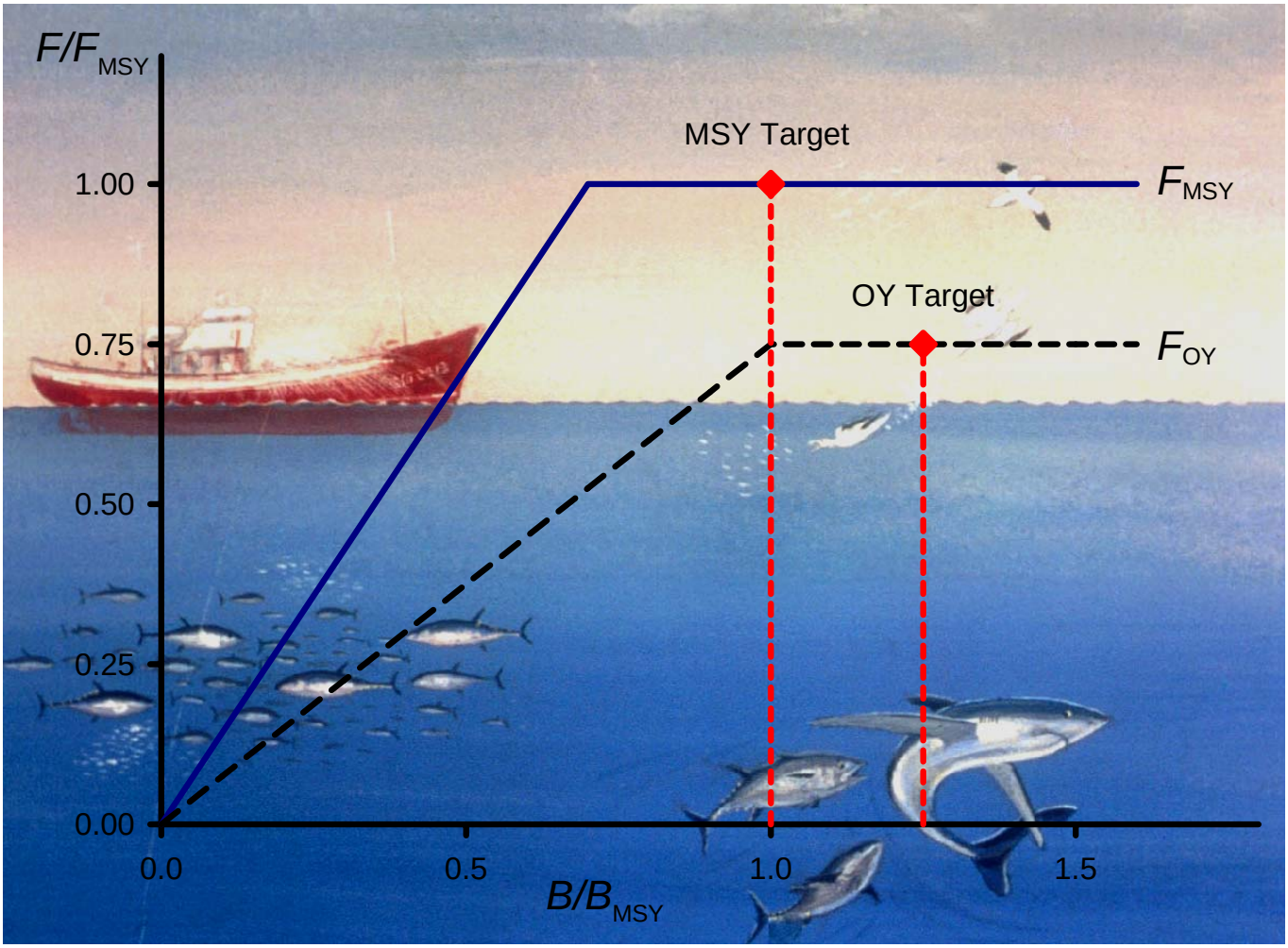
Proceedings of the 55th Annual Tuna Conference
Lake Arrowhead, California, May 24-27, 2004

Characterizing Productivity Of Highly Migratory Fish Populations In The Context Of Providing 'Good' Management Advice



Paul Crone and Kevin Hill, Co-chairs

Sponsored by the Inter-American Tropical Tuna Commission, Pacific Islands Fisheries Science Center, and Southwest Fisheries Science Center

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NOAA Fisheries
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
San Diego, CA 92037

PREFACE

Welcome to the *55th Tuna Conference*, which is sponsored jointly by the Inter-American Tropical Tuna Commission, Pacific Islands Fisheries Science Center, and Southwest Fisheries Science Center. This Conference reflects a long history of professional exchange between international researchers involved in a broad range of fields supporting 'tuna' science, from data collection in the field to evaluations in the laboratory to analysis in the office. The Conference continues to attract scientists from all over the world, which in effect, provides a unique forum for discussing marine-based research on a global scale. Traditionally, the Conference has focused on species of tuna; however, over the years, the development of ecosystem-based approaches in understanding and managing the expansive oceans has given rise to an increasing number of presentations regarding other highly migratory species and related ecology.

When brainstorming potential topics to consider for this year's Conference theme we kept coming back to arguably the most critical area of marine fishery science that still is only (at best) generally understood and possibly, (at worst) lacking tenable assumptions and theories. That is, the 'resiliency' of marine fish stocks within their respective ecosystems to both 'natural' (e.g., environmental conditions) and 'artificial' (e.g., fishing practices) influences. This qualitative 'resiliency' is commonly referred to and often quantified in terms of productivity and thus, we present this year's theme, "*Characterizing productivity of highly migratory fish populations in the context of providing 'good' management advice*." Over the next decade, fishery management bodies, as well as the public at large, will very likely need (and request) scientific guidance concerning development of marine resource management plans that directly or indirectly relate to this research topic.

The abstracts contained in these Proceedings received solely formatting-related revisions. All abstracts appear in alphabetical order by the first author's surname. If readers would like further information about these talks or wish to cite any information or ideas contained in the Proceedings, they should contact the author(s) for the appropriate citation.

Many individuals assisted in our overall effort as 'host' of this year's Tuna Conference. First and foremost, we would like to thank Suzy Kohin and Anne Allen for work 'over and above' their typical job assignments. We also thank the past Chair, Shelton Harley, for valuable tips regarding how best to handle various issues associated with planning an event of this size. Thanks are also in order to: Rand Rasmussen for maintaining our ongoing web site; Michelle Delafuente for assistance with the Conference data base and related backstopping; Don Petersen, Dave Itano, and Kim Holland for 'logistical' support associated with our sushi/sashimi night and tuna barbeque; Al Coan, Jim Kinane, Russ Vetter, and Ed Everett for 'chauffeuring' duties to and from the Southwest Fisheries Science Center; and Dan Margulies and Kevin Piner for serving as members of the Scholarship Committee. Finally, kudos are extended to this year's session moderators (truly, a thankless job)—Bill Bayliff, Kim Holland, Pierre Kleiber, Suzy Kohin, John O'Sullivan, Kevin Piner, and Jenny Suter.

Five student scholarships were awarded this year, including the *Caboz Memorial Scholarship* that was awarded to Andrij Horodysky and four *Tuna Conference Student Scholarships* that were awarded to Juan Pedro Arias Aréchiga, François Royer, Chugey Sepulveda, and Rebecca Shuford. Congratulations Andrij, Juan Pedro, François, Chugey, and Rebecca; the Tuna Conference is pleased to support each of you and your respective research interests and hope you find the Conference a valuable experience.

We gratefully acknowledge donations by the Federation of Japan Tuna Fisheries Cooperative Association, Lotek Wireless Inc., Monterey Bay Aquarium, Prime Time Seafoods, US Tuna Foundation, and Wildlife Computers Inc.—collectively, these 'parties' made possible our 'parties.' We do hope you are able to obtain useful information from the presentations, poster sessions, and discussions you will be involved in over the next few days and most importantly, have fun and enjoy yourselves!

Paul Crone and Kevin Hill, Co-chairs

AGENDA

Monday, 24 May 2004

13:00 Registration Opens in the Library

SESSION 1: Movement/Tagging and Stock Structure I (Moderator: Pierre Kleiber)

14:00 Welcome and Introduction

14:10 SEASONAL MOVEMENTS OF ATLANTIC BLUEFIN TUNA REVEALED WITH ELECTRONIC TAGS — Andre Boustany, Andreas Walli, Steven Teo, Kevin Weng, Tom Williams, Charles Farwell, Heidi Dewar, and Barbara Block

14:30 TRACKING OF PACIFIC BLUEFIN TUNA WITH ARCHIVAL TAGS—Charles Farwell, Andre Boustany, C. Perle, Tom Williams, Heidi Dewar, R. Schallert, A. Seitz, and Barbara Block

14:50 MOVEMENTS OF BIGEYE TUNA OFF THE EAST COAST OF AUSTRALIA—John Sibert, John Gunn, John Hampton, Naomi Clear, Karen Evans, and Anders Nielsen

15:10 MOVEMENT, BEHAVIOR, AND HABITAT OF JUVENILE WHITE SHARKS IN THE EASTERN PACIFIC AS REVEALED BY SATELLITE TAGGING—Kevin Weng, John O'Sullivan, Chris Lowe, and Barbara Block

15:30 Coffee Break

15:50 MOVEMENTS AND ENVIRONMENTAL PREFERENCES OF BLUE MARLIN (*Makaira mazara*) IN THE NORTHWESTERN PACIFIC OCEAN OBTAINED FROM PAT TAGS—Hirokazu Saito and Kotaro Yokawa

16:10 A MODELLING FRAMEWORK FOR STUDYING BLUEFIN TUNA BEHAVIOUR IN ITS ENVIRONMENT—François Royer, Philippe Gaspar, and Jean-Marc Fromentin

16:30 THE ANALYSIS OF ARCHIVAL TAG DATA (EASTERN PACIFIC BLUEFIN TUNA) WITH AN ALGORITHM THAT AUTOMATICALLY RESOLVES LATITUDE THROUGH THE USE OF SEA SURFACE TEMPERATURE—Michael Domeier, Dale Kiefer, Nicole Nasby, Adam Wagschal, and Frank O'Brien

16:50 TRIALS TOWARD OBJECTIVE ADJUSTMENT OF ARCHIVAL TAG GEO-LOCATION ESTIMATES—Sachiko Tsuji, Norio Takahashi, Kyohei Segawa, Seiichi Hara, and Kei Omura

17:10 Registration and Conference Center Check-in Continued

17:30 'Welcome Gathering Party' in the Tavern (Continued After Dinner)

18:30 Dinner
Socializing in the Tavern

Tuesday, 25 May 2004

8:00 Breakfast

SESSION 2: Movement/Tagging and Stock Structure II (Moderator: Kevin Piner)

9:00 SURVIVAL AND HABITAT PREFERENCES OF WHITE MARLIN (*Tetrapturus albidus*) RELEASED FROM THE WESTERN NORTH ATLANTIC RECREATIONAL FISHERY — Andrij Z. Horodysky

9:20 TAGGING OF PACIFIC PELAGICS: IDENTIFYING HOT SPOTS IN THE EASTERN NORTH PACIFIC—Heidi Dewar, Barbara Block, Dan Costa, Stephen Bograd, and Randy Kochevar

9:40 TESTING FOR POPULATION STRUCTURE IN STRIPED MARLIN, *Tetrapturus audax*, USING MITOCHONDRIAL AND NUCLEAR MARKERS—Catherine Purcell and Suzanne Edmands

10:00 NORTH PACIFIC ALBACORE TAGGING PROJECT: UPDATE AND PRELIMINARY ANALYSIS OF THE FIRST TAG RETURNED—John Childers, Suzy Kohin, Paul Crone, and John LaGrange

10:20 Coffee Break

10:40 MIGRATION ROUTE AND DIEL SWIMMING BEHAVIOR IN THE SPAWNING AREAS OF THE PACIFIC BLUEFIN TUNA AROUND THE RYUKYU ISLANDS, JAPAN, USING POP-UP SATELLITE TAGGING AND ULTRASONIC TELEMETRY—Kazunari Yano, Harumi Yamada, Takeharu Kosuge, Mio Takahashi, and Nobuaki Suzuki

11:00 GENETIC POPULATION STRUCTURE OF NORTH ATLANTIC BLUEFIN TUNA—Jens Carlsson, Jan McDowell, and John Graves

11:20 OTOLITH MICROCHEMICAL ANALYSIS OF JUVENILE YELLOWFIN TUNA FROM NURSERY AREAS IN THE ATLANTIC OCEAN—Rebecca Shuford, J. Dean, B. Stequert, E. Morize, M. Labonne, and Y. Pedron

11:40 DISTRIBUTION OF BILLFISH LARVAE AND EGGS OFF THE KONA COAST OF THE ISLAND OF HAWAII—Robert Humphreys, Jr., John Hyde, Eric Lynn, Michael Musyl, Russ Vetter, and Andrew West

12:00 Lunch

SESSION 3: Biological Studies
(Moderator: Kim Holland)

13:10 AGE, GROWTH, AND MATURITY OF BIGEYE TUNA (*Thunnus obesus*) IN THE AUSTRALIAN REGION—Jessica Farley, Naomi Clear, Bruno Leroy, Tim Davis, and Geoff McPherson

13:30 AN OVERVIEW OF ATLANTIC BIGEYE TUNA (*Thunnus obesus*) GROWTH STUDIES AND IMPLICATIONS FOR AGE-STRUCTURED STOCK ASSESSMENT—Craig Brown

13:50 REVIEW OF 2003-2004 ACTIVITIES AT THE IATTC'S ACHOTINES LABORATORY—Vernon Scholey, Dan Margulies, Jeanne Wexler, and Sharon Hunt

14:10 NATURAL AND EXPERIMENTAL DIET SHIFTS IN YELLOWFIN TUNA AS TRACKED BY STABLE ISOTOPE ANALYSES—Brittany Graham, Dean Grubbs, Kim Holland, Dave Itano, Brian Fry, Valérie Allain, Robert Olson, Felipe Galván-MagaZa, and Brian Popp

14:30 Coffee Break

14:50 THE THERMAL BIOLOGY OF THE SLENDER TUNA, *Allothunnus fallai*— Chugey Sepulveda and Jeffrey Graham

15:10 CHEMORECEPTION IN SEA TURTLES: IMPLICATIONS FOR LONGLINE FISHERIES INTERACTIONS—Amanda Southwood, Ben Higgins, Richard Brill, and Yonat Swimmer

15:30 AGE AND GROWTH OF BROADBILL SWORDFISH, *Xiphias gladius*, FROM AUSTRALIAN WATERS—Jock Young, Anita Drake, and Melissa Langridge

15:50 STATUS OF RESEARCH ON THE BIOLOGY AND ECOLOGY OF OPAH (*Lampris guttatus*) AND MONCHONG (*Taractichthys steindachneri*) IN THE NORTH PACIFIC—Donald Hawn, Michael Seki, and Robert Nishimoto

16:30 Poster Session (See List of Posters) and 'Sushi Party' in Lakeview

18:30 Dinner
Socializing in the Tavern

Wednesday, 26 May 2004

8:00 Breakfast

SESSION 4: Fisheries Oceanography (Moderator: Jenny Suter)

9:00 EFFECTS OF EL NIΨO DURING 1990-1999 ON THE MEXICAN YELLOWFIN TUNA (*Thunnus albacares*) PURSE-SEINE FISHERY AT THE ENTRANCE TO THE GULF OF CALIFORNIA—Arturo Muhlia-Melo, Ernesto Torres-Orozco, Armando TrasviZa, and Sofía Ortega-García

9:20 OCEANOGRAPHIC ATLAS OF THE PACIFIC: AN ACCESSIBLE INTERFACE TO MARINE ENVIRONMENTAL DATA—Russell Moffitt, Russell Brainard, Ronald Hoeke, Alan Strong, William Skirving, John Sibert, and David Foley

9:40 MONITORING PELAGICS WITHIN A NETWORK OF ANCHORED FADS—David Itano, Kim Holland, Laurent Dagorn, and Dean Grubbs

10:00 FISHING OCEANOGRAPHY OF THE GULF OF TEHUANTEPEC: THE CASE OF THE YELLOW-FIN TUNA (*Thunnus albacares*)—Juan Pedro Arias Aréchiga, Sofía Ortega-García, and Armando TrasviZa-Castro

10:20 Coffee Break

SESSION 5: Productivity and Uncertainty Analysis (Moderator: Suzy Kohin)

10:40 COMPARING PRODUCTIVITY IN PELAGIC SHARKS—Susan Smith, David Au, and Christina Show

11:00 ESTIMATING A LOCAL MSY FOR THE COMMON THRESHER SHARK—Dave Au and Christina Show*

11:20 A GENERAL MODEL FOR PROTECTED SPECIES: INFORMATION AND UNCERTAINTY—Mark Maunder and Simon Hoyle

11:40 UNCERTAINTY IN SPAWNER-RECRUITMENT DYNAMICS AND REFERENCE POINTS AND ITS IMPACT ON THE MANAGEMENT OF TROPICAL TUNAS—Shelton Harley, Simon Hoyle, and Mark Maunder

12:00 Lunch

SESSION 6: Fisheries—Operations and Data
(Moderator: Bill Bayliff)

13:10 A SYSTEMS APPROACH TO SUSTAINABLE OFFSHORE TUNA AQUACULTURE IN SOUTHERN CALIFORNIA—Orlando Amoroso, Paula Sylvia, and Paul Olin

13:30 DISTRIBUTION OF FRESH TUNA IN THE U.S. MARKET—Rex Ito

13:50 BLUE MARLIN (*Makaira nigricans*) RECREATIONAL FISHERY AT CABO SAN LUCAS B.C.S., MEXICO—Sofía Ortega-García, Alexander Klett-Traulsen, and Rubén Rodríguez-Sánchez

14:10 REDUCING BYCATCH FROM PURSE-SEINE FLOATING OBJECT SETS—Peter Nelson and Martin Hall

14:30 TUNA CATCHES IN THE EPO: COMPARING ESTIMATES FROM VESSEL LOGBOOKS, OBSERVER DATA, UNLOADING RECORDS, AND LENGTH FREQUENCY DATA—Jenny Suter and Shelton Harley

14:50 Coffee Break

15:10 RECENT PROGRESS IN STUDIES OF LOGBOOK DATA QUALITY FOR BILLFISHES IN THE HAWAII-BASED LONGLINE FISHERY—William Walsh

15:30 ANALYSIS OF SPORTFISHING CATCH RATES OF DOLPHIN FISH (*Coryphaena hippurus*) AT CABO SAN LUCAS, BAJA CALIFORNIA SUR, MEXICO—Marcela ZúZiga Flores, Sofía Ortega-García, and Alexander Klett Traulsen

15:50 OUTLINE OF JAPANESE TROLL FISHERY FOR PACIFIC BLUEFIN TUNA AND ABUNDANCE INDICES OF AGE-0 TUNA DERIVED FROM THE FISHERY—Harumi Yamada, Nobuo Takagi, and Daisuke Nishimura

16:10 ESTIMATION OF SPECIES- AND TRIP-SPECIFIC CATCHABILITY IN HAWAII LONGLINE FISHERIES: A MULTI-SPECIES APPROACH—Hui Huang and Pingsun Leung

16:30 CHANGES IN PELAGIC FISH COMMUNITIES WHEN LONGLINE FISHING COMMENCED IN THE TROPICAL PACIFIC OCEAN—Peter Ward and Ransom Myers

16:50 Business Meeting

18:30 Dinner – Tuna Barbeque
Socializing in the Tavern

Thursday, 27 May 2004

8:00 Breakfast

SESSION 7: Population and Ecosystem Modeling (Moderator: John O'Sullivan)

9:00 TROPHIC STRUCTURE AND TUNA MOVEMENT IN THE COLD TONGUE – WARM POOL PELAGIC ECOSYSTEM OF THE EQUATORIAL PACIFIC—Valérie Allain, Brittany Graham, Robert Olson, Brian Popp, Felipe Galván-MagaZa, and Brian Fry

9:20 APECOSM: A SPATIALIZED "Apex Predators ECOsystem Model" TO STUDY PHYSIOLOGICALLY STRUCTURED TUNA POPULATION DYNAMICS IN AN ECOSYSTEM CONTEXT—Olivier Maury

9:40 INTEGRATED POPULATION MODELING FOR THE NORTHEASTERN OFFSHORE SPOTTED DOLPHIN (*Stenella attenuata*)—Simon Hoyle and Mark Maunder

10:00 PELAGIC ECOSYSTEM OBSERVING SYSTEMS: UPDATE ON "SMART FAD," FADIO, AND HULA PROGRAMS—Kim Holland, Laurent Dagorn, Carl Meyer, Tim Clarke, and Yannis Papastamatio

10:20 Coffee Break

10:40 MULTIFAN-CL APPLICATIONS TO PACIFIC BLUEFIN TUNA—Yukio Takeuchi and Mio Takahashi

11:00 BY YOUR FOOD AND YOUR ENEMIES: SIMPLIFYING FOOD WEBS USING SOCIAL NETWORK THEORY—Jeffrey Dambacher, Klaas Hartmann, Alistair Hobday, and Cathy Bulman

11:20 MINIMAL MODELS FOR CENTRAL PACIFIC FOOD WEBS—Isaac Kaplan and James Kitchell

12:00 Lunch

13:00 End of Conference

LIST OF POSTERS

SPATIAL GENETIC DIFFERENTIATION OF EASTERN PACIFIC YELLOWFIN TUNA (*Thunnus albacares)*, BASED ON THE VARIATION OF SEVEN MICROSATELLITE LOCI—Píndaro Díaz-Jaimes, M. Uribe-Alcocer, and John Graves

PALMYRA REVISITED: USING A GENERALIZED ADDITIVE MODEL TO PREDICT BIGEYE CPUE AT THE PALMYRA FISHING GROUNDS—Evan Howell, Donald Kobayashi, and Jeffrey Polovina

FISHER INFORMATION AS AN INDICATOR OF REGIME CHANGE IN MARINE ECOLOGICAL SYSTEMS—David Kirby, Valérie Allain, Patrick Lehodey, and John Hampton

HIGHLY MIGRATORY FISH IN SOUTHWEST ROCK ART—Wesley Marx

ECOLOGICAL PATTERNS IN FLOTSAM-ASSOCIATED FISH ASSEMBLAGES FROM THE EASTERN PACIFIC—Peter Nelson, Enric Sala, and Martin Hall

A NEW ENVIRONMENTAL INFORMATION SYSTEM FOR TRACKING TAGGED MARINE ORGANISMS—Frank O'Brien, Michael Domeier, and Dale Kiefer (computer demonstration to accompany poster)

ULTRASONIC TAGGING OF PELAGIC FISHES AT SEAMOUNTS IN THE SOUTHERN GULF OF CALIFORNIA: AN INTEGRATIVE APPROACH—John Richert, Salvador Jorgensen, A. Peter Klimley, and Arturo Muhlia-Melo

ASSOCIATION BETWEEN BLUEFIN TUNA SCHOOLS AND OCEANIC FEATURES IN THE GULF OF LIONS—François Royer, Jean-Marc Fromentin, and Philippe Gaspar

AN OCEANOGRAPHIC CHARACTERIZATION OF THE LONGLINE FISHING GROUNDS FOR ALBACORE, *Thunnus alalunga*, AROUND AMERICAN SAMOA—Michael Seki, Jeffrey Polovina, Daniel Curran, Donald Hawn, and Evan Howell

TUNA ARTWORK AND MARINE BIOLOGICAL ILLUSTRATIONS— Kate Spencer

STUDIES ON SURVIVORSHIP OF SEA TURTLES POST-RELEASE FROM LONGLINE FISHING GEAR—Yonat Swimmer, Michael Musyl, Lianne Mailloux, Randall Arauz, Richard Brill, Gilberto Sales, and Christofer Boggs*

NEW NON-TOWED DROPNET SYSTEM FOR SCIENTIFIC RESEARCH & COMMERCIAL FISHING—Kent Thomas

Paper Abstracts

(Alphabetical by first author's surname)

TROPHIC STRUCTURE AND TUNA MOVEMENT IN THE COLD TONGUE – WARM POOL PELAGIC ECOSYSTEM OF THE EQUATORIAL PACIFIC

Allain, Valérie[1], Graham, B.[2], Olson, R.[3], Popp, B.[4], Galván-Magaña, F.[5], and Fry, B.[6]

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An upwelling-induced "cold tongue" of water with high levels of primary production characterizes the equatorial eastern Pacific Ocean, while the equatorial western Pacific has warmer surface waters ("warm pool") with lower levels of primary production. A larger proportion of the tuna catch in the Pacific originates from the warm pool, despite greater primary production in the cold tongue. We are combining diet and stable isotopic analyses with food web modeling to investigate the relationships between tuna ecology and primary productivity in the cold tongue–warm pool system. The main objectives of the study are: 1) to define the trophic structure of the pelagic ecosystems in the western, central and eastern parts of the tropical Pacific Ocean, 2) to establish an isotope-derived (upwelling-related) biogeography of the equatorial Pacific ecosystems, and 3) to characterize large-scale tuna movements related to upwelling regions along the equator.

To define the trophic structure, stomach content analysis is conducted in conjunction with stable-isotope analysis to assess trophic position of the different functional groups ($\delta\ ^{15}N$) and to trace how different sources of primary production, related to upwelling and other environmental factors, are important in supporting these groups ($\delta\ ^{13}C$). We will use the biodynamic modeling tool, *Ecopath with Ecosim* (*EwE*), to represent the trophic flows between the ecosystem components. The *EwE Ecotracer* routine should allow following isotopes through the food web; and trophic levels determined from isotopes could be used to constrain the diet compositions in the model. To establish an isotope-derived biogeography, an extensive sampling program has been implemented to collect specimens from as many functional groups as possible, from plankton to top predators. Through this isotope cartography, we are characterizing the food webs in the contrasting production regimes of the western, central and eastern Pacific. We are using $\delta\ ^{13}C$ values to identify different sources of primary production, especially rapid phytoplankton growth associated with upwelling. The combination of $\delta\ ^{15}N$ and $\delta\ ^{13}C$ of plankton, forage species and predators serve to map different regions of primary and secondary production. To characterize large-scale tuna movements, the previously established isotope biogeography will form the basis for identifying natural isotope tags. Isotope ratios will serve as internal chemical tags that are characteristic of areas where they are living. We will attempt to acquire a more refined view of tuna movements by comparing tissues and compounds that have different turnover rates.

Preliminary results of isotope data are presented for the first year of the three-year study. The study should help define the principal ecosystem linkages underlying tuna production and the effect of climate variability on the systems. This information is important for improving our understanding of fisheries production and ecosystem dynamics of the equatorial Pacific Ocean.

Study funded by the Pelagic Fisheries Research Program of the University of Hawaii, PFRP project #659559.

A SYSTEMS APPROACH TO SUSTAINABLE OFFSHORE TUNA AQUACULTURE IN SOUTHERN CALIFORNIA

Orlando Amoroso[1], Paula C. Sylvia[2], and Paul Olin[3]
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[2]Hubbs-SeaWorld Research Institute
[3]California Sea Grant Extension Program

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World production of farmed tuna surpassed 34,000 metric tons (MT) in 2003. Currently, northern and southern bluefin tuna are the primary species farmed (*Thunnus thynnus, T. thynnus orientalis* and *T. maccoyii*). However, bigeye tuna (*T. obesus*) and yellowfin tuna (*T. albacares*) have been farmed in Mexico and are now considered as alternative species for tuna farming, especially those in warmer water regions.

Offshore net-pen aquaculture of tuna can become an industry that will augment commercial tuna and other fisheries in a manner that is both economically and environmentally sustainable. A properly structured system of offshore tuna aquaculture would support and diversify commercial fishing fleets, contribute to onshore processing, handling and distribution infrastructure, and potentially add value to non-tuna commercial fisheries by expanding markets for their use in aquaculture diets. Fishing capacity in the local purse seine fishery could be reduced by actively engaging these boats in the business of aquaculture in at least three stages: the collection of juvenile wild tuna, the harvesting and transport of adult tuna from net-pens to markets, and the harvesting of locally abundant species for aquaculture feedstock. The successful realization of tuna aquaculture has the potential to be an economic driver in the region, at a time when many coastal fisheries are in decline and fishermen are exploring alternate harvesting opportunities. The success of this project could also contribute significantly to the Department of Commerce's goals of a five fold expansion in aquaculture production, reduction of the $8 billion annual seafood trade deficit, and the creation of over 400,000 new jobs in aquaculture by 2025.

This presentation provides an overview of tuna aquaculture around the world and outlines a research and outreach program to develop sustainable offshore tuna aquaculture in the Pacific United States. The effort is spearheaded by the Southern California Commercial Fishing Association (SCCFA), also known as the San Pedro Purse Seine Owners Association, and facilitated by Partnerships for Environmentally Sustainable Coastal Economies (PESCE), a not for profit organization committed to furthering collaboration between fishermen, scientists, and government regulatory agencies. The partners in the endeavor include members of the SCCFA, San Pedro fish processors, Hubbs-SeaWorld Research Institute (HSWRI), academics, resource managers and environmentalists working together to realize commercially viable and environmentally sustainable offshore aquaculture in California.

FISHING OCEANOGRAPHY OF THE GULF OF TEHUANTEPEC: THE CASE OF THE YELLOWFIN TUNA, *Thunnus albacares*

Juan Pedro Arias Aréchiga[1, 3], Sofía Ortega García[2, 4], and Armando Trasviña-Castro[2]
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One of the areas of traditional importance in the capture of yellowfin tuna is adjacent to the Gulf of Tehuantepec which, by its oceanographic characteristics and high productivity level has been qualified as a Biological Action Center. From October to March, cold winds from the Gulf of Mexico cross the Isthmus of Tehuantepec. These are instrumental in the formation of intense and dense saline thermal fronts. These oceanic fronts represent dynamic waves where fishing becomes highly efficient, making it possible to detect large concentrations of zooplankton which in turn attracts nekton for feeding purposes. Hence, the study of the generation and propagation of meso-scale eddies associated with events of upwelling and vertical mixing, allows one to forecast the abundance of fish under certain environmental conditions. The information used were logbooks records of the Mexican tuna fleet during 1996, coupled with oceanographic data provided by cruisers, which is contrasted with images from the satellite's sensor AVHRR. We are presenting a monthly distribution of sets over maps of sea surface temperature. Regarding seasonal variability, we have detected a larger catch per set during the second quarter in spite of the fleet's diminished activity in the area in relation to the first quarter. Upon analyzing *in situ* data on the isotherm depth of 20º for the month of February regarding the fleet's sets, one can detect a greater concentration of effort at a depth of between 30 and 60 meters. The majority of tuna catches take place close to the Oaxaca coastline and are closely related to the intrusion of warm water from the north, which is surrounded by the coastal upwellings and the anti-cyclonic eddy.

ESTIMATING A LOCAL MSY FOR THE COMMON THRESHER SHARK

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We estimate local MSY for the common thresher shark (*Alopias vulpinus*) off southern California by a non-traditional approach that circumvents the difficulties of estimating mortality on a long-lived slow-growing species and estimating sustainable production from catches reflecting unsustainable, non-equilibrium fishing and changing regulations. These are common problems in assessing low productivity species. The simple logistic production curve, utilizing estimates of the parameters B_0 (initial biomass) and r (intrinsic rate of population increase) was fitted to the 1981-1999 gillnet fishery's catch-CPUE relationship to estimate this shark's MSY. Intrinsic rate r was estimated from demographic parameters using a procedure we call intrinsic rebound potential. Parameter B_0 was prorated from B_t (biomass during 1992-1993 when the population was temporarily at equilibrium with natural production). This was estimated by dividing the catch of those years by the annual population growth rate then, based on the r of the population size at that time. Population size was based on CPUE, which was estimated as the annual weighted average catch (numbers of fish) per unit of net effort (length x hours soaked) in a time series since 1981 the inception of the fishery. Data from approximately 4000 sets per year were utilized. The resulting production curve applies to the portion of the stock accessed by U.S. fishers and does not include the unknown production from off Mexico. Thus MSY given by the curve (450 mt) is actually an estimate of local MSY (LMSY).

SEASONAL MOVEMENTS OF ATLANTIC BLUEFIN TUNA REVEALED WITH ELECTRONIC TAGS

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The Tag-A-Giant program (TAG) was initiated in 1996 to examine seasonal movements, habitat utilization and environmental preferences in Atlantic bluefin tuna. To date, 812 bluefin tuna have been tagged throughout the North Atlantic. The majority of these were deployed off the coast of North Carolina where 497 bluefin tuna have been tagged with surgically implanted archival tags and 215 have been tagged with pop-up satellite tags. Archival tags have provided records up to 3.8 years in length while pop-up tags have maximal records of 8.4 months. The PAT tags indicate high survivorship (>90%) of bluefin tuna tagged and released using both circle and J-hooks. The data from both tagging technologies are revealing migration corridors and areas of prolonged residency that, when coupled with information on the local oceanography, are providing insight into how bluefin tunas use the ocean environment. Both data sets show similar overall movement patterns although differences between tagging years and tag type are also evident. These differences appear to be due to age classes tagged, length of tag deployment and differences in oceanography between years. Tagged fish remain near the coast of North Carolina in the South Atlantic Bight in winter then move offshore and to the east or northeast in spring. Atlantic bluefin are distributed predominately in New England and Canadian waters in the summer months. A smaller number of electronically tagged Carolina bluefin move to the regions east of the Flemish Cap, the east Atlantic or Mediterranean Sea in spring and summer. Movement patterns, depth and ambient temperature preferences differ based on year classes. Mature fish tend to range more widely in the spring and summer than do adolescent fish. The new technology provide data that are vital for obtaining insights on how these fish use their oceanic habitat and are required for new approaches to fisheries management and conservation.

AN OVERVIEW OF ATLANTIC BIGEYE TUNA (*Thunnus obesus*) GROWTH STUDIES AND IMPLICATIONS FOR AGE-STRUCTURED STOCK ASSESSMENT

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Published studies on bigeye tuna growth in the Atlantic Ocean are compared with respect to methodology, geographic coverage, sample size, size range, and other relevant details (such as time-at-large for tagging studies). Differences between the studies are discussed, particularly as they pertain to determining applicability to Atlantic bigeye tuna stocks and assessments. The age-slicing technique used for the last (2002) ICCAT SCRS bigeye tuna stock assessment is explained; this was applied using various growth models to produce alternative catch-at-age matrices. The proportional changes between these matrices are examined. The results of this examination indicate that even moderate differences in the growth curves used to perform age-slicing produce dramatic differences in the catch-at-age matrices. The potential implications for age-structured stock assessment are considered.

GENETIC POPULATION STRUCTURE OF NORTH ATLANTIC BLUEFIN TUNA

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Global stocks of large predatory fishes, including the north Atlantic bluefin tuna, are declining. Adequate management of these species necessitates accurate data regarding the stock structure and migratory patterns of these animals. Historically, north Atlantic bluefin tuna have been managed as separate western and eastern Atlantic stocks, divided at 45ºW. The two-stock hypotheses is based on differences in long line catches, growth differences, timing of sexual maturity, and timing of spawning between the east and west Atlantic. However, the validity of the subdivision of bluefin tuna into two stocks has recently been challenged. Conventional and electronic tagging studies have revealed migration rates ranging from 2.2 to 4.3% between the west and the east Atlantic, respectively, suggesting the potential for extensive gene flow. While previous genetic work, using allozyme, microsatellite and single copy nuclear DNA markers suggests the possibility of population structure in bluefin tuna, other studies have shown no indication of stock structure. The discrepancies between studies can be attributed to insufficient sampling of cohorts and localities, as well as inadequate sample sizes and temporal replicates. In addition, the high migratory capacity of bluefin tuna makes it hard to be certain about the geographic origin of larger individuals.

The present study uses genetic markers to delineate the stock structure of north Atlantic bluefin tuna. Samples consisted of temporal collections of young of the year specimens from the Mediterranean Sea, the Gulf of Mexico and the United States Atlantic east coast as well as an extensive collection of aged bluefin tuna from the North Atlantic (south of Iceland). Collections were analyzed using data from 8 microsatellite DNA markers as well as sequencing of the mitochondrial control region. Preliminary analyses based on 300 Mediterranean individuals suggest that bluefin in the Mediterranean might be represented by more than one genetically discrete stock.

NORTH PACIFIC ALBACORE TAGGING PROJECT: UPDATE AND PRELIMINARY ANALYSIS OF THE FIRST TAG RETURNED

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A long-term archival tagging project was undertaken during the 2001 albacore fishing season in order to examine migration routes of juvenile North Pacific albacore (3- to 5-yr old fish) and to determine time, temperature, and depth utilization of the migrating fish. The project was structured as a five-year program that entails tagging approximately 120 fish in each of the years 2002-2005 for a total of 500 tags deployed by the end of 2005. Due to funding limitations, deployments fell short of the goals for the first 3 years, however, 159 tags have been deployed since 2001. All deployments were made in coastal waters off the Pacific coasts of southern California and northern Baja California during the months of July-November. The fish, ranging from 57-110 cm fork length, were captured near the surface on hand lines or with rod and reel. One archival tag has been recovered. The fish was at liberty for 12 weeks and utilized a relatively small area in the general vicinity of its release site. During the latter 8 weeks of the deployment period, the fish demonstrated a diurnal pattern of repetitive deep diving during the day while remaining near the surface at night. Dives routinely exceeded 150 m in depth. Successful feeding events were demonstrated by post-prandial metabolic and body temperature elevations as has been seen for other warm-bodied tunas. The return of the first tag has confirmed the successful achievement of one of the primary goals of the project, i.e. to develop field protocols for capturing, implanting tags, and releasing healthy, active juvenile albacore. Ultimately, as more tags are returned, the vertical and horizontal movement information obtained will be used to develop sound assumptions regarding stock structure, which are essential to improving overall population assessments. Tagging efforts are expected to continue through 2005.

BY YOUR FOOD AND YOUR ENEMIES:
SIMPLIFYING FOOD WEBS USING SOCIAL NETWORK THEORY

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The increasing popularity of compartment-flow models, such as Ecopath, is based in part on the practicality of converting stomach content and food-web data into a common currency of biomass pools and flows. Compartments are linked by trophic relationships with the goal of accounting for total biomass flow in the system. While the majority of models, especially those of marine ecosystems, represent myriad species, most have compartments numbering only in the tens. Thus, one of the first, and we argue, most important stages of model development is to aggregate species based on some measure of similarity. Typically, 'trophic similarity' is based on a comparison of diets, with some degree of restriction based on phylogeny, biology, and topical interests. While intuitively appealing, this approach can potentially lead to alternate models with contradictory behaviour. Recently, the notion of trophic similarity has been extended by a network approach pioneered by social scientists in the 1960's. Here it is important to know not only who you eat (or manage), but also who eats (or manages) you. Based upon a recursive graph/matrix algorithm, it is possible to provide a reduced-complexity view of a system that accounts for its entire set of interactions. We use this approach as a means of exploring the implications of community structure to the problem of model aggregation, and as a basis for comparing both qualitative (i.e. loop analysis) and quantitative models (*i.e.* Ecopath). We develop the notion of 'aggregation error' and present a refinement of the network algorithm that considers additional information within the aggregation process, such as population turnover rates or spatial structure. We believe food web simplification is a critical step in the development of model ecosystems, and by providing a more rigorous approach, we hope to better support frameworks for management decisions.

TAGGING OF PACIFIC PELAGICS: IDENTIFYING HOT SPOTS IN THE EASTERN NORTH PACIFIC

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Top pelagic predators such as tunas, sharks, turtles and marine mammals have historically been difficult to study due to their size, speed and range over the vast oceanic habitat. In recent years the development of small microprocessor-based data storage tags that are surgically implanted or satellite-linked provide marine researchers a novel avenue for examining the movements, physiology and behaviors of pelagic vertebrates. When biological and physical data from the tags are combined with complimentary information on regional oceanography, the relationship between the movements and behaviors of organisms can be linked to environment. The TOPP project is deploying electronic tags to examine the distribution and behavior of these pelagic organisms in relationship to the dynamic ocean environment of the North Pacific with to goal of deploying 4000 tags by 2010. Given the scope of the program it is being developed in phases. During phase I pilot projects, which have recently been completed, over 1,000 electronic tags were deployed on 18 species including, marine birds, fish, sharks, squid, pinnipeds and cetaceans. These projects tested tagging methods, tag technology and species. Phase II is currently being initiated and will build on the results of phase I to test three primary TOPP concepts 1) determination of pelagic hot spots and migratory corridors, 2) animals as ocean sensors and 3) use of electronic tagging data to for the conservation of leatherback sea turtles. We will describe the results from phase I and detail the plans for phase II.

THE ANALYSIS OF ARCHIVAL TAG DATA (EASTERN PACIFIC BLUEFIN TUNA) WITH AN ALGORITHM THAT AUTOMATICALLY RESOLVES LATITUDE THROUGH THE USE OF SEA SURFACE TEMPERATURE

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Archival and pop-up satellite tags used on marine animals provide data related to the timing of sunrise and sunset that are then used to estimate the geographic position of the animal for each day these data are available. Although light-based longitude estimates have proven to be fairly robust, similarly obtained latitude estimates are far less reliable. Matching sea surface temperature (SST) measurements between those sampled by the tag and those sampled from satellites has been identified as a means of refining latitude estimates. Using SST to help resolve latitude has been hindered by the difficulty in manually matching data. We have developed an algorithm that performs the task of SST matching automatically in a Windows environment. The program selects multiple candidate points for each day of SST data and then calculates the most efficient route that connects the data. The user has the ability to filter the data by entering the maximum velocity of the animal, the degree which the two temperatures must match, the time interval over which they must match, the area over which the program can search as well as other parameters. The resulting track and associated SST imagery is displayed in EASy, a Geographic Information System specifically designed for marine applications. The algorithm will be demonstrated using archival tag data from eastern Pacific bluefin tuna.

AGE, GROWTH AND MATURITY OF BIGEYE TUNA (*Thunnus obesus*) IN THE AUSTRALIAN REGION

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Little is known about the age and growth of bigeye tuna, yet it is one of the most valuable components of longline fisheries in the eastern and western Australian Fishing Zone (AFZ). Accurate age estimates form the basis of calculations of natural mortality, age-at-maturity and longevity; all vital inputs to population stock assessments models.

The annual age of bigeye tuna was estimated using transverse sections of sagittal otoliths. A strontium chloride mark-recapture experiment conducted in the Coral Sea showed that increment 2 to 9 visible in the otoliths were deposited annually. Unfortunately, it was impossible to validate the 1st annual increment because the smallest fish tagged and released (assumed to be 0+) had not been recovered. This prompted us to investigate the use of microincrement counts to confirm the position of the first two annuli in otoliths.

To obtain estimates of age structure, growth, longevity, and size/age at maturity, otoliths of 3200 fish were collected and analysed from the Australian region. The results show that bigeye are a relatively slow growing and long-lived species. Growth rate is most rapid in the first few years of life and asymptotic length is reached at about age 8 to 10 years. A maximum age of 15 years was obtained; although fish aged ≤five years dominate catches in the AFZ. Significantly, the study determined that growth rates of bigeye differ in the eastern Indian and western Pacific Oceans, suggesting that separate stocks exist within the Australian region. Length/age at 50% maturity for fish sampled in the north-western Coral Sea was estimated to be 102.4 cm FL in females (~2.4 years) and 86.6 cm in males (~1.7 years).

TRACKING OF PACIFIC BLUEFIN TUNA WITH ARCHIVAL TAGS

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We have deployed 181 Lotek LTD 2310 archival tags on Northern bluefin tuna, *Thunnus thynnus orientalis*, in the eastern Pacific Ocean. Tagging took place off the coast of Baja California, Mexico and the Southern California Bight in the summers of 2002 and 2003 on fish ranging in size from 71 to 125 cm. To date, 26 fish have been recaptured and 25 of the archival tags have been returned providing over 5000 days of data at 1 and 2' resolutions. Tracks ranged in duration from 5 to 365 days with a mean track length of 295 days. The tagging data are providing new insights into the seasonal movements, habitat utilization and residency time of Pacific bluefin in the eastern Pacific. The southern California bight region, Baja peninsula and waters offshore of Central California are emerging as peak regions of residency. Pacific bluefin of this size class appear to move in a seasonal cycle, remaining off the coasts of Southern California and northern Baja in spring and summer and migrating to Northern California waters in fall and winter. A single track records a west to east migration of a 35 kg bluefin that moved from the California coast to Japan. The data are revealing migration corridors along the west coast of North America, hot spots of aggregation, and physical movements in relation to physical oceanographic patterns that are key to understanding how northern bluefin tunas use the open ocean environment. In addition to data on movement patterns, archival tags are providing information on the physiological ecology of Pacific bluefin tuna. Strong signals from the specific dynamic action of feeding events show when and where tuna are feeding, providing further insight into the biology of Pacific bluefin tuna.

NATURAL AND EXPERIMENTAL DIET SHIFTS IN YELLOWFIN TUNA AS TRACKED BY STABLE ISOTOPE ANALYSES

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Tissues collected from wild tuna record feeding history by incorporating the isotope signatures of prey consumed. Depending on tissue turnover rates, feeding history is recorded on different temporal scales. Accordingly, isotope ratios of tuna tissues serve as internal chemical tags that are characteristic of shifts in diet or migration between isotopically distinct areas.

A clear ontogenic diet shift was recorded in liver and white muscle tissue isotopic signatures of yellowfin and bigeye tuna associated with fish aggregation devices (FADs) around the Island of Oahu. Yellowfin tuna, ranging from 25 to 45cm in fork length (FL) have similar carbon (C) and nitrogen (N) isotope values. Interestingly, individuals over 45cm also have similar C and N isotope values, but are approximately 5-7 ‰ higher in ^{15}N, which would normally indicate feeding at 1.5 to 2 trophic levels higher than smaller tuna. Extensive data from tuna stomach analyses also indicate a dietary shift from predominately stomatapod larvae to oplophorid shrimp around 40 to 50cm FL. Isotopic analysis of these prey indicate that the ontogenic shift in $\delta^{15}N$ results primarily from this shift in diet. Modeling this natural diet shift provides an estimate of turnover rates in yellowfin tuna liver and white muscle tissue.

To corroborate the data from the natural diet shift and to implicitly test our hypothesis that isotope ratios of tuna serve as internal chemical tags we conducted a diet shift experiment on captive tuna. Yellowfin tuna, all less than 45cm FL, were transferred from FADs northeast of the Island of Oahu to a tank at the Hawaiian Institute of Marine Biology. Once in the tank, tuna were fed a diet homogenous and isotopically distinct from the predominately stomatapod-influenced wild diet. Tuna were sacrificed weekly and C and N isotope samples were collected from a suite of tissues. Growth rates of these tissues were quantified using stable isotope analyses.

Growth rate estimates were similar between wild and experimental studies. Captive tuna experiments demonstrated the most rapid turnover times of days for blood, followed by red muscle and liver, and eventually white muscle tissue equilibrated with the new diet after several months. These documented tissue turnover rates will be used as a template in our future research examining large-scale tuna migration patterns in the equatorial Pacific.

UNCERTAINTY IN SPAWNER-RECRUITMENT DYNAMICS AND REFERENCE POINTS AND ITS IMPACT ON THE MANAGEMENT OF TROPICAL TUNAS

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In age-structured models MSY-based reference points are determined by a number of factors, *e.g.* natural and fishing mortality patterns, growth rates, and the spawner-recruitment relationship. In this study we analyze the sensitivity of MSY-based reference points to the shape of the Beverton-Holt spawner-recruitment relationship (defined by its steepness). First, we establish two important points, (1) that reference points are sensitive to the steepness of the spawner-recruitment model, and (2) it is difficult to accurately estimate steepness, given the high levels of recruitment variation observed for tropical tunas. Second, using management strategy evaluation, we estimate the potential consequences of mis-specifying steepness when harvesting a stock using F_{msy}. We find that the consequences of overestimating steepness are far greater than underestimating it in terms of loss of potential yield and reduction in spawner biomass. We discuss this finding in terms of the current assumption that steepness = 1 (no spawner-recruitment relationship) for tropical tunas in the eastern Pacific Ocean, and the requirement that the precautionary approach be incorporated when managing these stocks.

STATUS OF RESEARCH ON THE BIOLOGY AND ECOLOGY OF OPAH (*Lampris guttatus)* AND MONCHONG (*Taractichthys steindachneri)* IN THE NORTH PACIFIC

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Two important pelagic species incidentally caught by Hawaii-based longliners targeting bigeye tuna in the North Pacific are opah (*Lampris guttatus*) and monchong (*Taractichthys steindachneri*). Particularly valued by the restaurant trade in Hawaii and the US Mainland for their high quality white flesh, these exotic, deep-water fishes 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. A study to fill these gaps in our knowledge was undertaken and some of the highlights from the ongoing work are presented.

For opah, we fortunately discovered early on that opah exhibit sexual dimorphism thereby enabling the determination of sex without having to cut into the peritoneal cavity to access the gonads; this determination has saved considerable time and energy, allowing substantially more data collection both shoreside and in the field. Complementary studies where live opah are instrumented with archival tags have benefitted by this finding by allowing us to examine the movements of these fish by sex. With regards to age and growth, fin rays were deemed to provide the best opportunity for ageing these animals. Assuming that annuli are formed annually, opah taken in the fishery are presently best estimated between 1+ and 6+ years (i.e., 2 to 7 annuli). Both sagittal otoliths and fin rays are used for estimating age and growth parameters for monchong. If microincrements (on postrostrum and/or rostrum of sagittal otolith) are assumed 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; the oldest monchong sampled would be about 7 yrs.

We've been particularly successful in obtaining capture depth information for both opah and monchong as well as biological samples on cooperative commercial longline fishing trips. On four trips, a total of 149 monchong and 70 opah were caught on 45 longline sets. Of these, 18 monchong and 4 opah were caught on the sections of longline instrumented with a series of time-depth-temperature recorders (TDRs) and hook timers. Additionally, another 16 opah (8 males, 8 females) were instrumented with Wildlife Computers Popup Archival Transmitting (PAT) tags upon capture and released.

PELAGIC ECOSYSTEM OBSERVING SYSTEMS: UPDATE ON "SMART FAD", FADIO AND HULA PROGRAMS

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Three inter-related research projects are at various stages of implementation in attempting to develop autonomous or semi-autonomous systems for observing pelagic animals and the ecosystem within which they move. Within this general theme, specific emphasis is being placed on describing the dynamics the pelagic communities that associate with both anchored and drifting FADs.

In Hawaii, the Smart FAD project is researching new types of electronic tags that might be used to monitor the social milieu of pelagic fishes and also to determine feeding activity. Also, a rotating sonar system is being developed to monitor the waxing and waning of aggregations of fishes associated with anchored FADs.

In complementary experiments, two research cruises have been completed in the Indian Ocean where the FADIO project is attempting to characterize the dynamics of the aggregation of various pelagic fishes with drifting FADs of the type used by commercial purse seiners operating in that area.

HULA (Hawaii Undersea Listening Array) is in the planning stage. Conceptually, it will consist of a variety of active and passive acoustic monitoring devices that will be both "stand alone" and hard wired in an array deployed along the Kona coast of Hawaii. An existing array of passive acoustic monitors deployed in the same area to monitor the movements of manta rays is already demonstrating the potential utility of the HULA concept. In addition to providing long term and detailed data on the movements of manta rays, the existing array has been in used to detect the movements of jacks, tiger sharks and turtles.

SURVIVAL AND HABITAT PREFERENCES OF WHITE MARLIN (*Tetrapturus albidus*) RELEASED FROM THE WESTERN NORTH ATLANTIC RECREATIONAL FISHERY

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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 applied 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. Forty-one 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") hooks (n = 21) or circle hooks (n = 20) offshore of the U.S. Mid-Atlantic region, the Dominican Republic, Mexico, and Venezuela. Forty tags (97.6%) reported to the satellites of the Argos system, and 33 tags (76%) returned data consistent with survival over the deployment duration. Roughly 61% (range: 19-95%) of all data were successfully recovered from the tags. Fish caught on circle hooks experienced significantly higher survival (20 of 20; 100%) than those caught on straight-shank ("J") hooks (13 of 20; 65%) ($P < 0.007$). White marlin caught on straight-shank "J" hooks were significantly more likely to be hooked deeply ($P < 0.001$) and sustain hook-induced trauma ($P < 0.005$) between hook types. These results suggest that a simple change in hook type can significantly increase the survival of white marlin released from recreational fishing gear.

Data from surviving white marlin indicate that this species appears to spend the majority of time associated with warm surface waters. The maximum depths attained by tagged white marlin varied across locations (Mid-Atlantic: 161m, Dominican Republic: 149 m, Mexico 210 m, Venezuela 199 m). All fish displayed repetitive short duration (mean: 26.8 min +/-17.1) diving behavior to depths averaging 51.2 m (+/- 20.3). A census of complete dives recovered from surviving white marlin suggest two types of dives: one pattern was characterized as deep "v"-shaped excursions of relatively short duration (e.g., Type 1 dives) while the other featured dives that were more broadly "u"-shaped, showing behavior confined to a specific depth range for an extended period of time (e.g., Type 2 dives). Dive durations, depths, temperature gradients, and inter-dive intervals did not differ significantly between locations for Type 1 dives, but analysis of dive durations and inter-dive intervals of Type 2 dives revealed marginally significant differences between locations. Based on the frequency, persistence, and patterns of these dives, we infer that the diving behavior observed in this species may be associated with foraging. 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 pelagic longline deployments.

INTEGRATED POPULATION MODELING FOR THE NORTHEASTERN OFFSHORE SPOTTED DOLPHIN (*Stenella attenuata*)

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Restrictions on fishing operations have been increasing in an effort to protect species taken as bycatch. Informed decision-making requires quantitative analyses taking all relevant information into account, assessing both how bycatch affects these species and how regulations affect the fisheries, and describing the uncertainty in analyses. We combine Bayesian analysis and integrated analysis to develop a population dynamics model for the northeastern stock of offshore spotted dolphins (*Stenella attenuata attenuata*) in the eastern Pacific Ocean (EPO). The model includes the various types of data that are available for this population. Informative prior distributions are included for several model parameters. Forward projections are used to investigate different management options.

ESTIMATION OF SPECIES- AND TRIP-SPECIFIC CATCHABILITY IN HAWAII LONGLINE FISHERIES: A MULITI-SPECIES APPROACH

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While most of the existing research on catch-effort relationship of fishery considers only single species harvested by a specific technology, this paper develops an approach to estimate the catchabilities of multi-species harvested in different trip types. We use surplus production models as the basic theoretical framework and modify them to take into account of different catches and efforts in different trip types. Empirically, we use a seemingly unrelated regression model to take into consideration of possible correlations among catches for different species. Another feature of our empirical model is to use two steps' regression to take into consideration of different catchabilities for different trip types. Catch and effort data of Hawaii longline fisheries of three major species: Yellowfin tuna, Bigeye tuna and Swordfish harvested in three trip types: tuna, swordfish and mixed are used. Our empirical results provide information about technical and economic interrelationships among different species and trip types. The catch-effort relations revealed by our study can be further applied to cost-earning analysis for Hawaii's longline fishery industry.

DISTRIBUTION OF BILLFISH LARVAE AND EGGS OFF THE KONA COAST OF THE ISLAND OF HAWAII

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Surveys for swordfish (*Xiphia gladius*) larvae were conducted along an area 2-20 km offshore of the leeward (Kona) coast of the Island of Hawaii during eight 3-5 day sampling periods conducted over a six year period. Sampling gear consisted of a 1.83-m Isaacs-Kidd trawl towed through the surface (from the neuston to a depth of 1-m) at an average speed of 3.9 knots. Tows sampled an average surface area of 13,300 m^2 in one hr. A total of 112 swordfish larvae and 281 istiophorid larvae (predominantly shortbill spearfish, *Tetrapterus angustirostris*) were collected from 311 tows. Highest catch rates of swordfish and istiophorid larvae were associated with the occurrence of distinct sea surface salinity (SSS) and sea surface temperature (SST) conditions. Catches of swordfish larvae were most frequent during sampling periods when the SSS was 34.3-34.6 and the SST was 24.8-25.8 ^oC. Catches of swordfish larvae were low during sampling periods when SSS was 34.8-35.2 and absent when the SSS >35.2. Catches of istiophorid larvae were highest over a wider range of SSS (34.3-34.6 and 35.5-35.7) and SST (24.8-26.8 ^oC) conditions. Like swordfish, however, catches of istiophorid larvae were low at intermediate SSS conditions (34.8-35.2).

To identify catches of billfish eggs, a species-specific multiplex PCR assay (designed by J. Hyde in collaboration with E. Lynn and R. Vetter) was developed to amplify a single, unique size fragment of the mitochondrial cytochrome *b* gene for all six species of billfish inhabiting the Pacific. This technique was applied at sea off the Kona cruise during a May 2003 cruise where neuston tows using a 1.5 meter ring net (0.5 mm mesh) were conducted for billfish eggs. A total of 63 swordfish eggs were identified; spatial distribution of eggs was similar to larval catches from previous cruises. Additionally, 8 shortbill spearfish eggs were identified (planktonic egg stages of shortbill spearfish have not been previously described in the literature).

MONITORING PELAGICS WITHIN A NETWORK OF ANCHORED FADS

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The use of large-scale anchored fish aggregation device (FAD) arrays and rapid developments in drifting FAD technology have revolutionized industrial tuna fisheries. In recent years, more than half of the world catch of tropical tuna species was taken in association with a man-made raft or buoy. Increased utilization of FADs by purse seine fleets has lead to variety of concerns over increasing fishing mortality on juvenile tunas, increased bycatch levels and potential ecological impacts of FADs on the biology and movement patterns of wild stocks. To gain detailed information on the spatial and temporal dynamics of commercially exploited species in relation to artificial structures, we have equipped adjacent FADs surrounding the island of O'ahu (Hawaii) with automated fish monitoring receivers[*]. Approximately 100 yellowfin and bigeye tuna have been surgically implanted with coded sonic transmitters that record fine scale presence/absence data at each FAD location.

Size and species specific movement patterns and residence times have been continuously monitored since August 2002. Recapture rates of yellowfin have been very high at close to 40% overall suggesting locally intense fishing pressure on FAD associated tuna. Of the fish that have not been recaptured, interesting residence and movement patterns are emerging. Most tagged fish have remained at the same FAD where they were tagged or visited a few adjacent FADs. However, others have moved extensively throughout the FAD network over a period of several months. Some FADs appear to function as aggregative subsets of the whole array with fish repeatedly moving between a pair or small group of FADs. Arrival times and distances between FADs suggest that these animals are well aware of the location of adjacent FADs and can travel directly from one to the next.

The data retrieval and maintenance of an active listening station array is logistically difficult, but can easily accommodate simultaneous studies on a variety of species. In order to capitalize on this opportunity and address some ecological aspects of FAD aggregation, we are currently expanding the work to include billfish and oceanic shark species. Recently approved funding will further expand the work to examine size specific residence and vertical behavior of tuna on FADs using smaller and pressure (depth) recording sonic tags. This work is being conducted in collaboration with a series of integrated PFRP studies that will examine the trophic relationships, aggregation dynamics and schooling behavior of pelagic species.

[*] This work is funded by Cooperative Agreement #NA17RJ1230 from the National Oceanic and Atmospheric Administration. The views expressed herein are those of the authors and do not necessarily reflect the view of NOAA or any of its sub-agencies.

DISTRIBUTION OF FRESH TUNA IN THE U.S. MARKET

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Over the past ten years the fresh tuna business in the U.S. has not changed much, but in some ways there have been revolutionary changes that profoundly affect the fishing methods, product distribution, and ultimately, consumption patterns.

As an overview, consumption of fresh tuna either in the fresh or frozen-defrosted form has increased over the past ten years. Consumers are generally convinced that eating fish is healthier than eating red meat, pork or chicken, although the occasional negative publicity on mercury-levels in fish, mad cow outbreaks, or flu virus in chicken, sway the consumption patterns one way or the other. There is a general trend of increasing per capita consumption of fresh tuna, either as a staple in the ever-increasing sushi bars and prepared sushi market, or in the popular "seared ahi" preparation in most "white-tablecloth" restaurants.

The advent and widespread use of carbon monoxide-treated tuna has truly changed the sales and distribution strategies of fresh tuna fishing companies, exporters, distributors, and consumers. "Tasteless smoke" or other processes that treat fresh fish with carbon monoxide take advantage of the phenomenal side-effect that when the CO molecule attaches to the hemoglobin, the blood turns cherry red and never changes color. Whereas in natural oxidation in fish, the blood turns red when initially exposed to oxygen, but later turns brown with the "life" is gone from the flesh, CO-treated fish never turn brown, and maintain an almost artificial pink-orange red in the fresh, frozen, and defrosted state. With the increased eye-appeal of this product, the natural fresh tuna market – especially the lower grade of-color tuna has been replaced with "gassed" tuna. The obvious problem with this treated product is that you can never tell when the fish has gone bad, especially for raw applications. It can be very deceiving, and has been a subject of controversy for several years. However, the FDA has not banned it, though it is banned in Japan and Europe.

There is an increasing awareness of fish freshness and quality throughout the consuming public and food service (restaurant) sectors. As is with other products, the U.S. public is well-informed and makes purchasing decisions based on information or issues concerning contamination, supporting sustainable fisheries, habitat conservation in fish farming practices, etc. All these points must be considered these days when purchasing and marketing fish products.

MINIMAL MODELS FOR CENTRAL PACIFIC FOOD WEBS

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Ecosystem models for marine fisheries often include bewildering amounts of complexity. How much of the food web must really be modeled to make good management decisions? We found that for simulated populations of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) in the Central Pacific food web, optimal model complexity includes only 1-2 predator and 1-2 prey species when there is a realistic amount of process and observation error. This holds true regardless of whether we evaluate model performance with statistical indicators such as AIC, or with measures of management performance such as yield or the natural log of yield. The result is robust to a wide range of possible patterns of fishing effort. The optimal number of species to include in the model increases in cases where extreme environmental forcing (such as El Niño) causes bottom-up increases in the abundance of certain prey.

A GENERAL MODEL FOR PROTECTED SPECIES: INFORMATION AND UNCERTAINTY

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Management of protected species has to be made in the absence of adequate data to determine the exact outcome of alternative management strategies. Therefore, information should be obtained from all possible sources and the uncertainty in estimates described. We present methods to include the different types of information into a population model for protected species. We also outline methods to describe uncertainty.

APECOSM: A SPATIALIZED "Apex Predators ECOSystem Model" TO STUDY PHYSIOLOGICALLY STRUCTURED TUNA POPULATION DYNAMICS IN AN ECOSYSTEM CONTEXT

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We present the APECOSM model (Apex Predators ECOSystem Model) which aims at representing the spatialized dynamics of open ocean pelagic ecosystems. Physical forcings (winds, temperature, currents, etc. from OGCM), biogeochemical forcings (primary production, oxygen, etc. from biogeochemical models) as well as the effect of fishing are explicitly taken into account. The model represents the dynamics of the Open Ocean Pelagic Community (OOPC) with a size-structured energy flux equation in 4 explicit dimensions (space x, y, time t and organisms weight w). The surface community is distinguished from the deep migratory community. The energy input at the basis of the OOPC comes from a biogeochemical model. The tuna species under interest (YFT, SKJ, BET, ALB) belong to OOPC (i.e.: interact trophically with it) but have a finer structure. Tuna population dynamics is indeed represented with a physiologically structured advection-diffusion flux equation which transports individuals through a 6 dimensional space (space x, y, time t, reserves E, structure V, gonads G). A sub-model enables to take into account the small-scale vertical movements of tunas into the larger scale ecosystem dynamics model and drives the interactions between tunas and OOPC.

OCEANOGRAPHIC ATLAS OF THE PACIFIC: AN ACCESSIBLE INTERFACE TO MARINE ENVIRONMENTAL DATA

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Marine ecosystems are influenced by a broad range of oceanographic and environmental conditions and processes. Resource managers and researchers tasked with monitoring and studying such ecosystems are often hindered by the large amount of unsynthesized oceanographic data currently available. The Oceanographic Atlas of the Pacific is designed to provide a single point of access to environmental data from a variety of platforms (satellite, shipboard, moorings, and numerical models) in forms that are useful and accessible to both non-expert and expert users. Data coverage is provided at Pacific basin-wide and regional scales as well as for various biogeophysical sub-regions and, contingent upon data availability, individual islands, banks, or reefs. The Atlas enables straightforward visualization of numerous data products in formats such as climatologies, anomalies, time series, animations, and data snapshots and facilitates the retrieval of specific source data. The Atlas interface provides a means for understanding trends and patterns of spatial and temporal variation in environmental parameters influencing both pelagic and insular conditions, offering researchers, resource managers, policy makers, and other stakeholders a valuable source of information on the dynamics of particular ecosystems. As an example, users might choose to view sea surface temperature anomalies overlaid with wind fields or ocean current estimates while simultaneously exploring available in-situ observational time series from moorings located near a particular area of interest. Basic categories of data available through the Atlas include sea surface temperature and height, ocean color, salinity, oxygen, wind, storm tracks, currents, waves, bathymetry, and other derived data products contingent upon the needs of marine resource managers and researchers. The products available through the Atlas will be fully documented, allowing users to identify the data that best fits their needs. Distribution via an interactive website application allows users to customize various aspects of data selection and display, though limited print versions of regional atlases will also be made available for users in those areas lacking reliable Internet connections. An interactive prototype of the web interface will be demonstrated during the presentation.

EFFECTS OF EL NIÑO DURING 1990-1999 ON THE MEXICAN YELLOWFIN TUNA (*Thunnus albacares*) PURSE-SEINE FISHERY AT THE ENTRANCE TO THE GULF OF CALIFORNIA

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The entrance to the Gulf of California (from 18°N to 24°N and 104°W to 112°W), is located in the convergence zone of the North Pacific Gyre, where the California Current separates from the coast to feed the North Equatorial Current. It has a complex hydrographic structure due to the confluence of different water masses. This region is highly responsive to the El Niño phenomenon. Its main response is characterized by positive sea level anomalies, warming of the upper layer and a general alteration of marine current patterns. High abundance of yellowfin tuna *Thunnus albacares* (YFT) is reported in the area by a number of authors; however, studies about the interaction of the YFT with the physical environment of this area are scarce.

Latitudinal distribution of the catches in this area increased from south to north for the 10-year period. Within this area the highest catches and effort are concentrated between 22°N and 23° N. This area accumulated 48% of the total catch over the 10-year period. Variation of catches seems to be strongly correlated with El Niño (ENSO) events. At least two periods of exceptionally high catches were found to occur at two consecutive times, following El Niño events in 1991 and 1997. Peaks of catches are triggered by the arrival of positive anomalies of sea surface temperature (SST) to the area. A delay of 2 to 4 months is observed between the occurrence of maximum SST anomalies at the equator and peaks of catch. Prior to these two events, negative SST anomalies were the dominant feature in the area and catch was extremely low. This behavior of negative SST anomalies with low catches followed by positive SST anomalies and high catches suggest a northward migration pattern of YFT driven by El Niño forcing, however, this pattern contrasts to the know behavior of decreasing relative abundance of YFT tuna after El Niño events in the eastern Pacific.

REDUCING BYCATCH FROM PURSE-SEINE FLOATING OBJECT SETS

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Purse-seine sets on floating objects have contributed an increasing proportion of the the total commercial catch of tuna in the eastern Pacific Ocean due largely to the use of drifting Fish Aggregating Devices (FADs). Floating object sets, however, include a far higher proportion of bycatch compared to sets on free schools or dolphin-associated schools. Increasing concern regarding this bycatch has stimulated interest in developing means for reducing the incidental capture of non-target species. Here, we review gear technology currently under study for application to the tuna purse-seine fishery and the potential for modified fishing practices to affect bycatch/catch ratios. Trials in other fisheries (e.g. salmon and mackerel) suggest that size-selective sorting grids may permit the release of juvenile tunas while retaining larger, more valuable sizes, but major hurdles remain. Three sorting grid types are discussed. In addition, anecdotal reports from fishers and limited knowledge of the behavioral ecology of flotsam-associated fishes suggest that simple changes to current purse-seining procedures also deserve consideration.

BLUE MARLIN (*Makaira nigricans*) RECREATIONAL FISHERY AT CABO SAN LUCAS B.C.S., MEXICO.

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Cabo San Lucas is an important sport fishing zone, where blue marlin (*Makaira nigricans*) is the second target species after striped marlin. We analyzed the interannual and seasonal variation of blue marlin catch rates and eye-fork lengths during the 1990-2002 period. The information was obtained from the monitoring program of the Centro Regional de Investigacion Pesquera at La Paz, B.C.S. Biological data were recorded during three consecutive days each month. Eye-fork length, weight and sex of 1,017 landed blue marlin were recorded. A significant seasonal variation was found, being during summer when the highest average catch rate was recorded, coinciding with the highest sea surface temperatures. In average, during the analyzed period 97% of the landed fish were females. We also found a significant interannual variation in the eye-fork length. The average maximum value was recorded during 1996 and the minimum during 2002. Weight-length relationship was estimated.

TESTING FOR POPULATION STRUCTURE IN STRIPED MARLIN, *Tetrapturus audax*, USING MITOCHONDRIAL AND NUCLEAR MARKERS.

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In this study, striped marlin (*Tetrapturus audax*) are used to examine population genetic structure in a highly migratory species. Due to structuring already seen in this organism, they can be used to address important questions such as: (1) Will different loci show the same genetic pattern previously found? (2) Is the genetic structure temporally stable? (3) What is the underlying mechanism creating this population divergence? We are examining the population subdivision using both mitochondrial and nuclear DNA markers. PCR is used to amplify the mitochondrial control region, which is then sequenced to detect changes at the nucleotide level, and can be used to infer evolutionary history among populations. Nuclear microsatellites are used as independent measures of heterogeneity within and among populations. Because mitochondrial DNA is maternally inherited and microsatellites are biparentally inherited, comparisons between these two markers may help determine whether the population genetic structure is sex-specific. We are using a concurrent sampling scheme to collect adult tissue from 6 locations representative of their range in the Pacific: Mexico, Ecuador, Southern California, Hawaii, Japan, and Australia. This repeat sampling will be conducted over the course of 3 years to test for temporal stability among locations. Larval samples are also being added to this study to test spawning site fidelity as the mechanism creating/maintaining this population subdivision. Additionally, the larvae may be powerful in resolving the locations of distinct populations. Larvae comprise a single cohort, whereas adult populations typically consist of multiple cohorts. As a result, population boundaries may seem less defined in adults, while they are much more apparent in the larvae. We will present the goals of this project, our efforts to date, and a summary of our preliminary data.

A MODELLING FRAMEWORK FOR STUDYING BLUEFIN TUNA BEHAVIOUR IN ITS ENVIRONMENT

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We present a framework for the analysis of behaviour in a highly migratory species, northern bluefin tuna (BFT). Advances in this research area depend on our ability to link tuna behaviour data with actual variability of oceanographic fields, over a wide range of space and time scales: this can be achieved using a data-assimilation scheme, where ensemble-based methods offer particularly useful tools. In the single-particle case, a general class of Bayesian state-space models is applied to simulated archival tag data, allowing to fit non-linear models either in the motion process or the observation process. For example, a time-varying error or bias in the observation equation, possibly with abrupt changes, can be retrieved by assimilating the recorded ambient temperature. Accurate information from an external temperature field is needed: General Circulation Models combined with remote-sensing imagery may be considered for that purpose. Furthermore, it is possible to model movement and residency as a combined response to a temporally and spatially variable physical environment and unpredictable prey fields. Some advances in this field are presented. Finally, we show how this single-particle lagrangian approach can be extended to N-particle lagrangian systems, allowing to hypothesis testing at the population level.

MOVEMENTS AND ENVIRONMENTAL PREFERENCES OF BLUE MARLIN (*Makaira mazara*) IN THE NORTHWESTERN PACIFIC OCEAN OBTAINED FROM PAT TAGS

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We had deployed five pop-up satellite archival tags (PAT, Wildlife computers) on blue marlin (*Makaira mazara*) caught by commercial and recreational trolling boats in the northwestern Pacific Ocean in 2003, to examine vertical and horizontal distribution patterns of the fish. Data of four tags, among five, was successfully collected, though three of them popped off earlier than the day initially programmed.

Two tags were attached on blue marlins (they were estimated 80 and 60 kg) in the axis of the Kuroshio Current in the southwestern part of Ryukyu Islands (24°N, 123°E) in late May 2003, with attachment durations ranging 26 and 96 days. The amount of transmitted record for these fish was about 16 and 55 days, respectively. However, fisherman in the Ryukyu Islands had believed that the blue marlin had caught in this area swim northward along with Kuroshio Current like other large pelagic fishes such as skipjack, tags data indicated that tagged fish stayed in the area around Ryukyu Islands during periods when tags were attached.

Other two tags attached on blue marlins (100 and 120kg in weight) in the coastal area near the Izu peninsula (34°N, 139°E) in July and August, with attachment durations ranging 143 and 103 days. The amount of transmitted record for these fish was about 43 and 25 days, respectively. Tags data indicated that these fish stayed in the coastal waters near Kuroshio Current for about ten days after release, and moved to the eastward (30°N - 38°N, 145°E - 160°E). During summer, both two fishes swam across frontal zone between the warm Kuroshio and the cold Oyashio currents and stayed in the cold Oyashio area for several weeks. In the autumn when the sea surface temperature was down from 25-28 °C to 19-21 °C, both fish moved to the southern warmer water temperature area.

These four tagged blue marlin stayed in the surface (0-10 meters (62%) and 25-50 m (20%)). Detailed check of these data enables us to pick up possible environmental factors which would have influences on the vertical and horizontal movements of tagged blue marlins.

REVIEW OF 2003-2004 ACTIVITIES AT THE IATTC'S ACHOTINES LABORATORY

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Since October of 1996, a broodstock population of yellowfin tuna has been spawning nearly daily in a concrete, in-ground tank at the Achotines Laboratory. Larvae from hatched eggs are used for investigations of the effects of various environmental and biological factors on growth and survival. Recent analyses of yellowfin larval ecology have been completed and have focused on the *in situ* growth of early-juvenile yellowfin and the effects of microturbulence on survival of yellowfin larvae. We also have plans to continue collaborative vision studies with Drs. Ellis Loew (Cornell University) and William McFarland (University of Washington) to characterize the spectral sensitivity and visual basis for feeding in larval and juvenile yellowfin. As part of a joint research agreement with the University of Miami (UM) Aquaculture Program, Achotines Laboratory staff continued a series of experiments initiated by a UM graduate student examining the effects of antibiotics and probiotics on growth and survival of yellowfin tuna eggs and larvae.

Captive adult yellowfin are also utilized in trials and experiments. In early 2003 IATTC scientists implanted archival tags in the body cavities of 17 captive yellowfin tuna (52 to 63 cm in length). This trial continues work started in 2002 to investigate whether feeding and spawning events of yellowfin can be detected by evaluating data on the peritoneal cavity temperatures recorded by the archival tags. In early 2004 11 of these fish remained alive, and an additional 6 fish were implanted with archival tags in April.

Another component of the UM joint research is to investigate the feasibility of capturing, transporting, and culturing live Indo-Pacific sailfish, *Istiophorus platypterus*. The study is being conducted by Dr. Daniel Benetti, Director of the UM Aquaculture Program of the University of Miami, working in collaboration with the authors. Sailfish anesthetic trials were carried out in May of 2003 by the first author at Piñas Bay, Panama. These trials were followed by capture attempts near Achotines Laboratory when six sailfish were caught and transported alive to tanks at the Laboratory. None of these individuals survived in captivity but blood and tissue samples of these sailfish were taken and analyzed to seek methods to improve live capture results.

Achotines Laboratory is increasingly being used for seminars and field trips. Dr. Stephen W. Pacala brought his Princeton University field course, "The Biology of Coral Reefs" to Achotines Laboratory in April of 2003. In early July of 2003 the Organization of Tropical Studies (OTS) and the Smithsonian Tropical Research Institute (STRI) taught a segment of their graduate course, "Tropical Marine Ecology," at Achotines Laboratory. In late July of 2003 the University of Miami Center for Sustainable Fisheries and the IATTC held a workshop at Achotines Laboratory entitled "Physiology and Aquaculture of Pelagics with Emphasis on Reproduction and Early Developmental Stages of Yellowfin Tuna."

THE THERMAL BIOLOGY OF THE SLENDER TUNA, *Allothunnus fallai*

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Regional endothermy has been described for all but one of the five tuna genera, *Allothunnus*. *Allothunnus fallai*, the slender tuna, is a structural intermediate between the more derived warm-bodied tunas (Tribe Thunnini) and their ectothermic relatives (Tribe Sardini). Recent work has shown that the slender tuna has a modified central circulation (resembling the central heat exchanger of *Auxis*, *Euthynnus* and *Katsuwonus*) and an internal and anterior red muscle (RM) position. The morphological specializations exhibited by *A. fallai* suggest that it may be endothermic, but no studies have yet examined its thermal biology. *In-vivo* field studies were conducted off the coast of New Zealand. This paper reports on the heat maintenance capability of *A. fallai* and determines whether *Allothunnus* elevates the temperatures of its RM, or if it represents the only ectotherm within the Thunnini.

OTOLITH MICROCHEMICAL ANALYSIS OF JUVENILE YELLOWFIN TUNA FROM NURSERY AREAS IN THE ATLANTIC OCEAN

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Yellowfin tuna (*Thunnus albacares*) are a very important fishery resource in the Atlantic Ocean and are fished throughout their range. Three primary spawning grounds have been identified in the Atlantic: the Gulf of Guinea, the Gulf of Mexico, and the southeastern Caribbean Sea. Tagging data provides evidence of trans-Atlantic movements, however discrete oceanic circulation of the population has yet to be described. Determination of the contribution of the different nursery grounds to the Atlantic population will help to establish the relative importance of each site to the various fisheries, allow estimation of the rates of mixing, help elucidate unclear migratory behaviors, and greatly increase the available scientific data on yellowfin in the Atlantic.

Microchemical analysis using solution-based ICP-MS and ICP-AES has been conducted on whole otoliths of juvenile yellowfin from the Gulf of Guinea, the southeastern Caribbean Sea, and the Pacific, in an effort to establish the utility of using such methodology to delineate natal origin. The study consists of three analysis groups: 'Temporal' assessing inter-annual variation, including fish collected from the Gulf of Guinea at the same time of year in 2001, 2002, and 2003; 'Spatial' assessing variability within a given region, with fish landed on the same date but three distinct locations in the Gulf of Guinea; and 'Regional' testing for elemental fingerprints of natal origin, including fish from the Gulf of Guinea, southeastern Caribbean (Martinique), and Pacific (Tahiti). Of the elements analyzed, six appeared in consistently reliable concentrations for use in the study: Mg, Rb, Sr, Ba, K, and Na.

Univariate contrasts (size effect removed) of yellowfin indicate elemental differences between the various sites and years tested. For 'temporal' samples Rb and K were both significantly higher in 2001 than 2003, these two years showing the largest amount of difference among years. Also for both Rb and K, 2002 was significantly greater than 2003 and 2001 greater than 2002, although for Rb the difference between 2002 and 2003 was greater than that between 2001 and 2002. For K this was the reverse. 'Spatial' samples were differentiated by Mg and Na. Mg was higher in sample group 1062+ than in 1010+. For Na, sample group 1010+ had a higher mean concentration than 960+. Finally in the 'regional' part of the study, the Gulf of Guinea had a lower mean concentration of Rb than both Martinique and Tahiti. Martinique had a higher concentration of Sr than Tahiti. All groups were different for K. Martinique and the Gulf of Guinea had the largest difference among groups, with Martinique having a higher mean concentration than the Gulf. Tahiti's concentration of K was also higher than the Gulf's and Martinique was higher than Tahiti. For Na, the concentration was much higher in Martinique than in both the Gulf and Tahiti.

Elemental fingerprints were examined with discriminant analysis. Clear separation was seen between groups in both the regional and temporal parts of the study, whereas only moderate group separation was observed in spatial samples. Results indicate that elemental fingerprints may be useful delineators of natal origin for yellowfin in the Atlantic. Further studies should be conducted to assess the magnitude of inter-annual variation within a region versus that seen between regions.

MOVEMENTS OF BIGEYE TUNA OFF THE EAST COAST OF AUSTRALIA

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Fourteen bigeye tuna were tracked along the Queensland coast of Australia using archival tags for periods of up to 970 days. Geolocation errors, movement parameters and most probable tracks were estimated using the Kalman filter model. Systematic bias in latitude estimation from light data produced artifacts in the apparent north-south distribution of the tagged fish. Bias corrections introduced into the Kalman filter produced tracks that were much less extensive and which suggest an affiliation for the Queensland plateau. Sea surface temperature recorded by the tags is compared with remote sensing SST measurements for the estimated positions. Results of a preliminary method for objectively incorporating SST in the Kalman filter are presented.

COMPARING PRODUCTIVITY IN PELAGIC SHARKS

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Intrinsic rebound rates are calculated for 11 selected pelagic elasmobranchs. These rates are compared to those of 22 other shark species calculated by the same method. Each rebound rate, or $r_{Z(msy)}$ value, represents an estimate of maximum potential growth in a population hypothetically exposed to estimated levels of MSY harvest ($Z_{msy} = 1.5M$ *or* $Z_{msy} = 1.5M$) and then allowed to rebound from that condition in an unfished state. The method allows for direct comparison of productivities among species, a feature not possible using other methods. Rates of most species fell within the mid range of the shark productivity spectrum, but some extended nearly the entire range, from a low of 1 to 2 percent per year for the basking shark, *Cetorhinus maximus,* (and shortfin mako, *Isurus oxyrinchus,* if one assumes the one centrum band per year hypothesis) to a high of 6 to 10 percent for pelagic ray (*Dasyatis violacea*). All elasmobranch values were low compared to teleostean fishes, especially if $Z_{msy} = 1.5M$ is determined to be the most appropriate for producing maximum sustainable yield in sharks. This method works with a minimum of input values (maximum reproductive age, age at first female maturity, and average female fecundity), but as in any demographic analysis, results are strongly dependent on the reliability of the parameter estimates, especially age at first maturity.

CHEMORECEPTION IN SEA TURTLES: IMPLICATIONS FOR LONGLINE FISHERIES INTERACTIONS

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Incidental capture of endangered sea turtles in fishing gear is a cause of concern for fisheries managers, fishers, and environmentalists alike. The degree to which sea turtles are attracted to (and incidentally entangled in) fishing gear and bait is not well understood. A collaborative investigation is currently underway to characterize vision, hearing, and chemoreception in sea turtles so that a comprehensive assessment of potential sensory attractants and repellants may be made. The ultimate goal is to develop modified gear or bait that will be effective for catching fish but either undetectable or repellant to sea turtles. Use of such bait could potentially decrease the amount of sea turtle injury and mortality due to fisheries interactions.

Our research focuses on assessing the chemosensory abilities of loggerhead turtles. We conducted experiments at the NOAA-NMFS Sea Turtle Facility in Galveston, TX to investigate the behavioral responses of loggerhead turtles to various chemical stimuli. Our primary objectives were to *i*) develop an assay to effectively quantify the behavioral responses of sea turtles to chemical stimuli, *ii*) determine if sea turtles use chemoreception to identify and locate food in the aquatic environment, and *iii*) test chemical compounds that could potentially be used as turtle repellents.

We used a "choice tank" to assess behavioral responses of loggerhead turtles to chemical cues. All trials were conducted in complete darkness. Experiments began with turtle isolated in a central start chamber. After an acclimation period of 15 minutes in static water, bilateral flow was initiated by pumping seawater into opposite ends of the tank. Water drained out of the tank through a large grate on the floor of the central start chamber. During chemical trials, a chemical was presented on one side of the tank but not the other. The turtle was then free to explore the tank and the behavior of the turtle was monitored and recorded by an IR-sensitive video surveillance system. A control trial in which no chemical was introduced was also run for each turtle. Order of chemical and control trials was randomized. Data were analyzed using ANOVA to compare behavior during chemical and control trials. Variables analyzed included proportion of trial time spent in the area of tank where chemical was present and display of specific behaviors.

We used a food homogenate to test whether or not turtles showed signs of detection and attraction to food odors. Results show that turtles spent a significantly greater proportion of time in areas of tank where food odor was present, specifically in the central start chamber, during food trials compared with control trials ($P = 0.007$). Fluorescein dye tests revealed that flow above the drain grate in the central chamber was faster and more turbulent than flow in other sections of the tank. Turtles, like many other marine animals, may attempt to use flow cues to locate the source of food chemicals. During food trials turtles also displayed a detection/searching behavior in which they stopped swimming abruptly, put their nose to the tank floor, and used rear flippers to backup or spin in circles. This behavior was displayed with significantly greater frequency during food trials compared with control trials ($P = 0.009$).

In the absence of visual cues loggerhead turtles will respond behaviorally to the presence of food odors. Although sea turtles are thought to be primarily visual predators, our results show that chemosensory cues may also play an important role in aquatic food detection and location and may be a factor in attracting sea turtles to longline fishing bait. Potential means of masking bait odor are currently being investigated, and analysis of chemical compounds that may act as turtle repellants is ongoing.

TUNA CATCHES IN THE EPO: COMPARING ESTIMATES FROM VESSEL LOGBOOKS, OBSERVER DATA, UNLOADING RECORDS, AND LENGTH FREQUENCY DATA

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Accurate catch statistics are essential for providing "good" management advice for tunas. Two objectives of the IATTC are to estimate the total catch and size composition of the catches of tunas made by the surface fleet (purse-seine and pole-and-line) in the eastern Pacific Ocean (EPO). These estimates are based on data collected from captain's logbooks, and by scientific observers, from unloading records, and from the length frequency sampling program. In 2000, the IATTC began sampling the species composition of the catches during the vessel unloading process. These data are used in conjunction with the length frequency data to provide an estimate of the catches of the principal market species, independent of the other sources.

For many years, the catches reported in the annual and quarterly reports of the IATTC were generally based on logbook and unloading data. Logbook data has been used to describe the spatial and temporal structure of the fishery while unloading data has provided the most complete estimates of total catches by year, species, flag, and gear. Length frequency data has provided information on the size composition of the catches. At-sea hails from observers have always been an integral part of the estimation of catches for the weekly reports, but in the quarterly and annual reports, observer data has been presented separately from the logbook and unloading data. With the development of a new database system, data from the different sources are integrated, providing improved estimates of the total catch and size composition.

The purpose of this analysis is to determine the optimal integration of these data sources in order to produce the best estimates of catch. We used linear models to compare the catch estimates from the different data sources. We present vessel-level comparisons of the catches from the logbook, observer, and unloading data for 1995 – 2003. We also present estimates of the catch by species from the length frequency sampling program compared to estimates from observer and logbook data by sampling area, month and set type for 2000 – 2003. Comparisons of observer catch estimates by species to those that result from the length-frequency sampling program for 2003 show differences in the species composition of the catches at the well level.

MULTIFAN-CL APPLICATIONS TO PACIFIC BLUEFIN TUNA

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Multifan-CL (MFCL) is an age-, spatial-structured, size-based stock assessment model, which has been applied to many tuna stocks in Pacific and Atlantic Ocean. Since last year we have started a project to apply it to Pacific Bluefin tuna (PBT). Initial results are presented at bluefin working group of 4th meeting of the Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific (ISC) held in Jan. 2004. Though original Multifan-CL is capable to have special- structure in the population dynamics, current Pacific bluefin application to MFCL is limited to non-spatial structured modeling. In this presentation we make some comparison with the results from ADAPT VPA, which has been routinely applied to PBT. We also examine possibilities to extend our applications to have spatial structure or to include recent monthly data into the model.

TRIALS TOWARD OBJECTIVE ADJUSTMENT OF ARCHIVAL TAG GEO-LOCATION ESTIMATES

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Although archival tags are powerful tools to investigate migration and behavior of highly migratory species including tunas, raw estimates of locations derived from archival tags tend to jump around a quite wide area, partly because of low precision in latitude estimates. Historically in Japan, these raw estimates have been adjusted point by point by seeking the area where sea surface temperature from oceanographic observations matching with surface temperature measured by tags along the estimated longitude by tags. This has been cumbersome and time-consuming processes and heavily relies on personal experiences and judgment. Here, we will present the current effort to develop more objective and automated process in adjusting archival tag location estimates.

Adjustment of tag location estimates discussed here utilizes external information including sea surface temperature, bottom depth, and chlorophyll etc. Depending on sources of those external data as well as how to utilize them, three categories were identified: 1) simple matching of tag records and their corresponding external measurements (e.g. tag recorded SST vs. satellite SST), 2) inclusion further information obtained through tags, and 3) inclusion of other hypothetical factors controlling fish behaviors which will not be evaluated from tag records. This categorization intends to help users to select their appropriate procedures depending on their purposes. It should be noted that the higher the level becomes, the more interpretations are involved.

Two prototypes of the first level using satellite SST as external information were developed. Both follow the same basic process. First, a probability ellipse of true locations is determined for each data based on an accuracy and precision of archival tag location estimates. The standard deviation of one degree for longitude and three degrees for latitudes were used for this exercise. These were the values observed from tags kept with a fish in a cage for three months. Second probability area is determined by matching between satellite SST and SST recorded by tags. Then, those two probability areas are combined to give an overall probability area. Results obtained from either prototype were quite similar each other as well as with those from the historical adjustments.

One example of the second level and future plan will also be presented.

RECENT PROGRESS IN STUDIES OF LOGBOOK DATA QUALITY FOR BILLFISHES IN THE HAWAII-BASED LONGLINE FISHERY

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The accuracy of billfish (Istiophoridae) identifications in logbooks submitted by the Hawaii-based longline fleet is known to be an important monitoring challenge confronting the Pacific Islands Fisheries Science Center. This problem has been addressed by use of observer reports to fit statistical models of catch rates, which provide comparison standards for the commercial logbooks, and fish auction sales records that provide independent verification of these checks. A recently completed study indicated that the nominal catch of blue marlin, *Makaira nigricans*, from March 1994 through June 2002 was inflated by 29%, caused largely by misidentifications of striped marlin, *Tetrapturus audax*, and to a much lesser extent, shortbill spearfish, *T. angustirostris*, as blue marlin. This study also revealed that correction of the blue marlin catch data necessitated substantial changes in the nominal catch totals for the other species (e.g., correction of 2.7% of the longline sets indicated that the striped marlin total was at least 8.2% greater than reported).

This presentation describes sources of bias in billfish data from the logbooks and includes estimates thereof. Possible ramifications (e.g., introduction of error into official fishery statistics or population estimates generated by stock assessment models) will be discussed. Progress with the other species, representing a continuation and expansion of the blue marlin study, will be presented, and current and impending research activities will be described.

CHANGES IN PELAGIC FISH COMMUNITIES WHEN LONGLINE FISHING COMMENCED IN THE TROPICAL PACIFIC OCEAN

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We investigate changes in the pelagic fish community of the tropical Pacific Ocean by comparing recent data collected by observers on longline fishing vessels with data from a 1950s scientific survey when commercial longlining commenced. A major shift in standardized catch rates and the size composition of catches accompanied the start of longlining. The largest and most abundant predators, such as large tunas and sharks, showed the greatest declines in catch rates, and they also showed striking reductions in mean body-size. By contrast, the catch rates and mean body-size of several small and formerly rare species increased between the periods.

MOVEMENT, BEHAVIOR AND HABITAT OF JUVENILE WHITE SHARKS IN THE EASTERN PACIFIC AS REVEALED BY SATELLITE TAGGING

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Four juvenile white sharks were tagged in the Southern California Bight using pop-up satellite archival tags. Their movements and behavior were tracked for a cumulative total of 184 days, yielding information on geographic position, depth, ambient temperature and light. Two of the juvenile white sharks remained within the Southern California Bight for the duration of the tracks (24 and 63 days), while two sharks moved south into Mexican waters off the Baja Peninsula (37 and 60 days). The greatest distance traveled was 670 km (straight-line) to Sebastian-Vizcaino Bay on the Pacific Coast of Baja. All four animals remained within the California Current system. The four sharks spent 43 ± 8% (mean ± SE) of their time shallower than 5 m, and 62 ± 5% (mean ± SE) of their time in ambient temperatures of 16-20°C. Sharks also made frequent dives into the thermocline, reaching depths up to 308 m and temperatures of 8°C. The Southern California and Baja coasts appear to be an important nursery area for the white shark, such that management will require international efforts. The full extent of the nursery region is unclear and the location of pupping remains unknown. Supported by the Monterey Bay Aquarium Foundation, the Office of Naval Research, and the Tagging of Pacific Pelagics program.

OUTLINE OF JAPANESE TROLL FIFSHERY FOR PACIFIC BLUEFIN TUNA AND ABUNDANCE INDICES OF AGE-0 TUNA DERIVED FROM THE FISHERY

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An index derived from the Japanese troll fishery data could be a good indicator of abundance of Pacific bluefin tuna *Thunnus orientalis* (PBF) recruitment, since distribution of age 0 fish is confined to very coastal waters where the troll fishery operate with good time-area coverage of their habitat. The spawning of PBF occurs in the northwestern Pacific, and juveniles are transported to the Japanese waters. The juveniles of 20 – 30 cm fork length begin to recruit to the Japanese troll fishery. The Japanese troll fishery has developed along the Japanese coastal waters using vessels less than 10 GRT for small tunas. The yearly catches by this fishery fluctuate very largely, which seems to indicate yearly changes of recruit abundance. The indices will be of benefit to the stock assessment and management of this species, i.e. as a tuning index of VPA analysis and a future stock projection.

The catch from Nagasaki Prefecture faced the East China Sea and the Tsushima Straight has composed around 60-80 % of the total catch by troll fishery in each year. Catch in weight and fishing effort data were collected daily by a method of port sampling at 25 ports during 1980 – 2002 in the prefecture. The data at 25 ports were combined into four areas. Each area has about 80-150 trolling vessels in 1990's. Daily data collected was aggregated by the month-area strata. Only the data from the main fishing season from September to the following April were used (as a unit year), which were further sub-divided into two seasons of Sep. - Dec. and Jan. - Apr. The catch data corresponding to age 0 fish were also selected, based on the size category information. We applied general linear model (GLM) to natural log transformed CPUE (kg/vessel-days) to derive the abundance indices.

The age specific standardized CPUE in this study is more likely useful indictor of the recruitment, though the standardized CPUE trend was not so much different from nominal average. A large fluctuation of yearly changes of CPUE after 1992 was observed, which was compared with relatively stable CPUEs until 1992. Highly CPUEs of 1980, 1994, 1996 and 1999 were observed through all period analyzed.

MIGRATION ROUTE AND DIEL SWIMMING BEHAVIOR IN THE SPAWNING AREAS OF THE PACIFIC BLUEFIN TUNA AROUND THE RYUKYU ISLANDS, JAPAN, USING POP-UP SATELLITE TAGGING AND ULTRASONIC TELEMETRY

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The Pacific bluefin tuna *Thunnus orientalis* is one of the most important fishery resources and a highly migratory species present in spawning assemblages in the Ryukyu Islands, southern Japan from April through June. Results of migration and diel swimming behavior for the adult Pacific bluefin tuna from experiments using pop-up archival satellite tagging methods and ultrasonic telemetry are presented.

Twelve adult fishes (160-240 kg in body weight) caught with commercial tuna longlines in the southern Ryukyu Islands were released with attaching pop-up tags 2001-2003. Four tags successfully released from the fish within 40 days from a release. The bulefin tunas migrated southwards as well as staying near the releasing area during 2 weeks. One fish crossed the equator within 44 days. Four adult fish (130-180 kg) were released in the northern area in 2002. The tags popped up eastward waters south of mainland of Japan as well as the East China Sea.

Seven ultrasonic tagged bluefin tunas were caught with commercial tuna longline from the southern Ryukyu Islands. Ultrasonic tracking was conducted using a research vessel “Shoyo Maru” in 2001 and “Shunyo Maru” in 2002 and 2003. The bluefin tunas swam usually south/southeast or almost stayed around the spawning ground after release. Around sunrise and sunset hours, the fish usually began to descend and ascend to the deeper waters quickly.

The two tracking devices, ultrasonic transmitter and pop-up tag, were attached to six adult bluefin tunas. Both tags data were successfully determined from two bluefin tunas, one for 256 hours and 1,357 km tracked and the other for 29 hours and 242 km tracked. The pop-up tag geolocation data revealed the difference from the noon positions by the GPS during the tracking.

AGE AND GROWTH OF BROADBILL SWORDFISH, *Xiphias gladius*, FROM AUSTRALIAN WATERS

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We determined the age and growth of broadbill swordfish, *Xiphias gladius*, from fish collected from the longline fishing grounds off eastern and western Australia between 1997 and 2002. Although otoliths were useful for determining the age (in days) of fish up to 1 yr of age, the second anal fin ray was found to be the most convenient for all ages. Two measures of marginal increment formation provided indirect evidence of an annual cycle of ring deposition. The oldest female we sampled was 18 yr old; the oldest male was 16 yr old. The Von Bertalanffy Curve fitted to age at length (orbital fork length) for swordfish off eastern Australia gave growth parameters of L_∞, K and t_o of 296.0, 0.08, and -3.7 respectively for females and 224.2, 0.13 and -3.0 for males. The growth curve was not significantly different from a preliminary estimate of age at length for western Australian swordfish, and overlapped a group of growth curves generated for swordfish from the Atlantic, Pacific and Indian Oceans. From the resulting age length keys we retrospectively aged the catch of the fishery from 1997 to 2001. Age frequency histograms showed a decline in the age of the catch from mainly 4 to 6 yr old fish to fish mainly between 2 and 4 yr old over the study period. Off Western Australia, fish between three and seven years generally dominated the catch, with no trend evident in median age class over the same period. Both studies highlighted that the swordfish catch was dominated by immature females. Off eastern Australia the mean age of fish caught decreased over the study period, a characteristic of an intensively fished population. This pattern of declining age with time was not evident off Western Australia, possibly reflecting relatively lower fishing pressure in the latter region over the same period.

ANALYSIS OF SPORTFISHING CATCH RATES OF DOLPHIN FISH (*Coryphaena hippurus)* AT CABO SAN LUCAS, BAJA CALIFORNIA SUR, MEXICO

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The Dolphin fish (*Coryphaena hippurus*) is found in tropical and subtropical waters of the world, and is generally restricted by the 20°C isotherm. It represents one of the main sport and commercial fisheries worldwide. The sea surface temperature suggests migrations of this species, therefore affected by anomalous events like El Niño, which usually appear in the Pacific Ocean. The aim of this study is to determine the seasonal and interannual variations of the catch rate and the effect on these of the sea surface temperature and photosynthetic pigment concentration. The database used was the catch rate (number of organisms/trip) made by the main fleets that operated in Cabo San Lucas, B.C.S. from 1990-2000 (Solmar, Gaviotas, Pisces). With the purpose of identifying the existence of some tendency in the effort applied based on the tourist affluence, which could generate a bias in the use of the catch rates, as relative indices of abundance, were analyzed the daily data base on the effort (number of trips) that registers the Harbor authorities. Although interannual variation was not significant, the seasonal effect showed significant differences, with highest average catch rates in summer-autumn. A significant relationship between catch rate and sea surface temperature was found ($r = 0.66$). Although the relationship between the catch rate and the photosynthetic pigment concentration was significant ($r = 0.71$) with a delay of 5 months, this doesn't seem to be a "real correlation" due to the fact that the food chain in this area it is very short.

Poster Abstracts

(Alphabetical by first author's surname)

SPATIAL GENETIC DIFFERENTIATION OF EASTERN PACIFIC YELLOWFIN TUNA (*Thunnus albacares*), BASED ON THE VARIATION OF SEVEN MICROSATELLITE LOCI

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Five eastern Pacific yellowfin tuna samples and one Atlantic sample collected between 1994 and 2002 were analyzed for variation at eight microsatellite loci to assess the spatial genetic homogeneity. Samples were collected from fishing vessels operating in north equatorial and south equatorial waters. There were significant deviations of genotypic frequencies from Hardy-Weinberg at six of 48 tests after correction for multiple testing, three of which were from locus *Tth38*, which was thus subsequently excluded from the analyses. Mean observed and expected heterozygosity per locus ranged from 0.205 to 0.900 and from 0.272 to 0.865 respectively. Mean observed heterozygosity overall loci varied from 0.469 for Gulf of California sample, to 0.557 for the Atlantic sample. Significant homozygosity excess was found at locus *Tth5* in two collections, and at *Tth8* and *Tth21* in one collection (initial $\alpha = 0.05/8 = 0.0062$), but no heterozygosity excess was found. Significant differentiation in allele frequency was found by homogeneity exact tests at loci *Tth8* ($p = 0.0048$) and *Talb35* ($p = 0.0049$) across all samples, and marginally significant at locus *Tth5* (initial $\alpha = 0.05/7 = 0.007$). Pair-wise comparisons of multilocus allele frequency homogeneity revealed highly significant differentiation in comparisons between north equatorial and south equatorial samples, and no differences resulted from comparisons between Pacific and Atlantic samples (initial $\alpha = 0.05/15 = 0.003$, table 3) with the exception of the Gulf of California sample. Mean estimation of subpopulation division (F_{ST}) revealed significant differentiation ($p = 0.005$) resulting mainly from loci *Tth5* and *Tth8*. AMOVA analysis among Pacific collections grouped into two regions (north and south-equatorial eastern Pacific) displayed significant differentiation between them ($p = 0.011$; initial $\alpha = 0.05/2 = 0.025$). Furthermore, evidence of a small signal of differentiation between coastal and offshore samples as reported before, was confirmed. These results should be considered as evidence of the presence of discrete populations in the eastern Pacific yellowfin tuna. However, since no temporal collections are available, is not possible to attribute the signal of differentiation to temporal variation. Further studies including temporal replicates of collections from north and south equatorial regions, will provide valuable information about the stock structure of eastern Pacific yellowfin tuna populations in order to address the actual management strategies.

PALMYRA REVISITED: USING A GENERALIZED ADDITIVE MODEL TO PREDICT BIGEYE CPUE AT THE PALMYRA FISHING GROUNDS

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The fishing grounds around the Palmyra Atoll can account for up to 20% of bigeye and over 55% of yellowfin tuna landed in the Hawaii Longline Fishery since 1994. The observed availability of these two species of tuna appears to fluctuate based on environmental conditions, with catches around Palmyra dominated by yellowfin tuna, except in years of El Niño events. This variability in catch, when compounded with the travel time and cost for Hawaiian vessels, diminishes the desire to fish these productive waters. Modeling techniques were employed to attempt to decipher which parameters are important in determining the catch composition and to produce a basic prediction of the magnitude of bigeye catch. Generalized additive models (GAM) were used within a k-fold cross-validation framework to construct a predictive model of bigeye tuna (*Thunnus obesus*) catch rate on longline fishing gear around Palmyra Atoll. This approach was contrasted with commonly used stepwise model construction techniques to examine the effects of overfitting. Preliminary results revealed that two environmental parameters with date and locations were sufficient to account for close to 70% of the bigeye CPUE. The main environmental parameter required by the model was an ecosystem indicator derived from an empirical orthogonal analysis (EOF) of altimetry data in the Pacific equatorial region. A parsimonious model using several predictor variables was also constructed and found to be satisfactory for predicting longline fishing success.

FISHER INFORMATION AS AN INDICATOR OF REGIME CHANGE IN MARINE ECOLOGICAL SYSTEMS

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Fisher Information is a statistical metric derived from information theory, which can be formulated and interpreted as a measure of the state of order of a system. It has recently been proposed as an indicator of regime change/shifts in ecological systems (Fath *et al*. 2003 — J. Theoretical Biol. 222:517–530). We investigate the utility of the metric as an indicator of regime change in marine ecological systems. We reanalyze the climate and fisheries data used to identify a regime shift in the North Pacific in the late 1970s to see whether there is any change in Fisher Information over the same period. We find that there is a clear increase in Fisher Information at that time, with the signal in the climate data preceding that in the fisheries data by 1–2 years. This result supports the use of Fisher Information as an ecosystem indicator and we now intend to investigate additional systems, in particular the climate-recruitment system for tunas in the western and central Pacific Ocean. However, some important issues remain unresolved at present, such as the statistical and ecological relevance of time series analyzed, the statistical significance of changes in Fisher Information, and the physical interpretation of the results in terms of underlying process; further research should address these shortcomings.

HIGHLY MIGRATORY FISH IN SOUTHWEST ROCK ART

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Native Americans in the Pacific southwest region not only hunted highly migratory fish. These fish became subjects in the rock art they created. The Chumash lived in coastal villages that extended from Malibu north to Morro Bay and on the northern Channel Islands. They were capable of harpooning swordfish from their light but seaworthy plank canoes (tomols). According to ethnographic accounts, swordfish also played an important role in Chumash rituals and shamanistic customs. Swordfish were depicted in pictographs (paintings) located in what is now Oakbrook Park near Thousand Oaks, California and on Vandenberg Air Force Base. While most Chumash pictographs were done in a semi-abstract form, the swordfish images were done in a figurative style. The small red swordfish in Oakbrook Park was painted on a large sandstone boulder.

Some 500 miles to the south, one encounters a totally different style of fish images. The Piedras Pintas site near Mulege, Baja California Sur contains nearly 1,500 petroglyphs (incised or pecked images) of assorted fish species, including swordfish, sailfish and tunas. This is arguably the largest concentration of fish images in the global annals of rock art. Unlike the Chumash, little is known about the creators of this remarkable site. Rock art was apparently not practiced by the Cochimi, the local tribe that lived here when the Spanish arrived. The images occur on volcanic boulders that form a bluff alongside a possible trail between upland seasonal camps and fishing camps on the Gulf of California. The desert site itself is some two hours walking time from the Gulf coast. The manner in which different fish species are portrayed reflects an intimate knowledge of fish shapes. Most are portrayed in a vertical posture, rather than the horizontal position common in Western images. Nets, spears and other fishing gear are also depicted. Clearly fish played an important part in the spiritual as well as material world of the creators given the time and effort to create these images. While the term rock art is used in both popular and scientific literature, it is somewhat misleading. The images, while impressive to us today, were not created for aesthetic reasons. They were an integral part of rituals and ceremonies, including vision quests by shamans.

ECOLOGICAL PATTERNS IN FLOTSAM-ASSOCIATED FISH ASSEMBLAGES FROM THE EASTERN PACIFIC

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Multivariate analyses of tuna purse-seine catch data (1993-2002), including bycatch species, from sets on floating objects in the eastern tropical Pacific (ETP) are being conducted to look for patterns community composition. We are particularly interested in geographic effects, temporal variation, evidence for succession or a predictable pattern in recruitment to floating objects, and possible effects of repeated sets on the same object. Preliminary results suggest that there are two types of fish assemblages, determined largely by the presence/absence of two tuna species groups; the remaining species making up these assemblages remaining relatively constant. While no clear pattern of recruitment has been identified as yet, strong longitudinal effects are evident for some species. Significant spatial heterogeneity in the oceanographic characteristics of the ETP suggests that some corresponding differences in the pelagic fish community would be likely; initial results do not support this hypothesis and geographical effects appear minor compared to interannual differences.

A NEW ENVIRONMENTAL INFORMATION SYSTEM FOR TRACKING TAGGED MARINE ORGANISMS

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We will demonstrate new software for analyzing the data recorded by marine archival tags. This analysis system provides the tools to download data from tags and satellite imagery and integrate both types of information to obtain a more reliable estimate of the location of the tag than can be achieved by using the information from the tag alone. It also provides a dynamic, 4 dimensional (i.e. latitude, longitude, depth, and time) home for viewing this information. Our Marine Tracker software is an application of EASy (Environmental Analysis System) that has been developed specifically for marine applications by System Science Applications.

The processing of tags takes three steps, importing of tag data into a relational database and downloading imagery into a file server, computing the best path using a sophisticated search routine that we have developed, and displaying the results of the computation along with all associated tag and environmental information. Downloading and geo-referencing of tag data and imagery is automated. The computational scheme, which was written in visual basic and then plugged into the analysis system, matches tag information on the time series of temperature at the sea surface with time series information on the spatial distribution of temperature available from ocean thermal imagery. A global search of all possible paths is solved by finding the path that not only provides the best match between temperatures but also provides the most reasonable daily travel distances given the swimming speed of the tagged organism. All parameters that determine the best path are entered by the user into a simple graphical user interface. The graphical display of tracks superimposed upon imagery as well as the plots of tag data are displayed dynamically.

ULTRASONIC TAGGING OF PELAGIC FISHES AT SEAMOUNTS IN THE SOUTHERN GULF OF CALIFORNIA: AN INTEGRATIVE APPROACH

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Seamounts and islands in the southern Gulf of California attract an abundance and diversity of pelagic fishes, including sharks, billfish, tunas, and jacks. Fish may aggregate at seamounts because of greater opportunities to feed or because topographic features provide landmarks during migration. The potential of seamounts as marine protected areas emphasizes our need to understand the role they play within the ecosystem. Our effort to examine the pelagic fish assemblage at the Espiritu Santo Seamount (ESS) near La Paz, BCS, Mexico is part of a collaborative effort that has included comprehensive oceanographic and planktonic studies. Our integrative approach targets a diverse population of the pelagic community through visual census, fisheries observation, diet analyses using both gut contents and stable isotopes, and ultrasonic tagging studies. Seasonal underwater visual census has been conducted at ESS since 1998 and has delineated two seasonal fish assemblages, a winter community associated with cooler water and a summer community that appears at the seamount as the water warms. Fisheries catch data coarsely parallels water temperatures and can be used to track seasonal migrations of species into the southern Gulf. Stable isotope analyses are being used to compliment gut contents data in order to determine trophic structure and interactions in the seamount ecosystem. >800 gut samples and >100 muscle samples from fifteen predatory species of six families of pelagic fishes have been collected for diet analyses. Twenty-three yellowfin tuna were tagged with coded ultrasonic beacons between April and September 1998. Tunas were captured, tagged and released near two acoustic monitoring stations at the north and south peaks of ESS. The monitors were deployed between April 1998 to October 2000, during which time they recorded tagged tunas swimming within their 150m range of reception. The tunas stayed at ESS for varying time periods. Nine tunas left the seamount on the same day they were tagged, with two of the nine returning to the seamount twice for a single day. Five additional tunas stayed at the seamount for intermediate periods, ranging from 6 to 18 months. Tunas were present at the seamount at all times of day, and typically moved in and out of the range of the monitors. Most visits were <1 hour in duration, and intervals spent away from the seamount were also brief. The monitors were redeployed in September 2002 to investigate the residence of multiple species across trophic levels. Five planktivorous green jacks (*Caranx caballus*), five predatory yellowtail (*Seriola lalandi*), and two predatory hammerhead sharks (*Sphyrna lewini*) were tagged at ESS with coded beacons between September and November 2002. Records of these fish species have shown short-term residence patterns that are currently being analyzed. Ultrasonic tagging is a practical method for determining the residence of mobile pelagic species at seamounts. Integrating this technique with diet analyses will further understanding of how pelagic fishes use their environment.

ASSOCIATION BETWEEN BLUEFIN TUNA SCHOOLS AND OCEANIC FEATURES IN THE GULF OF LIONS

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We report some evidence of association between bluefin schools and oceanographic features in the Gulf of Lions, a well-known feeding area for juveniles of the year (< 1m FL). This study was conducted using fishery-independent data collected during aerial surveys in summer 2000, 2001 and 2002. Sightings data were correlated on a daily basis to sea surface temperature and ocean colour images, as derived from high-resolution radiometers (i.e. AVHRR and SeaWiFS). An edge detection technique was also applied to delineate eddies and frontal zones. We then performed geostatistics and point process analyses to evaluate the role of the environment in structuring the BFT spatial pattern. The distribution of spotted schools was strongly non-stationary both in space and time: this is believed to be an effect of the survey design (transect sampling) and the influence of transient oceanographic structures (surface fronts and eddies). The empirical variograms indicated a spatial range of the BFT schools at around 40 km, with substantial daily variability. The Ripley's K statistic revealed that the fish schools were clustered over a wider range of scales (from 10 to 80 km), indicating more spatial structure than expected from a random process. Finally, BFT schools distributions appeared well determined by the oceanic features, except at very small scales (< 10km) where over-aggregation occurred, and at the largest scales of our study (> 40km) where over-spreading was detected. Dynamical ecological processes, such as foraging, are likely to induce this complex spatial pattern: bluefins were reported in these surveys to hunt upon schools of small clupeids.

AN OCEANOGRAPHIC CHARACTERIZATION OF THE LONGLINE FISHING GROUNDS FOR ALBACORE, *Thunnus alalunga*, AROUND AMERICAN SAMOA

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The American Samoa domestic longline fishery has recently undergone extraordinary growth, particularly in the fleet composition of large (>50 ft in length) vessels that have fueled a fivefold increase in fishing effort and landings from 1999 to 2001. Prior to the sudden expansion, most longline fishing around American Samoa were accomplished through a fleet of smaller, 30 ft, open-decked catamarans known as *alia*. To illustrate the expansion, over 50 boats actively participated in the fishery during 2001 deploying 4,690 sets (over 5 million hooks) resulting in catch rates of about 40 fish/1000 hooks. By comparison, only 23 vessels made up the fishery in 1999, making 2,102 sets (ca. 912,742 hooks) yielding 32.38 fish/1000 hooks. Albacore tuna, *Thunnus alalunga* is the target species in the fishery and dominates the catch.

Oceanographically, there has been little study regarding the pelagic habitat in the American Samoa region, much less the spatial and temporal variability of the oceanographic climate. The current research undertakes the task of characterizing the pelagic habitat and fishing grounds occupied by the American Samoa longline fishery through the use of satellite oceanographic remote sensing and *in situ* shipboard surveys. Ultimately, the oceanographic assessment will be coupled with fishery information to develop a functional understanding of the spatial and temporal occupation and movement tendencies of large South Pacific albacore and the role of the environment on longline gear performance and catch. These data include albacore depth distribution and gear performance obtained from commercial longlines instrumented with time-depth-temperature recorders (TDRs) and the set level catch information from the American Samoa fishery logbook program. Current status of the study and in particular, results from the first of the oceanographic surveys conducted during April 2004, are presented.

STUDIES ON SURVIVORSHIP OF SEA TURTLES POST-RELEASE FROM LONGLINE FISHING GEAR

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The incidental capture of marine turtles in longline fishing gear has been implicated as a contributing factor to the decline of sea turtle populations in both the Pacific and Atlantic Oceans. In surface-set fisheries, such as those targeting mahi mahi (*Coryphaena hippurus*) or swordfish (*Xiphias gladius*), nearly 100% of longline-caught turtles are landed on-board and released alive. Because many turtles are released with hooks remaining in their gastrointestinal tracts or flippers, there is the potential for delayed mortality. Our research aims to quantify the survivorship of hard-shelled marine turtles after they have been incidentally caught and released from commercial longline fishing gear.

To achieve our goals, we are involved with two types of investigation—one that monitors the post-release movements (and survivorship) of turtles in the open ocean, and the other that monitors the long-term health of incidentally-caught turtles that have been brought into captivity. To accomplish our first set of goals, we have trained sea-going personnel to deploy pop-up satellite archival tags (PSATs) on incidentally-caught turtles. Personnel include NOAA-mandated fishery observers operating from Hawaii and California, as well as collaborating scientists from Costa Rica and Brazil. 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. Since November 2001, we have attached approximately 25 PSATs on three species of turtles incidentally captured in commercial gear. To date, we have 2 tracks that suggest a mortality: one of a loggerhead turtle (*Caretta caretta*) 6 months after the longline interaction, and the other of an olive ridley turtle (*Lepidochelys olivacea)* that was tagged while free-swimming and thus served as a control.

In our second line of inquiry, we have recently begun a collaboration with commercial longline fishermen in Brazil to bring incidentally-captured hard-shelled sea turtles into captivity to be monitored over time. Loggerhead turtles are brought into "pens" measuring approximately 8x12 m in an enclosed bay in the state of Sao Paolo, Brazil. Factors such as time of hook expulsion, visible infection, and mortality post-hooking event are monitored.

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