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SEPARATION/ATTRACTION RESEARCH ON THE TUNA-DOLPHIN BOND: REVIEW AND CRITERIA FOR FUTURE PROPOSALS

By

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ABSTRACT

The potential for using separation or attraction methods to "break the tuna-dolphin bond" and thereby reduce dolphin mortality incidental to purse-seine fishing in the eastern tropical Pacific Ocean (ETP) was discussed and evaluated during a workshop held at the Southwest Fisheries Science Center in La Jolla, CA on September 20, 1995. Workshop participants included scientists from the National Marine Fisheries Service, the Inter-American Tropical Tuna Commission, San Diego State University, and an experienced ETP tuna purse seine fisherman. Participants reviewed and/or discussed research proposed and/or conducted to date, and developed criteria to be followed in future in order to improve the effectiveness of research on this topic.

In the future, research proposals directed at breaking the tuna-dolphin bond for purposes of reducing fishery-related dolphin mortality must show clearly that the proposed research (1) is based on solid theory and on a demonstrated understanding of past efforts, (2) can be accomplished in a practical manner, (3) will result in significantly lower dolphin mortality rates at no greater risk to the fishermen involved, compared to current practices, and (4) will be tested in a scientifically, logistically, and economically feasible manner.

INTRODUCTION

Thirty years of curiosity about the basis for the unusually strong "tuna/dolphin bond" in the eastern tropical Pacific Ocean (ETP), coupled with great interest in reducing the fishery-related mortality of dolphins caused by the strength of that bond, has generated numerous proposals for research to study the association. Many of these proposals have suffered from two major problems - (1) an impractical approach to the problem, and (2) an obvious lack of background investigation. In order to summarize the current state of knowledge for future researchers and to reduce the high proportion of unsatisfactory proposals, a workshop was held at the Southwest Fisheries Science Center in La Jolla, CA on September 20, 1995 to develop criteria for future research proposals concerning the tuna-dolphin bond in the ETP. Workshop participants included scientists from the National Marine Fisheries Service, the Inter-American Tropical Tuna Commission, San Diego State University and an experienced ETP tuna purse seine fisherman. Participants reviewed and/or discussed extant research and research proposals, and developed criteria must be met by future proposals in order for those proposals to receive serious consideration.

To aid future researchers in this area, we provide here summaries (and appropriate literature references for more detailed information) of the current state of understanding with regard to (1) the dolphins, the tunas, and the tuna-dolphin relationship in the ETP, and (2) practical constraints on tuna-dolphin research. In addition, this report presents summary comments on existing proposals, and a list of criteria for future research proposals.

The references cited herein are either available from the authors as indicated or are located in the Southwest Fisheries Science Center Library.

CURRENT STATE OF KNOWLEDGE

Tuna-Dolphin Bond Research To Date

IATTC Research 1979-1996. In 1979, the Inter-American Tropical Tuna Commission (IATTC) initiated a tuna-dolphin research program. The activities of this program are summarized in the quarterly and annual reports of that organization. Much of the work by the IATTC has been directed toward (1) developing indices of relative abundance for the dolphins affected by the ETP tuna purse-seine fishery, using data collected by scientific observers on board the seiners during routine fishing operations, (2) improving fishing methods and gear involved in setting on dolphins in the ETP, and (3) investigating interactions between tunas and dolphins. Recent studies have tested the use of FADs to concentrate yellowfin tuna and have examined the bycatch associated with the different modes of purse-seine fishing in the ETP (log, school, and dolphin fishing). Because the Commission has access to much of the fishery and fishery data collected from the ETP tuna purse-seine fishery, but little regular access to research vessels, much of Commission's work has directly involved the fishery itself as the primary sampling platform.

NMFS Research 1972-1996. Soon after passage of the Marine Mammal Protection Act in 1972, NMFS initiated a number of behavioral and gear-related research projects directed at gaining a better understanding of the tuna-dolphin bond and, if possible, controlling it in order to reduce the extremely high mortality of dolphins occurring at that time.

The most extensive series of studies during this period occurred during the Cooperative Dedicated Vessel Research Program, which involved a chartered ETP tuna purse-seiner (the M/V *Queen Mary*) providing the research platform for a series of five cruises designed to investigate various aspects of (1) mortality reduction during seining procedures, (2) alternative fishing methods, (3) stock assessment, and (4) dolphin and tuna behavior during fishing activities.

The program was jointly planned and conducted by the National Marine Fisheries Service, the Marine Mammal Commission, and Living Marine Resources (a fishing industry consultant group). Research to reduce dolphin mortality was emphasized on Cruises I and V, research to design and develop alternative fishing methods was emphasized on Cruises I and III (Leg 1), stock assessment research was emphasized on Cruises II and IV, and behavioral research was emphasized on Cruise III (Leg 2).

Results from individual cruises appear in a series of cruise reports (Coe et al. 1979, Awbrey et al. 1979, Bratten et al. 1979, Powers et al. 1979, and Holts et al. 1979) and a contract report (Pryor and Kang 1980; see also Pryor and Kang-Shallenberger 1991). Summaries of overall results appear in DeBeer (1980) and in Coe *et al.* (1984)[1].

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[1] The summary information presented here is taken mostly verbatim from DeBeer (1980).

The alternative fishing methods tested included fish aggregating devices (FADs), tuna olfactory attractants, low frequency sound attractants, and tuna detection systems. None of the tests were conclusive. Prototype aggregating devices were deployed three times in known areas of log fishing during Cruise I. During their few days of deployment, the devices attracted only a few baitfish. Tuna olfactory attractants were tested during ten sets during backdown (to reduce loss of fish). Some tuna appeared to respond briefly to the attractant during two sets. Tuna approached the attractant, showed feeding bars or dorsal fin erections, then returned to the dolphins in the deep end of the net. Additional detail regarding this tuna olfaction study appears in Ikehara and Bardach (1981). Attempts to attract tuna to a low-frequency sound source during Cruise III (Leg 1) were also unsuccessful, eliciting no observable response from the fish.

Tuna detection using passive acoustic devices was apparently successful in ascertaining the presence of tuna near logs. Subsequent efforts to measure tuna sounds were unsuccessful, possibly due to equipment failure.

Behavioral studies provided 135 five-minute case observations of captured dolphins ranging in age from neonate to mature adults, plus additional notes on tuna behavior in the purse-seine after capture. Researchers identified subgroups of dolphins in the net, and discovered strongly different behavioral characteristics when observations were taken from above compared to under water, such that behavioral conclusions would be very different depending upon the location of observer. For example, behavior of captured groups differed significantly between sets in terms of the fraction of captured animals rafting, ranging from less than 1/5 in some sets to more than 2/3 in other sets. Additional detail regarding social behavior and school structure of dolphins during purse-seining appears in Norris et al. (1978), Pryor and Kang (1980), and Pryor and Kang-Shallenberger (1991).

During 1982-1991 considerable research was conducted by NMFS on various aspects of ETP dolphin stock structure, stock identification, and stock abundance, but relatively little work was directed specifically to the tuna/dolphin bond. Exceptions include a consideration of the overall ecology of birds, tunas and dolphins in the ETP (Au 1991), studies correlating dolphin distributions with various oceanographic characteristics (Reilly and Fiedler 1994), and a paper describing the ecological energetics of the tunas and dolphins in the association, and postulating a hydrodynamics and foraging basis for the bond (Edwards 1992). While the hydrodynamics aspect of the latter work has not been extended, more recent studies comparing diel activity patterns and stomach contents of associated tunas and dolphins in the ETP indicate that dietary overlap may not be as great as previously thought (see section below: *Food Habits of ETP Apex Predators*).

Research on FADS was also conducted during this period (Oliver and Armstrong 1996) but direct application of this work to the tuna-dolphin bond is not likely.

<u>*M/V Hornet* experiments</u>. During May 27-July 12, 1991, a variety of tuna-dolphin separation experiments were conducted at sea aboard the commercial purse-seiner *M/V Hornet*. These included (1) during five sets, acoustic broadcasts of tuna feeding sounds and ETP tuna-dolphin aggregation sounds (tuna attractant experiments), and acoustic broadcasts of killer whale and false killer whale sounds recorded from various natural environments (dolphin deterrent experiments), (2) during three sets, chemical lure experiments (Hodgson's Fish Frenzy and/or squid chum as tuna

attractants), and (3) behavioral observations (29 sets). More than one method was tested on some sets.

All of the tests were conducted after net closure. Observed behaviors of tunas and dolphins in the net were similar to behaviors observed during the *Queen Mary* dedicated vessel cruises (Bratten et al. 1979). None of the experiments provided any conclusive information. No consistent or strong responses by tunas or dolphins to any experimental protocols were observed during any of the sets.

<u>Tuna-dolphin bond studies in the Dolphin-Safe Research Program</u>. The Dolphin-Safe Research Program was initiated in spring of 1992 at the behest of the United States Congress. The major activities following initiation of the Dolphin-Safe Research Program have included an initial set of studies specifically directed toward better understanding the tuna-dolphin bond, and a subsequent focus, under directive by the U.S. Congress, on developing alternative fishing methods that do not involve fishing on dolphins. This subsequent focus has not included tuna-dolphin bond research.

During 1992, three major projects providing information specifically relevant to better understanding the tuna-dolphin bond were initiated by the NMFS and the IATTC; (1) tagging and tracking studies of simultaneously captured, tagged and released tunas and dolphins, (2) food habits studies of ETP apex predators, and (3) correlation of catches of associated vs. unassociated tuna with oceanographic characteristics. The tagging study shows unexpected looseness in the tuna-dolphin bond and differential diel behavior of tunas and dolphins in the ETP. The food habits study indicates that the majority of foraging takes place at different times of day for yellowfin tuna and dolphins, and that overlap in prey species is less complete than previously thought. The oceanographic study suggests that schools of large yellowfin tuna unassociated with dolphins can be found and captured in certain areas of the ETP during certain times of the year.

<u>Tagging and tracking studies</u>. During November and December of 1992 and 1993, the IATTC and NMFS conducted two tracking studies to investigate the temporal nature of the tuna-dolphin bond. During each tracking study, chartered commercial purse-seiners captured associated schools of yellowfin tuna and spotted dolphins, researchers placed radio tags on one or more dolphins and sonic-tags on one or more tuna, the dolphins and the tunas were released, and the tagged animals were tracked for 1-5 days. During the first year, six dolphins were tagged and successfully tracked for periods raging from 2.5 hours to two days. Three of the tagged dolphins were also equipped with time-depth recorders: two of these recorders were recovered, providing unprecedented data on diel patterns in dive behavior of the tagged dolphins. During the second year, in addition to tagging, tracking, and recovering TDRs again from purse-seined dolphins, three yellowfin tuna were tagged and tracked, for one hour, eight hours and 30 hours.

The major discoveries made during these cruises include; (1) the tuna-dolphin association is much looser than previously thought (tagged tunas and dolphins remained unassociated subsequent to release, even when within a few kilometers of each other), (2) tunas and dolphins have distinct, consistent diel patterns in vertical movements within the water column, and (3) those patterns are in opposition (i.e., during the day, yellowfin tuna tend to stay near the thermocline while dolphins tend to remain closer to the surface; at night, dolphins tend to dive below the thermocline, apparently following the deep scattering layer up and down with waning and waxing sunlight while tunas tend to remain nearer the surface)[2].

Food Habits of ETP Apex Predators. The IATTC has been collecting and analyzing stomach contents and stable isotope ratios of muscle from yellowfin tuna and dolphins captured by the ETP tuna purse-sine fishery. Analysis of isotope ratios is unfinished, but preliminary investigation of stomach contents indicate that strong differences between tunas and dolphins in stomach content composition and stomach fullness do exist at some times of day[3].

Large Yellowfin Oceanography. Punsly and Fiedler[4] found that medium and large yellowfin tuna (>7.5 kg) unassociated with dolphins were caught over a wider range of environmental conditions but in a more limited geographic area than were yellowfin tuna caught with dolphins. Subsequent fishing data has shown consistent albeit somewhat limited success in capturing schools of large unassociated yellowfin in certain relatively restricted areas of the ETP fishing region (e.g., southeastern tropical Pacific Ocean during January-October)[5].

Current Research Objectives. Subsequent to these three studies, the research focus of the Dolphin-Safe Research Program, under directive from the US Congress, has been redirected from tuna-dolphin bond research to determining whether commercial quantities of large, non-associated yellowfin tuna can be located and captured in the ETP. Tuna-dolphin bond research is currently suspended.

Summary Information

General References. The most recent comprehensive description of the tuna-dolphin relationship in the ETP and the fishery it supports appears in "Dolphins and the Tuna Fishery" (National Research Council 1992). Chapters include: background information, policy and economics, fishing gear, biology and ecology of yellowfin tuna, behavior of tunas and dolphins in the ETP, dolphin mortality and abundance, techniques for reducing dolphin mortality, and recommendations. The volume also includes an extensive bibliography. Prospective researchers should be thoroughly

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[2] More information about this study can be obtained from Drs. Michael Scott and Robert Olson, Inter-American Tropical Tuna Commission, c/o Scripps Institute of Oceanography, La Jolla, CA, 92038.

[3] More information about this study can be obtained from Drs. Robert Olson and Michael Scott, Inter-American Tropical Tuna Commission, c/o Scripps Institute of Oceanography, La Jolla, CA, 92038.

[4] Punsly, R. G. And P. C. Fiedler. ms in review. Purse-seiner catch rates of yellowfin tunas >7.5 kg, with and without dolphins, in the eastern tropical Pacific Ocean. Inter-American Tropical Tuna Commission, c/o Scripps Institute of Oceanography, La Jolla, CA 92038.

[5] More information about this study can be obtained from Mr. Richard Punsly, Inter-American Tropical Tuna Commission, c/o Scripps Institute of Oceanography, La Jolla, CA, 92038.

familiar with the information contained in that report, therefore most of the information is not repeated here in detail.

ETP Dolphins. Ten stocks of dolphins are affected by the tuna purse-seine fishery in the ETP but over 70% of sets are made on pure or mixed schools of the spotted dolphin (*Stenella attenuata*). This is the species with which the yellowfin tuna "bond" most closely, although relatively common associations also occur with spinner dolphins (*S. longirostris*) and common dolphins (*Delphinus delphis*). All of these dolphin species are relatively small compared to the primarily coastal species, (*Tursiops truncatus*), the dolphin most frequently seen on public display. ETP dolphins are approximately 5-6 feet long and 150-200 pounds as adults, but the three species differ in behavior and distribution.

The species differences among ETP dolphins that are relevant to this discussion include: (1) spotted dolphins appear to be more "calm" than either spinner or common dolphins during purse-seining operations (Pryor and Kang-Shallenberger 1991), (2) these "calmer" spotted dolphins have had a lower mortality rate and have been associated with larger schools of tuna than have either spinner or common dolphins (Edwards and Perrin 1993), (3) common dolphins tend to form much larger schools than either spotted or spinner dolphins (several hundred animals per school, compared to one or a few hundred for the other species; Edwards and Perrin 1993), and (4) common dolphins tend to be more coastal and occur in somewhat different ecological regimes (Reilly and Fiedler 1994). More specific information about spotted dolphins, which comprise the majority of fishery-affected dolphins, appears below.

Spotted dolphins live 25-30 years, start reproducing when they are 10-12 years old, produce single calves every 2-3 years, and tend to associate in mixed age and sex groups, with the possible exception of young adolescents (Barlow and Hohn 1984, Hohn et al. 1985). Dolphins are born after about one year gestation, at a length of 80-90 cm. They are apparently dependent entirely upon milk during the first year, begin to mix foods during the second year, and are generally weaned sometime during the third year. Schools of spotted dolphins in the ETP range in size from less than 100 to more than 1,000 individuals. Median school size sighted during research vessel surveys was about 100 dolphins, although median size of schools set upon by tuna seiners in the ETP is 560 dolphins[6].

Recent tagging studies (Scott 1994) have shown that individual spotted dolphins in the ETP have relatively regular diel patterns in depth distribution. During the day, the dolphins tended to stay relatively close to the surface. At dusk, the dolphins began diving deeper, apparently to meet and feed on organisms in the deep scattering layer as it ascends during nightfall. During the night, the dolphins dove relatively deeply and regularly, and followed the deep scattering layer down again for a time when the rising sun began to drive the layer deeper.

Recent stomach content studies (Olson 1994, 1995) indicate that spotted dolphins feed most frequently at night and/or early morning, based on a greater abundance of fresh prey in the morning

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[6] Perkins, P. And E. Edwards. ms in review. Capture frequency as a function of school size in spotted dolphins from the eastern tropical Pacific Ocean. Southwest Fisheries Science Center, P.O. Box 271, L Jolla, CA 92038.

and the absence of fresh prey later in the day in stomachs collected from dolphins which died in purse-seine sets.

Detailed under-water observations of spotted and spinner dolphin behavior during 11 purse-seine sets in the ETP have been reported by Pryor and Kang (1980) and Pryor and Kang-Shallenberger (1991). Norris et al. (1978) contains additional information and observations. Researchers interested in behavior-related separation/attraction methods should be thoroughly familiar with these observations and the implications they may have for proposed research.

Dolphin-Associated Yellowfin Tuna. In general, only one species of tuna and only one general size of that species "bonds" with dolphins in the ETP: large (approximately 100 cm total length; >20 kg) yellowfin tuna (*Thunnus albacares*). Smaller yellowfin tuna do occur with dolphins, but relatively rarely compared to the larger yellowfin tuna (Edwards, 1992). Captain Harold Medina, retired skipper, reports that the tuna tend to travel below the middle of the rear of the dolphin school.

Generally, yellowfin tuna enter the purse-seine fishery as "schoolfish" (unassociated with dolphins) and as "logfish" (associated with logs) at about one year of age (Age I), relatively close to the coast of Central and South America compared to the distribution of older, larger yellowfin tuna associated with dolphins. Age II and III yellowfin tuna tend to occur more frequently in dolphin sets than in log or school sets and are more often found further offshore. Age IV and older yellowfin tend to leave the purse-seine fishery and appear as long-line catch, deeper and further west in the Pacific Ocean. As a rule, schoolfish and logfish are prereproductive. Yellowfin tuna begin reproducing in late age I, so that most yellowfin tuna associated with dolphins are reproducing adults.

Schools of yellowfin tuna tend to contain fish of similar size, probably due to hydrodynamic constraints (little fish can't swim as fast for as long as big fish). The large yellowfin tuna that associate with dolphins are the same general length and geometric shape as newborn to one year old spotted dolphins (approximately 85-125 cm total length; torpedo-shaped with various appendages; powered by a rear fin). This size similarity may contribute to the association's persistence, because the extended care-giving period and social behavior of dolphins constrains the speed of the dolphin schools in general to speeds sustainable by their young (Edwards 1992). This same speed is also most efficient for yellowfin tuna of the size associated with dolphins, and is also the speed tuna of that size choose to swim voluntarily in nature (Edwards 1992).

Purse-seine catches of yellowfin tuna associated with dolphins range in size from a few animals to many thousands; most purse-seine catches are on the order of 5-20 tons yellowfin tuna/set.

Recent studies of stomach contents of yellowfin tuna captured by the ETP tuna purse-seine fishery indicate that yellowfin tuna tend to feed more or less continuously throughout the day, and relatively little at night (Olson 1994, 1995). Epipelagic prey dominate their diet.

Tuna-Dolphin Association.

Habitat/Location/Timing. The association occurs in a roughly triangular area extending along the coasts of Central and South America from the tip of Baja California to mid-Peru (about 25° N to 15° S), and out to approximately 10° N x 140° W. Concentrations of tuna-dolphin sets occur especially frequently in a band along 10° N from about 115°-135° W, and along the Central American coast, a few hundred miles offshore (IATTC 1988).

Fishing tends to occur along the 10° N band only during the summer months when sea-states are acceptable (less than Beaufort 4 or 5). During other seasons, fishing occurs relatively closer to shore though still not particularly often in very near-coastal regions (Perkins and Edwards 1995).

Fishing occurs only during the day, from sunrise until late afternoon. Sets that extend past sundown tend to incur unacceptably high mortality of dolphins, and are avoided by the fishermen (these "sundown" sets are specifically illegal for U.S. vessels and for those countries participating in the IATTC's dolphin protection program).

Composition of Association. Commercial tuna vessels in the ETP generally choose to set on schools of about 300 or more dolphins (bigger dolphin herds tend to "carry" more fish) although the fishermen currently minimize the number of dolphins actually enclosed in the net. Fishermen currently attempt to encircle only those segments of the dolphin school that are associated with at least 5-10 tons of fish; smaller amounts of tuna generally are not worth the time required to make a set.

Feeding Behavior. The diets of associated tunas and dolphins overlap to some degree, although recent studies indicate that diet overlap is smaller than previously thought (Olson 1994, 1995). Stomach contents of tunas and dolphins collected from purse-seine sets made between 6AM and 6PM showed differences between the species. The dolphins rarely had fresh food in their stomachs except during the early morning. Recently-eaten prey and full stomachs (>50% full) decreased steadily in occurrence from sunrise to sunset, suggesting that spotted and spinner dolphins feed principally at night and/or early morning. The yellowfin tuna had fresh food in their stomachs at all times of day. Also, both dolphin and tuna stomachs contained epipelagic prey, but mesopelagic prey were more important than epipelagic prey in dolphin stomachs.

Tracking studies (Scott 1994) support the indications from the stomach content data that the tunas and dolphins, while exhibiting some overlap in prey, also exhibit distinct differences in day-night behaviors that correlate with the type of prey found in their stomachs. The deep diving at sunrise and sunset and diving patterns at night exhibited by the spotted dolphins is consistent with the possibility that the dolphins are feeding during this time on mesopelagic prey in the nightly-ascending deep scattering layer. The presence of yellowfin tuna above the thermocline during the day and at night is consistent with a habit of visual feeding primarily on epipelagic prey. Captain Medina noted that, in his fishing experience, tuna were frequently observed to feed during the day but dolphins were rarely observed doing so and appeared to be traveling slowly while the tuna were feeding.

Association Behavior: non-threatened. Observations of tuna-dolphin association behavior prior to apparent recognition of the presence of a purse-seiner (Au and Perryman 1982, Hewitt 1985, Scott 1994) indicate that associations travel relatively slowly at about 2-4 knots, mill about relatively randomly, or engage in apparent feeding behaviors. Associated tunas are rarely seen at the surface at this time unless actively feeding. Even from helicopters, the distribution and abundance of associated tuna is often difficult to assess because the fish tend to be submerged below effective visual range.

Association Behavior: perceived purse-seiner. The association's physical behavior changes dramatically when the dolphins become aware of the presence of a commercial purse-seiner or a low-flying helicopter. In areas where fishing has been common, dolphins first appear to react to the presence of seiner at a distance of about seven miles, probably in response to the vessel's propeller and engine noise (dolphin schools reportedly react to seiners but not to freighters). The dolphins tend to turn away from the seiner and start moving more rapidly. At a distance of about two miles, the seiner will slow from it's cruising speed of about 15 knots to less than 10 knots and 4-5 speedboats will be deployed. When the dolphins become aware of the speedboats, they begin to "run" and/or scatter. The speedboats attempt to herd the dolphins as quickly as possible, tiring them with a several minute sprint then slowing them down and grouping them by controlling their movements through appropriate positioning of the speedboats. The dolphins usually are not entirely stopped until they are encircled by the net. The fishermen often report often using the foamy wakes created by the speedboats and purse-seiner to restrain the dolphin's flight.

Simultaneously with the flight behavior of the dolphins, the associated tunas tend to become visible (from a helicopter) near the surface but below the dolphins. The "attraction" of the tunas by the dolphins appears to be strengthened significantly by the dolphin's flight behavior. Fishermen report that the "running" dolphin school appears to "bring the tuna up" (from their previously invisible presence submerged near the thermocline) and to cause the tuna to school relatively tightly around and just below the dolphins.

Frequently during chase, certain segments of the dolphin school attract more tuna than other segments. At this time, the "bond" is so strong that fishermen specifically work to encircle only those segments with sufficient tunas associated to make a set worth the trouble, because the tunas will tend to remain with that segment of dolphins to the exclusion of others[7].

The dolphins selected for encirclement (and by default their associated tunas) are then surrounded by the purse-seine, the net is closed at the bottom, and about two-thirds of the net is pursed before the back-down procedure begins. During backdown, the dolphins are removed from the far side of the net. Details of this procedure, and the behavior of tunas and dolphins within the

[7] This strengthening of the bond during dolphin school movement has also been reported by fishermen familiar with the tuna-dolphin association during the bait-fishing days, when tuna were caught individually by pole and line. In that fishing method, the tuna could be convinced to feed by liberally throwing bait-fish into a tuna-dolphin school. However, fishermen report that the method only worked as long as the dolphins remained nearby. Regardless of the amount of bait available, or the apparent "hunger" of the tunas, when the dolphins moved away from the vessel, the tuna would follow (Harold Medina, pers. Comm.).

net, can be found in the NRC report (1992) as well as in Pryor and Kang (1980) and Pryor and Kang-Shallenberger (1991).

PRACTICAL CONSTRAINTS ON TUNA-DOLPHIN RESEARCH

Constraints due to the Animals Involved

Dolphins. Research relying on captive spotted dolphins is largely impractical because spotted dolphins adapt poorly to life in aquaria. Even if their survival could be assured, expenses for maintaining captive animals are massive and obtaining the necessary research permits from NMFS' Office of Protected Resources is no simple task. In addition, behaviors of captive animals will not necessarily reflect accurately behaviors of animals in the wild.

Research relying on experiments or behavioral research in the wild also tends to be impractical both logistically and economically. The animals live tens to hundreds of miles offshore, occur in widely scattered schools in largely unpredictable locations, and feed on prey that cannot be captured readily or consistently with existing technology. While capturing the dolphins is obviously possible with commercial purse-seiners (e.g., DeBeer 1979, Scott 1994), it is impractical to imagine that the animals could be maintained within purse-seine nets for more than a few hours at a time and even then, only when seas are relatively calm and currents relatively slow. Research based on catch and release studies (e.g., tracking studies) are also feasible but are extremely difficult, expensive and time consuming. Extensive research using a Porpoise Impoundment System[8] during the Dedicated Vessel Cruises in 1979 found the device to be so unwieldy and dangerous that it has never been used again.

In addition, results from a single or just a few sets may not always reflect the typical behavior of the associated tunas and dolphins. Dolphin behaviors during chase and set differ between species and even between areas within species. Dolphins inexperienced in fishery chase and capture often approach boats relatively readily to ride the bow and stern waves, but in areas where fishing pressure has occurred the dolphins typically avoid any vessel sounding similar to a tuna seiner. Concentrated chase by as many as five speedboats to overtake and encircle the fleeing dolphins is now required to capture dolphin schools. Some schools in some areas have actually developed evasive behaviors (e.g., diving under the net before it can be pursed) that make capture unlikely or impossible. Fishermen generally avoid these "untouchable" schools.

While experiments or research on the more easily captured, inexperienced schools might be simpler to accomplish, the more difficult, fishery-experienced schools are set on much more frequently and so are much more relevant to the current fishery.

Interested researchers are advised to demonstrate a thorough understanding of these constraints and will be expected to provide detailed discussions of how these problems are to be practically overcome.

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[8] A chute-like device designed for physiological processing of individual dolphins inside the purse-seine.

Tuna. Research relying on captive large yellowfin tuna is also very difficult. There are currently (1996) only two research facilities with extant large yellowfin in tanks; The Tuna Research Conservation Center, associated with the Monterey Bay Aquarium and Stanford University's Hopkins Marine Station, and IATTC's facility in Achotines, Panama[9]. Both facilities are very costly and research opportunities are controlled by the Institutes' Directors. Interested parties should contact the Institute Directors directly prior to submitting a proposal. In addition, as mentioned for dolphins, behaviors of captive animals will not necessarily reflect typical behaviors of animals in the wild, except perhaps at the most basic physiological levels.

Research on large yellowfin tuna *in situ* is also hugely difficult due to the expenses involved and the difficulty in handling the fish. Live yellowfin tuna are very difficult to handle and to keep alive, with much mortality occurring between capture and acclimation in tanks. Simply locating the animals is no simple matter, as the fish tend to occur far offshore. Capturing, maintaining, and feeding these animals *in situ* is no less complicated. There are no research vessels capable of either capturing these fish or maintaining them in any sort of healthy state after capture. Capture by commercial purse-seiners, while possible, is extremely expensive, and again, these vessels have no facilities for maintaining live tuna in any sort of healthy condition for any useful length of time after capture (other than perhaps in the fish storage wells, if these could be suitably prepared). Again, interested researchers are advised to demonstrate a thorough understanding of these constraints and to provide detailed discussions of how these problems are to be practically overcome.

Tuna-Dolphin Association.

Location. Although there are areas with relatively more or fewer associations in general, the tuna-dolphin fishing area is enormous and locating these associations is not a simple task. Often several days will pass with no sightings at all. The maximum sighting rate rarely exceeds three associations per day, and sightings on the order of one per day are about the best than can be reasonably expected. Because commercial seiners rarely set on schools smaller than about 300 dolphins (Perkins and Edwards 1996), many fewer schools tend to be set on than are sighted. In addition, transit to and from the fishing grounds requires several days each way.

This relative rarity of detection, plus the time involved in chasing, setting upon, and releasing dolphins means that relatively few replicated experiments will be possible during any single trip or cruise, and that trips on the order of 3-4 weeks will likely be the minimum effective length. This is a serious constraint because ship charters are very costly (see Economic Constraints, below).

Response to Perceived Threat (purse-seiners, predation). The primary feature of the tuna-dolphin "bond" that must be considered in terms of separation/attraction research is the association's persistence in the face of chase and set by tuna purse-seiners. The impression of most fishermen familiar with the association is that the chase prior to set actually "strengthens" the bond. While associated tuna often cannot be seen from the helicopter or may be visible only as scattered animals prior to chase, the act of chasing and herding the dolphins apparently causes the tuna to coalesce and

[9] The National Marine Fisheries Service facility in Kewalo Basin, Hawaii, has been involved in yellowfin tuna research for many years, but only small yellowfin can be held routinely there.

to move closer to the surface, apparently in order to remain close to the dolphins. The noise and disturbance of the chase appears to actually tighten the bond, implying that any separation/attraction method seeking to divide the association through any sort of "fright" technique is not likely to work very well. Obviously, chasing the dolphins away is not going to work; the tunas will simply follow. Chasing the tunas away from the dolphins is not likely to work either, given that the tuna apparently prefer to tighten their association with dolphins during disturbance. This reaction of "bunching up" into tight aggregations of one or more species is a common alarm response among schooling animals.

Another factor that will have to be considered in future research is the possibility that it is only the chase prior to the set which can coalesce and focus the tuna sufficiently to be caught in commercial quantities. Fishermen discussing alternative techniques to locate and capture large yellowfin tuna in the ETP without encircling dolphins (Edwards et al. 1994) were seriously concerned about the schooling characteristics of un-associated large yellowfin. As these fish are difficult to locate without dolphins as cues, their spatial distribution or behavior in the absence of dolphins is unknown. Many ETP fishermen believe that without the dolphins to "gather" the tuna, there will be no way to "hold" subsurface large yellowfin long enough to set the purse-seine around them (Edwards et al. 1994). For example, sets on "schoolfish" tuna that are not associated with dolphins or floating objects are only successful about 50% of the time; in contrast, dolphin sets and log sets are about 90% successful.

Physical Constraints

Constraints due to Habitat/Location. Physical constraints on tuna-dolphin research *in situ* are enormous. The study area comprises about 6 million square miles and the likelihood of locating tuna-dolphin aggregations is quite variable (even areas of relatively dense tuna-dolphin aggregations average only 2-3 sightings/day), changing with time of day, season, location, and any number of other unidentified factors.

Constraints on Research Platforms. Research *in situ* will require a research platform consisting of either vessels or aircraft. Aircraft would have to be capable of sustained flights several hundred miles offshore, would only be useful for observations, and would only be useful under benign environmental conditions. Vessels capable of working in the ETP environment would have to be large enough to sustain several weeks of absence from port.

Two types of vessel platform are possible; NMFS or university scientific research vessels and commercial tuna purse-seiners. Scientific research vessels generally have little time or space available for non-NMFS or university research and do not have any capacity for capturing or subsequently maintaining groups of large yellowfin tunas or dolphins. A temporary holding facility might conceivably be constructed, but it would have to be large, sturdy and not likely to endanger the stability of the vessel.

Large commercial purse-seiners are required to actually capture the animals. However, commercial purse-seiners, while occasionally willing to accommodate limited scientific experiments on a "not to interfere" basis, generally have no space or facilities available to accommodate scientific equipment or personnel, nor have they any facilities for maintaining animals post-capture (although on a charter basis, it might be possible to maintain large yellowfin in the storage wells).

In addition, research conducted on an opportunistic basis during tuna purse-seining operations has often been unsatisfactory because such research is usually possible only on a "not to interfere" basis. Commercial fishing operations take precedence in these cases with the result that research opportunities must be often eliminated or curtailed unexpectedly.

Trips to the fishing grounds generally take several days, and fishing operations generally consume several weeks, so that extended periods at sea are required.

In combination, these constraints severely limit the number of replicate experiments that might be conducted to investigate any suggested approach. This constraint on replication in turn severely limits any ability to determine the statistical variability and thus the scientific value associated with any results obtained.

Economic Constraints

Obviously, given the size of the study area, it's remote location, and the size and behaviors of the animals themselves, economic constraints on tuna-dolphin bond research are formidable. Purse-seiner charters for example, while possible, are extremely expensive. During 1992 a 30-day charter of a commercial seiner cost approximately $600,000. This covered only the vessel. Costs for research personnel and equipment during this cruise added an additional several hundred thousand dollars. Research vessels or aircraft of the size needed to work effectively in the remote environment of the ETP tuna purse-seine fishery will be similar in expense.

As stated repeatedly above, interested researchers will need to demonstrate a thorough understanding of these constraints and to provide detailed discussions of how these problems are to be practically overcome.

COMMENTS ON EXISTING PROPOSALS -

Many of the proposals received to date by the Dolphin-Safe Research Program have been quite similar so the proposals tend to fall into general categories. Rather than specifically identify any particular proposal, the general ideas and comments on those ideas are offered below in order to help future researchers avoid problems not foreseen in earlier work.

Acoustic Methods

An idea common to many proposals is that the tuna-dolphin association, and/or its components, can be controlled in some way by sound; either to lure or scare one component of the association away from the other. This does not appear likely to work, given the relatively extensive available literature and existing knowledge base about the acoustic abilities and characteristics of large yellowfin tuna and ETP dolphins, and given the lack of results from the relatively large number of preliminary attempts that have been made in this area. However, there is to date no solid quantitative evidence either supporting or refuting the idea that the tuna-dolphin association is in any way controlled by acoustics. Visual and perhaps olfactory cues may be at least as important, although no evidence exists supporting or refuting these possibilities either.

Some basic acoustic characteristics of the ETP tuna purse-seine fishing system are known and should be taken into consideration; these are summarized below. In addition, interested researchers should be thoroughly familiar with the large amount of information on marine mammals and ocean acoustics that has recently become available as a result of the large scale ocean temperature measuring experiment being conducted by Scripps Institute of Oceanography (the ATOC Program: Acoustic Tomography of Ocean Climate).

Technical considerations. The technical difficulties of working with acoustic systems at sea must be recognized. Even passive listening experiments, for example to characterize sounds emitted by tunas and/or dolphins, are not simple. Even single sonabouys need careful attention to remain in working order; listening arrays involving strings of hydrophones are considerably more complicated to deploy and maintain (e.g., Thomas et al. 1982).

Another aspect of acoustic-based separation/attraction methods that has yet to receive attention is the amount of power that would be required to ensonify a sufficient area of the ocean in order to elicit consistent responses from either tunas or dolphins. That acoustic requirement has never been calculated or estimated by any proposal to date, but it will be considerable given both the size of the areas involved and the ambient noise levels, particularly in proximity to a purse-seiner, a net boat (300-hp skiff), and up to 5 speedboats with large (noisy) outboard motors. For example, even if the acoustic signal did not have to project very far, it would still have to be louder than or discernibly different from vessel, outboard, or ambient ocean noise.

Playback acoustic experiments. Given their apparent dependence on acoustics, dolphins would appear to be more likely candidates than tuna for acoustic playback experiments, e.g., of potential predators such as killer whales. However, playback experiments, particularly *in situ*, are very difficult to design, execute, and interpret. Even in controlled laboratory-experiments, it is often difficult to interpret or relate an animal's actions in terms of acoustic signals generated and/or received. Future work in this area will have to address these issues, in addition to the major issue of alarm responses to perceived threats.

Acoustic signatures of yellowfin tuna and/or ETP dolphins, using captive and/or trained animals. Proposals to determine acoustic signatures of the association or its components using captive or trained dolphins have so far failed to recognize or acknowledge constraints on experiments with captive animals either in the laboratory or at sea (see section on Constraints, this report). In addition, there has been a failure to demonstrate how knowledge of such signatures could be used to manipulate the tuna-dolphin bond.

Acoustic deterrent systems. Various researchers have proposed to use sound in one way or another to control/break the tuna-dolphin bond. For example, an undefined acoustic device has been suggested that would create a "wall of sound" to separate the tunas and dolphins such that tunas would swim into net and dolphins would swim away. These proposals fail to cite any theory or body of knowledge that suggests tuna (or dolphins) might respond in the desired way, or in any way at all. In particular, proposals to control dolphin behavior with transmitted sounds of various sorts, e.g., proposals to "acoustically deter" (i.e., frighten) the dolphins, fail to recognize the apparent strengthening of the tuna-dolphin bond that occurs when dolphin herds begin to run. In addition, at least one proposal, suggesting that a "cigarette-case sized" acoustic deterrent could be developed, obviously failed to consider the power that would be required to sufficiently ensonify the ocean volume occupied by dolphins.

Many of these proposals have also inappropriately proposed to use computer modeling to determine behavioral responses of tuna. This can't be done effectively on a computer: live fish are required. However, proposals for behavioral research on yellowfin tuna have failed to recognize or acknowledge the considerable constraints on experiments with captive animals either in the laboratory or at sea (see section on Constraints, this report). In addition, few of these proposals have indicated any knowledge of the considerable amount of information already available on tuna and dolphin physiology, behavior, and acoustics.

Acoustic lure systems. Proposals to acoustically lure either tunas away from dolphins, or dolphins away from tuna, again fail to recognize the apparent strengthening of the bond that occurs under stressful conditions. Proposals also fail to demonstrate any knowledge of previous unsuccessful attempts to control fish or dolphin behavior with acoustic lures. For example, baitboat fishermen report that chumming separated tunas from dolphins only briefly, if at all. A researcher proposing to lure the tuna away from the dolphins will have to explain why the "lure" (usually a proxy for food) would be successful when real food items weren't.

Tuna and Dolphin Acoustics. Tuna hearing occurs in the range about 1 kHz. It is not very sensitive and at this low frequency will not be effective at sensing the dolphin's high frequency (4-20 kHz) whistles.

Ocean Acoustics. The oceanic environment is naturally characterized by a considerable amount of low frequency acoustic energy (50-150 Hz). Interested researchers should also show familiarity with several recent contract reports discussing acoustic signal propagation and yellowfin tuna school target strengths (Rees 1996, Nero 1996).

Vessel Acoustics. Tuna vessel engines generate low frequency sound, in the range of natural ocean noise (50-500 Hz). Speedboats generate quite a bit of local acoustic energy which falls within in the upper range of much dolphin signaling (15-20 kHz).

Gear Changes

Buoy System. Proposals suggesting that buoys be attached to the top edge of purse-seine so that the top edge could be lowered, allowing dolphins to swim out while tuna remain inside. Proposals have assumed, incorrectly, that dolphins are always spatially separated from tuna inside the purse-seine, and that separation is vertical. This assumption is critical, otherwise tuna near the surface will escape and deep-diving dolphins will die; however, tracking data and underwater observations all contradict this assumption. Potential problems with this suggestion include an increase in set time (to adjust buoys), a proposed method that is similar to, but less efficient than, the current backdown maneuver, an increased probability of net collapse, and dependence on un-demonstrated ability to herd dolphins in net. Researchers interested in variations of this techniques will need first to familiarize themselves with Pryor and Kang (1980) and Pryor and Kang-Shallenberger (1991), and with the current backdown procedure.

Net Submergence System. Suggests submerging entire net several meters below the surface, to allow the dolphins to escape. See comments on Buoy System.

Drop Net. Various permutations of suggestions to use a helicopter to drop cylindrical nets on various animals, sometimes tuna, sometimes dolphins, sometimes bycatch. Obvious problems include: ability of all animals to evade net, animal responses to helicopter disturbance, danger to personnel involved, inefficiency in number of animals that could be transferred, obvious lack of understanding of fish or marine mammal behavior, expense of equipment, dependence on benign environmental conditions, etc.

Dolphin Escape Hatch. These proposals offer various permutations of the idea that a hole of some sort will be created in the purse-seine, through which the dolphins will escape. Such suggestions ignore common knowledge of ETP dolphin's reluctance/refusal to voluntarily swim through any opening less than tens of feet wide, perhaps due to an evolutionary history largely without experience of walls.

Return to Baitfishing. Proposals to use acoustics to locate and track dolphin schools, then catch associated tuna with pole and line, and flash freeze the product for late sale as high quality fish. Does not address potential problems of availability and maintenance of bait, dolphins fleeing vessel, economic cost/benefit of introducing a new fishing method to the ETP, or economic probability of successful and expensive purse-seiner fleet moving to a much less productive fishing method.

In addition, the economic circumstances that may allow a few modernized baitboats to be profitable (i.e., secure high prices for restaurant quality fish) would disappear if the purse-seine fishery completely switched to a baitboat fishery. Such a switch would create a greater supply of fish on the market and cause prices to drop, making the new fishery less profitable.

Net Depression. Proposals to use lines to lower the far end of the net, with speedboats chasing the dolphins over the lowered area. Not a safe or effective improvement over the current backdown technique for either dolphins or fishermen.

Dividing the Purse-Seine. Suggestions to separate the tunas and dolphins once both have been encircled in the purse-seine, by dividing the net either vertically or horizontally. However, Pryor and Kang (1980) and Pryor and Kang Shallenberger (1991) observed that tunas and dolphins occupy all sectors of the purse-seine during most of the set, until the backdown procedure, and thus could not be separated either vertically or horizontally.

Mechanical separation using alternative gear (e.g., pair trawling). Capture devices other than purse-seines are generally not going to capture enough tuna to be economically competitive with current purse-seine procedures. One method has been proposed that might compete successfully with purse-seining on an economic basis, i.e., pair trawling, but it is not clear that the method would reduce dolphin mortality below current levels, or increase tuna production measurably (Edwards et al. 1994). The primary problem in terms of dolphin mortality is that the vertical separation between the tunas and dolphins is quite variable with time, so that the potential for dolphins inadvertently diving into the oncoming trawl is high.

Feeding (Olfactory Lure) Methods

Separation/attraction methods based on food do not appear very promising primarily because food-based separation/attraction methods would likely be effective only prior to perception of the tuna vessel by the dolphins. As detailed more thoroughly earlier in this report, it appears that any perceived threat simply strengthens the tuna-dolphin bond, virtually insuring that the tuna will go where the dolphin go regardless of the food supplies available.

Luring the dolphins away from the tuna with food is unlikely, given the 1) elusive behavior that purse-seine vessels evoke in dolphins, and 2) the observed propensity for tunas to follow the dolphins, even in preference to remaining in an area where food is being presented.

Luring the tunas away from the dolphins with food is also unlikely, also given 1 and 2 above. While some experiments have elicited cue-feeding by tunas in the laboratory (e.g., Ikehara and Bardach 1981), no such experiments have been successful for tuna in the wild or in purse-seines. Chemical attractants directed at inducing/controlling movements of tuna were tested *in situ* in the ETP during 1979 (Bratten et al. 1979, Ikehara and Bardach 1981 and again in 1992[10]. No consistent or conclusive responses were observed in either case. No attempts have been made to lure or otherwise control dolphin movements using chemical signals.

The obvious question is: even if tuna could be effectively lured away from dolphins with food, how would it be possible to get close enough to the tuna to lure them into a purse-seine without at some point alarming the dolphins and tightening rather than loosening the bond?

Electrical Methods

Electrical separation of tuna and dolphins during backdown. Proposals to date fail to indicate familiarity with previous studies of tuna and dolphin behavior in the net (e.g., Bratten et al. 1979, Pryor and Kang 1980, Pryor and Kang-Shallenberger 1991, Young and Armstrong 1992). Proposes a system that would be extremely dangerous to the fishermen and economically impractical in terms of the electrical power required. Proposal also assumes without substantiation that desired responses to electrical field will be elicited from both tunas and dolphins.

[10] Repeated attempts during 1992 and 1993 tracking cruises to capture large yellowfin tuna (for subsequent tagging) inside the purse-seine with baited hooks consistently failed. Few fish showed any evidence of interest. Only two strikes were felt on the handlines; no fish took the bait.

CRITERIA FOR FUTURE RESEARCH PROPOSALS

Relationship to Current Methodology

Under current practice, dolphin mortality is less than 0.5 dolphins per set, dolphin release takes approximately 15 minutes with very little or no injury to the dolphins, usually few or no tuna are lost during dolphin release, danger to fishermen is significant but controllable, and an entire set sequence usually takes no more than a couple of hours. These performance characteristics of the existing fishery "on dolphins" will have to be at least matched, and realistically bettered, for any new method to become accepted as a significant improvement over current practices in reducing dolphin mortality while capturing commercial quantities of tuna. Any new method will have to (1) kill or injure fewer dolphins, (2) take no more time per set than current methods, (3) lose no greater amount of fish, (4) improve safety for fishermen, and (5) be practical in terms of the behavioral, physical, and economic constraints of the ETP tuna-purse fishery, yellowfin tuna, and ETP dolphins.

Criteria

Based on the preceding information, workshop participants agreed that future proposals for research related to the tuna-dolphin bond in the ETP must demonstrate or include:

1. A thorough knowledge of tuna fishing conditions and constraints.

2. A thorough appreciation for the difficulties associated with research *in situ*, i.e., in the ETP as opposed to a laboratory environment.

3. A solid theoretical basis for the proposed research and clear hypothesis to be tested.

4. A complete review of relevant past research and a discussion of how the present proposal will accommodate the findings of that previous research. Ignorance of past research will automatically disqualify a proposal.

5. The basis for assuming, where applicable, that, e.g.:

   a. Schooling fish can be "lured"
   b. Various nets are functional and can catch large numbers of large, moving fish
   c. The tuna/dolphin "bond" can be manipulated
   d. Trained dolphins will work in the ETP under fishing conditions
   e. Results from non-ETP dolphins (and/or tuna) are applicable to the ETP
   f. Listening devices can detect and discriminate tuna
   g. Tuna or dolphins can be directed or controlled with electrical, chemical, or acoustic signals.

6. A clear statement of methods and why they should work.

Vague statements about research protocols are not acceptable. Proposals of "computer models", and "engineering research" must be detailed and supported by convincing evidence that they can work. Speculations with no body of knowledge to support them are not acceptable. The same is true for "engineering designs" with no underlying design concept.

Proposals for acoustical research must demonstrate an understanding of the practical constraints associated with the ETP fishing system, e.g., the signal power required to ensonify a huge piece of deep ocean and or the acoustic environments generated by large tuna purse-seiners and/or large herds of dolphins. Proposals must also state clearly the responses that will be investigated to produce a definitive result;, i.e., what will be measured that will (or will not) indicate whether the method works, and what results will cause a null hypothesis to be rejected at a given statistical power.

Proposals to record, analyze, and categorize dolphin sounds in the ETP and associate them with specific behaviors must show how the proposed study can succeed given decades of failed attempts to do the same in captivity.

Proposals to acquire more detailed knowledge of the sensory abilities of tunas and/or dolphins must review the current, relatively advanced state of knowledge about these systems, and provide a practical theory based on this knowledge that can be applied in the proposed circumstance to separate tunas from dolphins.

Proposals for feasibility studies or literature searches will not be considered; preliminary research is the responsibility of the interested researcher. The National Research Council (NRC) report, "Dolphins and the Tuna Industry" (National Academy Press, Washington, D.C., 1992), is required reading. Proposals demonstrating ignorance of the contents of this book will not be considered.

Proposals must also acknowledge the constraints peculiar to the tuna-dolphin fishing system in the ETP (e.g., vessel size, vessel acoustics, costs of equipment, availability of research or commercial platforms, etc) and address clearly how these constraints will be overcome.

Additional references that may contain useful information for some research proposals include Edwards (1996), Moore (1990), Myrick et al. (1986), Oliver and Edwards (in prep)[11], Rivers (1982), Scott (1991), and Stunz (1981).

Suggested Future Research Emphasis

Although much is known about the sensory systems of both dolphins and tuna, nothing about these systems suggests a simple and effective method for altering the tuna-dolphin association. Future focus on tuna rather than dolphins might be more productive, given the relatively simpler physiological and neurological systems of fish compared to mammals. Some insights might arise

[11] Oliver, C. And E. F. Edwards. In prep. Dolphin Safe Research Program: Progress Report II (1992-1996). Southwest Fisheries Science Center Administrative Report LJ-96-00.

from study of repeated video recordings obtained from helicopters, of dolphin and tuna activities prior to and during sets; at least these data would be relatively inexpensive to collect.

Overall, neither the research conducted to date, nor our current understanding of dolphins, tunas, and their associations, have led to any cost-effective, practical solutions for completely eliminating fishery-induced dolphin mortality. Future proposals demonstrating a solid understanding of the problem coupled with innovative and insightful proposals for effective research will be extremely welcome.

SUMMARY

An important point to remember in designing future studies is that the current state of the dolphin fishery is essentially the result of a thirty-year field experiment with approximately 10,000 replicate set experiments (statistical samples) per year. Alternative methods will have to demonstrate a strong potential to improve on the current situation.

Although current studies on tracking and food habits are advancing our understanding of the association, the basis of the unusually strong bond between dolphin and tuna in the ETP is still in question. Future research efforts may lead to methods that could "break" the bond sufficiently to allow capture of previously associated yellowfin without encircling or endangering dolphins, but testing and implementing these methods will be neither simple nor inexpensive.

Current understanding of the physiology, behavior, and ecology of the animals involved, and of the physical and economic constraints on practical research alternatives, does not provide any particularly encouraging future foci.

Future research efforts will have to more clearly and directly acknowledge and address these constraints, in order to be effective. Future work related to altering or controlling tuna behavior is probably more promising that attempts to control or alter dolphin behavior, but in either case, innovative and insightful approaches to the problem will be necessary to achieve progress.

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APPENDIX II: AGENDA

SEPARATION/ATTRACTION WORKSHOP
Dolphin-Safe Research Program
Southwest Fisheries Science Center
La Jolla, CA

September 20, 1995
9:00 A.M.- 5:00 P.M.
Large Conference Room

Objective: Evaluate practicality of further research into Separation/Attraction methods for eliminating dolphins from purse-seine sets on tuna-dolphin aggregations in the ETP.

Product: Handbook of Considerations and Recommendations for future research into developing PRACTICAL separation/attraction methods for eliminating dolphins from purse-seine sets on tuna-dolphin aggregations in the ETP.

AGENDA

9:00 A. M. Introductions and Review of Objective

9:15 A. M. Review and discuss proposals received to date, to aid in developing a list of factors, constraints, criteria, etc, that will have to be considered when trying to develop a PRACTICAL separation/attraction method for capturing dolphin-associated tuna without encircling the dolphins.

We will begin with these reviews in order to familiarize workshop participants with the level of understanding of the tuna-dolphin problem exhibited by most proposals, and to organize our thoughts about the types of information that should be included in the Handbook.

11:00 A.M. Develop a description of a "typical set sequence" scenario; i.e., a description of what typically occurs before and during a set on associated tunas and dolphins.

The purpose here is to provide future researchers with a description of the characteristics of dolphin-fishing, including details of animal behavior, school sizes and behavior, weather (e.g., wave heights, glare, etc), gear/equipment design (e.g., speed boat numbers and sizes, net skiff procedures and characteristics, length of time to set net, net size, vessel size, helo characteristics, etc etc.)

12:00 - 12:30 Lunch

12:30 P. M. Continue with "typical set scenario"

3:00 P. M. Review information/recommendations/considerations that have accumulated during the day, add any additional items or delete any that the group feels are irrelevant or extraneous, and discuss the potential for PRACTICAL solutions in the future.