THE TUNA-PORPOISE PROBLEM:

MANAGEMENT ASPECTS OF A FISHERY

by

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Internship Report

Submitted to

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School of Oceanography
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Master of Science

Internship: M/V Sea Treasure pilot/observer
tuna fishery
San Diego, California

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I. Introduction

In my application to the Marine Resource Management program I stated that it was my intention to forge a new career by combining my training and experience as a Naval officer with an education in marine science. As my education at Oregon State progressed through the first year and I began to consider internship alternatives, I defined my internship objectives with that goal in mind. As a result of my coursework, countless discussions on the nature of resource management, and much deliberation, it became clear to me that as a nascent manager of marine resources I would benefit most from an internship which required me to become as knowledgeable as possible with the use and the users of a specific marine resource. It was important to attempt to clarify and enlarge my appreciation and understanding of the problems and perspectives of those whose livelihood depends on utilizing the resources I am learning to manage. It was also my objective to accomplish this in a way that challenged my ability to adapt and to learn. From my internship experience in a specific area of marine resource use I hoped to distill a body of general principles which I could apply to my later work.

As so often happens, opportunity finally knocked - but unexpectedly, and at the back door. I learned of an aviation company in Albany, Oregon, which trains ex-military pilots and places then in civilian positions. I completed the program and secured a position with Aerial Spotters, Incorporated, a firm which contracts with the tuna purse seine industry to provide onboard aerial fish spotting service. My job was to fly an observation helicopter for M/V Sea Treasure, a 1200 ton net capacity seiner homeported in San Diego.

At last I was able to define my internship project. My initial objectives were to:

1. Become a competent shipboard helicopter pilot and fish spotter;

2. Participate in the livelihood of the commercial fisherman, and specifically to observe the relevant impacts of resource management actions, if any;

3. Learn the techniques of tuna purse seining, with particular reference to the tuna/porpoise interaction, and

4. Develop estimates of porpoise mortality associated with purse seining on a vessel unencumbered with a government observer, and to compare this information with government estimates.

This report summarizes my internship experience and focuses on the problem of the mortality of porpoise taken incidentally in fishing for yellowfin tuna, *Thunnus albacares*. The following sections describe the tuna resource, problems associated with its management, and my experiences and observations within the context of the problem.

II. The tuna resource and related management problems

Tuna has been fished in significant quantities in the eastern tropical Pacific Ocean since around 1920. The primary target species are yellowfin, Thunnus albacares, and skipjack, Katsuwonus pelamis. Although the total catch of tuna varies from year to year, it has steadily increased. In 1979, for example, a total of 370,478 short tons were taken from the eastern tropical Pacific Ocean; this catch represents the efforts of 17 nations and approximately 367 vessels (Pacific Packers Report, 1980).

The United States has historically been a leader in the tuna industry. Last year, the United States fleet of 140 boats captured 224,752 tons, or 60.7 percent, of the total eastern tropical Pacific harvest. Of the U.S. catch, 131,760 tons, or 58 percent, were yellowfin. At $1200 and $1100 per ton for yellowfin and skipjack, respectively, the U.S. catch in 1979 was worth $247 million to the fishermen and about $1.3 billion in retail trade (Pacific Packers Report, 1979).

Thus tuna is an ocean resource of significant economic importance. However, the tuna fishery is beset with a number of management problems which are becoming increasingly acute. The yellowfin resource in particular is in immediate danger of overexploitation. The imminent potential for overfishing resulted in a system of quota management by the Inter-American Tropical Tuna Commission (IATTC). This quota system has subsequently become the point of contention of several nations who feel entitled to more equitable (i.e. larger) allocations of the resource. The disagreement is now so serious that the future of the IATTC as a viable management entity is in doubt. Last, but by no means least, yellowfin are found in association with porpoise, for reasons not clearly known, and the mortality of porpoise taken incidentally in fishing for yellowfin is a major management problem. To set the scene for my internship experience, these management problems are outlined below.

Overfishing

Prior to 1958, the greatest fraction of the tuna catch in the eastern tropical Pacific was taken by bait-boats, which vessels are equipped with poles lines, and baited hooks. Subsequent to 1958, purse-seiners, those vessels which capture tuna by setting a seine net around an entire school of tuna, began to capture an increasingly larger share of the total yellowfin catch (Alverson, 1963). This section will briefly review the effect of this change in fishing technique on the abundance of yellowfin tuna. Of particular importance is the quantification of catch per standard day fishing, the index by which yellowfin abundance is estimated. The increasing efficiency of purse-seine vessels, which affects the validity of catch per unit effort data as an index of relative abundance, will also be examined.

The few purse-seiners which operated prior to 1958 were generally small (no greater than 200 tons net carrying capacity) and of little consequence to the fishery. However, three developments caused purse-seiners to assume a significant role in the yellowfin fishery: nets were woven of nylon twine, resulting in quicker sinking and longer net life; Puretic power blocks were installed, greatly reducing the time required to retrieve the net, and improved fish-carrying holds were installed (Broadhead, 1962). Additionally, after 1960 many of the larger bait-boats were converted for purse-seine fishing.

Over the years, improvements made in fishing techniques have increased fishing efficiency. Net dimensions were increased in both length and depth. The time required to complete a set decreased, allowing more sets to be made each fishing day. Aircraft, both land-based fixed wing and, recently, ship-based rotary wing, greatly increased the ability of the crew to spot fish.

Due to larger boats, better equipment, and improved fishing techniques, the amount of fish caught per unit fishing effort (CPUE) changed. Since CPUE data are used as an index of yellowfin abundance, it became necessary for the IATTC to revise its measure of CPUE in order to continue to effectively manage near-shore stocks of yellowfin tuna (Broadhead, 1962). Otherwise, estimates of yellowfin populations would be artifically high.

It was found that as the abundance of yellowfin increased, the CPUE for purse-seiners increased at a much more repaid rate than did the CPUE for bait-boats. For the period 1959-1960, the relationship between the two was

$$Y = 1.08X^{0.516}$$

where Y is CPUE for bait-boats and X is CPUE for purse seiners (Broadhead, 1962). This conversion factor gave results which were well within the range of experimental error. It was therefore possible to convert data taken from purse-seiners into indices of abundance which were comparable to indices derived from data taken from bait-boats (Figure 1).

Continuing refinements in equipment and techniques resulted in further increases in fishing efficiency. The four factors were greater vessel speed, increased probability of capturing sighted tuna schools, further reduction in time required to complete a set, and greater portions of schools caught per set. A revised model for computing yellowfin abundance was presented by Pella and Psaropulos (1975). It predicts expected changes in fishing success due to changes in the efficiency of searching and setting operations. The model can also be used to convert catch per standard fishing day (CPSDF) to an index of population biomass, $\hat{\gamma}$, which is unaffected by changes in fishing efficiency. The yellowfin biomass index computed from the revised model compares reasonably well with catch per day indices used historically by the IATTC (Pella and Psaropulos, 1975). Average annual biomass of yellowfin was greatest in 1960, prior to the major impact made by purse-seining; biomass declined rapidly until 1962 and remained at reduced levels until 1966. Another peak was attained in 1968, followed by declining levels until 1971 (Figure 2).

The recomputation of catch per standard day fishing (CPSDF) and of yellowfin biomass has allowed the IATTC to observe fishing trends over a relatively long period of time. Over the years, CPSDF has fairly closely followed trends in abundance (Figure 3). Data for catches over the last 10 years indicate that the fleet is probably overfishing the stock. This is evidenced by recent fishing effort for Class 3 (101-200 tons carrying capacity) and Class 6 (401 or more tons carrying capacity) vessels (Figure 4).

It is apparent that the shift in fishing effort from bait-boats to purse-seiners has had a significant impact on the stock of yellowfin tuna in the eastern tropical Pacific Ocean. The increasing fishing efficiency of the purse-seiners over the years has contributed to an observed decline in CPUE and therefore in stock levels. Further reduction in abundance will necessitate additional regulatory actions by the IATTC in order to preserve the stock from irreversible depletion.

Allocation

In a world faced with increasing demands on a fixed or diminishing supply of fisheries resources, fisheries management bodies are being sorely taxed in their efforts to devise equitable management plans. The IATTC is in just such a position. Pressure is being applied by developing countries bordering the eastern tropical Pacific Ocean to acquire a larger share of the yellowfin resource than they have historically received. The larger, developed countries with technologically advanced fishing fleets disagree; these nations feel that yellowfin tuna, as a highly migratory species, cannot be effectively managed by national jurisdictions. They further feel that yellowfin tuna, as a common property resource, is available to anyone with the capability to harvest it (Joseph, 1977).

The total annual catch of yellowfin tuna in the eastern tropical Pacific has remained roughly constant for the 1973-1978 period at 175 to 200 thousand tons (Figure 4). A constant harvest level indicates, at least superfically, that the fish stock is in a state of dynamic equilibrium. However, several measures of population dynamics suggest that yellowfin tuna is being overfished. Catch per unit effort has steadily declined, recruitment has become markedly more variable than was historically the case prior to purse seine fishing, and the average size of yellowfin caught has steadily decreased (IATTC, 1979). Continued close monitoring of the yellowfin catch will continue while additional data are acquired with which to make more accurate and precise stock assessments. In any case, it is becoming acutely apparent that the yellowfin resource is not an unlimited resource.

It became evident in 1960 that the yellowfin resource needed regulating in order to prevent depletion (Bayliff, 1975). It was not until 1966, however, that regulations were agreed to by all members of the IATTC. In that year a quota of 79,300 short tons of yellowfin was established for the Commission Yellowfin Regulatory Area (CYRA)(Table 1).

In order to comply with the Convention governing the IATTC, which states that the objective of the Commission is to maintain the stocks "at a level which will permit maximum sustained catches year after year", the quotas have been raised annually since 1966 in an effort to quantify maximum sustained yield (Table 2). In 1978, the quota was set at 175 thousand short tons, with additional increments of 20 thousand and 15 thousand tons to be added at the discretion of the Director of Investigations.

Prior to 1968, the quota of yellowfin was available on a "first come, first serve" basis. However, beginning in 1969, considerations other than the biological limitations on the resource were used in allocating the quota (Table 1). Special allocations were set aside for small vessels, which form a larger fraction of the fleets of developing nations than of the fleets of developed nations (IATTC, 1979). Special allocations were also set aside for member and cooperating nations having tuna canneries and insignificant tuna catches. In 1971, special allocations were made for newly constructed vessels of developing member nations. Thus over the years the schedule of yellowfin allocations has increasingly reflected the political and economic desires of the member nations as well as the stated intent of the Commission to establish and maintain the maximum sustainable yield of tuna.

A fundamental problem in fishery resource allocation is the widespread and time-honored belief that fishery resources are common property. As such, fish are owned by no one and are therefore free for the taking. However, the recent trend in national and international law is toward the concept of resource ownership by nations (Joseph, 1977). There are several benefits that accrue to society by regarding resources as controlled property: first, it provides incentives for the creation and improvement of assets; second, it provides incentives for efficient control of existing assets, and third, it rations the use of scarce assets to ensure that they will be used for those purposes which society values most highly (Bjork, 1969).

This is the position taken by the developing nations which border the eastern tropical Pacific, defined as resource-adjacent nations (RAN) by

Joseph and Greenough (1979). Some of these nations, for example Costa Rica, have already declared ownership and jurisdiction of marine resources within a 200 nautical mile zone. Other nations will probably follow the lead of the United States, which established fisheries resources management authority (but not ownership) within a 200 mile zone in 1976 with the Fisheries Conservation and Management Act. The RANs believe that they have special rights to shares of a resource that spends part of its life in their coastal waters. In fact this is exactly the position of the United States with respect to all marine resources excepting highly migratory species, i.e. tuna. But however the differences regarding the biology and management of tuna as migratory species are resolved, the problem of equitable allocation remains.

Joseph (1977) foresees that management based on unrestricted access and free competition will not continue indefinitely. Coastal states will demand and probably will receive special consideration for access to resources off their coasts. However, a viable yellowfin management scheme must acknowledge the historical levels of fishing by non-RANs, even though their future effort will probably have to be reduced or shifted to other species.

One proposed strategy is the partially allocated quota (PAQ) system (Joseph and Greenough, 1979). Management would be based on open access across national boundaries. An international agency would establish quotas, issue permits, collect participant fees based on catch, redistribute fees among member nations, enforce regulations, control fleet size, and establish partial allocations of catch quotas to RANs.

Clearly, neither this nor similar schemes will find unqualified acceptance by all nations with an interest in harvesting yellowfin tuna. It is equally clear that the fundamental requirements for the success of any plan for management and allocation are the willingness of concerned nations to compromise and the commitment to abide by the agreed upon regulations. If these minimum requirements cannot be met, then no plan for allocation, however equitable, can succeed.

The tuna-porpoise controversy

Of all the management problems associated with tuna, the most explosive one for the U.S. tuna fishing industry has been the porpoise problem. As more purse seiners fished for yellowfin associated with porpoise and as the nets used became larger, the number of porpoise mortalities increased dramatically. By the late 1960s, the annual number of porpoise mortalities resulting from U.S. fishing activities was estimated at approximately 300 thousand (Fox, 1978).

At the same time porpoise mortality was increasing, environmental concerns were receiving substantial legislative attention. The Marine Mammal Protection Act (MMPA) took effect on October 21, 1972. As an effort to codify the desire of the people of the United States to reduce the needless loss of marine mammal life, it is commendable. However, the Act suffers from serious deficiencies in wording and in definition of terms. Some of these deficiencies have resulted in litigation between parties whose interpretations of the law have differed. It is illuminating to examine the problems that arise when a legislative body attempts to deal with a problem in resource management without paying sufficient attention to scientific principles.

The first major court test of the MMPA was Committee for Humane Legislation, Inc., vs. Richardson (Nafziger and Armstrong, 1977). On May 11, 1976, the court enjoined the further taking of porpoise incidental to tuna fishing. The decision was upheld on appeal.

Although the conservation approach of the Act is straightforward, the terms and definitions used in the Act are not. A moratorium of indefinite duration was placed on the taking or importation of all marine mammals, with four clearly specified exceptions. Before taking or killing a marine mammal under an exception, a permit which complies with applicable regulations must be issued. The Humane Legislation case was based on the taking of marine mammals incidental to commercial fishing.

The Act provides a two-part test to determine the number and kind of marine mammals that can be taken incidental to commercial fishing (Erdheim, 1979). The first test, the "disadvantage" test, requires the Secretary of Commerce to insure, and the permit applicant to demonstrate, that takings will not be to the disadvantage of the affected species and stocks. Every permit must specify the number and kind of marine mammals to be taken, and it must be consistent with any regulations formulated for the taking of marine mammals. The court found that regulations must be formulated prior to issuing a permit, although the Act itself requires only that the Secretary "prescribe such regulations...as he deems necessary and appropriate" (MMPA, 1972). Before issuing such regulations, however, the Secretary must publish and make available, inter alia, a statement of estimated population levels of concerned species and stocks, and a statement of the expected impact of the regulations on the optimum sustainable population (OSP) of each species and stock involved (MMPA, 1972).

It was the above requirement to publish a statement of the expected impacts on the optimum sustainable populations which was at the core of this court case (Nafziger and Armstrong, 1977). Optimum sustainable population is defined in the Act as "the number of animals which will result in the maximum productivity of the population or species, keeping in mind the optimum carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element" (MMPA, 1972). This definition is neither scientifically precise nor operationally useful, especially since "maximum productivity" is undefined. Also, the National Marine Fisheries Service (NMFS) had to admit that "optimum sustainable populations have not been determined; therefore, no statement can be made as to the effect of the proposed action on the optimum sustainable populations" (Federal Register, 1975).

A definition of optimum sustainable population was published by NMFS (1976) in which OSP "is a population size which falls within a range from the population level of a given species or stock which is the largest supportable within the ecosystem to the population level that results in maximum net productivity." This definition, however, has been the subject of criticism. For example, lawyers Nafziger and Armstrong (1977), who have a strong protectionist bias, suggest that the OSP level should be set "at the limit of the environment to sustain healthy populations indefinitely, and that does not adversely affect the ecosystem of which it is a part. A population defined in this way will normally be the largest sustainable population of the species in a given region." On the other hand, the tuna industry has argued that the range of values used by the NMFS to estimate OSP has led to quotas which are not technologically feasible (Erdheim, 1979).

The second part of the test to determine the number and kind of marine mammals that can be taken is the "immediate goal" test, which states that "it shall be the immediate goal that the incidental kill or incidental serious injury of marine mammals permitted in the course of commercial fishing operations be reduced to insignificant levels approaching a zero mortality and serious injury rate" (MMPA, 1972). As with "maximum productivity," "health of the ecosystem," and "optimum sustainable population," the exact meanings of "immediate goal" and "rate" are not clear in the Act. However, the legislative history of the Act indicates that the immediate goal test requires setting quotas that are technologically feasible, use of the best available porpoise-saving techniques and equipment, support for gear research, training for fishermen, and enforcing of regulations and quotas. This was to be done, however, without adverse economic effects to the tuna industry. The immediate goal test was affirmed in this form on March 30, 1977, by the district court in the case of Committee for Humane Legislation vs. Kreps, with the added proviso that "once the interests of the mammals are assured, the interests of the industry can be served" (Erdheim, 1979).

At hearings in 1976 and 1977, the immediate goal test was defined in various ways by the several interest groups. The tuna industry and Pacific Legal Foundation contended that since porpoise mortality was an insignificant fraction of the total population, the immediate goal test was satisfied. The Committee for Humane Legislation argued that the immediate goal test required an immediate quota of zero mortality. The Marine Mammal Commission advocated quotas based on a standard of technological feasibility. On November 4, 1977, the administrative law judge determined that the immediate goal test requires a best technology standard, although he failed to adequately define the standard of technological feasibility to be used in setting mortality quotas. On December 23, 1977, the Administrator of the National Oceanic and Atmospheric Administration published his decision. The zero quota was rejected as being economically and technologically infeasible. Industry arguments for higher quotas were rejected because the proposed quotas failed to fulfill the "immediate goal" test. The quotas proposed by NMFS were adopted (Federal Register, 1977).

The trouble continues, unfortunately. The original quota of porpoise mortalities for 1980 was set at 31,150 animals. However, subsequent estimates of the population level of the northern offshore spotted dolphin stock, Stenella attenuata, resulted in a recommendation by NMFS to prohibit fishing on yellowfin associated with this stock of porpoise. The American Tunaboat Association responded that to impose such a restriction would reduce the U.S. yellowfin catch by 50 percent (Miller, 1980a). If the catch of yellowfin were reduced by that amount, the loss to U.S. fishermen would amount to some $79 million.

An increasingly frequent response of the tuna industry to such problems is re-registration under foreign flags. The American Tunaboat Association recently announced that ten large seiners are to be transferred to Mexican registry; the transfer is directly attributable to what the tuna fishermen refer to as "the doomsday regulations" (Miller, 1980b). This brings to 37 the number of U.S. owned boats which over the past six years have been sold or re-registered to foreign interests. An additional 19 tuna boats are now being, or have been, constructed for foreign owners over the past six years (Hudson, 1980).

The Marine Mammal Protection Act may, in the long run, induce severely adverse economic impacts for the tuna fishery of the United States. The well-being of the porpoise populations may suffer as well, since no other nations have made such a visible commitment to marine mammal protection.

III. The Internship Experience

On May 8, 1979, I departed for Sun Valley, California, for a checkout in the Bell 47 helicopter which I would be piloting. My initial assignment was with the M/V Gold Coast, which left San Pedro on May 12. However, after five weeks of fishing and one helicopter crash I was transferred to the M/V Sea Treasure, where I was to remain until the completion of the fishing trip.

The M/V Sea Treasure is fairly representative of the modern day tuna purse seiner fleet. She is 206 feet long and 45 feet wide; her holds carry 1200 short tons of fish when fully loaded. The fuel tanks hold in excess of 100 thousand gallons of diesel fuel, so that the boat and crew of 17 can remain at sea for about four months. Her top speed is approximately 13 knots, and she is equipped with a complete array of navigation and communication electronics.

On this trip, Sea Treasure fished the eastern tropical Pacific from approximately 4°N to 13°N and from 80°W to 135°W, an area of 500 square nautical miles (Figure 5). The trip lasted 115 days, and we returned to San Diego with 782 tons of yellowfin and skipjack (Table 3). This was a slightly longer trip than normal, the average trip historically requiring about 90 days. We made a total of 77 sets, resulting in an average catch of slightly over 10 tons per set. I quickly realized that harvesting fish is difficult, lonely, and oftentimes hazardous work. It is impossible to describe in words now the feelings I had then. However, I have gained a great deal of respect for tuna fishermen and can well appreciate the bitterness and frustration they often feel when they are forced to deal with regulations set by landlubbing bureaucrats.

Tuna fishing

Fishing in general, and tuna fishing in particular, consists of two phases of activity, the search and the capture. The search for tuna as presently conducted is a highly subjective, intuitive process which depends on the judgment of the captain in selecting search areas and on the visual acuity of the crew in spotting signs of fish. Finding fish is considered an art form by tuna fishermen and is therefore an expression of some sixth sense which can only partially be taught. Capturing fish, however, is a mechanical, routine procedure which can be relatively easily taught and perfected.

The search

It is up to the captain of the vessel to find fish. That is his primary responsibility. Search areas are selected on the basis of the captain's experience, information received by the captain from other captains in the code group, and the captain's hunches.

By far the most important determinant in selecting the search area is the captain's experience. Most captains have a great deal of experience as crewmembers and masters, and over the years they accumulate a store of knowledge that is not formally recorded. For example, the master of the Sea Treasure believes that he has better success when the water in the search area is "green," as opposed to blue. Perhaps the green color indicates the presence of phytoplankton in high concentration which supports a relatively abundant pelagic community, including tuna. However, to the captain, the link between water color and fishing success is wholly empirical, and there are different shades of green, difficult for the novice to discriminate but which are linked to probable success in locating tuna. There appears to be no systematic method used by tuna fishermen to locate green water, but once it is found, the captain remains in the area and searches it thoroughly.

In addition to the unwritten knowledge of experience, most captains keep charts upon which are recorded the location, the date, and the kind and amount of tuna caught in the past. Data from the current trip is usually recorded as well, and the charts are used to determine whether there are trends in abundance or migration. These charts are regarded as confidential, and access to them is restricted.

Code groups are formed of 12 to 14 boats which daily exchange information on catch success and intentions regarding search strategy. The code groups are formed among a group of masters who are friends, so that boats of competing companies can and often do exchange information. The exchange of information is not always candid, however. Despite the fact that the boats are far from home and despite the fact that the captains may be close friends, the competition is keen to get the biggest load in as little time as possible. The captain must infer the true meaning of the message received from a code group member; he must be able to judge from the tone of voice or turn of phrase what is really being said.

The choice of search strategy is not made scientifically, but neither is it made randomly or based upon mere superstition. Some fish-finding aids are occasionally used. Water temperature is watched; 80°C to 85°C is preferred. Acoustic fish-finders are sometimes used to distinguish "bait fish" from tuna. Nonetheless, deciding where to fish is largely a subjective process.

Once an area is selected, the search for fish begins. There are three indications which signal the potential presence of tuna: bird activity and water surface disturbances caused by feeding fish, a floating object such as a log, and porpoise swimming at the surface. Bird and fish activity indicate school fish, a school of tuna not associated with porpoise or a floating object. School fish are not often seen and are even less often caught due to the great speed at which tuna swim. Log fish are indicated by the presence of a floating object which may be as large as a tree or as small as a glass ball. Porpoise fish are tuna found in association with porpoise, most commonly the whitebelly, *Delphinus delphis*, the spotter, *Stenella attenuata*, or the spinner, *Stenella longirostris*. In every case, signs of fish are cross-checked. That is, when water surface signs such as a breezer or jumpers indicate the presence of tuna, the crew must also see birds overhead before committing the boat to a set. The birds sighted must be the "man of war" (scientific name unknown), as these birds, according to the fishermen, feed on some of the same bait fish that yellowfin consume.

The capture

Once the boat nears the school, the captain attempts to visually confirm the presence of tuna in a quantity sufficient to justify committing the boat to setting the net. The decision to set is not lightly made, as the opportunity cost is high. At least 1.5 hours and considerable fuel will be used even on a "skunk" set. Also, the net could conceivably be lost; it happens, and nets cost upwards of $1 million. When setting on a log, the captain watches the school from the crow's nest while the boat circles the log.

The procedure is somewhat modified when setting on porpoise. When a helicopter is available, the captain assesses the situation from the air. If he decides to set on porpoise, four or more speedboats are launched to assist in herding the porpoise into a tight, slowly swimming pack around which the seiner can set the net.

Getting the porpoise into a manageable group is a time-consuming, frustrating evolution. Many fishermen believe that porpoise have developed techniques to evade capture. As the chase begins, the school of porpoise fans out and swims downwind in long, flat jumps through the water. Often the school breaks into smaller groups which disperse, but if there are rain-showers within approximately five to eight miles, the porpoise almost invariably head toward it.

A successful porpoise set is accomplished when the speedboats, led by the helicopter, succeed in encircling the school of porpoise and maintaining the integrity of the school while the net is set. Once the ends of the net are secured aboard the seiner, the purse cables are quickly winched in and the purse rings are brought aboard. The porpoise and tuna are trapped inside the net.

The stern end of the net is now passed through the power block, and net retrieval commences. When approximately one half of the net has been brought aboard and stacked, the net is secured and backdown begins. Power is applied in reverse, and as the boat moves aft the net becomes elongated. At this stage the tuna generally separate from the porpoise and swim away from the back-down apron. The corkline in the apron area sinks as power is applied, and the porpoise, assisted by two crewmen stationed in a speedboat at the cork-line, escape over the top of the net.

When all the porpoise have escaped, the boat stops, the net is released from backdown and stacked aboard, and the fish is loaded into the refrigerated holds.

Observations on porpoise behavior

The reasons for the association between yellowfin tuna and porpoise are not clearly known. There is some overlap in components of diet, possibly indicating a link due to food gathering activities; among other suggestions is the possibility that yellowfin use to their advantage the superior navigational ability of the porpoise for orientation purposes (Smith, 1979).

Whatever the reason for the association, tuna fishermen have taken advantage of the fact since 1959 in fishing for yellowfin (Smith, 1979). Since that time, porpoise have displayed altered patterns of behavior when pursued and captured which indicate learning and adaptation to the purse seine fishing technique. The propensity of schools of porpoise to fan out and swim downwind and their predilection for swimming toward rainshowers to discourage pursuit has been noted above. Certain stocks of porpoise that inhabit coastal waters off Costa Rica are so adept at eluding fishermen that they are called "The Untouchables."

John Alexander, chief engineer on the Sea Treasure and inventor of the chilled brine refrigeration system now used universally by the purse seine fleet, has 35 years' experience in the tuna fishery. He believes that porpoise have adapted over time to purse seining and the backdown technique. The school of porpoise generally remains calm once inside the pursed net; they swim leisurely back and forth, seemingly biding their time until released. As backdown commences and the net elongates, the school of porpoise congregates at the back end of the net near the release apron. Although some porpoise appear to become confused and disoriented as the corkline sinks, many are able to leap free of the net unassisted while the rest calmly let themselves be guided to safety by the crewmen stationed at the net.

It therefore appears that part of the observed success of the porpoise-releasing equipment and techniques can be attributed to the adaptive behavior of the porpoise themselves.

Porpoise mortality

As noted in the sections above, porpoise mortality is the catalyst which has precipitated the most visible residue of conflict from a broth rich in management problems. Porpoise are gregarious and graceful. They give indications of being highly intelligent. Therefore those who are responsible for killing these harmless, gentle creatures must be stopped - in the view of many environmentalists. Yet tuna fishermen are not evil men. According to the chief engineer of the M/V Gold Coast, tuna fishermen have no inclination to "promiscuously kill" porpoise; they are extremely valuable to the tuna fisherman as indicators of the presence of yellowfin. Nonetheless I found evidence of careless fishing practices and disregard of porpoise conservation regulations.

The regulations published by the NMFS require annually decreasing quotas of porpoise mortalities, to fulfill the language of the NMPA that "it shall be the immediate goal that the incidental kill or the incidental serious injury of marine mammals permitted in the course of commercial fishing operations be reduced to insignificant levels approaching a zero mortality and serious injury rate" (MMPA, 1972). To achieve this goal, the utilization of certain equipment and procedures is required of tuna fishermen by the NMFS (Federal Register, 1977). All vessels licensed by the NMFS to take marine mammals incidental to commercial fishing operations must observe these regulations.

All large purse seiners are required to have installed in the net both a porpoise safety panel and a porpoise apron. The safety panel is a section of net consisting of small mesh, not to exceed 1 1/4 in. when stretched, approximately 180 fathoms long and 12.5 fathoms deep. The small mesh is intended to prevent porpoise entanglement. The porpoise apron is a triangular-shaped section of net attached between the corkline and the safety panel. During backdown the apron forms a chute which facilitates porpoise release.

Other requirements stipulate that two manned speedboats shall be in the water until backdown commences, for the purpose of preventing net collapse and consequent porpoise entanglement. Bow bunchlines, which gather up sections of corkline, are to be pulled in to ensure that the porpoise safety panel and apron are properly positioned during backdown. Backdown is to be performed following any set in which porpoise are captured. Continuous hand rescue of porpoise by a minimum of two crewmen is required until all live porpoise are released. One of these crewmen may operate the rubber raft which is required to be launched inside the net; this rescuer must use a facemask and snorkel to determine whether all live porpoise are out of the net and to make every effort to remove them before backdown is terminated.

Still other general regulations must be observed. The owner and operator of the vessel must both possess valid permits to take porpoise incidental to commercial fishing operations. Operators, in order to obtain their "certificate of inclusion," must attend and complete a formal training session conducted under the auspices of the NMFS. Significantly, the published training requirements do not include instruction on porpoise identification.

Of this plethora of rules and regulations, it is not surprising that those most commonly ignored or modified are those most difficult to enforce that is, the regulations concerning release procedures. In my experience, the greatest single factor affecting porpoise mortality is the attitude and commitment of the master to fulfilling the requirements of the law with respect to the rules and regulations addressing release of porpoise. The equipment, including net, safety panel, apron, and speedboats, was maintained according to specifications. A marine mammal log was maintained as required, although it was not truthful.

The release requirements, however, were routinely ignored. The two manned speedboats required to be in the water prior to backdown were never deployed; consequently on several occasions the net collapsed and the captured porpoise were able to breathe only by struggling against the net. During backdown there were one or two men in a speedboat stationed at the apron to assist in releasing porpoise, but a rescuer with facemask and snorkel in a rubber raft was never deployed. Had these two procedures been performed, it is my opinion that the observed porpoise mortality as indicated below would have been substantially reduced.

	Data from Ship's Records	Personal Observation (Table 3)
Number of porpoise sets	17	26
Porpoise mortalities	12	254
Tons yellowfin caught on porpoise	311	331
Mortalities per porpoise set	0.706	9.77
Mortalities per ton yellowfin caught on porpoise	0.039	0.767

Thus on this trip the vessel under-reported the total mortality, mortality per porpoise set, and mortality per ton yellowfin caught on porpoise by more than an order of magnitude. The estimate for the 1979 fishing season by the NMFS of mortality per porpoise set was 2.97; of mortality per ton yellowfin caught on porpoise, 0.29; and total mortality, 18 thousand porpoise (Porpoise Mortality Status Report, 1979). These estimates are calculated from trips monitored by an observer from the NMFS. The mortality rates I observed were greater than the NMFS estimates by a factor of three. The NMFS estimates total mortality by multiplying the average mortality per porpoise set by a total number of porpoise sets. Therefore, if my data are representative of the tuna fleet performance which is not subject to government observation, the total mortality for 1979 could have exceeded 50 thousand porpoise. Because crews receive no training in porpoise identification, and because mortality is reported by species rather than by stock, it is likely that certain depleted stocks of porpoise are not receiving the protection intended by the MMPA and the rules and regulations of the NMFS. The likelihood increases when one considers that tuna fishermen on unobserved trips are in the habit of setting on virtually any school of porpoise which appears to carry a sufficient quantity of yellowfin tuna.

IV Conclusions

My internship aboard a tuna purse seiner was an extremely valuable experience. As I look forward to my career in marine resource management, hopefully as a NOAA Corps officer, I feel certain that whatever management decisions I make, and in fact my very perceptions of resource management will have benefited from my four and one half months at sea. Looking back, I believe I achieved my stated goals. I became a fairly competent shipboard helicopter pilot and fish spotter; for 139 days at sea I knew the frustrations, hardships, exhaustions, and occasional joys that make up the life of a commercial fisherman; I saw first-hand that government regulations resulting from resource management decisions really do have a very tangible effect on resource users and harvesters, and that there are two or more sides to resource management questions; finally, I saw that man, in the act of utilizing a marine resource, must do so responsibly, and that he can do so if he is willing to make the commitment to responsible utilization.

The problems of managing yellowfin tuna can be solved. This is not to say that the solutions will be easy or that they are imminently forthcoming. As mentioned earlier, the prime requisite for resolving these problems is the dedication and commitment of all interests to achieve their solution.

Second only to dedication and commitment is the requirement for more data. The data for 1978 indicate that yellowfin tuna in the eastern tropical Pacific is being overfished (IATTC, 1979). Catch per unit effort was the lowest of the entire 19 year time series kept by the IATTC. The average weight of yellowfin taken in the CYRA was 5.8 kg, which is the lowest ever recorded. There has been greater apparent variability in recruitment during the 1973-1978 period than during the years previous to 1973. However, more convincing data will be required before a viable management plan agreeable to all concerned interests can be implemented.

Other problems may be self-resolving due to economic considerations. For example, the carrying capacity of the international fleet which fishes the eastern Pacific Ocean has increased by a factor of four since 1965, but the catch per ton carrying capacity, an index of economic efficiency, was for the 1978 yellowfin catch the lowest of any year since 1969. However, as fuel prices continue to increase, the trend toward overcapitalization might be expected to reverse. It is even possible that in order to better utilize fleet capability, the search phase of fishing may become better organized. Code groups may become formal search groups employing more efficient grid-type search patterns.

Our nation's experience with the Marine Mammal Protection Act of 1972 and subsequent legislation will hopefully reduce the amount of vaguely defined terminology appearing in resource management laws. Enforcement in the future should either be based on realistic standards or it should be abandoned. The elimination of penalties under the MMPA for illegal fishing operations might result in more reliable logbook data, in addition to the fact that the governing regulations are virtually impossible to enforce as presently written.

Finally, with respect to porpoise mortality, the goal of the MMPA to reduce the incidental mortality and serious injury rate to insignificant levels approaching zero could be achieved almost immediately. Research cruises sponsored by the NMFS have shown that mortality per porpoise set can be reduced to 0.1 when available equipment and techniques are diligently employed (Fox, 1978). The missing factor is the willingness of the tuna boat captains.

I am optimistic that with some changes the porpoise-tuna problem can be solved. Elimination of penalties might result in better logbook data for population estimates, it might stem the flow of United States vessels which are leaving for more favorable legal climates, and it might provide an incentive for U.S. tuna fishermen to redouble their efforts to reduce the mortality of porpoise taken incidentally to purse seining. Continuing the record of fleet productivity and improving the record of porpoise protection is worth the commitment and effort.

BROADHEAD 1962

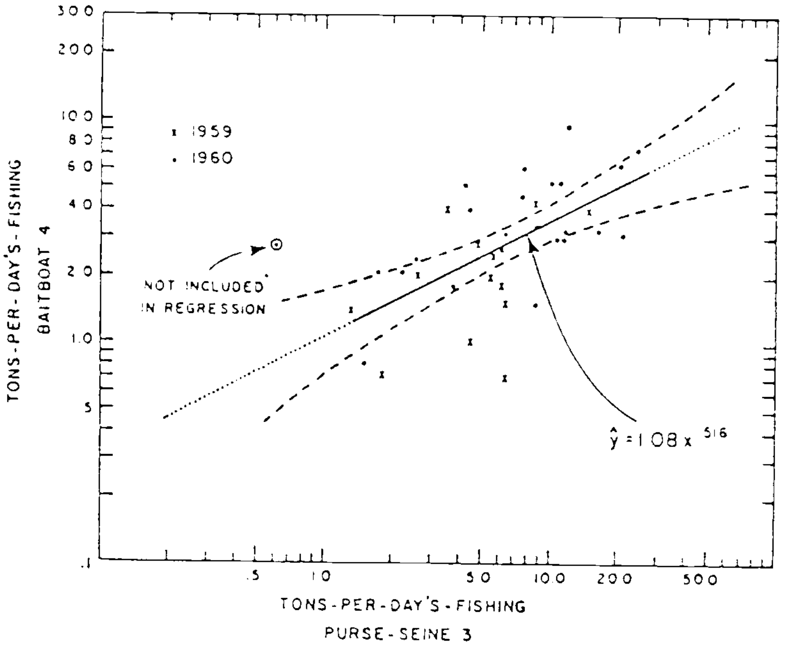

FIGURE I Series "A". The relationship of the success of purse-seiners and baitboats in fishing for yellowfin tuna, by month, by major area, during the period 1959-1960, plotted on logarithmic scales.

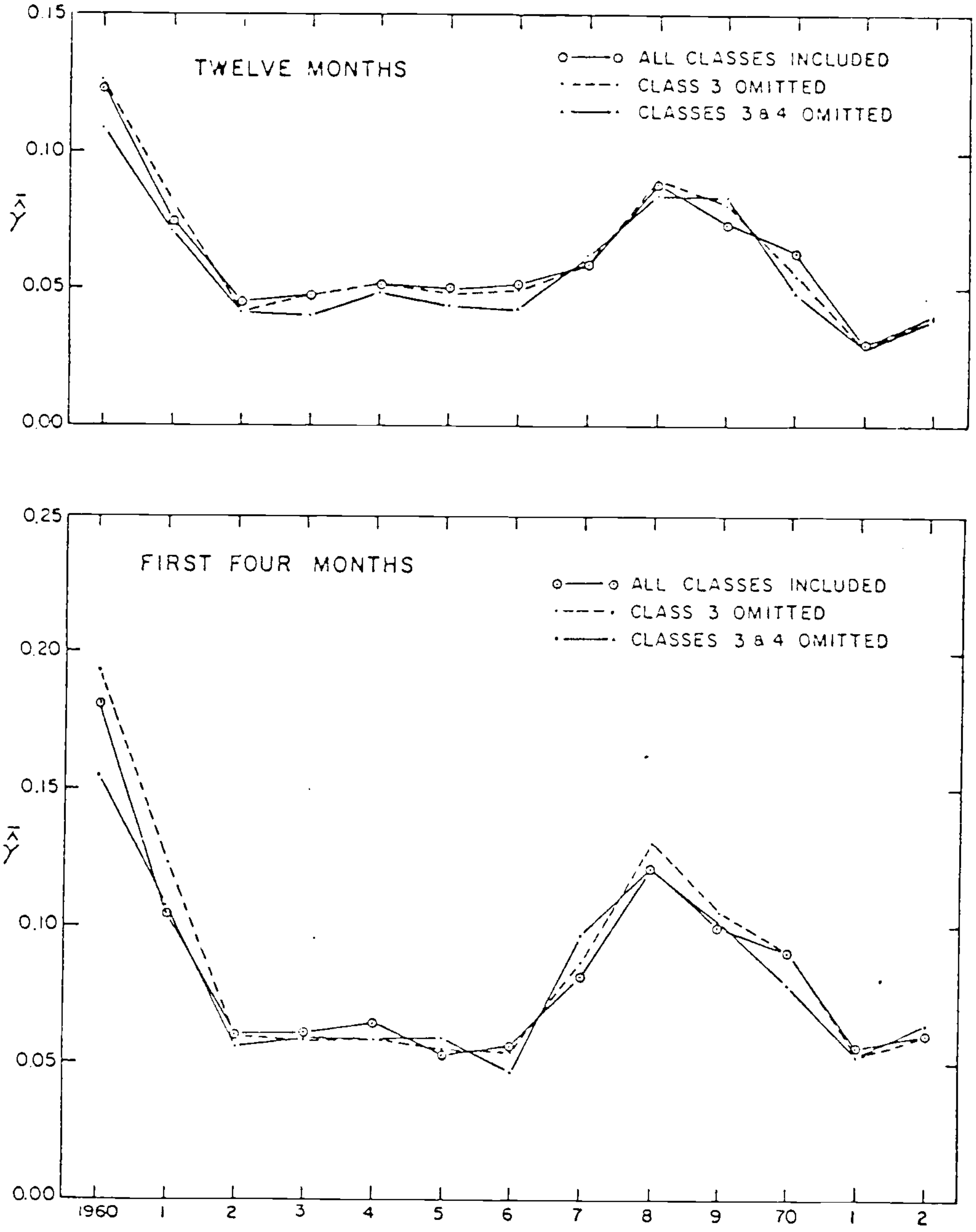

FIGURE 2 Annual biomass indices for yellowfin in the historic fishing region, 1960-1972, using information from vessel classes 3, 4, 5, and 6, 4, 5, and 6, and 5 and 6 only.

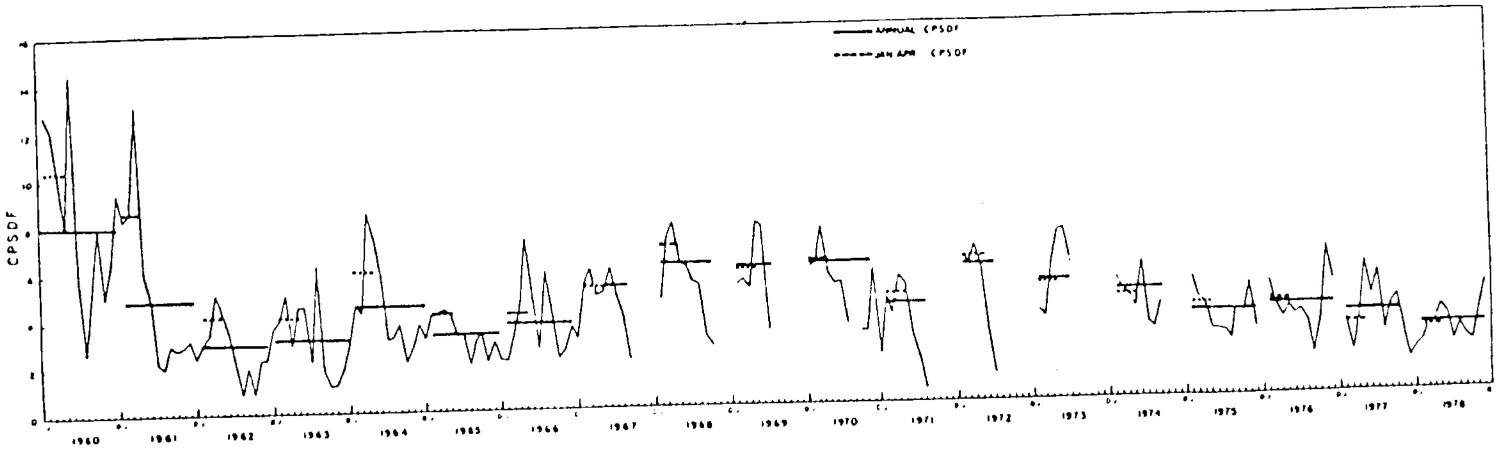

FIGURE 3 Catch per standard day's fishing for yellowfin in Class-3 purse-seine units in the CYRA during 1960-1978. Only the data from unregulated trips are used. The values for 1978 are preliminary.

FIGURA 3 Captura por dia normal de pesca de aleta amarilla, en unidades de la clase 3 de arqueo de barcos cerqueros en el ARCAA durante 1960-1978. Solo se usaron los datos de viajes sin reglamentar. Los valores de 1978 son preliminares.

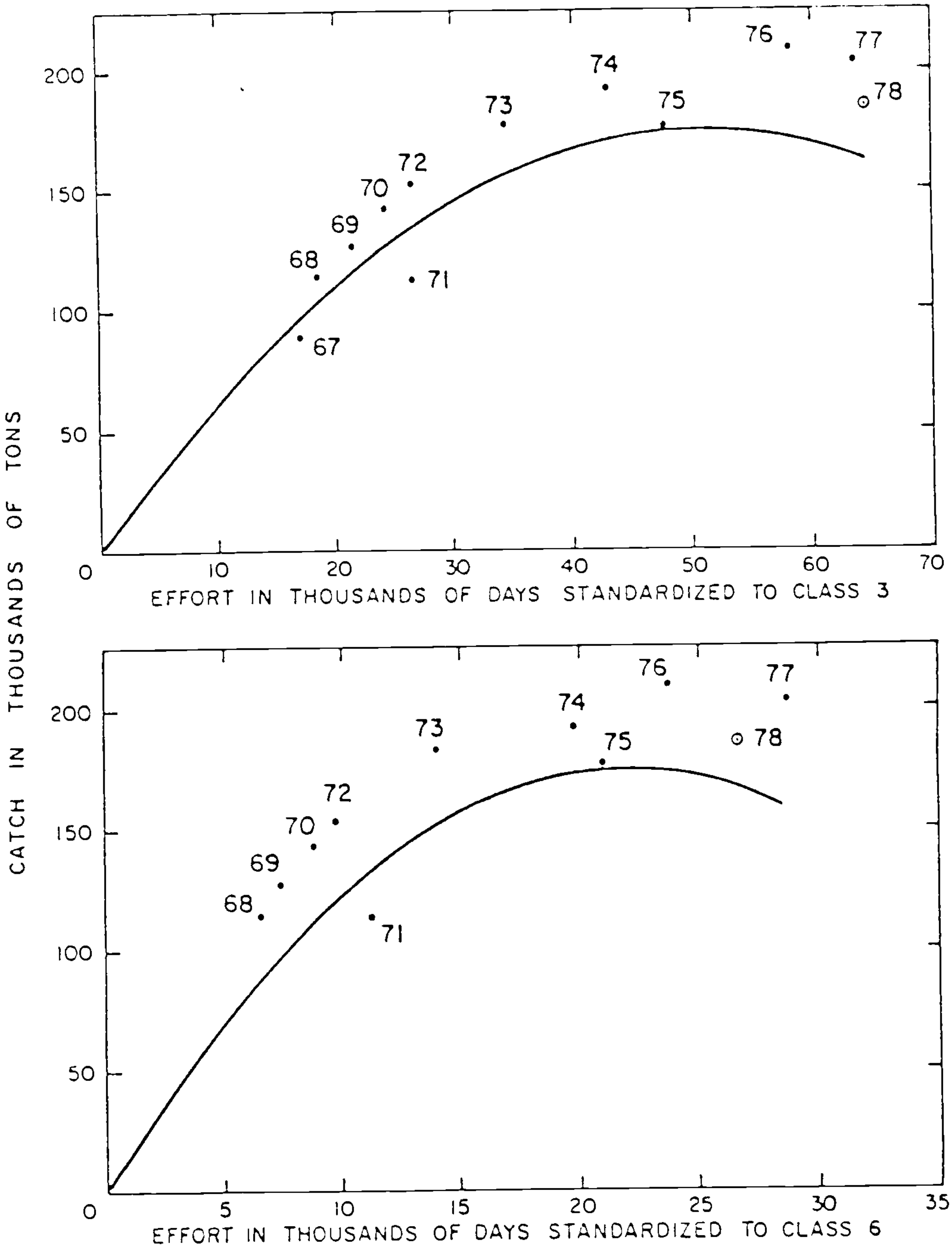

FIGURE 5'. Relationship between effort and catch for the yellowfin fishery inside the CYRA, 1967-1978 (upper panel) and 1968-1978 (lower panel).

Figure 5 Map of the eastern Pacific Ocean, showing the CYRA and the experimental area and track of M/V Sea Treasure, June 2, 1979 to September 24, 1979

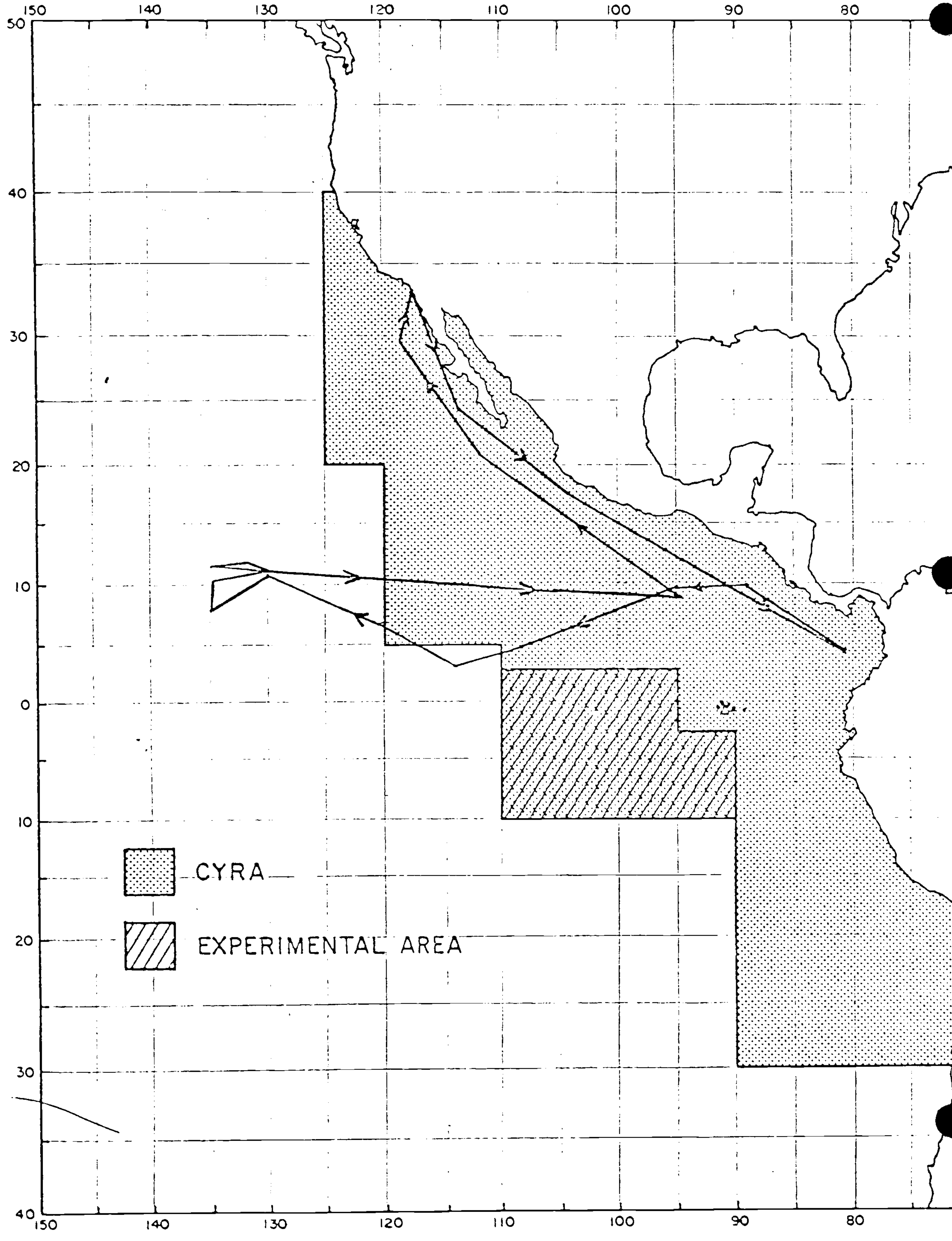

Table 1. Summary of regulations (proposed but not accepted for 1962-1965) for yellowfin in the eastern Pacific Ocean. From Bayliff, 1975.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Quota (short tons x 1000)	(83.0)	(79.0)	(74.5)	(81.8)	79.3	84.5	93.0	120.0	120.0	140.0	120.0	130.0	175.
Authorized increments to quota (short tons x 1000)	0	0	0	0	0	0	13	0	0	10+10	10+10	10+10+10	10+
Maximum quota (short tons x 1000)	(83.0	(79.0)	(74.5)	(81.8)	79.3	84.5	106.0	120.0	120.0	140.0	140.0	130.0	175.
Safeguard proviso for closure due to low CPUE (short tons per day)	–	–	–	–	–	–	–	3	3	3	3	3	3
Allowance for incidentally-caught yellowfin during closed season (percent)	(15)	(15)	(15)	(15)	15	15	15	15	15	15	15	15	15
Special allocations, small vessels (short tons x 1000)	–	–	–	–	–	–	–	4	6	6	6	6	6
Special allocations, new vessels of developing countries (short tons x 1000)	–	–	–	–	–	–	–	–	–	2	2	6	8
Special allocations, member and cooperating nations with canneries and small catches (short tons x 1000)	–	–	–	–	–	–	–	–	1	1	1	1	1
Unregulated fishing in experimental area	–	–	–	–	–	–	–	–	–	–	–	+	+
Closure date	–	–	–	–	Sep.15	Jun.24	Jun.18	Apr.16	Mar.23	Apr.9	Mar.5	Mar.8	Mar.1[illegible]
Grace period (days)	–	–	–	–	0	0	0	0	10	30	30	30	30
Catch (short tons x 1000)	87.0	72.7	101.9	90.0	91.2	89.6	114.6	126.5	142.7	113.5	152.4	178.0	

TABLE 2. Quotas, catches, CPSDF's (Class-3 purse seiners), and CPDFs (Class-6 purse seiners) for yellowfin in the eastern Pacific Ocean, 1967-1978. The quotas and catches are in thousands of short tons, and the CPSDF's and CPDFs in short tons. The CPSDF data are adjusted to compensate for increased success in capturing schools of fish that are encountered.

TABLA 2. Cuotas, capturas, CPDNP (clase 3 de cerqueros) y CPDP (clase 6 de cerqueros) correspondientes al aleta amarilla del Océano Pacífico oriental, 1967-1978. Las cuotas y las capturas se indican en miles de toneladas americanas y las CPDNP y las CPDP en toneladas americanas. Los datos de la CPDNP se ajustan para compensar el aumento de las pescas positivas al capturar cardúmenes de peces que se encuentran.

Year / Año	Inside CYRA / En el ARCAA: Quota / Cuota	Inside CYRA / En el ARCAA: Catch / Captura	Inside CYRA / En el ARCAA: CPSDF / CPDNP	Outside CYRA / Fuera del ARCAA: Catch / Captura	Outside CYRA / Fuera del ARCAA: CPDF / CPDP	Total Catch / Captura total
1967	84.5	89.6	5.1	0.0	--	89.6
1968	93	114.6	6.1	1.2	—	115.8
1969	120	126.9	5.9	19.2	20.4	146.1
1970	120	142.6	6.0	30.7	11.7	173.3
1971	140 + (2x10)*	113.9	4.2	22.8	10.6	136.6
1972	120 + (2x10)	152.5	6.0	44.8	12.5	197.3
1973	130 + (3x10)	177.8	5.2	49.5	13.0	227.3
1974	175 + (2x10)	191.3	4.6	41.1	10.2	232.3
1975	175 + (2x10)	176.4	3.6	47.5	12.2	223.9
1976	175 + (2x10)	209.4	3.8	50.7	12.7	260.1
1977	175 + (20+15)	203.6	3.3	16.9	10.2	220.5
1978**	175 + (20+15)	182.0	2.8	15.7	9.7	197.7

*"+ (2x10)" indicates two increments of 10 thousand tons each to be added to the quota at the discretion of the Director of Investigations.

**preliminary estimates of annual values

*"+ (2x10)" indica los dos incrementos de 10 mil toneladas cada uno que se han de agregar a la cuota a discreción del Director de Investigaciones.

**estimación preliminar de los valores anuales

TABLE 3 Log of trip of M/V Sea Treasure, June 2, 1979 to September 24, 1979

DATE 1979	LOCATION Lat.N	Long.W	TYPE SCHOOL	CATCH (TONS) Yellow-fin	Skip-jack	PORPOISE CHASED (1)	PORPOISE CAUGHT (1)	REPORTED (1) Mortali-ties	Serious Injury	OBSERVED (2) Mortali-ties	Serious Injury	REMARKS
6/2	San Diego, CA											Trip started
6/4	4°00'	81°00'	Jumper	0	0							
6/5	3°00'	82°00'	Jumper	0	0							
6/7	3°10'	82°00'	---	0	0							
			---	0	0							
6/8	4°00'	81°50'	Breezer	0	0							
			Breezer		2							
			Breezer	0	0							
6/10	3°30'	82°00'	---	0	0							
6/11	3°22'	81°50'	Breezer		2							
	3°50'	81°30'	Log	1	25							
6/12	5°18'	80°15'	Log	0	0							
6/23	8°28'	90°45'	Breezer w/ jumper	2	0	---	---	---	---	15 wb	0	(3)
6/24	9°44'	92°58'	Whitebellies	20	0	1000	500	1 wb	0	3 wb	0	
6/25	10°06'	93°33'	Porpoise	18	0	300	250	0	0	2 spt	0	
6/26	9°28'	94°49'	Spotters	6	0	1000	400	0	0	0	0	
	9°33'	95°21'	Spotters	29	0	1000	100	1 spt	0	2 spt		
6/27	9°17'	95°15'	Spotters	23	0	1500	300	1 spt	0	75 spt	0	
	9°13'	94°57'	Log	7	35							
6/28	9°22'	94°53'	Log	1	3							

DATE 1979	LOCATION Lat.N	Long.W	TYPE SCHOOL	CATCH (TONS) Yellow-fin	Skip-jack	PORPOISE CHASED(1)	PORPOISE CAUGHT(1)	REPORTED(1) Mortali-ties	Serious Injury	OBSERVED(2) Mortali-ties	Serious Injury	REMARKS
6/29	9°26'	95°15'	Log	2	18							
	9°44'	95°37'	Spotters	20	0	2000	200	0	0	26 spt	0	
	9°50'	95°39'	School fish	0	0	---	---	-	-	16 spt	0	(3)
6/30	9°40'	95°40'	School fish	1	0							
7/4	4°30'	108°30'	Spotters	1	0	400	100	1	0	10 spt	0	
7/6	3°00'	114°00	---	0	0	---	---	-	-	2 spt	0	(3)
7/7	5°53'	117°59'	Spotters	8	0	600	400	0	0	2 spt	0	
7/9	6°50'	120°40'	Spotters	3	0	800	500	0	1	2 spt	0	
7/12	10°50'	129°54'	Porpoise	38	0	700spt	700	1	0	1	3 spt	
	10°38'	130°15'	Rope	93	9	300spn						
7/13	10°34'	130°10'	Rope	12	0							
	9°55'	129°35'	Porpoise	18	0	1000spt	600	0	0	0	0	
7/14	10°12'	130°13'	Rope	0	0							
	10°50'	129°45'	Porpoise	35	0	3000spt	3000spt					
						1000spn	0	3spt	0	22 spt	0	
7/16	9°30'	132°30'	Log	0	0							
	8°49'	133°49'	Log	0	0							
7/17	8°50'	133°43'	Log	6	6							
7/18	7°40'	135°27'	Log	0	0	---	---	-	-	0	0	(3)
7/20	10°28'	134°03'	Breezer	0	0	---	---	-	-	3 spt	0	(3)
7/22	11°00'	130°21'	Log	0	0							

DATE 1979	LOCATION		TYPE SCHOOL	CATCH (TONS)		PORPOISE CHASED(1)	PORPOISE CAUGHT(1)	REPORTED(1)		OBSERVED(2)		REMARKS
	Lat.N	Long.W		Yellow-fin	Skip-Jack			Mortali-ties	Serious Injury	Mortali-ties	Serious Injury	
7/26	10°02'	130°17'	Log	2	0							
	9°17'	130°33'	Log	1	0							
7/29	11°00'	130°00'	Log	1	0							
	11°00'	130°00'	Log	4	0	---	---	-	-	1 spt	0	(3)
8/2	8°45'	129°41'	Log	1	0							
	8°38'	130°00'	Log	0	0							
8/3	11°40'	131°55'	Log	3	0	---	---	-	-	0	0	(3)
	11°50'	131°53'	Log	0	0							
	12°00	131°32'	Porpoise	30	0	2000spt	2000 spt	1 spt		1 spt		
8/6	12°00'	133°00'	Porpoise	2	0	300spt	300	0	0	0	0	
8/7	11°10'	135°20'	Porpoise	55	0	3000spt	2500	3 spt	0	4 spt	0	
										2 spn	0	
8/12	13°14'	132°32'	Log	7	0	---	---	-	-	2 spt	0	(3)
8/13	12°40'	132°50'	Log	5	0							
8/15	9°30'	132°35'	Log	2	0							
8/17	10°40'	131°55'	Log	5	23							
	11°00'	132°00'	Porpoise	3		---	---	-	-	32 spt	0	
										30 spn	0	
8/18	10°37'	132°00'	Log	1	4							
8/23	9°12'	106°32'	---	4	0	---	---	-	-	0	0	(3)
8/27	9°15'	103°10'	Porpoise	2	0	500spt	400spt	0	0	1 spn	0	
8/29	9°23'	100°12'	Log	20	0							
	9°23'	100°12'	Log	0	0							

DATE 1979	LOCATION Lat.N	Long.W	TYPE SCHOOL	CATCH (TONS) Yellow-fin	Skip-jack	PORPOISE CHASED(1)	PORPOISE CAUGHT(1)	REPORTED(1) Mortali-ties	Serious Injury	OBSERVED(2) Mortali-ties	Serious Injury	REMARKS
8/30	9°21'	101°03'	Log	0	0							
			Log	15	0							
8/31	9°14'	99°37'	Log	0	0							
9/1	9°01'	99°17'	Log	19	0							
9/2	9°05'	99°03'	Log	35	0							
9/3	9°09'	98°43'	Log	15	0							
	9°17'	98°30'	Log	5	0							
9/4	9°20'	98°23'	Log	0	0							
	9°09'	98°27'	Log	15	0							
	9°24'	98°28'	Log	3	0							
9/5	9°31'	98°11'	Log	7	0							
			Log	8	0							
9/6	9°24'	98°05'	Log	15	0							
	9°30'	98°00'	Log	2	0							
9/7	9°34'	97°52'	Log	8	0							
9/8	9°25'	98°00'	Log	0	0							
9/9	9°27'	97°07'	Log	12	0							
9/24	San Diego, CA											Trip completed
115 days			77 sets	650	132							TOTALS
			Delphinus delphis			1000	500	1	0	18	0	
			Stenella attenuata			18000	11750	11	1	203	3	
			Stenella longirostris			1300	0	0	0	33	0	

NOTES: (1) These figures taken from ship's log.

(2) spt = spotter porpoise, *Stenella attenuata*
spn = spinner porpoise, *Stenella longirostris*
wb = whitebelly (common) porpoise, *Delphinus delphis*

(3) These sets were made on schools of porpoise but were not entered in the ship's log as porpoise sets.

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