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REPORT OF THE 2nd WORKSHOP ON BYCATCH REDUCTION IN THE ETP PURSE-SEINE FISHERY

by

Jessica Kondel and Jeremy Rusin

ADMINISTRATIVE REPORT LJ-07-04

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Report of the 2nd Workshop
on Bycatch Reduction in the ETP Purse-Seine Fishery
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Background

Purse-seine fisheries for tunas in the eastern tropical Pacific Ocean (ETP) utilize three techniques to catch tuna: dolphin fishing, school fishing, and fishing on floating objects (primarily fish aggregating devices – FADs), each of which has significant differences in area, production, and size and composition of target catch and bycatch. Of the three, FAD-fishing is estimated to generate the largest amount of bycatch of many species, including sharks, sea turtles, mahi mahi, wahoo and small individuals of the target tuna species. Skipjack tuna compose the greatest amount of the bycatch of targeted tuna species. The distribution of bycatch varies both temporally and spatially. The least sustainable bycatch in floating object sets is believed to be sea turtles, small bigeye tuna, and silky and oceanic whitetip sharks. However, as there are no stock assessments for most of these species, the significance of the bycatch is not generally known either from the point of view of the stock or the ecosystem.

Improvements in the identification and estimation of bycatch are currently underway in this fishery. Data on bycatch are collected by observers on board purse-seine vessels and maintained by the Inter-American Tropical Tuna Commission (IATTC) and the participating national observer programs. While observers are on board 100% of the trips made by Class-6 purse-seine vessels (>400 short tons; 363 metric tons carrying capacity) in the ETP, observers are not required on the trips made by smaller size-class vessels. As a result, it is unknown if bycatches of smaller vessels are comparable. Several methods for obtaining better information on the fishing practices of small vessels, including on-board observers and video monitoring systems, have been discussed at meetings of the IATTC and the Parties to the Agreement on the International Dolphin Conservation Program. However, consensus has not been reached on this issue due to the financial costs and other tradeoffs associated with at-sea monitoring.

In response to direction from Congress, the Protected Resources Division of the Southwest Fisheries Science Center (SWFSC) consulted with the IATTC with the aim of funding a number of projects designed to conduct research on the "development of alternative gear for reducing bycatch of dolphins, turtles and other species in the ETP." The SWFSC, in coordination with the IATTC, conducted a bycatch reduction workshop in 2005 to examine a suite of promising research proposals and identify three or four which would then be forwarded for review and evaluation at a second workshop composed of a larger group of panelists, each an expert in some aspect of the proposed research. Results of this workshop were summarized by Archer.[1]

Participants at the first workshop identified three proposals as having the greatest potential conservation benefit and being the most cost effective. These proposals included: 1) Modifications to the design of FADs to reduce turtle entanglement, 2) Reducing incidental capture of sharks through use of bait and/or deterrents, and 3) Ecological approaches to bycatch reduction using fisheries data. A fourth proposal that combines a number of proposals requiring ship time discussed at the first workshop was also prepared in advance of the second workshop. During this workshop, NMFS interpreted the development of alternative fishing techniques for reducing bycatch in this fishery as consistent with the stated Congressional intent of developing alternative gear for the same purpose. As a result, not all proposals selected for further discussion at a second workshop focused on gear modifications.

The Southwest Regional Office (SWR) along with the SWFSC and IATTC convened this second workshop with a panel of experts to conduct a technical review of the four formal research proposals. The panelists were asked to flesh out the proposals and provide input on how to proceed with each proposal

[1] Archer, F. 2005. Report of the ETP Purse-Seine Bycatch Reduction Workshop. SWFSC Admin. Rpt. LJ-05-07. 29 p.

should funding become available to pursue the proposed research. A complete participant list from the second workshop is included in Appendix I.

Proposal Evaluation

Technical experts and other workshop participants evaluated the strengths and weaknesses of each proposal in their particular areas of expertise. Specifically, the panelists were asked to consider the following criteria when evaluating each of the proposals:

- Project design
- Feasibility
- Cost-effectiveness
- Relevance
- Acceptability to the fishing fleet
- Need for additional data

Several participants argued against including "cost-effectiveness" in their evaluations, preferring instead to focus first on the scientific merit and conservation benefits to the research. It was argued that the cost of a project should be considered later by fisheries managers in light of available resources.

Summary of Proposals

Four formal research proposals were prepared based on recommendations from the first workshop (see Appendix II for the full proposals). The goal of each proposal was to either avoid the capture of non-target species or to facilitate their release from the net or deck. All four proposals were generated based on the results and discussions of the first bycatch workshop.

Proposal 1: *Modifications to the design of FADs to reduce turtle entanglement*

On-board observers in the ETP tuna purse-seine fishery record turtle entanglements in the net webbing that is attached under FADs in many common

FAD designs. However, the mortality resulting from this entanglement is difficult to estimate and not known with certainty for a number of reasons.[2] Further, existing IATTC bycatch reduction resolutions do not mandate measures to eliminate entanglements or this source of turtle mortality. A variety of FAD designs including hanging ropes, nylon strips, "McIntosh kites," and "Spanish socks" were proposed as a replacement for the webbing in a typical FAD. Appendix III provides examples of these designs. Captive tests and field tests would be conducted to determine whether a) the experimental FAD design reduces or eliminates turtle entanglement, b) the tuna catch from the experimental design is not affected relative to that using the control FAD, c) the experimental FADs are as durable as the control FAD, and d) the experimental FADs are comparable in ease of deployment relative to control FADs.

Proposal 2: *Reducing incidental capture of sharks through use of bait and/or deterrents*

Bycatches in FAD sets include relatively slow-reproducing species such as sharks, billfish, and sea turtles. In the ETP, silky sharks in particular have been associated with the purse-seine fishery and have been taken in large numbers. Observations on board purse seine vessels indicate that once sharks are encircled during the set and "sacked up," their mortality may be very high due to compression and/or hypoxia. Therefore, an effective bycatch reduction measure for sharks in this fishery would have to eliminate or reduce the number of sharks within the net compass. Attracting the sharks away from the FAD before the set is made has been proposed as a way to reduce the incidental capture and mortality of sharks. Testing bait stations and other attractants in the field would allow for evaluation of the effectiveness of this technique in moving sharks away from FADs and subsequently reducing shark bycatch. Another important component of field trials will be to observe whether tuna are also attracted to the bait stations and lured away from the FAD as an unintended consequence.

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[2] IATTC. 2004. Interactions of sea turtles with tuna fisheries, and other impacts on turtle populations. Presented at the 4th Meeting of the IATTC Working Group on Bycatch, January 14-16, 2004, Kobe, Japan. Document BYC-4-05a. 8p.

Proposal 3: *Ecological Approaches to Bycatch Reduction using Fisheries Data*

The IATTC has been collecting observer data on tuna catches and the associated bycatch from purse seine sets in the ETP for many years. Fisheries data offer an opportunity to look for spatial and temporal patterns in the bycatch associated with FAD sets. By using fundamental environmental variables (*e.g.*, sea surface temperature, mixed layer depth) as well as other data collected by IATTC observers (such as catch and bycatch species composition and abundance, and FAD characteristics) key factors could be identified which could be used to predict likely bycatch in FAD sets.

Proposal 4: *Field Trials for a Suite of Potential Bycatch Reduction Devices and Techniques*

A number of methods to reduce bycatch in tuna purse-seine sets on FADs were discussed at the first workshop. Many of these methods would require field trials on a commercial fishing vessel to allow for an approach which most closely mirrors actual implementation of bycatch reduction efforts, offers the opportunity to fine-tune practical approaches based on direct observations, and enables commercial fishermen to be actively engaged in solutions for addressing the problem. Field experiments would include tests of FAD modifications and manipulations, observations of behavioral and physiological indicators of stress, and a comparison of technologies for removing bycatch from the seine or deck with minimal post-release mortality.

Discussion of Proposals

The workshop participants were asked to consider each of the four proposals individually in terms of the evaluation criteria previously mentioned. A primary goal of the workshop was to determine how best to proceed with each of these four research areas should funding become available. The discussions are summarized below.

Discussion of Proposal 1: *Modifications to the design of FADs to reduce turtle entanglement*

Under this proposal a pilot program would be instituted to compare the sea turtle entanglement rates of experimental FAD designs with control FADs with net webbing hanging into the water column. Out of the four types of experimental FAD designs (ropes, kites, nylon strips, and "Spanish sock") the rope design seemed most feasible because it is easy to construct and the materials would be readily available to most fishermen. Although some concerns were raised that ropes may entangle other animals depending on the spacing of the ropes and the tautness. Using bamboo or straight poles in place of the ropes may reduce the likelihood of entanglement of all species. The use of nylon strips instead of webbing has been used around Hawaii on anchored FADs. This design has not been tested on drifting FADs used by fisherman in the ETP. "McIntosh kites" have undergone some field testing but have not been as durable as some of the other designs. The "Spanish sock" design has had limited field testing. Both the "McIntosh kites" and "Spanish socks" are constructed of materials that are more expensive and are not always readily available to fishermen.

Some members of the group thought any experimental FAD design should first be tested in a controlled environment to observe the sea turtle behavior around the FAD and to ensure that the turtle does not become entangled. Without captive observations, this research would likely suffer from a low sample size (number of entanglements) and an unknown number of turtle encounters with experimental FADs. However, the lack of accessibility to captive turtles and efforts needed to acquire the required permits could make testing the designs difficult.

The focus of this proposal was to design a FAD that would reduce sea turtle entanglement, although it may be more effective to broaden the structure of the proposal to determine how to design a better FAD. In order for a FAD design to be effective, participants agreed that it must meet certain criteria: 1) avoidance of unintended animal entanglement, 2) construction with low-cost materials available to fisherman, 3) easy deployment, 4) avoidance of catch loss, and 5) reduced aggregation and bycatch of other species.

In order to promote any alternate FAD design, workshop participants agreed on the importance of consulting with the fishermen who will be deploying them, noting that fishermen have first-hand knowledge about the fishery and any new FAD designs will only be effective if the fishermen will use them. It was suggested that the ETP Captain's Workshops conducted by the IATTC could be a good avenue for getting the fishermen involved in the FAD design process. Ideas on FAD designs could be developed and presented at the workshops for evaluation and further development by the fishermen. IATTC staff indicated they would discuss and evaluate this idea further.

Workshop participants emphasized the importance of field testing FADs once several experimental designs have been established. This proposal presents a controlled experiment, testing control FADs with webbing underneath along with experimental FADs, to compare the performance of different designs relative to decreasing entanglement of sea turtles and maintaining or increasing the catches of tunas. One idea, for which there was significant support, was planting a number of experimental FADs in the ETP and encouraging fishermen to fish them at will after being notified of their location and radio frequency. Because all Class-6 purse seiners must carry an observer, data from each set would be provided through the observer records for the trip. Those FAD designs to which tuna are most attracted will be most fished upon and gain acceptance among the fleet. However, achieving a sufficient sample size of observations from the experimental and control FADs was thought to pose a problem in this project design relative to turtle entanglements; IATTC data from 2003-2005 show only 1.7% of FADs sighted had a sea turtle entangled. Therefore, it may be difficult to observe enough FADs to detect a significant statistical difference between the control and experimental FAD designs relative to the turtle entanglement question. However, if information about turtle behavior and entanglement can be made first in a captive setting, then several useful field observations about the experimental designs, their effectiveness in attracting/retaining tuna in the FAD aggregation, and the durability of each FAD design will still be possible.

Discussion of Proposal 2: *Reducing incidental capture of sharks through use of bait and/or deterrents*

The objective of this proposal is to use bait stations equipped with transducers emitting sounds to show whether sharks can be attracted away from a FAD prior to a purse-seine set and thus reduce bycatch. The success of this proposal depends on the effectiveness of the bait stations in attracting sharks associated with the FAD, while not attracting tuna. It was suggested that a plausible approach would be to start with a bait station near the FAD and drag it away slowly using a speedboat. Observations could then be made on whether or not the sharks are following the bait station. Visual and side-scan sonar observations could be used to track the concentration of sharks and tunas around the FAD and the bait station.

The most feasible way to conduct this study would be to accompany a purse seiner during a fishing trip. This proposal assumes that the vessel's owner and crew would be willing to cooperate on a voluntary basis and that the fishermen would be willing to bait the sharks away from the FAD to reduce their capture. However, some observer and anecdotal information indicates that fishermen prefer to retain sharks to supplement their income. Therefore, there is some uncertainty as to whether fishermen would be willing to sacrifice some income to reduce shark bycatch in the fishery and whether some captures of sharks should be considered directed catch rather than incidental bycatch. It was suggested that the possibility of future management actions to limit bycatch may promote cooperation in developing methods to reduce shark mortality.

Also, consideration must be given to how deploying and towing bait stations might impact normal fishing operations and the catch of tunas. It is important that the experimental design is set up in such a way that the observer makes consistent observations and records the same information for every set. Workshop participants indicated that conducting this type of simple study would be an important first priority. If this simple approach of attracting the sharks away from the FAD appears to be feasible, then a wider study to statistically compare experimental and control sets can be conducted. Additional studies could also include telemetric tracking of sharks and testing shark repellants in and around the net to determine if this would also reduce bycatch.

Participants suggested that conducting a literature review on shark behavior and responses to sensory stimuli such as sound, bait, and olfaction may also enhance this study. In addition, an equivalent literature review on the responses of tuna to these stimuli should be considered to ensure that the study is designed in such a way to ensure that sharks are taken out of the net while tuna are retained. It was pointed out, however, that such reviews have already been done by some of the experts in the workshop and could therefore be accessed rapidly.

Consideration was also given as to whether assessing the condition and stress levels of sharks brought on board would help to determine the survivability of the sharks. Thus, effort could be made to release the sharks which had the best chance of survival. However, it was ultimately agreed that the first priority should be avoiding the capture of sharks in purse-seine sets made around FADs.

Discussion of Proposal 3: *Ecological Approaches to Bycatch Reduction using Fisheries Data*

The IATTC maintains a database with data collected from every Class-6 purse-seiner in the ETP. The aim of this proposal is to use these data to determine if environmental factors can be used to predict bycatch in FAD sets. This proposal was considered by the participants at the first workshop and considered to be a cost-effective proposal because the data already exist and the results of this analysis might answer some of the basic questions related to the bycatch issue.

The IATTC maintains this data set and its staff analyze these data. The data are collected under the auspices of the international program and its member nations. Because of this, the IATTC Bycatch Working Group would have to be consulted before the fisheries data could be used by outside scientists in this or any similar study. IATTC scientists are collaborating with scientists from other institutions (*e.g.*, University of Washington and Duke University) and have been evaluating these data for many decades. For these reasons and because some questions raised in the proposal may already have been addressed, it was decided that the best approach would be for a subset of participants from this workshop to work with IATTC staff to develop a list of potential questions related to bycatch issues in FAD sets. The results from the sub-group could be presented to the IATTC Bycatch Working Group for consideration and potential approval for further study.

Discussion of Proposal 4: *Field Trials for a Suite of Potential Bycatch Reduction Devices and Techniques*

This proposal involves using a commercial purse seine vessel to test various gear modifications, devices, fishing strategies, and fishing practices to determine if they are effective at reducing bycatch in tuna purse-seine sets on FADs. This proposal includes many different components in an effort to maximize the use of the time aboard a contracted commercial purse seiner. The components of this study can be broken out into three areas: 1) testing FAD modifications and manipulations to reduce bycatch, 2) evaluating behavioral and physiological indicators of stress, and 3) removing the bycatch from the seine and deck to minimize mortality.

1. FAD Modifications and Manipulations

Many fishing captains attempt to capture tunas while preserving the FAD community during a set because they believe the smaller fishes typically found closer to the surface are an important factor in attracting the larger target fishes. It may be possible to remove the smaller fish and other non-target species after setting by having the vessel back-down after the net has been pursed. The backdown procedure submerges the corkline allowing for the FAD to be towed out of the net by a speedboat. Observations could be made to determine if non-target species are drawn out of the net with the towed FAD.

The feasibility of the backdown method was debated. Backdown is typically a procedure performed by vessels making sets on dolphins. These vessels carry nets equipped with a dolphin safety panel, containing finer mesh webbing than the rest of the net, making it easier to sink the corkline during backdown. On the other hand, fish that are small enough to escape through the normal 4 ½-inch mesh may not be able to escape through the 1 ¼-inch mesh of the typical dolphin safety panel. Another key to the success of this method in reducing bycatch of small and non-target fish is the observations of the behavior of the fish in relation to the FAD. Having a second net or collection pen into which the FAD could be towed would allow for continuous observations of the type, amount, and condition of the fish that were removed from the net. If a collection pen cannot be utilized, it was suggested that underwater cameras and video be used to collect qualitative data. This proposal also suggests the idea of testing a two-part FAD. If resources are available, both the backdown and tow and two-part FAD should be tested as a way to separate the community, although the two-part FAD may be easier to test and more successful because it does involve moving the associated fish community.

2. Behavioral and Physiological Indicators of Stress

Quantitative measures of fish stress during purse-seining operations may offer important information for designing effective release mechanisms and for predicting the survivorship of released fishes. One idea was to make underwater observations of fish behavior and school structure in the net to find a useful indicator of stress. As the net is being pursed and sacked, likely causes of mortality of fish include compression, stress, and low oxygen. Participants noted that observations of both the target species and non-target species should be made in effort to better understand survivorship. Because it is not feasible to hold the released fish for hours after being removed from the net, tagging a sub-set of the fish would be necessary to estimate survivability.

3. Removing Bycatch from the Seine and Deck

Several different mechanisms for separating target from non-target species were presented including sorting grids, bubble gates and vacuum pumps. Several sorting grids were discussed, some of which have been tested or used in other types of fisheries, and in a few cases tested on tunas in a lab setting. In general, there was support from the group in testing sorting grids. It would be important to be able to determine the survivability of the fish after release via a sorting grid. It was also suggested that greater consideration be given to designs which could be used for more than one purpose. For example, the bubble gate could be used to corral fish into certain areas of the net or separate fish. Vacuum pumps have been used in other fisheries and could be used to facilitate the release of small bycaught species within the net. In order for a vacuum pump to be effective the fish would have to be concentrated in one area which could cause additional stress. The use of a vacuum pump would minimize the handling of the animal which was thought to enhance their chances of post release survival. A feasibility study would need to be conducted to ensure that the system is easy to deploy, can be used at sea, and is not cost prohibitive. As with many of the other release methods, any impacts of the vacuum pump on post-release survivability would need to be evaluated.

Recommendations

The workshop participants were generally supportive of the four research proposals discussed at the workshop. As a result of this workshop, five areas of focus were identified for future consideration once funding becomes available. The five areas of research that should be pursued are as follows:

1) *Avoidance of sea turtle entanglement by modifying existing FAD designs.* Different FAD designs can be evaluated based on avoidance of unintended animal entanglement, reduction of sea turtle mortality, low-cost construction, ease of deployment, and maintenance of tuna catches at current levels or better. Workshop participants agreed that this is an achievable goal. Workshop participants also recommended that IATTC Captain's Workshops be utilized so fishermen can discuss and evaluate possible FAD modifications. In addition, participants

recommended exploring alternate FAD designs to reduce bycatch of non-mammal and turtle species (e.g., two-part FADs).

2) *Attraction of sharks away from FADs prior to the set to reduce bycatch.* A preliminary study is being conducted to determine whether sharks, and not tuna, can be attracted away from a FAD; if successful, larger-scale studies can be conducted.
3) *Development of mechanisms (vacuum pumps, sorting grids, backdown procedure, and towing) to release bycatch species from inside the net.* These studies should include of estimation of post-release survival.
4) *Time-area closures: use of historical bycatch data and simulations.* A sub-group of workshop participants should work with the IATTC staff to develop questions that could be explored with the fisheries data in the IATTC database.
5) *Generally applicable to reducing incidental catch of non-target species.* Behavioral observations of tuna and other fish species should be made to maximize the success of encircling large pure schools of tuna while minimizing encirclement of non-target species.

Work in these five areas is dependant upon funding by NMFS, the IATTC, and/or other sources. At this time, no source of funding is available. Workshop participants offered several recommendations for possible funding sources and to the general issue of successfully reducing bycatch in the ETP tuna purse-seine fishery:

- NMFS and the IATTC should continue to work with academic or other institutions that have the expertise in these areas;
- Because the incidental catches of small tunas, especially bigeye, is a pan-Pacific issue some of the work could be funded by international organizations or in collaboration with other countries;
- Marine conservation organizations, foundations, and corporations may also be interested in funding some of the proposed research;

- The tuna-canning industry has a vested interest in this fishery and may be supportive of funding proposals aimed at maximizing catches of tuna while minimizing bycatch;
- The use of waivers of the current time-area closures for tuna fishing may provide an incentive for fishermen to participate in research cruises during the closure periods; and
- NMFS and the IATTC should work with fishermen to establish a research foundation to fund research toward the long-term sustainability of the fishery.

Next Steps

With the exception of a relatively small contract let to the IATTC to conduct a feasibility study of the shark attraction proposal, NMFS does not have funding at this time to pursue the research proposals discussed in this report. However, the SWR, SWFSC and IATTC Secretariat plan to remain in contact with participants from this workshop, especially in case funding opportunities arise or the shark attraction study produces promising results. Workshop participants made this request and expressed interest in remaining part of this body even in the absence of a specific charge outside of this workshop.

Acknowledgments

This report benefited greatly from discussions with and reviews by (alphabetically) Eric Archer, Heidi Dewar, Siri Hakala, Suzy Kohin, Cleridy Lennert-Cody, Tony Morton, and Michael Scott.

APPENDIX I. WORKSHOP PARTICIPANT LIST

NAME	AFFILIATION
Eric Archer	NMFS, SWFSC
Kathy Castro	Rhode Island Sea Grant
Heidi Dewar	NMFS, SWFSC
Michel Dreyfus	Instituto Nacional de la Pesca, Government of Mexico
Tina Fahy	NMFS, SWR
Tim Gerrodette	NMFS, SWFSC
Martin Hall	IATTC
Kim Holland	University of Hawaii
Jessica Kondel	NMFS, SWR
Cleridy Lennert	IATTC
Flora Lichtman	Blue Ocean Institute
Takayuki Matsumoto	IATTC
Peter Nelson	California Sea Grant
Bob Olson	IATTC
Rebecca Regnery	Humane Society of the United States
Steve Reilly	NMFS, SWFSC
Jeremy Rusin	NMFS, SWFSC
Kurt Schaefer	IATTC
Carl Schilt	LGL Ltd. Environmental Research Associates
Michael Scott	IATTC
Dick Stephenson	Tuna Purse-Seine Captain
Yonat Swimmer	NMFS, PIFSC
Jordan Watson	University of Washington
Nina Young	Ocean Research, Conservation, and Solutions Consulting

APPENDIX II. RESEARCH PROPOSALS ON BYCATCH REDUCTION IN THE ETP PURSE-SEINE FISHERY

Proposal 1: Reducing entanglement of sea turtles in the tuna purse-seine fishery on Fish Aggregating Devices

Prepared and presented by Michael Scott

Introduction

Sea turtles are occasionally caught in purse seines in the tuna fishery in the eastern Pacific Ocean. Most interactions occur when the turtles associate with floating objects (for the most part fish-aggregating devices (FADs), and are captured when the object is encircled; in other cases, the net, set around an unassociated school of tunas or a school associated with dolphins, may capture sea turtles that happen to be in the location. In these latter cases, the presence of tunas and turtles together may be influenced by oceanographic features such as fronts, but is essentially a chance event because turtles cannot swim fast enough to travel with tunas or dolphins.

Once captured, the turtles may be released unharmed, injured, or dead. They can drown if they are entangled for a prolonged time and are unable to reach the surface to breathe. The olive Ridley turtle is by far the species taken most often by purse seiners. It is followed by black or green sea turtles (*Chelonia agassizi*), and, very occasionally, by loggerhead (*Caretta caretta*) and hawksbill (*Eritmochelys imbricata*) turtles. Only one mortality of a leatherback turtle (*Dermochelys coriacea*) has been recorded since IATTC observers began recording this information in 1993. The populations of olive Ridley, black, and loggerhead turtles are designated as endangered, and those of the hawksbill and leatherback turtles as critically endangered, by the International Union for the Conservation of Nature.

The annual mortalities of sea turtles in the purse-seine fishery reported by IATTC observers are shown in Table 1. The IATTC-observed mortality was about 130 individuals until 2003, mainly of olive Ridley turtles, but recent conservation measures by the IATTC have greatly reduced sea turtle mortality due to encirclement in the purse-seine fishery.

The mortality caused by entanglement of sea turtles in the net webbing that fishermen frequently attach under FADs, however, remains to be addressed. In 2005, 61% of all FADs sighted had net webbing attached. IATTC observer data show that 286 dead sea turtles and 534 live ones were found entangled during sets on floating objects from 1993-2005 (Table 2). Data from 2004-2005 indicated that 99% of the live turtles found during FAD sets were released.

IATTC observer sightings of FADs that were not involved in sets show that 616 dead sea turtles and 1753 live ones were entangled from 1993-2005 (Table 3). Of the live turtles entangled in 2004-2005, fishermen stopped to disentangle 87% of the turtles sighted on FADs even though no set was made.

In June, 2006, the IATTC (2006a) strengthened the mandates to release turtles and to prohibit the use of hanging mesh in the construction of FADs and develop and test of alternatives to net webbing hanging under FADs. One option that has been proposed to replace the webbing with polyethylene strips attached to a chain hung under the FAD. It was recommended by the IATTC that experiments to compare the effectiveness of these alternatives be carried out.

Proposed Research

This proposal would initiate a pilot program to replace net webbing on FADs with polyethylene strips and compare the sea-turtles entanglement rates of these experimental FAD designs with control FADS with net webbing underneath. If possible, a test first will be conducted in a captive environment to determine that indeed olive Ridley sea turtles cannot entangle in the polyethylene strips and that they won't attempt to engest the plastic.

The field test will be conducted aboard tuna purse seiners during 2008 in an area north of the equator where FADs are normally deployed and sea turtle entanglements occur (Figures 1-2). The IATTC will provide materials - polyethylene strapping bands and weighted lines (Venkatasami, 1989) and identifying marks to distinguish experimental FADs and controls - to replace the webbing used on half the FADs deployed by 10 purse seiners (enough materials will be purchased to build 120 experimental FADs). Typically, the boats fish on FADs previously deployed, relocating those FADs that have drifted to far west as they fish, and when the boat has filled its wells, deploy new FADs on their way back to port to allow the FADs time to "season" (that is, allow time for fish communities to aggregate around the FAD). The remaining FADs with webbing aboard each boat will serve as controls; and the seiner will deploy experimental and control FADs alternately to reduce the confounding factors of location and "seasoning" time. When the boat returns to sea, the purse seiners will regularly monitor the previously set FADs for the presence of tuna and make a set if sufficient tunas are present; the observers, as part of their normal duties, will record the presence or absence of entangled sea turtles, whether a set was made, and, if so, the tonnage of tuna caught. For each vessel, a comparison will be made of the bycatches of sea turtles and the catches of tunas between the experimental and control FADs deployed at the same time.

The likely outcome of the research is that the polyethylene straps will not entangle any sea turtles. The main problem will be to obtain a sufficient sample size of observations of experimental and control FADs. The 2003-2005 data showed that only 1.7% of FADs sighted had a sea turtle entangled; the bycatch rate of 1.7% observed on control FADs is so small that it may be difficult to observe enough FADs to detect a significant statistical difference. What is more tractable, however, is to determine if a) the experimental FAD design does indeed eliminate turtle entanglement, b) whether the tuna catch from the experimental FADs is the same or higher than from the control FADs, and c) whether the experimental FADs prove as durable as the controls. This information would provide a basis for management decisions to replace net webbing on FADs with viable alternative materials.

Timeline

Assuming that funding is available on 1 January 2007, the first 12 months will be spent conducting captive testing, obtaining cooperation of the IATTC member countries and purse-seine vessels that normally fish on FADs, obtaining any permits required, procuring materials and manufacturing polyethylene-strip understructures for FADs that are easy to attach and deploy, distributing the materials to cooperating vessels, and publicizing information about the study to the fleet and the observers that will be aboard all large seiners of the international fleet. Deployment of the experimental FADs will take place during 2008; data will be collected throughout 2008 for as long as the FADs remain fishing.

Potential Obstacles

As noted above, the key difficulty will be obtaining a statistically valid sample size to detect a difference in sea turtle entanglement between experimental and control FADs. Also, this project will rely on the willingness of purse-seine captains and owners to participate in this study, and on the cooperation of the IATTC countries in encouraging their national fleets to participate and issue any research permits that would be required.

Budget

Biological technician – half-time, 2 years	$60,000
Materials and manufacturing	$42,000
Travel	$6,000
IATTC overhead	$11,000
Total	**$119,000**

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Table 1. Estimated annual mortalities of sea turtles in the purse-seine tuna fishery in the EPO, by species. The estimates for the entire fleet were extrapolated from data collected by IATTC observers aboard large purse seiners (over 363 mt carrying capacity). An annual estimate was averaged for the 1993-2003 period (IATTC 2004), Sea turtle mortality declined afterwards (IATTC 2005; 2006b) as fishermen became more focused on sea turtle mortality reduction (IATTC 2003).

Species	**1993-2003**	**2004**	**2005**
Olive Ridley	76.8	11	15
Black	10.4	-	2
Hawksbill	1.0	-	-
Leatherback	0.1	-	-
Loggerhead	1.9	-	-
Unidentified	36.7	6	12
Total:	**126.7**	**17**	**29**

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Table 2. Turtles found entangled in IATTC-observed sets on floating objects, 1993-2005. These mortalities are minimum estimates because data were not available from all purse-seiners.

	Olive Ridley	Black	Hawks-bill	Leather-back	Logger-head	Unidenti-fied	Total
DEAD							
1993	6	-	-	-	-	-	6
1994	4	1	-	-	1	2	8
1995	11	3	1	-	1	10	25
1996	5	-	1	-	-	3	9
1997	7	-	-	-	-	16	23
1998	10	2	-	-	-	15	27
1999	22	1	1	-	-	22	46
2000	11	2	-	-	1	19	33
2001	23	3	-	-	-	21	47
2002	7	2	-	-	1	9	19
2003	9	2	-	-	1	6	18
2004	4	1	-	-	-	5	10
2005	5	1	-	-	-	8	14
	124	18	3	-	5	136	286
ALIVE							
1993	19	2	-	-	-	6	25
1994	13	6	-	-	-	14	33
1995	26	5	1	-	-	5	37
1996	15	1	2	-	-	15	33
1997	19	6	-	-	-	16	41
1998	33	11	1	-	2	13	60
1999	55	6	1	-	-	41	103
2000	17	9	1	-	-	10	37
2001	22	8	1	-	-	24	55
2002	18	2	-	-	5	11	36
2003	15	1	3	-	-	10	29
2004	12	-	-	-	-	8	20
2005	11	1	-	-	-	11	23
	275	58	10	-	7	184	534

Table 3. IATTC-observer sightings of turtles entangled in floating objects, 1993-2005. These mortalities are minimum estimates because data were not available from all purse seiners.

	Olive Ridley	Black	Hawks-bill	Leather-back	Logger-head	Unidenti-fied	Total
DEAD							
1993	5	-	-	-	-	9	14
1994	3	-	-	-	-	7	10
1995	13	5	1	-	-	19	38
1996	13	1	-	-	-	18	32
1997	9	1	1	-	-	36	47
1998	24	5	2	-	-	37	68
1999	50	5	2	-	2	30	89
2000	46	5	-	-	-	49	100
2001	38	4	-	1	-	36	79
2002	10	-	-	-	-	34	44
2003	5	2	-	2	-	20	29
2004	5	1	-	-	-	22	28
2005	12	-	-	-	-	26	38
	233	29	6	3	2	343	616
ALIVE							
1993	50	7	-	-	-	28	85
1994	22	6	-	-	-	46	74
1995	46	10	2	-	1	78	137
1996	24	8	1	-	-	45	78
1997	45	18	2	-	5	93	163
1998	71	24	9	-	3	102	209
1999	126	10	3	-	-	62	201
2000	102	11	4	-	-	48	165
2001	98	13	2	-	9	90	212
2002	43	11	2	-	2	67	125
2003	26	5	2	1	-	69	103
2004	24	5	-	-	-	58	87
2005	34	15	1	1	2	61	114
	711	138	28	2	22	847	1753

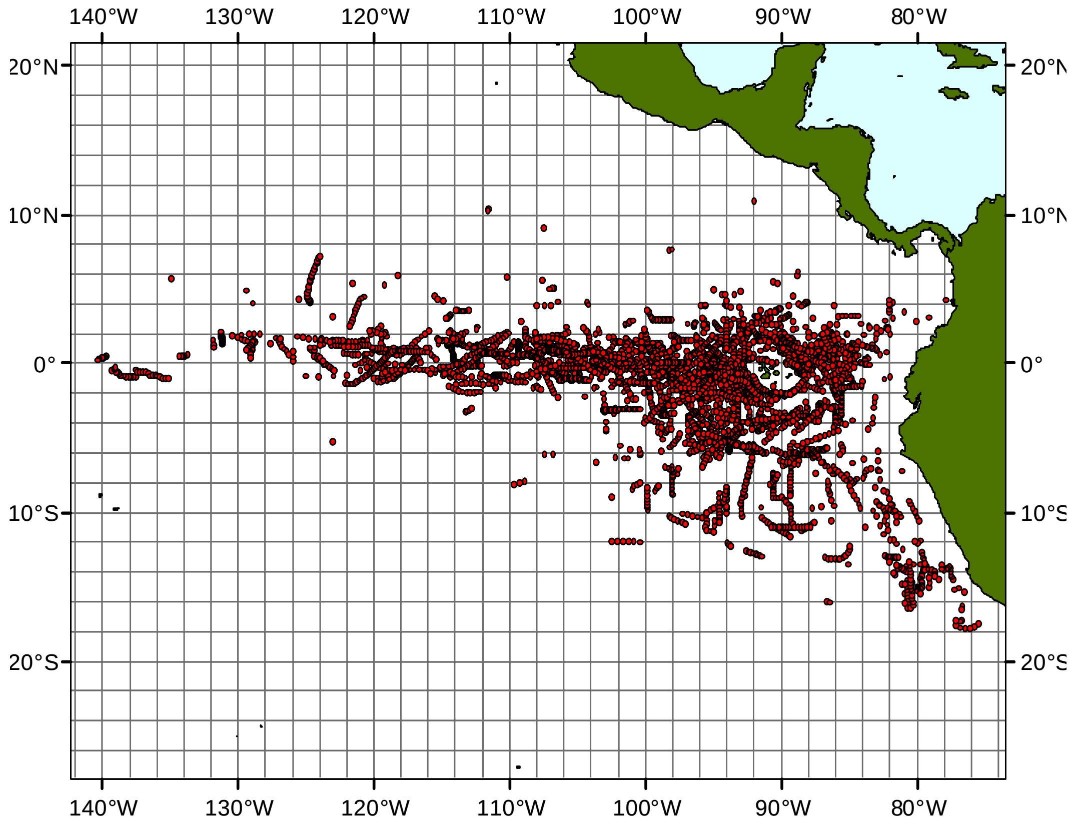

Figure 1. Locations of FADs seeded by IATTC-observed purse-seiners in the ETP during 2005-2006 (data as of 11 September 2006).

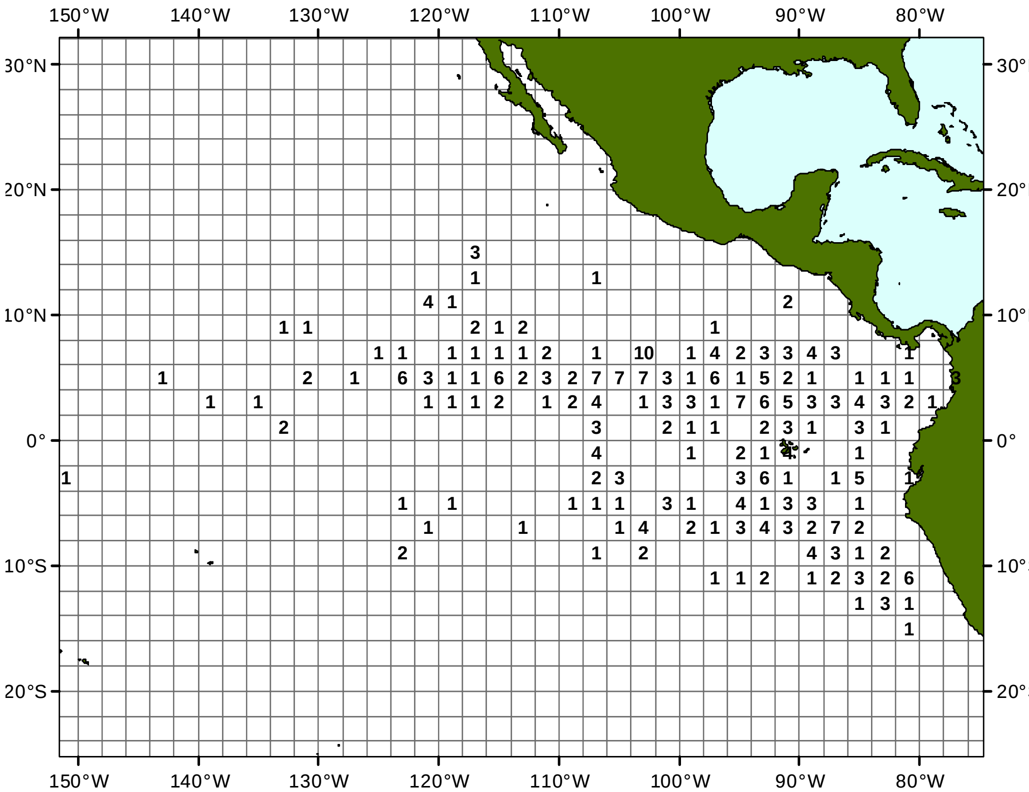

Figure 2. Numbers of sea turtles observed entangled in FADs by IATTC observers, 2004-2005.

Proposal 2: Reducing Shark Bycatch in the Tuna Purse-Seine Fishery in the Eastern Tropical Pacific Ocean

Prepared and presented by Michael Scott

Introduction

During purse-seine sets on for tunas associated with floating objects in the eastern Pacific Ocean, high amounts of bycatch are taken as well. Of particular concern is the effect of these bycatches on relatively slow-reproducing species such as sharks, billfish, and sea turtles. There is much concern about the viability of shark populations worldwide; in the eastern Pacific Ocean, silky sharks are particularly associated with purse-seine sets and have been taken in large numbers (Figure 1). In 2003-2005, 40% of the sets on floating objects ("log sets") resulted in shark bycatch; 33% of these sets resulted in bycatch of silky sharks. Little is known about historical and current abundances of sharks, but anecdotes from long-time fishermen and observers suggest that sharks associated with dolphins and tunas have greatly declined.

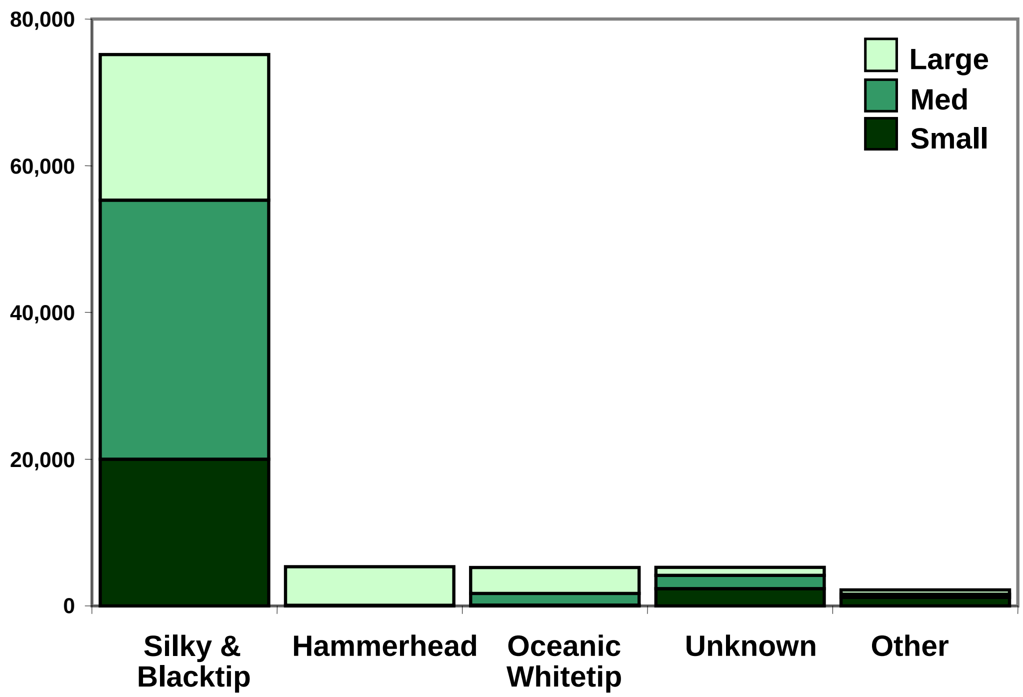

Figure 1. Numbers of sharks caught in log sets during 2000-2004. Small sharks are estimated by observers to be < 90 cm, medium sharks are 90-149 cm, and large sharks are $\geq$ 150cm.

One approach to reducing bycatch mortality of sharks is to determine whether the use of a bait attractant can draw sharks away from a FAD prior to a set. This proposal describes an exploratory operational study to determine the logistics of deploying a bait station prior to a log set and using side-scan sonar to detect movements of sharks to the station. If this approach appears feasible, then a wider study to statistically compare experimental and control sets can be conducted. Further studies using acoustic telemetry would be needed to determine how the attractants affect the movements of sharks or whether shark repellants could be used to reduce bycatches.

Proposed Research

Because funding for this exploratory study is not sufficient to charter a vessel, it is critical to convince a boat owner to volunteer the vessel and encourage the captain and crew to cooperate in the experiment. As a consequence, the experiment will have to be designed so as to impinge as little as possible on normal fishing operations and to not negatively affect tuna catches. An IATTC field office near the main port of operations for this vessel will purchase supplies to build the bait stations. At sea, the vessel will deploy FADs in an area north of the equator where bycatches of sharks are common on log and FAD sets and where the FAD fishery normally operates (Figures 2-3).

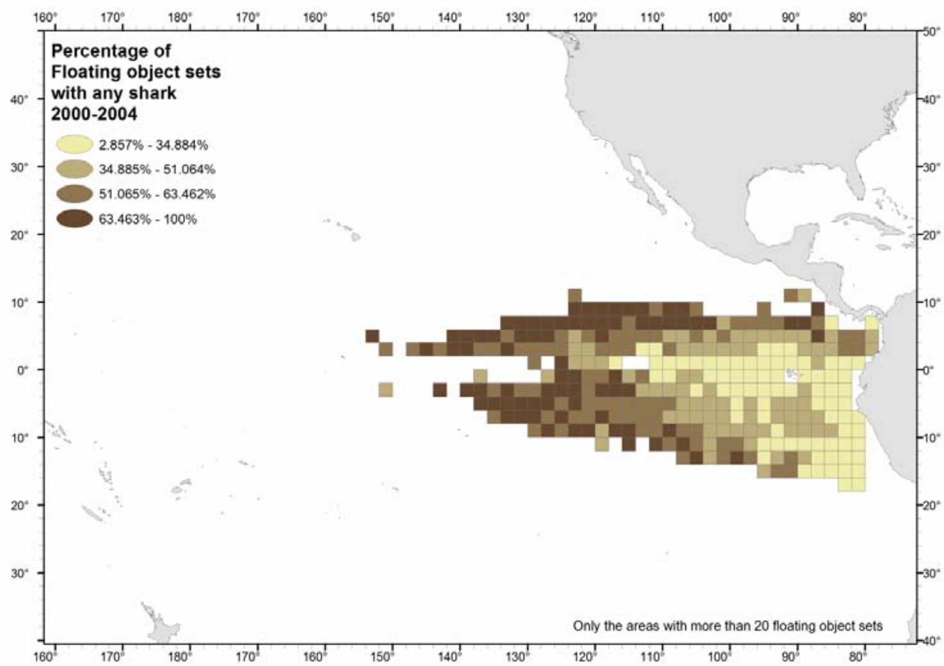

Figure 2. Percentages of floating object sets with shark bycatch by area, 2000-2004.

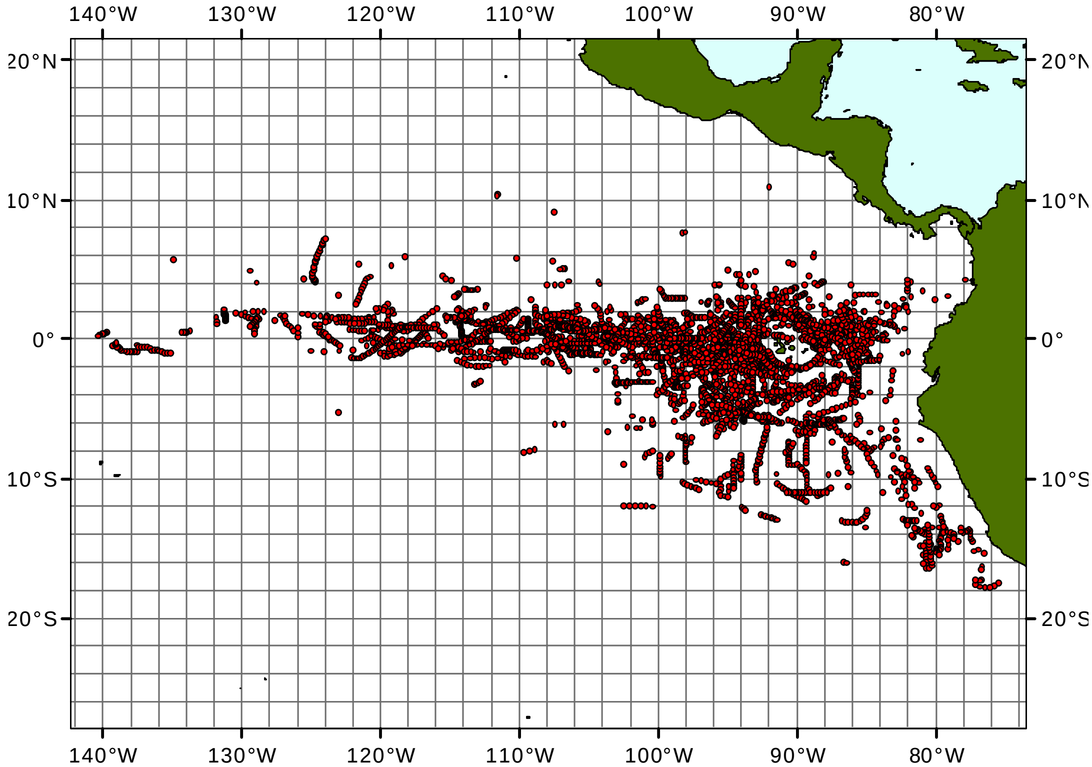

Figure 3. Locations of FADs seeded by IATTC-observed purse seiners in the ETP during 2005-2006 (data as of 11 September 2006).

A test of the relative drift rates of the bait stations and FADs will be conducted prior to the first set. Given the potential variability in the speed and direction of surface and subsurface currents, and the fact that both the FAD and the bait stations will be drifting and probably drifting at different rates, a critical question that will be need to be answered through experimentation at sea is "How do we know that the plume from bait station will be detected by any sharks associated with the FAD?" The bait stations will need to be deployed close enough to the FAD, so that the chemical plume from the bait station intersects the FAD aggregation, yet is far enough away at the time of the set so that the bait stations are well outside the net circle. The experiment will need to be adaptive as well, allowing the design to be modified as results of early sets dictate.

The initial plan will be to have the ship or its speedboats will deploy a line of bait stations about 200 m upcurrent or downcurrent from the FAD (depending on the relative drifting speeds), two or more hours prior to the set. The bait stations will be augmented with transducers emitting sounds believed to attract sharks (S2 Scientific Electronic Lures: http://www.makomagnet.com/fs-product.htm). At the time of the set, the observer will note the relative positions of the bait stations and the FAD and their subsequent movements. The ship's side-scan sonar and a fishfinder mounted on one of the ship's speedboats will be used to locate and track concentrations of tunas and sharks. If the helicopter is launched during the set, the aerial observer will be asked to determine whether sharks or tunas have congregated around the bait stations. The IATTC observer will collect normal data on the catch of tunas and the bycatch of sharks and other species. Three metrics will be used to compare experimental and control sets: the average tuna catch, the average shark bycatch per set, and the percentage of sets with zero shark mortality.

After the set, speedboats will retrieve the bait stations. If possible, two sets or more will be made on the FAD on successive days. The first set would be an experimental set (with bait stations deployed); the second will be a control set. Thereafter, experimental and control sets will continue to alternate until the FAD is "fished out." Normally one would expect that catches of tuna and bycatches of sharks would decline in succeeding sets (Scott *et al*. 1999). If the bait stations were successfully drawing sharks away from FAD sets, then one might expect that bycatch would increase on the second control set. However, if the bait station, directly or indirectly, were also drawing tunas away from the FADs, one might expect the catch of tunas to also increase.

While it is well known that sharks can be attracted with bait, the key question for this study is whether the use of bait stations is practical and efficient within the constraints of a purse-seine fishing operation. Because of the unknown difficulty of positioning a bait station in such a way that its drifting scent plume intersects a drifting FAD or log, it can not be determined *a priori* what the likely outcome will be. Given time, the bait station will likely attract nearby sharks, but we can not predict whether the procedure would be efficient enough to fit within the constraints of time and effort that the crew would be willing to exert during normal fishing operations.

Potential Obstacles

Because this is a feasibility study, finding a potentially workable procedure will be the main objective rather than obtaining a particular sample size. The main difficulty will be to determine, using sonar, whether sharks are moving from the FAD to the bait stations. This project will rely on the willingness of a purse-seine captain and owner to participate in this study and on the cooperation of the IATTC countries in encouraging their national fleets to participate.

Timeline

Assuming that funding is available on 1 January 2007, the first 6 months will be spent obtaining cooperation of the IATTC member countries and purse-seine vessels that normally fish on FADs, obtaining any permits required, designing and building the bait stations. Field tests would be scheduled to place during September-November 2008.

Follow-Up Studies

If the results of the feasibility study look promising, more-detailed studies can be conducted. One could be a scaled-up version of the preliminary study to gain a large enough sample size to detect statistical differences in shark bycatch between experimental sets using bait stations and control sets with no bait stations. Another potential study could use tagging and acoustic monitoring of sharks caught on hook-and-line at a FAD to detect not only whether a bait station attracts sharks, but in fact attracts them away from FADs.

Budget

Biological technician – three-quarter-time, 1 year	$45,000
Travel and expenses	$10,000
Sea pay	$2,000
Notebook computer for at-sea use and computer supplies	$4,000
Bait stations (20 buoyed 10-gallon buckets)	$1,000
2 commercial food grinders	$1,000
3 MakoMagnet transducers, power sources, and mounts	$1,500
Fishfinder	$2,500
Miscellaneous expenses (frozen bait, tools and other gear)	$2,500
IATTC overhead	$6,950
Total	**$76,450**

Reference

Scott, M.D., W.H. Bayliff, C.E. Lennert-Cody, and K.M. Schaefer. 1999. Proceedings of the International Workshop on the Ecology and Fisheries for Tunas Associated With Floating Objects, February 11-13, 1992. IATTC Special Report 11. 480 p.

Proposal 3: Bycatch in tuna purse seine sets on FADs: ecological approaches to bycatch reduction using fisheries data

Prepared and presented by Peter Nelson

She may guess what I should perform in the wet, if I do so much in the dry.
Don Quixote de la Mancha, Miguel de Cervantes

Introduction

This proposal argues for an analysis of Inter-American Tropical Tuna Commission (IATTC) data on tuna catches and the associated bycatch from purse seine sets in the eastern tropical Pacific Ocean. Justification for an interest in reducing bycatch associated with tuna FAD sets can be found elsewhere (e.g.Anonymous, 2005, Archer, 2005, Gaertner et al., 2002, Menard et al., 2000) and will not be detailed here. Funding would provide for a graduate research assistantship with the work conducted with the support and assistance of IATTC staff scientists. Faculty associated with the Department of Fisheries Biology at Humboldt State University (P. Nelson & D. Hankin) are prepared to supervise a student in this capacity.

Fisheries data offer a low-cost opportunity to look for spatial and temporal patterns in the bycatch associated with tuna purse seine sets, including those on Fish Aggregation Devices (FADs). By using multivariate analyses to incorporate the influence of fundamental environmental variables (space and time) as well as other data collected by IATTC observers (species richness & abundance, SST, water clarity, % coverage of fouling organisms, etc), we can compare literally thousands of sets in an effort to identify key factors that could predict bycatch in FAD sets.

Preliminary Analyses

Preliminary analyses from a limited dataset identified patterns that are pertinent to bycatch reduction strategies:

1. Sets initiated during twilight had a significantly higher mean ratio of small bigeye to total bigeye caught than did day-time sets[3].

[3] Fish behavior including movements to and from FADs varies between night and day. Using IATTC data (1993 – 2003), I distinguished between sets that were initiated during day (0610 – 1750), at twilight (0510 – 0610 and 1750 – 1850) and at night (1850 – 0510); these categories were based on observations of coral reef fish behavior by Hobson Hobson, E.S., 1972. Activity of Hawaiian reef fishes during the evening and morning transitions between daylight and darkness. *Fishery Bulletin*, **70**(3), 715-740. as they seemed the least arbitrary of available options. Because tuna vessel captains generally avoid making sets at night, there were very few of these (n = 98). Dawn and to a lesser extent dusk are generally considered good times to set (n = 6,384), but day time sets were the most common (n = 16,275). The data available contained no non-tuna bycatch information, but data on bigeye (*Thunnus obsesus*) catch, separated into three size categories, was available. I calculated the ratio of small bigeye to the total number of

2. Following an initial set, bigeye & skipjack recruit to the FAD quickly, but yellowfin appear to take significantly longer[4].
3. A repeat set ~24 hours following the initial set has lower species richness despite no significant reduction in tuna captured[(see footnote 2)].

These results are certainly not definitive, but do demonstrate that potentially useful ecological patterns can be drawn from existing IATTC data. For example, sets initiated during the day (0610 – 1750) appear to contain proportionally fewer small bigeye tuna. Eliminating twilight sets would presumably reduce the incidental mortality of this form of bycatch. A closer examination of the data as well as a thorough consideration of the potential for bycatch reduction (10% less? 2% less?), would clearly be necessary before the IATTC might propose such a measure. Similarly, differences between 'virgin' sets and repeat sets shortly thereafter suggest that some forms of disturbance (e.g. towing a FAD at an experimentally-determined velocity to shed small fishes) might retain large fish

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bigeye caught for each set and transformed these data Zar, J.H., 1996. *Biostatistical Analysis*. Upper Saddle River, New Jersey: Prentice Hall.. ANOVA indicated that there was a significant difference in the mean ratio of small to total bigeye among sets from the three time period categories ($F_{(2, 22754)} = 7.1325$, $P = 0.0008$), and pairwise comparisons with a Bonferroni adjustment produced the following results:

Paired comparisons (adjusted P values)	**Day**	**Night**
Night	0.97724	
Twilight	0.00069	1.00000

[4] IATTC data from purse seine sets between lat 0-5 N and long 95-100 W (1993-2002); the first known ('virgin') set on a FAD was distinguished from subsequent sets occurring ~24 hours after the initial set and those with a 7+ day interval. Tuna catch for each set was divided among species/size categories (yellowfin small & medium+large, bigeye small & medium+large, total skipjack). Data were transformed (ln + 1). Statements (above) reflect ANOVA and paired comparison (with Bonferroni adjustment) results:

tuna spp/size & set interval	*df*	*SS*	*MS*	*F*	*p*
spp	4	4280.5	1070.1	109.9	<0.0001
interval	2	6.1	3.1	0.315	0.7296
spp:interval	8	530.5	66.3	6.811	<0.0001
residuals	1335	12997	9.7		

set interval	*df*	*SS*	*MS*	*F*	*p*
Interval	2	182.5	91.3	8.381	0.0003
Residuals	508	5532.3	10.9		

pairwise t tests, pooled SD bonferroni-adj p values	*virgin*	*24 hour*
24 hour	0.0006	
7+ days	1.0000	0.0022

but significantly reduce bycatch.

Proposed Approach

Some of the questions or approaches that should be considered include:

- Can bycatch composition can be partially explained by select environmental variables (e.g. time of set)?
- Are FAD-associated aggregations separable by location, season or community composition (using multivariate analyses)?
- What can a time series analysis of, for example, total monthly shark catches tell us (or juvenile bigeye, small & medium skipjack, non-tuna bycatch, species diversity, etc.)?
- Is there a predictable spatial pattern to the distribution of bycatch (e.g. by key species or total biomass)?
- Estimate the predictability (sensu Colwell, 1974) for select bycatch species and areas; are these levels independent of fishing pressure?
- Apply BIO-ENV (Clarke, 1993) procedures by geographic location, within years and within seasons.
- Ordination of catch data by geographic location; apply procrustes comparisons between locations.

Of particular interest is relating the bycatch composition to environmental variables (location, time of set, SST, number of prior sets, interval since last known set, floating object type, object characteristics). A number of quantitative methods have been developed that are particularly suitable to community ecology. Initially, indirect and direct gradient analyses on log-transformed data should be performed. At a minimum, a detrended correspondence analysis (DCA) should be performed on the species matrix (set by species). The length of the DCA gradients should indicate next steps (e.g. canonical correspondence analysis, CCA, in the event of unimodal responses). CCA provides a means of assessing the relationship between assemblage structure and environmental variables (Jongman et al., 1995). Non-metric multidimensional scaling (NMDS) might be applicable to limited datasets, such as sets from trips with particularly skilled and reliable observers; NMDS with near-complete datasets has been problematic. The BIO-ENV procedures developed by Clarke (Clarke, 1993, Clarke & Ainsworth, 1993) also warrant consideration.

<u>Objectives and Budget</u>

Objective	*Responsibility*	*Cost estimate*
Test key hypotheses relevant to reducing FAD-associated bycatch in the ETP tuna purse seine fishery using IATTC data; provide a detailed written report to IATTC and NOAA	HSU graduate student and P. Nelson over two years	$18,000 + $19,500*

based on a Masters thesis. computer dedicated to data analysis **two years of graduate student funding*	$4,000
Total	$41,500

Conclusion

While the data are obviously not fishery-independent, have been collected by different observers under varying conditions, etc., the IATTC already has these data and there is no monetary cost to acquiring it. By funding its analysis through graduate student support, the expense of dedicating IATTC or NOAA scientists to the task is avoided, and, with good supervision, I believe that excellent results may be obtained. Further, most of proposed solutions that might come from this approach would be comparatively easy to implement from a technical (if not political) perspective—they would be of the sort to suggest time/area closures or 'no FAD/log sets 3 hours pre/post sunrise.'

The underlying concepts here are similar to those for the simulation studies proposed by the IATTC(Archer, 2005); it would make use of the same data set, but would use standard quantitative ecological methods. We would ask similar questions as well, but could test several additional hypotheses that the simulation proposal does not (e.g. fine scale environmental criteria measured by the observers can predict elements of the bycatch—quantity, composition, probability, etc.). Note that the simulations offer an excellent complement to this approach and that the two proposals are not mutually exclusive.

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Proposal 4: Bycatch in tuna purse seine sets on FADs: field trials for a suite of potential bycatch reduction devices and techniques

Prepared and presented by Peter Nelson

The proof of the pudding is in the eating.
Don Quixote de la Mancha, Miguel de Cervantes

Introduction

This proposal describes a number of possible means for reducing bycatch in tuna purse seine sets on FADs (Fish Aggregating Devices), and outlines a set of experiments for testing their efficacy. These means are restricted to gear modifications, devices, fishing strategies, and fishing practices that are amenable to testing in the field with a commercial purse seine fishing vessel, although some mention is made where preliminary experiments in a laboratory setting may be advantageous. I describe a number of separable experiments that should be performed in the course of a single cruise for the sake of economy of funding, political expediency, and effort.

Justification for an interest in reducing bycatch associated with tuna FAD sets can be found elsewhere (e.g. Anonymous, 2005, Archer, 2005, Gaertner et al., 2002, Menard et al., 2000) and will not be detailed here. The importance of field trials (versus laboratory experiments or theoretical exercises) lies in that (1) these most closely approach actually implementing bycatch reduction efforts, (2) they offer the opportunity to fine-tune practical approaches based on direct observations as they are evaluated, and (3), by working with commercial fishermen, the fishery participants are engaged and invested in addressing the problem.

The crux of this proposal is the charter of a commercial tuna seiner to observe flotsam- and FAD-associated fishes and to conduct empirical tests of gear and methods while fishing pre-soaked experimental FADs in the eastern Pacific Ocean. Commercial fishing vessels, their captains and crews have the expertise to deploy FADs, locate tuna and fish them. Support from a second research vessel could add enormously to the efficacy of the venture...as well as to its costs. This proposal outlines a series of experiments that do not depend on the availability of a second vessel, but I have attempted to provide some indication of how, despite the expense, this is worth consideration.

The proposal is divided into the following sections:

- reducing capture of bycatch,
- behavioral & physiological indicators of stress,
- removing bycatch from the seine,
- releasing bycatch from the vessel’s deck, and
- an incentive program for tag-recovery.

I have attempted to present a wide array of possible questions, ranging from what offers a high probability of success to the rather improbable. My assumption is that, if the basic research cruise is funded, nearly all of these ideas could be pursued safely, practically and for little additional cost or effort. Also, no one solution will be 100% or, unfortunately, even 50% effective; success—however that is defined—will come only by applying multiple methods, which together reduce bycatch to an appropriate level. Finally, I make no attempt here to prioritize bycatch species, though there may be good reasons for doing so.

In considering this proposal, the reviewer is asked to bear in mind that the single largest expense is simply getting to the fishing grounds in an appropriate vessel. The experiments that would follow are all comparatively cheap and easy to perform. For this reason, I include experiments that range from those virtually certain to work to the highly speculative, even improbable. However, concepts closer to the latter end of the spectrum, if successful, could both reduce bycatch drastically and be far easier to implement than some of the more conservative approaches from the other end of the spectrum. The point I wish to make here is that, once we have someone on a fishing boat prepared to work on bycatch reduction gear and methods, it would behoove us to explore as many options as we reasonably can, even those that may seem comparatively unlikely.

Timeline

Start date +/- months	*Action*
T – 12	Interview select fishing captains for feedback on existing ideas and solicit new ones; design & build experimental gear (e.g. grids, chutes, grabs, etc.).
T – 6	Build FADs.
T – 2*	Deploy FADs. *Must be loaded on contracted vessels prior to last trip before a scheduled FAD fishing closure.
T = 0	**Research charter leaves port.** Locate and fish deployed FADs.
T + 2	Conduct FAD assemblage observations using visual and acoustic methods.
T + 2	Test techniques for reducing bycatch (e.g. backdown-tow procedure)
T + 2	Test fixed gear for releasing small fishes—sorting grids. Recapture, sample, tag and hold ‘released’ fishes prior to final release.
T + 2	Test devices for removing/releasing bycatch—brailing devices, tail grab, shark slide, etc. Tag fishes prior to release.
T + 2	Twenty-four hour hold on ‘released’ fishes probably (?) sufficient to determine likelihood of short-term survival and effects of techniques.
T + 18	Analyze results; prepare reports and manuscripts
T + 18	Identify skippers/vessels for trials of select techniques & technology.
T + 24	Await tag returns; distribute reward money.

Action items

Interviews

Interviews with fishing captains selected for their skills, status amongst their peers and willingness to collaborate with scientists offer the opportunity to fine-tune research plans, avoid logistical mistakes, and solicit new ideas. Several suitable skippers are already regularly contacted for their contributions, and, if necessary, could likely identify additional individuals. Rather than an impromptu approach, however, asking six to eight captains to participate in a formal interview with pre-selected questions offers a better controlled means for obtaining informed feedback and innovations.

Specific questions that should be addressed include:

- How do FADs used in the western, central and eastern Pacific vary in design and construction?
- How are FADs deployed (spacing, placement, soak duration, etc.)?
- What kind of FAD losses should we anticipate?
- Are acoustics a useful tool for reducing bycatch?
- How might you modify *technique X*?
- How would you design *bycatch release device Y*?
- What suggestions can you offer for reducing bycatch?

Approach: Using two to three conference calls and electronic communications, a subset of the NMFS/IATTC Bycatch Reduction Working Group can identify fishing captains and develop a list of appropriate questions. Persons familiar with purse seine operations and the objectives of the working group should contact these individuals and arrange to conduct formal interviews, either in person or via telephone. Prior consideration should be made regarding recording the interviews; taking notes is less intrusive but also more subjective. Regardless, all participants should be assured that individual responses will be confidential and any reports or publications will honor this agreement. We should also consider providing a modest ($100) honorarium to participants.

Objectives and budget

Objective	*Responsibility*	*Cost estimate*
Determine composition of the subcommittee	NMFS/IATTC Bycatch Reduction Working Group	No cost
Identify likely candidates to interview.	Subcommittee to interview vessel captains	No cost
Draft list of questions for review	Subcommittee	No cost
Solicit feedback on questions from full working group	Subcommittee	No cost
Finalize questions	Subcommittee with input	No cost

	from full working group	
Conduct & record interviews		$100 x 8 = $800 honoraria $50 media (e.g. DV tape)
Archive interview media; available to full working group	Subcommittee	Copy and distribute audio records $100 to transfer digital audio/video to compact disc; mail.
Total		$950

Building and Deploying Research FADs

FADs for use in this research project should likely be built in the home port of the charter vessel. These FADs must be completed and loaded on to contract vessels so that they can be deployed approximately two months—the generally accepted minimum soak time—before the research charter vessel embarks. Note that the vessel chartered for the actual research need not deploy the FADs and there may be logistical advantages to contracting with other vessels to deploy the research FADs.

Ideally an IATTC employee familiar with the appropriate port and resources locally available would take charge of purchasing materials and assembling the FADs. Working with one of the fishing companies, given their access to materials (e.g. net scraps) and labor would greatly simplify the operation and probably reduce costs as well. Such an operation would also offer a secure place to store expensive GPS buoys in the midst of surrounds that may not otherwise be very safe.

Objectives and budget

Objective	*Responsibility*	*Cost estimate*
Identify a commercial fishing company, amenable to assisting with the project, with a base of operations in a suitable port.	IATTC	No cost
Negotiate a (formal? informal?) agreement with this company.	IATTC	No cost
Contract with an IATTC employee to acquire components and assemble FADs.	NMFS/IATTC	No cost
Purchase FAD components (bamboo, webbing, chain, rope, GPS buoys). GPS buoys ± $1600 ea. + 35% duty & shipping (assumes vessel has compatible receiver & software)	Contract holder	$28,000

Remainder ± $2000 total Assemble 12 FADs; includes salary replacement, local labor + travel.	Contract holder	$4,800
Load FADs and GPS buoys on vessel(s); deploy ($100/FAD).	IATTC/comm. fishing company	$1,200
Total		$34,000

Charter Commercial Fishing Vessel

The logistical crux of this proposal is the charter of an appropriate commercial purse seiner with an experienced captain and crew. Because the techniques and equipment I propose testing rely on the skilled execution of commercial fishing practices and the operation of commercial fishing gear, it is imperative that the 'real thing' and the right people are hired for this occasion.

Fishing technology evolves at sea; perhaps the most powerful opportunity afforded by hiring a commercial vessel and crew is the chance to fine-tune gear and techniques with aid of those who best understand their use in an environment where innovations can be tested almost immediately. This is particularly important, given the difficulty and expense of accessing this fishery. For this reason, a skipper (and a deck boss) known for their innovation and their ability to modify or fabricate gear would be an important asset. An additional consideration would be to charter a scientific research vessel to accompany the commercial vessel: The purpose would be to provide engineering and fabrication support (as well as scientific assistance) to the cruise. While this would increase the budget considerably, such a plan could greatly improve the potential scope of the proposed experiments.

Objectives and budget

Objective	*Responsibility*	*Cost estimate*
Identify a commercial tuna purse seine vessel with an experienced captain and crew company, amenable to assisting with the project.	IATTC with contract scientist*	No cost
Charter[5] commercial tuna purse seine vessel for 45 day research cruise, port fees, etc.	NMFS/IATTC	$140,000

[5] Assumes the cost of vessel, captain & crew to be $3000 per day + $5000 in port fees and miscellaneous expenses. Actual cost could be much higher, depending on the vessel size and other factors. This total could be reduced through the sale of tuna captured in the course of completing the research cruise, but there is a very real danger that this could compromise the relationship of captain and crew towards the primary objective—completing the research. One possibility would be use the sale of fish as a way of covering operating costs (money to vessel owner) and to raise money for subsequent research. Some portion of the sale beyond that needed to cover costs might

Negotiate a (formal? informal?) agreement with vessel owner and captain.	NMFS/IATTC	No cost
Purchase or fabricate gear to be tested or used in experiments.	Contract scientist* with NMFS & IATTC	$6,000 +
Contract* with scientist and two assistants to conduct observations, experiments and trials in the field. ($9000 + 2 X $4500 + travel for six weeks)	NMFS	$21,800
Equipment and supplies (recapture net; camera & housing; tags & awards; recording media; other)	Contract scientist*	$12,800 +
Contract with scientist and grad student to analyze data and complete a report (nine months).	NMFS	$24,000
Contract scientist and grad student: write manuscripts for publication with NMFS & IATTC scientist co-authors.	NMFS/IATTC	No cost
Total		$

Field Observations

Field observations to document tuna behavior around FADs under undisturbed conditions and during purse seine sets are critical; the behavior of FAD-associated should inform the following experiments, techniques and gear modifications. In particular, details regarding how fishes behave around FADs and within purse seines are crucial to the successful design of sorting gear and how this gear should best be deployed. New information regarding such behavior may also suggest alternative fishing strategies, including those potentially keeping bycatch species out of the net altogether. Field observations on these aggregations of pelagic fishes will, in many instances, be new to science—the two studies (Gooding & Magnuson, 1967, Hunter, 1968, Hunter & Mitchell, 1967, Hunter & Mitchell, 1968) with published results took place in significantly different habitat (coastal Central America and the vicinity of the Hawai'ian Islands) and did not include observations of large tuna schools.

Observations should include direct visual observations, supported by video recordings and ship-board active acoustic observations[6]. A series of observations should cover all daylight hours (minimum: 5 FADs at dawn or dusk,

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also be used to provide captain and crew with a bonus and encouraging future collaborative efforts.

[6] Additional technology to supplement direct visual observations might include the use of night vision equipment, passive hydroacoustics and the acoustic tracking of tagged individual fish. In addition, a low-cost (~$12,000) autonomous video unit (AVU) mounted on a FAD that samples a pre-set vertical range between the surface and 60 meters depth with modest low-light capability has been designed (three alternative designs available, including cost estimates). These units could be deployed from multiple FADs as long as a tender was available to guard against tampering or theft.

and another 5 FADs between 10 and 2 local time). Principle objectives include the identification or documentation of

- temporal patterns in species-specific FAD association behavior
- spatial patterns in species-specific FAD association behavior
- layering with depth (i.e. size class- or species-specific patterns of shoal formation such as small fish on top, large fish below)
- changes in behavior with regard to fishing operations.

The spatial positioning of different sizes and species with regard to each other and to the FAD will inform strategies for positioning sorting gear in the purse seine (i.e. depth below the corkline and position relative to the bow ortza). If small fishes retain a surface position during initial stages of the set, grids near the corkline, rather than deeper, may be more effective. If sorting grids prove to be effective only during latter stages of the set after putative size segregation has broken down, these grids might be placed at various depths to ensure that more small fishes encounter the gear particularly due to the vertically elongate shape of a typical sack.

Better information on the behavior of fishes prior to any set as well as inside the purse seine may also suggest fishing strategies for reducing bycatch. Currently, some skippers use the closer affiliation between small fishes and the FAD to lead bait species and some bycatch out of the set while retaining valuable fish deeper in the water column and farther from the FAD. Such methods do not appear to be widely practiced, but any technique that offers the chance to remove bycatch from the seine early on deserves careful investigation.[7]

These observations (and the experiments that follow) depend on encountering a minimum number of FAD-associated fish assemblages; six such assemblages is probably a bare minimum. Because the experiments involve setting on and retrieving the captured fishes, at some point the chartered vessel will reach capacity and further sets can only result in wasted fish. However, even after the vessel capacity is reached, we should still be able to make observations on FAD assemblages. The number of sets to fill the ship depends on the tonnage of the fish in the sets and the capacity of the vessel. FAD sets average about 50 mt of tuna, but vary considerably and sets greater than 100 mt are not uncommon. Nonetheless, it seems reasonable to expect that a modestly-sized vessel with a 600-700 mt capacity should offer the opportunity for the minimum number of six sets with a reasonable likelihood of getting in 8 or more.

The data that should be collected during these observations include

- narrative and focal animal observations

[7] Ben-Yami, M. 1994 Purse Seining Manual (FAO), Fishing News Books, Oxford, p.56: A Malaysian method for purse seining mackerel, carangids & sardinella is described, involving moving target schools from an anchored FAD ("tua") to one attached to a small auxiliary boat whereupon the set is made on these fish associated with the replacement tua. Clearly some fishes can be manipulated using such techniques, providing additional support for the possibility of using similar methods for separating FAD-associated fishes by species and/or size in the tuna fishery.

- underwater video—diver operated (and from an AVU[2])
- timed observations (e.g. 20 minute observation period: count abundance and frequency of appearance for different size classes and species of tunas)

It is important to consider the possibility that a diver, no matter how discrete, may spook the fish around a FAD, hence the value of the AVU (or a ROV/AUV)—the project can be completed successfully without this support, but this capability would likely add significantly to the outcome.

Objectives and budget

Objective	*Responsibility*	*Cost estimate*
Quantitative observations of flotsam-associated fishes	Contract scientist & two assistants	included[8]
Record visual observations	“	“
Edit recordings to include an annotated video of relevant behaviors and a photo library	“	“
Digital media for recordings		$550
Underwater housing, SLR digital camera & wide angle lens		$8,000
Batteries, storage hard drive, etc		$500
Total		$9,050

Field experiments

These field experiments depend on making a minimum number of FAD sets; six is probably a bare minimum, but, as discussed above (“Field observations”), a 600-700 mt capacity seiner is likely to offer ample opportunity without wasting fish before filling its wells. Ideally, a at least eight comparable FAD sets would be made. In the experiments described below, treatments would be alternated rather than randomized for all the obvious statistical reasons (limited opportunities for replicates, etc).

FAD modifications and manipulations

These experiments are based on flotsam-associated fishes’ fidelity to a floating object and ‘layering with depth’ (sensu Parrish, 1989): Flotsam-associated fishes will maintain that association despite considerable interference, including towing a FAD and switching the original object for another, often an object considerably different in its physical characteristics (e.g. substituting a

[8] Observations should be considered one of the responsibilities under the contract referred to under “Charter Commercial Fishing Vessel: Objectives and budget.”

fishing vessel for a log). This observation is based on numerous anecdotal reports, the ‘slingshot’ method of purse seining tunas on anchored deep-sea buoys, and Nelson (2003). Hunter and Mitchell (1967) observed flotsam-associated assemblages with their component species distributed in a predictable fashion along a depth gradient.

Tests of the following procedures are described below:

- back-down and tow FAD & small fishes out of the seine
- two-part FAD
- test of a related hypothesis; that FADs can be exchanged with negligible effects on the behavior of associated fishes

Flotsam-associated fishes are typically segregated in space, to some extent by depth (‘layering with depth’), with smaller fishes generally closer to the surface (Hunter & Mitchell, 1967, Hunter & Mitchell, 1968). Many tuna boat captains believe that the smaller fishes are an important factor in attracting larger tuna and some regularly attempt to preserve the smaller FAD-associated fishes when making a set (Captain Alan Parker, FV Atlantis 2, personal communication). There are a number of strategies for doing this—‘backing down’ the fishing vessel during a set to submerge the corkline and towing the FAD out over the top of the net with a speed boat, or using a separable, two-part FAD to divide the surface-oriented fishes (i.e. bycatch species) from the deeper (and presumably desired) fishes. Tests of these two procedures are described below.

The efficacy of each of these methods would be evaluated by completing the set (Back-down & tow) or by setting on the deep portion of the FAD (Two-part FAD). The catch (large tuna + bycatch) would be quantified following standard procedures for IATTC observers (estimate quantities of small, medium and large tuna species as well as bycatch species). Subsequently, the FAD would again be set (Back-down & tow) or the shallow portion of the FAD (Two-part FAD) would be set; catch and bycatch would be recorded. Efficacy would probably best be tested (statistically) by comparing the bycatch component (numbers of key species or sizes, diversity) to the bycatch associated with comparable sets from the IATTC database (controlling for area (lat long), catch size (total tonnage), season, etc.), but comparisons between the two methods and the subsequent sets (e.g. sets on the shallow portion of a two-part FAD) are also worth making.

Back-down & tow

To test this method, alternating FAD sets would employ the following procedure: After the seine has been pursed, the skipper would submerge the corkline farthest from the vessel by accelerating the engine in reverse and pulling the corkline several meters under water. A speedboat previously tied off to the FAD would then slowly tow the FAD (< 5 km/hr) out of the net. Details would depend on the advice and experience of the skipper.

Two observers in the water would accompany the FAD, protected by the speedboat mentioned previously, during the set. One observer would operate an underwater video camera, recording the behavior of flotsam-associated fishes and, if reasonable, tracking individuals for focal animal observations. The second observer would take underwater photographs, but concentrate most of their efforts on basic observations. These observers should be able—underwater visibility and fish behavior permitting—to collect qualitative data on the fishes that accompany the FAD as it is towed out of the seine. Some quantitative data, too, should be recorded; depth, species and orientation of associated fishes at critical stages during the operation, etc. The third scientific observer would work from the tower, recording observations on the fishing operation (e.g. the occurrence of malfunctions) as well as the behavior of fishes. Once the FAD has been removed, the observers would move to other experiments, such as observations of sorting grid performance or the use of removal devices from the sack or deck.

Two-part FAD

Alternating FAD sets—those not testing the back-down & tow procedure—would exchange conventional FADs with associated fishes for a two-part FAD prior to making a set. My assumption is that this switch will have negligible effects on the behavior of the fish assemblage, and the hypothesis to be tested is that the use of a two-part FAD will permit the separation of a substantial component of the bycatch from a FAD-associated assemblage.

Upon locating a FAD with associated tuna, the vessel would deploy a two-part FAD (Figure 1) next to the FAD. With the aid of a speedboat to keep the two-part FAD as close as possible without getting it tangled the vessel would then pull the standard FAD from the water. Timed underwater observations before and after the switch and monitoring the fish schools with the ship's sonar should be used to record any change in the size of the FAD-associated assemblage.

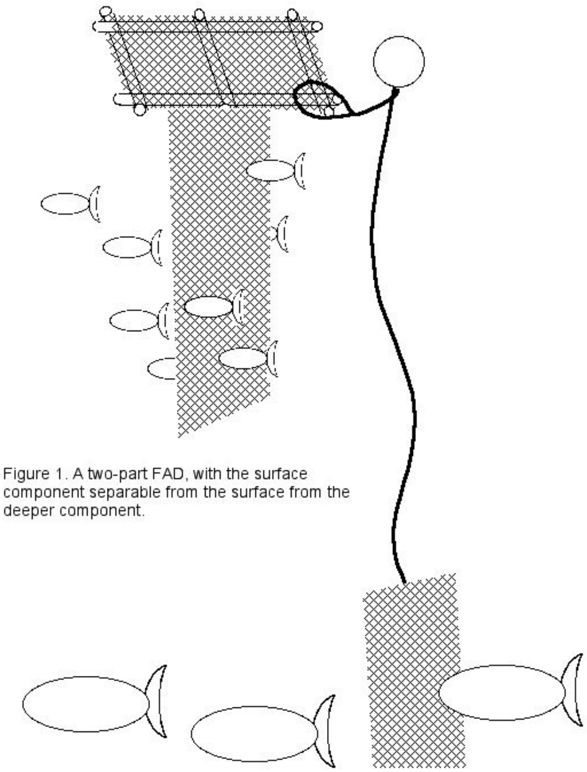
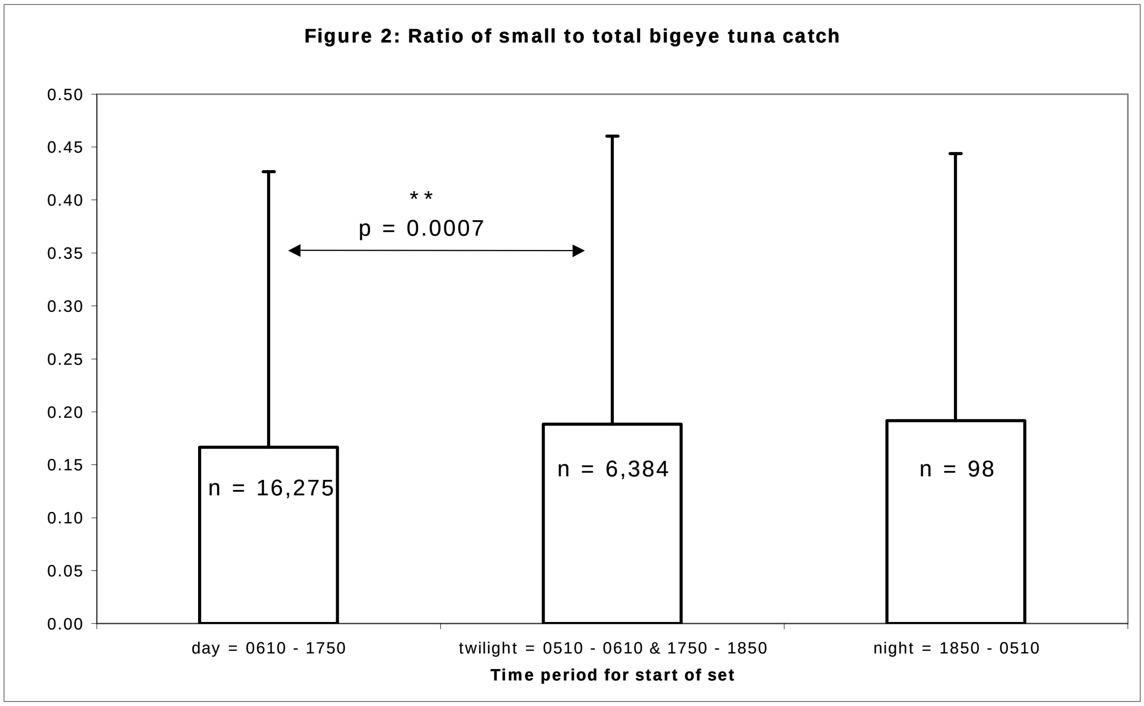


Figure 1. A two-part FAD, with the surface component separable from the surface from the deeper component.

It may also be worth testing this empirically by documenting pre- and post-switch assemblages where several 'switches' are alternated with sham switches—deploy the two-part FAD but retrieve it rather than the original (standard) FAD. Setting on these FADs and using the catch as the metric for testing the hypothesis that switching FADs has no effect on the associated assemblage size or composition probably would not be wise, given the variability at least in assemblage size. Rather, the difference between pre- and post-(sham) switch visual and acoustic surveys in a paired comparison would offer better statistical power.

Time of day may be an important factor in this experiment: Skipjack, bigeye and yellowfin all exhibit diel shifts in FAD-associative behavior (e.g. Schaefer & Fuller, 2005) and the ratio of small bigeye to total bigeye catch is significantly greater in sets initiated during twilight (sensu Hobson, 1972) than day-time sets (Figure 2, Nelson, unpublished data).



Once the FADs have been switched, the vessel should move away from the scene and allow a speedboat to separate the FAD components and tow the surface portion away from the deep portion. Underwater observations would be critical here as well. Methods would follow those described above (under 'Two-part FAD').

Behavioral and physiological indicators of stress

Stress-induced changes in behavior will affect the efficacy of bycatch reduction strategies, and the physiological effects of stress or physical trauma will impact post-release mortality rates. Therefore, quantitative measures of fish stress during purse seining operations offer an important metric for exploiting fish behavior to release bycatch during fishing operations and for predicting the survivorship of released fishes. Below, I outline several measures of stress as well as a potentially important environmental variable (dissolved oxygen content). I argue for their importance and describe how these data may be collected in the course of field observations and experiments during a research fishing cruise.

Behavioral measures of stress. Underwater observations should include documenting the schooling behavior of the fish; school structure is a useful indicator of stress (Hobson, 1978, Parkinson, 1990, Radakov, 1973) and qualitative observations could be supplemented with photography, quantifying the polarity of schooling fishes (or lack thereof). Observations of tuna behavior in purse seine sets (Nelson, unpublished observations) suggested that school structure breaks down at some point during sacking up as the volume of the net is reduced. Because schooling may actually interfere with the efficacy of sorting grids, this may represent a critical period for bycatch reduction and might be exploitable. For this reason, underwater observations of fish behavior are crucial. Such observations should be used during field trials to modify plans and suggest new approaches.

importance of dissolved oxygen (DO). As the seine is reduced in volume, fishes are increasingly crowded and are likely to experience hypoxic conditions. This may contribute to the breakdown of schooling behavior, and may also affect survivorship of released bycatch well before they are actually removed from the water. Divers could place a DO probe in the sack from outside the net. These measurements should be compared to measurements taken outside and up-current from the net. Such measures may suggest a number of actions. For example, bubbling pure oxygen into the bottom of the sack, could improve not only survivorship of released bycatch, but may improve the condition of the fish retained for commercial purposes.

measuring survivorship: holding and tagging. While holding released fish for hours or days may be desirable, it is unlikely to be practical. (Holding them over-night may be an option.) For this reason, tagging some subset of these fish is critical to measuring survivorship. See the discussion of this issue under ‘Tail grab’, below.

Removing bycatch from the seine

Once a few sheep have crossed the bridge, the whole flock follows.
Letter from Vincent van Gogh to Theo van Gogh, Etten, September 1881

There is an enormous literature on the use of devices to be incorporated into net gear, and intended to permit the escape of non-target species or fishes below some minimum size. These range from altering the mesh size of the net to the use of a grate or a selection of panels containing openings sized to allow the release of bycatch. The latter will be referred to as sorting grids. Sizing the mesh of a purse seine (or the use of square mesh webbing) to allow small tuna (< 2 kg) to escape is not an option because of problems with fishes gilling themselves in the mesh, blocking the escape of fishes small enough to pass through and resulting in a significant removal task. Grids generally seem to represent a much small fraction of the net surface area, so problems with gilling are less dramatic, and they are placed, at least in purse seines, so as to permit careful monitoring and their rapid removal in the case of difficulty.

Prior investigations into the value of sorting grids, devices built into a net with openings sized to permit the escape of fishes smaller than some minimum size, have shown that

- yellowfin and skipjack tunas will pass through a grid and grid-like devices,
- other species, including carangids, kyphosids and ballistids, will also move through a grid,
- visual and physical design characteristics affect grid efficacy, and
- some means of crowding fish against such a grid is likely to be critical.

Large catches of small (<40 cm fork length) bigeye and yellowfin tunas cost fishermen time and effort and may reduce the future capture of valuable sizes for these species. A sorting grid built into the seine has the potential to release these fishes unharmed including non-tuna species, and improve the value of the catch retained.

Here, I propose testing the efficacy of sorting grid prototypes. 'Efficacy' includes ease of use (installation, deployment & retrieval, net integrity) as well as the rate at which bycatch escape through the device and proportion of bycatch released. The quantitative dependent variables that should be measured include size composition, species composition, survivorship, ratio of potential to actual escapees (size-based), and sorting efficiency (in terms of time to reach some standard e.g. 50% sorted).

The actual design of sorting prototypes for testing at this stage is problematic: There are a great many potential designs, very few of which have even been built, much less tested. However, conceivably all of these could be tested in the field using controlled experiments, given the resources onboard to install and modify the various devices. Below, I list a number of sorting grid designs and gates worthy of consideration. Hopefully, there will be an opportunity to discuss these in detail with net building experts and fishing captains so as to add likely ideas not mentioned here and to modify or eliminate those in need of such treatment.

Design	*Tested*	*Promise*	*Reference*
Rigid sorting grids	Yes, pelagic mackerel trawls	Poor	(Kvalsvik et al., 2002)
Multi-panel rigid grid	No	Good	
Flexible sorting grids	Yes, 2003 trial on the FV Ile Aux Moines	Poor	(Nelson, unpublished data, Anonymous, 2003, Anonymous, 2004)
Semi-rigid sorting grids	No	Good	
Sewn-in steel rings	Yes, various trials, field and laboratory	Marginal	(Captains Dick Stevenson and Alan Parker, Nelson et al., in review)

Clear PVC panels	Yes, experimental Canadian salmon fishery, laboratory	Marginal	(Paul Brajcich, personal communication, Nelson et al., in review)
Bubble gate	Yes, laboratory study	Good	(Nelson et al., in review)

In the table above, 'Promise' is the entirely objective consideration given to each of these designs by me. The astute reviewer will notice that there is a decent inverse correlation between 'promise' and the existence of prior tests. That said, here is the rationale behind these measures:

Rigid sorting grids: This design, while apparently efficacious (Kvalsvik et al., 2002), has not been well received by tuna boat captains shown the design. These sorting grids are large, unweildy and would have to be deployed and retrieved in the midst of a set. It is unclear where such a large piece of equipment could be stored on a purse seiner, and would significantly slow fishing operations. Further, it is unclear how such a large grid would be deployed in a purse seine.

Multi-panel rigid grids: This is an entirely untested concept as far as I know, but attempts to blend the ability of the (large) rigid grids to sort fish with some design characteristics that would lend itself (better) to tuna purse seiners. Briefly, the design consists of multiple, wire-reinforced, 1.5 m by 1.5 m 'windows' built into the top strip of the seine near the bow ortza. Steel or semi-rigid nylon grids could be installed or removed by clipping/unclipping a number of steel carabiners along the perimeter of each of the windows; this operation could take place at several points during a set or whenever there was sufficient slack in the net, perhaps aided by the vessel's hydraulics. The advantages would be a net, sans grids, that would pass through the power block, grids could be readily modified or switched for those of a different design, and net integrity should be very high.

Flexible sorting grid: A flexible sorting grid, constructed of steel wire, was tested in the field on the FV Ile Aux Moines in June, 2003. The grid readily passed through the power block, appeared very strong, but did not effectively permit bycatch to escape. Based on extensive underwater observations, I concluded that the flexibility of the device meant that the openings changed size rapidly and unpredictably preventing small fish from escaping and then flexing so that large (desirable) fish escaped (Anonymous, 2003). Also, few fishes encountered the device until late in the set when the probability of physical trauma was high and when the captain was inclined to pull the device above the surface of the water.

Semi-rigid sorting grid: This design is based on the flexible sorting grid described above, but made semi-rigid by framing the device with a fire hose. The hose would be pressurized using a pump onboard dedicated to this purpose, thus providing resistance to flexing during those times when fishes are nearby. Critical to success (in this an all sorting grid trials) would be concerted efforts towards crowding fishes against the device. Crowding devices are described below.

Sewn-in steel rings: Captain Dick Stephenson conceived of sewing large steel rings into the webbing of his net to permit the escape of small fishes. He has reported good success with this device, as has Captain Alan Parker. My concern about this method lies in the number of rings necessary to significantly reduce the bycatch composition (hundreds?) and the fact that this device, tested in the laboratory (Nelson et al., in review), did not produce encouraging results (no fish went through it, while all of the other devices enjoyed some success). Nevertheless, the concept deserves further consideration given that two successful fishing captains report good success with the device

Clear PVC panels: Clear PVC plastic panels (55 by 100 cm) with oblong cut-outs to permit under-size fishes to escape have been sewn into the webbing of an experimental salmon purse seine fishery, apparently with excellent results. These panels also showed real promise in laboratory tests with the design using yellowfin tuna (Nelson et al., in review). The principle difficulty I anticipate with this design is the poor tensile strength of PVC; sewing these directly into the webbing of a tuna seine may well compromise the strength of the net. It seems worth exploring the possibility of using ‘windows’ framed in steel wire (as described for the multi-panel rigid grids, above) as a means of deploying these devices. In this case, even if the PVC panel failed, the net should remain intact.

Bubble gate: Laboratory tests of a bubble curtain (Nelson et al., in review) suggest that such a device could be used to open and close openings in a net as well as herding or crowding fishes within a net. Conceivably, a large (100 m?) portion of the seine could be turned into a gate by suspending the webbing some distance (1 m?, 5 m?, 10 m?? needs to be tested in the field) below the corkline. This could be closed by pressurizing a sand-filled 17 mm diameter porous canvas hose running along the top of the webbing. The result would be a dense curtain of bubbles between the top of the webbing and the corkline. The curtain could be maintained (closed) as long as no desirable species/size were in the vicinity, and opened (i.e. the air turned off) when small fishes were nearby. Such a device could also be used in association with any of the sorting grids to keep larger fish from plugging the grids.

Finally, the use of a bubble curtain should be explored for the purpose of herding or crowding fishes against a sorting device. The curtain probably would not be useful until late in the set (during sacking up?), when the device could be deployed near a ‘floor’ in the sack. A speedboat could manipulate one end of the canvas hose, perhaps with the aid of a diver to monitor fish behavior.

Experimental design: Test sorting grid prototypes by comparing two grid designs deployed simultaneously (see Figure 2, Archer, 2005) in the net of a working fishing vessel with a secondary net (or ‘bag’) for each of the grids to recapture fishes escaping the main net. The contents of these secondary bags would be examined for size and species composition and evidence for physical damage to the escapees (e.g. abrasions on flanks or caudal fin attributable to passing through the grid). This paired experimental design would allow the direct comparison of multiple grid designs (e.g A vs B, B vs C, C vs A). A sample of fishes from the main net (i.e. fishes that did not pass through the grid) should be examined similarly. Samples should be limited to 150 fishes, selected randomly. Additional samples from the control (main net) and the recapture nets should be held in net pens to compare survivorship rates.

Objectives and budget

Objective	*Responsibility*	*Cost estimate*
Assemble prototype grids, purchase materials & tools for their modification	Contract scientist, NMFS, IATTC	$18,000
Behavioral observations	Contract scientist & two assistants	Included
Sampling released & retained fishes	Contract scientist & two assistants	Included
Additional recording supplies & materials		$300
Total		$18,300

Tail grab

The fishery for tunas on fish aggregation devices (FADs) captures incidentally large numbers of sharks, billfishes, and other large pelagic fishes. The objective of this section is to identify and develop practical measures to reduce the mortality of these animals coincident with tuna purse seine fisheries. Here, the objective is to look specifically at the potential for using a ‘tail grab’ to allow the live release of large fishes from within a purse seine. Our research will combine trials using technology developed for the live capture of mammalian dolphins with satellite tagging technology to monitor the subsequent survival of animals released. The immediate objectives are to test a ‘tail grab’ device developed for the live capture of dolphins as a means for releasing captured sharks and other large fishes, and to estimate their survival probabilities.

Sharks and billfish are frequently accessible from the surface as the seine is pursed and the crew begins to pull in the net. I propose at-sea trials using a modified dolphin grab. A dolphin grab is a spring-loaded device that, when pushed down over the caudal peduncle (the narrow portion of the body, just forward of the tail) of a swimming animal, clamps around the animal. Using a cable anchored to the grab, a small animal can then be pulled out of the net, while a larger one can be lifted using the boat’s hydraulics and released in open water. I anticipate that the grab could be operated from a speedboat working within the seine, or, later in the set, from the deck of the boat itself.

A minimum of four sharks should be tested with this device. Each animal should be tagged with an archival, pop-up tag prior to release (assuming no apparent indications of traumatic injury). An equivalent number of sharks should be caught using hook and line, subjected to minimal handling, similarly tagged and released. Archival pop-up tags, despite the high cost, are probably the only practical means of testing post-release survivorship. The archival tags would permit a direct comparison of the behavior of the two treatment groups (fishes captured in the seine and freed through the use of the tail grab versus those captured using hook and line and minimally handled), while conventional tags would depend on a comparison of tag return rates. The former might require tagging four sharks from each treatment; the latter should probably involve hundreds, far more than we would be capable of tagging in the course of the cruise proposed here.

The objective is a tool whose implementation will reduce the mortality of all non-target large fishes (> 100 kg) by at least 25%, an average of about two sharks per set. By tagging animals released, we can monitor the effectiveness of the device.

Releasing bycatch from the deck

There is a remedy for all things but death,
which will be sure to lay us out flat some time or other. *Cervantes*

In the event of a set capturing many sharks (>12), it may not be possible to release all individuals using the tail grab device and some sharks may be brought on deck during brailing operations. Martin Hall (Inter-American Tropical Tuna Commission) has proposed constructing a chute to aid the speedy release of large fish that come onboard. Such a chute could be pre-fabricated and stored below deck for assembly in the event of a set that warrants its use. The chute may also aid in the rapid release of sea turtles, small mantas, sting rays and other bycatch species. Although the probability of survival may not be very high after a prolonged, high stress period of time in the sack, the physical effects of removal from the net (brailed) and handled on the deck, the chances of survival could only be improved by a quick return to the water (see Cervantes, above). All individuals released from the deck should be tagged; although a control to compare treatment groups would be desirable, such a program is likely beyond the scope of this project and the successful return of any of these tags should justify some confidence in the method.

Objectives and budget

Objective	*Responsibility*	*Cost estimate*
Build shark grab (materials & fabrication)	Contract scientist	$1000
Test shark grab (as many sharks/billfish as possible; tag with archival pop-up tags	Contract scientist & two assistants	included[9]
Capture sharks & tag controls (hook & line)	Contract scientist & two assistants	included
Design/build deck chute (materials: $500)	Contract scientist & two assistants	$500
Tags, applicators & reward (eight archival tags @ $4000 ea. + $5000 for conventional tags, etc.)	Contract scientist & two assistants	$37,000
Total		$38,500

FAD design—future program?

Does FAD design affect species composition? Simple experiments with juvenile reef fish suggest that some basic design elements or deployment strategies (e.g. FAD size, fouling community presence) may have significant effects on the size and diversity of a FAD-associated assemblage (Nelson, 2003), and fishermen can offer a myriad of testable hypotheses on how FAD design affects fish recruitment. Captain Dick Stevenson (ex-F/V Connie Jean, San Diego), for example, maintains that the color of the lights he placed on FAD streamers had a strong effect on the species of tuna attracted. This suggests that some simple experiments could lead to significant findings. Such a venture, would again depend on initial interviews to gather plausible and testable ideas. Do these interviews suggest a testable hypothesis (e.g. blue lights attract higher proportion of juvenile bigeye than green lights, white streamers result in fewer sharks, etc)? I doubt that there would be much reluctance on the part of these captains to discuss their views on FAD design as FADs are regularly 'pirated' and innovations are unlikely to remain secret within the fishing community for long. Such experiments, being several steps removed from any practical application from bycatch reduction, should probably be left for future efforts. Alternatively, given the resources, IATTC personnel could probably organize and implement these experiments using select observers and fishing captains.

[9] Observations should be considered one of the responsibilities under the contract referred to under "Charter Commercial Fishing Vessel: Objectives and budget."

Critical considerations

- commercial seiner whose time and expense is guaranteed; there can be no conflict between the financial motives of the fishermen and the objectives of the scientific endeavor
- minimum of two scientists or one scientist and a very capable graduate student for the field work, ideally supported by an additional technician; all must be highly capable swimmers and divers
- maximal adaptability to unpredictable elements of the effort—for example, if a school set captures multiple mantas, the team should be able to respond to this relatively unlikely event or if some unanticipated observation suggests a new approach to, say, the design of a sorting grid, materials and building capabilities should be sufficient to test that approach

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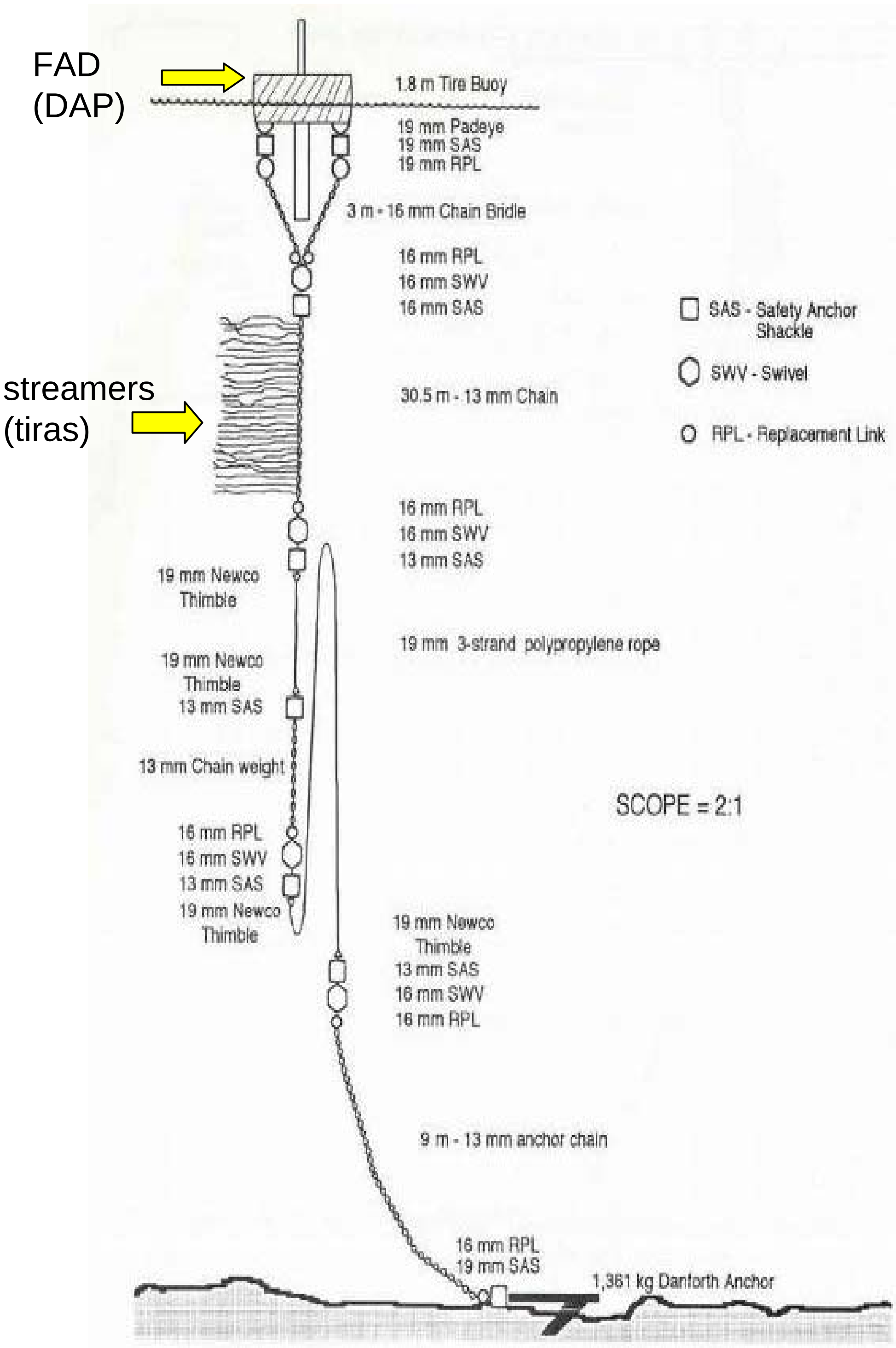
APPENDIX III. ALTERNATIVE FAD DESIGNS

1. Hawaiian design (Diseño hawaiano)



Higashi 1994

2. Spanish sock-type FAD

Size: cylinder of 3m – 6m length by Ø 1.5 m - 2 m.

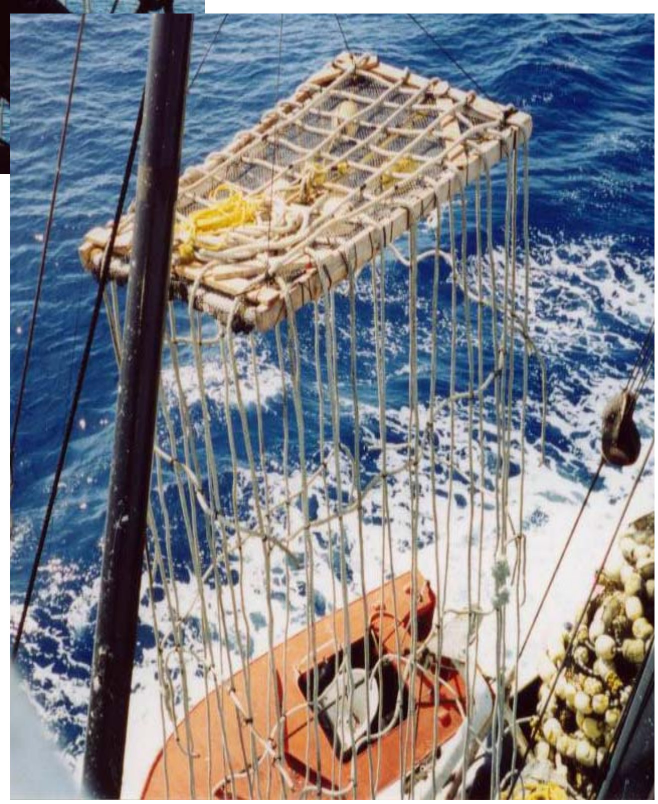
Material: rubber tubing, sailcloth, and ropes.

Colour: green

Description: cylinder with frame composed of a different number of hoops (according to size); the top and bottom hoops are rubber tubing (Ø 50 mm) filled with sand for ballast, while the central hoops are empty rubber tubing (Ø 25 mm). The covering is green sailcloth, fixed to the hoops by several ropes. It has no extension.

These are underwater and not surface objects.

3. Rope structure (estructura con sogas)



4. McIntosh Kites (Barriletes de McIntosh para DAPs)