrimp catches by 7 percent when a TED is installed.

The separation ability of the TED towards fin-fish varies by species. Strong fast swimming species have an escape rate of nearly 100 percent while others may have more difficulty. Possible by-catch reductions of 70 percent should be possible during daylight hours with a drop to less than 50 percent at night.

Because by-catch reduction of fin-fish is so important to both Gulf shrimpers and other fishermen, current development studies are being directed toward increasing the TED screening capabilities.

International interest in the TED was recently found at an International Sea Turtle Symposium in San Jose, Costa Rica, Several foreign governments expressed interest in TED's both for the conservation of sea turtles, as well as for by-catch reduction. Mexico, the Netherlands, Malaysia, Australia, Honduras and South Africa have all sought further information and possible demonstrations. Indonesia has actually implemented the use of TED's by the Japanese fleet in Indonesian waters to avoid a total closure of the area due to a growing concern over the depletion of fin-fish resources.

Hopefully, this paper has demonstrated a need to recognize and rationally address the problem of incidentally captured by-catch and discards. Social pressures are increasing in our protein-deficient world to use the by-catch for food or reduce its magnitude by means of selective fishing gear. It has been stated that "The wastage in throwing back fish into the sea should be seen as no worse than the underutilization of some stocks, or the overfishing of others."[15] I must reply that a lack of response to the issue today, could lead to a disasterous fishery resource denouement.

TABLES

FIGURES

THE SPECIAL PROBLEMS OF PORPOISE AND

BILLFISH CONSERVATION

TABLE I

Estimated Porpoise kills by vessels of all flags in the Eastern Pacific Ocean, 1959-77 (Thousands of animals).

YEAR	TOTAL
1959	109
1960	853
1961	713
1962	169
1963	213
1964	407
1965	475
1966	449
1967	311
1968	262
1969	529
1970	492
1971	315
1972	338
1973	194
1974	115
1975	171
1976	134
1977	23

BY-CATCH SAMPLE AND SPECIES LIST

TABLE 2

VESSEL	SIDE	STA. NUMBER	TOTAL LIVE CATCH	TOTAL SHRIMP CATCH

FINFISH CATCH	OTHERS	SAMPLE WT.	SELECTED SPECIES

SPECIES	SAMPLE NO.	SAMPLE WT.	SELECTED SPECIES NO.	SELECTED SPECIES WT.
Anchoa				
Arius felis				
Bothidae				
Brevoortia tyrannus				
Chaetodipterus faber				
Chloroscombrus chrysurus				
Chondrichthyes				
Cynoscion spp.				
Larimus fasciatus				
Leiostomus xanthurus				
Lutjanus campechanus				
Menticirrhus spp.				
Micropogon undulatus				
Opisthonema oglinum				
Paralichthys spp.				
Peprilus paru				
Peprilus triacanthus				
Pomatomus saltatrix				
Prionotus spp.				
Scomberomorus cavalla				
Scomberomorus maculatus				
Scorpaenidae				
Soleidae				
Sphyraena guachancho				
Stellifer lanceolatus				
Symphurus spp.				
Synodus spp.				
Trichiurus lepturus				
Urophycis spp.				
Rajiformes				
Anomura				
Arenaeus cribrarius				
Brachyura				
Callinectes spp.				
Limulus polyphemus				
Ovalipes spp.				
Penaeus aztecus				
Penaeus duorarum				
Penaeus setiferus				
Portunus spp.				
Squilla spp.				
Sicyonia spp.				
Cephalopoda				
Cnidaria				
Echinodermata				
Gastropoda				

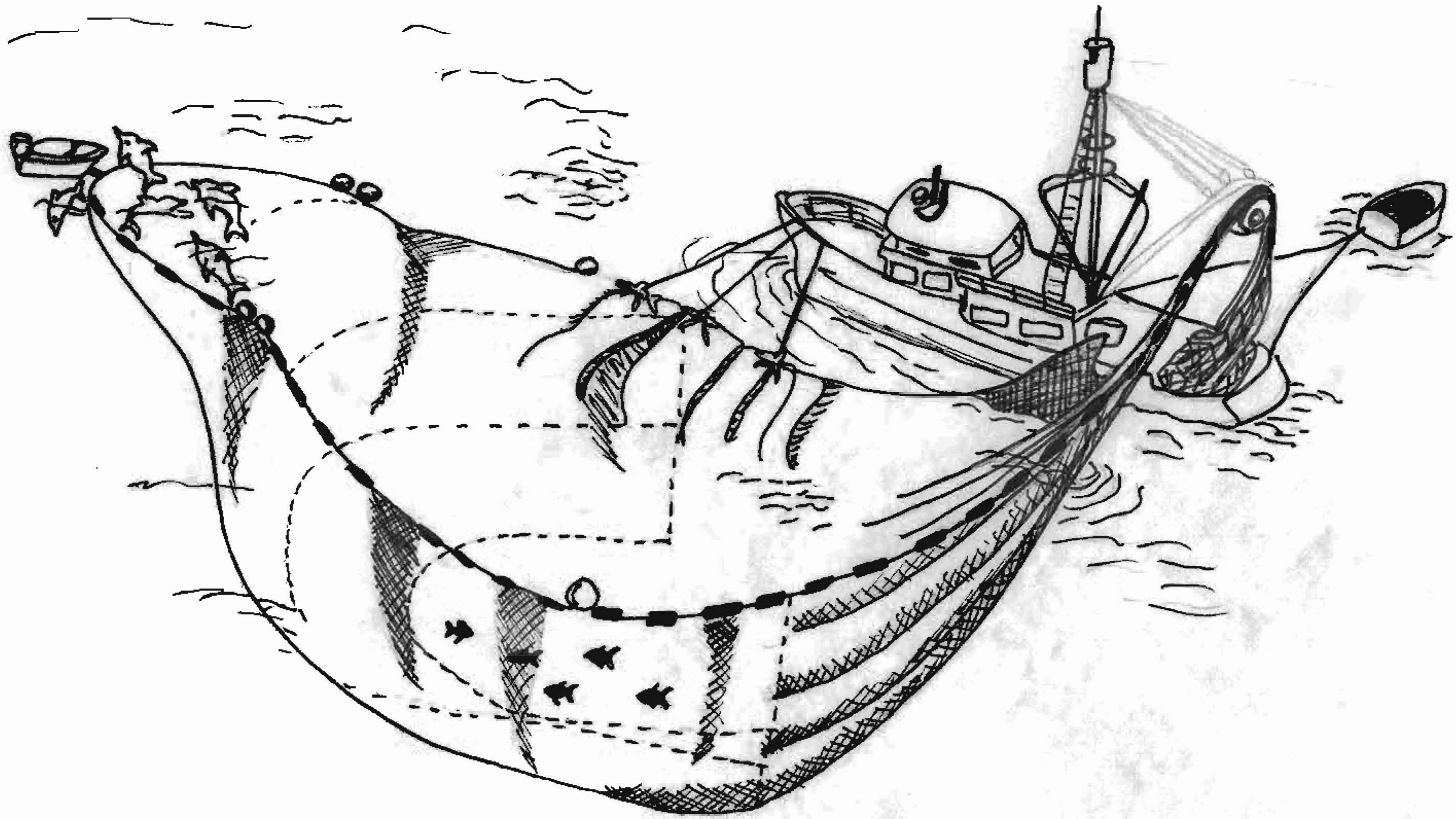


Figure 1. PURSE SEINING OPERATIONS

Figure 2. LONGLINE GEAR

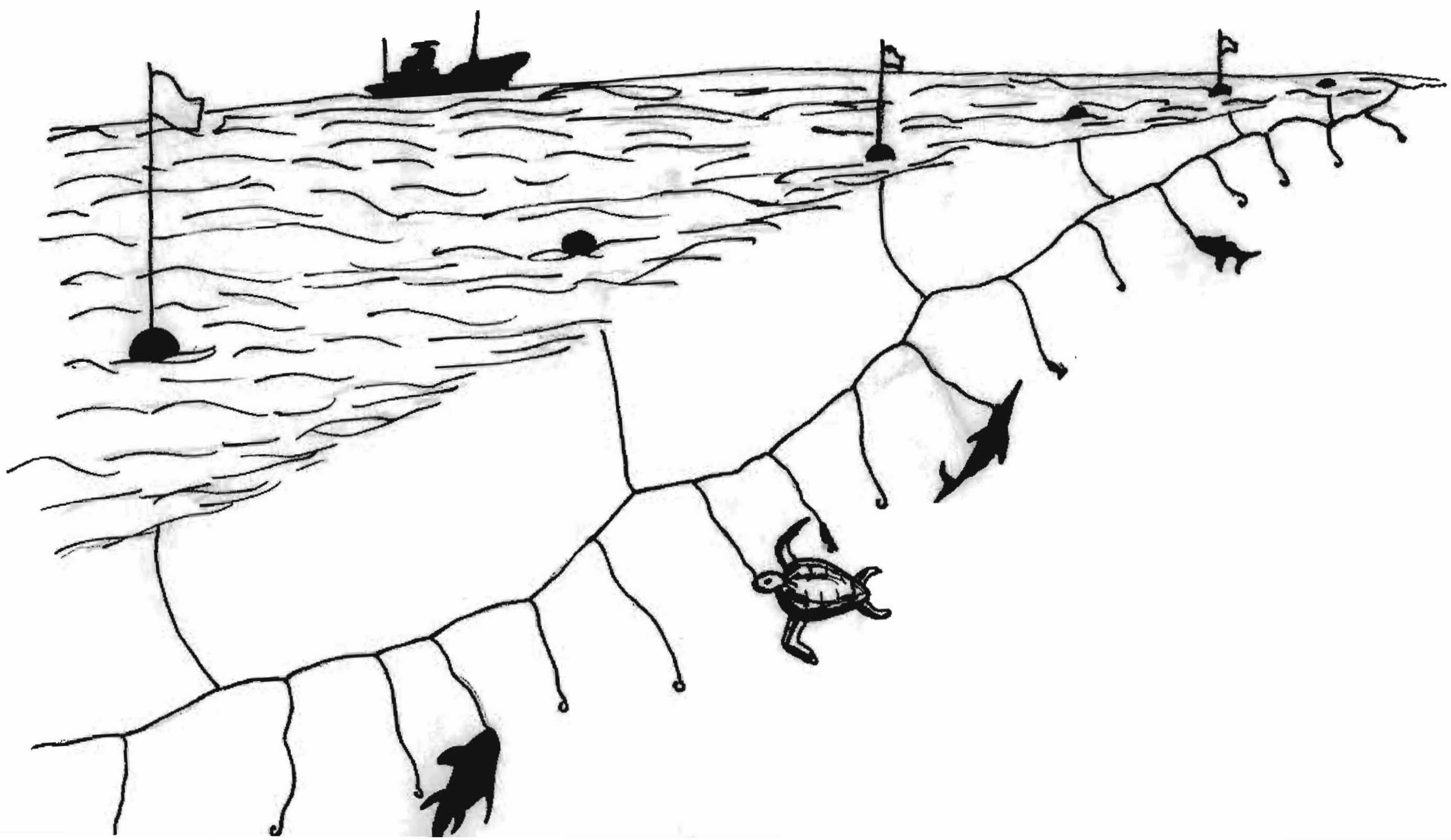


Figure 4. POTS

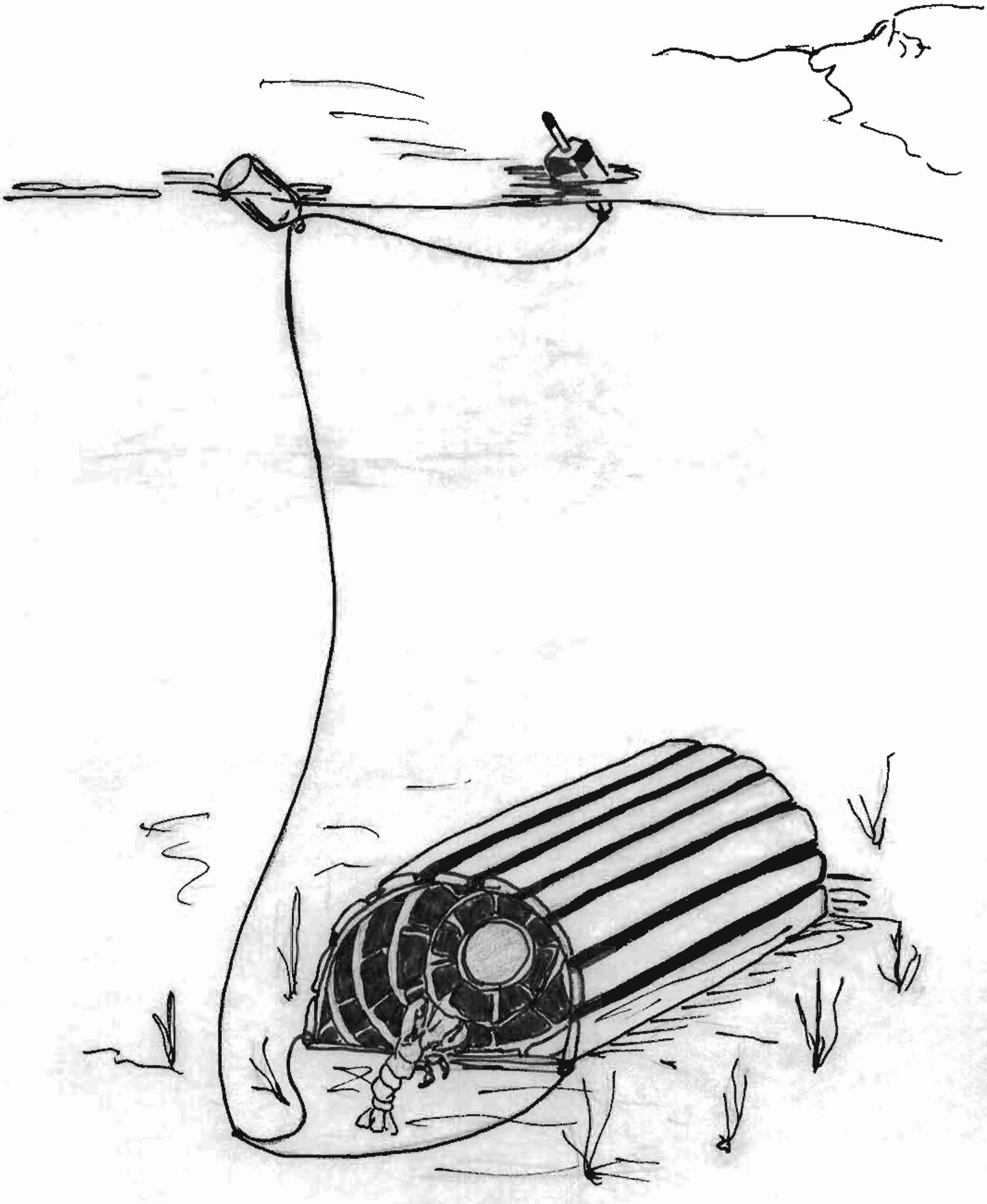
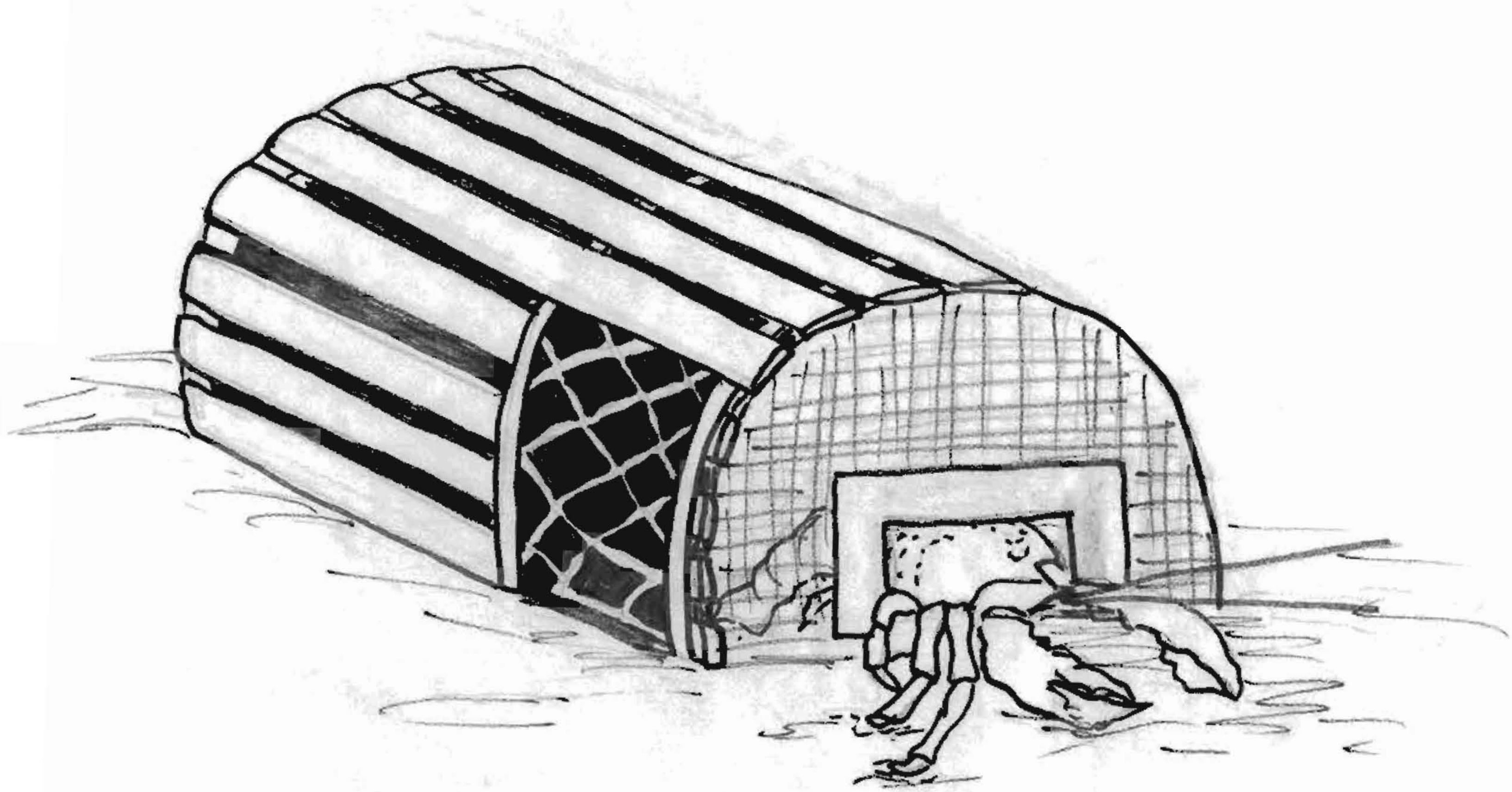


Figure 5. LOBSTER POT WITH AN ESCAPE VENT



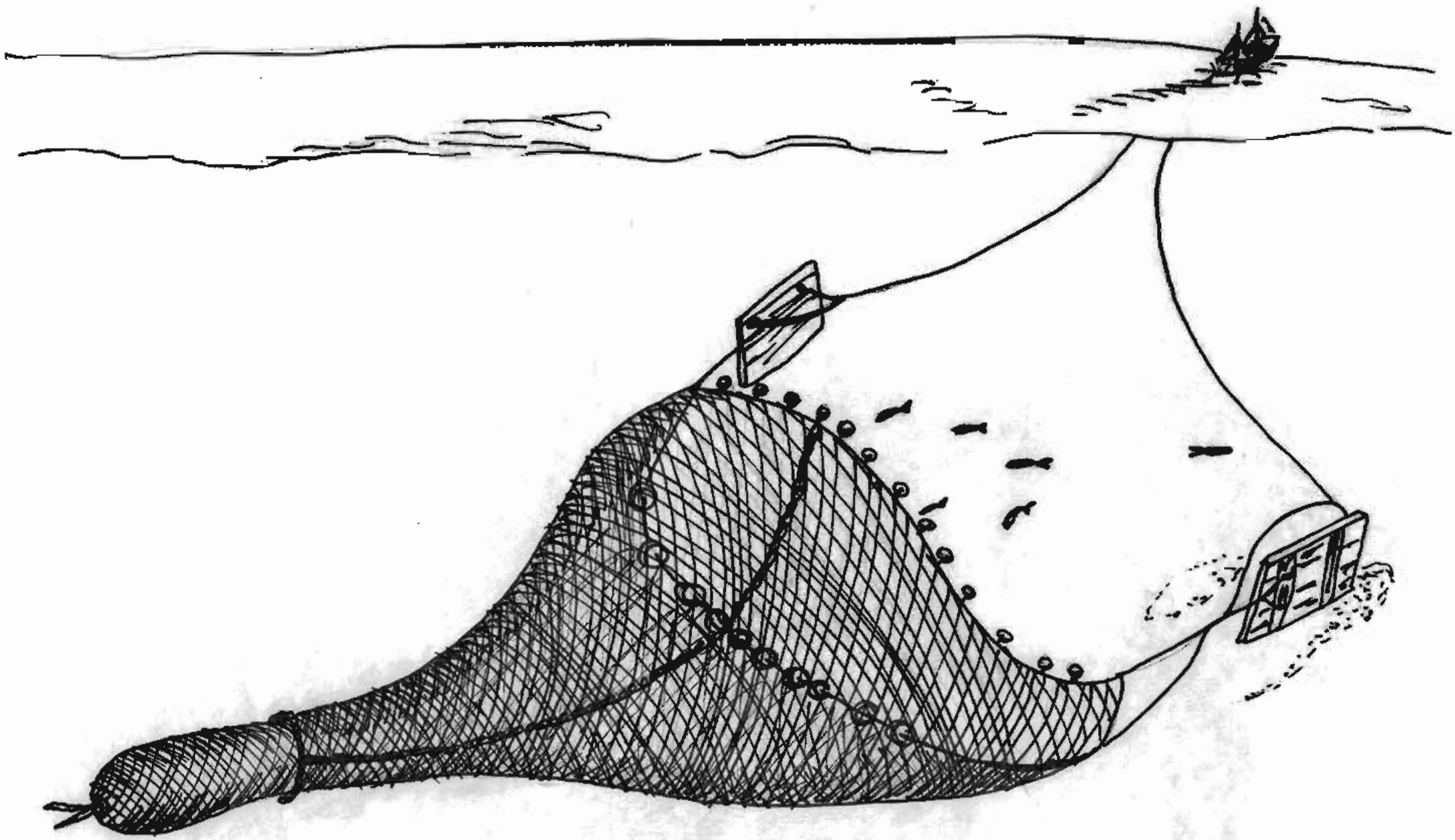
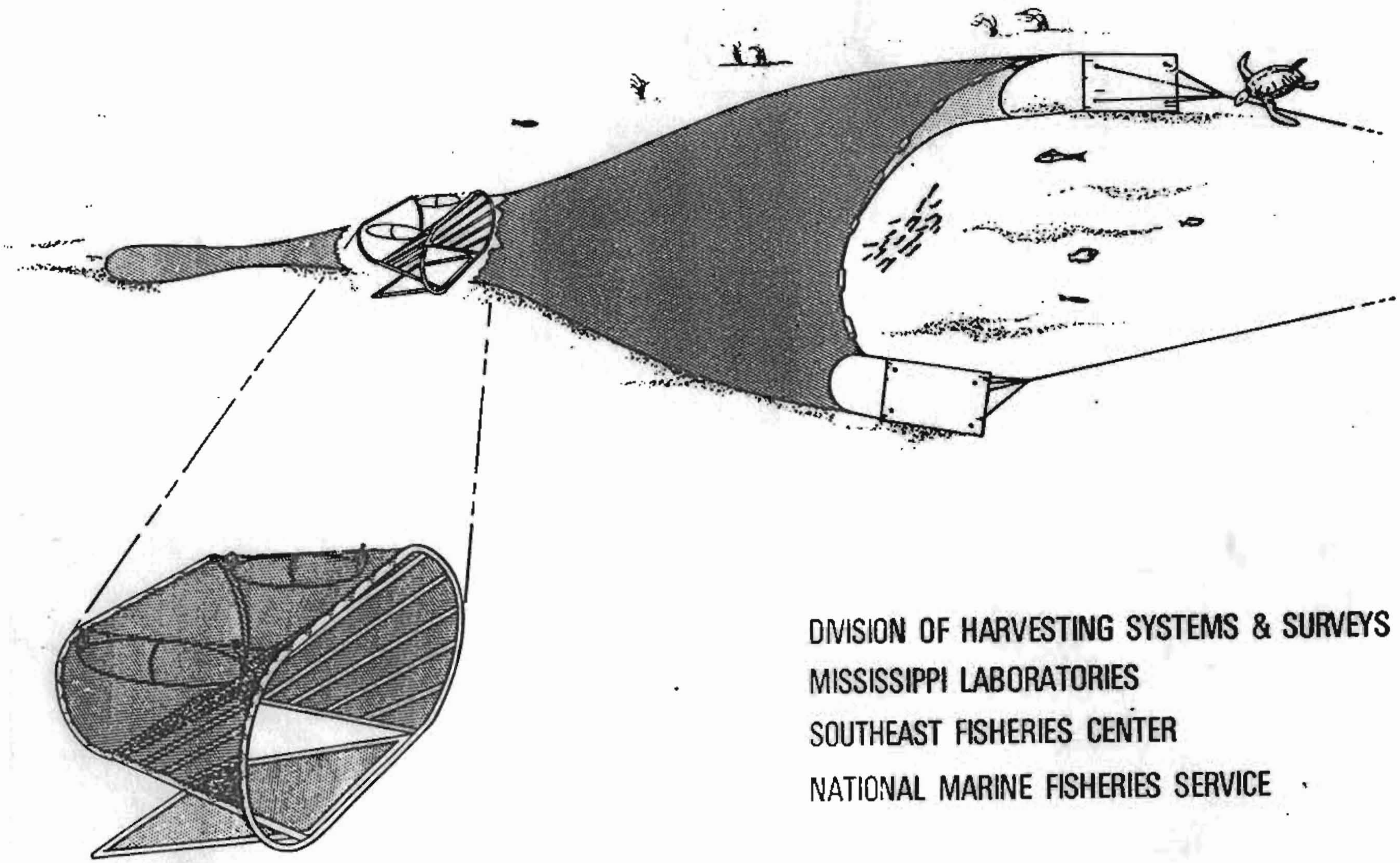


Figure 6. OTTER TRAWL

SEA TURTLE "EXCLUDER" DEVICE
BOTTOM - OPENING DESIGN



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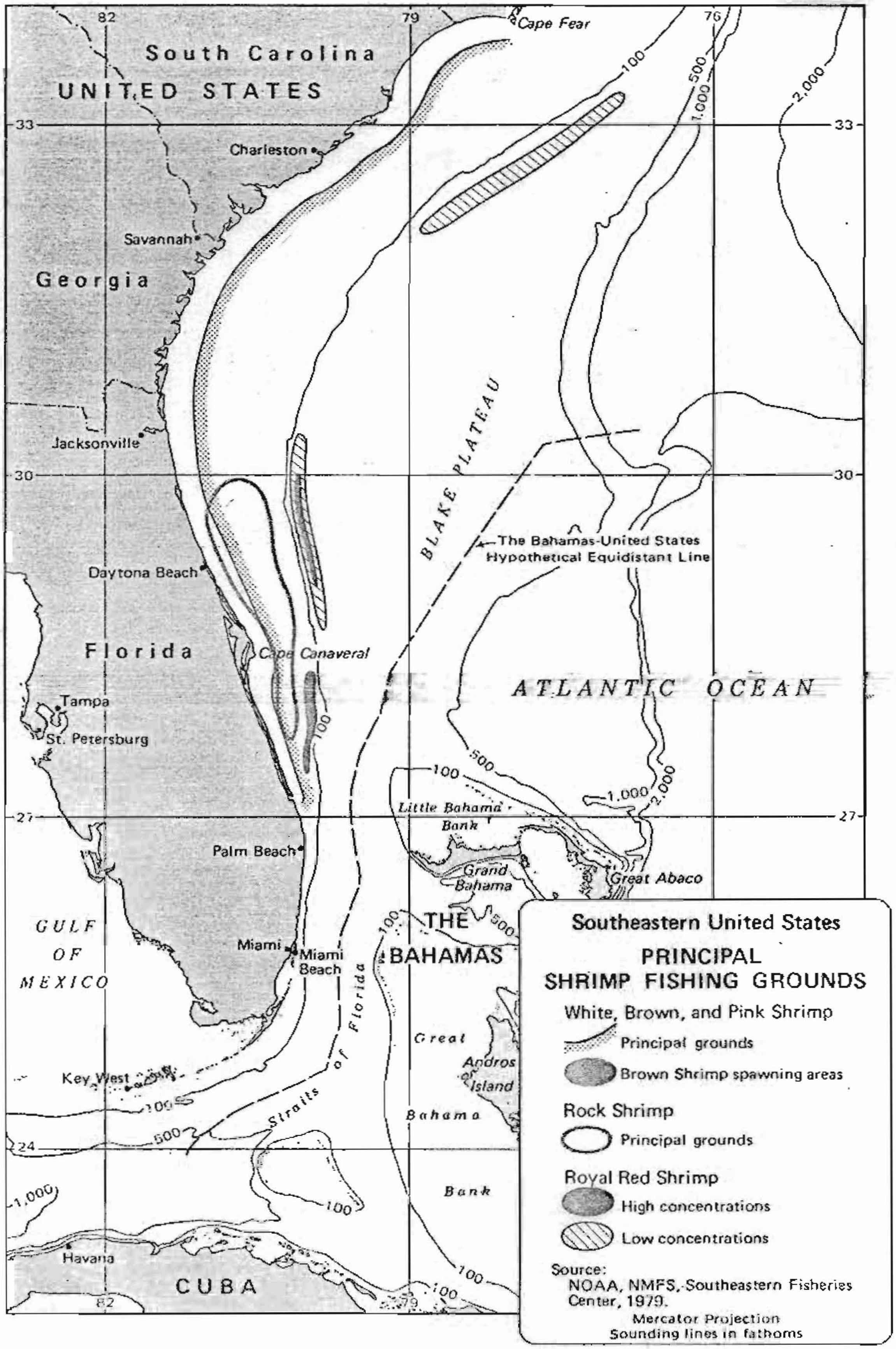
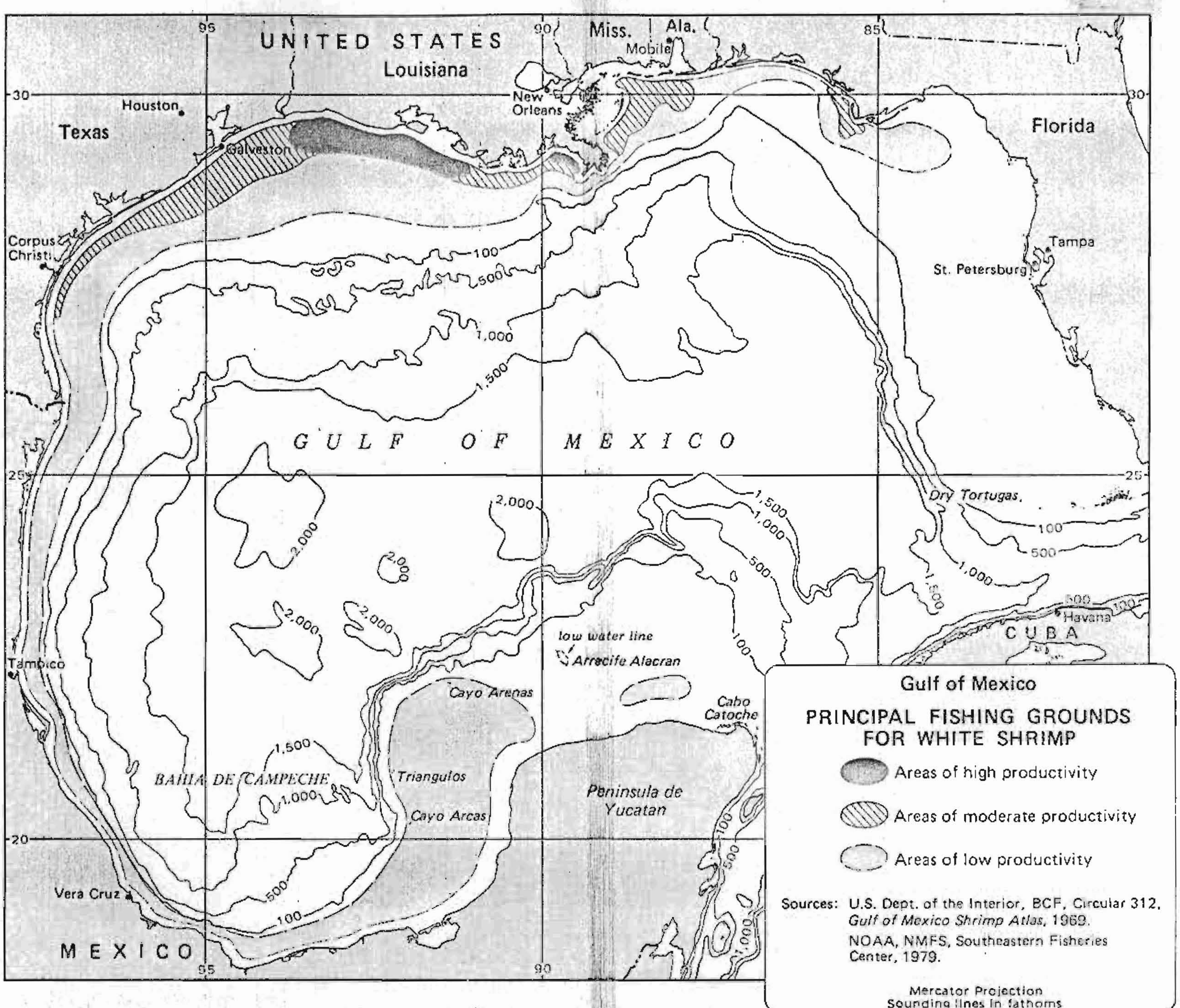
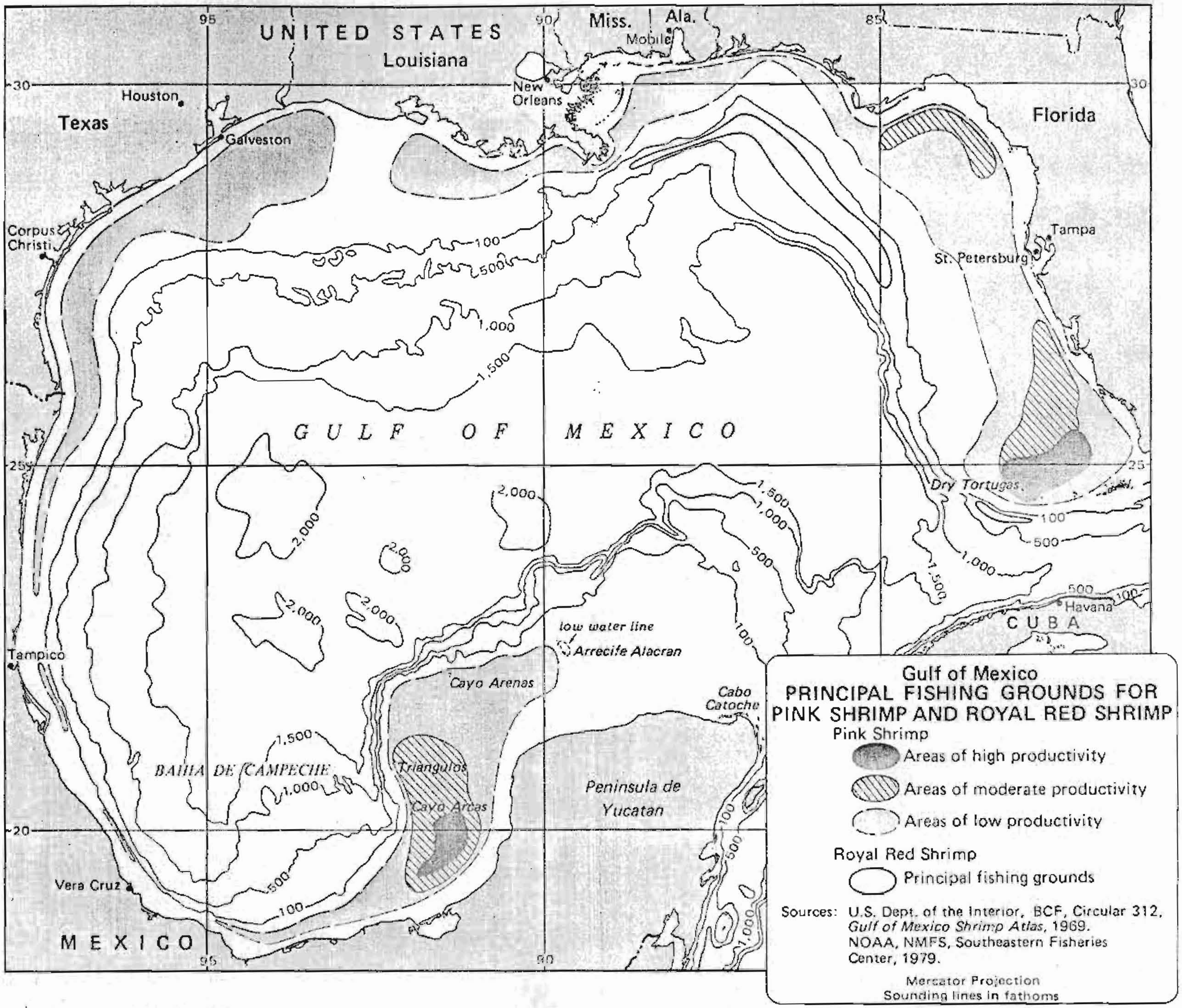
MISSISSIPPI LABORATORIES
SOUTHEAST FISHERIES CENTER
NATIONAL MARINE FISHERIES SERVICE

Figure 7. TRAWLING EFFICIENCY DEVICE


South Carolina
UNITED STATES
Cape Fear
Charleston
Savannah
Georgia
Jacksonville
Daytona Beach
Florida
Cape Canaveral
Tampa
St. Petersburg
Palm Beach
Miami
Miami Beach
Key West
Havana
CUBA
GULF OF MEXICO
BLAKE PLATEAU
The Bahamas-United States Hypothetical Equidistant Line
ATLANTIC OCEAN
Little Bahama Bank
Grand Bahama
Great Abaco
THE BAHAMAS
Great Bahama Bank
Andros Island
Straits of Florida
Southeastern United States
PRINCIPAL SHRIMP FISHING GROUNDS
White, Brown, and Pink Shrimp
Principal grounds
Brown Shrimp spawning areas
Rock Shrimp
Principal grounds
Royal Red Shrimp
High concentrations
Low concentrations
Source:
NOAA, NMFS, Southeastern Fisheries Center, 1979.
Mercator Projection
Sounding lines in fathoms


UNITED STATES
Louisiana
Miss.
Ala.
Mobile
Texas
Houston
Galveston
New Orleans
Florida
Tampa
St. Petersburg
Corpus Christi
GULF OF MEXICO
Dry Tortugas
Havana
CUBA
Tampico
Vera Cruz
MEXICO
low water line
Arrecife Alacran
Cayo Arenas
Cabo Catoche
Triangulos
Cayo Arcas
BAHIA DE CAMPECHE
Peninsula de Yucatan
100
500
1,000
1,500
2,000
95
90
85
30
25
20
Gulf of Mexico
PRINCIPAL FISHING GROUNDS FOR WHITE SHRIMP
Areas of high productivity
Areas of moderate productivity
Areas of low productivity
Sources: U.S. Dept. of the Interior, BCF, Circular 312, Gulf of Mexico Shrimp Atlas, 1969.
NOAA, NMFS, Southeastern Fisheries Center, 1979.
Mercator Projection
Sounding lines in fathoms


UNITED STATES
Louisiana
Miss.
Ala.
Mobile
New Orleans
Houston
Texas
Galveston
Corpus Christi
Florida
Tampa
St. Petersburg
Dry Tortugas
Havana
CUBA
Tampico
Vera Cruz
MEXICO
GULF OF MEXICO
BAHIA DE CAMPECHE
Triangulos
Cayo Arcas
Cayo Arenas
low water line
Arrecife Alacran
Cabo Catoche
Peninsula de Yucatan
95
90
85
30
25
20
100
500
1,000
1,500
2,000
Gulf of Mexico
PRINCIPAL FISHING GROUNDS FOR PINK SHRIMP AND ROYAL RED SHRIMP
Pink Shrimp
Areas of high productivity
Areas of moderate productivity
Areas of low productivity
Royal Red Shrimp
Principal fishing grounds
Sources: U.S. Dept. of the Interior, BCF, Circular 312, Gulf of Mexico Shrimp Atlas, 1969. NOAA, NMFS, Southeastern Fisheries Center, 1979.
Mercator Projection
Sounding lines in fathoms

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NOTES

1. The Magnuson Fishery Conservation and Management Act defines a "fishery" as: a) one or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; and b) any fishing for such stocks. MAGNUSON ACT sec. 3(7), 16 U.S.C. Sec. 1802 (7) (1976).
2. U.S.D.O.C.-NOAA-NMFS "Fisheries of the United States, 1982" Current Fishery Statistics No. 8300, April, 1983.
3. F.A.O. "Agriculture Toward 2000".
4. Joseph, James and Greenough, Joseph International Management of Tuna, Porpoise, and Billfish p. 139-142.
5. Ibid., p. 141-142.
6. Ibid., p. 143.
7. Shyam, p. 51
8. Saila, p. 8.
9. Webster's Dictionary
10. Boxer, Baruch; "Mediterranean Pollution: Problem and Response," Ocean Development and International Law Journal, Vol. 10, No. 3/4 (1982) p. 354.
11. Note, supra note 2, at V.
12. Watson, et al, p. 1.
13. Pellegrin, 1982, p. 51.
14. Saila, supra note 8, at 14.
15. Saila, supra note 8, at 13.

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