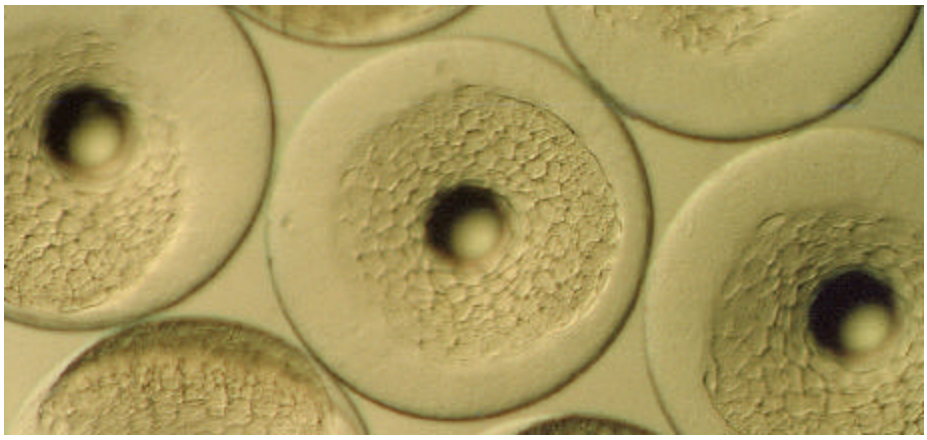
Proceedings of the 54th Annual Tuna Conference
Lake Arrowhead, California, May 13-16 2003

Back to Basics in Pelagic Fisheries Research



Shelton Harley Chair
Sponsored by the Inter-American Tropical Tuna Commission and the
Southwest Fisheries Science Center NMFS

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Inter-American Tropical Tuna Commission
8604 La Jolla Shores Drive
San Diego, CA 92037

PREFACE

Kia ora and welcome to the 54th Tuna Conference. This conference occurs in an informal environment where international scientists from diverse fields can exchange concepts and foster collaboration for future research. This years theme is "Back to Basics in Pelagic Fisheries Research". Successful ecosystem-based management is strongly reliant on a solid understanding of single-species population dynamics. Unfortunately, there are three major hindrances in our understanding of even the most important commercial and recreational species: (1) limited knowledge of basic biological parameters; (2) lack of fishery-independent estimates of abundance; and (3) often limited catch statistics. Within this conference, I hope we can examine these fundamentals so that we can move forward to ecosystem-level management with a strong foundation. I thank all presenters (both paper and poster) for their contributions towards this theme.

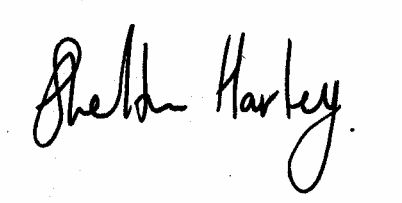
The abstracts contained in these Proceedings were edited solely for formatting. All abstracts appear in alphabetical order by the first authors surname. If readers would like further information about these talks or to cite any information or ideas contained in the Proceedings, they should contact the author(s) so the proper citation can be obtained.

There is no way that we would have a tuna conference this year if it was solely up to my organizational skills. I would like to extend gratitude to Alejandra Ferreira and JoyDeLee Marrow for their extraordinary assistance in the planning of this years event. They managed to keep track of all the people, the money, and all the important deadlines. I must also thank the following ex-chairs for their extremely useful advice: Keith Bigelow, Michael Hinton, Mark Maunder, and Sharon Hunt. I would also like to thank Ed Everett for assisting with organizing transportation and many other important tasks (i.e., making sure that there was sufficient beer supplies), Sharon Booker for help with the banking, Randall Rasmussen for updating the web site, Don Petersen for the tuna pickup, and Kim Holland and his team of sashimi cutters. John Graves, John Gunn, and Jaime Alvarado Bremer provided very prompt and useful reviews as members of the Scholarship Committee. The efforts of the session moderators are also appreciated – Rich Brill, Bruce Collette, Paul Crone, John Graves, Michael Hinton, Kim Holland, and Molly Lutcavage.

The Caboz Memorial Scholarship was awarded to Terrence Dammannagoda for his research on "GENETIC STOCK STRUCTURE AND INFERRED MIGRATORY PATTERNS OF SKIPJACK TUNA (*KATSUWONUS PELAMIS*) AND YELLOW FIN TUNA (*THUNNUS ALBACARES*) STOCKS AROUND SRI LANKA". The Tuna Conference is pleased to support the participation of Terrence and hope he will find the conference a valuable experience.

We gratefully acknowledge donations by the US Tuna Foundation, the Federation of Japan Tuna Fisheries Cooperative Association, Wildlife Computers, Monterey Bay Aquarium, and Prime Time Seafoods. Our Tuna Conference experience will definitely be enhanced by their generosity.

Have a productive conference.



Shelton Harley, Chair

NOTES

AGENDA

Tuesday, 13 May 2003

16:00 – 17:30 Registration

17:30 Welcome gathering in the Tavern - sponsored by Wildlife Computers.

18:30 Dinner
Socializing in the Tavern. Tagging Party - sponsored by Wildlife Computers

Wednesday, 14 May 2003

8:00 Breakfast

Session 1: Fish behaviour I (Moderator: Michael Hinton)

09:00 Conference Begins - Welcome and Introduction

09:10 MOVEMENT PATTERNS AND BODY TEMPERATURES OF FREE-SWIMMING JUVENILE MAKO SHARKS, *ISURUS OXYRINCHUS*, IN THE SOUTHERN CALIFORNIA BIGHT – Chugey Sepulveda, Suzanne Kohin*, Russ Vetter, Jeff Graham, and Corey Chan

09:30 BACKING OFF: ADAPTIVE MODELLING OF TUNA BEHAVIOUR FROM BIOLOGICAL FIRST PRINCIPLES – David Kirby

09:50 FORAGING BEHAVIOUR OF TUNA FEEDING ON SMALL SCHOOLING *VINCIGUERRIA NIMBARIA* IN THE SURFACE LAYER OF THE EQUATORIAL ATLANTIC OCEAN – Frédéric Ménard, Emile Marchal, and Francis Marsac

10:10 Coffee Break

10:30 USE OF POP-UP SATELLITE ARCHIVAL TAGS (PSATS) TO DETERMINE THE MOVEMENTS AND POST RELEASE SURVIVABILITY OF SWORDFISH, MARLINS, SHARKS, AND TUNAS IN THE CENTRAL NORTH PACIFIC OCEAN – Richard Brill and Michael Musyl

10:50 MOVEMENT AND SITE FIDELITY OR GEOLOCATION ERROR OF BIGEYE TUNA IN THE CORAL SEA AS DETERMINED BY ARCHIVAL TAGS — PRELIMINARY RESULTS – John Sibert, John Gunn, Naomi Clear, and John Hampton

*presenter if not senior author

11:10 THE TRANS-PACIFIC MIGRATION OF YOUNG BLUEFIN TUNA IN THE PACIFIC OCEAN RECORDED BY ARCHIVAL TAGS – Mio Takahashi, Yukio Takeuchi, Makoto Okazaki, Kyohei Segawa, and Harumi Yamada

11:30 SIMULATION MODEL TOWARD DEVELOPMENT OF ASSESSMENT PROCEDURES OF TAGGING DATA – Hiroyuki Kurota, Kazuhiko Hiramatsu and Sachiko Tsuji

11:50 Registration and check-in continued

12:00 Lunch

Session 2: Stock structure and genetics (Moderator: Bruce Collette)

13:10 THE GENETIC STOCK STRUCTURE OF THE SAILFISH, ISTIOPHORUS PLATYPTERUS, BASED ON MITOCHIONDRIAL AND NUCLEAR DNA MARKERS – Jan McDowell and John Graves

13:30 A MOLECULAR PHYLOGENY OF THE TUNAS AND BILLFISHES, SCOMBROIDEI AND XIPHIOIDEI – Thomas Orrell, Bruce Collette, and David Johnson.

13:50 PATTERNS OF GENETIC VARIATION OF NORTHERN BLUEFIN AND ALBACORE TUNA IN THE MEDITERRANEAN: HISTORICAL DEMOGRAPHY OR THE EFFECTS OF FISHING PRESSURE? – Jordi Vinas, Jaime Alvarado-Bremer, and Carles Pla

14:10 GENETIC STOCK STRUCTURE AND INFERRED MIGRATORY PATTERNS OF SKIPJACK TUNA (*KATSUWONUS PELAMIS*) AND YELLOW FIN TUNA (*THUNNUS ALBACARES*) STOCKS AROUND SRI LANKA – Terrence Dammannagoda and Peter Mather

Session 3: Management and technology (Moderator: John Graves)

14:30 EXPANDING SCIENCE NEEDS OF INTERNATIONAL HMS ARRANGEMENTS IN THE PACIFIC ?WILL NMFS SCIENTISTS MARK TIME OR KEEP UP? – Gary Sakagawa

14:50 Coffee Break

15:10 COMPARISON OF FOUR CLOSED-AREA MANAGEMENT REGIMES IN THE WESTERN NORTH ATLANTIC AND CENTRAL PACIFIC HIGHLY MIGRATORY SPECIES LONGLINE FISHERIES: EFFECTIVE MARINE POLICY IMPLEMENTATION OR LIMITED ALTERNATIVES – David Kerstetter

15:30 SURVIVORSHIP AND BEHAVIOR OF SEA TURTLES POST-RELEASE FROM LONGLINE FISHING GEAR – Yonat Swimmer, Richard Brill, Randall Arauz, Jorge Ballestero, Lianne Mailloux, Michael Musyl, Keith Bigelow, Anders Nielsen, and John Sibert

15:50 HISTORY AND IMPORTANCE OF FISH AGGREGATING DEVICES IN HAWAII'S RECREATIONAL TOURNAMENT FISHERIES – Daniel Curran, Jennifer Schultz, Paul Dalzell, and Stewart Allen

16:10 REGULATORY IMPACT ANALYSIS FRAMEWORK FOR HAWAII PELAGIC FISHERY MANAGEMENT – Keiichi Nemoto and Samuel G. Pooley

16:30 AT-SEA OBSERVATIONS OF THE CALIFORNIA-BASED SWORDFISH LONGLINE FISHERY 2001-2003 – Don Petersen and Lyle Enriquez

16:50 DROP NET SUBSURFACE APPLICATIONS – Kent Thomas

18:30 Dinner

Sushi party in the Tavern – Party sponsored by Japan Tuna Fisheries Cooperative Association, the US Tuna Foundation, and Prime Time Seafood, Inc.

Poster Session in the Tavern

POPULATION STRUCTURE ANALYSIS OF NORTH ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS THYNNUS*) USING MICROSATELLITE DNA LOCI – Pindaro Díaz-Jaimes, Jan McDowell, and John Graves

ASSESSMENT OF POPULATION STRUCTURE OF EASTERN PACIFIC YELLOWFIN TUNA BY RANDOM AMPLIFIED POLYMORPHIC DNAS (RAPDS) – E. Castillo-Olguín, Pindaro Díaz-Jaimes*, and M Uribe-Alcocer

USING STABLE ISOTOPES TO EXAMINE THE DIET AND TROPHIC STATUS OF NORTH ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*) – James A. Estrada, Molly Lutcavage*, and Simon R. Thorrold

SURVIVAL AND HABITAT PREFERENCES OF WHITE MARLIN (*TETRAPTURUS ALBIDUS*) RELEASED FROM THE WESTERN NORTH ATLANTIC RECREATIONAL FISHERY – Andrij Horodysky and John E. Graves

SPATIAL SCALES OF TUNA SCHOOLS AND AGGREGATIONS IN SURFACE LONGLINE DATA – David Kirby

BAIT MODIFICATION RESEARCH: REDUCING INCIDENTAL INTERACTIONS BETWEEN SEA TURTLES AND LONGLINE FISHING GEAR – Lianne Mailloux and Yonat Swimmer

PREDATOR SIZE-PREY SIZE RELATIONSHIPS OF TROPICAL TUNA IN THE OPEN-SEA ECOSYSTEMS – Frédéric Ménard, Yunne Shin, Céline Labrune, François-Xavier Bard, Francis Marsac

SPATIAL DISTRIBUTION OF SILKY SHARK *(CARCHARHINUS FALCIFORMIS)* BYCATCH IN THE TUNA PURSE-SEINE FISHERY OF THE EASTERN PACIFIC OCEAN – Marlon H Roman-Verdesoto

AN EXAMINATION OF MANTA RAY BYCATCH IN THE EASTERN TROPICAL PACIFIC, TUNA PURSE SEINE FLEET – Niki Woodward, Heidi Dewar*, Marlon Roman, and Mauricio Orozco

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Thursday, 15 May 2003

8:00 Breakfast

Session 5: Modelling (Moderator: Paul Crone)

9:00 STOCK ASSESSMENTS OF NORTH PACIFIC ALBACORE USING STATISTICAL MODELS – Paul Crone and Ray Conser

9:20 STOCHASTIC ASPECTS OF BIOLOGICAL REFERENCE POINTS AND POPULATION PROJECTIONS FOR NORTH PACIFIC ALBACORE – Ray Conser and Paul Crone

9:40 INDIAN OCEAN FAD FISHERY : AN ENDEAVOUR FOR TUNA RESEARCH AND MANAGEMENT – Alain Fonteneau and Jean Pierre Hallier

10:00 ASSESSING INTERANNUAL VARIABILITY IN CATCH OF TUNA AROUND THE PALMYRA FISHING GROUNDS FROM 1991 TO 2002 – Evan Howell and Jeffrey Polovina

10:20 Coffee Break

10:40 DATA RESCUE PROJECT FOR THE CREATION OF THE COMPUTER DATABASE FOR TUNA RESEARCH IN THE INDIAN AND ATLANTIC OCEANS – Evgeny Romanov, Gary Sakagawa, and Al Coan

11:00 MIXED-RESOLUTION MODELS FOR INVESTIGATING INDIVIDUAL TO POPULATION SCALE SPATIAL DYNAMICS – Patrick Lehodey

11:20 MAIN OUTPUTS OF THE EUROPEAN STROMBOLI PROJECT ON ATLANTIC BLUEFIN TUNA – Jean-Marc Fromentin

11:40 FISHERY-INDEPENDENT ABUNDANCE ESTIMATION OF ATLANTIC BLUEFIN TUNA (THUNNUS THYNNUS) IN THE GULF OF MAINE:

INTEGRATING TRACKING, TAGGING AND AERIAL SURVEY DATA – Nathaniel Newlands, Molly Lutcavage, and Tony Pitcher

12:00 Lunch

Session 7: Fish behaviour II (Moderator: Richard Brill)

13:10 BRIEF OVERVIEW OF THE CENSUS OF MARINE LIFE, TAGGING OF PACIFIC PELAGICS PROGRAM – Heidi Dewar, Barbara Block, Dan Costa, Randy Kochevar, and Steve Bograd

13:30 TEMPORAL CHARACTERISTICS OF FAD-ASSOCIATED BEHAVIOR OF TUNA – Kim Holland, Laurent Dagorn, and David Itano

13:50 PRELIMINARY ANALYSIS OF POTENTIAL HABITAT DISTRIBUTIONS OF SOUTHERN BLUEFIN TUNA AND FISHING VESSEL – Norio Takahashi, Sachiko Tsuji, Denzo Inagake, and John Gunn

14:10 POP-UP ARCHIVAL TAGGING OF BLUEFIN TUNA (*THUNNUS THYNNUS*) IN THE NORTHWESTERN ATLANTIC OCEAN: MOVEMENTS AND ENVIRONMENTAL PREFERENCES – Steven Wilson, Molly Lutcavage*, Richard Brill, Michael Genovese, Anne Everly, Julie Porter, and Sean Smith

14:30 AN ESTIMATION OF HOOKING DEPTH, TIME AND TEMPERATURE FOR BIGEYE TUNA BY USING SMALL BATHYTHERMOGRAPH IN THE ATLANTIC OCEAN – Hirokazu Saito and Takayuki Matsumoto

14:50 Coffee break

Session 8: Analysis of catch and effort data (Moderator: Molly Lutcavage)

15:10 SPATIAL AND TEMPORAL VARIATION OF YELLOWFIN TUNA SETS ASSOCIATED WITH SPOTTED DOLPHIN AND THEIR RELATIONSHIP WITH SEA SURFACE TEMPERATURE – Erika Bistrain-Meza and Sofía Ortega-García

15:30 ON THE INFLUENCE OF MESOSCALE EDDIES IN YELLOWFIN TUNA CATCHES IN THE EASTERN TROPICAL PACIFIC OCEAN – Hector Manzo-Monroy

15:50 WHY WE DON'T NEED ARCHIVAL TAG DATA AND WHO NEEDS BASICS WHEN WE HAVE NEURAL NETWORKS – Mark Maunder and Michael Hinton

16:10 ANALYSIS OF THE FISHING SUCCESS AND SIZE-STRUCTURE OF THE DOLPHINFISH *CORYPHAENA HIPPURUS* CAPTURED IN FREE FORM AND WITH FISH AGGREGATING DEVICES (FADS) – Sofía Ortega-García and Rodolfo Beltrán-Pimienta

16:30 THE HAWAII-BASED LONGLINE LOGBOOK COLLECTION PROGRAM – Russell Ito, Walter Machcado, and Frederick Dowdell

16:50 ANALYSIS OF BLUE MARLIN (MAKAIRA MAZARA) CATCH RATES IN THE HAWAII-BASED LONGLINE FISHERY BY APPLICATION OF A GENERALIZED ADDITIVE MODEL, WITH COMPARISONS TO OFFICIAL FISHERY STATISTICS – William A. Walsh, Russell Ito, Kurt E. Kawamoto

18:30 Dinner – Tuna conference BBQ
Party sponsored by Monterey Bay Aquarium.

Socializing in the Tavern and campfire at the Amphitheatre

Friday, 16 May 2003

8:00 Breakfast

Session 9: Biological studies (Moderator: Kim Holland)

9:00 REPRODUCTIVE DYNAMICS OF SOUTHERN BLUEFIN TUNA DETERMINED FROM SAMPLING THE INDONESIAN LONGLINE FISHERY BASED IN BENOA, BALI – Tim Davis, Jessica Farley, Mark Bravington and Retno Andamari

9:20 GROWTH, FEEDING AND THERMOREGULATION IN FARMED SOUTHERN BLUEFIN TUNA – Toby Patterson, John Gunn, and Kirsten Rough

9:40 TUNA TROPHIC DYNAMICS IN THE WESTERN AND CENTRAL TROPICAL PACIFIC – Brittany Graham, Kim Holland, Brian. Popp, V. Allain, Robert Olson, F. Galvan, B. Fry, Dean Grubbs

10:00 YELLOWFIN AND BIGEYE TUNA IN HAWAI'I: DIETARY OVERLAP, PREY DIVERSITY AND THE TROPHIC COST OF ASSOCIATING WITH NATURAL AND MAN-MADE STRUCTURES – Dean Grubbs and Kim Holland

10:20 Coffee Break

10:40 RECENT STUDIES ON TUNA AND BILLFISH AT THE ACHOTINES LABORATORY IN PANAMA, REPUBLIC OF PANAMA – Sharon Hunt, Jeanne Wexler, Vernon Scholey and Dan Margulies

11:00 DEVELOPMENT OF VISION IN YELLOWFIN TUNA – Daniel Margulies, Ellis Loew, and William McFarland

11:20 INVESTIGATING THE LIFE HISTORY AND ECOLOGY OF OPAH AND MONCHONG IN THE NORTH PACIFIC – Donald R. Hawn, Michael P. Seki, and Robert Nishimoto

11:40 Business Meeting

12:00 Lunch

13:00 End of Conference – Check Out

*presenter if not senior author

Abstracts
(In alphabetical order by first authors name)

SPATIAL AND TEMPORAL VARIATION OF YELLOWFIN TUNA SETS ASSOCIATED WITH SPOTTED DOLPHIN AND THEIR RELATIONSHIP WITH SEA SURFACE TEMPERATURE

Erika Bistrain Meza[1*] & Sofía Ortega García[2**]
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Because the presence of a shallow thermocline favors the association of tuna and dolphin, the yellowfin tuna capture obtained using this fishing type and its relationship with the thermal structure of the sea were analyzed. The analyzed information corresponds to the logbook records of the Mexican tuna purse-seine fleet that operated during 1990 -1999. Because approximately 50% of sets are made on tuna associated with spotted dolphin, the analysis was focused on this species. The sea surface temperature (SST) used corresponds to the logbook records. For the analysis of 1998, the database of the World Ocean Atlas 1998 (WOA98), which contains values of temperature at different depths (0-100 m), and information of the SST inferred through satellite images (AVHRR) were used. With the information of latitude and longitude of each set, we determined its temporal and spatial variability. During 1994, 1998, and 1999, we recorded the lowest value of the average catch per set. Although a defined annual pattern was not found in the set distribution, the largest set concentration was recorded north of Ecuador and along a warm tongue of water to a longitude of 145° at the equator. There was a high set concentration to the northwest of 20°N during 1997 and 1998. The seasonal distribution of sets indicates that this high concentration is found in the third quarter of the year. To avoid bias in the unit of effort, for the analysis of the thermal structure the information from vessels with carrying capacity greater than 1090 tons was used. This type of vessel made 80% of the total sets. Using the depth of the 20° C isotherm as the depth of the thermocline, the values of temperature of 20 ± 0.5 °C at each one of the different depths of the WOA 98 were extracted. The topography of the 20 °C isotherm was determined during that year, analyzing its variability and its possible relationship to the fishing success. The greatest number of yellowfin tuna sets associated with spotted dolphin was at SST 28 °C.

USE OF POP-UP SATELLITE ARCHIVAL TAGS (PSATs) TO DETERMINE THE MOVEMENTS AND POST RELEASE SURVIVABILITY OF SWORDFISH, MARLINS, SHARKS, AND TUNAS IN THE CENTRAL NORTH PACIFIC OCEAN

[1]Richard Brill and [2]Michael Musyl

[1]NMFS, Northeast Fisheries Science Center
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To date we have deployed pop-up satellite archival tags (PSATs) on 28 swordfish, eight marlin (blue, black, and striped), six tunas (bigeye, yellowfin), and 57 sharks (bigeye thresher, blue, oceanic white-tip, shortfin mako) in the central north Pacific Ocean. The objective of the project is to determine horizontal and vertical movement patterns, and rates of survival following release from longline and recreational trolling gear. (A companion study is trying to predict rates of morbidity and mortality in PSAT-affixed specimens based on a suite of biochemical assays from simultaneously collected blood samples.) PSAT tethers were either harpooned using nylon and metal tag heads (swordfish, tunas, marlins, and bigeye thresher sharks), or attached to the dorsal fin of sharks using a cable harness. PSATs were programmed to release 1, 2, 4, 8, and 12 months following deployment. Early detachment has been a continual problem. Only 8% of the devices reported on schedule and we have found no attachment method to be clearly superior to any other. However, our latest tether (including a stainless steel ball-bearing swivel) and tag head design (with speargun flopper blades to promote greater resistance) appears to be working well and numerous colleagues have requested the design and materials.

Of the 87 PSATs scheduled to report to date, we have received data from 39 devices (45% overall reporting rate). In aggregate we have 527, 279, 119, and 2582 days of observations from swordfish, marlins, tunas and sharks, respectively. There have, however, been species, year, and sex related differences in reporting rates. Of the eight swordfish tagged in 2001, four PSATs reported (50%). But of the 17 PSATs deployed on swordfish in 2002, only five reported (29%). Of 22 male sharks tagged, only 23% of PSATs have reported. In contrast, of the 22 PSATs deployed on female sharks, 73% have reported. This difference occurs irrespective of shark species. Rates of survival of sharks following release from longline fishing gear, however, appear excellent. We have only one clearly confirmed mortality.

PSATs have provided excellent data on vertical movement patterns. Swordfish have been shown to exhibit a diurnal vertical movement pattern, where they are shallow at night (less than .80 meters), but descend to .500-800 meters during the day. Bigeye thresher sharks and bigeye tuna show similar patterns. These behaviors, however, prevented the on-board software from providing daily geolocation estimates. Either the low ambient light levels exceeded the limits of the light sensor, or the changing ambient light conditions caused by the fishes' rapid crepuscular movements did not allow the on-board software to accurately calculate times of dawn and dusk. Of the 1015 days (in aggregate) where PSATs remained attached to swordfish and bigeye thresher sharks, we received only 44 estimates of daily geolocations. These observations, along with data from mooring line and double tagging studies, suggest that it is highly unlikely that light-based geolocation estimates from these species (or those with similar vertical movement patterns) can be correlated with mesoscale satellite-derived oceanography. We also found blue sharks to have a larger vertical range (. 0 to 720 meters), and to spend less time at surface than previously thought. They are, therefore not a candidate species for conventional ARGOS PTT satellite transmitters.

STOCHASTIC ASPECTS OF BIOLOGICAL REFERENCE POINTS AND POPULATION PROJECTIONS FOR NORTH PACIFIC ALBACORE

Ray Conser and Paul Crone
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

The use of biological reference points as a formal basis for management of fish populations has become commonplace in all of the world's oceans. Fishing mortality rate (F) -based reference points (e.g. $F_{20\%}$, $F_{40\%}$, $F_{0.1}$, F_{MAX}, etc.) are most commonly used but biomass-based reference points have received increased interest in recent years. However, for most tuna stocks – including North Pacific albacore (*Thunnus alalunga*) – no agreed-upon biological reference point has been adopted as a formal part of the fisheries management process. With international management of tuna stocks in the western and central Pacific Ocean approaching, it is likely that consideration of appropriate biological reference points will receive renewed interest.

Traditionally, the choice of a biological reference point has been a tradeoff between taking maximum yield from a stock while ensuring its long-term sustainability. In most cases, simple models (e.g. SSB/R) are used to calculate the point estimate of an agreed-upon, F-based reference point for comparison with the point estimate of recent F from a stock assessment model. Considerable uncertainty is common in both of these point estimates but it is usually ignored in the process of judging whether recent F exceeds an established F-based reference point.

Using North Pacific albacore as an example, methods for formally incorporating the stochastic aspects of reference point estimation, recent F estimation, and population projections are illustrated. Results indicate that some reference points are more difficult to estimate than others (i.e. the precision of the estimates can vary considerably). Consequently, in addition to the traditional tradeoffs used for selecting reference points (i.e. yield vs. sustainability), consideration of the precision of the estimates may be warranted as well.

STOCK ASSESSMENTS OF NORTH PACIFIC ALBACORE USING STATISTICAL MODELS

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The albacore (*Thunnus alalunga*) population that inhabits the North Pacific Ocean was evaluated using two 'statistical' age-structured models. That is, recently, 'uncertainty' (variability) associated with stock assessments in general has received considerable attention from both the scientific community and general public. Ultimately, the overriding goal of this research effort is to objectively evaluate areas of uncertainty associated with albacore stock assessments through different interpretations of the available sample data and most importantly, different modeling platforms (i.e., traditional vs. contemporary age-structured models).

One modeling approach was based on 'virtual population analysis' (backward estimation) methods, which generally assumes that a single, broadly-defined fishery targets the fish population (i.e., ADAPT model analysis). The assessment of the population based on ADAPT model analysis provided estimated stock parameters (e.g., time series of population number, biomass, spawning stock biomass, and recruitment) that were considered useful in a management context, i.e., analysis reflected a thorough evaluation of sample data applicable to the albacore population, as well as critical review of assessment methods within a workgroup forum. A second modeling approach is well underway that is based generally on 'predictive' (forward estimation) methods and a highly-structured fishery supposition, which allows issues surrounding catchability and selectivity, as well as movement, to be examined on a multiple fishery-specific basis (i.e., MULTIFAN-CL model analysis). Currently, the assessment of the population based on MULTIFAN-CL is considered strictly preliminary, given baseline models still require rigorous examination of the input data, further attention to fish- (e.g., longevity and natural mortality) and fishery-specific (e.g., selectivity and catchability) assumptions relied upon in the model, and finally, inclusion of tagging-related information for objective examinations of migration habits. Although the research goal, ecological theory, and sample data associated with the two modeling approaches are generally similar, assumptions and estimation techniques are markedly different between the two models.

In this presentation, we generally discuss the similarities and differences between the two modeling efforts, particularly, contrasts between baseline models generally developed within each analysis. Also, we present the estimated time series and associated error from thorough sensitivity analyses associated with the ADAPT model analysis. Finally, for primarily illustrative purposes, we present estimated time series generated from exploratory runs associated with the MULTIFAN-CL model analysis.

HISTORY AND IMPORTANCE OF FISH AGGREGATING DEVICES IN HAWAII'S RECREATIONAL TOURNAMENT FISHERIES

Daniel Curran[1], Jennifer Schultz[1], Paul Dalzell[2], and Stewart Allen[3]

1. Joint Institute for Marine and Atmospheric Research
2. Western Pacific Regional Fisheries Management Council
3. National Marine Fisheries Service

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The Recreational Meta Data Project was initiated to document and compile into database formats sources of Hawaii's pelagic recreational and sports fishing information from the past 50 years. Though no official record of Hawaii's recreational fishery sector exists, there are many sources of information that do exist in the form of surveys, previous studies, club records, newspapers, and fishermen logbooks. This project has collected over 100 papers and reports that have previously been difficult for other researchers to obtain and scanned them to computer files.

To date, we have also received information on 30 different tournaments from 8 different clubs. Some tournaments are well documented and we have annual information covering over 40 years of catch and effort in Hawaiian waters. The number of boats participating in different tournaments ranged from 6 to 260 boats. The area information received from all islands showed that tournament participants utilize fish aggregating devices (FAD) and the majority of fish caught in tournaments comes from fishing areas with a FAD. The Hawaii FAD program was originally intended to aid the commercial skipjack fleet, but tournament records indicate that the FAD placements have also become a major fishing target area for all the tournaments throughout the Hawaiian Islands.

Information on effort, catch, and tournament totals also reflect the unique nature of tournament reporting habits. Most tournaments do not differentiate between bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*T. albacares*) and these species are listed simply as "ahi". Marlin reports can also be one or more of several billfish species and skipjack tuna (*Katsuwonus pelamis*) may or may not be included in the radio logs and weigh in slips. Despite the inherent vagaries of species identification, this information does provide insight into hook up rates, catch composition, and average weight of catch. Data from a single tournament plotted across a time series are also useful in determining cyclical peaks in abundance of different species. Catching a thousand pound marlin is one goal of tournament participants, but the catch of mahimahi (*Coryphaena hippurus*) and ahi dominates the catch totals.

GENETIC STOCK STRUCTURE AND INFERRED MIGRATORY PATTERNS OF SKIPJACK TUNA (*KATSUWONUS PELAMIS*) AND YELLOW FIN TUNA (*THUNNUS ALBACARES*) STOCKS AROUND SRI LANKA

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Tuna are the major marine fishery in Sri Lanka and Skipjack (SJ) and Yellow fin Tuna (YF) are the most important component species. In 1998, the total oceanic tuna catch was 66,777 metric tonnes and 94% of that consisted of YF and SJ tuna (IOTC data summary No.20, NARA 1999). The Tuna catch is increasing rapidly each year in Sri Lanka (IOTC d.s.No.20). To date however, no genetic studies have been done to assess wild stock structure around Sri Lanka for management purposes. The current study will be the first attempt to document wild genetic resources of Tuna in Sri Lanka.

Samples of both SJ and YF were collected from eight major fishing grounds around Sri Lanka referred to as West, Southwest, South, Southeast, East, Northeast and Northwest. Approximately 100 samples of each species were collected from fishermen from each fishing ground and samples preserved in 95% ethanol. Sample locality (GPS), body length and sex data were recorded.

mtDNA and nDNA variation was examined to document the genetic diversity within and among populations and hence to determine stock structure and to infer migratory behaviour for both species. Control region sequence (D-loop) of the mitochondrial genome was amplified using PCR and genetic variation determined using TGGE (Temperature Gradient Gel Electrophoresis) technique. Haplotypes were determined from banding patterns and each unique haplotype was sequenced.

Frequencies of unique haplotypes at three sites around the Sri Lankan coast suggest evidence for stock differentiation in both YF and SJ. While population sizes appear to be very large for both species given the number of haplotypes observed, it is unclear at this stage whether the patterns observed represent historical isolation or contemporary restricted gene flow.

Genetic variation in the nuclear genome is being accessed using microsatellite loci. Microsatellite markers are currently being developed for both species through DNA cloning. Three and one Tetra-nucleotide repeats have been isolated so far in YF samples and SJ samples respectively. In addition four tri-nucleotide repeats have been isolated so far for each species. Primers designed for one Tetra-nucleotide repeat in SJ have been optimized for the gel scan system (Gel-Scan 2000, Corbett research). Very high heterozygosity was evident at the locus among SJ samples within a single fishing ground.

REPRODUCTIVE DYNAMICS OF SOUTHERN BLUEFIN TUNA DETERMINED FROM SAMPLING THE INDONESIAN LONGLINE FISHERY BASED IN BENOA, BALI

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In 1992, a longline catch monitoring program was set up in Bali to monitor landings of SBT caught on their spawning grounds in the NE Indian Ocean. The monitoring infrastructure that was established enabled biological samples to be collected from SBT in 1992-1995 to study their reproductive dynamics. Considerable information was obtained and this was reported at the 47th Tuna Conference. A new field program was carried out in 1999-2002 to provide additional samples needed to refine previous estimates of spawning parameters and to facilitate investigation of size/age and fisheries related trends in these parameters. The intention was to determine population egg production which needed more detailed information on size at first maturity, and changes in spawning frequency, batch fecundity, and spawning duration with size. A better understanding of size and fishery related trends in these spawning parameters, enabled us to use proxies where there were insufficient direct observations to obtain a sufficiently precise relationship with size. These data have been used to infer relative per capita egg production as a function of fish length, incorporating the proportion mature, the number of spawning events, and the number of eggs released each spawning. Results depend somewhat on the choice of stock assessment and assumptions about depth distributions on the spawning ground, but it is clear that large fish contribute more eggs than their spawning stock biomass would suggest. In the example given, 50% of asymptotic spawning potential is reached at age ~17 years compared with ~11 years for asymptotic spawning stock biomass.

BRIEF OVERVIEW OF THE CENSUS OF MARINE LIFE, TAGGING OF PACIFIC PELAGICS PROGRAM.

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The Tagging of Pacific Pelagics (TOPP) program, a pilot project of the Census of Marine Life, is a large, multi-disciplinary research program focusing on the ecology of the Eastern North Pacific. The plan is to simultaneously deploy a large number of electronic tags on a range of taxonomically diverse species from tunas to turtles to marine mammals to seabirds. On a large scale, results will be examined in relation to oceanographic conditions to identify the location of aggregation sites and migratory corridors and determine the physical and biological features that define these areas. In addition, data collected by the tags will be provided to oceanographers to allow testing and improvement of various models and to augment existing oceanographic databases. To implement this large-scale program there are a number of on going efforts to 1) develop new electronic tags and expand the variable that can be sampled, 2) construct data management, analysis and visualization software, 3) test existing electronic tags and improve tagging methods for a range of species through pilot projects, and 4) develop an education and outreach program. Full-scale deployments will be initiated in 2004 and build on the results from current efforts. We provide a summary of the goals of the TOPP program, our efforts to date, and the future program plan.

POPULATION STRUCTURE ANALYSIS OF NORTH ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS THYNNUS*) USING MICROSATELLITE DNA LOCI (Poster)

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North Atlantic bluefin tuna have been managed as distinct eastern and western stocks separated at 45ºW by the International Commission for the Conservation of Atlantic Tunas (ICCAT) since 1982. Conventional tagging studies and recent investigations using electronic tags indicate considerable mixing between the putative stocks, but it is not known if individuals demonstrate fidelity to eastern and western spawning grounds. To investigate the genetic basis of stock structure within Atlantic bluefin tuna we developed six variable molecular markers and used them to survey collections of young bluefin tuna from the eastern and western Atlantic. A total of 350 samples comprising six collections of young-of-the-year or age 1 individuals were obtained over a period of three years. Two temporal collections were obtained in the U.S. Mid-Atlantic Bight in the western North Atlantic (n = 117), and two temporal collections were obtained from two locations (Spain and Italy) in the Mediterranean (n = 233). Collections were surveyed at six tetranucleotide repeat microsatellite loci. There were no significant deviations of genotypic frequencies from Hardy-Weinberg expectations for five loci in any collection after correction for multiple testing, while 3 of 36 tests for the locus *Tth38* indicated significant departures from Hardy-Weinberg expectations, thus this locus was not considered further. Observed heterozygosities over all loci averaged 0.628, with fairly similar values in the pooled eastern Atlantic (0.638) and western Atlantic (0.610) collections. There was no evidence of significant temporal variation of allele frequencies among collections at the same location in different years, consequently samples from different years were pooled at a location for subsequent analyses. Tests of allele frequency homogeneity demonstrated significant genetic differences between western Atlantic-Spain and western Atlantic-Italy at two loci, although heterogeneity was only marginally significant at one locus (*Tth10*) when comparing the western Atlantic to the pooled eastern Atlantic collections. No significant genetic differences were found between the collections from Spain and Italy. Multilocus F_{ST} (which does not incorporate allele relationships) did not reveal any genetic structuring among locations, although multilocus R_{ST} (which accounts for allele relationships) showed a small but statistically significant difference at the *Tth10* locus between western and eastern Atlantic collections. These results are consistent with at least a minimal level of gene flow between eastern and western spawning grounds.

ASSESSMENT OF POPULATION STRUCTURE OF EASTERN PACIFIC YELLOWFIN TUNA BY RANDOM AMPLIFIED POLYMORPHIC DNAS (RAPDS) (Poster)

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Tuna fishery in Mexico represents a valuable alimentary and commercial resource. Yellowfin tuna (*Thunnus albacares*) is the main species caught in the eastern Pacific by Mexican fleet. Population structure studies on this species have been focused mainly in a wide range area in the Pacific ocean. Divergence within eastern Pacific population has been suspected since morphological and tagging studies have shown latitudinal differences between populations separated by the 15-20° N, along with the limited movements of yellowfin adults that might be promoting an isolation by distance event. Twelve collections of muscle tissue samples from individuals caught in different zones of the eastern Pacific were analyzed by random amplified polymorphic DNAs (RAPDs) and variation levels compared looking for genetic divergence between them. Forty loci were resolved, and mean observed heterozygosity was found to be moderately high (0.368), ranging from 0.283 to 0.406. Pairwise tests of allele frequencies homogeneity showed significant values in 17 of 66 comparisons after correction for multiple tests, resulted from comparisons mainly between coastal and oceanic samples. Overall population subdivision estimation was significant (0.096) after Bonferroni correction, but associated with a large standard error. Pairwise comparisons of subdivision estimates displayed four significant values after correction for multiple tests in comparisons involving coastal and oceanic collections, agreeing with the allele frequencies heterogeneity pattern and consequently with the significant subdivision found. However lack of adjustment to the isolation by distance model when comparing the number of migrants per generation versus geographic distance, was observed. Results showed evidence of some signal of differentiation, although influenced considerably by sampling error. This stresses the need to establish powerful sampling designs to study divergence in large pelagic mobile species.

USING STABLE ISOTOPES TO EXAMINE THE DIET AND TROPHIC STATUS OF NORTH ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*) (Poster)

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Stable ^{13}C and ^{15}N isotopic analyses were conducted on adult and juvenile North Atlantic bluefin tuna (*Thunnus thynnus*) tissues and prey, as well as other pelagic predators to examine the diet and trophic position of bluefin tuna in New England waters. A total of 86 individuals were sampled between June and October 2001; 65 were processed for isotopic analysis. Significant changes in the dressed weight and length/weight ratio identified a critical change in the overall quality of fish landed late in the season. Mean (± SD) $\delta^{15}N$ values for all bluefin tissues were consistent throughout the study, with muscle (14.0 ± .88‰) significantly more enriched than scale (12.0 ± .70‰) and bone (11.71 ± .95‰). The $\delta^{13}C$ and $\delta^{15}N$ values of bluefin tuna muscle indicated a recent diet of pelagic fish, while $\delta^{15}N$ values for scale and bone were very similar to known prey items such as Atlantic herring (*Clupea harengus*), hake (*Merluccius bilinearis*) and American sandlance (*Ammodytes americanus*), as well as basking sharks (*Cetorhinus maximus*). The mean $\delta^{15}N$ values of juvenile bluefin tuna muscle were 2.4‰ more depleted than adult muscle, suggesting a shift in prey choice. The trophic position of adult bluefin tuna, calculated from muscle $\delta^{15}N$ values, was 4.1, similar to values reported for shortfin mako sharks (*Isurus oxyrinchus*) (4.0), blue sharks (*Prionace glauca*) (3.9), and porbeagle sharks (*Lamna nasus*) (4.2). Potential explanations for isotopic results will be discussed.

INDIAN OCEAN FAD FISHERY : AN ENDEAVOUR FOR TUNA RESEARCH AND MANAGEMENT

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This paper will first develop an overview of the drifting FAD fisheries in the Indian Ocean. The percentage of FAD associated tunas taken by purse seiners in the Indian Ocean is the highest worldwide. These FAD associated catches have been quickly increasing during recent years. The main species targeted under FADs is skipjack tuna, but this fishery is also increasingly catching large quantities of yellowfin and bigeye, primarily taken at small sizes. Quite large but still unknown quantities of associated fauna and small tunas are taken and discarded in relation with these FAD catches. These increasing catches are now a source of serious worry among scientists and managers of the Indian Ocean tuna stocks. One source of concern is that, following the "ecological trap" hypothesis, the numerous FADs seeded by fishermen could modify the biological characteristics of tunas associated to FADs, such as their growth, migration patterns and natural mortality. Tuna scientists working under the Indian Ocean Tuna Commission (IOTC) framework have been doing comprehensive analysis of these changes in the FAD fisheries. They have proposed a wide scale tagging programme on Indian Ocean tunas that will be widely targeting an estimate of the effect of this FAD fishery on the sustainability of the Indian Ocean yellowfin, bigeye and skipjack tuna stocks. The planned tagging will use large numbers of dart tags, as well as some electronic tags that will be briefly presented. Due to the quite poor stock assessment presently done on Indian Ocean tuna stocks, it is still impossible to precisely evaluate the long term effects of these increased FAD associated catches on the stock productivity. Realistic analysis could only be done at the end of the large scale tagging programme. However, the large catches taken on FADs are already a major and increasing source of concern for the IOTC. Various measures, such as a moratorium on the use of FADs in the Somalia area during several months are presently studied by the IOTC. In June 2003, its scientific Committee will evaluate the potential yield per recruit consequences of such a moratorium. The first results tend to estimate that such a moratorium would seriously decrease skipjack catches, when only very minor positive effects could be obtained for yellowfin and bigeye stocks. These projections will remain widely uncertain because of the lack of biological knowledge and because of major uncertainties concerning the behaviour of the purse seine fleets facing such a moratorium There is however a good probability that the IOTC during the 2003 December Commission meeting, applying a precautionary approach, will decide on the implementation of some management measures intending to limit the fishing mortality of the FAD associated fishery.

MAIN OUTPUTS OF THE EUROPEAN STROMBOLI PROJECT ON ATLANTIC BLUEFIN TUNA

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This presentation aims to present the results of the EU-Project STROMBOLI that has been completed at the end of 2002. STROMBOLI focused on the Atlantic bluefin tuna (BFT) and included three main items: (i) collection and analysis of historical data from the ancestral Mediterranean BFT traps, (ii) comparison of the life history traits of the main tuna species and their relative resistance to exploitation and finally (iii) direct assessment through aerial spotting. The analyses of the historical data indicated that BFT population displayed conspicuous long-term fluctuations of about 100-120 years, together with cyclic variations of about 20 years. Further numerical analyses showed that these variations appeared to be negatively and significantly related to long-term trends in temperature, so that we finally hypothesized that these long-term fluctuations could be related to changes in migration patterns. STROMBOLI also validated through modelling that tropical tuna could sustain higher levels of fishing mortality than BFT. Concerning the biological reference points, our study pointed out the difficulty of using traditional benchmarks for BFT and stressed the importance of reinforcing the current measures and controls on BFT size limits. The various aerial surveys showed that the reliability of such an approach clearly depends on weather and oceanographic conditions and the relative stability of BFT spatial dynamics. Contrary to prior information, our results clearly indicated that aerial spottings towards BFT spawners are unsuitable to compute a fishery-independent index of abundance. However, the surveys towards juveniles BFT are encouraging and could be used in future to obtain useful fishery-independent information.

TUNA TROPHIC DYNAMICS IN THE WESTERN AND CENTRAL TROPICAL PACIFIC

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By utilizing stable isotope analysis, regional variations in tuna trophic dynamics in the tropical Pacific are being explored by two PFRP projects (#657282 and 659559). Carbon and nitrogen isotope values in marine organisms provide insight on (1) the sources of organic matter available to a consumer's diet and (2) the trophic position of an organism within the pelagic food web. An organism's isotopic signature represents a time-integrated diet, and is influenced by metabolic turnover rates of the tissues analyzed. Liver, red, and white muscle tissues sampled from tunas reveal systematic differences in both carbon and nitrogen isotope values, which are suggestive of either recent changes in diet or differences in isotopic fractionation among biochemical pathways.

In Hawaiian waters of the central tropical Pacific, we are examining differences between bigeye and yellowfin tuna feeding strategies in relationship to structure-associated food webs. In particular, we have sampled a size spectrum of fish to determine the length at which the tunas can be trophically defined as adults. Initial work suggests that juvenile bigeye and yellowfin tunas, ranging from 25 to 40 cm in fork length, sampled at fish aggregating devices (FADs) have similar carbon and nitrogen isotope values. However, one subset of juvenile yellowfin tuna was characterized by abnormally high nitrogen isotope values that could be indicative of either localized nutrient upwelling or starvation. Adult yellowfin and bigeye tunas sampled at a seamount 200 km southwest of Hawai'i exhibited $\delta^{15}N$ values approximately two trophic levels higher than the FAD-associated juveniles (i.e. 6 % difference).

In the western and eastern Pacific, we are beginning a study to elucidate the trophic structure of the pelagic ecosystem by sampling the tunas, associated pelagic fishes and their stomach contents using observers onboard tuna fishing vessels. Preliminary results for the western Pacific show $\delta^{15}N$ values are greater for bigeye relative to yellowfin tuna, signifying either differences in diet or an isotopic difference at the base of the food web where the tuna forage. In concert, both projects will provide information about tuna biology and trophic interactions, and in turn, this information when coupled with ecosystem modeling will be used to characterize large-scale relationships between food-web structure, oceanography, and fishing at upper trophic levels.

YELLOWFIN AND BIGEYE TUNA IN HAWAI'I: DIETARY OVERLAP, PREY DIVERSITY AND THE TROPHIC COST OF ASSOCIATING WITH NATURAL AND MAN-MADE STRUCTURES

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We are investigating the trophic ecology of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*T. obesus*) in an effort to better understand the biological significance of aggregation and association behaviors. Hawai'i offers an ideal setting for this study due to an abundance of natural and artificial aggregation sites. The primary sites of interest are four offshore NOAA weather buoys, the Cross Seamount, and the fourteen nearshore FADs surrounding Oahu. Our objectives are to compare the trophic ecology of the two species across these sites, to evaluate the potential trophic benefit of aggregating, and to assess the effect of artificial aggregative structures on tuna trophic biology. More than 1400 samples have been collected (47% yellowfin, 53% bigeye) and approximately 75% of these have been analyzed in the laboratory.

The forage base of both species is extremely diverse. In this study, 34 families of fishes and at least 14 invertebrate taxa were identified as prey of yellowfin tuna while 53 families of fishes and at least 25 invertebrate taxa were identified as prey of bigeye tuna. These results are comparable to other published studies. The vertical distributions of yellowfin and bigeye tuna are known to differ. Bigeye tuna generally select deeper, colder waters (150 to 250 meters) while yellowfin are known to be concentrated near the thermocline and in the mixed surface layer. Telemetry and fishery data suggest that these patterns break down when associated with FADs, buoys, and seamounts where the two species overlap considerably and are caught in mixed aggregations near the surface. Our trophic data indicate that the separation in vertical distribution is maintained during feeding however. Yellowfin tuna feed primarily on epipelagic prey from the mixed-layer while bigeye tuna feed on mesopelagic prey from the deep-scattering layer. According to our data, dietary overlap is insignificant between yellowfin and bigeye tuna regardless of association. Dietary overlap is also insignificant between associations within individual tuna species. Preliminary data recently collected on the feeding ecology of young-of-year yellowfin and bigeye tuna suggest there may be an ontogenetic shift in dietary overlap between the two species.

Our data also suggest that associating with the Cross Seamount imparts a significant trophic advantage to bigeye tuna but may offer little or no advantage to yellowfin tuna. The biomass of mesopelagic organisms, especially oplophorid shrimp and myctophid fishes, is very large around the seamount. This result may explain why the residence time of bigeye tuna on the Cross Seamount was estimated to be longer than that of yellowfin. In addition, our data indicate that associating with the man-made structures (offshore weather buoys and nearshore FADs) may impart a small trophic advantage to yellowfin tuna since epipelagic prey are attracted to these surface structures. In contrast, associating with these structures may be metabolically costly to bigeye tuna. The mesopelagic forage the bigeye tunas typically feed on are largely absent around these structures and they do not appear to switch to the available epipelagic forage. If true, this would suggest that detailed evaluations of the ecological impact of man-made structures in tropical waters might be warranted.

AN UPDATE ON ONGOING OPAH AND MONCHONG LIFE HISTORY AND ECOLOGY STUDIES.

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Studies on the life history and ecology of opah, *Lampris guttatus*, and monchong, *Taractichthys steindachneri*, in the North Pacific continue at the Honolulu Laboratory. These two pelagic species, incidentally caught by Hawaii-based longliners targeting bigeye tuna, are generally harvested in small, but nevertheless significant, quantities. Since neither are targeted species, these fishes have historically been poorly studied and as a result available information pertaining to the biology and ecology are virtually nonexistent.

The project activities for both the opah and monchong resources fall under two major categorical subprojects: (1) a comprehensive shore-based biological sampling program designed to monitor landings and catch composition and to obtain the metrics (length, weight, sex) and samples (ovaries, otoliths, and stomachs) required for a comprehensive biological and ecological assessment and (2) an analysis of spatial distribution patterns, preferred habitat, faunal associations, and trophic relationships which involves the analysis and merging of industry, research, and environmental datasets, and capture depth information collected from vessels of opportunity.

To date, several findings in particular are worth highlighting. It was fortunately discovered early on that opah exhibit sexual dimorphism thereby enabling the determination of sex without having to cut into the body cavity to access the gonads. This determination has saved considerable time and energy, allowing substantially more data collection. During efforts to estimate age-and-growth, preliminary examination of hard parts indicated that the second dorsal fin ray for opah and both sagittal otoliths and fin rays for monchong provide the best opportunity for ageing these animals. As suspected, sagittal otoliths in opah are of vaterite form and are not conducive for daily increment enumeration. Assuming that annuli are formed annually, opah taken in the fishery are estimated between 1+ and 6+ years (i.e., 2 to 7 annuli) and the oldest monchong would be about 7 yrs. If microincrements (on postrostrum and/or rostrum of sagittal otolith) are daily, monchong appear to grow rapidly in the first year; ages of 42-49 cm fork length fish ranged from ~1 year - 13.5 months.

We've been particularly successful in retrieving information pertaining to the vertical distribution, as well as obtaining biological samples, from cooperative commercial longline fishing trips. On two trips, a total of 108 monchong and 34 opah were caught on 26 longline sets. Of these, 15 monchong and 1 opah were caught on the sections of longline instrumented with a series of time-depth-temperature recorders (TDRs) and hook timers. Additionally, another 7 opah (4 males, 3 females) were instrumented with Wildlife Computers popup satellite archival tags (PATS) upon capture and released.

Progress and current status of the study is presented.

TEMPORAL CHARACTERISTICS OF FAD-ASSOCIATED BEHAVIOR OF TUNA

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Little is known about the long-term temporal dynamics of the FAD-associated behavior of tunas and yet this type of information is central to evaluating the influence that FADs have on the behavior and distribution of these species. Although it is known from tag-and-recapture and acoustic tracking experiments that tunas move between adjacent FADs, it is not known if there is any meso-scale temporal pattern or spatial limit to this behavior. A related topic is whether or not there is any cohesion or school fidelity of the individuals that are present at a FAD at any given time. To address these issues, we have placed Vemco VR2 data loggers on all the thirteen nearshore FADs that surround the island of O'ahu, Hawaii and we are in the process of releasing approximately 100 FAD-associated tuna equipped with individually coded sonic transmitters. In some cases, we have successfully released multiple individuals at the same FAD in less than an hour. Although similar work has been conducted by previous researchers (Ohta in Japan, Klimley and Holloway in Hawaii), our work represents a significant increase in the number of fish released, the longevity of the transmitters and the number of FADs that have been equipped with data loggers. Preliminary data will be presented.

SURVIVAL AND HABITAT PREFERENCES OF WHITE MARLIN (*TETRAPTURUS ALBIDUS*) RELEASED FROM THE WESTERN NORTH ATLANTIC RECREATIONAL FISHERY (Poster)

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The Atlantic-wide stock of white marlin (*Tetrapturus albidus*) is overexploited, with current biomass about 12% of that necessary for maximum sustainable yield. Member nations of the International Commission for the Conservation of Atlantic Tunas (ICCAT) are required to release all live white marlin from commercial fisheries (pelagic longline and purse seine), and the vast majority of these fish caught by the directed recreational fishery are released voluntarily. Whether these measures will significantly decrease white marlin fishing mortality is uncertain as relatively little is known of their fate following release. This project applies short-duration (5-10 day) pop-up satellite archival tag (PSAT) deployments to estimate survival and elucidate habitat preferences of white marlin released from western North Atlantic recreational fisheries. Twenty-two tags, recording temperature, pressure, and light level readings every two (5-day tags) or four (10-day tags) minutes, were deployed on white marlin caught using dead baits rigged on straight shank (J) or circle hooks offshore of the U.S. Mid-Atlantic region, the Dominican Republic, and Venezuela. Twenty-one tags (95%) reported to the satellites of the Argos system, and 16 of 21 tags (76%) returned data consistent with survival over the deployment duration. Roughly 80% of all data were successfully recovered from the tags. A higher mortality was noted for fish caught on straight shank (J) hooks (5 of 15; 33%) relative to those caught on circle hooks (0 of 6), presumably due to the greater incidence of deep-hooking and tissue trauma associated with the use of straight shank (J) hooks.

Data from surviving white marlin indicate that this species spends the majority of its time in the upper 10m of the water column, but frequently undertakes repetitive, short-duration (20-40 min) dives to depths in excess of 60m. Strong diel patterns in diving behavior were noted in some individuals. The duration and periodicity of dives varied within and among individuals, but fish consistently returned to surface waters for extended intervals of time (30 – 90 min) between dives. Based on the frequency, persistence, and patterns of short-duration dives, we infer that the diving behavior observed in this species is associated with foraging. Our results also suggest that white marlin may spend large periods of time in warm surface waters for purposes other than feeding; instead, some of this surface association may be an artifact of the need to increase core temperature and restore cardiac function between frequent foraging dives into cooler waters. The nature and extent of observed diving behavior indicate that this species may direct a considerable proportion of foraging effort beyond surface waters, which may explain relatively high catch rates of white marlin on some deep-set pelagic longline deployments.

ASSESSING INTERANNUAL VARIABILITY IN CATCH OF TUNA AROUND THE PALMYRA FISHING GROUNDS FROM 1991 TO 2002

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The Hawaii Longline Logbook data set spans more than 10 years and provides a long-term view of the fishery from federally permitted domestic longline vessels based in Hawaii. These logbook data were used to study the interannual variability of bigeye and other tuna catch in the region below 10°N, where the bulk of the fishery is associated with the area around Palmyra Island. Catch data for the span of the set was filtered to focus on deep sets to limit the effort used to sets that would be optimal for bigeye catch. Deep sets were defined by taking only sets that were reported to have used either more than 10 hooks per float or no light sticks. The fishery catch around Palmyra appears to be dominated by yellowfin tuna except in years of El Niño events. The average percent catch of yellowfin and bigeye tuna for non-El Niño event years is 59% and 18% of the longline landings, respectively, while in El Niño the percent catch for yellowfin and bigeye tuna is 28% and 46%, respectively. Closer inspection of the data revealed anomalously high catches of bigeye tuna in this Palmyra area for the first two quarters of 1998 and 2002, which are the years associated with these El Niño events. The average landings of bigeye tuna in non-El Niño years (1991-1997, 1999-2001) is 1,821 while in the El Niño year of 1998 there were 19,014 total bigeye landings and there were 13,911 total bigeye landings in 2002. The month of March for both years yielded the highest numbers, with over 8,500 bigeye tuna landed in 1998 and over 5,500 in 2002. These two time periods correspond roughly to the past two El Niño events and also to times of high physical dynamics in the region below 10°N where there is a reversal of the equatorial current system. Empirical Orthogonal Function analysis performed on sea surface height data from the TOPEX/POSEIDEN and JASON satellites shows that the equatorial current underwent a reversal in 1997/1998, with eastward flow being greater than 50 cm/sec. This same feature was also seen in 2002 to a smaller extent. It is thought that these reversals in the equatorial current system may cause eastward horizontal advection of mid- to higher level trophic organisms into new areas and also form mesoscale features around Palmyra Island. These features may act to contain these organisms and are located outside the area of high current shear, which would allow for easier placement of deep sets.

RECENT STUDIES ON TUNA AND BILLFISH AT THE ACHOTINES LABORATORY IN PANAMA, REPUBLIC OF PANAMA.

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Since October 1996, a spawning population of yellowfin tuna has been held at the Achotines Laboratory in large, in-ground tanks and spawning takes place almost daily. This broodstock was developed as part of a joint project conducted by the IATTC, the Overseas Fishery Cooperation Foundation (OFCF) of Japan and the government of the Republic of Panama. The joint project ended in 2001 but yellowfin studies have continued at the Laboratory. Larvae from hatched eggs have been used for investigations of the effects of factors such as microturbulence, prey selectivity, density, and diel patterns on growth and survival. Building on these experiments, several new research projects have developed over the past year. Recent studies include the effects of prey type and light intensity on yellowfin larvae, genetic studies of captive yellowfin, vision studies of yellowfin, and joint University of Miami- IATTC studies on sailfish.

In May 2002 a 12 day food selectivity experiment was conducted. Larvae were reared to a mean length of 6.5 mm SL, using cultured food items, and then exposed to mixed-prey assemblages containing wild zooplankton (mostly copepods) and newly-hatched yellowfin larvae. A second experiment was conducted to determine the optimal light intensity for rearing of yellowfin larvae. Three levels of light intensity (with two replicates) were tested over a ten day period. Larval survival was greatest for the highest level of light intensity.

Genetic samples have been taken from broodstock yellowfin and their eggs and larvae to determine the amount of genetic variation in both adults and their offspring. This study is being carried out by scientists of the IATTC, the OFCF of Japan, and the National Research Institute of Far Seas Fisheries of Japan. Any new broodstock fish that are introduced to the captive population are sampled for genetic analysis. The spawning periodicity and frequency of spawning of individual females can be estimated by analyzing the genotypes occurring in eggs and larvae from captive spawns.

In June 2001 a study was initiated to examine the spectral sensitivity of vision in several life stages of yellowfin tuna. The research, was carried out by Drs. William McFarland, University of Washington, Ellis Loew, Cornell University and Dan Margulies. The studies were continued in mid-2002. Trials were conducted to analyses of the spectral characteristics of nearshore, mixed-layer oceanic waters and the feeding environment in larval rearing tanks in the Laboratory. In addition, some preliminary feeding behavior and vision trials were conducted with yellowfin larvae and early-juveniles.

The facilities of the Achotines Laboratory are being used in a joint study with the Aquaculture Program of the Rosenstiel School of Marine and Atmospheric Science, University of Miami, to investigate the feasibility of capturing, transporting, and culturing live sailfish, *Istiophorus platypterus*. The study is being conducted by Daniel Benetti, Director of the Aquaculture Program of the University of Miami, working in collaboration with IATTC scientists. The studies are being funded by the Center for Sustainable Fisheries, University of Miami. Several sailfish were caught and transported to tanks at the Laboratory during 2002. To date, none of these individuals has survived in captivity.

THE HAWAII-BASED LONGLINE LOGBOOK COLLECTION PROGRAM

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The National Marine Fisheries Service (NOAA Fisheries), Honolulu Laboratory, Fishery Monitoring and Economics Program (FMEP) began collecting data on Pelagic Management Unit species in 1986. The program initially collected market data (e.g., fisherman, date of sale, individual fish weights, price, and buyer) from the United Fishing Agency Ltd. public auction, where most Hawaii-based longline vessels and some smaller vessels off-loaded and sold their catch. FMEP later expanded its activities for several reasons. The market data were used to estimate landings and ex-vessel revenue for the longline fishery. The need for more detailed information increased as the number of vessels participating in this fishery grew considerably in the late 1980s. Among the reasons were gear conflicts between small trolling and handline vessels verses longliners and reports of protected species interactions in the Northwestern Hawaiian Islands with longline gear. Consequently, the Western Pacific Regional Fishery Management Council (WPRFMC) instituted several management measures in 1990, among which was mandatory daily longline logbooks to be submitted promptly after each trip. The first version of the logbook was designed, printed, and distributed to longline fishermen by November 1990; the first completed logbook was submitted the following month. The data summarized fishing operations, effort, positions, catch, and protected species interactions.

Standard procedures were developed for monitoring compliance by fisherman as well as logbook data handling, editing, archiving, and reporting at the HL. Monitoring is facilitated by the fact that almost the entire Hawaii-based longline fleet is docked in Honolulu Harbor or Kewalo Basin. The work entails daily tours of the docks to maintain an inventory of longline vessels in port, at sea, or in dry dock. Newly arrived vessels are asked to submit logs at the dock. If available, each logbook page is examined for missing and questionable data entries, and any errors found can be corrected if approved by the vessel operator. These dockside checks reduce the need for return interviews for additions or clarifications and foster good rapport with fishermen. Minor editing (e.g., expressing as the 24-h clock) is also done before keypunching. The data are keypunched twice by different data entry clerks and are archived when there is full agreement. The original data (i.e., the log sheet transcript with only the minor edits) are archived and then run through a computer program with range checks for each field. "Out of range" values are checked against the original log sheets, that are maintained in secured storage to ensure confidentiality. The output from this research database is also archived. After the research database is edited, summary files are generated and reports issued 45 days after the end of each quarter. Annual reports are generated similarly. All of these reports are publicly available in print or on the FMEP website.

The mandatory daily longline logbook program is now in its twelfth year. These data represent the most important resource available to NMFS scientists and the WPRFMC concerning fleet activity, effort, and catch. These data are also used in several collaborative research projects with the Joint Institute of Marine and Atmospheric Research (JIMAR) of the University of Hawaii, in compiling statistics for fisheries of the United States, in international data sharing agreements, and in studies on the status of highly migratory stocks.

COMPARISON OF FOUR CLOSED-AREA MANAGEMENT REGIMES IN THE WESTERN NORTH ATLANTIC AND CENTRAL PACIFIC HIGHLY MIGRATORY SPECIES LONGLINE FISHERIES: EFFECTIVE MARINE POLICY IMPLEMENTATION OR LIMITED ALTERNATIVES?

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The U.S. National Marine Fisheries Service (NMFS) has closed large areas to pelagic longline fishing operations for several reasons, including protecting nursery grounds, restoring depleted stocks, or protecting endangered species. However, little post-implementation analysis on these closures has been conducted to evaluate whether the pre-implementation goals were achieved by these measures. The current regulatory framework allows relatively high levels of public comment on proposed regulatory actions, although some of the applicable federal statutes, e.g., the Endangered Species Act (ESA), are relatively inflexible regarding policy alternative outcomes. Courts have traditionally given broad legal standing to potential plaintiffs, allowing post-implementation legal challenges. This study examines four areas with management measures that closed or severely restricted longline fishing within a policy-oriented analytical framework: 1) the 1999 mid-Atlantic seasonal closure, 2) the 2001 closure of the East Coast of Florida, 3) the 1991 Northwest Hawaiian Islands (NWHI) year-round closure, and 4) the 2000 central Pacific swordfish fishery closure.

All four closures were examined for post-implementation biological and economic effects, which were compared with pre-implementation expectations by NMFS. Each closure has experienced different trajectories following implementation, summarized in this work. Of the four, the closure for the Hawaiian monk seals has been the most successful, with no documented interactions with U.S. fisheries since the designation of the NWHI as a protected species zone. Of the other three areas, the mid-Atlantic closure is currently being re-evaluated by NMFS, only limited data are available for the Florida closure, and the central Pacific swordfish closure is within the broad range of expectations, yet likely to be biologically ineffective by itself in restoring turtle populations. Furthermore, even the "successful" closures remain subject to external pressures such as international fleets, marine debris, and market pressures.

More research examining the effects of specific environmental parameters (e.g., temperature) on the behavior of pelagic species is needed. Such data may allow increasingly spatially- and temporally-limited area closures. Ultimately, several pieces of legislation may need to be revisited to allow for international fisheries-related impacts rather than simply those from the U.S. fleets. Such legislative changes to domestic environmental law, while perhaps more biologically appropriate than the status quo, remain hampered by perceived weak international fisheries enforcement and will likely be met with stiff resistance by the environmental community.

BACKING OFF: ADAPTIVE MODELLING OF TUNA BEHAVIOUR FROM BIOLOGICAL FIRST PRINCIPLES

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An individual-based life-history model has been developed to simulate the spatial population dynamics of Pacific skipjack tuna *Katsuwonus pelamis* in relation to ocean variability and productivity. The spatial domain is the tropical/sub-tropical Pacific Ocean and multi-year time series of input data from satellite and in situ observation and from numerical ocean model output are used. Interactions between skipjack and their environment are mechanistically considered, as are the motivations for the behaviour determining spatial dynamics. Detailed energetics-based biological modelling is carried out for a relatively small number O(103) of model agents, each representing a much larger number O(106) of individual fish. This allows a computationally feasible model population to be scaled to realistic natural levels of abundance. Mortality rates that are age-, density- and environment-dependent are then applied to the numbers of fish represented by the model agents. An artificial neural network (ANN) allows agents to evolve movement and spawning behaviour, and a genetic algorithm (GA) is used to mimic sexual reproduction, with offspring having characteristics (i.e. weights for the ANN) derived from each parent. After 'training' the ANN with the input data, the model may be used to hindcast and ultimately forecast the spatial population dynamics of Pacific skipjack; these predictions can be compared with those from other types of model and with observed tagging and commercial catch data. The work shows that it is possible to model fish population dynamics on a whole-ocean scale with deliberate inclusion of relevant physiological and behavioural detail and incorporation of interactions between fish and environment. This type of model unites oceanography with physiological, behavioural and computational ecology, and might find useful practical application in fisheries science.

SPATIAL SCALES OF TUNA SCHOOLS AND AGGREGATIONS IN SURFACE LONGLINE DATA (Poster)

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The overdispersion of CPUE in surface longline data for tunas, particularly after non-random targeting of effort by experienced fishers, implies discontinuous spatial distribution at the scale of the set (75 km) or larger. This would indicate aggregation, i.e. the response of individual tunas to favourable extrinsic conditions such as mesoscale oceanographic features. But further analysis at a higher resolution (i.e. individual hooks along each set) reveals mean nearest neighbour distances of <200 m compared with >500 m for randomly distributed fish. The results suggest that these adult tunas were either schooling (i.e. responding to each other) or aggregating at a much finer scale at the time of capture. Therefore the overdispersion of CPUE may be related either to social behaviour or to sub-mesoscale oceanographic features. Distinguishing between these processes in observed longline catch data is not trivial but if achieved may yield important information about the ecology of tunas, the productivity of fishing grounds, 'catchability' and the effectiveness of fishing effort.

SIMULATION MODEL TOWARD DEVELOPMENT OF ASSESSMENT PROCEDURES OF TAGGING DATA

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We started to develop a framework to analyze tagging data of Southern Bluefin Tuna (SBT), *Thunnus maccoyii*. First, we construct simulation models which mimic spatiotemporal SBT dynamics and simulate tag returns under a set of known parameter values. Then, we estimate target parameters by various different methods from the tag returns predicted by the simulation models and compare robustness of the estimation methods.

As a first step, we developed a simple simulation model with spatial structure and investigated robustness of a maximum-likelihood method based on a multinomial distribution. The simulation model assumed two seasons, two fishing areas and two fisheries. We aimed to clarify influence of inappropriate assumptions of reporting rates and fish movement between areas on estimates of fishing mortality rates.

The analyses showed that incorrect reporting rates resulted in biased estimates of fishing mortality and it was difficult to estimate both fishing mortality and reporting rates only from the tag returns even under an ideal situation. We also found that if tag releases were conducted in a specific area and fish did not migrate frequently between areas, spatial heterogeneity of tagged fish distribution resulted in biased estimates of fishing mortality rates. Tagging programs across a wide range would be necessary to obtain detailed information on migration and mixing of SBT.

MIXED-RESOLUTION MODELS FOR INVESTIGATING INDIVIDUAL TO POPULATION SCALE SPATIAL DYNAMICS

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This new PFRP project addresses ways to improve upon two classes of models: Individual Based Models (IBMs) and Advection Diffusion Reaction Models (ADRMs) that would help to model from ocean basin to individual scale. Both these types of models have been successfully applied to predicting tuna behaviors; IBMs at the very fine scale and ADRMs at the population level. The two classes of models can provide complimentary approaches to investigating the problems of scale integration when going from individual to the population level and from individual movements to advection-diffusion patterns. However, the approach needs a unifying framework combining large and small spatio-temporal scales i.e., the mixed resolutions in a same model domain. Mixed resolution models use a stretched grid system with greater resolution at one of multiple locations of the model domain.

The specific objectives of the project are:

- To develop a unifying framework based on the development of mathematical solutions for using mixed-resolution in ADRMs and combine IBM and ADRM approaches.
- To develop a range of IBMs for tunas (skipjack, yellowfin, bigeye, albacore) and other species of importance for tuna fisheries management. For instance, enhanced understanding of turtles' spatial dynamics might lead to effective bycatch mitigation.
- To produce predicted field of key variables (temperature, currents, primary and zooplankton production, forage biomass) at the scale of the Pacific basin, with several focus areas where the resolution will be enhanced. The predicted environment in these focus areas will serve for IBMs simulations.
- To select focus areas according to their interests and the existence of data allowing validation of the simulations and (consequently) parameterization of the models.
- To analyze scale effects and compare movement generated from IBMs and ADRMs between them and with observations.
- To investigate impacts of seamounts, anchored or drifting FADs on individual behavior from IBM simulations and observations, in the search for deducing consequences at large-scale population level.

This project forms part of a series of studies that are being conducted to facilitate the ambitious multi-national Oceanic Fisheries and Climate Change Project (OFCCP) of the International GLOBEC Program - a component of the International Geosphere-Biosphere Programme (IGBP), sponsored by the IOC and SCOR. The OFCCP will investigate the effect of climate change on the productivity and distribution of oceanic tuna stocks and fisheries in the Pacific with the goal of predicting short-to long term changes and impacts related to climate variability. The ultimate goal of the OFCCP project is to conduct simulation with ecosystem models that include the main tuna species, using an input data set predicted under a scenario of climate change induced by greenhouse warming as defined by the Intergovernmental Panel on Climate Change (IPCC). However, analyses of simulations based on retrospective series of oceanographic and fishing data sets are necessary to improve upon the predictive capacity of the ecosystem models, particularly the inter-annual (ENSO) and the decadal (Pacific Decadal Oscillations) time scales.

BAIT MODIFICATION RESEARCH: REDUCING INCIDENTAL INTERACTIONS BETWEEN SEA TURTLES AND LONGLINE FISHING GEAR (Poster)

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We are involved in research aimed at abating the interactions of sea turtles with commercial longline fishing gear. Specifically, we are attempting to identify a simple bait modification that would decrease the incidence or severity of hooking, but that would not significantly reduce catch rates of the targeted fish species (e.g., tunas and billfishes). Behavioral experiments have been conducted using subadult green turtles (n=23) (*Chelonia mydas*), loggerhead turtles (n=49) (*Caretta caretta*), and Kemp's ridley turtles (n=28) (*Lepidochelys kempii*). The former have been maintained at the Kewalo Research Facility (NMFS-Honolulu Laboratory) and the latter two species at the Sea Turtle Research Facility (NMFS-Galveston Laboratory).

Our first experiments, investigated the role of food color in turtles' decision to bite bait. Studies have found that sea turtles do indeed use vision, specifically color vision, in attracting them to bait. More specifically, turtles' attraction to food is a function of food color, whereby blue is least attractive and red apparently most attractive, and that this color "preference" is conserved in all three species tested. While all three species initially avoid food-colored food items, this rejection is extinguished after a few trials.

Our experiments are also aimed to determine turtles' reliance upon vision vs. taste or smell in attracting them to bait. To do so, we have recorded turtles' responses (e.g. eat, ignore) to food items that appeared similar, yet differed in their chemical composition. Specifically, we devised "artificial baits" that contained either known food items (squid) vs. either an unknown food (fish) or nothing ("control"), which we presented to the turtles on hooks and recorded turtles' responses. Upon visual inspection with the naked human eye, baits comprised of different food and chemical compounds looked indistinguishable. At time of first experiment, all turtles had been feeding on squid exclusively. Initial results showed that green turtles avoided the "control" in the squid vs. control experiments and avoided the "fish" in the fish vs. squid experiments, thereby suggesting that turtles can discern food items by either taste or smell alone. Studies to isolate turtles' sense of smell vs. taste are forthcoming.

In our efforts to identify a potential feeding deterrent, we've also presented to turtles baits marinated in various chemical compounds with known or hypothesized repellent properties. Squid were marinated overnight in the following chemical solutions: lactic acid (pH=2.5), urea (10% solution), quinine hydrochloride (10 and 100 mM), 25 % solution Hibiclens® (=1% solution chlorhexidine gluconate). We also marinated squid with some common strong natural flavors, many of which are known feeding deterrents in terrestrial vertebrates. Marinades included strong dosages of garlic, cilantro, capsaicin (via Habanero chili pepper [*Capsicum chinense*] extract), wasabi oil, lemon juice, 100% squid ink. Turtles and captive yellowfin and skipjack tuna willingly ate all.

ON THE INFLUENCE OF MESOSCALE EDDIES IN YELLOWFIN TUNA CATCHES IN THE EASTERN TROPICAL PACIFIC OCEAN.

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In this research it is proposed that mesoscale eddies (~ 400km) are appropriate for tuna forage production and/or concentration. And tuna forage is the principal variable for tuna concentration in the eastern tropical Pacific Ocean.

This mesoscale eddies that are formed by upwelling events in the Gulf of Tehuantepec (Mexico) and Gulf of Papagayo (Central America) moves westerly, along ~ 8N to ~ 12N, in a seasonal pattern.

The purpose of the present study is to analyze the variance and correlation structure between tuna fleet distribution and mesoscale eddies, mainly along the 10N band (5N to 15 N).

It is done an exploratory data analysis with multivariate statistical techniques, such as; Empirical Orthogonal Functions, Canonical Correlation, and Time Series Cross Correlations. Variables used are yellowfin tuna catches, sea surface height anomaly (satellite) and wind pseudo-stress (assimilation). Time period of study is from 1993 to 1998 with a time-space units are 1x1x1 (longitude-latitude-month).

Sea surface height anomaly (SSHA) is used for detection of the mesoscale eddies. It is found two main regions of SSHA variability separated at 115W-120W. In the east, tuna fishing activity is concentrated in the first half of the year. In the western region, fishing is done in the second half year. Inter-annual signals (El Niño) are clearly defined for some of the environmental variables analyzed, but not so clearly for tuna catches. This event is identified at the Equator and all along the Mexican coast.

Two indices for sea surface variability in the coastal upwelling areas are defined. One is the gradient or the difference of SSHA at two locations, which are at each side of the region of the jet winds in both Tehuantepec and Papagayo. The second index is the time rate of change of SSHA for a given position, in both Tehuantepec and Papagayo. The pseudo-stress in Tehuantepec and Papagayo is significantly correlated the SSHA variability. The SSHA variability in Tehuantepec is significantly (statistical) correlated with catch rates at two important oceanic areas. This correlation is not significantly for Papagayo ssha variability.

DEVELOPMENT OF VISION IN YELLOWFIN TUNA

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Tunas are highly active predators that rely heavily on vision to detect, track and capture prey. Adult tunas exhibit some of the highest visual resolution capabilities known for teleost fishes. They are also characterized by a large, well-developed optic tectum in the brain, underscoring the importance of vision. Though less is known of the visual development in larval and early-juvenile tunas, studies to date have indicated that visual development in larval tunas is precocious and the visual acuity and optomotor abilities of young tunas are advanced. A short summary of the authors' research on retinal development and behavior in tunas is presented.

Previous studies have suggested that adult tunas have only two visual pigments in their retinas, while the spectral sensitivity of larvae and early-juveniles has been undescribed. In this study, we report the results of a microspectrophotometry analysis of the visual pigments of larval, juvenile and adult yellowfin. The studies were conducted at the IATTC's Achotines Laboratory in Panama in 2001 and 2002. We confirm the presence of a $?_{max}$ 483 nm visual pigment in the rods of adults and a $?_{max}$ 485 nm pigment in the twin cones, as reported in earlier studies. However, all single cones contain a previously undetected violet visual pigmet with $?_{max}$ 426 nm, making the adult yellowfin a photopic dichromat.

The situation for larvae and early juveniles is different from that of the adults. Preflexion larvae show a wide distribution in cone absorbances, suggesting not only mixtures of the two adult pigments, but the presence of at least a third pigment with $?_{max}$ greater than 560 nm (green-sensitive). The functional ecological significance of the presence of green-sensitive cones in larvae and early juveniles is discussed and the adaptive importance of stage-specific variability in spectral sensitivity is considered.

WHY WE DON'T NEED ARCHIVAL TAG DATA AND WHO NEEDS BASICS WHEN WE HAVE NEURAL NETWORKS

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We develop and test a method to estimate relative abundance from catch and effort data using neural networks. Most stock assessment models use time series of relative abundance as their major source of information on abundance levels. These time series of relative abundance are frequently derived from catch-per-unit-of-effort (CPUE) data using general linearized models (GLM). GLMs attempt to remove variation in CPUE that is not related to the abundance of the population. However, GLMs are restricted in the types of relationships between the CPUE and the explanatory variables. An alternative approach is to use structural models based on scientific understanding to develop complex non-linear relationships between CPUE and the explanatory variables. Unfortunately, the required scientific understanding to develop these models may not be available. In contrast to structural models, neural networks let the data estimate the structure of the non-linear relationship between CPUE and the explanatory variables. Therefore neural networks may provide a better alternative when the structure of the relationship is uncertain. We use simulated data based on the habitat based method of Hinton and Nakano (1996) to test the neural network approach and compare it to the GLM approach. Cross validation and simulation tests show that the neural network performed better than nominal effort and the GLM approach. However, the improvement over GLMs is not substantial. We applied the neural network model to bigeye tuna (*Thunnus obesus*) in the Pacific Ocean. (Full paper submitted to CJFAS).

THE GENETIC STOCK STRUCTURE OF THE SAILFISH, ISTIOPHORUS PLATYPTERUS, BASED ON MITOCHIONDRIAL AND NUCLEAR DNA MARKERS

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Little is known about the within-ocean stock structure of the sailfish or about the relationship of sailfish among the three oceans. Researchers have postulated the presence of distinct stocks in the Pacific based on dissimilarities in catch rates and spawning locations (Shomura, 1980; Skillman, 1989), and Williams (1970) concluded that Indian Ocean sailfish were closely related to those in the western Pacific based on maximum size. However these theories have never been rigorously tested. In the present study, approximately 647 sailfish were collected from throughout the species' range over a six-year period from the Atlantic, Pacific, and Indian Oceans including 164 individuals from the western Atlantic, 130 from the eastern Atlantic, 149 from the eastern Pacific, 113 from the western Pacific and 91 from the Indian Ocean.

To investigate the genetic basis of stock structure, a 1700 bp region of mitochondrial DNA spanning the entire control region as well as the flanking tRNAs and portions of the cytochrome *b* and 12S RNA gene regions, was surveyed with five variable restriction endonucleases, and representative individuals from each haplotype and geographic region were subsequently sequenced. MtDNA analysis resulted in a total of 54 composite haplotypes based on restriction fragment length polymorphism analysis. Haplotypic diversities ranged from 0.94 (Venezuela) to 0.11 (Papua, New Guinea) and nucleotide diversities ranged from 0.024 (Senegal) to 0.0019 (Australia). Comparison of the overall distribution of haplotypes found in the Atlantic, Pacific and Indian oceans resulted in a calculated probability of homogeneity of <0.0001, indicating a highly significant non-random distribution of haplotypes among collections from the three oceans. Within the Atlantic Ocean, the distribution of haplotypes was not significantly heterogeneous. However significant differences in the distribution of haplotypes were noted within the Pacific and Indian Oceans. In addition, the distribution of haplotypes between Indian Ocean collections and those from the western Pacific were found to be significantly non- random ($p<0.0001$). However, when the Persian Gulf collection was removed from the analysis, collections from the Indian and western Pacific did not differ significantly ($p=0.2312$). Mitochondrial data also revealed the presence of diverse clades, which were probably formed during Pleistocene glaciation.

In addition, five nuclear microsatellite loci were assayed. Sailfish clearly exhibited stock structure based on the analysis of microsatellite loci and these results generally agreed with conclusions based on mtDNA analyses, which indicate that sailfish are minimally comprised of Atlantic, eastern Pacific, Indo-west Pacific, and Persian Gulf stocks. Whether or not additional stocks of sailfish exist could not be determined within the bounds of this study due to sampling limitations. However, if additional stocks exist they are most probably located with the Indo-west Pacific since stock structure was not found within the Atlantic or eastern Pacific.

FORAGING BEHAVIOUR OF TUNA FEEDING ON SMALL SCHOOLING *VINCIGUERRIA NIMBARIA* IN THE SURFACE LAYER OF THE EQUATORIAL ATLANTIC OCEAN

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The feeding behaviour of small tuna on the mesopelagic fish *Vinciguerria nimbaria* was studied in an equatorial area of the Atlantic Ocean (10-20°W, 0-5°N). Acoustic data (from a scientific cruise) and tuna stomach content data (from the tuna purse-seine fishery) were combined. *V. nimbaria* formed loose schools that occurred in clusters during daytime, and large aggregations during the night. The characteristics of the schools and clusters were analysed. The average length, size and packing density of the day-school were estimated at 48.5 m, 24 400 individuals, and 5.8 fish m^{-3}, respectively. The average length of clusters was close to 10 km. The packing density of night-school was estimated at 1.6 fish m^{-3}. The preying of tuna on *V. nimbaria* was modelled as a stochastic process based on two Poisson processes. Daily rations of tuna were estimated at 3.5 and 7% of the body weight. Taking into account the swimming performance of the prey and the predator, we showed that tuna were able to feed on day-schools in a very short time, whereas feeding during the night by filtering was not competitive. Furthermore, a cluster is able to feed a single tuna school during two months, proving the sustainability of the biomass of small tuna in the area by *V. nimbaria*.

PREDATOR SIZE-PREY SIZE RELATIONSHIPS OF TROPICAL TUNA IN THE OPEN-SEA ECOSYSTEMS (Poster)

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In order to test the hypothesis that fish size is a structuring factor of trophic interactions within open-sea ecosystems, a statistical analysis is conducted on the size composition of stomach contents from bigeye (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) which were caught by longliners in the Polynesian Exclusive Economic Zone. The relationships between prey size and predator size are studied using quantile regressions, and tuna's mouth measurements are compared with prey size. The results show that the size of the prey increases as the predator grows. The size distribution of prey in tuna stomachs is very asymmetrical, of lognormal or gamma types with the feature that, while they grow up, tuna still feed on little prey. Moreover, the analysis of the prey size/predator size ratios and their comparison to observations made on other piscivorous species living in different ecosystems, underline the fact that tuna feed on very little prey compared to their size. These results are used to parameterize a model of matter flux along a gradient of organisms size, using a formalism of partial differential equations. An important prospective work is undertaken while formalizing the different functions of fish life cycle (predation, growth, reproduction, mortality) in order to reconstitute a theoretical size spectrum for open-sea ecosystems. The general shape of the simulated size spectrum and the influence of different predation functions are discussed, in the light of observations and knowledge gathered in other types of marine ecosystems.

REGULATORY IMPACT ANALYSIS FRAMEWORK FOR HAWAII PELAGIC FISHERY MANAGEMENT

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A number of issues confront pelagic fisheries management in Hawaii, including longline interactions with protected species (sea turtles and sea birds), catch competition with small-scale fisheries such as blue marlin, and by-catch related issues (e.g., shark finning). Understanding how regulatory policies would change fishing activity and related benefits and costs is critical to sound fisheries management in a complex fishery system such as the Hawaii pelagic fishery. Regulatory policies to ban longline fishing around the Hawaiian Islands were changed several times since 1999 (e.g., time area closure and ruling out all swordfish-targeted sets), while a number of alternative policies were proposed and discussed (see the Final Environmental Impact Statement by NMFS). Thus, an effective and efficient research and analytical modeling tool is needed to compare regulatory impacts associated with management options in the range of areas.

Although a couple of PFRP-sponsored projects have developed economic models (Pan et al., 1999; Chakravorty and Nemoto, 2000) and evaluated time-area closures, neither model is completely satisfactory in analyzing a range of potential management measurements. In particular, the area designations - the five concentric areas in the MMPM or 5° square in Chakravorty's model - are too large for current regulatory issues where the ranges of various policy options may differ by 1° square. Since area closure is a common practice in fishery management, the analytical model needs the capability to incorporate a flexible area (and time) classification.

The objective of this research is to improve the multilevel and multiobjective programming model (MMPM) developed by Pan et al. (1999) to incorporate more flexibly-defined fishing areas, while a data engine to support a flexible area, season, target, and species classification system for the model and sensitivity analysis is developed. We evaluate the improved model by comparing the predicted allocation of fishing effort by the Hawaii longline vessels under the time-area closure/ruling out swordfish-targeted sets during 1999-2002, with the actual allocation of effort. Results demonstrate that the improved model is useful to predict the impact of those regulations, though the parameters related to the longline operating and fixed costs need to be updated with more recent survey data (e.g., O'Malley and Pooley, 2002).

FISHERY-INDEPENDENT ABUNDANCE ESTIMATION OF ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*) IN THE GULF OF MAINE: INTEGRATING TRACKING, TAGGING AND AERIAL SURVEY DATA

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From 1993-1997, the New England Aquarium conducted fishery-linked aerial surveys with spotter pilots to document the surface abundance, distribution, and environmental associations of bluefin tuna schools in the Gulf of Maine. The long-term goal of this program is to develop fishery-independent estimates of abundance. Information obtained by direct monitoring of surface schools allowed us to conduct spatial analyses, modeling and simulations that are not usually available in CPUE based approaches.

Our presentation will address measurement bias and uncertainty in population abundance estimation from bluefin tuna movement, spatial aggregation and distribution data. We used an integrated approach to analyze, calibrate, and correct the aerial survey data in order to obtain more reliable estimates of regional abundance. Bias and uncertainty in the size and aggregation of schools were directly estimated from the survey data, adjusted by additional data on movements and dispersal from electronic and hydro-acoustic tagging studies.

We will present the results of simulation tests of different survey designs, including random, systematic, stratified, adaptive and spotter-search aerial sampling. Recommendations for achieving greater precision in abundance estimation in aerial surveys will be discussed. Our work demonstrates how fishery-independent data can be integrated to provide more reliable estimates of bluefin tuna abundance, and a broader understanding of spatial heterogeneity in fish populations.

A MOLECULAR PHYLOGENY OF THE TUNAS AND BILLFISHES, SCOMBROIDEI AND XIPHIOIDEI

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Despite numerous morphological studies, the taxonomic limits of the scombroid fishes remains problematic. Competing morphological cladistic hypotheses of the group places the swordfish plus billfishes (Xiphioidei) as either sister to the Scombridae, or sister to the wahoo *Acanthocybium solandri* within the Scombridae. A published molecular hypothesis based on mitochondrial (cytochrome *b*) sequences does not agree with morphological hypotheses. The placement of the butterfly kingfish *Gasterochisma melampus* also remains unstable within the scombroids. The snake mackerels (Gempylidae) and the cuttlassfishes (Trichiuridae) were included within the molecular scombrid clades. It is likely that cytochrome *b* was not able to clearly rectify the limits of the scombroids due to homoplastic transitional saturation that occurs with this gene. Our novel phylogenetic hypothesis, based on 511 bp of the single copy nuclear locus TMO-4c4, does not recover a monophyletic Scombroidei as previously proposed. There is no support for a close relationship between the xiphioids and the scombroids, and thus, none for a sister relationship between the wahoo and the billfishes. In addition, there is no support for a close relationship between barracudas (Sphyraenidae) and the Scombroidei. The longfin escolar, *Scombrolabrax heterolepis* and the snake mackerels plus cutlassfishes are sister to the Scombridae. Within the Scombridae, the wahoo is found to be sister to the dogtooth tuna *Gymnosarda unicolor*. The primitive mackerels (Scombrini) comprising *Rastrelliger* and *Scomber* are monophyletic, but neither the Spanish mackerels (Scomberomorini) nor the tunas (Thunnini) are monophyletic. The placements of *Gasterochisma* and the slender tuna *Allothunnus fallai*, which have been in dispute, will be considered. Our Scombroidei *sensu strictu* comprise the Scombridae, Gempylidae, Trichiuridae, and *Scombrolabrax*. The Xiphiidae and Istiophoridae (Xiphioidei) are sister to the basal percoids and this suggests that the billfishes are derived within the percoids rather than from the scombroids. The latter hypothesis is not supported by any of the morphological data, but is similar to the cytochrome *b* amino acid phylogeny previously published.

ANALYSIS OF THE FISHING SUCCESS AND SIZE-STRUCTURE OF THE DOLPHINFISH *CORYPHAENA HIPPURUS* CAPTURED IN FREE FORM AND WITH FISH AGGREGATING DEVICES (FADS)

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The use of fish aggregating devices (FADs) has become, in recent years, an element of important support for a greater fishing success for different species. Off southern Sinaloa, the capture of dolphinfish, generally reserved for sport fishing, is an important part of the capture by the artisanal fleet that operates in the region, and is aided with the installation of FAD's.

Approximately 90% of the total catch of dolphinfish is obtained with the use of FADs that are located between 1 and 30 miles off the coast, most between 6 and 10 miles. We made 23 samplings to analyze the capture of dolphinfish in the area, using hand lines around the FADs and using longlines and trolling in open ocean. A total of 808 organisms were sampled. The fishing success of the dolphinfish capture using FADs is between 70% and 90% greater that that done in the open ocean using fishing lines and trolling. No significant differences in the average size caught by the two fishing systems were found, but there was between males and females taken. A high variability was found in the monthly average size in the organisms captured associated with FADs.

GROWTH, FEEDING AND THERMOREGULATION IN FARMED SOUTHERN BLUEFIN TUNA

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This talk details the results of recently-completed experiments examining the relationships between growth, feeding, and thermoregulation in farmed Southern Bluefin Tuna (SBT).

Gunn et al. (2002) demonstrated that visceral heating in juvenile SBT is closely related to food intake. Using archival tags and the visceral warming : intake relationship, our first experiment examined seasonal variation in feeding behaviour and food intake for a representative sample of fish in three pontoons where food was offered either 4, 5 or 6 days per week, respectively.

Archival tag estimates of individual consumption were compared to observations of feed input and generally found to be considerably smaller than the nominal amount provided to the pontoon, indicating the possibility of "over-feeding". A statistical model of the expected intake of an individual fish was developed that allows for standardization of intake estimates and prediction of average intakes, based on the amount of feed offered and the ambient water temperatures. The regression models of the feeding behaviour of farmed SBT allow for two different hypotheses: that SBT individual intake is limited by the fish's ability to consume feed per unit time or optimal feed levels (total amount of feed per fish provided) are dependent upon temperature and annual changes in metabolic or growth rates.

A second experiment examined the relationship between muscle temperatures and visceral temperatures in juvenile SBT. Despite confirmation of the presence of extensive retia in SBT, no studies have investigated empirically whether or not SBT actively thermoregulate. The use of farmed specimens means that the signal was not confounded by diving or rapid changes in ambient temperatures. Both muscle and visceral temperatures were maintained at a constant average differential with respect to the ambient water temperatures. Digestive processes appear to be the cause of the observed variation temperature and we hypothesize that the variation in the observed red muscle temperatures might be a result of daily activity patterns associated with feeding. While this dataset is too limited for generalization, the observations show that there may be considerable variation between individual SBT in their day-to-day thermal characteristics.

AT-SEA OBSERVATIONS OF THE CALIFORNIA-BASED SWORDFISH LONGLINE FISHERY 2001-2003

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The California-based pelagic longline fishery primarily targets swordfish (*Xiphias gladius*) and occasionally tuna, especially bigeye (*Thunnus obesus*). Due to Federal area and gear restrictions established in 2000-01 to Hawaii limited entry permit longline vessels, the number of vessels participating in the California-based pelagic longline fishery increased to 35, most of which de-registered from their Hawaii permits. Currently, 24 pelagic longline vessels operate out of California ports, representing approximately one million hooks of fishing effort each year. Although these vessels are prohibited, by state regulations, from fishing within 200 miles of the California coast, they often fish 1200 miles or more offshore in areas once fished when Hawaii-based. Vessels target swordfish from mid-September until early June.

National Marine Fisheries Service (NMFS) observer data from the Hawaii-based swordfish longline fishery shows sea turtles and seabirds are commonly found in this geographic area. As protected species interactions with commercial fisheries are the focus of observations in the California/Oregon swordfish drift gillnet fishery and the Hawaii-based longline fishery, NMFS initiated observer coverage for the California-based pelagic longline fishery. The Southwest Region (SWR), Long Beach Office, began placing observers aboard California-based pelagic longline fishing vessels on a voluntary basis in October 2001 as a pilot project to assess levels of sea turtle interactions and to collect socio-economic data from vessel owners and operators. To be consistent in pelagic longline data collection, NMFS, Hawaii Longline Observer Program data forms with current seabird and sea turtle handling and releasing techniques were adopted. Three vessels volunteered to carry an observer during the 2001-02 fishing season and the overall coverage level achieved was <5%. In August 2002, NMFS notified the fleet of its Marine Mammal Protection Act, Category II fishery, mandatory obligation to carry observers at the 20% fleet coverage level during the 2002-03 fishing season. The SWR conducted a voluntary California-based Pelagic Longline Skipper Workshop to provide outreach to captains and crew on upcoming mandatory requirements for observer coverage, sea turtle and seabird bycatch sampling, and sea turtle and seabird handling and release techniques.

Limited observer data demonstrates that the California-based pelagic longline fishery does interact with loggerhead, leatherback, and olive ridley sea turtles as well as black-footed and Laysan albatrosses. Currently, observers are at-sea aboard California-based pelagic longline vessels targeting swordfish. If a seabird or sea turtle interaction occurs, all observers are equipped to take identification photographs, collect tissue biopsies, remove or apply tags, and employ current safe handling and release techniques.

The U.S. West Coast Highly Migratory Species Fisheries Management Plan will recommend continued observer coverage to obtain reliable and statistically valid data on takes of protected species as well as the mandatory use of sea turtle and seabird avoidance measures. Further, the United States' "*National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries*" requires that NMFS, in cooperation with the U.S. Fish and Wildlife Service, conduct an assessment of all U.S. longline fisheries to determine whether a seabird incidental catch problem exists.

SPATIAL DISTRIBUTION OF SILKY SHARK *(CARCHARHINUS FALCIFORMIS)* BYCATCH IN THE TUNA PURSE-SEINE FISHERY OF THE EASTERN PACIFIC OCEAN (Poster)

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Sharks and rays are particularly vulnerable to over fishing due to slow growth, delayed ages at maturity, low fecundity, and long gestation periods. The silky shark *(Carcharhinus falciformis)* is the most abundant shark in the bycatch of the Eastern Pacific Ocean (EPO) tuna purse-seine fishery. Despite this fact, little is known about silky sharks in the Pacific Ocean. Data collected by observers of the Inter-American Tropical Tuna Commission (IATTC) between 1993 and 2001 are currently being used to study spatial distributions of silky shark bycatch. Because silky sharks can easily be confused with other pelagic carcharhinid sharks, the IATTC staff has adopted measures to improve shark identification by observers at sea and to estimate misidentification rates in the bycatch data. A special sampling form, the Registro de Características de Tiburones (RCT), was developed for the latter purpose. The RCT contained illustrations of the key characteristics of silky, blacktip, and other sharks in a format designed to confirm or correct the observers' shark identifications at sea. The database has been revised according to these criteria.

Spatial patterns in the size composition of silky sharks in the bycatch and bycatch per set were examined by year and purse-seine set type. Most of the silky shark bycatch between 1993 and 2001 occurred in sets on floating objects. Marked spatial patterns are apparent in the data, with very high proportions of small sharks (<90 cm) caught north of 7°N latitude and northeast of the Galápagos Islands, high proportions of large sharks caught south of the equator, and about equal proportions of small (<90 cm), medium (90-150 cm), and large sharks caught west of the Galápagos Islands between the equator and 7° N. In some of the areas, the bycatch rates showed marked declines over time. IATTC staff is analyzing these figures in a more complete statistical study, because the interpretation of these rates is a complex issue, responding to changes in the population, in the environment, and in the fishing practices and gear.

Understanding spatial variability in silky shark bycatch is an essential part of the development of bycatch reduction measures in this fishery. The member governments of the IATTC are committed to reducing the bycatch of pelagic sharks in the tuna purse-seine fishery of the EPO, and to that effect have passed resolutions recommending the release of sharks and other provisions. In particular, the resolutions of the Annual Meeting of the IATTC in June, 2002, made recommendations regarding the following topics: (1) release sharks, (2) survival experiments, (3) spatial studies, (4) expanding sampling coverage, and (5) bycatch data availability from longline vessels.

DATA RESCUE PROJECT FOR THE CREATION OF THE COMPUTER DATABASE FOR TUNA RESEARCH IN THE INDIAN AND ATLANTIC OCEANS

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YugNIRO (formerly AzCherNIRO, till 1988), Kerch, Ukraine started tuna research in the Indian Ocean in early 1960-ies and such studies continued till early 1990-ies. For research purposes there were used medium-sized fishing trawlers (up to 55 m LOA) converted for pelagic longlining owned by Yugrybpoisk . Yugrybpoisk carried out also their own searching expeditions to Indian and Atlantic Oceans, which were arranged within framework of YugNIRO research. At present, all the data collected are stored in YugNIRO archives.

Recent data inventory accounted about 130 research, searching, and fishing pelagic longline cruises for 1961-1989 targeted tunas (generally Thunnus), billfishes (Makaira, Tetrapturus, Xiphias), pelagic sharks (Carcharhinus, Isurus, Alopias, Prionace, Galeocerdo). Other pelagic species recorded as bycatch. More than 5200 longline sets with about 2.5 millions nominal hooks were shot. For every research cruise the following data were colleted on set by set basis: number of hooks, hooks distribution by depth, total catch, catch by species. All fishes from the catch were measured, weighed, and analyzed. Catch depth of every fish was recorded. Environmental data and MBT station data generally available. Some data were collected by scientific observers aboard commercial fishing vessels.

Due to lack of computer equipment and limited funding throughout years of data sampling till now this valuable data still storing on paper as logbooks of longline catches and biological analysis. These data represent unique dataset for Indian Ocean which could be used as an independent long-term biological and fisheries database as well as additional information to databases of IPTP/IOTC and national databases of research centers from Japan, China (Taiwan), Korea Republic and countries of the region. Small subset of data collected in Atlantic may be used as additional research data.

In spite the careful treatment by YugNIRO personnel, these unique data may be lost due to natural deterioration of media under time impact, accidents, natural disasters, other extraordinary situations, etc. At present and in the nearest future YugNIRO is unable to transfer them on up-to-date media because of absence of appropriate equipment and funds. In late 2002 under support of NMFS and NFWF data "rescue" project which principal goal is preparation of computer database, make this data available for joint YugNIRO/SWFSC analysis and for IOTC and ICCAT was started. "Rescue" is carried out by digitizing of the data, which exist only as manuscripts, in order to store them on computer media in the form of relational database. Database structure, first results of the database creation, data digitizing, and analyses, will be presented.

AN ESTIMATION OF HOOKING DEPTH, TIME AND TEMPERATURE FOR BIGEYE TUNA BY USING SMALL BATHYTHERMOGRAPH IN THE ATLANTIC OCEAN

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The hooking depth, time and temperature for bigeye tuna (*Thunnus obesus*) were examined based on the data collected by a small bathythermograph system (TDRs) that were attached to branch lines of longline gear. Data were collected from Japanese commercial longline operations in the three areas of Atlantic Ocean (off Angola, off Abidjan and off Dakar) during the period from December 2001 to March 2002.

TDRs were placed to branch lines about 10m above hooks and set to record time, depth and temperature in every 10 seconds. Hooking time of fish was determined from the time when sudden changes in depth were observed in TDR records. The same type of sudden change in depth was used to identify the time for hit in neighboring hooks to the one with TDR, where hooking depth was calculated assuming a shape of main line as a catenary. The observed temperature at estimated hooking depth was taken as a hooking temperature of fish.

The hooking depths of 60 bigeye tuna (96cm – 177cm in FL) could be obtained. The majority of fish were caught at the depth below 200m in the areas off Abidjan and off Dakar, while all large individuals (167cm – 177cm in FL) caught in off Abidjan were hooked at the shallower depth of 90m – 170m. This observation is not consistent with the previous knowledge on a vertical distribution of bigeye tuna during daytime. In the area off Angola where the longline gear was set in a relatively shallow layer comparing to the other two areas, estimated hooking depth was also shallower than those in the other areas. 56 fish out of 60 were hooked during daytime. The hooking temperatures were between 9.6ºC and 18.5ºC with the modes between 10ºC to 14ºC in all areas.

EXPANDING SCIENCE NEEDS OF INTERNATIONAL HMS ARRANGEMENTS IN THE PACIFIC – WILL NMFS SCIENTISTS MARK TIME OR KEEP UP?

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The United States has a major stake in the Highly Migratory Species (HMS) of the Pacific Ocean owing to concentrations of HMS in its extensive EEZ, significant catches by U.S. commercial, sport and subsistence fishers, and moral obligation as a nation with consumers consuming a significant share of the world's catch of tunas. As a result, it has promoted international arrangements for advancing conservation and fishery management of Pacific HMS through cooperation. Arrangements that the U.S. is a party to include, the Inter-American Tropical Tuna Commission (adherence year, 1949), Canada-United States Albacore Treaty (1981), South Pacific Tuna Treaty (1988), the Interim Scientific Committee on Tunas and Tuna-like Species in the North Pacific (1995), and the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (pending).

Each of these agreements require support from the contracting parties for science and fishery data. Depending on the agreement, the support can be in the form of financial contribution to the organization for its staff to carry out required science and fishery data tasks, services provided by the contracting parties to meet organizational needs, or a combination of both.

U.S. support for scientific services to Pacific HMS arrangements is provided by the NMFS, specifically personnel of the Southwest Fisheries Science Center. The level of U.S. support for each arrangement is reviewed and an outline of needs for improving the level of support is provided in this presentation to the 54th Conference. It is noted that future funding will dictate whether NMFS scientists will mark time or keep up with meeting U.S. obligations and participating in scientific studies that address issues facing international HMS arrangements in which the U.S. is a contracting party.

MOVEMENT PATTERNS AND BODY TEMPERATURES OF FREE-SWIMMING JUVENILE MAKO SHARKS, *ISURUS OXYRINCHUS*, IN THE SOUTHERN CALIFORNIA BIGHT

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Acoustic telemetry was used to study the vertical and horizontal movement patterns and monitor stomach temperatures of 7 juvenile mako sharks in the Southern California Bight (SCB) from July-November 2002. Chummed makos (84-150 cm TL) freely fed on a mackerel containing a V-22 temperature and pressure sensitive acoustic transmitter and individuals were tracked for 7 to 43.5 h. Data reveal fine-scale movements, movement patterns in relation to oceanographic and topographic features, as well as ontogenetic differences in the stomach temperature and depth records between sharks. Stomach temperature records and the subsequent recapture of 4 of the 7 tracked makos verified feeding events.

MOVEMENT AND SITE FIDELITY OR GEOLOCATION ERROR OF BIGEYE TUNA IN THE CORAL SEA AS DETERMINED BY ARCHIVAL TAGS — PRELIMINARY RESULTS

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Archival tags were in an attempt to determine whether bigeye tuna are year-round residents in the Coral Sea or whether they return to the areas of aggregation in an annual migration. Ten tags were recaptured after times at liberty ranging from 46 to 874 days. Six of these tags yielded data allowing position estimates for all or a portion of the days at liberty. The geolocation estimates were analyzed using a state-space Kalman filter model to estimate movement parameters, *in situ* geolocation errors, and probable tracks. Only one of these tagged fish appeared to make a substantial eastward movement. All others were recaptured near their points of release. All fish appeared to make synchronous north-south movements. The possible role of geolocation bias in producing these apparent north-south movements cannot be dismissed.

SURVIVORSHIP AND BEHAVIOR OF SEA TURTLES POST-RELEASE FROM LONGLINE FISHING GEAR

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Our research aims to determine survivorship and behaviors (horizontal and vertical movements) of sea turtles caught and released from commercial longline fishing gear. To achieve our goals, we have trained various sea-going personnel to deploy pop-up satellite archival tags (PSATs) on incidentally-caught turtles. The primary advantage of using PSATs as opposed to conventional tags is the tag's ability to receive tracking data even in the event of a mortality. Specifically, the tag will detach under certain conditions that would suggest a dead turtle (e.g. tag reaches 1,200 m depth), thereby allowing for the distinction between a dead turtle and a shed tag. Raw light-based geolocation data are processed using a state-space Kalman filter model, which provides a better estimate for a turtles' most probable horizontal movements.

Since March 2001, PSATs have been taken to sea on ca. 270 longline fishing trips, resulting in ca. 3,120 observed longline sets in the Hawaii fishery. Due to current fishing regulations specifically designed to minimize turtle-longline interactions, however, opportunities to tag turtles have been few. One PSAT remained on an olive ridley (*Lepidochelys olivacea*) for 4.5 months and provided excellent data on horizontal and vertical movements. The turtle spent more than 60% of its daytime depth within the top 50 m, and remained slightly deeper at night. In general, the turtle did not exceed depths of 250 m, except on a few rare occasions. No correlations were found between turtle movements and temperature and chlorophyll fronts. However, data suggest that the turtle's horizontal movements were correlated with the North Equatorial current. No mortality was indicated at the time of tag release

We have also trained sea-going personnel to attach PSATs in California's longline fishery as well as in Costa Rica, where sea turtle bycatch is high. During Fall 2002 and Winter 2003, four hard-shelled turtles incidentally caught in longline gear from California vessels were tagged with a PSAT, each set to release in October 2003. In Costa Rica, ten sea turtles (nine olive ridleys, one green turtle) have been tagged with PSATs, seven of which were caught in longline gear and three captured while free-swimming. These later individuals served as controls to which the behaviors of longline-captured turtles could be compared. To date, 11 tags have reported data, which range in duration from six to nine weeks, considerably shorter than expected. From the vertical movement data obtained so far, there have been no apparent mortalities. In preliminary analysis of dive depth data for both turtle groups, it appears that free-swimming turtles made deeper dives than longline-caught turtles.

THE TRANS-PACIFIC MIGRATION OF YOUNG BLUEFIN TUNA IN THE PACIFIC OCEAN RECORDED BY ARCHIVAL TAGS.

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Pacific bluefin tuna (PBT) is the highly migratory species, and mainly distributed in the temperate zone in the northern hemisphere. The life history and migration of PBT have been estimated by conventional tag-recapture data and fishery catch data, and it is known that some of them conducts a trans-Pacific migration from coastal water of Japan to off North America at the age 0-1. However, information on migration is still fragmentary, because of sparse PBT catch in north central Pacific.

We have conducted a tagging project of the PBT since 1995 and have released dozens of tuna tagged with archival tag every year. So far about 340 fish were released around Japan with archival tags in their body cavities, about 90 fish with tags were recovered, and five of them conducted the trans-Pacific migration. Though the season of the crossing migration varied, there are some similarities in migration pattern of them. And the migration route seemed to be influenced by the oceanographic condition such as water temperature.

PRELIMINARY ANALYSIS OF POTENTIAL HABITAT DISTRIBUTIONS OF SOUTHERN BLUEFIN TUNA AND FISHING VESSEL

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In this short paper, we report results of preliminary analysis of potential habitat distribution for both Southern Bluefin Tuna (SBT), *Thunnus maccoyii*, and fishing vessel, focusing on sea temperature as an oceanographic factor. We applied the concept of Habitat Suitability Index (HSI) model to generate a seascape map that represented habitat potential (in relative values) for SBT, utilizing the archival tag data (ambient water temperature and depth) and sea temperature database. We also applied HSI model, similar to SBT case, and generated a potential map of fishermen's "habitat", based on sea surface temperature data obtained from the Real Time Monitoring Program, RTMP.

Regions that have high habitat potentials distribute along the longitudinal direction for both SBT and fishing vessel. Latitudinal width of the regions is broader for fish than for fishing vessel. High habitat potential regions for fishermen overlap with regions that have relatively low habitat potential for SBT. Application of the result to longline fishery that targets larger fish is limited because habitat potential indices were mainly determined from information of juvenile fish due to data availability. Thus, archival tag data for adult SBT are needed and tag recovery is strongly expected. For future research, other oceanographic factors will be included in the model.

DROP NET SUBSURFACE APPLICATIONS

Kent Thomas
Ocean Friendly Co., Inc.
P.O. Box 609
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Ocean Friendly Co.'s drop net is being sought out to assist NOAA's research vessels in sampling micronecton ------ (from SBIR proposal)

Utilizing a solid _------- for mounting a light and camera, the drop net is now suitable for subsurface applications including remote sampling at depth.

Other attributes include:

- Live fish capture, all non targeted and undersize (by-catch) released uninjured back to the open ocean.
- The drop net can be utilized for live fish holding pens and grow out pens
- Uncomplicated, simplistic operation
- Low cost
- Easy adaptability to all existing commercial fishing vessels
- Netting mesh size can be changed on board vessel in approximately 30 minutes
- Drop net can be manufactured in third world countries or developed countries
- Fishing crews can be trained in a short time

A poster presentation will show Ocean Friendly Co.'s drop net as a working prototype model for NOAA's deep ocean water column -----

PATTERNS OF GENETIC VARIATION OF NORTHERN BLUEFIN AND ALBACORE TUNA IN THE MEDITERRANEAN: HISTORICAL DEMOGRAPHY OR THE EFFECTS OF FISHING PRESSURE?

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Atlantic bluefin and albacore tuna have been extensively fished since ancient times in the Mediterranean. Currently, these two species are considered to be over exploited in this region as well in the North Atlantic. One documented effect of overfishing in other fish species is the loss of genetic variation. The northern Atlantic bluefin tuna presents lower levels of genetic variation compared to other scombroid fishes. The mitochondrial control region of bluefin tuna is characterized by a star phylogeny and a unimodal mismatch distribution, both indicative of population expansion after a late Pleistocene bottleneck. This outcome is not concordant with the expected loss resulting from overfishing. With regard to albacore tuna, its control region phylogeny depicts two sets of lineages separated by relatively shallow levels of differentiation. This pattern was probably modeled by the stochastic extinction of intermediate lineages concordant with the demographic factors that model large stable populations over long period of time, as opposed to have resulted from overfishing. Although the high levels haplotypic diversity in these two tuna species could also be accounted by a particularly fast pace of molecular evolution in mtDNA, this hypothesis can be rejected for reasons discussed here. While our results point out that the genetic variability has not been seriously affected by fisheries, efforts to minimize the potential reduction of genetic variation due to overexploitation have to be placed in the forefront.

ANALYSIS OF BLUE MARLIN (*MAKAIRA MAZARA*) CATCH RATES IN THE HAWAII-BASED LONGLINE FISHERY BY APPLICATION OF A GENERALIZED ADDITIVE MODEL, WITH COMPARISONS TO OFFICIAL FISHERY STATISTICS

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The Hawaii-based longline fishery takes at least five istiophorid billfishes (striped marlin, *Tetrapturus audax*, shortbill spearfish, *T. angustirostris*, blue marlin, *Makaira mazara*, black marlin, *M. indica*, and sailfish, *Istiophorus platypterus*), often as incidental catch in tuna-targeted fishing or in mixed species assemblages targeted en masse. These species comprise a substantial fraction (ca. 5%, numerical basis) of the total catch of this fishery, are of moderate commercial value, and are ecologically important predators. Blue marlin is also highly prized in the charter boat recreational fishery in Hawaii. As such, these species are of general interest, but the first four of these species also represent a major monitoring challenge for the Fishery Monitoring and Performance Investigation (FMEP) of the Honolulu Laboratory (HL) of the National Marine Fisheries Service (NMFS) because misidentifications are known to occur to an as yet undetermined extent in the daily longline logbook reports that must be submitted upon landing fish for sale in Honolulu. These inaccuracies, in turn, affect the official fishery statistics obtained by compilation of the logbook reports.

This objective of this research was to present corrected catch rates for blue marlin in the Hawaii-based longline fishery during the 100-month period from March 1994 through June 2002, which necessarily entailed examination of the catch reports for the other species as well. The objective was met by developing a generalized additive model (GAM) of blue marlin catch rates from environmental and operational data gathered by fishery observers, which demonstrated that the principal extrinsic factors affecting catch rates were the season, geographic position, sea surface temperature, and gear configuration and deployment, and then applying the model coefficients fishery-wide to the logbook reports from unobserved trips to serve as a Asurrogate observer@. Analytical results, which included patterns of misidentifications within particular sectors of the fishery and other biases, were then verified by comparison to sales records from the public fish auction that serves as the principal outlet for the landings of this fleet. The availability of this independent data source to verify analytical results, and the fact that this fleet when in port lies clustered so as to permit daily monitoring of vessel movements and thereby ensure a high rate of logbook compliance, mean that the HL is in highly favorable circumstances to investigate the accuracy and other statistical properties of logbook data. As such, this paper should be of general interest to scientists and managers who are involved in fishery monitoring and concerned with fundamental aspects such as collection of accurate and comprehensible data.

POP-UP ARCHIVAL TAGGING OF BLUEFIN TUNA (*THUNNUS THYNNUS*) IN THE NORTHWESTERN ATLANTIC OCEAN: MOVEMENTS AND ENVIRONMENTAL PREFERENCES

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During the late summer/ autumn of 2002, 67 pop-up archival tags (Microwave Telemetry, Inc.) were implanted into spawning size bluefin tuna (90-360 kg) in the northwestern Atlantic Ocean (66 in the southern Gulf of Maine and one off Nova Scotia). Most of these were deployed from a purse-seine fishing vessel (n = 64), while three were deployed from rod and reel boats. We report here on a preliminary analysis of data received from tags that were prematurely released (n = 41), with attachment durations ranging from 6 to 190 days. We used the Kalman filter (Sibert *et al.*) to obtain geolocation estimates from data returned by the tags. Bluefin tuna displayed anisotropic dispersal from the Gulf of Maine, with directional bias toward the southwest (Carolina shelf), northeast (Canadian shelf) and east (offshore). Our analysis focuses on an examination of both horizontal and vertical movements (including dusk/dawn diving behavior and the effects of moon phase on vertical patterns). We also examine school fidelity and present utilization distributions comprising 50 and 95% of the geolocation data. Our environmental analysis, currently in progress, includes a spatial analysis of movements in relation to a number of GIS data layers: bathymetry, sea floor slope, distance from coast, sea surface temperature, distance from sea surface temperature fronts and primary productivity. The extensive amount of fishery-independent information obtained from this assemblage will help address critical gaps in knowledge on bluefin tuna overwintering behavior.

AN EXAMINATION OF MANTA RAY BYCATCH IN THE EASTERN TROPICAL PACIFIC, TUNA PURSE SEINE FLEET (Poster)

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A number of elasmobranch populations around the globe are declining due to interactions with fisheries as well as other environmental factors. One specific group that is at risk is the manta rays. These rays have only one young every one to two years and as a result can likely sustain little harvest. Manta rays (both the smaller *Mobulids* and the larger *Manta*) are both targeted and taken incidentally in a number of fisheries around the globe including the Eastern Tropical Pacific tuna purse seine fleet. Using the bycatch database from the IATTC observer program, we examined the patterns of take of mantas by the tuna purse seine fleet dating back to 1993. Results indicate that approximately 2000 mantas are taken each year. Most often, the rays are captured in nets set on tuna schools or marine mammals such as dolphins and whales. There appears to be an association between catch rates and regional productivity. Highly productive coastal regions, the Costa Rica Dome and the Galapagos Plume have relatively high catch rates. Other areas were large numbers of mantas are caught include areas around the Baja Peninsula and Sea of Cortez and occasionally locations far offshore away from any important oceanographic feature.

One challenge in interpreting the existing data is that while there are at least 5 species (*Mobula japanica, M. thurstoni, M. munkiana, M. tarapacana,* and *Manta birostris)* that are caught in the ETP region, the current observer program groups all species together and only separates them by size. To improve the value of the data collected, additional efforts are underway to develop a simple key stating more specific characteristics for the 5 species. The species identification will then help to improve our ability to identify patterns in abundance and examine the potential impact of the take in this fishery and others around the world.

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