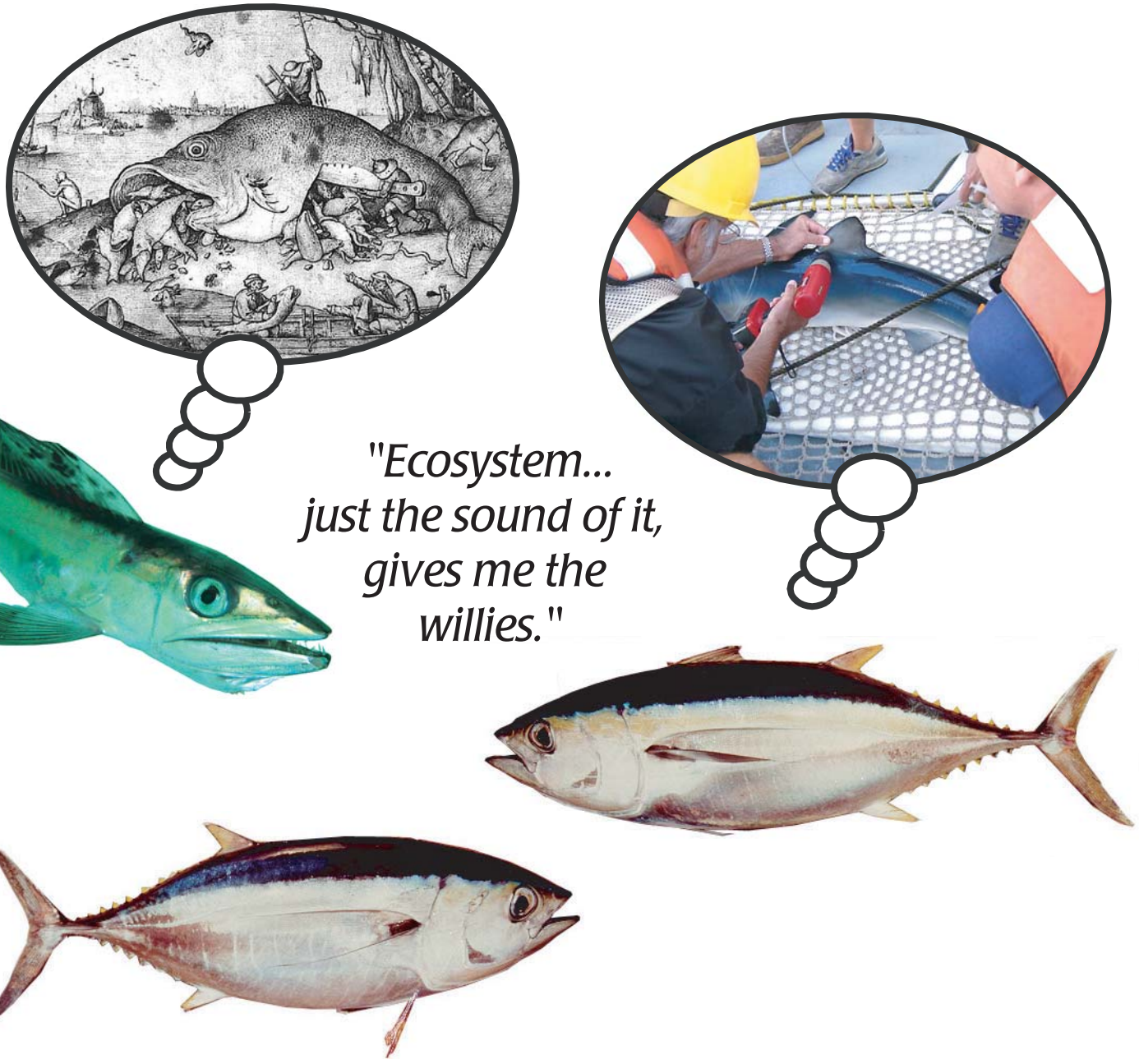
Proceedings of the 53rd Annual Tuna Conference
Lake Arrowhead, California, May 20-23, 2002

Ecosystem-Based Research in Support of Pelagic Management Plans



Keith Bigelow and Randy Chang, Co-chairs
Sponsored by the Southwest Fisheries Science Center NMFS and
the Inter-American Tropical Tuna Commission

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National Marine Fisheries Service
Honolulu Laboratory
Southwest Fisheries Science Center
2570 Dole Street, Honolulu, HI 96822

PREFACE

Greetings and welcome to the 53rd Tuna Conference. This conference occurs in an informal environment where international scientists from diverse fields can exchange concepts and foster collaboration for future research. Each Tuna Conference has a theme and I initially thought of "Tuna and Their Friends", a broad topic virtually everyone could address. However, my colleagues persuaded me towards something more timely, thus the theme developed into "Ecosystem-based Research in Support of Pelagic Management Plans". Ecosystem-based management has received increased attention recently as an alternative option within fisheries management, but applications of such approaches are uncommon. Admittedly, I do not have a firm understanding of ecosystem-based management, but objectives typically include concepts of sustainability and maintenance of biodiversity and ecosystem structure. Tuna fishing affects each of these management concepts. There are a number of presentations that address the theme and I hope that we all can acquire a better understanding of the complexity of ecosystem-based research as required within a management framework.

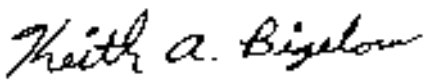
I edited the abstracts contained in these Proceedings mainly for formatting. All abstracts appear in alphabetical order by the first authors surname. I attempted to clarify a few abstracts that were submitted by participants where English is a second language and take responsibility for any errors that may result.

The Tuna Conference is not organized by one person, rather some new people such as Randy and myself are assisted by a cast composed of former chairpersons, vital logistical support from the IATTC and NMFS and the patient UCLA Conference Center. Randy and I would like to thank former chairs Christofer Boggs, Sharon Holt and Mark Maunder for advice. We would also like to thank Ed Everett for assisting with organizing transportation and refreshments for social events, Mike Hinton and John Childers who transported many people to Lake Arrowhead so they could participate, Randall Rasmussan for updating the web site, Wende Goo for assistance with the Proceedings and Jerry Wetherall and Mike Hinton for Scholarship Committee duties. The efforts of the session moderators are also appreciated – Christofer Boggs, Tim Essington, Michael Hinton, Pierre Kleiber and Bob Olson.

The Tuna Conference Scholarship was awarded to Chugey Sepulveda for his research on "The swimming energetics of the eastern Pacific bonito (*Sarda chiliensis*): one step closer to understanding the tuna-bonito relationship. The Caboz Memorial Scholarship was awarded to Charlotte Girard for her research on "FADs: fish aggregating devices or fish attracting devices?". The Tuna Conference is pleased to support the participation of these students.

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

Have a productive conference.



Keith Bigelow, Co-chair

AGENDA

Monday, 20 May 2002

11:00 – 13:00 Registration

13:00 Conference Begins - Welcome and Introduction

Session 1: Ecosystem Modeling (Moderator: Chris Boggs)

13:15 THE PELAGIC ECOSYSTEM IN THE EASTERN TROPICAL PACIFIC OCEAN: A MODELING APPROACH – Robert J. Olson and George M. Watters

13:40 FISHERY EFFECTS ON PELAGIC FOODWEBS IN THE PACIFIC: APPLICATION OF AN ECOSYSTEM MODEL **–** Isaac C. Kaplan, Sean P. Cox, Timothy E. Essington, James F. Kitchell, Steven J.D. Martell, Carl J. Walters and Christofer Boggs

14:05 DEVELOPMENT AND SENSITIVITY ANALYSIS OF BIOENERGETICS MODELS FOR SKIPJACK TUNA (*Katsuwonus pelamis*) AND ALBACORE TUNA (*Thunnus alalunga*) **–** Timothy E. Essington

14:30 IDENTIFICATION OF BIODIVERSITY HOTSPOTS IN THE OPEN OCEAN: CAN COMMERCIAL CATCH DATA BE USED TO DO THIS? – Shelton Harley, Boris Worm, Heike Lotze and Ransom A Myers

14:55 Coffee Break

15:20 COUPLED PLANETARY WAVES AND TUNA LONGLINE CATCHES IN THE SOUTH INDIAN OCEAN – Francis Marsac, Warren B. White and Yves M. Tourre

15:45 AN OCEANOGRAPHIC ATLAS FOR FISHERIES APPLICATIONS IN THE PACIFIC OCEAN – Ramzi Mirshak, Dave Foley, Rusty Brainard and John Sibert

16:10 BEHAVIORAL CHANGES DURING TUNA MIGRATION REVEALED BY STATISTICAL ANALYSIS OF TRACKS DERIVED FROM POP-UP ARCHIVAL TAGGING DATA – John Sibert, Molly Lutcavage, and Rich Brill

16:35 AUTOMATED THRESHOLD-FREE GEOLOCATION FROM LIGHT **–** Phil Ekstrom

17:00 Announcements

17:15 Registration and check-in continued

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

18:30 Dinner

Socializing in the Tavern. Tagging Party - sponsored by Wildlife Computers.

Tuesday, 21 May 2002

8:00 Breakfast

Session 2: Stock Assessment (Moderator: Tim Essington)

9:00 INTEGRATED ANALYSIS OF WORLD TUNA STOCKS – Mark N. Maunder

9:25 STATUS OF STRIPED MARLIN STOCKS IN THE EASTERN PACIFIC OCEAN **–** Michael G. Hinton

9:50 A COMPARISON OF BIOLOGICAL AND FISHERY INDICATORS FOR SOUTHERN BLUEFIN TUNA - 1988:2001 – John Gunn, Tom Polacheck, Tim Davis, Ann Preece, Dale Kolody, Jessica Farley, Naomi Clear and Bill Hearn

10:15 COFFEE BREAK

10:40 AN INTEGRATED APPROACH TO USING A NEURAL NETWORK IN AN ADVECTION DIFFUSION REACTION MODEL FOR ESTIMATING LARGE-SCALE MOVEMENTS OF TUNAS: PRELIMINARY INVESTIGATION USING MALDIVES TAGGING DATA – M. Shiham Adam and John. R. Sibert

11:05 MOBILITY OF TROPICAL TUNAS AND THE IMPLICATIONS FOR FISHERIES MANAGEMENT **–** John Sibert and John Hampton

11:30 STANDARDIZING LONGLINE FISHING EFFORT IN STOCK ASSESSMENT MODELS: EFFECT OF OCEANIC CONDITIONS – Pierre Kleiber

12:00 Lunch

Session 3: Fishery Descriptions and Technology (Moderator: **Michael Hinton)**

13:00 HISTORY, DATA COLLECTION, AND SAMPLING OF THE EASTERN PACIFIC OCEAN SURFACE TUNA FISHERY (EPO FOR DUMMIES) – Ed Everett and Jenny Suter

13:25 THE HAWAII AND AMERICAN SAMOA PELAGIC LONGLINE FISHERIES: ECONOMICS ANALYSIS AND RECENT DEVELOPMENTS IN THE FISHERIES **–** Joseph M. O'Malley and Samuel G. Pooley

13:50 RECREATIONAL META DATA COLLECTION: USING TOURNAMENT DATA TO DESCRIBE A POORLY DOCUMENTED FISHERY **–** Daniel Curran, Joseph O'Malley, Paul Dalzell and Samuel Pooley

14:15 TECHNOLOGY, FISHING POWER AND EFFORT IN THE FSM TUNA FISHERY – Tim Park

14:40 DROP NET, TWIST CLOSURE FISHING NET – Kent Thomas

15:05 Coffee break

15:30 – 17:30 Poster and Demonstration Session

SUMMARY OF THE 2001 U.S. NORTH AND SOUTH PACIFIC ALBACORE TROLL FISHERIES – John Childers

HAWAII TUNA TAGGING – ANALYSES AND RESULTS – David Itano, Kim Holland, Shiham Adam and John Sibert

COMPARISON OF GROWTH MARK PATTERNS ON SCALES OF DOLPHINFISH (*Coryphaena hippurus*) OFF NORTHWEST MEXICO – Concepción Enciso Enciso, Sofía Ortega-García*, Rubén Rodríguez-Sánchez and Minerva Torres-Alfaro

SUCCESSFUL COMPLETION OF OCEAN FRIENDLY CO.'S "DROP NET TWIST CLOSURE DROP FISHING NET," IN NEW ZEALAND WATERS – Kent Thomas

18:30 Dinner

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

Wednesday, 22 May 2002

8:00 Breakfast

Session 4: Ecosystem and Bycatch Considerations (Moderator: Pierre Kleiber)

9:00 DISCARDS OF TARGET AND INCIDENTALLY CAUGHT FISHES BY THE HAWAII-BASED LONGLINE FISHERY **–** William A. Walsh and Samuel G. Pooley

9:25 AUSTRALIA'S EAST COAST YELLOWFIN – LINKS TO THE WESTERN PACIFIC OCEAN. THE ORIGIN OF RECRUITS TO AUSTRALIA'S EAST COAST YELLOWFIN TUNA FISHERY **–** Naomi Clear and John Gunn

9:50 EVIDENCE FOR REGIONAL STRUCTURE WITHIN POPULATIONS OF YELLOWFIN TUNA IN THE SW PACIFIC? – John Gunn, Naomi Clear, Peter Grewe, Bob Ward, Sharon Appleyard and Bronwyn Innes

10:15 Coffee Break

10:40 NMFS HONOLULU LABORATORY RESEARCH TO REDUCE LONGLINE FISHING SEA TURTLE BYCATCH AND MORTALITY – R. Michael Laurs, Yonat Swimmer, and Rich Brill

11:05 FISHING EXPERIMENTS ON REDUCING PELAGIC LONGLINE INTERACTIONS WITH PROTECTED SPECIES – Christofer H. Boggs and R. Michael Laurs

11:30 INVESTIGATING THE LIFE HISTORY AND ECOLOGY OF OPAH AND MONCHONG IN THE NORTH PACIFIC – Michael P. Seki, Donald R. Hawn and Robert N. Nishimoto

12:00 Lunch

Session 5: Trophic Ecology and FADs (Moderator: Bob Olson)

13:00 ON-GOING RESEARCH ON TROPHIC ECOLOGY OF TUNA AND SWORDFISH IN EQUATORIAL ECOSYSTEMS OF THE ATLANTIC AND INDIAN OCEANS – Michel Potier, François-Xavier Bard, Richard Sabatié, Frédéric Ménard and Francis Marsac*

13:25 TROPHIC ECOLOGY OF STRUCTURE-ASSOCIATED TUNA: EXPERIMENTAL RATIONALE AND PRELIMINARY RESULTS – Dean Grubbs and Kim Holland

13:50 FEEDING AND BREEDING MIGRATIONS OF ATLANTIC BLUEFIN TUNA – Barbara A. Block, Steven L. H. Teo*, Jason Blank, Jeff Morrissette, Ana Landiera, Andreas Walli, Chuck Farwell, Andre Boustany and Tom Williams

14:15 THE SWIMMING ENERGETICS OF THE EASTERN PACIFIC BONITO (*SARDA CHILIENSIS*): ONE STEP CLOSER TO UNDERSTANDING THE TUNA-BONITO RELATIONSHIP – Chugey Sepulveda

14:40 THE DOLPHINFISH FISHERY IN THE MOUTH OF THE GULF OF CALIFORNIA, MEXICO – Sofía Ortega-García, Alexander Klett-Traulsen, Rodolfo Beltrán-Pimienta, Sergio Hernández-Vázquez and Oscar Sosa Nishisaki

15:05 Coffee Break

15:30 FADS: FISH AGGREGATING DEVICES OR FISH ATTRACTING DEVICES? – Charlotte Girard, Laurent Dagorn and Simon Benhamou

15:55 ABOUT RESIDENCE TIMES OF TUNAS AROUND FADS – Laurent Dagorn, Kim Holland and David Itano

16:20 CURRENT TRENDS IN FAD-RELATED RESEARCH IN HAWAIIAN WATERS – Kim Holland and Laurent Dagorn

18:30 Dinner – Tuna conference BBQ

Socializing in the Tavern and campfire at the Amphitheatre

Thursday, 23 May 2002

8:00 Breakfast

Session 6: Biology and Economics (Moderator: to be determined)

9:00 TEMPORAL VARIATION OF *IN SITU* GROWTH RATES OF YELLOWFIN TUNA (*Thunnus albacares*) LARVAE COLLECTED IN THE PANAMA BIGHT REGION **–** Jeanne Wexler, Seinen Chow and Dan Margulies

9:25 VALIDATION FOR DAILY INCREMENT FORMATION WITHIN OTOLITHS OF SKIPJACK TUNA (*Katsuwonus pelamis*) **–** Toshiyuki Tanabe, Sadaaki Kayama, and Miki Ogura

9:50 OVERVIEW OF 2001-2002 RESEARCH AT THE IATTC'S ACHOTINES LABORATORY – Vernon Scholey, Dan Margulies, Jeanne Wexler and Sharon Hunt

10:15 Coffee Break

10:40 REPRODUCTIVE DYNAMICS OF BROADBILL SWORDFISH, *Xiphias gladius*, IN THE EASTERN AUSTRALIAN FISHING ZONE **–** Jock Young, Anita Drake and Toby Patterson

11:05 ANALYZING TECHNOLOGICAL AND ECONOMIC INTERRELATIONSHIPS IN HAWAII'S LONGLINE FISHERY **–** Naresh C. Pradhan, Khem R. Sharma and PingSun Leung

11:30 Business Meeting

12:00 Lunch

13:00 End of Conference – Check Out

Abstracts
(in alphabetical order by first author's surname)

AN INTEGRATED APPROACH TO USING A NEURAL NETWORK IN AN ADVECTION DIFFUSION REACTION MODEL FOR ESTIMATING LARGE-SCALE MOVEMENTS OF TUNAS: PRELIMINARY INVESTIGATION USING MALDIVES TAGGING DATA

M. Shiham Adam and John. R. Sibert

Pelagic Fisheries Research Program
Joint Institute for Marine and Atmospheric Research
SOEST, University of Hawaii at Manōa
Honolulu, Hawaii.

We explored integration of a simple feed forward neural network in an advection diffusion reaction model to estimate large-scale movement of tunas using conventional tagging data. The neural network is used to compute the movement parameters from series of inputs signals. The inputs, considered as proxies for the spatio-temporal patterns in the model domain, include time (calendar years and months), space (latitude / longitude), water depth, seabed topography, and distance from land. The estimates of the movement parameters from the neural network are coupled with the tag-attrition parameters (natural and fishing mortality rates) to predict tag recoveries from the numerical approximation of the advection diffusion reaction model. The training of the neural network and simultaneous estimation of model parameters is achieved by minimizing the negative log of a Poisson likelihood function that relates the observed and predicted tag recoveries. Trials conducted with various neural net configurations show that a three-layer neural network with five-nodes in the input layer performs adequately well for the Maldives tagging data set. Significant improvements in fit of the model, compared with an earlier analysis of the same data set where movement parameters were mapped into two-seasonal (bi-annual) and two-regional parameters, is very encouraging. The flexible modeling framework allows incorporating any number of input nodes, such as forage density or any oceanographic variable, deemed important for explaining tuna movements observed in the tagging data.

FEEDING AND BREEDING MIGRATIONS OF ATLANTIC BLUEFIN TUNA

Barbara A. Block, Steven L. H. Teo, Jason Blank, Jeff Morrissette, Ana Landiera, Andreas Walli, Chuck Farwell, Andre Boustany and Tom Williams

Tuna Research and Conservation Center, Hopkins Marine Station, 120 Oceanview Blvd. Pacific Grove, CA 93950

Archival tags reveal that Atlantic bluefin make extensive feeding migrations for up to six months into cold temperate and subpolar waters. These same fish make shorter breeding migrations into warm temperate and tropical waters. These two ecological phases place distinct demands on the bluefin tuna's physiology. Feeding migrations are to three major regions: the continental shelf waters of New England and North Carolina and the North Central Atlantic south of Iceland. Breeding migrations are to the Gulf of Mexico, Bahamas, Caribbean and the Mediterranean. Archival tagging data indicates that bluefin tunas often encounter the coldest temperatures during feeding migrations (3°-12°C) while maintaining endothermic muscle and visceral temperatures of 23°-30°C. During breeding migrations, ambient and body temperatures approach 30°C creating a high metabolic demand for oxygen. The hearts of bluefin operate at ambient temperature due to close proximity to the gills and the absence of a heat exchanger in the coronary circulation. This creates a physiological paradox as the tuna heart must meet the oxygen demands of warm, aerobic tissues in both cold and warm waters. We investigated the effects of temperature on cardiac function in Pacific bluefin tuna using an *in situ* perfused heart preparation. Perfused bluefin hearts have a heart rate of ~23/min at 5°C and ~110/min at 30°C. At 10°C and 20°C, isolated bluefin hearts maintain higher heart rates than comparable preparations on yellowfin tuna, which exhibit a more restricted thermal niche in the wild. Bluefin tuna hearts maintain high cardiac outputs at both 5 and 20°C. High heart rates, such as those that would occur in the Gulf of Mexico, would likely place large aerobic demands on the myocardium. Our data demonstrate that changes in heart rate and stroke volume are involved in maintaining cardiac output during temperature changes in tunas and that bluefin have enhanced physiological cardiovascular characters that may improve performance in warm as well as cold waters.

FISHING EXPERIMENTS ON REDUCING PELAGIC LONGLINE INTERACTIONS WITH PROTECTED SPECIES

Christofer H. Boggs and R. Michael Laurs

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Honolulu, Hawaii 96822-2396 USA

Longline fisheries are increasingly regulated in the U.S. to reduce interactions with protected species and experiments are underway to develop gear modifications that minimize such interactions. Successful albatross deterrent techniques tested in the Hawaii longline fishery in the late 1990's included bird-scaring streamer lines, weighted branch lines, dying bait with food coloring, and strategic discarding of offal and spent bait. These methods were expected to reduce albatross fishery interactions by over 90%, but swordfish-style longlining was banned in 2001 to reduce turtle bycatch, and this ban eliminated the fishery sector that interacted with albatrosses.

The largest element of the Honolulu Laboratory's fishing experiments to reduce sea turtle bycatch involves 12 swordfish longline vessels testing the use of blue dyed squid bait and branch lines arranged >40 fathoms away from float lines on half of 1,040 research sets per year, with the other half serving as the control. Hawaii fishery observers report branch lines attached <40 fathoms from float lines catch the most turtles and have only average success in capturing target fish species. An Endangered Species Act Section 10 Research Permit obtained by the Honolulu Laboratory in January 2002 allows several smaller experiments to be conducted, but the largest experiment awaits evaluation of a similar experiment in the Atlantic. Unfortunately, the Atlantic experiment did not move branch lines far enough away from the float lines (only 20 fathoms). Meanwhile, research is underway in Hawaii to test the use of stealth (camouflaged) swordfish longline gear and deep daytime swordfish fishing to see if these modifications retain viable economic performance. Stealth gear will also be tested on tuna longline gear later this year. Research is also underway using hook timers and time depth recorders to document when and where turtle bycatch occurs most frequently in the sequence of longline deployment and retrieval. A piggyback project will test whether large (18/0) circle hooks have better catch rates for swordfish than the smaller circle hooks tested by other researchers in 2000-01. Circle hooks reduce the degree of injury to captured turtles. At most, seven vessels will work part time on these experiments and conduct about 250 research sets.

If the swordfish fishery is to be re-opened, improved albatross deterrent methods will be needed. In March 2002 tests were completed on an underwater line setting machine designed to prevent longline interactions with seabirds in a collaborative effort by the Audubon Society, the Hawaii Longline Association, the Western Pacific Fishery Management Council, NMFS, and USFWS. The machine was 99.8% effective in reducing contacts between birds and fishing gear during setting operations and was 100% effective in eliminating captures of albatross.

SUMMARY OF THE 2001 U.S. NORTH AND SOUTH PACIFIC ALBACORE TROLL FISHERIES (poster presentation)

John Childers

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U.S. troll vessels have fished for North Pacific albacore since the early 1900's and for South Pacific albacore since 1986. North Pacific albacore fishing areas range from Vancouver Island to the Mexican border and from the U.S. West Coast to approximately 170° E. The fishing season begins in late April and can last into early November. The size of the troll fleet ranges from 500 to more than 1,000 vessels. Approximately 860 U.S. troll vessels fished for North Pacific albacore in 2001. South Pacific albacore fishing areas extend from the East Coast of New Zealand to approximately 110°W. This fishery begins in late December and continues until early April. The troll fleet in the South Pacific consists of 20 to 60 vessels. Thirty-three U.S. troll vessels fished for albacore during the 2000-2001 season. Fifty-four logbooks (out of 442 logbooks received from the 2001 North and South Pacific fisheries) recorded catching other fish species while fishing for albacore. These species include skipjack, yellowfin, bigeye and bluefin tunas, mahi mahi (dolphinfish), yellowtail, various shark species, salmon, pomfret, wahoo and pompano.

U.S. troll vessels landed 10,888 metric tons (t) of North Pacific albacore in 2001 compared to 9,540 t landed in 2000. Annual catches over the last 10 years averaged 10,500 t. The most productive fishing areas in 2001 were in waters off of Washington and Oregon and offshore near 170°E. U.S. catches of South Pacific albacore decreased from 2,562 t in the 1999-2000 season to 2,251 t in the 2000-2001 season. South Pacific catches averaged 1,970 t over the past 10 years.

Catch-per-unit-effort (CPUE), for the 2001 North Pacific fishery, increased from 39 fish/day in 2000 to 68 fish/day in 2001. CPUE's in the North Pacific fishery have fluctuated greatly since 1995. Total effort decreased by 34% from 36,669 days in 2000 to 24,255 days in 2001. CPUE, for the 2000-2001 South Pacific fishery, decreased from 70 fish/day in 1999-2000 to 48 fish/day.

A total of 14,105 albacore were measured during the 2001 North Pacific season. The average fork length of sampled albacore is 68.5 cm (14.5 lb or 6.6 kg) compared to 68.9 cm (14.8 lb or 6.7 kg) in 2000. Two size class modes are evident at 65 cm (3 years old) and 75 cm (4 years old) fork length in the North Pacific length-frequency samples. A total of 3,670 albacore were measured during the 2000-2001 South Pacific season. The average fork length of South Pacific albacore that were sampled is 71.0 cm (16.2 lb or 7.3 kg) compared to 72.6 cm (17.3 lb or 7.8 kg) in the 1999-2000 season. A single size class mode is centered at 71 cm (4-5 years old).

AUSTRALIA'S EAST COAST YELLOWFIN – LINKS TO THE WESTERN PACIFIC OCEAN. THE ORIGIN OF RECRUITS TO AUSTRALIA'S EAST COAST YELLOWFIN TUNA FISHERY

Naomi Clear and John Gunn

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To investigate the relationships between yellowfin tuna (*Thunnus albacares*) from the western Pacific and those caught in the Australian east coast fishery off New South Wales, otoliths were collected from juvenile yellowfin tuna at five known natal sites around the western Pacific Ocean and from the fishery. Concentrations of 24 elements at the otolith core were measured by either a wave dispersive electron microprobe or by proton induced x-ray microanalysis; the otolith microconstituents were examined to determine 'chemical fingerprints' of natal origin. At three of the natal sites, Indonesia, Philippines and Solomon Islands, otoliths were collected during the same months in different years to examine temporal stability of the chemical fingerprints. Significant interannual variation between elemental concentrations from each site was indicated by results of MANOVA and subsequently otoliths collected in different years at the same site were analysed separately. Eleven elements differed significantly among locations. The elemental concentrations from NSW otoliths were examined using discriminant analysis to determine which of the natal sites they most closely resembled: 74% of the 1994 New South Wales yellowfin and 63% of the 1995 New South Wales yellowfin were found to have otolith chemical compositions closest to the chemical fingerprint of the Coral Sea yellowfin. These results provide evidence that the Coral Sea spawning area is a major source of yellowfin tuna recruits to Australia's east coast tuna fishery.

RECREATIONAL META DATA COLLECTION: USING TOURNAMENT DATA TO DESCRIBE A POORLY DOCUMENTED FISHERY

Daniel Curran[1], Joseph O'Malley[1], Paul Dalzell[2] and Samuel Pooley[3]

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

National Marine Fisheries Service, 2570 Dole St., Honolulu, HI 96822

The Recreational Meta Data Project was initiated to document and compile into database formats sources of Hawaii's pelagic recreational and sports fishing information from the past 50 years. Recreational fishery data have not been routinely collected in the State of Hawaii over the past 50 years, although there are several sources of information including previous recreational and small fishing boat surveys, boating registration data, angling club records, fishing tournament records, newspapers, and fishermen logbooks. Much of the existing literature is unpublished or "gray literature" and difficult for fishery scientists and researchers to obtain. This project has collected over 80 papers and reports and incorporated them as part of the database files. Further, the data tabulated therein have been reentered into spreadsheet files so as to make them available to other researchers.

The project has also received information on 27 different fishing tournaments from seven different angling and boat clubs and expects to obtain information covering an additional four more tournaments. Several of these tournaments are well documented, and the project has amassed annual information covering over 40 years of catch and effort in Hawaiian waters. The number of boats participating in different tournaments has ranged from 6 to 260 boats. The majority of tournament catch is caught by fishing in association with Fish Aggregating Devices (FADs), which may provide valuable feedback to the Hawaii Division of Aquatic Resources (HDAR) in monitoring the success of its FAD deployment program, Pervious attempts by HDAR to monitor FAD performance through voluntary recreational fishery reporting have been unsuccessful.

Information on effort, catch, and tournament totals reflects the unique nature of each tournament's reporting procedures. Most tournaments do not differentiate between bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*T. albacares*), and these species are listed simply as "ahi." Marlin reports can also be comprised of one or more billfish species, and skipjack tuna (*Katsuwonus pelamis*) may or may not be included in the radio logs and weigh-in slips. The potential for constructing weight frequency charts from tournament radio logs to monitor size trends in tournament catches was investigated but was confounded by the practice of rounding estimated weights in conjunction with species identification problems. Despite these limitations, this information does provide insight into hook-up rates, catch composition, and average weight of catch. Time series catch rate data from a single tournament are also useful in elucidating cyclical peaks in species catch abundance. Although catching a thousand-pound marlin continues to be a major goal of most tournament participants, catches of mahimahi (*Coryphaena hippurus*) and ahi are the mainstay of the tournament catches in Hawaii.

ABOUT RESIDENCE TIMES OF TUNAS AROUND FADS

Laurent Dagorn [1], Kim Holland [2] and David Itano [3]

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Tropical tunas and other pelagic species are often found in association with floating objects. The exact effects of FADs (Fish Aggregating Devices) on the spatial dynamics of tunas (movements, residence time) are still not known, while it is of primary importance for stock assessment and fishery management. Among the different parameters that must be collected to improve our knowledge on this associative behavior, the residence time of fish around FADs appears to be of a particular interest.

Different techniques (mainly electronic tags) have been used to measure the time tunas spend around FADs. Tracks of yellowfin tuna (limited to a maximum of 4 days) as well as studies using listening stations and coded ultrasonic transmitters revealed contrasting results: very short visits to FADs (from a few minutes to a few hours) versus associations lasting several days.

Preliminary data from a new study conducted in Hawaii (U.S.A.) will be shown. A network of 14 listening stations have been deployed on all the FADs around the island of Oahu for an exhaustive coverage. We present results from different technical tests done to estimate the range of detection of tags, and the possible effects of collisions between tags on the interpretation of future data. Ideas for future protocols will be discussed.

AUTOMATED THRESHOLD-FREE GEOLOCATION FROM LIGHT

Phil Ekstrom

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For observations made in narrow-band blue light, the shape of the light curve (irradiance vs. sun elevation angle) between +3 and -5 degrees elevation angle (87 to 95 degrees zenith angle) is rigid. While the overall intensity will vary, the shape of the curve and the location of that shape vs. angle are not significantly affected by cloudiness (unless that changes during the sunrise or sunset transient), horizon details, atmospheric refraction or atmospheric dust loading.

This remarkable fact is predicted by a theoretical analysis of blue twilight and is borne out in field data. In short, blue light at the surface under those conditions is essentially all diffuse scattered light from the blue sky, not direct beam from the red horizon. Events occurring in an atmospheric layer many kilometers overhead are the ones that govern, and they lead to the rigidity.

The resulting curve shape is also distinctive. It can be located reliably in measured data, and that provides the basis for a new approach to animal geolocation. One begins with the theoretical model of this rigid shape vs. sun elevation angle, and then re-expresses it in terms of time-of-day, season, and the adjustable parameters latitude and longitude. Two more parameters represent the overall illumination (or cloudiness) of morning and evening, and all four are adjusted to fit the model curve to measured data over those two regions of the model lying between the elevation angle limits. The best fit is ordinarily obtained only for a single choice of parameters, and those values of the latitude and longitude parameters become the geolocation results.

The only other numerical inputs to the model are the atmospheric density lapse rate and the radius of the earth; the resulting method need not be and indeed cannot be "tuned". Thus any test of its accuracy is a realistic absolute test whenever there is an absolute position to compare with.

Theoretical estimates are available for the way errors in the latitude and longitude parameter values depend on location and season. They predict that while the accuracy of latitude determination will decrease at the equinoxes, useful estimates will be possible throughout the year so long as the animal is not too near the equator. The latitude estimate inherently moves its attention to sunrise and sunset rate, which is faster in the tropics and slower near the poles, as an equinox approaches and day length begins to carry less and less information.

Initial trials against field data taken in known locations begin to confirm these predictions. While more work is needed, early indications are that the new method is about twice as good as a threshold-based method for longitude, and offers an even greater advantage for latitude.

Efforts are underway to implement the method alongside earlier methods as an automated onboard process in existing archival tags. Eventually the method should allow extremely small tags with limited memory to still return daily positions of high quality for most of the year and most of the globe, based entirely on depth-corrected light data.

DEVELOPMENT AND SENSITIVITY ANALYSIS OF BIOENERGETICS MODELS FOR SKIPJACK TUNA (*Katsuwonus pelamis*) AND ALBACORE TUNA (*Thunnus alalunga*)

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This study aims to synthesize existing data on metabolic rate, growth rate, and reproduction into bioenergetics models for two pelagic predators, skipjack tuna (*Katsuwonus pelamis*) and albacore tuna (*Thunnus alalunga*), with particular emphasis on quantifying key rates of energy flux at a population scale. I contrasted these estimates to those calculated from a previously-developed bioenergetics model for yellowfin tuna (*Thunnus albacares*) and with those generated from an empirical regression model based on fish morphometrics. Based on observed growth rates, metabolic costs and calculated population size structure, I estimated consumption:biomass ratios (Q:B) of 36.3, 17.9, and 13.6 yr^{-1} for skipjack, yellowfin, and albacore tuna, respectively. Skipjack and yellowfin populations allocated roughly 18% of consumed energy to somatic and gonad growth, compared to only 6% for albacore tuna, indicating that the different life history strategies of these fishes are manifest in their energy budgets. Much of the contrasts between the populations were due to differences in the size-structure of the populations, not due to individual mass-specific rates. The skipjack model was largely robust to most parameter estimates, and was most sensitive to the effect of swimming speed on metabolic rate. The albacore tuna model was more sensitive to its parameters, particularly parameters describing swimming speed and the effect of swimming speed on metabolic rate. The empirical regression models commonly used to predict Q:B grossly underestimated Q:B for all three species, possibly because those models do not account for endothermy.

COMPARISON OF GROWTH MARK PATTERNS ON SCALES OF DOLPHINFISH (*Coryphaena hippurus*) OFF NORTHWEST MEXICO (poster presentation)

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The dolphinfish is widely distributed in tropical and subtropical waters in all oceans. Because it is a highly migratory species, comparative studies among fish captured in different areas in the Pacific Ocean are scarce. The possibility of geographical variability should be considered before population parameters are estimated. We make a description of the pattern of increase in growth-mark number through the development of *C. hippurus* in fish larger than 60 cm fork-length (FL). The aim is to describe the pattern in fish from three areas with different environmental conditions off northwest Mexico and compare them.

A total of 587 individuals from Mazatlan, Sin., Los Barriles and Punta Lobos, B.C.S. were sampled in September-December 2000. Fork-length, weight, and sex were recorded and scales samples were taken for each organism. The growth-mark counts were made visually under a stereomicroscope for "*annuli*" (*sensu lato*) and automatically using commercial software for digital-imaging analysis for "*circuli*" (*sensu lato*). For each type of growth-mark, the total number was plotted against FL for males and females.

Our preliminary analysis of "*circuli*" counts vs. FL in females suggests that an asymptotic equation describes the observations for individuals off Punta Lobos whereas linear relationships describe the observations for individuals off Mazatlan and off Los Barriles.

In females off Punta Lobos, the "*circuli*" increase rapidly until the fish is approximately 80 cm FL, thereafter the pattern of increase is relatively constant. In females from other areas the pattern of increase is relatively constant from fish 60 cm FL. Between Mazatlan and Los Barriles there are statistical differences in the fitted linear models.

If juvenile dolphinfish have less mobility than adults and they grow close to were they born, the differences in females between 60 -and 80 cm FL could suggest that environmental conditions affect the growth rate during preadult stages and these differences are more evident in individuals influenced by waters from the California Current system.

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HISTORY, DATA COLLECTION, AND SAMPLING OF THE EASTERN PACIFIC OCEAN SURFACE TUNA FISHERY (EPO FOR DUMMIES)

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Inter-American Tropical Tuna Commission

The IATTC operates under the authority and direction of a convention originally entered into by Costa Rica and the United States. Since its inception the IATTC staff has collected catch and landing statistics, studied the biology of tunas and related species, and made recommendations regarding management of the tuna resource in the eastern Pacific Ocean (EPO). The EPO is defined as the area bounded by the coastline of North, Central and South America from 40°N to 40°S and extending to 150°W.

The EPO surface tuna fishery was dominated by the U.S., California baitboat fleet for 30 years prior to the rapid conversion to tuna purse seiners during 1959-1962. U.S. flag purse seiners continued to dominate the EPO surface tuna fishery until about 1985, but since then their numbers have steadily decreased, and currently comprise only 4% of the total EPO fleet. In 2001 the Mexican, Ecuadorian and Venezuelan fleets accounted for 68% of the total EPO fleet capacity.

Catches of yellowfin, skipjack and bigeye tuna from the EPO have increased from about 171,000 metric tons in 1961 to about 574,000 metric tons in 2001. Catches of yellowfin in the EPO reached a record high of about 391,000 metric tons in 2001. A record catch of about 268,000 metric tons of skipjack was recorded in 1999. Prior to 1994, the average catch of bigeye tuna in the EPO by the surface fleet was about 5,000 metric tons. In 2000, the bigeye catch reached a high of nearly 70,000 metric tons, but decreased in 2001 to about 42,000 metric tons.

The IATTC has scientists and technicians located in La Jolla, California, and at its field offices in Ensenada and Mazatlan, Mexico; Panama, Republic of Panama; Manta and Las Playas, Ecuador; Cumana, Venezuela; and Mayaguez, Puerto Rico. IATTC personnel collect landings statistics, abstract tuna vessel logbooks, collect biological data, and train, place, and debrief observers participating in the International Dolphin Conservation Program. Another important project assigned to the field offices is taking length frequency and species composition samples. The catches of yellowfin and skipjack were first sampled in 1954, and sampling has continued to the present. Currently, length-frequency samples of yellowfin, skipjack, bigeye, Pacific northern bluefin, and occasionally black skipjack from purse-seine, baitboat, and recreational catches made in the EPO are taken on a regular basis.

Previously, a length frequency sample was defined as a 50 fish sample of a single species taken from a well that contained fish caught in the same calendar month and same sampling area. Beginning in 2000, the sampling methods were revised. A third criterion has now been adopted; all the fish in the well must have been caught in the same type of set (floating-object, unassociated school, or dolphin). Now, a length frequency sample of 25 to 50 fish of each species in the well is taken. In addition, 100 to 400 randomly-selected fish are identified to species and counted to determine species composition.

The species composition and length data are used to estimate the total catches and size compositions of each species taken by purse seiners and baitboats in the EPO. Along with the changes to the sampling protocols, the estimation procedures have been revised as well.

FADS: FISH AGGREGATING DEVICES OR FISH ATTRACTING DEVICES?

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Tropical tuna are known to associate with objects floating at the surface of the oceans. Man-made floating objects are called Fish Aggregating Devices (FADs), but if this wording clearly suggests that fish aggregate around these objects, there was no demonstration of this behavioral process. The high probability of finding tuna around FADs, which is not to be proven, can actually be due to aggregation (high density of fish because fish stay for a long time around FADs) or to attraction processes (high flows of individuals/schools through FADs). Fourteen tracks of yellowfin tuna (equipped with ultrasonic tags) around FADs have been analyzed to determine if the observed individual movement patterns are likely to represent aggregation or attraction processes. The results show that fish are clearly attracted by FADs, likely from distances up to 7-9 km, but it has not been possible to determine which mechanism between taxis or differential klinokinesis was involved. No results, however, argue in favor of any aggregation processes: fish do not seem to modify their movements to stay for a long time around FADs. If FADs are certainly Fish Attracting Devices, more studies are needed to clarify if/when they can be Fish Aggregating Devices.

TROPHIC ECOLOGY OF STRUCTURE-ASSOCIATED TUNA: EXPERIMENTAL RATIONALE AND PRELIMINARY RESULTS

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The formation of aggregations is common among tropical tunas. Aggregations typically form in association with large physical entities that may be natural such as cetacean pods, seamounts, and floating debris or artificial such as weather buoys, drifting vessels, or structures deployed specifically as Fish Aggregating Devices (FADs). Regardless of the associated structure, the underlying biological significance of these behaviors is poorly understood. These unknowns are compounded when one considers mixed-species aggregations. Theoretically, aggregating may be highly adaptive by decreasing the risk of predation, increasing foraging efficiency, and increasing reproductive success. This behavior has the maladaptive side effect, however, of increasing the susceptibility to exploitation by modern fishing gear by locally increasing fish density. Indeed, the majority of tropical tunas captured by commercial and recreational fishers worldwide are "associated". The effects of the industrial-scale removal of aggregated tuna on stocks and the ecosystem from which they are removed is largely unknown. Understanding the trophic dynamics of associated tuna is critical to evaluating these effects.

In March 2001, we began an intensive investigation of the trophic ecology of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*T. obesus*) aggregations in Hawaiian waters. Hawai'i offers an ideal setting for this study due to an abundance of natural and artificial aggregation sites. The primary sites of interest are four offshore NOAA weather buoys, the Cross Seamount, and the multitude of nearshore FADs. The objectives are to compare the trophic ecology of the two species across these sites, to evaluate the potential trophic benefit of aggregating, and to evaluate the effect of artificial aggregative structures on tuna trophic biology. Port samples are collected from returning commercial vessels and with the cooperation of Honolulu seafood buyers and field samples are collected aboard commercial hand-line vessels. The majority of fish landed are juveniles. To date, more than 800 samples have been collected, primarily from the Cross Seamount and the offshore NOAA weather buoys, and 80% of these have been analyzed in the laboratory. Approximately 75% were collected from bigeye tuna while only 25% were from yellowfin tuna.

Preliminary analyses indicate the prey of both species include an extremely diverse assemblage of fishes, crustaceans, and cephalopods. More than 60 families of fishes from 15 orders have been identified. At least 13 of the prey families in this study are absent from other studies. Of samples with prey, eight fish families were found in more than 10% of bigeye samples and seven families were found in more than 10% of yellowfin samples. Only two of these families were common to both tuna species. Telemetry studies have shown that the vertical distribution of bigeye tuna is much deeper than yellowfin tuna. This pattern is reflected in the prey distribution and stomach fullness in this study. Common prey fishes of bigeye tuna were mesopelagic while those of yellowfin tuna were mostly epipelagic. A similar pattern was observed for crustacean and cephalopod prey. Mean stomach fullness for bigeye tuna was much higher in samples collected from the Cross Seamount, a feature that peaks in the mesopelagic zone, while stomach fullness for yellowfin tuna was much higher in samples from the epipelagic weather buoys. These preliminary results suggest there are significant differences in the trophic ecology and aggregation behavior of these two species. Continued sampling from these and other aggregation sites and comparison with samples from unassociated tuna will further our understanding of aggregation phenomena and provide insight into the effects of aggregating on tuna trophic ecology.

EVIDENCE FOR REGIONAL STRUCTURE WITHIN POPULATIONS OF YELLOWFIN TUNA IN THE SW PACIFIC?

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In the Coral and Tasman Seas, in the SW Pacific Ocean, a small scale (7000 tonne) but lucrative (US$ 50-60 million) Australian longline fishery targets yellowfin and bigeye tuna and swordfish within and adjacent to the Australian EEZ. Japanese, Taiwanese, New Caledonian, and New Zealand longline fisheries target the same species in neighboring EEZ's and on the adjacent high seas. Bound by national legislation, Australian fishery managers are required to develop management plans designed to ensure the sustainability of catches within "their" fishery. The manager's question (similar to that posed by island and coastal states throughout the range of many tuna and billfish stocks) : Is there any point in restricting domestic catch and effort when the catch of yellowfin and bigeye in equatorial waters are orders of magnitude higher than in the Coral and Tasman Seas? For the science community the question requires us to examine the movements, residence times/ regional fidelity and mixing rates of fish between these areas.

We have used tagging, genetic, otolith chemistry, catch and effort and physical oceanographic data in an attempt to answer the question for yellowfin in the Coral and Tasman Seas.

Although there is evidence for significant variation among yellowfin collected through the Pacific, microsatellite genetic data do not allow us to reject the null hypothesis of a single panmictic yellowfin tuna population in the western Pacific Ocean. However, this does not mean that the null hypothesis is true, just that there is insufficient evidence to reject it.

Tagging programs within and outside the Coral and Tasman Seas suggest a high degree of localised movement of yellowfin – most fish do not move more than a couple of hundred miles from their point of release, regardless of time at liberty. Tagging conducted by SPC in the early 1990's demonstrated the potential for large-scale movement by yellowfin out of the Coral Sea – individuals were recaptured as far afield as south of Japan and eastern FSM – but only one of over 40,000 yellowfin tagged outside the Coral Sea was recaptured within it, or further south in the Tasman Sea.

Otolith chemistry suggests a close link between yellowfin spawned in the Coral Sea and those caught in the Tasman Sea, and patterns of recruitment into the Tasman Sea fishery suggest that pulses of fish spawned in the summer months are the major sources of recruits to the domestic longline fisheries. The patterns of recruitment align closely with regional circulation in which there is a high degree of recirculation of water between the Coral and Tasman Seas.

On the basis of these varied data sources, we conclude that in many years there is limited immigration of yellowfin into the Coral and Tasman Seas from the equatorial regions to the north, and that in these years spawning in the Coral Sea is likely to be the major source of recruits to the Australian fishery.

A COMPARISON OF BIOLOGICAL AND FISHERY INDICATORS FOR SOUTHERN BLUEFIN TUNA - 1988:2001

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The 1988 SBT Trilateral Scientific Committee (SC) meeting reviewed "indicators" of the health of the SBT stock, based on information available through 1986. The SC developed these indicators to provide managers a broad perspective on the recent changes in the status of the SBT stock and these indicators formed a critical component in the SC recommendation for substantial reduction in catches. At the same time, the SC recommended, "catch reductions should be maintained until such time that significant improvement to SBT stock status can be demonstrated". A decade later, the 1998 CCSBT Scientific Committee meeting agreed "that each member would develop a set of indicators to be presented to next year's SAG".

This paper presents results for a range of indicators, first reviewing changes in the status of the indicators first assessed 13 years ago, and then examining another 12 based on our review of new sources of information. The status of most indicators is negative or neutral when compared with 1988.

In conclusion, we examine the use of stock indicators in the CCSBT stock assessment process, in which complex VPA and SCALIA stock assessment models are the primary tool used to examine the health of the SBT population.

IDENTIFICATION OF BIODIVERSITY HOTSPOTS IN THE OPEN OCEAN: CAN COMMERCIAL CATCH DATA BE TO DO THIS?

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A number of studies have attempted to identify biodiversity hotspots in the terrestrial environment but there have been far fewer studies for the marine environment. Furthermore, most marine studies have been limited to examining benthic or plankton communities, with few studies directed at macro-fauna. Here, we will describe our attempts to identify hotspots of biodiversity of large pelagic fish in the ocean.

We will present our initial analyses of biodiversity hotspots using commercial catch and effort data (logbook and observer) collected during pelagic longline fishing operations. Ideally one would like data collected as part of a survey with sampling protocols controlling the distribution of sampling effort and the way in which the sampling device is used. It is clear that a surface longline used under commercial fishing conditions does not meet these criteria. We will describe our attempts to overcome these data problems.

We will present analyses for three areas, Hawaii, Australia, and the Northwest Atlantic, indicating areas of high species diversity, using a range of indicators including a rarefaction index. We discuss how the hotspots that were identified coincide with oceanographic structures and previously identified hotspots in marine diversity for various species groups.

STATUS OF STRIPED MARLIN STOCKS IN THE EASTERN PACIFIC OCEAN

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Inter-American Tropical Tuna Commission

The status of striped marlin in the eastern Pacific Ocean was investigated using general linear models incorporating the "normal suite" of characters, including time, area, gear, and indicators of large scale environmental conditions, such as SOI, SOI* and NOI. The significantly different results obtained by standardizing catch-per-unit-nominal-effort (CPUE) and catch-per-unit-standardized-effort (CPUSE), where standardized effort is that obtained from application of habitat-based standardization for striped marlin prior to fitting with linear models, will be discussed.

CURRENT TRENDS IN FAD-RELATED RESEARCH IN HAWAIIAN WATERS

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This presentation will provide a brief overview of several interrelated research activities that are focusing on the elucidation of structure-associated aggregation behavior in tuna. These activities include the recording and analysis of ambient sounds occurring in the vicinity of FADs. These acoustic signatures are being evaluated by comparing them with the results of contemporaneous active sonic surveys that evaluate the size and composition of tuna schools associated with the FAD. Other studies have involved the deployment and evaluation of 'communicating histogram archiving transmitters' (CHAT tags). Conceptually, "ecology" CHAT tags that are sensitive to pertinent ambient sounds could be developed for deployment on tuna. Based on the detection of appropriate acoustic signatures, these tags could record whether or not the fish had been associated with a school of conspecifics or how much time was spent in the vicinity of a FAD (or both). The stored data would be sonically downloaded to receivers mounted on "smart FADS". The concept of 'smart FADS' designed to act as observatories of pelagic ecosystems will be briefly discussed.

HAWAII TUNA TAGGING – ANALYSES AND RESULTS (poster presentation)

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In Hawaii, a mix of pelagic fisheries harvest tuna, billfish and associated species for domestic and export markets. Tuna landings (albacore, bigeye, bluefin, skipjack, yellowfin) account for close to 45% of total pelagic landings in recent years and 60% of the landed value of the catch. Yellowfin and bigeye tuna have been identified as the priority tuna species for management-based research due to their economic and social importance to Hawaii's subsistence, recreational and commercial fisheries.

Tagging studies have been designed and conducted by the Pelagic Fisheries Research Program to better define movement patterns, residence times and exchange rates useful for interaction studies. They also provide empirical data on the role of aggregation to the schooling behavior and vulnerability of yellowfin and bigeye tuna in the central Pacific region. Almost 18,000 conventional tags were released between 1995 – 2001 (9,537 bigeye, 8,449 yellowfin) resulting in 2,266 recaptures, which represent an overall recapture rate of 12.6% (as of April 2002). Recapture rates for each species are similar at 12.6%, as reported from Hawaii-based domestic handline, troll, pole-and-line and longline fisheries that land approximately 7,000 metric tonnes of the principal market tuna species per year. These fisheries compete for tuna at similar or sequential size classes and for various markets, creating conflict between subsistence, recreational and commercial sectors.

These issues are set within the framework of distinct pelagic fishing grounds, that include: inshore anchored FADs surrounding the main islands, inshore handline areas, offshore seamounts, offshore FADS, and offshore open-water areas fished by longline gear. Analyses were focused to address issues of competition, interaction and sustainability of local tuna fisheries. Size specific bulk transfer models were developed to estimate transfer rates between fishery components and to estimate species and size specific natural mortality, fishing mortality and residence times. A poster detailing the design and implementation of the tagging experiment, recapture rates, movement trends and transfer rate model outputs are presented. The results of the tagging analyses with implications to management will be discussed during an author attended poster session.

FISHERY EFFECTS ON PELAGIC FOODWEBS IN THE PACIFIC: APPLICATION OF AN ECOSYSTEM MODEL

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Pelagic fisheries in the Pacific Ocean target both large (*Thunnus* spp) and small tunas (juveniles of *Thunnus* spp; *Katsuwonus pelamis*), but also take billfishes (*Xiphias gladius, Makaira spp., Tetrapturus spp., Istiophorus platypterus*) and sharks (*Prionace glauca, Alopias superciliosus, Isurus oxyrinchus ,Carcharinus longimanus, Galeocerdo cuvieri*) as bycatch. We developed a multi-species model using the Ecopath with Ecosim software that incorporated time-series estimates of biomass, fishing mortality, and bycatch rates (1952-1998) to evaluate the relative contributions of fishing and trophic changes in driving observed dynamics of tunas in the central north Pacific. The model generally reproduced the observed trends in abundance indices and biomass estimates for tunas and billfishes. Declines in predation mortality owing to depletion of large predators were generally overwhelmed by much larger increases in fishing mortality, particularly for small yellowfin and skipjack tuna. Our results suggest that within-species interactions have combined with fishing effects to drive tuna dynamics in the central Pacific.

STANDARDIZING LONGLINE FISHING EFFORT IN STOCK ASSESSMENT MODELS: EFFECT OF OCEANIC CONDITIONS

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A workshop was held May 8—10, 2002 at the NMFS, Honolulu Laboratory to consider use of oceanographic data as part of a strategy for standardizing longline effort in stock assessment analyses. An important issue with longline effort is the degree of congruence between the depth distribution of longline hooks and the depth distribution of particular fish species. Various fish species are known to prefer particular depth ranges. It is also well-known that longline hooks do not always fish at intended depths often as a result of certain oceanographic conditions, notably current shear, leading to lack of congruence between locations of fish and hooks and diminished effective effort. To account for the degree of congruence requires knowledge of the depth behavior not only of fish but also of longline hooks, and it is the latter issue, the behavior of longline gear, that was the focus of the workshop.

Previous attempts have been made to standardize longline effort for use in stock assessment models by considering the degree to which the depth distribution of hooks intersects the depth distribution of the species in question. These were reviewed by the workshop. Experimental and theoretical information about the effects of oceanographic conditions and gear configuration on behavior of longlines was also reviewed. It was evident that to advance effort standardization beyond what has already been done would require input of detailed historical data on current shear, particularly vertical shear, in place of sea surface current as a proxy for shear.

Oceanographic information relevant for the task of calculating an index of fish-longline congruence was discussed with focus on availability of current data from which to calculate current shear. It was evident that general circulation models (GCMs) would be the only source of such data with sufficient historical depth (1950 to present), geographic scope (Pacific Ocean), and fine resolution in time and space (10s of km by 1—2 weeks). Though high resolution output from a GCM was viewed as necessary, a demand for historical pin-point accuracy was not. Such accuracy was felt to be unattainable from GCMs in any case. However, the pertinent demand would actually be for accuracy in the statistical properties of current structure within large scale areas, a more realizable goal. Though there was some discussion of how to derive an appropriate mathematical form of an index of fish-longline congruence, a precise formulation was not achieved during the workshop.

As an alternative strategy for determining the effective depths sampled by longlines it was suggested that plots of abundance of the different species in the catch against their rank order of abundance in the catch could be related to the effective longline depth. Experience in French Polynesia indicates that the shape of such a plot is characteristic of the maximum depth achieved by a longline set. After much discussion, data sets from US observers and Japanese research vessels were identified that might be used to determine if this suggested strategy would be applicable in other areas of the Pacific.

NMFS HONOLULU LABORATORY RESEARCH TO REDUCE LONGLINE FISHING SEA TURTLE BYCATCH AND MORTALITY

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Court actions due to fishery interactions with Pacific sea turtles have completely closed the swordfish segment of the Hawaii longline fishery and closed the tuna segment of the fishery in a large area during April and May.

NMFS Honolulu Laboratory is conducting research to develop “sea turtle safe" longline fishing with the objectives 1) to reopen the swordfish segment of the Hawaii longline fishery, and 2) to provide information and technologies on “sea turtle safe” longline fishing for transfer to foreign countries operating longline fisheries in the Pacific. Categories of research include: 1) fishing experiments planned to be conducted over three years on contracted Hawaii longline fishing vessels with NMFS technicians to test fishing gear and tactics to reduce sea turtle bycatch; 2) experiments conducted on contract with academic scientists and by NMFS scientists on captive sea turtles and pelagic fishes to define physiological and behavioral differences that may assist in the development of new or modified longline fishing gear and tactics; 3) definition of sea turtle oceanic habitat, migration patterns, and post-hooking survival using satellite technology; and 4) simulation modeling related to sea turtle population dynamics and evaluation of alternative mitigation and management strategies developed on contract with academic experts.

It is critical that experiments for “sea turtle safe” longline fishing methods for use in the Pacific be conducted in the Pacific because pelagic longline fishing strategies and tactics differ between the Pacific and Atlantic Oceans. These inconsistencies are related to fundamental differences in oceanic structure between the two oceans, with the U.S. fisheries in the two oceans operating in distinctly dissimilar types of pelagic ecosystems.

The scope of fishing experiments was greatly reduced due to conditions associated with ESA research permit, nevertheless, limited initial results are encouraging. Good progress and favorable findings are being made in research on captive sea turtles and pelagic fishes. Significant new understanding on sea turtle habitat and movement patterns is emerging using satellite technology. Comprehensive population simulation models have been developed for leatherback, loggerhead, and Hawaiian green sea turtles.

COUPLED PLANETARY WAVES AND TUNA LONGLINE CATCHES IN THE SOUTH INDIAN OCEAN

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The study of processes linking climate variability, ecosystems and fisheries has become a major issue for understanding the dynamics of marine resource systems. The air-sea interaction generate signals at a variety of scales, from quasi-biennial to multi-decadal, which are known to effect distribution and movement of pelagic fish. Tuna species respond to climate oscillations, but emphasis has been laid essentially on the El Niño Southern Oscillation (ENSO) signal. Here, we put emphasis on interannual coupled planetary waves, the coupled Rossby waves and the Antarctic Circumpolar Wave (ACW), in the subtropical and temperate domains of the South Indian Ocean. In the eastern subtropical ocean, coupled Rossby waves have been observed propagating westward from the coast of Australia, taking ~3 to 4 years to transit half the basin at a phase speed of ~0.05 m s^{-1}. In the middle latitudes, the Antarctic Circumpolar Wave (ACW) has been observed propagating into the Indian Ocean from the Southern Ocean in covarying SST, SLP, and SLH anomalies, taking ~2 years to transit the basin from Africa to Australia at a phase speed of ~0.08 m s^{-1}. Already these coupled planetary waves have been linked to interannual variability in rainfall over Australia and over India during the summer monsoon.

The space-time features of Sea Surface Temperature (SST), depth of 18°C isotherm (D18) and longline catch, for the period 1982-1999 are described by Extended Empirical Orthogonal Functions (EEOF). We show that tuna catches display a low frequency variability in relation with the propagation of coupled planetary waves which are well illustrated by the SST and D18 variability. For example, the positive anomalies of tuna catches propagate across the ocean in phase with the coupled waves, and in relation with surface cooling and rising of the depth of the 18°C isotherm. The coherence between phytoplankton (from SeaWifs data) and Rossby waves has already been demonstrated in a previous study. This supports the hypothesis that the dynamics of the wave, which favors an enrichment of phytoplankton in the surface layer, is likely to enhance the development of a food chain leading to forage-species for tunas and other apex predators.

INTEGRATED ANALYSIS OF WORLD TUNA STOCKS

Mark N. Maunder

Inter-American Tropical Tuna Commission

Historical methods have used a two-step approach to including multiple data sets into a stock assessment. Initially, an analysis (e.g. GLM) is used to summarize the raw data (e.g. catch and effort data) then the summarized data (e.g. standardized CPUE data) is fit in the population dynamics model. This two step approach has several disadvantages: information is lost in the summarization process, inconsistencies in assumptions, difficulty in determining error structure, difficulty in including uncertainty, and reduced diagnostic ability. These problems can be overcome by using the newly developed framework of integrated analysis. Integrated analysis attempts to use the raw data and integrate the different analyses together. The general approach is to formulate each analysis so that they use the same parameters for processes that they have in common, share the parameter values between analyses, and combine objective functions. The parameters of all analyses are estimated simultaneously while optimizing the combined objective function. I describe different types of integrated analysis: integrating data, integrating prior information, integrating analyses (e.g. integrating length-frequency analysis with catch-at-age analysis, integrating catch-at-age analysis with a stock recruitment analysis, integrating growth estimation with a length based model, integrated tagging and catch-at-age analysis, integrating the standardization of CPUE data, integrating the correlation with environmental data), integrating stocks (meta-analysis), integrating species, and integrating management control laws with assessment models. I describe how integrated analysis can be applied to the world tuna stocks.

AN OCEANOGRAPHIC ATLAS FOR FISHERIES APPLICATIONS IN THE PACIFIC OCEAN

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Information pertaining to the structure and dynamics of the ocean is essential to understanding the marine ecosystem and to interpret fishery resources within the context of habitat and large-scale environmental patterns. Oceanographic data, therefore, have potential application in many areas of fisheries research and management including predicting effects of seasonal, interannual and decadal variability on fishery performance, and providing environmental information required for driving population dynamics models. We are currently developing an ocean atlas that compiles a wide array of remote sensing and in situ data, providing a useful tool for understanding the variability of the physical environment in the Pacific basin.

Using the acquired datasets, we are now developing products that give regional climatologies and time series, characteristic depth profiles, convergence and divergence patterns, and geostrophic and Ekman currents, along with other products designated during two workshops at the 13th and 14th Annual SCTB meeting in Noumea, New Caledonia. An overview of the data and products contained within this atlas is presented.

THE PELAGIC ECOSYSTEM IN THE EASTERN TROPICAL PACIFIC OCEAN: A MODELING APPROACH

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An ecosystem approach to fisheries management is important for maintaining sustainable fisheries and healthy ecosystems. Although the objectives of ecosystem-based management are difficult to define, a general awareness exists that modeling is an important tool for improving our knowledge of how ecosystems function and exploring the ecological consequences of fishing.

We built a multispecies trophic model of the pelagic ecosystem in the eastern tropical Pacific Ocean. Our objective was to develop a hypothesis describing the pelagic ecosystem in hopes of gaining insight into the relationships among the various species in the system and the ecological implications of harvesting tunas. We represented the biomasses of and fluxes between the principal elements in the ecosystem with Ecopath, and examined the ecosystem's dynamic, time-series behavior with Ecosim. We conducted sensitivity analyses of the model, for both the Ecopath mass-balance and the dynamic trajectories predicted by Ecosim. The analysis showed that changes in the basic parameters for two groups, cephalopods and *Auxis* spp., at middle trophic levels exert the greatest influence on the system. We fitted the model to historical time series of catches per unit of effort and mortality rates for several species in simulations that incorporated historical fishing effort and a climate driver to represent the effect of El Niño-Southern Oscillation-scale variation on the system.

In this presentation, we briefly describe the model and discuss the sensitivities and fits mentioned above. We examine the interannual variability of model-predicted trophic levels of target and non-target catches by the different fisheries and purse-seine fishing methods. Comparing simulations with and without fishing mortality allowed us to identify which ecosystem components are primarily top-down controlled by fishing and which are primarily bottom-up controlled by resource dynamics.

THE HAWAII AND AMERICAN SAMOA PELAGIC LONGLINE FISHERIES: ECONOMICS ANALYSIS AND RECENT DEVELOPMENTS IN THE FISHERIES

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The Hawaii and American Samoa pelagic longline fisheries experienced considerable changes during 2000-01. The Hawaii fleet lost its swordfish (*Xiphias gladius*) component in 2000 due to litigation over protected species bycatch issues and is now operating as a fishery solely targeting sashimi grade tuna (*Thunnus obesus* and *Thunnus albacares*). This required a significant portion of the fleet to either leave Hawaii or switch target species from swordfish to tuna, which entailed changing fishing gear and methods. The American Samoa longline fleet, which was primarily composed of small, local catamaran style *alias*, expanded rapidly with the entrance of many large, modern longline vessels. In 2000, there were only two active large (>50') vessels, but by the end of 2001 28 domestic large vessels were targeting albacore (*Thunnus alalunga*) for the canneries located in Pago Pago. This recent entrance of the modern longliners in American Samoa has drawn considerable attention primarily because of social, economic, and fishery sustainability concerns. Management efforts, such as limited entry and nearshore area closures, are underway to restrain the growth of this segment of the fleet.

This presentation summarizes results from two ongoing studies that are intended to document changes in these fleets, especially from an economic viewpoint. The objectives of these studies are to describe the physical characteristics of the American Samoa vessels and to provide baseline economic information associated with operating longline vessels in Hawaii and large longline vessels in American Samoa. Cost and revenue information, fishermen's opinions of specific management devices, and other fisheries related issues will be presented.

THE DOLPHINFISH FISHERY IN THE MOUTH OF THE GULF OF CALIFORNIA, MEXICO

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The catch of dolphinfish within 50 nautical miles of the coast of Mexico is reserved by law for the sport fishery. However many local fisheries catch this species along the Pacific coast, but the amount that is caught is unfortunately not recorded. In the sport fishery, the fishing method is with poles and lines using live bait or lures with barbless hooks, which are trolled at moderate speed. The artisanal fisheries usually catch dolphinfish associated with natural floating objects or fish aggregating devices, which fisherman called “muertos”.

In this study, we analyzed the catch rates and size-composition of dolphinfish caught in the sport fisheries of Mazatlan, Cabo San Lucas, and Buenavista, and in the artisanal fishery of Mazatlan. This information was obtained through monthly samples and catch records taken in the fish landings. We compared the results with sea-surface-temperature and phytoplankton-pigment-concentration data derived from satellite images.

On average the sport fishery caught larger organisms than the artisanal fishery. Fork-lengths between 33-164 cm were recorded. The catch rates showed seasonal variability: they were highest at the end of summer and during fall, coinciding with high sea-surface temperatures and low pigment concentrations.

TECHNOLOGY, FISHING POWER AND EFFORT IN THE FSM TUNA FISHERY

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The Federated States of Micronesia (FSM) laying in the low latitudes in the west of the Western and Central Pacific Ocean statistical area positions the FSM in some of the Pacific's most productive tuna waters.

The sale of license fees to foreign fleets of purse seine, long line and pole-and-line gears comprise the largest source of income to the country after U.S. aid. The sale of these licenses by the FSM and other Pacific Island Nations in the region attracts vessels forming fleets of diverse nationalities. Thus the purse seine and longline fisheries in the Central and Western Pacific are conglomerates of fleets of diverse origins.

The differences in the operating profiles of these fleets within each geartype were discussed at last year's Tuna Conference. This year the differences in technology employed by the vessels, gear and resultant 'fishing power' among fleets will be examined. Fishing power is viewed in terms of size and composition of the catches of the fleets. This has some implications in estimating the effective effort among fleets.

In particular the fluctuating numbers of vessels of each fleet, their relative numerical dominance in the fishery and the changing technologies of some fleets affect estimations of the overall effective effort.

Examining the technology and relative fishing power of these fleets is an important adjunct to methods of effort standardization such as those using a habitat model to estimate effective effort. Better understanding of the diversity of fleets in the Central and Western Pacific is also important for future management regimes of the region.

ON-GOING RESEARCH ON TROPHIC ECOLOGY OF TUNA AND SWORDFISH IN EQUATORIAL ECOSYSTEMS OF THE ATLANTIC AND INDIAN OCEANS

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The Institut de Recherche pour le Developpement (IRD) has initiated in 2001 a program on trophic ecology of pelagic predators to study structure and functioning of offshore ecosystems of the Atlantic and Indian oceans (Thetis program). Two methods are used, stomach contents and nitrogen stable isotope analyses on muscle samples. The results of the latter are not yet available, thus only the results based on stomach contents are presented. The data collection concerns all predator species that can be caught by purse seine or longline gears, but tuna is indeed the most represented species, followed by swordfish.

Observations on stomach content of large yellowfin tuna were carried out aboard a purse seiner operating in the Eastern equatorial Atlantic (Gulf of Guinea) in February 2001, during the spawning season. Large unassociated schools of this species are observed every year between 2°N and 5°S, in relation with reproductive activity. These large fish were found feeding on a single-species concentration of *Cubiceps pauciradiatus*. This prey fish were essentially juveniles aggregated in a dense layer between 40 and 80 m depth and preying upon zooplankton. The particular fact is that juveniles *Cupiceps*, unlike adults, do not exhibit diel vertical migration. Therefore, they can be highly vulnerable at daytime to predators like tunas. A similar situation of stable concentrations of the mesopelagic fish *Vinciguerria nimbaria* had been described in another area of the Gulf of Guinea, where this prey species constitutes a considerable source of forage for skipjack and juvenile yellowfin and bigeye. In the West Equatorial Indian ocean, around Seychelles, unassociated schools of tunas caught by purse seine and longline are often observed foraging on single-species concentrations, but crustacea dominate over fish. Converging information from interviews with purse seine skippers and observations reported by staff at the canning factory in the Seychelles suggest that a small pelagic stomatopod, *Natosquilla investigatoris*, became highly dominant in the tuna diet from 1999. This has been confirmed by at-sea observations in 2000 and 2001. Size measurements of this stomatopod show a clear modal progression of this population from May (close to the East African coast) to October (around Seychelles, 600 nautical miles to the West).

Observations made from swordfish stomach contents in the Indian Ocean point out a diet dominated by fish (especially *Cubiceps pauciradiatus*), followed by cephalopods (Ommastrephidae) and then crustacea (shrimps). It has been possible to stratify the longline sets between oceanic and drop off areas (close to the Seychelles plateau). Surprisingly, it appears that squids dominate over crustacea in the drop off area when the opposite pattern should be expected. Compared to other studies, the large proportion of fish over squids for swordfish is also not so common, but the small size of the current sample (26 swordfish) does not allow conclusive results.

The results gathered in both oceans emphasize a remarkably short food chain (zoopk – *Cubiceps* or stomatopod - tuna) according to the size of the apex predators (30 to 100 kg). So far, cannibalism has not been observed as a major characteristic in the ecosystems studied. Nitrogen stable isotopes ratios should bring valuable information to locate tuna in trophic levels, as those should not be as high as expected if short food webs are dominant patterns.

ANALYZING TECHNOLOGICAL AND ECONOMIC INTERRELATIONSHIPS IN HAWAII'S LONGLINE FISHERY

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The paper analyzes the technological and economic interrelationships in Hawaii's multispecies pelagic longline fishery. An understanding of these relationships is important from a fishery management perspective to avoid any externalities associated to species or catch regulation. A multi-product dual revenue function is specified to analyze these interrelationships by estimating own-price, cross-price, and effort elasticities of supply for selected species or groups of species in each trip strategy. Six species were considered for the analysis: bigeye tuna, yellowfin tuna, albacore, swordfish, marlins, and rest other pelagic species. Own-price elasticities suggest that fishers' output supply decisions are independent of expected fish prices. The cross-elasticities indicate not only the possibility for technical and economic interactions between species but also the type of interactions, i.e. if the species are substitutes or complements. However, such relationship was found to be quite limited except for swordfish being substitutes with bigeye tuna and yellowfin tuna in the swordfish trip; yellowfin tuna being substitute with bigeye tuna in the tuna trip; and a complementary relationships exists between bigeye tuna & albacore, and between marlin & swordfish in the mixed trip. Other interactions are largely insignificant. The results from the tests of technology indicate that Hawaii's longline fishery is characterized by a joint production process meaning that the exploitation of one species would affect the harvest of other species. This finding implies that a single species regulation may not be appropriate in managing the fishery. The prospects for effective management by regulating few key species are also limited, indicating the need for a management of the entire fishery as a whole. Some implications for the ecosystem based fishery management are also drawn from this study.

OVERVIEW OF 2001-2002 RESEARCH AT THE IATTC'S ACHOTINES LABORATORY

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As part of a joint project carried out by the Inter-American Tropical Tuna Commission (IATTC), the Overseas Fishery Cooperation Foundation (OFCF) of Japan, and the government of the Republic of Panama, a spawning population of yellowfin tuna was developed at the Achotines Laboratory, Republic of Panama. Although the joint project ended in March of 2001, the yellowfin broodstock continue to spawn and support studies of reproductive behavior and egg and larval development. During 2001-2002, several research agreements were formed between the IATTC and other institutions to study tuna biology.

During the past year the IATTC Early Life History Group has continued its research on the early life history of yellowfin tuna. Two experiments were carried out to estimate the density-dependent growth of late-stage yellowfin larvae. The diel feeding abilities of late-larval/early-juvenile yellowfin were also examined. As part of a joint research agreement with the University of Miami (UM), a UM graduate student carried out experiments examining the effects of antibiotics and probiotics on growth and survival of yellowfin tuna eggs and larvae. Scientists from Cornell University, the University of Washington and the IATTC initiated a study of the spectral sensitivity of vision in larval and adult yellowfin tuna utilizing microspectrophotometry techniques. The vision study is expected to continue for several years.

Genetic studies of yellowfin broodstock and their progeny have continued at the Laboratory as part of a joint study between the IATTC and the National Research Institute of Far Seas Fisheries of Japan. The DNA profiles of broodstock yellowfin were compared with the profiles of yolk-sac larvae that were collected from the broodstock tank over the period of one year. Genotypes of individual female broodstock were identified in larvae from individual spawns, and estimates were made of size at first spawning and spawning frequency of the females. In a separate study by IATTC scientists, archival tags were implanted into the body cavities of 12 young-adult yellowfin. The trial is being conducted 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.

Additional areas of research will be briefly discussed.

INVESTIGATING THE LIFE HISTORY AND ECOLOGY OF OPAH AND MONCHONG IN THE NORTH PACIFIC

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The opah, *Lampris guttatus*, and monchong species complex, *Taractichthys steindachneri* and *Eumegistus illustris*, are deep dwelling pelagic fishes taken incidentally in longline fisheries targeting bigeye tuna. Valued by the restaurant trade particularly in Hawaii, these exotic fishes are generally harvested in small, but nevertheless significant, quantities. For the period 1987-99, as much as 300,000 lbs. of monchong were landed at United Fishing Agency (UFA) with individual fish averaging 14.2 to 17.7 lbs. Mean price ranged from $1.35 to $2.06 per lb. with annual ex-vessel revenue ranging from negligible (<$10K) to $420K. Over the same time period, 150,000 to 1.2 million lbs of opah have been landed annually with individual fish weighing 97-111 lbs. Annual ex-vessel revenue for opah ranged from $240K to $1.4 million at a price per lb ranging from $0.87 to $1.40. Since neither are targeted species, these fishes have historically been poorly studied and as a result available information pertaining to the biology and ecology of this resource are virtually nonexistent.

A new study was recently undertaken to investigate and define some of the fundamental life history and ecological characteristics of the opah and monchong resources in the North Pacific. A combination of comprehensive shoreside data and biological sample collection, analysis and merging of industry (NMFS observer and logbook, North Pacific driftnet, fish auction), research, and environmental datasets, and capture depth information collected from vessels of opportunity and archival tags are being used (1) to generate comprehensive seasonal and where possible, interannual biometric summaries and relationships (e.g. length-weight, sex ratio, etc.), (2) to define reproductive parameters (e.g., size and age at maturity, fecundity, spawning season, gonadosomatic index), and (3) to elucidate distribution patterns, preferred habitat, faunal associations, and trophic relationships for both resources. Progress and current status of the study is presented.

MOBILITY OF TROPICAL TUNAS AND THE IMPLICATIONS FOR FISHERIES MANAGEMENT

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We apply an advection-diffusion-reaction model to data from three different tuna tagging experiments in the western and central Pacific Ocean (WCPO) to reexamine the question of to what extent the population dynamics and spatial characteristics of tropical tunas require international cooperation for effective management. The median lifetime displacement of skipjack ranges from 420 to 470 nautical miles. The lifetime displacement of yellowfin is about 20% less. The median half-life, a measure of residence time, of skipjack and yellowfin in WCPO exclusive economic zones (EEZs) is three to six months. Fishing decreases the lifetime displacement and increases the half-life. We conclude that international arrangements between neighboring EEZs are essential for effective conservation, but that Pacific Island countries can achieve benefits from domestic conservation and fishery development policies.

BEHAVIORAL CHANGES DURING TUNA MIGRATION REVEALED BY STATISTICAL ANALYSIS OF TRACKS DERIVED FROM POP-UP ARCHIVAL TAGGING DATA

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We analyzed geolocation estimates from pop-up satellite-transmitting archival tags (PATS) attached to Atlantic bluefin tuna using a state space Kalman filter to estimate movement parameters, geolocation errors and most probable tracks. Estimated rates of directed movement ranged from 2 to 10 Nautical miles per day. Diffusivity estimates were around 500 square Nmi per day. Longitude errors were approximately 0.5 degrees and latitude errors about 1.0 degrees. We applied several measures of sinuosity to analyze the estimated tracks. We also examined the rate of data recovery from the PATs. Gaps in the record and uneven distribution of data during the time at liberty exacerbated the difficulty of deducing behavioral changes from uncertain position estimates.

THE SWIMMING ENERGETICS OF THE EASTERN PACIFIC BONITO (*Sarda chiliensis*): ONE STEP CLOSER TO UNDERSTANDING THE TUNA-BONITO RELATIONSHIP

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Fishes in the family Scombridae have morphological adaptations for fast, efficient locomotion. The most derived scombrids, the tunas (tribe *Thunnini*), appear to further increase swimming efficiency by elevating aerobic locomotor muscle temperature above that of the ambient water (endothermy). Despite apparent adaptations for efficient locomotion, tunas have maintenance costs several times higher than those of other teleosts. Studies to determine the role of tuna endothermy in swimming efficiency and the basis of the tuna's high standard metabolic rate (SMR) require comparative studies on the sister taxa to the tunas, the ectothermic bonitos (tribe Sardini). A swimming tunnel respirometer was used to estimate the swimming energetics of the eastern Pacific bonito (*Sarda chiliensis*) and test the hypothesis that endothermy increases tuna swimming efficiency (despite their high maintenance metabolism). Oxygen consumption rates (VO_2), SMR, and the incremental cost of locomotion, or net cost of transport (COT_{net}), were determined for 12 eastern Pacific bonito at several sustainable swimming velocities. The mean (+/- SEM) COT_{net} at 18°C was 2.36 +/- 0.37 J g^{-1} km^{-1}, and the mean SMR was 0.097 +/- 0.017 mgO_2 g^{-1} h^{-1}. When adjusted for temperature differences and compared to published data for similar-sized tunas, the eastern Pacific bonito appears to have a similar COT_{net} and a lower SMR. This does not support the hypothesis that endothermy increases swimming efficiency. Rather, the data suggest that bonitos swim as efficiently as do tunas with a lower overall metabolic expenditure.

VALIDATION FOR DAILY INCREMENT FORMATION WITHIN OTOLITHS OF SKIPJACK TUNA (*Katsuwonus pelamis*)

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Daily increment formation in sagittal otoliths was verified in the two life stages, juvenile and young skipjack tuna using two different methods.

The marginal increment analysis for otoliths was applied for juvenile skipjack (12-40 mmSL). Specimens for the analysis were collected in the tropical western Pacific from early November to early December 1995 and in early February 1999. A high-speed (5 knots) midwater trawl net with a large-mouth opening (20 x 20 m) was used for the sampling. The trawl net was operated 4-6 times a day. Otoliths were embedded and polished, and then were observed by using the otolith measurement system that was equipped with a light microscope and a 3-CCD video camera (Ratoc System Engineering Inc., Tokyo). The width of marginal growth increments was measured for each individual. The marginal growth increment clearly indicated a diel change. The index of marginal increment formation increased from early morning to evening and a new increment was completed in midnight.

The otolith marking with oxytetracycline (OTC) for captive skipjack was carried out. Young fish for the experiments (20-30 cmFL) were caught by hook and line in coastal waters off Kagoshima, southern Kyushu during late August 2000 and 2001. The OTC solution was injected into the experimental fish, with a dosage of about 2.8mg / 100g BW according to Wild and Foreman (1980). These fish were reared in a floating net cage (8 x 8m) for 1-1.5 month. The number of increments that were formed during each experiment was counted by the otolith measurement system. There was no significant difference between the number of increments and rearing days for each fish in the all experiments.

We confirmed that age determination by the analysis of otolith daily increments could be applied for the growth study in skipjack tuna.

DROP NET, TWIST CLOSURE FISHING NET

Kent Thomas

Ocean Friendly Co., INC, 229 S. Lomita St., Burbank, CA 91506

The results Ocean Friendly Co.'s "drop net twist closure drop fishing net," in New Zealand waters will be discussed. Results include:

- Live fish capture, all non targeted and targeted, undersize (by-catch), released uninjured back to the open ocean.
- The drop net, can be used for live fish holding pens and grow out pens.
- Uncomplicated, simplistic operation.
- Low cost.
- Easy adaptability to all existing commercial fishing vessels.
- Diameter can be made to any commercial fishing vessel size.
- Netting mesh size change can be completed on board vessel on our 40' X 60' in 30 minutes.
- Drop net can be manufactured in third world countries or developed countries.
- Fishing crews can be trained in short time.
- Obtained U.S. Patent #6,065,239.

A poster presentation will show successful completion of Ocean Friendly Co.'s "drop net twist closure drop fishing net," in New Zealand waters and a hands on working model, drop net-twist closure drop fishing net 20" X 37 ½."

DISCARDS OF TARGET AND INCIDENTALLY CAUGHT FISHES BY THE HAWAII-BASED LONGLINE FISHERY

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The National Marine Fisheries Service (NMFS) relies upon a mandatory logbook program and fishery observers to monitor the Hawaii-based pelagic longline fishery. Previous studies that involved direct comparisons of logbook and observer reports, use of generalized additive models (GAMs) to evaluate logbooks from unobserved trips, and use of fish auction sales data have documented that logbook reporting for all species landed by this fishery is negatively biased (i.e., reported catch totals tend to be lower than actual totals of kept + discarded fish, as determined by comparisons with observer and auction sales data). This presentation will describe results from an ongoing study of the incidental catches of this fishery that demonstrate the importance of discards in the context of this reporting bias. The underlying premise is that logging of discards appears to reflect at least two tendencies, although these are not always entirely distinct. The first is that many fishermen seem to regard the logbook report as equivalent to a landings report. Consequently, there is low negative bias (ca. 5-10%) for highly valuable target species (e.g., bigeye tuna, *Thunnus obesus*, and yellowfin tuna, *Thunnus albacares*) and moderately valuable species taken incidentally in low numbers (e.g., opah, *Lampris guttatus*). The second factor considered relevant is that negative logbook reporting bias tends to be inversely proportional to catch sizes. Thus, blue shark, *Prionace glauca*, albacore, *Thunnus alalunga*, and mahimahi (i.e., dolphin, *Coryphaena hippurus*) are sometimes underreported to a considerable extent when large numbers are taken and then discarded.

The analyses to be described were conducted by comparing the reporting frequencies for discards in observer and corresponding logbook reports and by summarizing the dispositions of discards in the observer data. We expect the results so generated to prove useful for at least three important reasons. The first is that clarification of error patterns should improve understanding of both logbook reporting behavior and the accuracy of the logbook reports. The second is that generation of species-specific estimates of both rates and dispositions of discards should contribute to ecological studies and stock assessments for which the meaningful response variable is the number of fish removals, rather than landings. The third is that these results should help fishery managers anticipate the magnitude of discards in both established and developing fisheries.

TEMPORAL VARIATION OF *IN SITU* GROWTH RATES OF YELLOWFIN TUNA (*Thunnus albacares*) LARVAE COLLECTED IN THE PANAMA BIGHT REGION

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Growth rates and sizes-at-age were compared among yellowfin larvae collected in the coastal region of the Azuero Peninsula, in the Republic of Panama. Late-stage larvae (postflexion stage) were collected by dipnet with an underwater light at night and by light traps during the reduced upwelling periods in 1990, 1991, 1992, and 1997. Individuals were aged by counting daily increments in their otoliths, and growth rates were estimated from the length-at-age data.

Because field-collected yellowfin (*Thunnus albacares*) larvae cannot be differentiated from bigeye (*T. obesus*) larvae by meristic and pigmentation patterns, mitochondrial DNA from tissue samples of the larvae was amplified by the polymerase chain reaction technique and restriction fragment-length polymorphism analysis was used to identify the species in the collections as *T. albacares*.

Significant differences in growth rates occurred among the different years. These differences may be associated with sea-surface temperature anomalies during El Nino years, productivity levels, and/or the physical dynamics of the region.

REPRODUCTIVE DYNAMICS OF BROADBILL SWORDFISH, *Xiphias gladius*, IN THE EASTERN AUSTRALIAN FISHING ZONE

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The reproductive dynamics of ~ 1,500 broadbill swordfish were examined from fish caught off eastern Australia between June 1999 and March 2001. Swordfish spawned off eastern Australia over an extended period between September and March, although the peak spawning period was mainly between December and February. Male reproductive activity extended from October through April mirroring that of the females. Batch fecundity was linearly related to fish size with the number of eggs ranging from 1.2 and 2.5 million hydrated oocytes in females from 173 to 235 cm orbital fork length (OFL). Oocyte development was asynchronous and the presence of hydrated oocytes and post-ovulatory follicles in the same ovaries of a number of females indicated multiple spawning. Spawning activity was restricted to waters with a sea surface temperature greater than 22.5° C and sea surface Chlorophyll < 0.2 ug l^{-1}. Although spawning females were captured across the latitudinal range of the fishery, significantly more females in spawning condition were found inshore than offshore, apparently associated with warm Coral Sea water and its southward extension, the East Australia Current. That no mature-sized spawning females were found in colder waters off northern New Zealand during the spawning period underlined the relationship between water temperature and spawning. We found no evidence to support an alternative hypothesis that swordfish distribution was related to feeding. The length at which 50% of females reached maturity (L_{50}) was estimated at 193.6 (±0.51 SE) cm OFL using a logistic model. The male L_{50} was 85.8 cm using a Gompertz model although further sampling will be required to reduce the uncertainty around the male estimate. The ratio of females to males in the fishery was approximately 2.5 to 1. We estimated that ~75% of the females captured by the fishery were immature. Whether the take of these immature fish will impact on the spawning biomass is unclear as we are yet to determine whether the fishery covers the range of the parental stock. However, as similarly high catches of immature fish reported in the Atlantic fishery were thought to be impacting on the spawning biomass, continued monitoring is advised.

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