PFRP Pelagic Fisheries Research Program

Volume 6, Number 3 July-September 2001

New Discoveries in Visual Performance of Pelagic Fishes

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This is a preliminary report of results obtained in collaboration with Dr. Richard Brill, of the National Marine Fisheries Service (NMFS), in a continuing study of visual abilities in pelagic fish and sea turtles. The experiments were undertaken in March/April 2001 at the NMFS Kewalo Research Lab in Honolulu, and aboard the National Oceanic and Atmospheric Administration (NOAA) ship Townsend Cromwell.

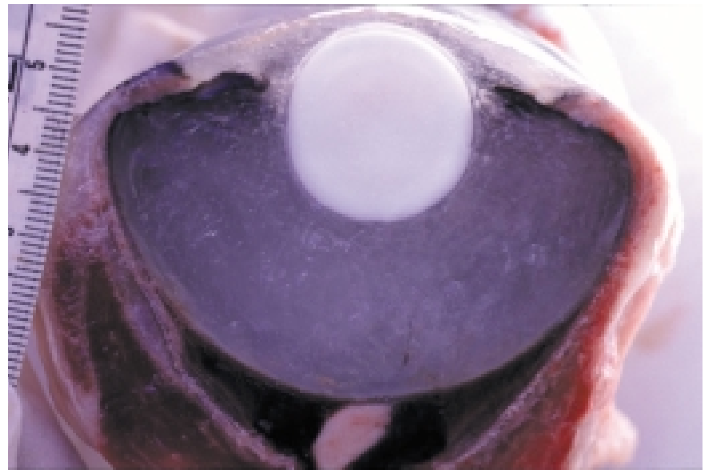

Figure 1. Frozen cross section of a bigeye tuna eye will help researchers determine the internal dimensions of the eye, which will improve their understanding of optical adaptations in pelagic eyes.

Introduction

Large ocean predators like billfishes and tuna rely heavily on vision to catch their prey. These powerful animals can swim tremendous distances, often at very high speed and in very deep water, in search for prey. A visual world as dim and cold as that of pelagic predators places considerable strain on the evolution of good vision, especially for fast-swimming species. Exactly how well do these animals see? How have they overcome restrictions of cold water and dim light to enable them to catch their prey? These questions so far have remained unanswered because of the extreme difficulty of obtaining live specimens– especially billfishes. However, following a highly successful cruise on the NOAA ship Townsend Cromwell, we are pleased to report fascinating new insights into the visual capabilities of pelagic fishes. Beyond the purely scientific, our results also have implications for current fishing practices.

Optics of Huge Pelagic Eyes Imply Active Predation in Very Dim Light

To see well in dim light, one strategy is to have a very large eye with a large pupil. In this respect we can show that the eyes of tuna and billfishes are ideally adapted for the task. For instance, in the largest swordfish we studied (~2.5m in length) the eyes were 9 cm wide and the pupils almost 4 cm. According to our new theoretical model of visual performance, and optical measurements we made on the Townsend Cromwell (figure 1), we can predict that nocturnal and deep-water predators like swordfish and bigeye tunas are efficient visual hunters in dim light. The model also allows us to simulate the visual behaviour of these fishes and predict their ability to capture fast-moving prey in dark water.

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Significant Variations in the Speed of Vision Between Different Species of Pelagic Fishes

For fast-swimming hunters in dim light, the optimal speed of vision poses a dilemma since fast vision requires high light intensities, while slowing down the temporal resolution of the eye in dim light blurs the image of prey moving at speed. The speed of vision is commonly determined by using electroretinography to measure the response of the eye to individual pulses of light from a flickering light source, thereby creating an electroretinogram (ERG). "Flicker fusion" is reached at a frequency when the eye loses its ability to resolve individual pulses of light. During our research expedition we succeeded in determining the Flicker Fusion Frequency (FFF) of a number of pelagic fish, including the swordfish, yellowfin tuna and bigeye tuna.

In this preliminary study, fast swimmers such as the swordfish and bigeye showed surprisingly slow FFF of 17 and 25 Hz (figure 2), which nevertheless is in keeping with their nocturnal lifestyle. On the other hand, the day-active yellowfin tuna was capable of significantly higher temporal resolution, resolving light pulse frequencies at up to 45 Hz (figure 2). We hope to confirm these findings with further experiments that will specifically include determining the FFF at different light intensities. However, the present results indicate that speed of vision is dependent on the lifestyle of the fishes and can vary significantly between species.

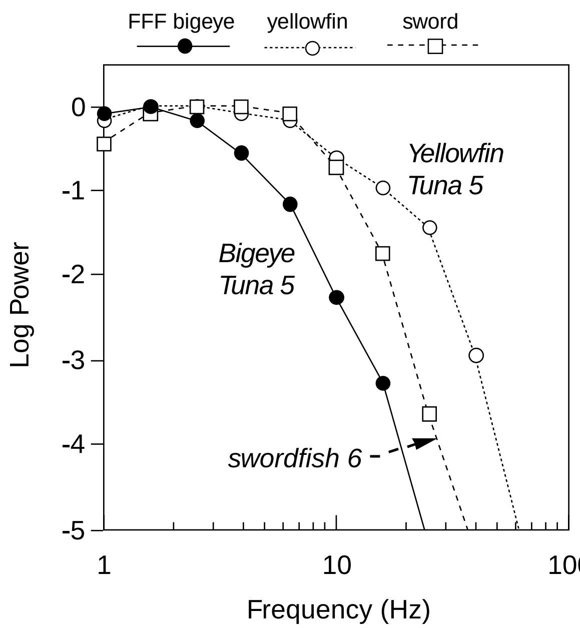

Figure 2. The flicker fusion frequency (FFF) in swordfish, yellowfin tuna and bigeye tuna is determined using the power function over frequency. From visual inspection of the recording trace and the resulting spectrum of dominant frequencies, we determined the frequency at which a response to individual light sources was no longer detectible; this point was usually reached at a power of -3.5 log units, which we then defined to be the FFF. Hence the FFF of swordfish and bigeye tuna in this figure was found at about 17 and 25Hz, reflecting the dim deep-water habitat of the two species. The shallow-living yellowfin tuna was found to have an FFF of 45 Hz.

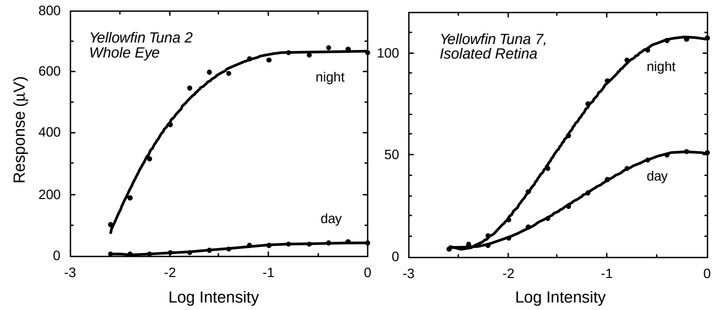

Figure 3. The sensitivity of the yellowfin tuna eye improves significantly during the day-night shift. We found a 10-fold increase in sensitivity during the in vivo experiments (left). Surprisingly, the isolated retinae also showed a clear circadian shift (right).

Marked Changes in Visual Performance from Day to Night

Shallow-living species like the yellowfin tuna experience a large change in light intensity from day to night, and we have discovered the first evidence in pelagic fishes that vision changes accordingly. Eight-hour-long continuous electrophysiological recordings from pieces of isolated retina showed clear differences in visual function between day and night (figure 3). In the night-adapting retina, the response to light grew markedly stronger, indicating that the eye increased its sensitivity for vision in dim light. This behaviour clearly reflected an intrinsic clock of the retina,

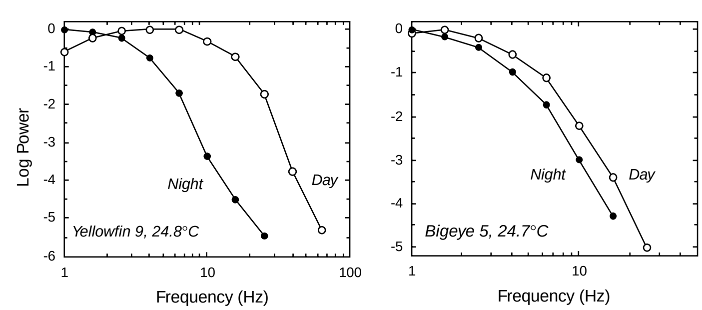

Figure 4. FFF in both the yellowfin tuna (left) and the bigeye tuna (right) measured during the day and night in isolated retinae. The FFF in yellowfin tuna is markedly reduced at night, while the bigeye tuna shows little difference in its FFF from day to night.

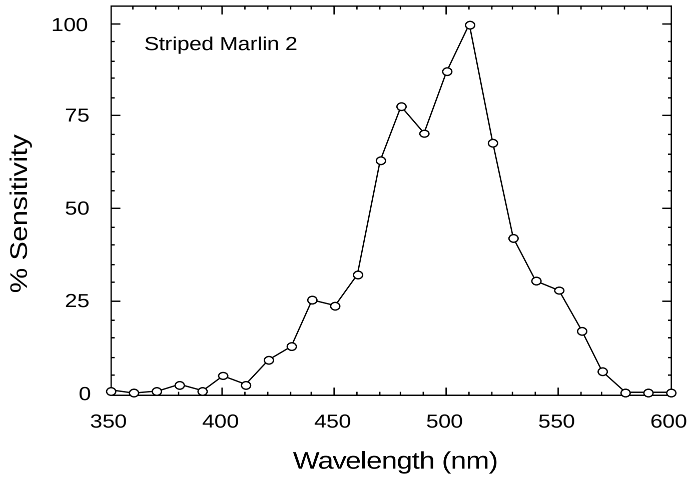

Figure 5. **Spectral sensitivity curve of a striped marlin: best sensitivity is reached in the blue-green waveband, while the two peaks indicate that this fish might have two different visual pigments.**

adapting for night vision irrespective of the surrounding light.

A very interesting species-specific difference emerged between the day-active yellowfin tuna and the nocturnal bigeye tuna (figure 4). The circadian adaptation seen in the yellowfin tuna was substantial, reflecting highly different visual capabilities over a 24-hour period. The bigeye tuna, which in recent archival tagging studies has been shown to remain in dim light at depth during the day and ascend with fading daylight, did not significantly change the sensitivity or temporal resolution of its eye in the day-night shift. This result shows the close relationship of visual environment and adaptations of the visual system in different species. The implications of this finding are especially interesting for estimating visual performance at different times of the day with respect to attractiveness and visibility of prey objects.

Colour Perception is Best in the Blue-Green

Light entering the ocean is very quickly reduced to a narrow bandwidth of wavelength in the blue-green. A visual system optimally adapted to these conditions should be tuned to this blue-green light, and this is what we found in a number of pelagic fish such as the striped marlin (figure 5). We also have evidence from the ERG recordings that these species of billfish show two peaks of colour sensitivity,

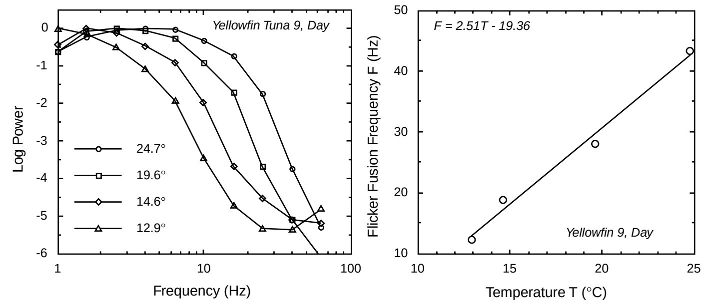

Figure 6. **If yellowfin tunas heat their eyes like bigeye tunas, then these data imply that a yellowfin tuna in 15˚C water without heating has a flicker fusion frequency of 18Hz, but with heating could achieve 36Hz. This assumes that the eye temperature is 22˚C in 15˚C water (as in bigeye tuna).**

indicating that they might have two visual pigments. Using frozen samples obtained on the Townsend Cromwell, the ERG recordings will be complemented by microspectrophotometry (MSP) measurements to confirm the presence of colour discrimination in the marlin.

Retinal Heating Speeds Up Vision for High-Speed Predation

Many pelagic fish can maintain their eye and brain temperatures above the ambient water temperature when diving into colder depths of the ocean. The physiology of the heater is well known, while the reasons for the need to maintain relatively warm temperatures have never been tested in pelagic fish. With our ERG recordings we were able to show convincingly that the speed of vision is highly affected by changes in temperature (figure 6), and consequently that maintaining warm eyes leads to improved temporal resolution and more accurate vision at high speeds.

PFRP

Kerstin Fritsches is funded by an Australian Research Council SPIRT grant in collaboration with the GFAA Research & Development Foundation and Tailored Marine Accessories; additional support was provided by a University of Queensland start-up fund. Eric Warrant is funded by the Swedish Research Council and the Swedish Foundation for International Cooperation in Research and Higher Education.

The Associated Tuna-School Fishing Technique[1]

Jean-Pierre Hallier [2]

The baitboat, or pole-and-line, fishermen of Senegal, West Africa have developed a unique fishing technique called the "associated school fishing method" that is based on a permanent association between a baitboat and a tuna school.

Tuna naturally associate at night with drifting logs, which are fished by purse seiners and tend to be left by the fish at sunrise. The strategy of the baitboat fishermen is to maintain a strong association with a school of tuna throughout the night and day— an association that can be maintained for weeks and months. Schools must be exchanged between boats in order to preserve the association. When one boat is full of tuna or needs more live bait, she passes her school to a fresh boat just arriving from port. This requires that boats work at least in pairs, but more often in groups of three or more. The exchanges can also be partial if a "taking boat" needs a school while a "giving boat" hasn't yet finished fishing.

Partial or complete exchanges between boats are an essential component of this fishing technique, so the exchanges are generally recorded in logbooks; however, data on exchanges are not exhaustive, and some are not logged.

A file documenting these exchanges from 1976 to 2000 was built by compiling old and recent data on exchanges; a follow-up of these exchanges provides valuable information on the evolution of this technique, its increased monitoring by the fishermen, and the innovations developed over the years. Scientists further improved their understanding of the technique by interviewing the fishermen, taking trips at sea, and analyzing catch and effort data from logbooks; an intensive tagging program was also conducted using traditional dart tags.

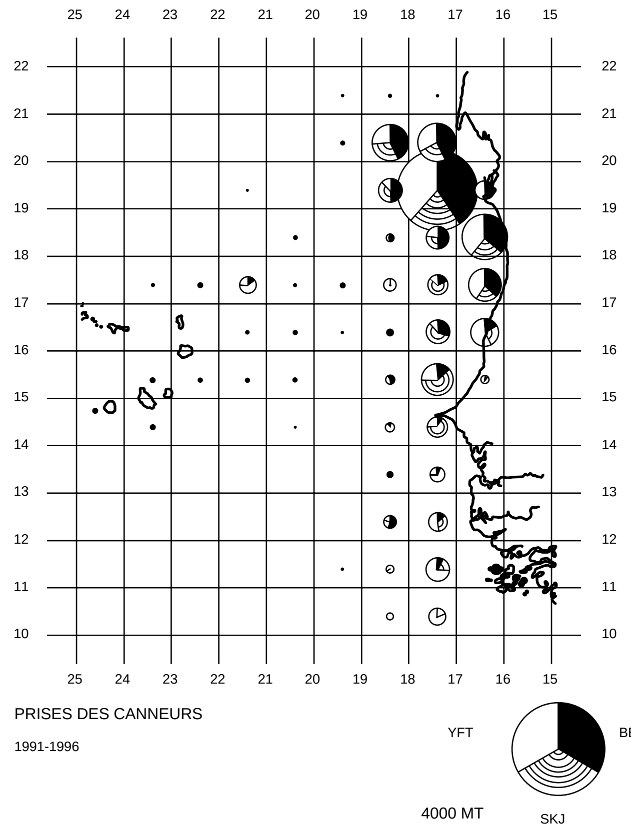

Figure 1. Average fishing area of the baitboat fleet of Dakar (1991–1996); each section of a circle is proportional to the annual species catch by one degree of latitude and longitude.

Location and Season of the Fishery

This Atlantic tuna fleet is based in Dakar, Senegal, West Africa, and its activities are mostly spread from 10°N to 21°N, and from the continental shelf to 19°W (Figure 1). Catch distribution by latitude and month was very stable from 1985 to 1997. Fishing starts generally in May or June, and activity is at its peak from July to November; it takes place mostly west of Mauritania between 18°N and 21°N (Figure 2). As fishing moves gradually to the south in mid-November, yields decrease. In February, the baitboat fleet is generally spread from 10°N to 14°N, and boats have started to leave the fishery for rest and repairs. By the end of March or beginning of April, all boats have stopped fishing.

SST and Catch Distribution

This north-south displacement of the fleet along the coast is directly related to the sea surface temperature (SST) in this area (Figure 3). Fishing occurs mostly in waters whose SST is between 22°C and 27°C, especially where

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[1] The detailed results of this study have been published in Le Gall J. Y., Cayré P., Taquet M. (eds), 2000. Pêche thonière et dispositifs de concentration de poissons. Ed. Ifremer, Actes Colloq., 28, « Baitboat as a tuna aggregating device », pp 553-578.

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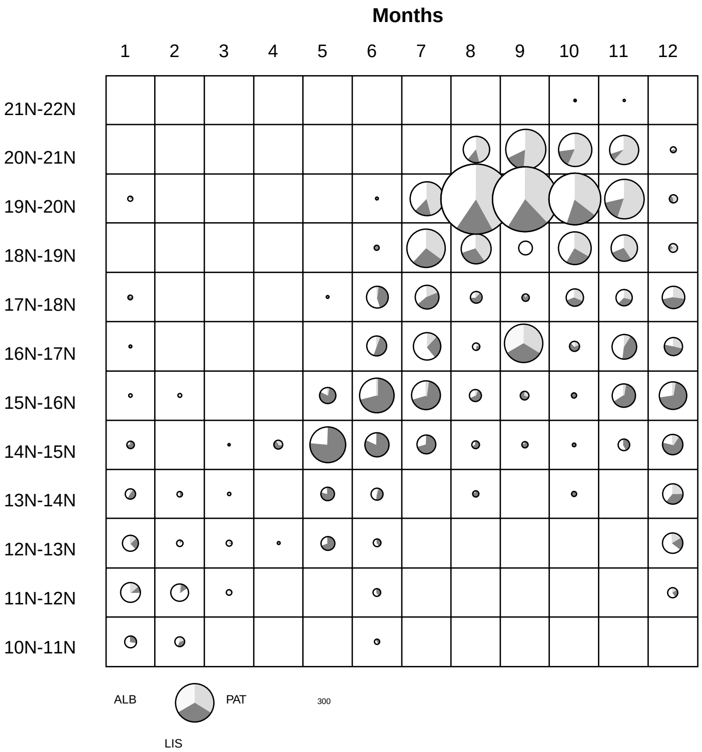

Figure 2. Distribution by latitude and month of the baitboat catch by species (average 1985–1996) from 10°N to 22°N; each section of a circle is proportional to the average species catch by 1° of latitude and one month. (Circle scale= 300 mt)

isotherms are close together. In fact, the fishery follows the movement of the thermal front associated with coastal upwellings. From July to November, this front is stabilized north of Mauritania where fishing and the associated school fishing technique are the most efficient. At the end of the year and during the first term, favorable SSTs are limited to the south of the area and fishing success is low. During the second term, upwellings along the coast of Senegal gradually disappear from south to north, and fishing starts when the thermal front is more or less stabilized north of 21°N.

Catch Composition, CPUE and Fish Sizes

Catch is more or less equally distributed between yellowfin, skipjack and bigeye tuna (Figure 4). Bigeye, quite rare in the catch before 1975, became a main component. Yellowfin has become less abundant since 1993 relative to the two other species. Despite a continuing decrease in the

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Upcoming Events

July 23–27, 2001

2nd SPC Heads of Fisheries Meeting

Noumea, New Caledonia; contact SPC Director of Marine Resources Tim Adams, TimA@spc.int, +687 26 01 24, fax +687 26 38 18, or Secretary for Marine Resources Helene Lecomte: HeleneL@spc.int, +687 26 09 53

NOTE: the SPC meeting will be preceded by The FAO Coordinated Working Party on Fisheries Statistics (CWP-19) from July 9–13; the FAO Pacific Island Fisheries Statistics Workshop, from July 16–18; the 1st Coordination Meeting of the proposed EU/SPC South Pacific Comparative Assessment of Reef Fisheries project, from July 19–20; an Aquaculture Workshop (partly sponsored by ACIAR) on July 20; the 9th FFA/SPC collaborative work-programming colloquium on July 21; and the 7th CROP Marine Sector Working Group Meeting on July 22.

Pelagic Fisheries Research Program Newsletter

Volume 6, Number 3 **July-September 2001**

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Layout May Izumi

Printing PRINTER'S NAME

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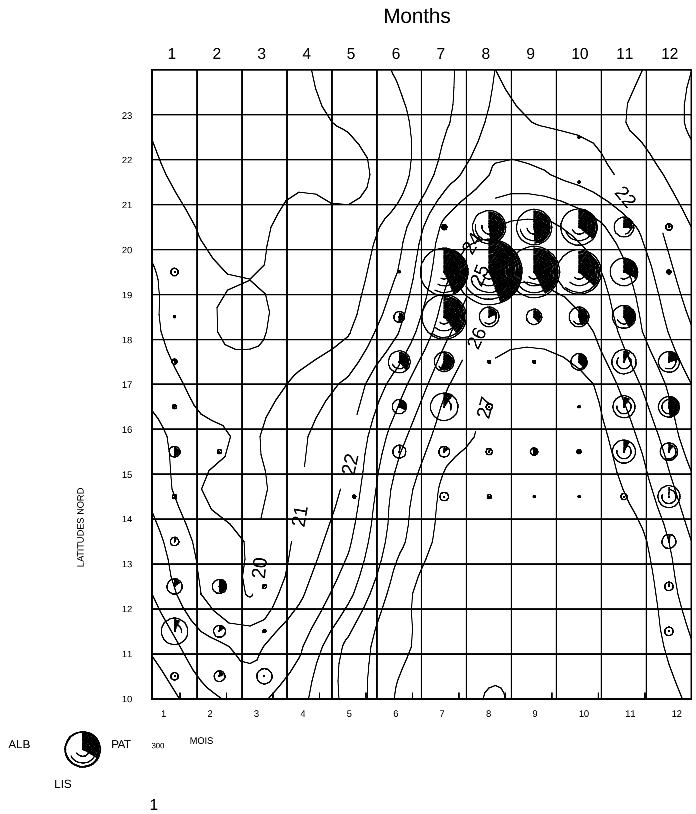

Figure 3. Seasonality of the baitboat fishing zones and sea surface temperatures: average monthly catch and SST by one degree of latitude between 10°N and 24°N for the period 1991–1996; (circle scale= 300 mt).

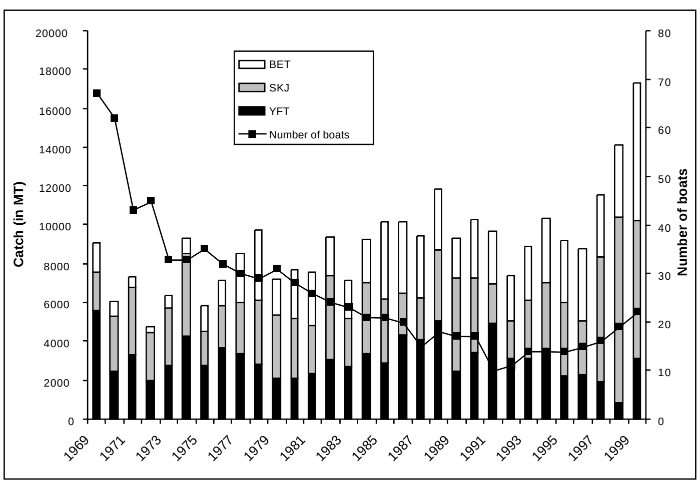

Figure 4. Number of baitboats and catch species composition for Dakar baitboat fleet (1969–1999).

number of vessels in the 1970s and 80s, the catch remained on average at 10,000 mt; this was made possible by a dramatic increase in CPUE, from 1.9 mt/day (1969–75) to 5.2 mt/day (1994–99). The fleet has slowly grown since 1993, so the catch also has increased, reaching 17,300 mt in 1999.

Average weights for caught fish are 6.3 kg for yellowfin, 8.9 kg for bigeye (juveniles and pre-adults) and 2.5 kg for skipjack (juveniles and adults).

Cooperation in Fishing and School Exchange

At the beginning of the season, fishing groups are set up whose members will collaborate on exchanges. Collaboration is based on verbal agreements, and may change during the season. Figure 5 illustrates the exchange process for the 1997–98 and 1998–99 seasons. The 1997–98 season could be described as ordinary: 5 or 6 schools were fished by 16 vessels; groups were more or less homogeneous, but some vessels shifted between groups and partial exchanges occurred between different schools.

From October 1997 on, 1 or 2 boats excluded themselves from this process and fished alone, generally on seamounts to the south of the area. These vessels were banned by the rest of the fleet because from July to September they collaborated with purse seiners. Purse seiners fish seasonally in the Senegal area from May to October, and, since 1992, in the Mauritania area from July to September. At the beginning of the 1997–98 season, catches were not very good in spite of the abundance of skipjack, which did not respond very well to baiting. Some purse seiners and baitboats therefore decided to collaborate, the baitboat allowing the purse seiner to fish her school, with the resulting catch shared.

Relations between baitboats and purse seiners are generally difficult, as the former accuse the latter of destroying the stocks and causing the disappearance of baitboat fisheries. Therefore, the collaborative baitboats were regarded as traitors by the rest of the fleet and banned. When purse seiners left to fish other areas of the Eastern Atlantic in October, these few baitboats had nowhere to fish but the seamounts in the south. This punishment was effective, as the collaboration with purse seiners has not been repeated.

Improvement in Fishing Technique

For the first time in this fishery, during the inter-season from March to June 1998, some schools were kept and therefore carried from one season to the next. According to fishermen, this practice was motivated partly by the decrease in

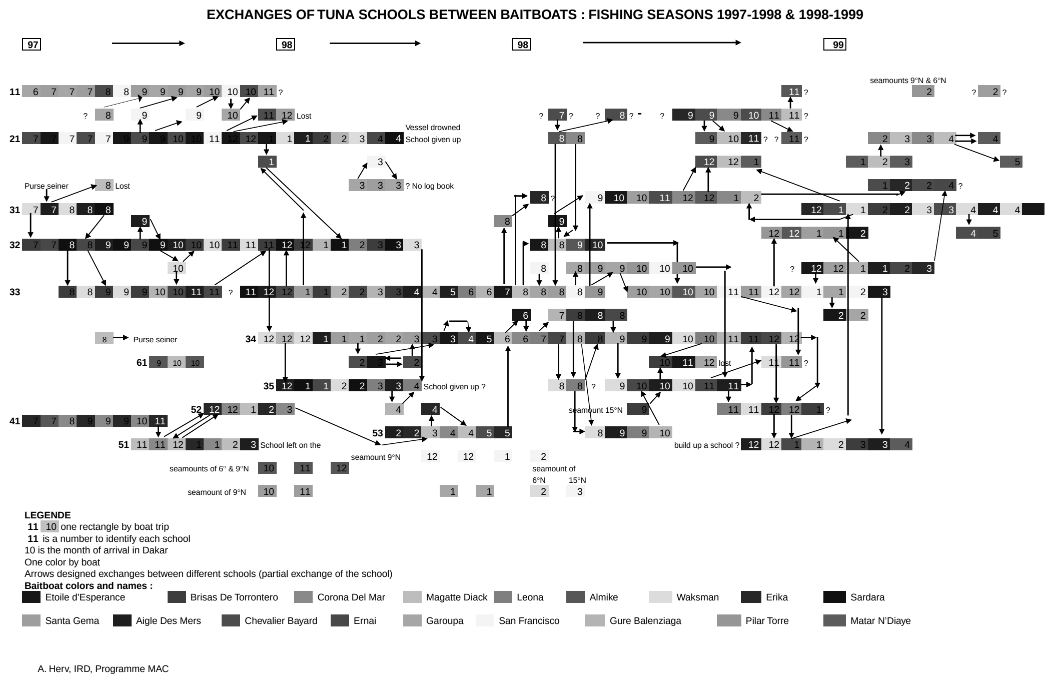

Figure 5. Exchanges of tuna schools between baitboats: Fishing seasons 1997–1998 and 1998–1999

tuna abundance, which made it difficult to form and keep schools. The situation would also have been responsible for the numerous school partial exchanges and the less homogenous groups of the 1998–99 season. By multiplying school exchanges, each fisherman gained credits with many others, which gave him more chances to obtain a school if he lacked one. It seems, therefore, that extensive collaboration and carrying of schools from one season to the next has been found to be rewarding, as it has been continued since, in spite of more abundant tuna (especially bigeye) in the 1999–2000 season.

School Life Span and Number of Exchanges

Figure 6 shows average school life span and number of exchanges by school from the 1976–77 season to the 1999–2000 season.

The first parameter— the time elapsed between the formation of a school and its loss— is dependent upon the extent to which the associated school fishing technique has been mastered: the greater the mastery, the longer the school can be kept and exchanged between boats. The second parameter is related to the first: the longer a school is kept, the greater the number of exchanges it can undergo.

At first, school life span was low, increasing slowly from 8 days in 1976 to 28 days in 1981— but it jumped suddenly to 124 days in 1984 and then fluctuated mostly between 80 and 120 days. This sudden increase corresponded to the evolution from a passive association, in which the baitboat was no more than “a drifting log,” to a dynamic association, in which the boat moved with the school.

In the 1970s, baitboats were gathering tuna schools at night and fishing them in the early morning— but often at sunrise most of the fish left. The boats then drifted with the remaining tuna during the day, and on the next night perhaps gathered other fish. However, when fishing in Mauritanian waters, the prevailing winds and currents carried boats in a southwesterly direction. After a few days they were too far from favorable fishing grounds and lost their schools and/or had to go back to their original positions. In any case, this passive association resulted in a small increase in CPUE and a higher abundance of bigeye in the catch.

In 1982, fishermen discovered that they could keep most of the tuna around a vessel if they started moving at slow speeds early in the morning, instead of drifting. They also added powerful lights, which enabled the tuna to forage around the boats at night (yellowfin and skipjack rely on sight to chase their prey). By moving during the day, the boats could then stay in the most favorable fishing grounds, increasing their chances for an improved catch.

This discovery occurred gradually, as it was not obvious how to keep several tens, or sometimes more than 100 mt, of tuna around a boat. Therefore, despite the rapid increase

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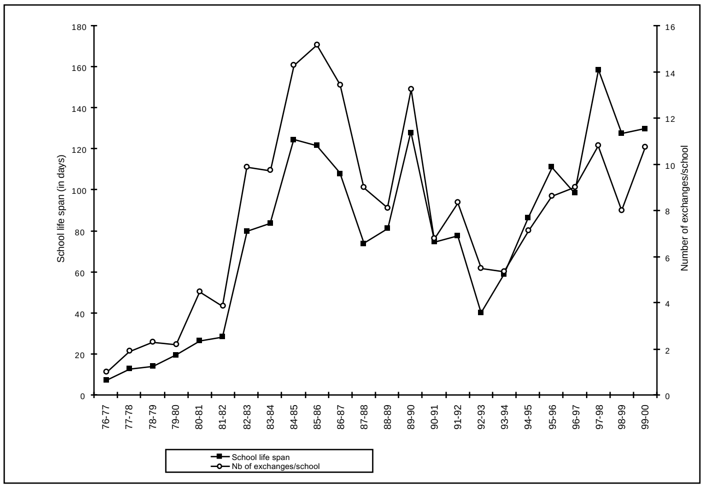

Figure 6. Average school life span and number of exchanges by school for the fishing seasons 1976-77 to 1999-2000

in school life span, CPUE increased only gradually from 2 mt/day in 1976 to 5 mt/day in 1987, when it stabilized below the very high CPUE of 1991 and 1992 (more than 7 mt/day) with catches consisting mainly of yellowfin and a small number of skipjack.

In recent years, each school was exchanged an average of 10 times, and one school, which was kept from May 28, 1999 to February 23, 2000, was exchanged 33 times.

Exchange Procedures

Exchange of schools takes place both night and day. At night, boats are illuminated (each vessel is equipped with 10–20 lights of 1000–2000 watts). A taking boat with lights on slowly approaches a giving boat, also illuminated. When they are side by side, the giving boat switches off her lights and steams full speed away from the taking boat. During the day, a taking boat approaches a giving boat that is actively fishing (throwing baits, poles at sea and water sprays on). When side by side, the giving boat steams full speed away from the taking boat.

Most partial exchanges take place during the day between boats that are actively fishing. Partial exchanges are not as “effective,” in that the fraction of the school that splits is not as great as at night. If one of the vessels is not happy with the split, it can be repeated. In recent years, fishermen have come to favor night exchanges.

When associated with a school, a baitboat moves at between 1 and 5 knots; when drifting at night, the boats cover an average of one mile each hour.

An Explanation for the Association?

At night, tuna gather around boats in the same way they gather around drifting logs, but the association is strengthened by the bright lighting on the boats that makes foraging possible.

During the day, baitboats often encounter foraging tuna while slowly steaming in rich feeding areas; the association between baitboats and tuna may be similar to that between whales and tuna. Because they seek the same prey, tuna may follow whales to optimize their chances of hunting success; also, whales may provide tuna with shelter from predators. The associated school fishing technique is most efficient in the very rich area north of Mauritania from July to November. Tuna associated with baitboats are there for trophic reasons; after that period, fishermen manage to keep schools, but not as successfully as they do in the north.

Tuna Behavior and Movement

Through December of 1999, 9,750 tuna were tagged and released; 2,606 have been recaptured so far, with recapture rates of 53.5% for yellowfin, 19.1% for skipjack, and 40.5% for bigeye. These high recapture rates, which are attributable to the associated school fishing technique, demonstrate the high exploitation rate of the schools, which, in turn, indicates a continuous in-migration of new tuna. The high exploitation rate is further illustrated by the distribution of time at liberty for tagged tuna: 55% of recaptures occur in the first two weeks after tagging, and 82% in the first two months. Skipjack are recaptured more rapidly, yellowfin less rapidly. On average, 3% of recaptures occur more than 6 months after tagging, some a year after (for all 3 species), and even 2 years after for yellowfin and bigeye, generally in the same location and in schools associated with baitboats.

Very few recaptures come from outside the baitboat-fishing zone (Figure 7). More surprisingly, very few recaptures come from the purse seine catch: only 81, including 47 from baitboats associated with schools fished by purse seiners. In the area 6°N–22°N/15°W–25°W, baitboats have recaptured 360 tagged tuna for each 10,000 mt fished, and purse seiners 1.5 tagged tuna. Purse seiners are very active in the baitboat area (annual catch of 32,000 mt from 1994 to 1999) and just south of this area; nevertheless, they caught very few tagged tuna, mostly skipjack. Skipjack is the most tagged tuna (6,574 tagged), and the size distribution of tagged skipjack is almost identical to that of skipjack caught by purse seiners, so this lack of recapture by purse seiners is astonishing— we have no explanations for it.

Furthermore, we have found that in the month after tagging, 77% of recaptures come from the school in which tagging took place. Three months after tagging, half of the recaptures still occur in the tagged school, and half are recaptured from associated schools. This study was conducted on data from 1994 to 1997, as it was easier to follow schools in that period than afterwards. The results show that tuna easily change schools, but their fidelity to their original school is surprisingly high. When they leave their school, most of the time it is to join an associated school— only rarely to join or form a free school that will be vulnerable to purse seining. Altogether two thirds of the recaptured skipjack and bigeye are from the same school; this proportion is a little bit lower for yellowfin, perhaps because the yellowfins' average time at liberty is longer than the two other species.

On average, for 100 recaptures, 61 come from the same school, 32 from an associated school, 4 from a purse seiner that has set on an associated school, 2 from a free school fished by a purse seiner, and 1 from outside the baitboat fishing area (i.e. caught by a purse seiner).

Conclusions

The association of tuna with floating drifting objects fished by purse seiners, or with anchored FADs fished by sport and artisanal fisheries, is not yet well understood and has inspired numerous studies. The association of tuna schools with baitboats has some similarities with these associations, but it remains distinctive in several ways, especially by virtue of its dynamic aspects. At night, the baitboat is not just another drifting object, as it allows tuna to feed by illuminating the water around it. During the day, because the baitboat is steaming, the probability is increased that tuna will find food, compared to an association with a drifting log. Whatever the reasons behind these behaviours, this capacity for tuna to establish associations with different elements at sea is now used on a large scale to the fishermen's advantage. Furthermore, these practices always increase the vulnerability of tuna to fishermen, so they should be monitored closely and better understood in order to protect the stocks.

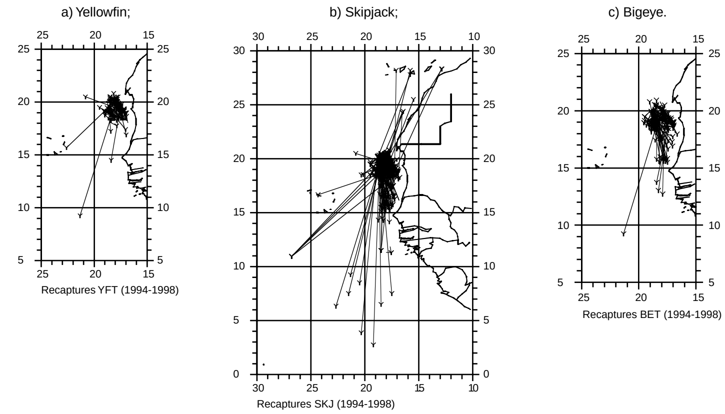

Figure 7. Theoretical tuna movements between tagging and recapture by Dakar baitboats (1994–1999)

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MHLC7—Evaluation & Comment

Following is the second in a series of commentaries on the Multilateral High-level Conference on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific, concluded with the Convention and Final Act adopted September 2, 2000 in Honolulu.

The goal of this series is to share the evaluations of scientists and other interested persons who are well informed about the MHLC, in the hope that continued frank discussion can contribute to the most effective and mutually agreeable implementation of the convention. We have accepted the assessments of persons recommended as knowledgeable about MHLC7 and are seeking additional comment. Our principal criteria are that contributors are familiar with the proceedings, the science and the proposed management schemes, and are willing to answer the same questions, with an opportunity for open comment.

Responses are presented in a Q&A format for ease of comprehension, and biographical information about contributors is held till after the assessment; it is hoped this will encourage readers to consider each assessment on its merits, rather than on the basis of who provided it.

Comments, questions, and requests for inclusion as a contributor may be addressed to Editor, PFRP News / MSB 313 / 1000 Pope Road / Honolulu, Hawai'i 96822, or e-mailed to andercox@aol.com.

General Questions:

1. *MHLC meetings attempted to resolve international concerns and develop a formal means of managing "Highly Migratory Fish Stocks in the Western and Central Pacific." Do you feel this goal was achieved by the MHLC meetings? Why or why not?*

The MHLC achieved the goal it set for itself in 1997, which was to develop a formal mechanism for the management of highly migratory fish stocks in the Western and Central Pacific, taking account of developments in the framework for international fisheries management. While the UN Fish Stocks Agreement established principles and guidelines to be considered by regional fisheries management organizations, it lacked a specific regional context. The MHLC process seeks to apply those internationally accepted principles to the Western and Central Pacific and to establish a framework for the conservation and management of highly migratory fish stocks through establishment of a Western and Central Pacific Fisheries Commission (W&CPFC). In this, the MHLC process significantly advances conservation and management in the region while maintaining the spirit and context of the UN Fish Stocks Agreement. The framework set out in the Convention will be implemented by the new Commission, and that work now falls to the Preparatory Conference for the W&CPFC.

2. *Do you feel MHLC7 was a good conclusion to these meetings? Why or why not?*

Yes— while it was unfortunate that some participants were not able to support adoption of the final text, more time did not seem likely to resolve the remaining differences. When the MHLC process was begun, all participants agreed that elaboration of a Convention was to be completed within a specified time. It was also generally acknowledged that some details would need to be elaborated in the rules and procedures of the eventual W&CPFC. And it was clear from the outset that some issues would be particularly difficult and would occupy several sessions. By the start of MHLC7 most of the important issues had been agreed, and the remaining critical issues (particularly dispute settlement and decision-making) appeared close to resolution.

The Convention as it stands reflects compromise on all sides. Although it may not reflect any one participant's ideal outcome, the final text as a whole meets the agreed objective of the MHLC process, and contains several critical features necessary for effective conservation and management of tunas. The Convention area together with that of the IATTC covers the entire range of the stocks. There is explicit recognition of the obligation to cooperate with regional fisheries management organizations and arrangements, and provision for involvement of the IATTC, SPC and others. It covers all highly migratory fish stocks while retaining a focus on the primary target species of tuna fisheries in the region. It provides for peer review of scientific work. It allows the W&CPFC the freedom to obtain stock assessments and supporting research from outside researchers, and attempts to balance the perceived weaknesses of existing science structures based on national bodies and science secretariats. The Convention also seeks to promote participation by all members regardless of their state of development, thus leveling the playing field for all members.

3. *Should there be an MHLC8, and if so, what should be addressed at this meeting?*

No— the MHLC followed the procedures it adopted; also, negotiations were the result of compromise on all sides, and they reflected a balance achieved after nearly 7 years of discussions (MHLC1 was in December 1994). Given the positions at the end of MHLC7, I doubt that the remaining issues could be resolved by consensus even if further negotiations were undertaken.

Specific Questions Regarding MHLC7

1. *In terms of research and data gathering, what advantages do you feel the MHLC Convention has over other conventions dealing with highly migratory fish stocks (e.g., IATTC, IOTC, ICCAT, CCSBT)?*

One of the difficulties faced by existing commissions is that scientists are limited by the data their members are willing to provide. In many cases this data may be aggregated at such coarse spatial/temporal scales as to be limited in commercial value. This was not a problem before the advent of modern computers, because processing large amounts of data, particularly fine-scale spatial data, was difficult. Now, however, it is possible for commissions with advanced data security protocols to protect sensitive data and also to conduct a wide range of intensive stock assessment analyses.

One advantage of the MHLC is that by endorsing Annex I of the UN Fish Stocks Agreement, members of the W&CPFC will be bound to collect data in more detail and at finer spatial/temporal scales than some currently do. The MHLC also leaves to the W&CPFC the issue of what data is to be provided for stock assessment; this means that, for the first time, a minimum standard will apply to all fleets with respect to collecting data— and the data that is required for stock assessment will be determined by common consent of the W&CPFC, not by an individual member. Furthermore, the W&CPFC will coordinate and promote collaborative research specific to its needs, and cooperate with other regional fisheries organisations and arrangements.

2. *What are the disadvantages of the MHLC Convention with regard to data collection and research?*

I can't think of any significant disadvantages; however, the W&CPFC will almost certainly require staff to compile and disseminate data and coordinate any external research it may contract, as well as to convene and support Scientific Committee meetings.

3. *What do you consider to be the major obstacles facing the scientific arrangements associated with the Commission?*

Probably the greatest hurdle will be financing scientific and technical support for the W&CPFC, especially depending on the degree to which it embarks on programmes to enhance the data collection, port sampling, observer programmes and scientific capacity of less developed members. Another significant hurdle is likely to be the difficulty of cultivating trust in the fishing industry that data from one sector will not be accessible by competitive fleets.

4. *What do you consider to be the major obstacles facing the MHLC Commission over the next few years?*

The W&CPFC will not exist until the Convention enters into force. Therefore, while the Preparatory Conference proceeds over the next several years, decisions will not be binding and actions taken will be on a voluntary basis. During this time, major obstacles will be similar to those facing other management organizations. In terms of stock assessment, it must be determined how to incorporate the Precautionary Approach and specific biological reference points into conservation and management advice. No other organization has yet done this effectively, and this challenge remains for the new W&CPFC. Also requiring elaboration is how to treat non-target species; it will be neither practical nor necessary to treat all species equally, and the W&CPFC will need to establish priorities for dealing with non-target, associated and dependent species.

5. *In the wake of MHLC7, how will management of high-seas fisheries in the Western Pacific change over the next ten years?*

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The biggest change I envision would not be in management but in information and data gathering. At present, most stocks are considered relatively healthy, so while we can expect assessment and monitoring data to improve, this doesn't necessarily mean greater conservation and management measures will follow.

6. *As far as scientific research is concerned, what needs to be done during the approximately 3 years of Preparatory Conferences that take place between adoption of the text and enactment of the Convention?*

The lead-up to establishing the W&CPFC provides an opportunity to identify the data and research requirements for assessment of key tuna stocks and any other highly migratory stocks that may require assessment. It also provides time to develop a coherent research plan to underpin the science information needs of the W&CPFC, as well as ways to assess non-target species.

The next three years will also allow Preparatory Conference participants to explore different ways of working together, in essence serving as a transition period during which to adapt the current ad hoc research arrangements into a formal Commission-based science structure.

7. *How will Northern Subcommittee interests be accommodated in MHLC scientific arrangements?*

Scientific support will be required for the Convention area as a whole and for sub-regions within it, including the area of the Northern Committee. In the North Pacific, as in the SPC area, groups of scientists have participated in ad hoc arrangements for many years, building specific sub-regional expertise that will become available to the W&CPFC. This represents a particularly strong science base for the Commission to build upon.

One question the W&CPFC will need to address is how to integrate the research requirements of the northern region within the spectrum of research interests of the whole Commission. While I do not have a clear view of how this might progress, I see the development of strategic research plans by the Scientific Committee as a cornerstone to developing a coherent scientific research programme. I also anticipate that some groupings of scientists based on common research interests will continue naturally, much as they have in the past (for example, the North Pacific Albacore Research Group and others).

PFRP

Talbot Murray is a research scientist specializing in pelagic fisheries for the New Zealand National Institute of Water & Atmospheric Research. He was a scientific adviser to New Zealand's delegation to the MHLC meetings, and notes that his comments here are his own views and not necessarily those of his employer, the New Zealand government, or other members of the NZ delegation.

Blue Shark Study Nets Early Results

Michael Musyl (with Chris Anderson)

Preliminary findings have started surfacing (literally) in the initial stages of a three-year research project intended to determine, among other things, the survivability of blue sharks (*Prionace glauca*) caught on commercial longline gear. University of Hawaii/JIMAR researcher Michael Musyl and NMFS Fisheries Biologist Richard Brill are using Pop-up Satellite Archival Tags (PSATs) in their PFRP-funded project, which will support tagging of up to 50 blue sharks to resolve a number of environmental and behavioral details about the animals, including:

- daily depth distribution and horizontal and vertical movement patterns;
- the effects of oceanographic conditions on the sharks' vulnerability to longline gear;
- the survival rates of sharks captured and released from longline gear; and,
- stock identification, dispersal and possible fishery interactions.

According to Musyl, 14 sharks were tagged in April during the spring 2001 research cruise of the NOAA vessel Townsend Cromwell, and one of the PSATs has already returned dividends. "The system works just like we thought it would for showing the mortality of tagged individuals," Musyl says. "One of our tagged sharks died and sank, and its tag automatically jettisoned and uploaded its data. According to the temperature and depth chart (figure 1), the shark showed some apparently normal vertical behaviors for the first five days, then expired."

Musyl and Brill have ruled out tag shedding because they have confidence in their attachment system (see photo); they also are confident that the PSAT's redundant pressure-sensitive depth-release mechanisms worked properly (though they don't know which mechanism caused the PSAT to detach), and are similarly satisfied with its downloading procedures and the analysis of ARGOS satellite data.

Musyl doesn't view the mortality as a failure because he expected results like this for some of the deployments. "We faced a Hobbesian choice in this study. On one hand we didn't want to tag moribund sharks that were obviously going to die, because that wouldn't provide useful information. But we also didn't want to tag only extremely vigorous animals, because that would skew our conclusions as to rates of post-release mortality."

Chris Moyes, a colleague of Musyl and Brill at Queens University, will conduct analysis of blood samples to look for biochemical correlates of post-release survivability; with some luck, his data should confirm that the tagged shark was in bad shape when released.

Postscript: Turtles and Waylaid Tags

In view of the results to date, Musyl and Brill think PSATs deployed on turtles should act in a similar fashion, allowing researchers to determine unequivocally the mortality of released animals.

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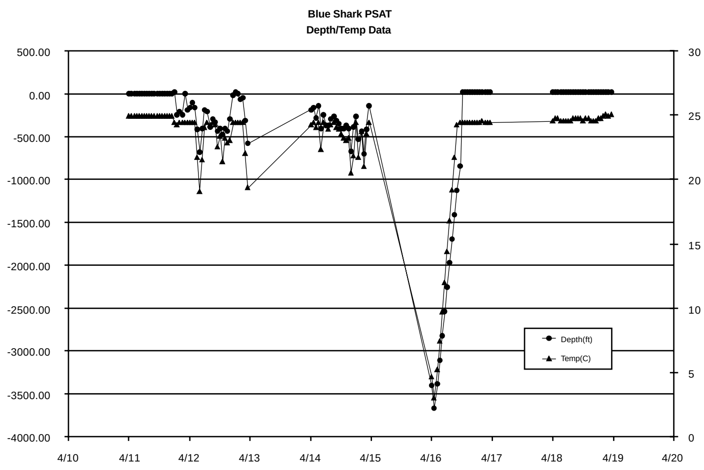

Figure 1. Blue shark PSAT depth and temperature data.

As for the mortality of tags, Musyl notes that there are perils out there besides loss due to sinking and implosion. "I got an e-mail from a Japanese longliner to let me know they'd pulled in one of our tagged sharks. The funny thing was, no data had uploaded from the tag even though it should have. So I contacted them to ask about it, and it turned out the crew had put the tag in a tackle box or something, and stored it in the wheelhouse.

"We figure the tag couldn't establish a link with the satellite because its signal couldn't penetrate the metal of the box or the wheelhouse roof." So Musyl asked the ship's crew to move the tag outside, and it began immediately to transmit its archived data: nearly a month's worth of temperature and depth recordings.

PFRP

MHLC: Years Remain to Bring Order to High Seas Tuna Fisheries

In September 2000, the final session of the Multilateral High-Level Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific (MHLC7) established a Preparatory Conference (PrepCon) to create the Commission that will manage the fish stocks. The job of the PrepCon is to decide how the Commission will function.

The first meeting of the PrepCon was held April 23–28 in Christchurch, New Zealand; it was chaired by Ambassador Michael Powles of New Zealand and attended by representatives and observers from most Pacific island states and distant water fishing nations, as well as several regional organizations. Japan did not participate. It was announced at the PrepCon that 16 nations have signed the Convention, while Tonga, Solomon Islands and the Marshall Islands have ratified it.

The PrepCon considered draft rules and procedures for the Commission based on a document submitted by the United States, and established two working groups. Working Group I (WG 1) considered organizational structure, budget and financial contributions; its work consisted largely of articulating the needs of the Commission, which include a secretariat, scientific advice and information, and compliance services to monitor fishing activities.

WG 2 considered scientific structure and provision of interim scientific advice, but in spite of fairly clear guidance from the Convention, was unable to agree on either a structure or means by which to obtain interim scientific advice. However WG 2 did manage to identify the following principles to guide its work:

- conduct deliberations transparently;
- provide for participation by small island states in the scientific work of the Commission, as well as prior to the Commission's establishment;
- maintain a range of options for the provision of scientific services and advice within the scope identified in Articles 12 and 13 of the Convention;
- to the extent possible, use the scientific resources of various national and regional organizations to ensure economy and avoid duplication of scientific effort;
- in subsequent meetings, consider using information from other organizations to identify requirements for scientific advice and data, and plan research; and,
- depending on the process accepted for providing the PrepCon with scientific advice, consider using information from outside organizations to determine whether the PrepCon may need to recommend conservation and management measures.

The next meeting of the PrepCon is planned for early 2002 in Papua New Guinea, with subsequent meetings every six to nine months for three years.

PFRP

PSATs Will Tell Swordfish Secrets

Richard Brill

During a March/April cruise aboard the NOAA research vessel *Townsend Cromwell*, eight swordfish (*Xiphias gladius*) were equipped with pop-up satellite archival tags (PSATs) that will record the fishes' daily locations and swimming depths, as well as ambient water temperatures. PSATs were also attached to 14 blue sharks, 2 yellowfin tunas, and 1 oceanic white tip shark. The data gathered by the PSATs will be uploaded to orbiting ARGOS satellites when the tags automatically detach 3, 6 and 13 months after deployment.

The overall objective of the study is to develop a better understanding of the movements and distribution of swordfish in the North Pacific in relation to oceanographic conditions. This knowledge will help fishery managers more effectively conserve this commercially valuable species, and aid in development of fishing strategies that minimize the interaction of sea turtles with longline fishing gear.

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(above) Having attached a PSAT to this healthy specimen of yellowfin tuna, NMFS scientists prepare to return the fish to the ocean.

(left) NMFS researcher Rich Brill leans over the side of the NMFS research vessel Townsend Cromwell to harpoon a 70-kg swordfish caught on commercial longline gear.

PSATs Will Tell Swordfish Secrets (continued from page 15)

The swordfish were captured using standard commercial longline gear. As shown in the accompanying photos, fish were brought alongside the ship and a tether (attached to the PSAT and equipped with a nylon dart head) was "harpooned" into the dorsal musculature using a long wooden tagging pole.

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Rich Brill is a NMFS Fishery Biologist; his collaborators on the tagging cruise were fellow biologists and researchers Mike Musyl (PFRP), Dan Curra (UH), Dave Itano (UH) and Tom Kazama (NMFS).

(right) Swordfish must be tagged in the water because, unlike tunas, they're too dangerous to be brought aboard ship.

All photos in this article by Phil White and Dave Itano.

PFRP Pelagic Fisheries Research Program

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