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PROCEEDINGS OF THE 41ST ANNUAL TUNA CONFERENCE

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PREFACE

The 41st Tuna Conference was held 21-24 May 1990 at the traditional site, the University of California Conference Center at Lake Arrowhead, California, U.S.A. Close to 100 participants gathered for this year's conference from the U.S.A., Canada, Mexico, France, Japan, Australia, New Zealand, The Federated States of Micronesia, Pakistan, and Senegal. From Rome traveled a representative of the United Nations Food and Agriculture Organization (FAO); from Madrid came a representative from the International Commission for the Conservation of Atlantic Tunas (ICCAT). Whatever may be said of tuna, tuna scientists are highly migratory. Although careful examination of the data shows that the majority of the participants traveled less than 200 miles to attend the conference, participants may have traveled thousands of miles during the interval between last year's conference and this year's.

The Tuna Conference was sponsored by the U.S. National Marine Fisheries Service and the Inter-American Tropical Tuna Commission. Over 40 papers and 9 posters were presented in an informal, friendly atmosphere. The theme for this year's conference was "Pelagic Community Relations," with emphasis on species that co-occur in the same habitats as those of tunas, especially billfishes. For the second year in a row, the proceedings were prepared in advance of the meeting. For this, we are indebted to last year's conference chair, Mike Hinton, who was the persuading force behind what should become an annual tradition.

Each year, the Tuna Conference helps sponsor selected, full-time students to present their research results. Last year, the Tuna Conference business meeting declared and agreed to establish a scholarship fund. The Manuel Caboz Memorial Fund was established on 25 May 1989. The first Manuel Caboz Memorial Scholarship was awarded this year to Simon Thorrold. In addition, the 41st Tuna Conference provided a scholarship to Charles Barr.

My thanks to everyone who helped me to organize this year's conference and to everyone who put time and energy into making presentations. My particular thanks to those who kept to the deadlines for submitting payments and abstracts and to those who patiently awaited responses while I was migrating.

Christofer H. Boggs
Chair
41st Tuna Conference

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BILLFISHES

Behavior and Vertical Distribution of Pacific Blue Marlin in Hawaiian Waters as Determined by Ultrasonic Telemetry

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Six Pacific blue marlin, weighing between 60 and 160 kg, were tracked in Hawaiian waters for durations between 7 and 42 hours. Their vertical movements were analyzed with respect to ocean temperature strata as determined by expendable bathythermographs. All six fish were caught by using artificial lures and sportfishing gear. Four were caught, tagged, and released by sportfishermen; two were tagged by the scientific crew on the National Marine Fisheries Service's research vessel *Kaahele'ale*.

Certain results were common to all six tracks. For instance, immediately upon release, all of the fish dove into the upper layers of the thermocline, where they remained for 4 to 6 hours. Also, all of the fish initially headed directly offshore for several hours, and their rates of swimming during these first few hours were greater than during the remainder of the tracks. Average swimming speeds ranged between 1.2 and 2.2 kn. None of the fish demonstrated diel horizontal patterns of behavior (e.g., patrolling a "home territory"), although there were consistent differences in vertical distribution between daytime and nighttime, with nighttime activity generally being closer to the surface. Pooling the data from all six fish indicates that about 36% of the daytime and 60% of the nighttime was spent within 30 m of the surface, the rest of the distribution being deeper. The interface between the top of the thermocline and the bottom of the mixed layer appears to represent the bottom of the normal distribution for this species in Hawaiian waters: 82% of the daytime and 97% of the nighttime distribution was contained within the surface mixed layer. There was no indication that any of these animals suffered permanent damage from the trauma of capture and release, even though some of them appeared to be completely exhausted at the time the transmitter was attached. Recovery time appeared to be between 4 and 6 hours. These results are currently in Holland et al. (1990).

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Estimating Age and Growth of Young Atlantic Blue Marlin, *Makaira nigricans*, from Otolith Microstructure

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Otolith microstructure analysis was applied to sagittae from 18 larvae (5 to 10 mm notochord length, NL) and 77 juvenile and young adult (4.3-212 cm lower jaw fork length, LJFL) Atlantic blue marlin, *Makaira nigricans*, for estimation of age and growth rate. The seasonal distribution and peaks of back-calculated spawning months of the aged samples (May to November) matched those reported in the literature. In addition, the microstructure of larval blue marlin sagittae was almost identical to larval otoliths of other tropical species where conclusive age validation has been accomplished. These results provide indirect validation of this method of age determination. Average percent error of the ageing method was 1.6% of the estimated age in days for the age range of confidence and represented a high degree of repeatability (precision).

Estimated ages of larvae ranged from 9 to 12 days, while estimated ages of juveniles and young adults ranged from 21 to 495 days (1.4 years). Otolith microstructure analysis could not be applied with confidence to blue marlin older than 1.4 years, because of the inherent problems of discriminating and counting increments in older fish. Allometric equations for the length-weight relationship of immature (≤140 cm LJFL) and mature (>140 cm LJFL) male and female blue marlin are presented. Sexual dimorphism in Atlantic blue marlin appears to begin at 140 cm LJFL, as evidenced by the significant difference in length-weight relationships between mature (140-277 cm LJFL) males and females.

Both the maximum and sustained growth rates in length during the first 100 days indicate that Atlantic blue marlin are one of the fastest growing of all teleosts, particularly for the early stages of development. Analysis of otolith microstructure patterns associated with presumed annuli on adult (>212 cm LJFL) blue marlin was unsuccessful in providing evidence for validating methods of ageing older age/size categories.

Sexual Maturity of the Swordfish (*Xiphias gladius*) in the Pacific Ocean During the 1968-1985 Period

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The maturity of swordfish, *Xiphias gladius*, has been studied by many authors, mainly in the eastern Pacific (see short review by Miyabe and Bayliff (1987)). Nakamura's (1985) results, based principally on the larvae distribution, indicated that spawning apparently occurs in three areas of the Pacific Ocean: in the central part in spring and summer (March trough July), in the western South Pacific in spring (September to December), and in equatorial Pacific waters year-round. The objectives of the present study are to analyze the temporal and spatial trends of the gonad index values of the mature female swordfish during 1968-85 and to evaluate the structure of the Pacific Ocean population.

All data for this study were provided by the National Research Institute of Far Seas Fisheries, Shimizu, Japan. In this study, only data from female swordfish were used; data from male swordfish were excluded because the high selectivity for females during sampling resulted in few male specimens. Data from each female consisted of the date, location, mideye-to-fork length (in centimeters), and ovarian weight (in grams). The gonad index (GI) was used to indicate the maturity of the fish by the following formula:

$$GI = (\text{ovaries weight}/(\text{eye-fork length})^3) \times 10^4.$$

The total area sampled covers latitudes up to 35°N and 35°S and longitudes up to 95°W in the northeastern Pacific and 75°W in the southeastern Pacific and up to 130°E in the western Pacific. However, the whole area was not always sampled each month. The eastern Pacific data (east of 145°W) for 1970-79 included in this study are from Miyabe and Bayliff (1987).

Following the Miyabe and Bayliff (1987) criteria for the maturation (mature female = >7.0 GI), 1,686 specimens (18.5 %) of 9,132 examined were mature. To determine the body size at first spawning, mideye-to-fork lengths were grouped in 10 cm intervals and mature female percentage for each interval were tabulated. These data suggest that, although very few specimens were mature in small size (70 cm), most individuals of the population reach sexual maturity at about 160 cm. The geographical mean monthly distributions of gonad index by a 5° area from >160 cm specimens were analyzed. From these distributions, four places with a periodical concentration of mature specimens were characterized: the equatorial area, the central north Pacific (waters around Hawaii), the Coral Sea, and the area between 10°S and 30°S and west of 110°W. For further analysis, the total area was divided into five subareas. The equatorial subarea, between latitude 10°N and 10°S in the Pacific; the northwestern subarea, north of 10°N and west of 150°W; the northeastern subarea, north of 10°N and east of 150°W; the southeastern subarea, south of

10°S and east 150°W; and the southwestern subarea, south of 10°S and west of 150°W.

Comparisons among subareas indicated temporal differences in mature specimen concentrations and length frequencies. In the equatorial subarea, mature females were present in all the months, but the number was comparatively low. In the northwestern subarea, mature specimens were remarkably present around Hawaiian waters during the April to July period. For the northeastern subarea, although ≥160 cm long specimens were present, a very low mature percentage (3.7%) was determined, and the mature individuals were more geographically related with the equatorial subarea. In the southeastern subarea, the occurrence of mature fishes was largely west of 110°W during the last quarter of the year. In the southwestern subarea in the Coral Sea, the concentration of mature females was high during the November-February period, and in waters around Fiji, they were abundant during June and July. The sizes at first maturity were similar in the equatorial and northwestern subareas (150 cm length), whereas in the southern subareas, size at maturity was considered to be 180 cm. Our data show a clear agreement with swordfish larval distribution (Nishikawa et al. 1985), indicating the occurrence of subpopulations in the Pacific swordfish population. However, further studies--including other population dimensions such as size composition and trends in relative apparent abundance--will provide a clearer understanding of this subpopulation composition.

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Swordfish Fishery Development in Hawaii

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Swordfish probably have been an incidental component of the catch taken by the Hawaii longline fishery since its inception some 40 years ago, but a longline fishery directed at swordfish did not develop until 1989. The growth of the swordfish longline fishery, the available information on fishing activities, and the composition of the catch are described.

Albumin as a Biomarker for Serological Identification of Billfish Carcasses

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The dockside identification of billfishes caught by foreign longline boats is difficult because morphological characteristics are generally absent from butchered carcasses. Thus, accurate catch statistics for the various billfishes cannot presently be obtained. The Atlantic Billfish Management Plan of 1988 prohibits the sale of white marlin (*Tetrapturus albidus*), blue marlin (*Makaira nigricans*), longbill spearfish (*Tetrapturus pfluegeri*), and Atlantic sailfish (*Istiophorus albicans*) and mandates minimum size limits if these fishes are kept for any reason. A means to identify butchered carcasses is essential in order to enforce this legislation. The goal of the present study is to investigate the utility of antisera produced against billfish albumin as a means of identifying muscle samples taken from butchered carcasses of these species. Albumin is one of the most rapidly evolving proteins and has been used by a number of workers in taxonomic, systematic, and evolutionary studies (Sarich 1969; Lowenstein 1985). Recently, antibodies to albumin have been used to accurately discriminate between populations of striped bass (Shill and D'orazio 1990).

Albumin was purified from the sera of sailfish, blue marlin, and white marlin by a combination of chemical extraction (caprylic acid, ammonium sulfate), ultrafiltration against 30,000 dalton filters, and high pressure liquid chromatography (Bio-Sil TSK 400 gel filtration). The purity of the albumins and their biochemical characteristics were assessed by SDS polyacrylamide gel electrophoresis and isoelectric focusing. Albumin purified from sailfish had a molecular weight of 65,000 but exhibited considerable isoelectric point heterogeneity. Purified albumin from a single species injected into rabbits resulted in the production of polyclonal antibodies with a precipitin titer in excess of 1:1,000. To remove cross reacting antibodies, the antisera were adsorbed with heterologous albumins or heterologous red muscle, which had been previously coupled to cyanogen bromide-activated Sepharose 4B. When red muscle extracts were employed, buffer solutions were adjusted to pH 6.0 to minimize spontaneous precipitation of muscle proteins. Double gel diffusion analysis conducted at pH 6.0 was used to assess the degree of cross reactivity that species-specific antisera showed toward red muscle extracts from each of the three species. A polyclonal antiserum showing specificity for sailfish red muscle and lacking reactivity with blue marlin or white marlin red muscle was obtained. The antiserum preparation specific for sailfish can be incorporated into a kit that could be implemented by fishery biologists to obtain accurate catch statistics and by marine officers enforcing the Atlantic Billfish Management Plan.

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Sailfish Bladder Tissue as a Source of Cells for the Establishment of *In Vitro* Cultures

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Knowledge about the physiology of billfishes, especially at the cellular level, is scant, owing to their large size and pelagic nature. In vitro cultures of cells established from billfish tissues would provide a means to study physiological requirements, identify and isolate growth factors, and determine the susceptibility of billfishes to environmental pollutants. The purpose of this study is to attempt to culture cells from the swim bladders of Atlantic sailfish (*Istiophorus albicans*), leading to the eventual establishment of a cell line.

The sailfish used in this study were caught 5-7 hours prior to removal of tissues for cultivation. The ventral surface of each fish was sterilized with a 10% Clorox™ solution, and the tissues to be studied were transferred to Dulbecco's phosphate buffered saline solution (PBS), modified by adding NaCl to achieve an osmolarity of either 350 or 460 mOsm. Tissues were washed twice with PBS and minced to 1 mm^3 with scalpels. Half of each sample was added directly to tissue culture flasks, following the method of Wolf and Quimby (1976). The remaining half of each sample was incubated with PBS containing 0.25% trypsin and was then added to tissue culture flasks. The pieces of tissue from both protocols were allowed to adhere for 1 hour, then medium was added gently so as not to dislodge the fragments. Leibovitz L-15 (Leibovitz 1963) and Optimem (Grand Island Biological Co., Grand Island, NY) were prepared according to the manufacturer's specifications. They were then supplemented with 10% sailfish serum or heat inactivated 10% fetal bovine serum. The media were adjusted to the desired osmolarity by addition of NaCl. The L-15 medium was tested at 320, 350, 375, 400, 425, 450 and 500 mOsm, whereas the Optimem was tested at 390, 440, 460, 490, and 550 mOsm.

In the course of this study, over 200 cultures were attempted from 8 sailfish. Tissues that were plated directly into flasks without exposure to trypsin produced the best growth. Of the tissues examined, testis, ovary, and bladder tissue could be prompted to grow. However, bladder tissue was the best source of tissue in terms of ease of culture. Rapidly dividing cells could be seen surrounding the majority of plated bladder tissue clumps after only 2 weeks of cultivation. Medium with 10% sailfish serum, either fresh or heat inactivated at 56°C for 30 minutes to destroy complement, proved toxic to the cells; media supplemented with 10% fetal bovine serum supported rapid growth, which was evident within 1 week after plating the tissue. The addition of 0.1% purified sailfish albumin to medium already supplemented with fetal bovine serum improved growth. The optimum osmolarity for growth of billfish cells was 490 mOsm, and Optimem medium appeared to be superior to

Leibovitz. Cells could grow in a medium with the osmolarity as low as 350 mOsm, but the growth was much slower and the cells more vacuolated.

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Hawaii's Longline Fishery: Interactions with Regulated Pelagic Species (Billfish)

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The tuna longline fishery in Hawaii has almost tripled its landings in the past 3 years. Much of this growth has been in the "distant water" operations, but a number of new entrants into the fishery have concentrated on relatively nearshore fishing locations. The result has been physical gear interactions and purported biological interactions with a variety of small-scale trollers operating in Hawaii's coastal waters. This paper discusses the growth of the longline fleet and considers the significance of these interactions, particularly in light of the potential regulation of the longliners' by-catch of pelagic species (blue and striped marlin).

Analysis on Size and Weight-Length Relationship of the Striped Marlin (*Tetrapturus audax*) at Baja California Sur, Mexico

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The area of Los Cabos, Baja California Sur, Mexico, presently support an important billfish sport fishery. However, there are only a few biological studies on this fishery, these being mostly limited to *Tetrapturus audax*. Determinations of size classes in a fish stock are essential since the size distribution might be composed of annual spring groups or cohorts with size or age frequencies indicating a definite stock structure. The present work attempts to determine the size structure of the *T. audax* stock in the area of Los Cabos, Baja California Sur, Mexico, through analysis of the size-frequency distribution.

Information utilized in this paper was gathered from 1977-89 taxidermic records and biological sampling from 1987 to 1989. The distribution of post-orbital length data (including data derived from a weight-length relationship) was analyzed as a whole. The resulting frequency distribution of post-orbital length for 1977-89 showed a mode at 182.5 cm (about 20% of the relative frequency), with minimum and maximum values of 107.5 cm and 225.5 cm, respectively. When the data were examined by trimesters, the mode at 182.5 cm was observed to be uniform with no seasonal changes. In addition, the third trimester showed a bimodal distribution--the previously cited mode and another at 157.5 cm. There was a decreasing trend in the size of the modal size class in annual frequency distributions of postorbital length from 1983 to 1985, but in general, the mode at 182.5 cm prevailed most of the time. The weight-length relationship equation was as follows:

$$W = 0.00009272\ L^{2.56},$$

where 2.56 is the *b* value.

When comparing our data with other studies (Miyabe and Bayliff 1984), a lesser size range was observed in the present work, which is explained by a characteristic of the sport fishery: having a limited size range. Occurrence of two modes in the third trimester might reflect a recruitment of young animals in the area, but modal progression was not evident. A decrease in the postorbital length of the modal size class between 1983 and 1985 may have been related to large-scale climatic changes since those years were anomalously warm, coinciding with the El Niño phenomenon. Afterwards, the mode shifted back again to the typical value of 182.5 cm. Comparison of *b* values obtained by this study and by Wares and Sakagawa (1974) working at the nearby areas of Buenavista, B.C.S., and Mazatlan, Sinaloa, allow us to conclude that our *b* value for Cabo San Lucas seems to indicate an allometric growth tendency.

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Pelagic Communities

A Novel Method for the Collection of Larval and Juvenile Scombrids

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The effectiveness and efficiency of sampling methodologies is an important consideration in the design of any ichthyoplankton study. Almost all investigators rely on "active" techniques (i.e., involving the passage of water through a mesh) to capture fish larvae. These techniques may be inappropriate, however, for organisms with well-developed sensory and locomotory abilities. Recently an automated light trap was developed to collect larval reef fish (Doherty 1987). Light traps are "passive" samplers and may collect organisms that are able to avoid capture in nets. The objective of this study was to assess the effectiveness of light traps as samplers of larval and juvenile fishes.

The study area was located within the central Great Barrier Reef lagoon, off the coast of northeastern Australia. Light traps were used to sample larval and juvenile fishes along two cross-shelf transects (approximately 0-50 km from the coast) in the summer months (October to January) of 1988-89 and 1989-90. Six light traps were deployed at each of four localities along the transect. The traps were allowed to fish for an hour before being emptied and redeployed at the next locality. Three replicate surface tows were also made at each locality with a 50 cm ring net, while the light traps were fishing. NOAA and LANDSAT satellite images were collected during the sampling periods to characterize water masses over the study area.

A total of 3,720 fish from a sampling effort of 206 light-trap-hours, and 4,149 fish from 379 light-trap-hours, were collected in 1988-89 and 1989-90, respectively. The catch in both years was dominated by the family Pomacentridae. Significant numbers of individuals from the families Lethrinidae, Mullidae, and Clupeidae, and juvenile lologinid squids, were also captured. A total of 153 scombrid larvae and juveniles, representing at least 7 species, were collected over the 2 years. The most abundant species was the Spanish mackerel, *Scomberomorus commerson*, but appreciable numbers of *S. semifasciatus*, *Euthynnus affinis* and *Thunnus* sp. were also captured.

The pooled size frequencies of all mackerels captured in the light traps were compared with those of fish collected during an earlier study off Townsville using a 2 m Tucker trawl (Jenkins 1981). In addition, the size-frequency distributions of several tuna species collected from northwestern Australia using a 70 cm ring net (Davis et al. 1990) were compared with those of tunas collected in this study. Both comparisons suggested that there was very little overlap in sizes collected by the two techniques. Light traps caught significantly larger mackerels and tunas than either the Tucker trawl or ring net. A sampling design incorporating both towed nets and light traps would give a more complete description of larval scombrid abundances than either technique in isolation.

Attempts to relate abundances of scombrids to water masses as indicated from satellite imagery were unsuccessful, probably due to insufficient numbers of larvae. Peaks in the abundance of reef fish larvae did, however, coincide with the position of a strong water-colored front detected from LANDSAT TM satellite imagery. Larvae may thus find enhanced feeding conditions by positioning themselves on the frontal boundary. This relationship is speculative but serves to emphasize the benefits of multidevice sampling, as the correlation was not evident from concurrent net tows.

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Polyspecific Tuna Schools

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"Polyspecific" associations consist of two or more species that travel together for some time, feeding and otherwise interacting. Such associations are increasingly recognized as being not uncommon. Examples are the mixed species associations formed by schools of tropical reef fishes and by flocks of certain songbirds and troops of certain monkeys. These associations seem to form circumstantially with interspecies interactions loosely coupled and generally agonistic. It often appears that a more behaviorally versatile species takes advantage of another species that is unable to avoid the relationship. The species may stay together for hours or days or possibly months or even years. While investigators generally agree that the species join up for better foraging or avoidance of predators, exactly how this is accomplished and with what interactions have been difficult to determine, even in the primate studies that logged hundreds of hours of observations.

This paper discusses the multispecies aspects of yellowfin (YF) tuna schools and how the relationships could be interpreted in the context of polyspecific associations. Observer data from 1,762 purse seine sets obtained during 1974 and 1975 in the eastern Pacific were examined, by set type, for percentages of sets with different species associated with YF tuna. Overall, sharks were present in 40% of logfish sets, but only 10% of porpoisefish sets. The silky shark was the usual species identified. Other species with YF tuna were in the 10% or less association rate range. These included rays (mostly mantas in schoolfish sets), billfish (in all set types), bullet tuna (mostly in logfish sets), and other fishes and turtles. More than 80% of the YF tuna schools were accompanied by seabirds. The changes in association rate with set type suggest a situation-dependent, opportunistic advantage taking as in polyspecific associations. The culminating association is that of dolphins with larger YF tuna. In the polyspecific sense, this association should be loosely coupled so that abundance of the tuna should not be critical for the well being of the dolphins.

Evaluation of Food and Feeding of Northern Bluefin Tuna (*Thunnus thynnus*) and Yellowfin Tuna (*Thunnus albacares*) off the Coast of Virginia

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Stomach samples from 220 bluefin and 259 yellowfin tunas were collected from June through September 1988 and 1989 from Virginia's recreational pelagic fishery. Samples were collected from the two primary centers of fishing fleet activity: Rudee Inlet at Virginia Beach and Wachapreague on Virginia's eastern shore. Catches from these ports represent over 11 prime tuna fishing areas off the coast of Virginia located between 36°22'N to 37°30'N and extending 80 miles offshore to the edge of the continental shelf.

Tuna stomach samples were collected dockside as the recreational fishing boats returned with their catch. Stomach contents were measured volumetrically using water displacement, and food items were counted and identified to the lowest possible taxon. Comparison of diets were made based upon the index of relative importance (IRI) using individual prey numbers and volumes. Spearman rank correlation coefficients were then applied to the IRI values. Clearing and staining techniques were employed to aid identification of partially digested small and juvenile percoid fish.

Bluefin and yellowfin tunas are opportunistic feeders preferring small schooling fish or other organisms. The Virginia data illustrate the dominant role of *Ammodytes* sp. as the primary food source for both bluefin and yellowfin tunas. A single stomach from a 25 lb (11 kg) bluefin tuna contained as many as 128 individual *Ammodytes* specimens. The *Illex* squid comprised a significant portion of the food items ingested by yellowfin tuna but was less significant for bluefin tuna. *Peprilus* sp., *Monocanthus hispidus*, and *Sphoeroides* sp. were commonly found. Juvenile fish included *Priacanthus* sp., *Coryphaena hippurus*, *Decapterus punctata*, *Dactylopterus volitans*, and a member of the Chaetodontidae. Benthic forays were made by tuna, as evidenced by the occurrence of *Lophius* sp., juvenile *Homarus americanus*, and bits of coarse sand and shell fragments in some stomachs. Other prey organisms of interest included large numbers of *Hippocampus erectus* and various megalopae. An assortment of plastic materials also was found.

The sampled bluefin tuna averaged 10.9 kg (range, 3.4-53.1 kg), with an average length of 80-68 cm (range, 54.4-142.1 cm). These fish were less than 3 years old. The water temperature at the time of capture ranged from 18°C to 26°C (average, 22°C). Yellowfin tuna averaged 94.0 cm (range, 60.1-135.5 cm) in length. As with bluefin, this size range represents fish less than 3 years old. The yellowfin tuna showed a preference for water averaging 24°C (range, 20°-27°C).

The results of this study present similarities and differences in the feeding habits and strategies of young bluefin and yellowfin tunas. Evidence

from this study indicates that young bluefin and yellowfin tuna caught in the Mid-Atlantic Bight feed opportunistically on small schooling organisms such as *Ammodytes*, *Illex*, and *Peprilus*. The high abundance of *Ammoydtes* found in the stomachs of bluefin and yellowfin indicates that *Ammodytes* is the major prey organism off the coast of Virginia. Feeding locations of the two tuna species appear to be temperature related, resulting in tuna species segregation. Bluefin tuna were more frequently caught closer to shore on the continental shelf over benthic hills with depths averaging 10-20 fathoms. Yellowfin tuna were more frequently caught farther offshore towards the edge of the continental shelf (depths of 100-1000 fathoms). Yellowfin tuna also exhibited a higher abundance of sea grasses (*Zostera*) in their stomachs (22% frequency of occurrence) compared with bluefin tuna (6% frequency of occurrence).

MOPS in TOPS: Effects of Track Length, Environmental Bias, and Nonrandom School Distributions on Line Transect Estimates of Dolphin School Abundance Derived from Research Surveys

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A mathematical simulation model (TOPS), testing the efficacy of an ongoing line transect survey of dolphin abundance in the eastern tropical Pacific Ocean (MOPS), showed that reasonably precise and accurate estimates of dolphin school abundance could be derived using current sampling levels, even under conditions of relatively limited sampling effort, environmental bias, and strongly nonrandom, nonstationary distributions of dolphin schools.

Simulation results verify theoretical assertions that adequate estimates of density for nonrandomly distributed, nonstationary (but relatively slow moving) objects can be derived from line transect surveys, provided that the transects are chosen randomly with respect to the sighted objects, biases remain consistent, sampling artifacts are minimal, and sampling levels are sufficient. As sampling levels decrease, violations of assumptions become increasingly important.

On TOPS Once More: Assessing a Dolphin Assessment Proposal to Charter the Entire U.S. Eastern Tropical Pacific Purse-Seine Fleet

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We have implemented a new version of our tuna observer program simulator (TOPS). This version is designed to evaluate a proposal to charter the entire U.S. tuna purse-seine fleet for a short period of 1 or 2 days to gather data on dolphin abundance. During the charter, each vessel in the fleet would stop normal fishing activities and just count dolphin schools while steaming along a given transect line. It was hoped that this would be a less biased sampling scheme than that of data collected during fishing, when the vessels tend to concentrate on areas of high dolphin density and avoid areas of low density, thereby tending to overestimate abundance.

We have simulated several fleet-charter scenarios, varying the degree to which dolphins are aggregated, the number of aggregations, and the terms of the charter. Abundance estimates based on numbers of schools sighted and track miles accumulated by 30 vessels are calculated during simulated normal fishing and during a simulated charter period.

When fishing vessels are introduced at random positions, they first tend to underestimate the true dolphin abundance, but as the vessels aggregate on patches of high dolphin density during the normal fishing period, the estimates climb above the true value. The results from the charter period are highly variable, depending on the details of the charter arrangement and on the number and tightness of the dolphin aggregations. In all cases tested, the data collected during the first 12 hours of the charter greatly overestimated the dolphin abundance, and the data collected during the second 12 hours yielded much lower estimates, underestimates in some cases.

The overestimation results from a disparity in sampling intensity between regions of high and low dolphin density--high density regions being oversampled and low density regions being undersampled. Whether in the normal fishing mode or the charter mode, the sampling intensity depends on the number of track miles accumulated in each type of region, not on the number of vessels. During normal fishing, the vessels tend to congregate in high density regions, but they are impeded in their accumulation of track miles by delaying to process each school encountered. Therefore, fewer track miles are sampled per vessel in high density regions than in low density regions. During the charter period, however, the vessels are not delayed by sighting schools. They accumulate track miles at the same rate as vessels in low density regions. As a result, until the vessels steam out of the high density regions, the disparity in sampling intensity can be larger in the charter mode than in the normal fishing mode.

The shift in the distribution of track miles explains why, in some cases, the abundance estimates from the first 12 hours of the charter period are biased to even higher levels than the normal fishing period estimates. These estimates correspond to a case where the charter period begins at dawn, giving approximately 12 hours of daylight for sighting at the start. On the other hand, if the charter were to start at dusk and the vessels were to steam all night along their tracks, the results would correspond more to the model results from the second 12 hours. In all cases except the non-aggregation case, the estimates from the second 12 hours were considerably lower than from the first. In some cases, they were biased in the opposite direction. This is because, in the second 12 hours, most of the vessels have steamed out of the patches of high density, and most of their track miles in this time are in regions of low dolphin density.

It is apparent from our results that the notion of chartering the fleet does not hold much promise in reducing the bias inherent in dolphin abundance estimates from tuna vessel observer data.

IATTC Tuna-Log Project: Circulation Patterns and Log Drift in the ETP

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In 1989 the Inter-American Tropical Tuna Commission (IATTC) initiated a project to determine the drift patterns of floating objects to which skipjack tuna, small yellowfin, and other fauna are attracted in the eastern tropical Pacific (ETP). A two-stage modeling approach was used. First, the circulation vectors and the depth of the mixed layer were obtained using an adaptation of the equatorial Pacific model of Busalachi and O'Brien (1980) and Pares-Sierra and O'Brien (1989). The output of this wind-forced model was monthly circulation vectors from 1962 to 1987, by 1° squares. These vectors and objectively analyzed wind were used as input for the second stage of the model. Floating objects were tracked in a Lagrangean manner from the main source areas in South and Central America until they disappeared from the system as a result of waterlogging, beaching, etc., using prescribed space-time functions. The results show that logs may drift on gyres in the Panama Bight for a considerable time, eventually ending up in productive areas along the coast of Central America and in the 10°N fishing area. These results are consistent with a previous hypothesis on the movement of yellowfin tuna in the eastern tropical Pacific. The simulation approach may be useful for the study of ecological problems related to the transport and dispersal of other organisms such as sea turtles, dolphinfish, and other log-associated fauna that return to coastal waters to reproduce.

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IATTC Tuna-Log Project: Floating Objects, Associated Biota, and FAD Design in the ETP

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In 1987 a research project was started to characterize the floating objects to which skipjack tuna and small yellowfin tuna are attracted in the eastern tropical Pacific. It was found that logs (mostly unidentified tropical trees) account for two-thirds of all floating objects; the remaining third consists mainly of wooden objects (pallets, crates) but also of assorted plastic debris (trash, fishing gear). Approximately one-half of the objects (all man-made objects and cut trees) are of anthropogenic origin. Most objects are small (1-4 m), but logs up to 18 m long have been reported. Faunal aggregations seem to constitute a highly dynamic species complex, with high rates of species renewal. The most important groups, besides skipjack tuna and small yellowfin tuna, are sharks (mostly requiem sharks) in 60% of the records, dolphinfish (50%), triggerfish (35%), other small baitfish (33%), yellowtail and rainbow runners (15%), sea turtles (13%), and frigate tuna, wahoo, and billfish (10%). Association and catches of tunas by flotsam type and by faunal complex seem to be very variable, with spatial and seasonal components related to log production and current patterns. The description of fauna and flotsam, and the areas of capture, could be useful for the design and deployment of fish aggregating devices in the eastern tropical Pacific.

Predator-Prey Dynamics of Yellowfin Tuna in the Eastern Pacific Ocean: A Bioenergetics-Based Population Model

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Predation by piscivorous fishes has been shown to be a dominant force instructuring entire ecosystems via successive effects on planktivore, herbivore, and phytoplankton populations. By considering species assemblages at the community level, it becomes possible to evaluate the impact of predation by fishes and exploitation of those fishes by man on ecosystem production dynamics. The purpose of this study, which is still in progress, is to assemble a population-level bioenergetics model for eastern Pacific Ocean (EPO) yellowfin tuna and to use it to examine intra- and interannual predator-prey dynamics.

Growth can occur only when energy consumption exceeds the sum of maintenance costs and waste losses. Thus, growth represents surplus energy, and is the most sensitive variable in the energy budget to changes in abiotic conditions and food availability. The weight or energy balance,

$$C = R + SDA + F + U + DB,$$

assumes that energy intake via the animal's food (C, consumption) must be used (R, metabolism; SDA, specific dynamic action), lost (F, egestion; U, excretion), or accumulated (DB, growth). The model uses observed growth rates over any time frame of interest to reconstruct consumption. Gonadal growth is included in DB. Gametes lost are considered as a component of the weight gained previously through additional consumption.

The parameters of the yellowfin tuna bioenergetics model were adapted from previous studies. Estimates of yellowfin metabolism were based on measurements by Boggs (1984) of total body energy losses in free-swimming, captive yellowfin tuna from weight losses and changes in energy density during starvation. A model describing the size dependence of swimming speed was developed using composite diel activity patterns measured during ultrasonic telemetry experiments on free-ranging yellowfin tuna by Carey and Olson (1982) and by Holland and Brill (unpubl. data). The maximum weight-specific consumption rate (C_{max}), which places an upper limit on the growth potential of a fish, is represented by a negative power function of body weight derived from previous studies. SDA and U are modeled as constant proportions of the assimilated food (C - F) based on experimental data for other fishes, and F was modeled as constant proportion of the food consumed (C). Growth of the average individual male and female in the EPO was simulated by iteratively adjusting C to a proportion of C_{max} until the desired weight end point for a particular quarter was attained within 10.05%.

Model simulations were made to follow an unexploited cohort of 1 million males and 1 million females over 6 years, starting at an initial age of 1.117 years on 1 April. Size at age and population numbers at the beginning of each quarter were calculated using differential growth equations (Wild 1986) and differential instantaneous annual natural mortality rates for males and females according to the Inter-American Tropical Tuna Commission's (IATTC's) current age-structured biomass models (P. K. Tomlinson, pers. commun.).

The model provides a tool to estimate the relative difference in spawning costs of males versus females, based on the assumption that a reduced growth rate in females relative to males above age 2.1 years (about 95 cm) (Wild 1986) is due to females expending more energy in spawning than do males. Model simulations using the sexually dimorphic growth equations and differential spawning energy costs for the males were made until the growth curves matched. Then average daily spawning costs for females were calculated for four spawning seasons using data for the relative batch fecundity (Joseph 1963), the average wet weight of the ova (assumed equal to that of *Scomber japonicus*, Hunter et al. 1986), and the spawning frequency (1.27 days, Bayliff 1988). Average daily spawning costs for males were calculated by subtracting the male-female spawning differential derived by the bioenergetics model from the spawning cost estimates for the females.

The bioenergetics model is being implemented for the EPO population in the CYRA during 1970, 1971, and 1972 according to the IATTC's age-structured biomass analyses (P. K. Tomlinson, unpubl. data). Size-specific diet data (stomach contents adjusted for differential rates of gastric evacuation), by quarters, for those years are added to the model to produce population-wide estimates of predation rates for the major prey categories.

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FISHERIES

Fisheries and Stock Status of Yellowfin Tuna in the World

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Development of yellowfin tuna fisheries and stock assessments for major yellowfin stocks were briefly reviewed with emphasis on western Pacific and western Indian stocks with which the assessment of stock status had been hampered by the lack of biological and statistical data as well as relatively short history of the fisheries. Constraints for rational management of the yellowfin tuna stocks were noted and desirable direction in the future management was suggested.

During the past quarter century, total production of commercially important tunas (i.e., southern bluefin, northern bluefin, albacore, bigeye, yellowfin, and skipjack) has nearly been doubled. This increase in production is largely due to increased catches of yellowfin and skipjack tunas, whereas the production of bluefin tuna stocks has been on a steady decline with more or less stable albacore catch and a moderate increase in the bigeye tuna catch. As for the yellowfin tuna stock, as early as the mid-1960s, there has been concerns of overfishing on eastern Pacific and eastern Atlantic stocks. However, the expansion of fishing grounds to the offshore areas and various technical innovations in catching the fish, especially with the use of purse seining supported the much higher sustainable catches for the eastern Pacific and eastern Atlantic stocks than formerly estimated. Population study of the eastern Pacific stock revealed the significant variation of recruitment strength, possibly correlated with the global scale environmental changes such as El Niño. In addition, there is a growing perception that such environmental change affects the fishing efficiency of the gears, hence, the index of abundance. However, for yellowfin tuna, movement or migration and gear interaction between the longline and purse seine fisheries remain still unclear despite of highly required information for management of the stocks.

Like the similar development pattern of the yellowfin tuna fishery for the eastern Pacific and eastern Atlantic stocks, western Pacific and western Indian tropical tuna fisheries followed the same pattern in their fishery development. Finding of the yellowfin and skipjack tuna schools associated with drifting logs that can be captured by the purse seining in the western Pacific in the mid-1970s by Japanese fishermen led the revolutionary development of the tropical tuna fisheries comparable to the discovery of dolphin-associated-fish fishing in the eastern Pacific. Various coastal fisheries for tropical tunas with the use of FADs characterize the fisheries in the Southeast Asian countries represented by the Philippines and Indonesia. Spanish and French tuna fishermen initiated the experimental surface fishing in the western Indian Ocean in the turn of the 1980s, seemingly searching for the substitute for already heavily exploited eastern Atlantic yellowfin stock. The substantial purse seine production encouraged by higher catch rates with

bigger yellowfin than that in the eastern Atlantic soon outnumbered the catch of yellowfin by longline fishery.

In general, it is noted that the stock condition of yellowfin tuna in the world is good, and there is no yellowfin tuna stock with serious concerns on the stock status. However, lack of the management body with practical binding force in the western Pacific and western Indian Oceans will put big potential hazards in the near future. Namely, the continued increase of the demands for tunas has been absorbed hitherto by the increased catch of purse seine fishing and the finding of the new fishing grounds resulted in diffusion of the fishing effort by transfer of the purse seine fleets from the eastern Pacific to the western Pacific and from the eastern Atlantic to the western Indian Ocean. However, it is obvious that the uncontrolled increase of the fishing effort, especially for the western Pacific yellowfin stock and to a lesser degree for the western Indian yellowfin stock inevitably gives destructive impact on the stocks because there is open question whether or not further increase of yellowfin tuna catch by the surface fisheries is able to be sustained in those stocks, in addition to dim outlook on finding new fishing grounds elsewhere. At present, only tuna stocks of the Atlantic are under practical management scheme, with the exception of southern bluefin stock that has circum-polar distribution.

It can be mentioned that the present unsatisfactory situation in management of the stock had been expressed exactly in the same way more than quarter century ago. Both coastal and distant water fishing nations should discard selfish thought over the exploitation of the highly migratory species and initiate sincere discussions on the rational conservation of the stocks. Particular emphasis should be placed on release of any fishing data to the public. This is a minimum requirement for continuation of the fishing. Establishment of the competent management structure in the western Pacific and western Indian Ocean is urgently needed. Concerted activities among the regional management bodies is desirable given the high mobility of the tuna fishing fleets.

Towards the Development of a Yellowfin Tuna Abundance Index for the Western Tropical Pacific

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The U.S.A. and Japan are the two main countries purse seining in the western tropical Pacific. The U.S. purse seiners commonly use a helicopter to spot tuna and skipjack tuna schools, thereby greatly enlarging the possible search area by vessel. Though the Japanese boats do not utilize helicopters, their searching ability is increased by sharing information on location of schools. Both helicopter spotting and an information sharing system create some problems in using a simple search time by boat as an index of effort. The improvement of searching ability also causes a quick aggregation of boats to a certain area of high density of fish which jeopardizes the random sampling hypothesis critical for unbiased estimation.

The movement, behavior, and distribution of Japanese purse seiners were analyzed to determine the effect of information sharing on abundance estimates by catch per search time and to develop a more reliable abundance index for yellowfin tuna utilized by purse seine.

The catch of yellowfin and skipjack tunas and effort (in fishing and search days) both showed very patchy distributions, but the catch per unit effort (CPUE, catch per days) was evenly distributed. This nominally suggested that fishermen operated in a small and limited area despite the universal distribution of fish, which is highly unlikely. The frequency distribution of yellowfin tuna catch per day was skewed to the lower side with the mode at 0-5 metric tons per set. Zero catch and extremely high catch per day were both observed in strata with low effort.

The seiners targeted free-swimming schools as well as tunas associated with floating objects, including logs and payaos. While free-swimming schools mostly consisted of one species, skipjack or yellowfin tuna, schools associated with floating objects generally contained 20-25% yellowfin tuna and 75-80% of skipjack tuna.

The abundance index, using the number and size of patchiness of tuna schools and the possibility of finding these aggregations, was developed and compared with simple CPUE.

What is a Highly Migratory Species?

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Section 3(14) of the Magnuson Fishery Conservation and Management Act defines highly migratory species as ". . . species of tuna which, in the course of the their life cycle, spawn and migrate over great distances in waters of the ocean."

Annex I of the 1982 United Nations Convention on the Law of the Sea defines highly migratory species as

1. Albacore tuna: *Thunnus alalunga*
2. Bluefin tuna: *Thunnus thynnus*
3. Bigeye tuna: *Thunnus obesus*
4. Skipjack tuna: *Katsuwonus pelamis*
5. Yellowfin tuna: *Thunnus albacares*
6. Blackfin tuna: *Thunnus atlanticus*
7. Little tuna: *Euthynnus alleteratus; Euthynnus affinis*
8. Southern bluefin tuna: *Thunnus maccoyii*
9. Frigate mackerel: *Auxis thazard; Auxis rochei*
10. Pomfrets: Family *Bramidae*
11. Marlins: *Tetrapturus angustirostris; Tetrapturus belone; Tetrapturus pfuleugeri; Tetrapturus albidus; Tetrapturus audax; Tetrapturus georgei; Makaira mazara; Makaira indica; Makaira nigricans*
12. Sailfishes: *Istiophorus platypterus; Istiophorus albicans*
13. Swordfishes: *Xiphias gladius*
14. Sauries: *Scomberesox saurus; Cololabis saira; Cololabis adocetus; Scomberesox saurus scombroides*
15. Dolphin: *Coryphaena hippurus; Coryphaena equiselis*
16. Oceanic sharks: *Hexanchus griseus; Cetorhinus maximus;* Family *Alopiidae; Rhincodon typus;* Family *Carcharinidae;* Family *Sphyrinidae;* Family *Isuridae*
17. Cetaceans: Family *Physeteridae;* Family *Balaenopteridae;* Family *Balaenidae;* Family *Eschrichtiidae*; Family *Mondontidae;* Family *Ziphiidae*, Family *Delphinidae*

Japan and Korea both enacted domestic extended jurisdiction legislation including consideration of highly migratory species before the LOS Convention was completed (J. W. Salisbury, Attache for Oceans and Fisheries Affairs, U.S. Embassy, Tokyo, pers. commun., 18 February 1990). Both Korea and Japan assert jurisdiction over highly migratory species within their exclusive economic zones (EEZ's), but allow, in theory at least, foreign fishing for those species within their zones.

Japan's Cabinet Order No. 212 of 17 June 1977, amended in 1986, established highly migratory species as

(1) skipjack tuna, *Katsuwonus pelamis*; black skipjack, *Euthynnus affinis yaito*; frigate mackerel, *Auxis thazard*; and bullet mackerel, *Auxis tapeinosoma*;

(2) albacore, *Thunnus alalunga*; yellowfin tuna, *Thunnus albacares*; bluefin tuna, *Thunnus thynnus*; bigeye tuna, *Thunnus obesus*; and longtail tuna, *Thunnus tonggol*;

(3) broadbill swordfish, *Xiphias gladius*; blue marlin, *Makaira mazara*; black marlin, *makaira indica*; striped marlin, *Tetrapturus audax*; sailfish, *Istiophorus platypterus*; and shortbill spearfish, *Tetrapturus angustirostris*.

The case of Korea is different, in that highly migratory species are not defined by law. Foreign fishing for highly migratory species is allowed by law; it is up to the National Fisheries Administration to determine on a case-by-case basis what is an appropriate fishery for highly migratory species within Korea's EEZ. Consideration is given, for example, not only to the target species, but also to likely incidental catch species, in determining whether the fishery qualifies as being only for highly migratory species.

The present Magnuson Fishery Conservation and Management Act (MFCMA) approach is too narrow. For example, most if not all of the billfishes are as highly migratory as the tunas; this weakens the argument for keeping the present U.S. definition of the basis of its biological soundness. The Japanese approach also is narrow; it includes some but not all tunas and billfishes.

The LOS definition is both too narrow and too broad. Naming species (in one case even a subspecies) closes the door to any other species; they cannot be added except by the cumbersome process of amending the Convention. Naming families may eventually lead to taxonomic squabbles. Also, there is room for doubt that everything named is highly migratory. For example, there is evidence that little tuna and blackfin tuna are mostly if not entirely isolated local populations. There is also the question of severability. If a biologist succeeds in proving that some members of the Bramidae are not very migratory, does that throw the family out?

A question that lurks in the background is the one of animals such as spiny lobsters that in their planktonic stages are transported over long distances.

The current date in the U.S. Congress over the proposed inclusion of tunas under the MFCMA, recommended by many, including the Center for Marine Conservation, would be clarified by a better definition in U.S. law. This debate and international debate on the same subject will continue to be

confused until general agreement is reached on a definition of a highly migratory species.

The Albacore Catch by the Japanese Large-Mesh Drift Gillnet Fishery in the South Pacific

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The Japanese large-mesh drift gillnet (driftnet) fishery targeting albacore in the South Pacific Ocean began in about 1983. This fishery developed in part as a substitute for the North Pacific driftnet fishery that targets billfish (Nakano et al. 1989), which occur in austral summer. In combination with the North Pacific fishery, the driftnet fishery provides a year-round fishing season for the vessels. In the driftnet fishery, nets are set at sunset, and retrieval, which takes several hours, is started at about midnight. There is usually just one set per day. Gillnet mesh size for the albacore fishery ranges from 165 to 220 mm, with most nets having 170-180 mm mesh. Typical Japanese driftnet vessels have a carrying capacity of about 300-400 metric tons and have a crew of 15-20. The number of vessels operating in the South Pacific Ocean has increased slightly from year to year because of poor fishing conditions for North Pacific albacore. In the 1988-89 fishing season, 63 Japanese fishing vessels fished albacore in the South Pacific. After considering international relationships in the area, the Japanese Government unilaterally limited the number of vessels fishing driftnets in the South Pacific in 1989-90 to one-third the number of vessels in 1988-89.

Logbook reports and results of interviews with Japanese fishermen during the 1983-84 to 1988-89 fishing seasons were used to describe and analyze the fishery. The number of vessels that operated in the South Pacific from 1983-84 to 1987-88 were estimated from records provided by the National Drift Gillnet Association and follow-up interviews of fishermen. Starting in 1988-89 fishermen were required to report fishing logbook data, and statistical coverage increased to 100%. Length data were collected during the 1988-89 fishing season from 10 of 63 vessels participating in the fishery.

Catch and Effort

During the 1983-89 period, the number of vessels operating driftnets for albacore in the South Pacific Ocean ranged from 9 to 63. The fishing season begins in late November to early December and ends in late February to early March. Average days of operation in a fishing season ranged from 27.5 to 52.6 during the 1983-89 period, and the overall average was 43.7 days. The main fishing grounds were the central Tasman Sea and east of New Zealand. The driftnet vessels enter the Tasman Sea at the start of the fishing season and shift to the east of New Zealand late in the fishing season. The fishing grounds east of New Zealand overlap the U.S. albacore troll fishery grounds (Majors et al. 1989).

The catch per unit effort (CPUE, number of albacore per set) was calculated for each monthly 5° x 5° strata for the 1988-89 fishing season. From

the distribution of CPUE, good fishing grounds were found in the Tasman Sea in December (CPUE = 990.5) and on the eastern edge of the fishing ground east of New Zealand in February (CPUE = 2,023.0).

The seasonal average CPUE ranged from 253.3 to 937.0 for the 1983-84 and 1988-89 seasons, with an overall average of 542.4. Over the same period, the annual average weight of albacore in the catch ranged from 5.0 to 6.9 kg, with an overall average of 6.0 kg. Annual total catch estimates were made as (CPUE X average fish weight X average fishing days X number of vessels) and ranged from 587 to 13,161 metric tons.

Length Frequency and Catch Composition

Albacore from the South Pacific fishery ranged from 40 to 90 cm fork length (FL). In the Tasman Sea, there were few fish caught above 80 cm FL: there was a small mode in the size distribution of fish below 50 cm FL. Off eastern New Zealand, only one area, east of the northern island of New Zealand, had a mode below 50 cm FL. The FL tended to be larger in albacore taken eastward and southward of New Zealand. East of New Zealand, in the area overlapping the U.S. troll fishery, the length-frequency distributions of the U.S. catch (Laurs et al. 1987) and Japanese catch were almost the same, and it is considered that both fisheries targeted the same age classes of albacore.

Analysis of catch composition for the 1983 to 1988 fishing seasons showed that six billfish, five tuna, and two shark species were the major catch items, with other species constituting less than 5% of the total number of fish caught in each season. Based on the number of fish caught, albacore and skipjack tuna constituted 62-93% and 3-31% of the catch, respectively. Apparently, the albacore fishing grounds have become well known to fishermen, and the skipjack tuna catch has drastically decreased. Thus, it is considered that the fishery operates in a manner making it highly select for albacore over other species.

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Status of Japanese Bluefin Tuna Fisheries in the Northwestern Pacific Ocean

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In the Pacific Ocean, there are two spawning grounds of bluefin tuna. The main spawning ground is in the vicinity of Taiwan and Nansei Islands. The sub-spawning ground is in the Japan Sea. It is known that spawning season is May to June in the Nansei Islands area and August in the Japan Sea. Some fish remain in the western Pacific throughout their lives, and others migrate to the eastern Pacific. They are mature when their weight reaches about 60 kg (ages 5 to 6). The size by age has been estimated by various researchers. The estimates of the average size are about 50 cm and 3 kg at age 1, about 160 cm and 70 kg at age 6, and about 210 cm at 170 kg at age 10.

Japan and the U.S.A. are the major countries for bluefin tuna fisheries in the Pacific Ocean. In the official statistics of Japan, bluefin tuna is classified to *Maguro* and *Meji*. *Maguro* includes some large and medium bluefin tuna; *Meji* means medium- and small-sized tuna including bluefin tuna and bigeye tuna. Therefore, it is necessary to divide the amount of *Meji* into each species when we estimate the catch weights for bluefin tuna. Catch weights were estimated by using some assumptions and information from fishermen. Various gears were used to catch bluefin tuna in Japan. It is estimated that about 60% of the bluefin tuna catches (by weight) are landed by purse seine in recent years, 15% by trap net, 10% by trolling, 5% by pole and line, 5% by longline, and 5% by gillnet. The catches in 1970-77 equaled 8,000-19,000 metric tons (t) per year. As the catches by purse seine increased, the total catches for bluefin tuna increased, peaking in 1981 at 30,000 t. Since 1984, the total catches have equaled 10,000-15,000 t.

Tentative analysis has been made to estimate the catch-at-large for bluefin tuna caught by Japanese fisheries. The findings are as follows. The age 0+ fish were caught mainly by trolling and by trap net. The age 1+ and older fish were caught mainly by purse seine. Medium-sized bluefin tuna were not caught much before 1975, but thereafter, they tended to be caught frequently by purse seine. It is suggested that 1973 and 1978 year classes were the dominant year class between 1966 and 1986. The 1973 year class could be caught in some quantities after the mature age; however, the 1978 year class disappeared after the mature age. It is supposed that the 1978 year class have been exhausted before the mature age. No dominant year class has appeared after 1978. Therefore, the stock abundance would continue at a low level.

The present catch statistics and size-frequency statistics for bluefin tuna caught by the Japanese fleet are not perfect. The sampling systems for catch and size data that cover all gear types and whole-sized fish should be made. The number of measurements for the length of bluefin tuna should

increase, especially in the trolling and the net traps, to get accurate and reliable estimates of the catch at age.

An Approach Toward Measuring Capacity Utilization: Capacity Utilization in the U.S. Tropical Tuna Purse Seine Fleet

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In this presentation, we examine capacity utilization as a measure of the extent to which a given stock of capital is put to use within an industry. The degree to which a stock of capital is being utilized indicates the potential for investment, or disinvestment, within an industry. In this context, capacity utilization is inherently a short-run concept, and therefore, any measures of capacity utilization should be based on the short-run objectives of the individual firms comprising the industry.

In fishing industries, revenue maximization is often considered the appropriate short-run objective of fishing firms because all inputs (costs) during the fishing season may be quasi-fixed (fixed in the short-run, variable in the long-run) while outputs are each firm's decision variables. Under these conditions, we develop an approach toward recovering measures of capacity utilization from the firm's revenue function. We then use this approach to analyze capacity utilization in the U.S. tropical tuna purse seine fleet.

Evaluation of Length-Frequency Sampling Methods

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Examination of the length-frequency samples collected in the eastern Pacific from the 1988 yellowfin tuna purse-seine fishery indicates that the precision of the estimated number of fish in different age groups is primarily dependent upon the number of vessels sampled (n) rather than sample size (m). At the same time, estimates for the scarce age groups, such as the smallest and largest fish, tend to be more imprecise, or have larger coefficients of variation, than those for age groups that are well represented in the fishery. In simulation studies, departures from random sampling contribute to biased estimates that are independent of the effects of n or m, and presumably this is also the case in the real situation. An increase in precision may be accomplished by further stratifying purse-seine sets by three categories of set types rather than by month and area alone.

Estimating Catch at Age from Size Composition Data

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Estimates of the catch at age over time are requisite data for commonly used stock assessment methods, such as Virtual Population Analysis (VPA). One of the attractive features of VPA is the commonly held belief that its historical estimates of population size and fishing mortality rates are relatively invariant to the input parameters. This often ascribed characteristic is valid only if the errors in the catch at age estimates are negligible, and the natural mortality rate is known with certainty.

For many of the demersal species found at the more temperate latitudes, the catch is routinely sampled for length, and subsamples are aged using various hardparts. From these data, age-length keys are constructed to provide estimates of the age distribution within a length interval for appropriate time-area strata. Provided the sampling level is adequate, the estimation of catch at age in this setting is reliable and fairly routine. However, the sampling and the hardpart work are expensive, and maintaining adequate levels of sampling may be difficult when population size is at low levels.

For many other economically important species, such as tunas and billfishes, the development of annual age-length keys is often impractical. The numerous time-area strata, fishing nations, gear types, etc., create a difficult sampling problem. Further, most tunas and billfishes are more difficult and time consuming to age than their more temperate counterparts.

Because of the practical difficulties and the expense in developing annual age-length keys, length-based assessment methods have received considerable attention in the literature in recent years. While these methods do not require catch at age estimates, they do require growth parameters (either as input parameters or estimated internally). Most of the length-based methods move the size composition through time (age) internally by assuming that the population is in equilibrium--an unrealistic assumption for most economically important species. More recent length-based methods do not impose the equilibrium assumption but are complicated mathematically, and are yet to be fully tested in a variety of assessment settings. Consequently, VPA and other age based methods remain the most commonly used tools for assessment.

For most tunas and billfishes, catch at age is estimated using a general growth curve, i.e., one assumed to represent growth rates for all cohorts in the catch. Deterministic breakpoints (in length) are calculated for each age from the growth curve (given the month of catch and a birth date). These breakpoints are then used to "slice" the catch (recorded in length categories) into age categories. Several alternative procedures for estimating catch at

age from size composition data have been developed based on least-squares and maximum likelihood procedures. The performance of the "age slicing" method is evaluated and compared with least-squares procedures initially in a deterministic framework and then by using Monte Carlo simulation. Sensitivity to error in the underlying growth curve is examined.

Pelagic Fisheries of Balochistan (Northern Arabian Sea)

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Balochistan is located on the northernmost part of the Arabian Sea (Indian Ocean). The area is well known for its high productivity at the primary level, monsoonal reversal of currents, and the presence of an oxygen minimum layer in shallow water. The continental shelf along the coastline is very narrow, ranging from 30 miles in the Sonmiani Bay area to about 4 miles in the Gwader area.

Although a number of fishing gears are used for harvesting fish, fishing for pelagic resources is the most important economic activity in the area. The pelagic fisheries in Balochistan waters can be categorized as small pelagic and drift gillnet fisheries.

Small Pelagic Fisheries

Small pelagic resources support subsistence *cum* commercial fisheries concentrated in shallow coastal waters and in semi-enclosed bays and creeks. The main fishing grounds for small pelagics are located near the fishermen's settlements. Important among them are Bundewari, Sonmiani, Phor, Ormara (West Bay), Pasni, Kappar, Sur, Gwader (East Bay) and Gwader (West Bay), and Ganz and Jiwani. Cast net is the main fishing gear used for harvesting the small pelagic resources. In addition, fixed gillnets, beach seines, and stake nets also are used. The fishing is carried out on board small wooden boats locally known at "Katti." These boats are about 4 to 8 m LOA and are propelled with longtail or outboard engines (5 to 13 hp).

A number of species of small pelagics are harvested: *Sardinella longiceps, S. sindensis, S. fimbriata,* and *S. albella; Thryssa mystax, T. hamiltoni, T. malabarica, T. setrostris,* and *T. vitirostris;* kelee shad, *Hilsa kelee;* Indian mackerel, *Rastrelliger kanagurta;* Indian scad, *Decpaterus russelli;* and a number of species in the family Leiognathidae. Among these, *Sardinella* spp., *Thryssa* spp., and kelee shad are the main species, contributing up to 80% of the total landings.

Small pelagic species are sun-dried for conversion into fish meal. Small quantities are used as bait and for direct human consumption. Total production of small pelagics is estimated to be about 12,000 metric tons (t), which can easily be enhanced to about 30,000 t by using appropriate gears including purse seines. However, under the Balochistan Fisheries Ordinance of 1970 and

Balochistan Fisheries (Amendment) Act of 1986, there is a ban on the use of encircling nets within the territorial waters of Balochistan.

Drift Gillnet Fisheries

Drift gillnetting is the main fishing activity of the Balochistan coast and may be categorized into two types: drift gillnet fishing in the continental shelf area and drift gillnet fishing in the outer shelf, slope, and deep-sea areas.

These fisheries use medium-sized wooden boats of Balochistan, known as "Rachin" (LOA up to 5 to 15 m), and nets made of nylon and other synthetic materials. Most of the fishing grounds are located in shallow (40-100 m) water. The nets are laid down in the evening and retrieved in the morning, Usually 1-day trips are taken; however, some boats undertake fishing operations lasting 3 to 15 days. Prime food fishes are kept with ice, whereas the remaining catch is eviscerated and salted. Wet-salted fish are landed and further processed into dried, salted products for export to Sri Lanka. The main pelagic species are white pomfret, *Pampus argenteus;* black pomfret, *Parastromateus niger;* queenfish, *Scomberoides commersonianus* and *S. lysan;* spanish mackerels, *Scomberomorus commerson, S. guttatus,* and *S. lineolatus;* shads, *Tenualosa ilisha* and *T. toli;* torpedo scad, *Megalaspis cordyla;* and pompanoes, *Trachinotus* spp. Driftnet fishing is done mostly on the shallow shelf waters; therefore, in addition to pelagic species, a number of demersal fishes of the genera *Epinephelus, Pomadasys, Argyrops, Acanthopagrus, Muraenosox, Sphyraena, Carcharhinus, Rhizoprionodon, Scoliodon, Johnius, Otolithus, Protonibea,* and *Lethrinus* are also caught in good quantities. Most of these species are to be considered good food fishes.

Large pelagics are fished in offshore waters over the outer shelf, slope, and deep sea. Comparatively larger boats locally known as "Beri," "Churpuk," or "Launch" (LOA 15 to 25 m) are employed in this fishing. These vessels undertake fishing trips lasting more than 15-23 days. Except for some prime food fishes that are kept in ice, the remaining catch is eviscerated and salted. The catch is processed later in the curing yards and sun-dried before being exported to Sri Lanka. Tunas constitute about 48% of the total landings of large pelagics. Pelagic sharks (38%), sailfish and marlins (6.7%), dolphinfish (1.5%), spanish mackerels (1.2%), and other species (4.6%) are also represented in the catch. Among the tunas, longtail tuna, *Thunnus tonggol,* and yellowfin tuna, *Thunnus albacares,* are dominant, representing by 33.6% and 31.2%, respectively, of the total estimated landings (12,000 t/year) of tunas. Other tuna species such as skipjack tuna, *Katsuwonus pelamis,* and kawakawa, *Euthynnus affinis,* also are caught and represent 22% and 13%, respectively, of the tuna landings. The main fishing season for tuna is between September and May.

The paper describes in detail the various aspects of pelagic fisheries of Balochistan, especially future prospects--including those in processing and production of value added products.

Tuna Biology

Factors Related to Muscle Temperature Elevation in Juvenile Black Skipjack Tuna (*Euthynnus lineatus*)

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Tunas are endothermic fishes, able to generate heat internally (by muscle contraction during continuous swimming) and to conserve that heat within the body. Their ability to maintain muscle temperatures elevated above ambient water temperature depends upon the function of vascular, counter-current heat exchangers (retia) serving the red myotomal muscle. Many benefits, including increased swimming speed, have been attributed to elevated muscle temperatures in tunas. However, tuna larvae are not endothermic, and it is not known when tunas acquire this capacity. The objective of this study is to determine what factors limit the minimum size or age at which tunas can elevate muscle temperatures.

Black skipjack tuna (*Euthynnus lineatus*) early juveniles [10-20 mm fork length (FL)] were captured by nightlighting in the eastern tropical Pacific Ocean near the Frailes Islands off the coast of Panama, at approximately 7°20'N 80°9'W, during summer 1988. Fish were raised to larger sizes (up to 279 mm FL) at the Inter-American Tropical Tuna Commission (IATTC) laboratory at Achotines, Panama. Muscle temperatures of 13 individuals within the size range of 50.2-114.7 mm FL were not significantly elevated above ambient water temperature. The maximal muscle temperature of the largest laboratory-raised individual, FL = 279 mm, was elevated 3.8°C above water temperature. Thus, this species apparently acquires the ability to elevate muscle temperatures at a size between 115 and 279 mm FL.

Histological analyses of paraffin-embedded and sectioned fish specimens (25-109 mm FL) have shown that internalized red muscle is present in black skipjack tuna as small as 25 mm FL. The amount of red muscle, and thus the fish's capacity to generate heat by swimming, increases with fish size. Blood vessels comprising small central and lateral counter-current heat exchangers were present in fish specimens >94 mm FL. In smaller specimens (54.8 and 60.1 mm FL), the central and cutaneous blood vessels from which heat exchangers arise were present, but the presence or absence of the vessels comprising the retia could not be established unequivocally. Additional specimens will be analyzed, and retia surface areas will be computed.

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Nutritional Condition of Late Larval/Early Juvenile Tropical Scombrids in Relation to Food Availability

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The early life history of tropical scombrids is characterized by fast growth and rapid ontogenetic development. The larvae and early juveniles of these species develop in oceanic systems where the potential for food limitation exists. This paper presents results from an ongoing study investigating the nutritional condition and ontogenetic development of both first-feeding and late larval/early juvenile scombrids in waters off the Pacific coast of Panama. Results of the study of nutritional condition of first-feeding larvae have been reported previously (Olson et al. 1989); this report centers on the nutritional condition of older larvae and early juveniles.

Black skipjack (*Euthynnus lineatus*) late larvae and juveniles (10-20 mm standard length (SL)) were collected by nightlighting in nearshore waters off the Azuero Peninsula of Panama from May through July 1988 (the early wet season in Panama). Some individuals were immediately sacrificed for histological analyses of development and in situ nutritional condition. Other individuals were transported live to the Inter-American Tropical Tuna Commission (IATTC) Achotines Laboratory for use in nutritional response experiments. Nutritional responses of these fishes were examined in relation to (1) high versus low zooplankton food levels, (2) delayed high-food levels, and (3) nutritional point of no return. Individuals were sacrificed at various time intervals for histological analysis of nutritional condition.

Fixed samples (laboratory and field) were processed for histology, sectioned, and stained with haemotoxylin and eosin. Cellular condition of a number of tissues was examined under light microscopy, and a grading system was developed to characterize overall nutritional condition. Tissues that were most responsive to food availability included the epithelium of the anterior intestine, the stomach (especially the gastric glands), pancreas, and liver hepatocytes. These four tissues were graded to develop a composite score for each fish.

Black skipjack began to show cellular responses to food deprivation in 9 to 12 hours. The liver hepatocytes showed the earliest deterioration with loss of intracellular vacuoles (presumably areas of glycogen and lipid storage. Overall, nutritional scores were significantly reduced after 12-15 hours of malnourishment. Nutritional recoveries, however, were exhibited by some survivors after either 24 or 48 hours of malnourishment. Nutritional point of no return occurred after 72-96 hours at low food levels. Preliminary analyses of in situ levels of malnourishment in nightlight-caught black skipjack showed a very low level of nutritional stress. Analysis of additional samples of nightlight-caught sierra, *Scomberomorus sierra*, and bullet mackerel, *Auxis* sp., showed the same trend--nearly all individuals graded out as very healthy.

These preliminary data for late larvae/juveniles show a reversed pattern compared to that for first-feeding larvae. Estimates of nutritional condition of first-feeding larvae collected during the same time period indicated a high incidence of malnourishment (Olson et al. 1989). Possible limitations to the late larval/juvenile nightlight data exist; these are discussed. It does appear, at least during the wet season, that first-feeding scombrids are quite vulnerable to starvation. Older larvae and juveniles, although moderately vulnerable to malnourishment in laboratory trials, may experience a much lower level of starvation under natural conditions.

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Tuna Early Life History Studies at the Achotines Laboratory, Panama

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Little is known about the biology of tunas during larval and early juvenile stages. This motivated the Inter-American Tropical Tuna Commission (IATTC) to establish a research center at Achotines Bay in the Republic of Panama dedicated to the study of the early life histories of scombrid fishes. Achotines Bay is located on the southern tip of the Azuero Peninsula in the Los Santos Province of Panama. It is less than 10 km (5 nmi) from year-round tuna spawning grounds and provides access to clean ocean water suitable for holding live tunas in the laboratory. Ten hectares (24.7 acres) of land were purchased in 1983, and research, housing, and support facilities have gradually been developed over subsequent years.

Much of the early work at the Achotines Laboratory was concentrated on developing methods of capturing, transferring, and maintaining live scombrids in captivity. The following species have been held in the laboratory with varying degrees of success: yellowfin tuna, *Thunnus albacares*; bigeye tuna, *T. obesus*; black skipjack tuna, *Euthynnus lineatus*; frigate mackerel, *Auxis thazard*; bullet mackerel, *A. rochei*; sierra, *Scomberomorus sierra*; chub mackerel, *Scomber japonicus*; and Indo-Pacific bonito, *Sarda orientalis*. Since 1986, four early juvenile black skipjack have survived in captivity in excess of 130 days. The longest-lived specimen survived for 231 days and attained a total length of 341 mm and a weight of 659 g.

Efforts are being made to maintain algae and rotifers in large batch cultures at the Achotines Laboratory and to develop cultures of locally occurring copepod species to serve as food for captive larval scombrids. Recent efforts have centered on improving culture methods and expanding the algae and zooplankton cultures. Subcultures of the following algae were routinely maintained during 1989: *Tetraselmis chuii*, *Isochrysis* sp. (Tahitian strain), and *Gymnodinium splendens*. Rotifers (*Brachionus* sp.) also were maintained in subculture. Efforts were begun in 1989 to establish a stock of adult mullet (*Mugil* sp.) in one of the seawater ponds to produce larval fish from laboratory brood stock to feed to captive scombrids. Preliminary trials to induce spawning through hormone injections were unsuccessful.

The IATTC's early life history research program involves concurrent laboratory and field studies aimed at gaining insight into the recruitment process and the factors that affect it by addressing the interaction of the biotic system with the ocean and atmospheric environment. Data from a study designed to examine the development and nutritional condition of scombrid larvae and juveniles collected in coastal waters off Achotines suggest that the incidence of starvation in first-feeding larvae, at least during the early rainy season, may be very high (see abstract by D. Margulies in this volume).

The age and growth of 103 late larval and early juvenile black skipjack have been analyzed using growth increments in their sagittae.

Preliminary work to develop criteria necessary for counting the increments and validation of increment periodicity was described in a presentation made at the 1989 Tuna Conference. To further investigate increment formation rates and the factors that affect them, a series of validation and growth experiments was initiated in 1989 and will be continued this summer using tetracycline hydrochloride and calcein in seawater solution in laboratory aquaria. Late larval black skipjack are immersed in the solutions to mark their otoliths. This research is designed to determine: (1) the minimum concentrations and immersion times of tetracycline and calcein that produce detectable marks; (2) the survival rates of fish immersed in tetracycline or calcein; (3) the rates of increment formation at high and low food concentrations; and (4) fish and otolith growth at high and low food levels.

The early life history research program was amplified considerably during 1989 with the initiation of studies of the local environment inhabited by larval and juvenile scombrids in coastal waters off Achotines, in parallel with quantitative sampling of scombrid larvae. A 25-foot (7.6-m) Boston Whaler--equipped with a custom-made mast, boom, and hydraulic winch for deploying and retrieving plankton nets and oceanographic gear--was put into service at the Achotines Laboratory. Observations at sampling stations on the continental shelf, slope, and basin off the Azuero Peninsula include weather and ocean environment parameters measured with meteorological instruments, water sampling bottles, and a CTDO. To sample larvae and their forage, bongo nets are towed obliquely from about 50 m to the surface, a manta net is towed at the surface, and a parovet or mini-bongo net is hauled vertically. Surface drifter deployment and tracking procedures were established to measure short-term variability of observations and processes, and an initial series of observations at a surface drifter was completed. CTDO casts were made at intervals of 10 to 30 minutes at a surface drifter launched at the shelf break. The results will be used to optimize sampling frequencies during future drifter series and to describe the short-period variation of the physical habitat.

An additional sampling program is being implemented to examine the vertical distribution of scombrid larvae and their diel patterns by using a Tucker trawl in coastal waters off Achotines.

Sex Ratios of Yellowfin Tuna in the Eastern Pacific Ocean: A New Method for Old Data

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Data on the sex ratio of yellowfin tuna in the eastern Pacific Ocean were collected for the surface fishery in 1953-62 and 1970-73 and for the longline fishery in 1958-62. Chi-square tests have traditionally been used to test whether the sex ratios deviate from 1:1 for a given length interval. For a chi-square test to be valid, however, the samples must come from a homogeneous population. It is necessary, therefore, to determine whether gears (surface and longline), areas, years, and seasons are homogeneous with respect to the sex ratios in order to know which categories should be pooled and which should be kept separate before chi-square testing is performed.

This is a multivariate problem in which many of the factors are confounded. For example, there is a greater percentage of males in the longline fishery than in the surface fishery. Is this only because longlines catch larger yellowfin tuna, which are predominantly males, or is there a gear effect in addition to the size effect? Similarly, years, areas, gears, and sizes are all confounded. Therefore, a stepwise procedure was used to build a generalized linear model (GLM) that tests the significance of each factor on sex ratio above and beyond the other factors.

A GLM usually uses an *F*-statistic to test for significance of factors. An *F*-test requires that the dependent variable be normally distributed; therefore, the arcsin (square root(females/total)) was used as the dependent variable. Since preliminary tests on a few subsets of the data showed that individual samples were not homogeneous with respect to sex ratio, the samples were weighted equally, rather than by the sample size.

The results indicate that sex ratios are heterogeneous over years, areas, gears, and sizes, but homogeneous over quarters within a year. Although the interactions of year, gear, and area with size make the results complicated, there consistently appears to be a rapid decline in the percentage of females around 140 cm. Three possible explanations for this rapid decline in females may be sex-specific differences in mortality and growth, and availability to the fishery.

An Overview of the 1990 Japan Tuna Conference

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The 1990 Japan Tuna Conference was held on 13 and 14 February 1990. The conference provided a forum for research coordination between the government research sector and the faculty of fisheries high schools. Reviews of major tuna fisheries around the world and the prognosis for yields were presented. Additionally, several scientific reports dealing with yellowfin tuna morphometrics, bigeye tuna spawning, and bluefin tuna rearing were presented. Official copies of the proceedings are available from the authors.

An Examination of Tag Shedding Assumptions: with Application to Southern Bluefin Tuna

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The technique of double-tagging experiments, in which two tags are attached to each fish, is a well-established means of providing a measure of the extent to which tags are shed, by observing the proportion of recapturing tagged fish that have one tag. This commonly requires an assumption that the probability of a tag being shed is a random process, which is unaffected by the presence of the other tag on the same fish. In theory, this allows an estimate of the unobservable number of caught fish that have shed both tags.

This paper (Hearn et al. in press) examines biases that may follow if data are pooled (sometimes unwittingly) from experiments with dissimilar tag shedding rates. It is found that the bias in tag shedding estimates, due to pooling, can be markedly lowered by reducing either the rate of shedding and/or variability between experiments in the tagging technique. In some situations, a comparison between experiments, of the proportions of fish recovered, may be used to support the existence of bias. Southern bluefin tuna, *Thunnus maccoyii*, data subsets are analyzed to illustrate how tag shedding bias could be serious.

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Tuna Distribution and Movement

About Some Results from the ICCAT Yellowfin Year Program

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Beginning in early 1984, a spectacular decrease of the purse seine fishing effort has been observed in the eastern Atlantic, following a dramatic reduction of large yellowfin catch rates (economically the most important) in this fishery. Consequently ICCAT decided in 1985 to develop intensive studies in order to explain this low apparent abundance of adult yellowfin, and to analyze in detail the recovery of the stock which was expected from the dramatic reduction of purse seine fishing effort. The fishing effort has remained low since 1984. Detailed results from this program will be published by ICCAT in 1991; some results from it have been selected for presentation at the tuna conference.

The major topics covered in this presentation are

* The effects of an environmental anomaly (El Niño type) that was observed during the first quarter of 1984.

* Changes in fishing patterns of purse seiners linked with this anomaly and with the reduced fishing effort.

* Increased fishing efficiency of purse seiners due to new technologies and to reduced competition between boats (reduced effort).

The major cause of the crisis in the 1984 fishery was, in fact, the El Niño effect on the catch rates. This factor is usually neglected in ICCAT research. Present work clearly shows the misleading nature of the stock assessment conclusions obtained when the environmental anomalies are not taken into account. Such errors lead to the conclusion that the biomass is very low, when in fact only the fishing mortality is low.

A Tuna Tagging Project in the Maldive Islands

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The Government of the Maldive Islands recently initiated a tuna tagging project in their coastal waters. Financial and technical support for this 1-year tagging project is being provided by the UNDP/FAO Indo Pacific Tuna Development and Management Programme (IPTP).

In recent years the pole-and-line tuna fishery of the Maldive Islands has landed more than 70,000 metric tons of skipjack and yellowfin tunas. This total catch makes the Maldive Islands among the largest pole-and-line tuna fisheries in the world, definitely the largest among the Third World nations. Part of the Maldive's tuna catch is canned at the government-owned cannery in Filivaru (Laviyani Atoll) for export to the European market; the bulk of the remaining catch is exported in the international market trade as frozen product for canning purposes.

A total of 1,481 tunas (1,008 skipjack and 473 yellowfin tunas) were tagged and released during 21 boat-days of fishing. Tagging was conducted on commercial pole-and-line *mas dhonis* based at Naifaru in the Laveyani Atoll.

This report provides a description of the fishery and details of the tagging operation.

Movement of Bigeye and Yellowfin Tunas Around Payaos Tracked by Sonic Tags in the Water off Okinawa, Japan

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Since around 1985, the utilization of payao (a fish aggregating device) has become popular in the southern part of Japan, particularly around Okinawa Island. Main components of the catch are yellow-fin, bigeye, and skipjack tunas. The catch from this fishery increased significantly and reached 2,000 metric tons in 1986. Most fishes caught were small, with minor catches of large fish over 10 kg. Reportedly there was some friction between the fishermen who owned payaos and visiting fishermen from other parts.

Under these circumstances, it is important to know the behavior of fish around payaos from the standpoint of fisheries strategy and management.

Sonic tags were attached to three bigeye (46-55 cm fork length (FL)) and two yellowfin tunas (44-79 cm FL) both in 1988 and 1989 around payaos constructed by JAMARC in the MIYAKO bank area (1,300-1,600 m), about 120 miles southwest from Okinawa Island.

The tracking time ranged from 6 to 79.5 hours, and the average was 33 hours. Out of 10 fishes tracked, only 2 stayed around payao. Most of the others moved north or east. This direction of movement was in agreement with the tagging results. The tracking speed ranged from 1 to 5 kn and usually was less than 3 kn. The vertical movements differed, depending on the fish, and there was no clear difference between bigeye and yellowfin tunas. However, there is a tendency that the fish stayed shallower waters during night than during day.

These results are somewhat different from those of Holland (1985) and Holland et al. (1986), which showed a diurnal pattern (excursions during nighttime and remaining around the payaos during daytime). The oceanographic features might be attributable to these discrepancies.

Direct Assessment and New Remote Sensing Tools

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In the field of fishery management, direct methods of assessment with, for example, echo sounders have raised difficulties that were quite prohibitory for assessment of surface fish stocks and tunas in particular. Therefore, nondirect methods and statistics are preferred over direct methods, despite the necessary--and sometimes constraining--link with catch data. However, for surveys of unfished grounds, some aerial methods have been developed and assessment models built for cetaceans (Barhams et al. 1980) and for tuna (Petit 1984). One of the major limitations of these studies is the difficulty of getting the full inventory of surface schools from the plane track and over large ranges, because of spotter fatigue or waves disturbing the sea surface.

Against this background have come some very recent experiments (1988-89) exhibiting the potential of new remote sensing tools for use in halieutics (the exploitation of living marine resources) and in particular for use in tuna assessment. These experimental methods could very quickly become operational for aerial survey work and could be the basis for satellite experiments. We present two examples.

The first example shows results from a Canadian device called the "compact airborne spectrographic imager" (CASI) used for recognizing and monitoring the distribution of capelin schools during the summer spawning season. This method works in the visible wavelengths of light, using a multispectral combination.

In the second example, we report on an experiment named HAREM: HAlieutic Radar Experiment in the Mediterranean Sea. With HAREM, we try to check whether the distortion generated in the sea surface by tuna schools (boiler, splasher, and even breezer schools), cetaceans (jumping), nets, and boats could be sensed by synthetic aperture radar (SAR) devices. During the experiment, the "sea truth" was collected by the Mediterranean French purse seine fleet and their own commercial aircraft. We used a DLR (German Aerospace Research Establishment) sensor and platform: a radar E-SAR mounted on a Dornier 228 aircraft. It was possible to clearly identify some known targets: boats, nets, and, above all, cetaceans and tuna schools. The weather and fishing conditions were quite good, and we succeeded in the reverse experiment in finding tuna schools from targets visible on the radar screen. On the indicated positions, fishermen could catch 150 tons of bluefin tuna. Of course, our aim is not at all to develop a new tool for fishing, but rather to develop a new tool to measure potential tuna yield over a large area, fished or unfished, as well as to improve fisheries management through direct surface stock assessment.

In another experiment using the same HAREM equipment, we flew above the Languedoc Roussillon lagoons, while a second small aircraft mapped the boats, oyster tables, nets, and all fishing tackle.

The next step is to observe the relationship between tuna school density and the radar signal, which could lead to conversion from counts of schools to abundance estimates, the essential goal in halieutic surveys.

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Micro-Constituent Analyses of Skipjack Tuna (*Katsuwonus pelamis*) Otoliths

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The identification of a natural marker within the otolith of skipjack tuna may improve our ability to understand the amount of exchange and interdependence between stocks of distinct ocean areas and fisheries. I attempt to characterize x-ray spectra from skipjack tuna collected from the eastern tropical Pacific with skipjack tuna caught in Hawaiian waters. Three scans were collected from each transverse section of otolith representing an area of early, midlife, and most recent growth. Each of these subgroups are compared among and within the two geographic categories. I identify sources of variability associated with the technique and discuss the potential to detect natural markers. I also present results from an experiment assessing the sensitivity of the element concentrations to different otolith preparation methods.

To date, a total of 364 x-ray spectra from skipjack tuna otoliths have been collected and processed. Preliminary results indicate that, for some element concentrations, most noticeably strontium, significant differences exist between growth regions of the otolith. Sample sizes need to be increased, however, to discriminate differences between the geographic regions examined. Several interpretations of possible differences at the early growth phase for eastern Pacific and Hawaiian skipjack tuna are discussed.

Geographic Variation in Morphometric Characters and Gill Raker Counts of Yellowfin Tuna, *Thunnus albacares*, from the Pacific Ocean

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Thirteen morphometric characters were measured, and gill raker counts were taken on samples of yellowfin tuna, *Thunnus albacares*, from five different areas of the Pacific Ocean during January to May 1988. Univariate and multivariate statistical procedures were used to assess geographic variation of the morphometric characters and gill raker counts. One-way analysis of variance indicated significant difference in the mean total gill raker counts among areas. The morphometric data were statistically adjusted, using allometric formulae, incorporating the common within-group slopes to partition size. Stepwise discriminant analyses were applied to the morphometric and meristic data. The percent-correct classification from the stepwise discriminant analysis for the 5 groups and the 12 adjusted morphometric characters, plus total gill raker counts, was a total of 79.3%, which is 74.0% (Cohen's kappa statistic) better than would have occurred by chance. These results indicate significant meristic and morphological differences of yellowfin tuna from these areas, which suggests separate biological groups.

During January to April 1990, morphometric measurements and the first left gill arch were taken from yellowfin tuna from each of the same five locations conducted in 1988. In addition, hearts were collected to be used for examination of genetic variation utilizing mitochondrial DNA analyses. Multivariate statistical procedures will be employed on both the 1988 and 1990 data to investigate geographic variation in yellowfin tuna morphometric characteristics and gill raker counts, and particularly to assess temporal stability. These studies should provide further understanding of the spatial and temporal dynamics of distribution and movements of yellowfin tuna.

POSTERS

The 1989 U.S. Pacific Albacore Fisheries

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Logbooks, collected from the 1989 U.S. North Pacific albacore fishery, indicate that the season started in late June and lasted through the first half of October. Fishing was concentrated north of 40°N latitude in the inshore areas off of northern California, Oregon, Washington, and British Columbia. No fishing effort was reported from areas offshore (west of 140°W). Logbook sampling coverage increased slightly from 32% of the total catch in 1988 to 35% in 1989, and length-frequency coverage remained constant at 3% in 1988 and 1989.

The total 1989 north Pacific albacore catch reached a record low of 1,600 metric tons (t), a decrease of approximately 67% from 1988 catches. Average sizes of fish caught remained relatively stable at approximately 12.6 lb (12.4 lb in 1988). Catch rates were calculated using two different methods. Both methods indicate a decrease in catch rates of 45% to 50% from those in 1988. Total catch remains very low compared with the 20-year average of 15,000 t. Low catches in 1989, as in 1988, were probably caused by a relatively good salmon year that contributed to decreased fishing effort in the albacore fishery. Decreasing catch rates and apparent missing year classes in the Japanese albacore fishery indicate that reduced recruitment to the fishery may also be contributing to decreased catches.

Vessels participating in the 1989 South Pacific fishery were concentrated west of New Zealand between 35° and 40°S latitude and 135° and 160°W longitude. The catch from the southern fishery was approximately 3,800 t, a slight increase over the 1988 catch of 3,500 t. Average sizes of fish remained relatively the same as in 1988 (15.0 lb). Nominal catch rates (total catch/total effort) decreased 8% from 242 fish per day in 1988 to 223 fish per day in 1989.

1989 Tuna/Dolphin Observer Data Collected from U.S. Purse Seiners Fishing in the Eastern Tropical Pacific

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The National Marine Fisheries Service (NMFS) and the Inter-American Tropical Tuna Commission (IATTC) place observers on U.S. tuna purse seiners fishing in the eastern tropical Pacific Ocean. These observers collect data relating to the incidental dolphin mortality associated with this fishery. The information presented here is based on combined NMFS and IATTC data sets for calendar years 1976 through 1988 and on NMFS-only data for 1989.

In 1989, NMFS observers were on board for 75 fishing trips resulting in a total of 2,204 sets on dolphins, compared with the 1988 combined NMFS and IATTC totals of 81 trips and 1,988 sets on dolphins. The estimated number of dolphins killed by the entire certificated U.S. fleet for 1989 was 12,643, down 36% from the 1988 estimated kill of 19,712. The U.S. allowable dolphin kill may not exceed 20,500.

The geographic patterns of fishing on dolphins in 1989 differed somewhat from 1988 by an increase in fishing activity west of 120°W, a heavier concentration of dolphin sets north of 10°N between 100° and 110°W, and a decrease in activity between 6-10°N and 95-100°W. Otherwise, the fishing patterns in 1989 generally reflected those of recent years.

In 1989, as in 1988, an area of low dolphin kill-per-ton rates (the number of dolphins killed per ton of tuna caught) tended to be centered on 10°N and 100°W. Areas of higher dolphin kill rates were located along the western and southern peripheries of the fishing grounds and within 300 miles of the coastline between 7° and 15°N.

The observed dolphin kill-per-ton rate in 1989 was 0.20 dolphin, down 35% from the 1988 rate of 0.31 dolphin. The dolphin kill-per-set rate in 1989 was 3.7 dolphins, down 30% from the 1988 rate of 5.3 dolphins. When examined on a yearly basis since 1982, there appears to be a trend toward a lower dolphin kill-per-ton rate, but no such trend is apparent for the kill-per-set rate. The lower dolphin kill-per-ton rates since 1984 are at least partially the result of much higher, concurrent tuna catch-per-set rates.

The Shortfin Mako Shark in the Southern California Bight

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Recreational and commercial fishing effort directed at the shortfin mako shark, *Isurus oxyrinchus*, off the coast of southern California has increased tremendously in the last few years. This trend towards maximum utilization of available shark resources has prompted the need to know more about these resources.

Very little is known about the population size, stock structure, or movements of shortfin mako sharks off the Pacific Coast States. The Southern California Bight (SCB) may be a pupping and nursery area for the shortfin mako sharks; however, little information exists concerning the resource in the offshore and southern areas. Still less is known about short-term behavior patterns of individuals. This information could be valuable to fishery managers if it became prudent to control the development of coastal shark fisheries.

Acoustic telemetry was used to identify the short term horizontal and vertical movements of three shortfin mako sharks in the SCB during summer of 1989. All three sharks were 2 years old and were tracked for periods of 18-25 hours. The straight-line distances covered ranged from 13 to 31 nmi. The first two sharks tracked averaged 0.72 kn while the third averaged 1.38 kn.

One of the major features of the study is that shortfin mako sharks oriented to the surface waters above the thermocline. They spent 90% of their time above the 20 m thermocline depth, with only infrequent excursions into deeper waters. There was little difference in time spent in the mixed layer during the day or at night. Vertical dive profiles indicated an apparent post-capture trauma period lasting from 30 to 90 minutes.

Vertical and horizontal movements did not indicate any diel activity patterns associated with shore, nearby islands, or bottom topography. Tracks of several days may be required to identify such patterns, because of the complex topography in the area.

Fish Aggregation Devices: An Underutilized Tool for Tuna Research

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Past studies of fish aggregation devices (FADs) have been primarily concerned with the evaluation of the relative costs and abilities of different designs to attract fish. FADs are, however, a potentially powerful aid to research, underutilized in studies of tuna and other pelagic fishes. Advantages of sampling around FADs compared with more traditional forms of sampling include a greater consistency of availability of fish, the opportunity to sample with a range of gear types, access to a range of species including juvenile tunas, improved sampling designs, and cost effectiveness. This poster illustrates the potential values of FADs in pelagic fisheries research with examples from studies undertaken in Papua New Guinea.

Catch and Effort Assessments of Bluefin and Yellowfin Tunas in Virginia's Recreational Pelagic Fishery with Comments on Billfish Catches

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Following a reduced dockside and telephone sampling effort in 1988, compared with 1987, Virginia's recreational pelagic fishery was sampled more intensively during the 1989 fishing season. Interviews with boat owners targeting marlin or tuna provided data on 376 fishing trips (dockside sampling) in 1988 compared with 1,160 interviews collected by port samplers in 1989. Random telephone sampling of boat owners in the approximately 1,000 boat fleet provided data on only 244 trips in 1988 compared with 324 trips in 1989.

Virginia's trolling fishery continued to demonstrate a relatively unchanged catch rate for school size Atlantic bluefin tuna, *Thunnus thynnus*, when examining the dockside data set (1987-89). The random telephone sampling program, however, indicated bluefin tuna catch rates may have improved slightly over 1988 but were still relatively unchanged compared with 1987. Combining the distinctive telephone and dockside data sets--as is currently done by the Southeast Fisheries Center, National Marine Fisheries Service, for recreationally caught bluefin tuna from Virginia through Massachusetts--indicated that catch rates (catch per boat trip) were similar in 1988 and 1989. Catch rates for 1989, however, were not equal to those in 1987. Examining private boat catches versus those of charter boats indicated that no significant differences existed in bluefin tuna catch rates from 1987 to 1989 in the private boat component of the fleet. Differences did occur, however, over the 3-year period in the charter fleet, with 1989 catch rates probably slightly lower than those achieved in 1987.

Yellowfin tuna, *Thunnus albacares*, catches were considerably reduced in the fishery off Virginia in 1989 compared with the previous 2 years. Telephone interview data indicated a possible reduced catch rate in yellowfin tuna for the entire fleet from 1987 to 1988. The private boat component of the fleet may have been primarily responsible for the apparent drop in fleet catch rates between the 2 years. Combined dockside and telephone interview data for the fleet in 1988 and 1989 documented the observed decline in yellowfin tuna catches for the latter year. Separating private and charter data indicated that, compared with 1987 and 1988, both fleet elements experienced significant declines in yellowfin tuna catch rates in 1989.

In contrast to catch rates for tunas, marlin catches were better than had been observed in several years. White marlin, *Tetrapturus albidus*, catch rates for the fleet overall were up somewhat in 1989 in comparison to both 1987 and 1988. Differences between 1987 and 1989 were primarily attributed to better catch rates in the private boat component of the fleet during the

latter year. Blue marlin, *Makaira nigricans*, catch rates also were better in 1989 in comparison to either of the two earlier years. Both private and charter boat data supported this trend for 1988-89, but only private boats appeared to demonstrate significantly different catch rates in 1989 compared with 1987. Charter boat blue marlin catch rates remained statistically constant between 1987 and 1989 but were possibly higher in 1989 compared with 1988. The highest number of releases of blue marlin ever recorded in the 23-year history of the Virginia Saltwater Fishing Tournament occurred during the 1989 fishing season.

Oxytetracycline Tagging

The Billfish Foundation
Miami, Florida, U.S.A.

Chemical labeling of hardparts in teleosts is one of the most effective ways to validate methods of age determination. However, this approach has not had widespread use on Istiophoridae, because most members of this family have prohibitively low tag-recapture rates (i.e., less than 2%) and methods of tagging these large and often dangerous species have not been resolved. The Billfish Foundation has had a program of injecting oxytetracycline (OTC) into Atlantic sailfish, *Istiophorous platypterus*; white marlin, *Tetrapturus albidus*; and blue marlin, *Makaira nigricans*, since 1988, in an effort to resolve problems with tagging procedures for fish caught by recreational vessels. Although tag-recapture rates are so low that the probability of a recapture is extremely remote, there is at least some chance of a return provided enough fish are tagged and sufficient financial incentives and program publicity are provided for recaptured fish. Sampling techniques have included both in and out of water procedures, depending on the species and size of the fish tagged. To date, 31 sailfish (most from south Florida and Mexico), 12 white marlin (from Venezuela and the U.S. east coast), and 7 blue marlin (from Jamaica and Venezuela) have been injected with OTC, tagged with at least two external tags for identification, and released in good condition. No tag-recaptures have been reported so far.

New Tag for Billfish

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The tag-recapture rates for Istiophoridae worldwide are all less than 2%. There are probably many different factors that contribute to this low recapture rate: (1) nonreporting of recaptured billfish by offshore longline fleets, (2) poor tagging procedures by recreational anglers, (3) failure to submit release data by recreational anglers, (4) problems in reading tag legends after long-term marine exposure, and (5) shedding of the stainless steel anchor tags presently used by most tagging programs for billfish. The Billfish Foundation has undertaken a project to lower the long-term component of tag shedding for billfish by developing a new biologically compatible intermuscular tag, made out of surgical grade nylon, to encourage the attachment of muscle tissue. The short-term anchoring mechanism of this tag will depend on two very stiff barbs and will not necessitate placement between pterigiophores (common with other anchoring mechanisms). To ensure easy penetration of tough istiophorid skin, a very sharp stainless steel applicator is placed through the middle of the tag for initial insertion but is pulled out with only the nylon anchor left in the fish. The streamer portion of the tag, including the legend, is completely covered by shrink tubing and is secured to the nylon anchor by a mechanical rather than adhesive method of attachment. A double tagging study is planned to test the performance of this new tag with the commonly used stainless steel anchor tag. Additional studies are also planned using other species held in captivity for specific time intervals to monitor tissue growth on the nylon anchor.

Studies of the Early Life History of Billfish

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Very little is known about the early life history of billfish because these species (Istiophoridae) do not lend themselves easily to artificial propagation and culture, and they are very rarely captured in the juvenile stages with standard fish sampling methods. The lack of available juvenile specimens for scientific study has hindered early life history investigations, particularly age and growth studies. The Billfish Foundation has initiated a program to collect juvenile billfish out of the stomachs of larger predators. These samples will be provided to interested scientists who are working on early life history studies of Atlantic istiophorids.

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APPENDIX A

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Appendix B

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center Honolulu Laboratory
2570 Dole St. • Honolulu, Hawaii 96822-2396

41st Tuna Conference

Christofer H. Boggs, Chair

AGENDA

Monday, May 21, 1990

1500-1830 Check-in

1830 Dinner

1930 Tavern social (BYOB)

Tuesday, May 22, 1990

0800 Breakfast

0845 Opening remarks. Christofer H. Boggs, Conference Chair (Southwest Fisheries Center, National Marine Fisheries Service (NMFS), Honolulu, Hawaii).

BILLFISHES (Session I)

0855 Introduction. David Grobecker, Session Chair (Director, Pacific Oceanic Research Foundation, Kailua-Kona, Hawaii).

0905 Behavior and vertical distribution of Pacific blue marlin in Hawaiian waters as determined by ultrasonic telemetry. Kim N. Holland (Hawaii Institute of Marine Biology, University of Hawaii) and Richard W. Brill and Randolph K. C. Chang (Southwest Fisheries Center Honolulu Laboratory, NMFS).

0930 Estimating age and growth of young Atlantic blue marlin, *Makaira nigricans*, from otolith microstructure. Eric D. Prince, Dennis W. Lee, and James R. Zweifel (Southeast Fisheries Center Miami Laboratory, NMFS) and Edward B. Brothers (EFS Consultants).

0955 Sexual maturity of the swordfish (*Xiphias gladius*) in the Pacific Ocean during the 1968-1985 period. Oscar Sosa-Nishizaki and Makoto Shimizu (University of Tokyo).

BILLFISHES (Session I--Continued)

1020 Break

1045 Swordfish fishery development in Hawaii. Robert A. Skillman (Southwest Fisheries Center Honolulu Laboratory, NMFS).

1110 Albumin as a biomarker for serological identification of billfish carcasses. J. X. Hartmann, R. E. Waldner, J. C. Poyer, and E. A. Rossi (Florida Atlantic University).

1035 Sailfish bladder tissue as a source of cells for the establishment of in vitro cultures. J. C. Poyer, E. A. Rossi, and J. X. Hartmann (Florida Atlantic University).

1200 Lunch

1300 Hawaii's longline fishery: Interactions with regulated pelagic species (billfish). Samuel G. Pooley (Southwest Fisheries Center Honolulu Laboratory, NMFS).

1325 The billfish fishery at Baja California, Mexico: general remarks. Analysis of two years in commercial catch: actual situation. Alma Susana Mungaray Lagarda (Pesquera Integral Isla Bonida).

1350 Analysis on size and weight-weight relationship of the striped marlin (*Tetrapturus audax*) at Baja California Sur, Mexico. Pedro R. Gonzalez, Sofia G. Ortega, and German Ponce Diaz (CICMAR - IPN)

1415 Stock assessment analysis of sailfish in Mexican waters of the Pacific coast. Arturo Muhlia Melo (Centro de Investigaciones Biologicas de Baja California Sur).

1440 Conclusion of Session I. Dave Grobecker (Pacific Oceanic Research Foundation).

1445 Awards

1450 Break

PELAGIC COMMUNITIES (Session II)

1505 Introduction. Izadore Barrett, Session Chair (Director, Southwest Fisheries Center, NMFS, La Jolla, California).

PELAGIC COMMUNITIES (Session II--Continued)

1510 A novel method for the collection of larval and juvenile scombrids. Simon R. Thorrold (Australian Institute of Marine Science).

1535 Polyspecific tuna schools. David W. Au (Southwest Fisheries Center, NMFS).

1600 Evaluation of food and feeding strategy of northern bluefin tuna (*T. Thunnus*) and yellowfin tuna (*T. albacares*) off the coast of Virginia. Charles G. Barr (College of William and Mary).

1625 Direct assessment and new remote sensing tools. Michel Petit and Jean-Michel Stretta (ORSTOM). [From Session V.]

1650 Pelagic fisheries of Balochistan (northern Arabian Sea). Mohammed Moazzam (Directorate of Fisheries, Government of Balochistan) and S. Altaf Hussain, Aftab Javed, and Syed Ajazuddin (University of Karachi). [From Session III.]

1715 Sushi (complements of the United States Tuna Foundation) and beer (complements of the Federation of Japan Tuna Fisheries Cooperative). [Terrace or tavern, depending on weather.]

1830 Dinner

1930 Discussion session. Future directions of billfish research. Introduced by Dave Grobecker (Pacific Oceanic Research Foundation). Moderated by Ken Hinman (National Coalition for Marine Conservation, Savannah, Georgia).

2030 Tavern social (BYOB).

Wednesday, May 23, 1990

0800 Breakfast

PELAGIC COMMUNITIES (Session II--Continued)

0845 MOPS in TOPS: Effects of track length, environmental bias, and nonrandom school distributions on line transect estimates of dolphin school abundance derived from research surveys. Elizabeth F. Edwards, Pierre M. Kleiber, and Cheryl Glick (Southwest Fisheries Center, NMFS).

PELAGIC COMMUNITIES (Session II--Continued)

0910 On TOPS once more: Assessing a dolphin assessment proposal to charter the entire U.S. eastern tropical Pacific purse-seine fleet. Pierre M. Kleiber and Elizabeth F. Edwards (Southwest Fisheries Center, NMFS).

0935 IATTC tuna-log project: Circulation patterns and log drift in the ETP. Alejandro Pares (Scripps Institution of Oceanography) and Martin Hall and Pablo Arenas (Inter-American Tropical Tuna Commission).

1000 IATTC tuna-log project: Floating objects, associated biota, and FAD design in the ETP. Pablo Arenas and Martin Hall (Inter-American Tropical Tuna Commission).

1025 Break

1040 Predator-prey dynamics of yellowfin tuna in the eastern Pacific Ocean: A bioenergetics-based population model. Robert J. Olson (Inter-American Tropical Tuna Commission).

1105 Conclusion of Session II. Izadore Barrett (Southwest Fisheries Center, NMFS).

FISHERIES (Session III)

1110 Introduction. David Mackett, Session Chair (Southwest Fisheries Center, NMFS, La Jolla, California).

1115 Fisheries and stock status of yellowfin tuna in the world. Ziro Suzuki (National Research Institute of Far Seas Fisheries).

1140 Towards the development of a yellowfin tuna abundance index for the western tropical Pacific. Sachiko Tsuji (National Research Institute of Far Seas Fisheries).

1205 Lunch

1300 What is a highly migratory species? John P. Wise (Consultant to the Center for Marine Conservation).

1325 The albacore catch by Japanese large-mesh drift gillnet fishery in the South Pacific. Hideki Nakano, Yoh Watanabe, and Yasuo Nishikawa (National Research Institute of Far Seas Fisheries).

FISHERIES (Session III--Continued)

1350 Status of Japanese bluefin tuna fisheries in the northwestern Pacific Ocean. Yoshio Ishizuka (National Research Institute of Far Seas Fisheries).

1415 An approach toward measuring capacity utilization: Capacity utilization in the U.S. tropical tuna purse seine fleet. Dale Squires and Samuel F. Herrick, Jr. (Southwest Fisheries Center, NMFS).

1500 Evaluation of length-frequency sampling methods. Alex Wild (Inter-American Tropical Tuna Commission).

1525 Break

1540 Estimating catch at age from size composition data. Ramon J. Conser (Northeast Fisheries Center, NMFS).

1605 Conclusion of Session III. David Mackett (Southwest Fisheries Center, NMFS).

TUNA BIOLOGY (Session IV)

1610 Introduction. Kim Holland, Session Chair (Hawaii Institute of Marine Biology, University of Hawaii, Kaneohe, Hawaii).

1615 Factors related to muscle temperature elevation in juvenile black skipjack tuna (*Euthynnus lineatus*). Kathryn A. Dickson (California State University Fullerton).

1640 Nutritional condition of late larval/early juvenile tropical scombrids in relation to food availability. Daniel Margulies (Inter-American Tropical Tuna Commission).

1705 Tuna early life history studies at the Achotines Laboratory, Panama. Robert J. Olson (Inter-American Tropical Tuna Commission).

1730 Sex ratios of yellowfin tuna in the eastern Pacific Ocean: A new method for old data. Ed Everett and Richard Punsly (Inter-American Tropical Tuna Commission).

1755 Conclusion of Session IV. Kim Holland (Hawaii Institute of Marine Biology, University of Hawaii).

1830 Dinner

TUNA BIOLOGY (Session IV--Continued)

1930 Informal presentations

An overview of the 1990 Japan Tuna Conference. Norman Bartoo (Southwest Fisheries Center, NMFS) and Sachiko Tsuji (National Research Institute of Far Seas Fisheries).

An examination of tag shedding assumptions: with application to southern bluefin tuna. William S. Hearn (CSIRO Division of Fisheries, Marine Laboratories), George M. Leigh (CSIRO Division of Mathematics and Statistics), and Raymond J. H. Beverton (University of Wales College of Cardiff).

2000 Albacore workshop (for albacore working group only).

2030 Fire circle (if fire permit is obtained).

Thursday, May 24, 1990

0800 Breakfast

TUNA DISTRIBUTION AND MOVEMENT (Session V)

0845 Introduction to Session V. Michael Hinton, Session Chair (Inter-American Tropical Tuna Commission, La Jolla, California).

0850 About some results from the ICCAT yellowfin year program. Alain Fonteneau (Coordinator, ICCAT Yellowfin Year, Centre de Recherches Oceanographiques de Dakar).

0915 A tuna tagging project in the Maldive Islands. Richard S. Shomura (University of Hawaii).

0940 Movement of bigeye and yellowfin tunas around payaos tracked by sonic tags in the water off Okinawa, Japan. Naozumi Miyabe (National Research Institute of Far Seas Fisheries) and Takashi Koido (Nagasaki University).

1005 Micro-constituent analyses of skipjack tuna (*Katsuwonus pelamis*) otoliths. James Ianelli (University of Washington).

1030 Break

TUNA DISTRIBUTION AND MOVEMENT (Session V--Continued)

1045 Models of western Pacific skipjack tuna movement. John Sibert (Otter Software).

1110 Geographic variation in morphometric characters and gill raker counts of yellowfin tuna, *Thunnus albacares*, from the Pacific Ocean. Kurt M. Schaefer (Inter-American Tropical Tuna Commission).

1135 Trends in Western Atlantic bluefin tuna abundance as estimated in recent international assessments. Steve Turner (Southeast Fisheries Center, NMFS). [From Session III.]

1200 Conclusion of Session V. Michael Hinton (Inter-American Tropical Tuna Commission).

1205 Lunch

1245 Check-out

1310 Business meeting (all conference participants may vote).

Conference chair's report and election of next year's conference chair.

1330 Adjournment of the 41st Annual Tuna Conference.

POSTERS

The 1989 U.S. Pacific albacore fisheries. Atilio Coan and Gary Rensink (Southwest Fisheries Center, NMFS).

1989 tuna/dolphin observer data collected from U.S. purse seiners fishing in the eastern tropical Pacific. Alan R. Jackson (Southwest Fisheries Center, NMFS).

The shortfin mako shark in the Southern California Bight. Dave Holts (Southwest Fisheries Center, NMFS).

Fish aggregation devices: An underutilized tool for tuna research. S. D. Frusher (Australian Institute of Marine Science).

Catch and effort assessments of bluefin and yellowfin tunas in Virginia's recreational pelagic fishery with comments on billfish catches. Jon A. Lucy, Nancy J. Chartier, and Charles G. Barr (College of William and Mary).

Oxytetracycline tagging. The Billfish Foundation.

New tag for billfish. The Billfish Foundation.

Studies of the early life history of billfish. The Billfish Foundation.