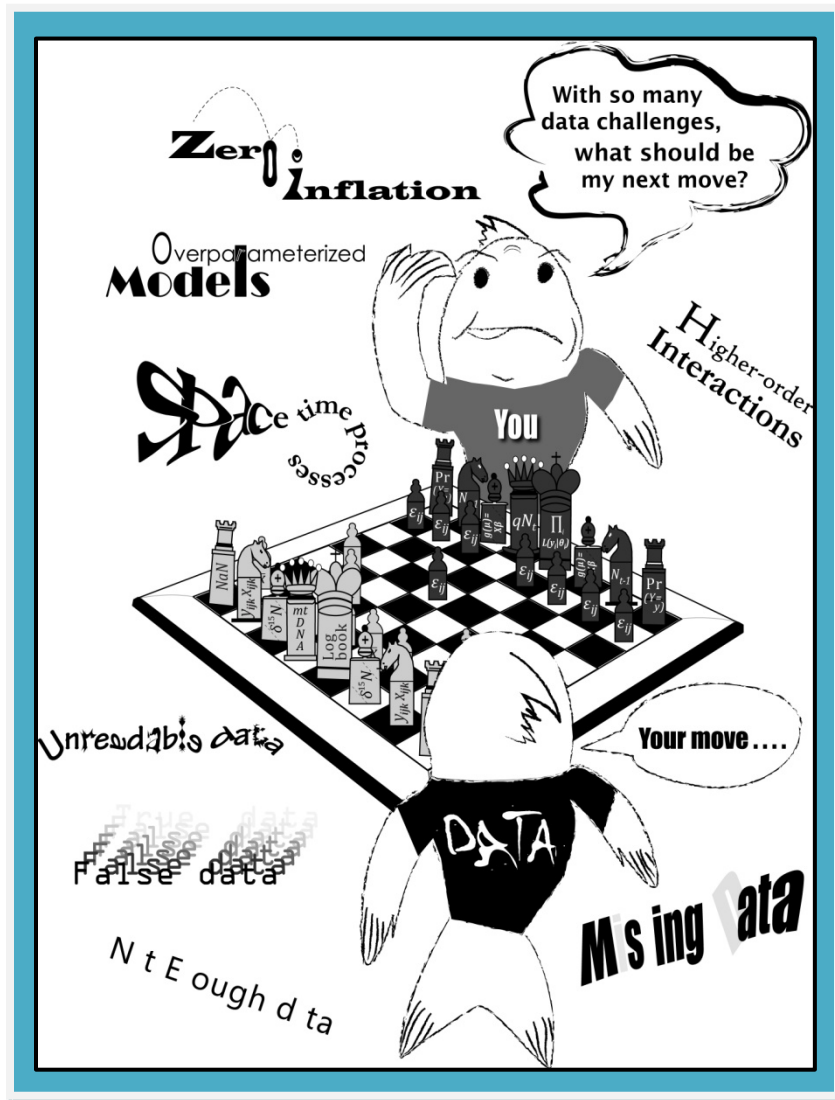


Proceedings of the 62nd Annual Tuna Conference
Lake Arrowhead, California,
May 16-19, 2011

DATA CHALLENGES



Cleridy Lennert-Cody and JoyDeLee Marrow, Co-Chairs

Sponsored by the:
Inter-American Tropical Tuna Commission
NOAA, NMFS, Southwest Fisheries Science Center

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

This meeting is for frank discussion of ideas, some of which may not be fully developed by the presenter(s). These proceedings are produced as an aid to the meeting and as an informal memory guide; they should not be cited. If readers wish to cite information or an idea from these pages, they should contact the author(s) so that a more proper citation can be used.

PREFACE

We warmly welcome you to the 62nd Tuna Conference. The goal of the Tuna Conference is to provide an open and informal forum for scientists, engineers, managers, fishermen and non-governmental organizations from around the world to exchange information and ideas including recent research findings on tunas and ‘tuna-like’ species. The free and open exchange of ideas is the key to the Conference’s success.

This year the theme of the conference is **“Data Challenges.”** Fisheries scientists, regardless of their area of expertise, often find themselves confronted with data-related challenges, from experimental design to data analysis, and encompassing both data-poor and data-rich situations. For example: 1) Estimation of catch and effort for artisanal fisheries can be plagued by a fundamental lack of data due to the difficulties of monitoring large numbers of small vessels landing at numerous small fishing camps, and often fishing multiple gears. By contrast, in commercial fisheries, accurate estimation of catch and effort is challenged by large quantities of dubious quality data (*e.g.*, logbook data). 2) Efforts to define stock structure and develop ecosystem indicators are both challenged by the need to reconcile pattern amongst multiple types of possibly noisy data (*e.g.*, age/size composition data, morphometric data and relative trend indices). 3) Estimation of key quantities and rates, such as movement and natural mortality, from conventional tagging data are problematic because of poor reliability of recapture information. On the other hand, archival tags produce copious quantities of highly detailed time-series data, which makes processing extremely resource intensive. Moreover, the results are often difficult to interpret in a management context. 4) Novel applications of genetics data, such as the estimation of population size from genetic diversity, are challenged by the need for new analytic procedures. Beyond these four specific examples, many aspects of fisheries research are challenged by the need to develop models for data that are characterized by complex and poorly known interaction structures, including temporal and spatial changes brought about by evolving natural processes and management actions. In the face of this reality, answers are needed for questions of general interest, including: How can we best use limited data to inform management and research decisions? How do we make the best use of new, detailed data types? How do we most efficiently improve the collection of data in data-poor situations?

A total of 46 papers and 11 posters touching on various aspects related to the theme of the 62nd Tuna Conference will be presented over the course of the next four days. In addition, a special session on management of electronic tagging data with the freeware Tagbase will be held on Tuesday afternoon. We encourage all attendees working with electronic tagging data to participate. Special thanks to Chi Hin Lam and Vardis Tsonotos for hosting this special session.

Five student scholarships were awarded this year. The Tuna Conference Scholarship was awarded to Mitchell Zischke for his research on “Out with the old and in with the new: Estimating recreational catch and effort for the specialized pelagic sportfish fishery off eastern Australia.” The Manuel Caboz Memorial Scholarship was awarded to C. Anela Choy for her work on “FAT-scinating Pelagic Fishes: Comparing Fatty Acid Biomarker Profiles in Hawaiian Surface- and Deep-dwelling Predators.” In addition, our industry partners graciously sponsored three scholarships. The Desert Star Systems Scholarship was awarded to Jenny Fenton for her work on “Post-Release Survival and Habitat Utilization of Juvenile Swordfish in the Florida Straits Recreational Fishery.” The GeoEye Scholarship was awarded to Marianne Robert for her

research on “Tuna in free-swimming schools are in better condition than those associated with natural floating objects: why do they associate with floating objects?” The Wildlife Computers Scholarship was awarded to Heather Marshall for her studies of “Habitat utilization and movement patterns of juvenile porbeagle sharks (*Lamna nasus*) in the northwest Atlantic.” All these students demonstrated impressive research goals and progress, and we wish them continued success in their graduate careers.

Hosting the Tuna Conference is an arcane and tradition bound process, and cannot be carried out without the assistance of a team of volunteers. We thank Keith Bigelow, Heidi Dewar, Marty Golden, Shane Griffiths, Kim Holland, Richard Holmquist, Eunjung Kim, Tim Sippel and Chris Wilcox, for moderating the scientific sessions. We thank the William Bayliff, James Hilger, Michael Hinton, Mark Maunder, Robert Olson and David Wells for reviewing the student scholarship applications. Christine Patnode updated the Tuna Conference web site and designed this year’s t-shirt and proceedings cover. Thanks to WikiTiki for offering our Conference Apparel. Anne Allen, past Tuna Conference Coordinator, provided advice. Millie DeLosReyes helped with banking and photocopying. We thank Scott Aalbers, Craig Heberer, Kim Holland, John Hyde, David Itano, Russell Ito, Chukey Sepulveda, Owyn Snodgrass and James Wraith for continuing the sashimi and poke cutting tradition to help supply the Sushi Social/Poster Session, and Prime Time Seafood for donating sashimi-grade tuna. Marty Golden kindly offered to pick up the tuna for the Tuna Barbecue and Sushi Social/Poster Session. William Bayliff continues in the esteemed role of Tuna Conference Historian. A special thanks to the U.C.L.A. Conference Center personnel for accommodating our numerous requests. We are grateful to a whole team of IATTC and SWFSC staff members, too numerous to be named here, for general assistance with transporting supplies and people to this year’s Conference.

We gratefully acknowledge generous donations to the Tuna Conference to help support Student Scholarships, the Sushi Social/Poster Session and the Tuna Barbecue. Donations this year were received from the American Tuna Boat Association, Desert Star Systems LLC, GeoEye, International Seafood Sustainability Foundation, King’s Seafood Company, Lotek Wireless Inc., Monterey Bay Aquarium Foundation, Prime Time Seafood Inc., and Wildlife Computers, Inc.

The abstracts contained in the Proceedings are considered reports of preliminary work. If readers are interested in the information presented in the abstracts, they should contact the author(s) directly, and no abstract should be cited without prior consent from the author(s).

In closing, we would like to thank you all for participating. We hope you had a productive and enjoyable time and look forward to seeing back next year at the 63rd Tuna Conference!

Cleridy Lennert-Cody and JoyDeLee Marrow
62nd Tuna Conference Co-chairs

The block contains two handwritten signatures. The signature on the left is for Cleridy Lennert-Cody, written in a stylized, cursive script. The signature on the right is for JoyDeLee Marrow, also in a cursive script, with the last name 'Marrow' being more legible than the first name.

AGENDA

Monday, 16 May 2011

11:00 Registration opens in the Skyview (continued throughout Monday and Tuesday morning)

SESSION 1: Fish Aggregating Devices (FADs) (Moderator: Keith Bigelow)

13:20 Welcome and Introduction (Pineview)

13:30 DOES THE SPECIES AND SIZE COMPOSITION OF TUNAS CAPTURED UNDER FADS DEPEND ON TIME SINCE DEPLOYMENT? – **Marlon Roman** and Martin Hall

13:50 THE DISTRIBUTION OF FADS AND ITS INFLUENCE ON SKIPJACK TUNA MOVEMENT IN THE WESTERN AND CENTAL PACIFIC OCEAN – **Eunjung Kim** and John Sibert

14:10 DATA FROM DOUBLE-TAGGED ANIMALS ELUCIDATES THE IMPACT OF FADS ON BEHAVIOR AND FEEDING ECOLOGY OF YELLOWFIN TUNA – **Kim Holland**, David Itano, Laurent Dagorn and Todd Lindstrom

14:30 TUNA IN FREE-SWIMMING SCHOOLS ARE IN BETTER CONDITION THAN THOSE ASSOCIATED WITH NATURAL FLOATING OBJECTS: WHY DO THEY ASSOCIATE WITH FLOATING OBJECTS? – **Marianne Robert***, Laurent Dagorn and Jean Louis Deneubourg

*GeoEye Student Scholarship / International Seafood Sustainability Foundation donation winner

14:50 Coffee Break

SESSION 2: Ecosystem and trophic studies (Moderator: Shane Griffiths)

15:10 COMPOUND SPECIFIC NITROGEN ISOTOPE ANALYSIS OF AMINO ACIDS: A NEW TOOL FOR STUDYING THE TROPHIC ECOLOGY OF MARINE ANIMALS – **Brian N. Popp**, Karen Arthur, Christina Bradley, C. Anela Choy, Elizabeth Gier and Natalie Wallsgrove

15:30 A BAGGED CLASSIFICATION TREE APPROACH FOR PREDICTING FISH DIET COMPOSITION – **Petra M. Kuhnert**, Leanne M. Duffy, Jock W. Young and Robert J. Olson

15:50 DECADAL-SCALE DIET COMPOSITION OF YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN: A CLASSIFICATION TREE APPROACH – **Leanne M. Duffy**, Robert J. Olson, Petra M. Kuhnert, Felipe Galván-Magaña, Noemi Bocanegra-Castillo and Vanessa Alatorre-Ramírez

- 16:10 VERTICALLY MIGRATING MESOPELAGIC MICRONEKTON IN THE WESTERN CENTRAL PACIFIC – **Andrey Suntsov** and Reka Domokos
- 16:30 THE CHALLENGES TO COLLECTING FORAGING ECOLOGY DATA FROM FISH LANDED AT RECREATIONAL FISHING TOURNAMENTS – **M.D. Staudinger**, A.K. Koske, F. Juanes and F.S. Scharf
- 16:50 DIET AND MERCURY CONTAMINATION OF HIGHLY MIGRATORY FISHES IN THE NORTHWEST ATLANTIC – **A.K. Koske**, M.D. Staudinger and F. Juanes
- 17:10 FAT-SCINATING PELAGIC FISHES: COMPARING FATTY ACID BIOMARKER PROFILES IN HAWAIIAN SURFACE- AND DEEP-DWELLING PREDATORS – **C. Anela Choy***, Peter Nichols, Rick Phelger, Brian N. Popp and Jeffrey C. Drazen
*Manuel Caboz Student Scholarship / International Seafood Sustainability Foundation donation winner
- 17:30 ECOSYSTEM EFFECTS OF BLUEFIN TUNA AQUACULTURE IN THE NORTH-WESTERN MEDITERRANEAN SEA – **F. Forrestal**, M. Coll and D. Die
- 18:30 Dinner
‘Welcome Gathering’ in the Tavern

Tuesday, 17 May 2011

8:00 Breakfast

SESSION 3: Tagging studies – Part 1 (Moderator: Richard Holmquist)

- 9:10 OPTIMIZING TAGGING EXPERIMENTAL DESIGN - APPLICATION TO PACIFIC BLUEFIN TUNA – **Shigehide Iwata**, Momoko Ichinokawa and Yukio Takeuchi
- 9:30 A DISCRETE CHOICE APPROACH TO ANALYZING MOVEMENT PATTERNS BASED ON LIGHT AND GPS TAG DATA FOR BROADBILL SWORDFISH – **Chris Wilcox**, Mark Bravington, Marinelle Basson, Karen Evans and Heidi Dewar
- 9:50 INTEGRATED MANAGEMENT AND VISUALIZATION OF ELECTRONIC TAG DATA WITH TAGBASE – **Chi Hin Lam** and Vardis M. Tsontos
- 10:10 TUNA MANAGEMENT AT SUB-REGIONAL SCALES: SCIENTIFIC, ECOLOGICAL AND SOCIO-ECONOMIC ASPECTS OF AN OLD DEBATE – **David Itano**, Kim Holland, Jay R. Rooker and R. J. David Wells
- 10:30 Coffee Break
- 11:10 HABITAT PREFERENCES OF JUVENILE BLUEFIN TUNA IN THE NW ATLANTIC – **Benjamin Galuardi** and Molly Lutcavage
- 11:30 COMBINING AERIAL AND ACOUSTIC METHODS TO DEVELOP FISHERY

INDEPENDENT ASSESSMENTS OF ATLANTIC BLUEFIN TUNA IN THE NW ATLANTIC – **Molly Lutcavage**, Tom Weber, Benjamin Galuardi, Michele Heller, Maddie Schroth-Miller, Shachak Pe’eri and Yuri Rzhanov

11:50 RESTRICTED VERTICAL AND CROSS-SHELF MOVEMENTS OF LONGTAIL TUNA (*THUNNUS TONGGOL*) IN AUSTRALIAN WATERS AS DETERMINED BY POP-UP ARCHIVAL TAGS – **S.P. Griffiths**, C.H. Lam and M. Zischke

12:00 Lunch

SESSION 4: Tagging studies – Part 2 (Moderator: Chris Wilcox)

13:10 OCEAN SCALE HYPOXIA-BASED HABITAT COMPRESSION OF ATLANTIC ISTIOPHORID BILLFISHES – **Eric D. Prince**, Jiangang Luo, C. Phillip Goodyear, John P. Hoolihan, Derke Snodgrass, Eric S. Orbesen, Joseph, E. Serafy, Mauricio Ortiz and Michael J. Schirripa

13:30 MOVEMENTS AND BEHAVIORS OF A BASKING SHARK DETERMINED WITH A SATELLITE TAG – **Heidi Dewar**, Suzanne Kohin, Chi Hin Lam, Dave Ebert, Joseph Bizzarro, John Hyde, Owyn Snodgrass and Russ Vetter

13:50 HABITAT UTILIZATION AND MOVEMENT PATTERNS OF JUVENILE PORBEAGLE SHARKS (*LAMNA NASUS*) IN THE NORTHWEST ATLANTIC – **Heather Marshall***, Diego Bernal, John Chisholm, Ben Galuardi, Lisa, Natanson, Nancy Kohler and Greg Skomal
*Wildlife Computers Student Scholarship / International Seafood Sustainability Foundation donation winner

14:10 EVALUATING THE EFFECTS OF TRAILING GEAR IN THE CALIFORNIA RECREATIONAL THRESHER SHARK FISHERY – **C. Sepulveda**, S. A. Aalbers, S. Kohin, N. Spear and C. Heberer

14:30 POST-RELEASE SURVIVAL AND HABITAT UTILIZATION OF JUVENILE SWORDFISH IN THE FLORIDA STRAITS RECREATIONAL FISHERY – **Jenny Fenton*** and David Kerstetter
*Desert Star Systems Student Scholarship / International Seafood Sustainability Foundation donation winner

14:50 Coffee Break

15:15 **SESSION 5: MINI-WORKSHOP ON THE MANAGEMENT OF ELECTRONIC TAGGING DATA** – Chi Hin Lam and Vardis Tsonetos
(www.tagbase.org)

18:30 Dinner

Sushi party in the Tavern – Sashimi donated by Prime Time Seafood, Inc.

POSTER SESSION IN THE TAVERN

USE OF SIMULATION ANALYSES TO INVESTIGATE YELLOWFIN TUNA (*THUNNUS ALBACARES*) GROWTH MODELS IN THE ATLANTIC OCEAN INCORPORATING GEAR SELECTIVITY – **A. Karch**, A. Hirons, S. Cass-Calay and D. Kerstetter

FEEDING HABITS OF THE BROADBILL SWORDFISH (*XIPHIAS GLADIUS*) SAMPLED FROM THE CALIFORNIA-BASED DRIFT GILLNET FISHERY, 2007-2010 – **Antonella Preti**, Heidi Dewar and Suzanne Kohin

TISSUE TURNOVER RATES AND TROPHIC ENRICHMENT FACTOR OF $\delta^{13}\text{C}$ AND $\delta^{15}\text{N}$ IN PACIFIC BLUEFIN TUNA, *THUNNUS ORIENTALIS* – **Daniel J. Madigan**, Steven Y Litvin, Aaron B. Carlisle, Charles J. Farwell and Barbara A. Block

AGE AND GROWTH OF NORTH PACIFIC ALBACORE (*THUNNUS ALALUNGA*) – **R. J. David Wells**, Suzanne Kohin, Owyn E. Snodgrass, Steven L. H. Teo and Koji Uosaki

POTENTIAL BENEFITS OF VISCERAL ENDOTHERMY IN THE SHORTFIN MAKO SHARK, *ISURUS OXYRINCHUS* – **Kyle Newton**, James Wraith and Kathryn Dickson

RESEARCH EFFORTS ON THE BIOLOGY AND FISHERIES FOR THE COMMON THRESHER SHARK (*ALOPIAS VULPINUS*) ALONG THE U.S. WEST COAST – **Natalie Spear**, Suzanne Kohin, James Wraith, Sue Smith, Heidi Hermsmeyer, R.J. David Wells and Antonella Preti

THE EFFECTS ON THE HEALTH AND BEHAVIOR OF AN ADULT SHORTFIN MAKO, *ISURUS OXYRINCHUS*, FOLLOWING PROLONGED ENTANGLEMENT IN FISHING GEAR – **Nicholas C. Wegner** and Daniel P. Cartamil

FORAGING ECOLOGY AND OCCURRENCE OF OPAH, *LAMPRIS GUTTATUS*, IN THE SOUTHERN CALIFORNIA BIGHT – **Owyn Snodgrass**, Heidi Dewar, Natalie Spear, James Wraith and Suzanne Kohin

VALIDATION OF THE PERIODICITY OF GROWTH-MARK FORMATION IN CROSS SECTIONS OF THE FOURTH DORSAL FIN SPINE IN THE BLUE MARLIN *MAKAIRA NIGRICANS* – Ulianov Jakes-Cota, Rubén Rodríguez-Sánchez, **Sofía Ortega-García** and Michael L. Domeier

THE IMPROVEMENT OF POSITION ACCURACY THROUGH INTEGRATION OF MAGNETIC SENSING – **Thomas Gray**

TROPHIC DYNAMICS AND ECOSYSTEM CHANGES WITHIN THE SE FLORIDA COASTAL PELAGIC FISH COMMUNITY – **Travis A. Moore** and David W. Kerstetter

Wednesday, 18 May 2011

8:00 Breakfast

SESSION 6: Fish biology

(Moderator: Heidi Dewar)

- 9:10 STUDIES OF YELLOWFIN TUNA EARLY LIFE HISTORY CONDUCTED AT THE IATTC'S ACHOTINES LABORATORY, 2010-2011 – **Dan Margulies**, Vernon Scholey, Jeanne Wexler and Maria Santiago
- 9:30 ANALYSIS OF FOOD SELECTIVITY AND FEEDING BEHAVIOR OF YELLOWFIN TUNA LARVAE, *THUNNUS ALBACARES*, DURING THE FIRST THREE WEEKS OF AGE – **Maria Santiago**, Dan Margulies, Jeanne Wexler and Vernon Scholey
- 9:50 THE EXTRA-OCULAR MUSCLES AS A POSSIBLE HEAT SOURCE FOR CRANIAL ENDOTHERMY IN LAMNID SHARKS – **Christopher Kehrier**, Suzanne Kohin and Kathryn Dickson
- 10:10 Coffee Break

SESSION 7: Fisheries monitoring

(Moderator: Tim Sippel)

- 10:30 OUT WITH THE OLD AND IN WITH THE NEW: ESTIMATING RECREATIONAL CATCH AND EFFORT FOR THE SPECIALIZED PELAGIC SPORTFISH FISHERY OFF EASTERN AUSTRALIA – **Mitchell T. Zischke***, Shane P. Griffiths, Kenneth H. Pollock and Ian R. Tibbetts
*Tuna Conference Student Scholarship / International Seafood Sustainability Foundation donation winner
- 10:50 AN EFFICIENCY APPROACH TO OPTIMIZING THE LEVEL OF OBSERVER COVERAGE – **Stephen Stohs** and Sturla Kvamsdal
- 11:10 CHALLENGES FOR MONITORING ALLOWABLE CATCH LIMITS OF U.S.-ASSOCIATED PELAGIC LONGLINE FISHERIES IN THE WESTERN CENTRAL PACIFIC – **M. Kimberly Lowe**
- 11:30 FAST-TRACK MONITORING OF U.S. LONGLINE BIGEYE TUNA CATCHES IN THE WESTERN-CENTRAL PACIFIC OCEAN – **Russell Ito**
- 12:00 Lunch

SESSION 8: Management and mitigation

(Moderator: Marty Golden)

- 13:10 EVALUATION OF LONGLINE MITIGATION TO REDUCE CATCHES OF NORTH PACIFIC STRIPED MARLIN IN THE HAWAII-BASED TUNA FISHERY – **Keith Bigelow** and Bruno Mourato

- 13:30 FISHERIES BYCATCH RESEARCH AND FISHERIES MANAGEMENT...IS THERE A CLEAR LINK? – **Yonat Swimmer**, John Wang and Christina Fahy
- 13:50 MODELING POPULATION PROCESSES FOR TUNA STOCK ASSESSMENT: WHAT ASSESSMENT SCIENTISTS NEED FROM BIOLOGISTS – **Mark N. Maunder** and Alexandre Aires-da-Silva
- 14:10 RED LISTING TUNAS AND BILLFISHES – **Bruce B. Collette** and Kent E. Carpenter
- 14:30 Coffee Break
- 14:50 MANAGEMENT OPTIONS FOR NORTH PACIFIC STRIPED MARLIN- CMM 2010-01 AND BEYOND – **Valerie Chan**, Raymond Clarke and Richard Ambrose
- 15:10 MEASURING THE IMPACT OF LEATHERBACK TURTLE CONSERVATION REGULATION ON WEST COAST DRIFT GILLNET FISHERY ATTRITION – James Hilger and **Stephen Stohs**
- 15:30 LATEST STRATEGIES IN BLUEFIN RANCHING – **Rex Ito**
- 15:50 Tuna Conference Business Meeting
- 18:30 Dinner – Tuna Barbeque sponsored by American Tunaboat Association, GeoEye, Lotek Wireless Inc. and Monterey Bay Aquarium
- Frontier Village – for gas campfire and social

Thursday, 19 May 2011

8:00 Breakfast

SESSION 9: Environment and catches (Moderator: Eunjung Kim)

- 9:10 RECRUITMENT HABITAT OF PACIFIC TUNAS AND BILLFISH: META-ANALYSIS, PREDICTIONS AND NEEDS – **Tim Sippel** and Steve Teo
- 9:30 HABITAT MAPPING OF EASTERN PACIFIC TUNA SPECIES FROM SATELLITE IMAGERY AND ITS APPLICATION TO THE FISHERY – **M.G. Hinton**, D. Kiefer, D. Harrison, E. Armstrong and F. O'Brien
- 9:50 ENVIRONMENTAL INFLUENCES ON ATLANTIC BLUEFIN TUNA CATCH RATES IN THE SOUTHERN GULF OF ST. LAWRENCE – **A.S.M. Vanderlaan**, A. Hanke, J. Chassé and J.D. Neilson

10:10 FACTORS INFLUENCING SWORDFISH DISTRIBUTION AND ABUNDANCE OFF THE U.S. WEST COAST – **Candan Soykan**, Suzanne Kohin, Heidi Dewar and Tomo Eguchi

10:30 Coffee Break

SESSION 10: Stock structure
(Moderator: Kim Holland)

10:40 DIDYMOZOID GILL PARASITES OF AGE-0 PACIFIC BLUEFIN TUNA *THUNNUS ORIENTALIS* FROM THE WESTERN NORTH PACIFIC OCEAN AND THEIR USE AS BIOLOGICAL TAGS FOR ESTIMATION OF THE HOST'S NATAL ORIGIN – **Izumi Yamasaki**, Wataru Doi, Toshiyuki Tanabe, Yukio Takeuchi and Kazuya Nagasawa

11:00 OTOLITH CHEMISTRY OF ALBACORE (*THUNNUS ALALUNGA*) IN THE EASTERN PACIFIC OCEAN – R. J. David Wells, **Charlene Renck**, Suzanne Kohin, Heidi Dewar, Owyn Snodgrass and Drew M. Talley

11:20 ASSESSMENT OF GENETIC MARKERS AND THEIR ANALYSIS IN POPULATION GENETICS OF SWORDFISH – **Helen Bradman**, Peter Grewe and Belinda Appleton

11:40 POPULATION GENETIC STRUCTURE OF THE SPINETAIL MOBULA (*MOBULA JAPANICA*) IN THE PACIFIC AND INDIAN OCEAN BASINS – **M. Poortvliet**, K. Newton, G. Bernardi, D. Croll and J.L. Olsen

12:00 Lunch

ABSTRACTS

(oral presentations and poster session, in alphabetical order by senior author)

EVALUATION OF LONGLINE MITIGATION TO REDUCE CATCHES OF NORTH PACIFIC STRIPED MARLIN IN THE HAWAII-BASED TUNA FISHERY

Keith Bigelow and Bruno Mourato

NOAA Fisheries, Pacific Islands Fisheries Science Center, 2570 Dole Street, Honolulu, HI 96822 USA

Striped marlin in the North Pacific are primarily harvested in longline fisheries targeting species such as tunas (*Thunnus* spp.) and swordfish (*Xiphias gladius*). Annual catches by all nations have declined from ~17,000 mt in the early 1960s to ~3,000 mt in 2006. The International Scientific Committee for Tuna and Tuna-like species in the North Pacific (ISC) completed a striped marlin assessment in 2007 considering a single stock in the entire North Pacific. Two assessment scenarios were based on alternative assumptions about the steepness of the stock-recruitment relationship and under these two scenarios the spawning biomass of the North Pacific striped marlin stock was estimated to have been fished down to between 6% and 16% of its 1952 abundance. This low range of spawner abundance suggested that the stock was in a depleted condition.

Given the depletion of the North Pacific stock of striped marlin, the objectives of this study were to conduct analyses of potential longline striped marlin catch reductions while maintaining target bigeye tuna catches. The analysis was conducted on the Hawaii-based longline fishery and is well suited to analyses of longline mitigation because detailed operational and catch data have been gathered by the Pacific Islands Regional Observer Program since 1994. Aspects of gear mitigation considered in the study were the efficacy of removing shallow hooks adjacent to longline floats and conversion of terminal gear from Japanese style tuna hooks to 18/0 circle hooks. An evaluation of establishing tuna longline fishery closures was conducted with the trade-off between striped marlin catch reductions and loss of target bigeye catch. A spatial and temporal analysis was conducted to investigate the existence of striped marlin catch rate (CPUE) hot spots. The largest longline catch reductions in terms of percentage occurred for striped marlin. Reductions of 19%, 34%, and 47% were achieved by removing hooks #1, hooks #1–2 and hooks #1–3 adjacent to the float, respectively. Target bigeye catches declined 1.5%, 4% and 7.8%, respectively. Using relatively large (18/0) circle hooks instead of tuna hooks reduced striped marlin catch rates more (by 42%) than removing shallow hooks. The spatial and temporal analysis did not identify any consistent areas of catch rate hot spots. The closure analysis did not identify areas of potentially high striped marlin reductions with minimal reductions of target bigeye catch, as there is a co-occurrence in catch of both species.

ASSESSMENT OF GENETIC MARKERS AND THEIR ANALYSIS IN POPULATION GENETICS OF SWORDFISH

Helen Bradman¹, Peter Grewe² and Belinda Appleton¹

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² CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001 Australia

Accurate information regarding the stock structure of swordfish (*Xiphias gladius*) is required to plan effective management strategies. Previous research using molecular markers has divided swordfish into four distinct stocks: Mediterranean, North Atlantic, South Atlantic, and Indo-Pacific. However, the structure within the Indo-Pacific stock is not well understood. We compared the effectiveness of two mitochondrial markers for examining swordfish population structure. While the commonly used control region is highly variable, it appears that homoplasy within the marker has led to an underestimation of genetic differentiation between populations. Tetranucleotide microsatellite markers were developed analysed using *F*-statistics and *R*-statistics. Analysis of these markers reveals fine-scale structure within the Indo-Pacific region.

MANAGEMENT OPTIONS FOR NORTH PACIFIC STRIPED MARLIN – CMM 2010-01 AND BEYOND

Valerie Chan^{1,2}, Raymond Clarke¹ and Richard Ambrose²

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Honolulu, HI 96814 USA

² University of California, Los Angeles, Los Angeles, CA USA

At the 7th Regular Session of the Western and Central Pacific Fisheries Commission (WCPFC) meeting members adopted a Conservation and Management Measure (CMM) for North Pacific striped marlin that over a three year period would restrict catch of individual members to 80% of the highest catch levels from 2000-2003. While adoption of the CMM signaled that members were concerned over the status of the stock, it was unclear whether the restrictions would be sufficient to reduce fishing mortality for N. Pacific striped marlin and the CMM may be reopened at WCPFC8 pending results from the upcoming ISC stock assessment. This study plans to examine the CMM, identify through surveys management options that may be considered more favorable for reducing catches of N. Pacific striped marlin, and consider potential ecosystem effects from various management options.

FAT-SCINATING PELAGIC FISHES: COMPARING FATTY ACID BIOMARKER PROFILES IN HAWAIIAN SURFACE- AND DEEP-DWELLING PREDATORS

C. Anela Choy¹, Peter Nichols², Rick Phleger², Brian N. Popp³ and Jeffrey C. Drazen¹

¹University of Hawaii, Dept. of Oceanography, 1000 Pope Road, Honolulu, HI 96822 USA

²CSIRO Marine and Atmospheric Research, CSIRO Food Futures Flagship

³University of Hawaii, Dept. of Geology & Geophysics, 1680 East-West Road Post 701, Honolulu, HI 96822 USA

The deep waters of the open ocean comprise the largest habitat on the planet. Yet, little is known about the ecology of the animals that live in the deep sea even though many support production for numerous commercially harvested species. Recent analysis of fishery data from the central North Pacific reports a concurrent shift in relative abundances of increasing (incidental) mid-trophic level fishes (e.g. *Taractichthys steindachneri*, *Lepidocybium flavobrunneum*, *Gempylus serpens*) and decreasing (target) apex predators (e.g. *Thunnus obesus*, *Prionace glauca*, *T. alalunga*) over the past decade (Polovina et al. 2009). Very little is known about the basic biology and trophic ecology of these increasingly abundant (incidental) mid-trophic level fishes, many of which primarily inhabit mesopelagic waters. This study provides some of the first fatty acid biomarker data on these large mesopelagic fishes (incidental species *Alepisaurus ferox*, *Lampris guttatus*, *Lepidocybium flavobrunneum*, *Gempylus serpens*), and their pelagic counterparts (target species *T. obesus*, *Coryphaena hippurus*, *Xiphias gladius*, *T. albacares*), all of which inhabit and forage at various depths.

Organisms can have unique fatty acid (FA) and sterol profiles, and many of these lipid biomarkers are transferred from predator to prey without modification, making them useful dietary tracers. Animals typically have 30 or more fatty acids and 10-20 sterols which can be used to infer trophic connections. Their profiles can be compared to potential prey, and similarity between profiles implies a trophic connection. For instance, the FA profiles of the Southern Ocean squid, *Moroteuthis ingens*, was most similar to three species of myctophids that had been confirmed as their most important prey from diet studies (Phillips et al. 2001). Other studies have been able to identify the major prey of zooplankton using FA profiles (e.g., Phleger et al 1998; Nelson et al 2000). This technique has not yet been applied to the food web in the central N. Pacific.

At the time of abstract writing we currently have no preliminary results as analyses are on schedule for January-February of 2011 at CSIRO in Tasmania. However, the objectives of the project are to use FA techniques to evaluate variation in diet between commercially important top predators and their lesser known incidental mesopelagic counterparts. Differences in FA profiles will imply differences in forage and will be examined relative to depth of forage/occurrence of the predatory fishes. The second stage of the project will examine the lipid biomarkers of important prey items to explain possible differences in predatory lipid biomarkers. This data will help to augment scant stomach content data on these incidental species and provide some of the first food habits data to improve the resolution of mass balance ecosystem models, such as Ecosim with Ecopath. Ultimately, the results of this research are expected to directly improve the understudied trophic connections between commercially important open ocean predators and their prey in the subtropical gyre ecosystem of the central N. Pacific.

RED LISTING TUNAS AND BILLFISHES

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Four IUCN Red List workshops assessed the threat of extinction to 64 species in four families of epipelagic marine fishes: Scombridae (tunas and mackerels), Istiophoridae (billfishes), Xiphiidae (swordfish), and Coryphaenidae (dolphinfishes). Previous Red List workshops on marine species concluded that all species of sea turtles and a large proportion of marine mammals, sharks and rays, and groupers fall into one of the threatened categories. However, 2/3 of the highly valuable and heavily fished species of tunas and billfishes fall into the category of Least Concern and only 17% are in one of the three threatened categories: Critically Endangered (2%), Endangered (2%), and Vulnerable (5%) or the next lower threat category, Near Threatened (8%).

Why the discrepancy between the threats to tunas and billfishes compared to sharks and rays? Fisheries target many species of tunas and billfishes for their high commercial value as food fishes while most sharks are harvested as bycatch of other fisheries. One major reason may be the difference in life histories between the two groups of species. Sharks and rays reproduce at a very low rate while most species of tunas and billfishes produce large numbers of eggs enabling populations to recover from overfishing much more rapidly. Another reason may be that tunas are usually targeted for intensive management while sharks and rays are not. In addition, when management of tunas and billfishes fail, the IUCN Red List criteria may or may not make a distinction between well managed stocks and those that have failed, depending on the time since crash of the stock.

Evaluating the threat status of commercial species has revealed several problems in using IUCN Red List criteria. It is considered "normal" by many fishery biologists for a virgin stock to be fished down to 50% of its original spawning stock biomass in the first few years of a new fishery. If measured relatively soon after a fishery begins (within three generation lengths), this 'ski jump' picture might lead to an evaluation as Critically Endangered under Red List criteria. Populations of many species level off after the initial reduction so they may be able to be managed sustainably, although at a much lower level than in the original situation. However, in the cases of species like the Atlantic (*Thunnus thynnus*) and Southern (*T. maccoyii*) bluefin tunas which have restricted spawning sites, population reduction by overfishing has been so severe that these populations may not be able to recover.

MOVEMENTS AND BEHAVIORS OF A BASKING SHARK DETERMINED WITH A SATELLITE TAG

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The eastern North Pacific basking shark (*Cetorhinus maximus*) population appears to have declined dramatically in the last 50 years with no evidence of a recovery despite the lack of direct targeting by fisheries and/or eradication programs. Consequently, along the coast of North America, the basking shark was listed as endangered in Canada and as a NOAA Species of Concern in 2010 and is protected in Mexico. Unfortunately, efforts to understand trends and develop a recovery plan are hampered by the lack of basic data on movements, the influence of environment on abundance and distribution, information on the full geographic range of the eastern North Pacific stock, and basic life-history information. To begin to address some of these data gaps, NOAA fisheries and the Pacific Shark Research Center at Moss Landing Marine Laboratories started a research program in the eastern North Pacific. One element includes deploying satellite tags on basking sharks to examine small and large-scale movements and behaviors.

One MK10-AF transmitting fast-GPS tag from Wildlife Computers was deployed on a basking shark off Southern California on June 6th of 2010. The shark was estimated at ~ 3 m in length and swam away before sex could be determined. The tag released after 53 days off Morro Bay, CA. After its release it transmitted four GPS locations as well as temperature, depth, and light data. No transmissions were obtained before the tag released.

Using both light-based and GPS locations an estimate of the track between tag and release was obtained. It appears that the animal moved north-west from San Diego, shortly after being tagged, towards the Channel Islands where it remained for some time before it moved north of Point Conception. Given the small spatial scale and errors in light-based location estimates, a more precise description of the track cannot be obtained. Over the course of the deployment the shark appears to have remained over the continental shelf and slope with general focal areas being the Channel Islands and Morro Bay. Basking sharks in the Atlantic show a similar preference for near-shore regions where complex flow patterns and convergence zones act to concentrate prey, which is critical to filter feeders.

Overall, the basking shark experienced a broad range of temperatures and depths. Sea surface temperature (SST) ranged from 10.7 to 18.3°C [average $12.8 \pm 1.9^\circ\text{C}$ (SD)] and daily minimum temperatures ranged from 6 to 10.2°C [average $8.9 \pm 1.4^\circ\text{C}$ (SD)]. The maximum depth was 544 m and during most 6-h time intervals, the shark came to the surface. Depth and temperature data showed considerable variability across the track, coincident with changes in SST. At SST below 12-13°C the maximum and modal depths were less than 200 m compared to depths up to 500 m in areas of higher SST. In addition, there was a significant correlation between SST and the temperature range experienced with a maximum of a 10°C temperature range at SST = 18°C. The shift to shallower depths at cooler temperatures may be associated with some thermal constraint on vertical movements; however, additional information on resource distribution is necessary. Basking sharks show impressive plasticity in vertical behaviors in our study as well as in the Atlantic. They can apparently adjust their foraging strategy according to the vertical distribution of their prey. These dramatic shifts in behavior make estimating abundance based on aerial surveys and predicting overlap with fisheries challenging. Additional information on the patterns in vertical and horizontal movements is needed.

DECADAL-SCALE DIET COMPOSITION OF YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN: A CLASSIFICATION TREE APPROACH

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One of many challenges for ecosystem-based fisheries science is to improve the understanding of food-web relationships so that community ecology may contribute to the process of setting management policy. Changes over time in the structure of pelagic open-ocean food webs are difficult to quantify, and fisheries-independent trawl surveys are expensive and biased against larger micronekton. Tropical tunas, however, are considered opportunistic, non-selective predators due to their broad diet and high energy requirements in oligotrophic habitats. Assuming tropical tunas are effective biological samplers of middle-trophic-level communities, comparative diet studies across temporal scales have the potential to provide valuable clues of changing ecological interactions within the food web. Yet, the analysis of diet data has suffered from the lack of robust statistical methods due to their multivariate nature, non-linearity, unbalanced distributions, and missing values.

To examine the feeding ecology of yellowfin tuna, *Thunnus albacares*, in the eastern Pacific Ocean, we applied a bagged classification tree approach to explore the relationships of spatial, temporal, environmental, and biological predictor variables to yellowfin diet composition. Stomach samples from 6810 yellowfin tuna were taken from 433 purse-seine sets during 2 sampling periods separated by a decade. We analyzed a subset of 18 dominant groups of prey taxa based on their gravimetric contribution to the diet of 3122 yellowfin tuna whose stomachs contained food of certain taxa: three groups of cephalopods, three groups of crustaceans, and twelve groups of fishes. A spatial bootstrapping technique was utilized, to account for spatial dependence between samples and estimates of precision were provided accordingly. We quantified the importance of predictor variables and produced partial dependence plots to explore relationships between the predicted prey composition and covariates included in the model.

Classification tree results and variable importance measures indicated that spatial covariates, latitude and longitude, are important covariates in the prediction of yellowfin tuna diet composition followed by quarter, the Pacific Decadal Oscillation index, year, and yellowfin size. Results revealed that yellowfin consumed a diversity of prey overall, but often high proportions of one or two dominant prey characterized the diet of fish at different regions. The classification tree highlighted differences in yellowfin diet composition north of 17°N versus south of that latitude. In the north, diet composition was diverse, consisting of crustaceans, squid, and fishes, whereas various fish taxa were the predominant prey in the south. A tree split on year revealed feeding differences between the two decadal sampling periods, with crustaceans and mesopelagic fishes the predominant prey during the 2003-2005 sampling period. In contrast, epipelagic fishes dominated the diet during the 1992-1994 sampling period.

Classification tree methodology explores differences in complex feeding dynamics and examines their variation in relation to potential shifting environmental and fishing conditions. Our findings highlight the importance of conducting diet studies across temporal scales to elucidate changes in the feeding ecology of yellowfin tuna.

POST-RELEASE SURVIVAL AND HABITAT UTILIZATION OF JUVENILE SWORDFISH IN THE FLORIDA STRAITS RECREATIONAL FISHERY

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The use of pop-up satellite archival tags (PSATs) allows a researcher to overcome limitations associated with acoustic, conventional, or AT type tags. With PSATs, both data collection and retrieval are fishery-independent. Previous research techniques have provided information on longer-term movements, migrations, and behavior patterns, but there is still a need for additional tagging studies with “second generation” tags with depth and light data and increased memory that will further define the short-duration activity patterns and habitat utilization of juvenile swordfish in the North Atlantic. PSATs have been successfully used on other large pelagic fishes, but have yet to be used on juvenile swordfish.

This project will investigate four topics: the post-release survival rates of juvenile swordfish (defined as < 119 cm LJFL, the minimum domestic retention length) after being released from the recreational rod-and-reel fishery in the Florida Straits, habitat utilization of juvenile swordfish following release, an exploratory analysis of the effectiveness of minimum size and bag limits in the recreational swordfish fishery, characterization of catch composition and disposition of the catch and bycatch. High-resolution PSAT technology will be used to estimate the post-release survival of 20 individual juvenile swordfish captured with standard recreational fishing gear and techniques in the southeast Florida recreational swordfish fishery. These data will also be used to analyze behavioral interactions with the fishing gear, such as habitat utilization patterns. By combining the PSAT data with data from temperature-depth recorders (TDRs), additional information on swordfish interactions, such as effective fishing depths, will be assessed. Data gathered by the PSATs and TDRs will also be compared with other descriptions of swordfish behavior.

This study will be a collaborative effort with the local recreational swordfish fishery, utilizing local fishermen to conduct the field work. Data from this study will aid in determining better management practices in terms of the efficacy of mandatory release of undersized fish. The data from the tags will also provide experimentally-generated estimates of recreational fishing mortality that can be used in ICCAT stock assessments. Providing more robust estimates of mortality and evaluating the size limits will aid in determining if the yield per recruit and the spawning potential ratio target values are being reached.

ECOSYSTEM EFFECTS OF BLUEFIN TUNA AQUACULTURE IN THE NORTH-WESTERN MEDITERRANEAN SEA

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The Eastern stock of Atlantic bluefin tuna (*Thunnus thynnus thynnus*) has, in recent decades, declined to probably a quarter of its virgin biomass, mainly driven by excessive catches mediated by the growth of the capture-based aquaculture of this species in the Mediterranean. This study addresses the potential food-web effects on trophic linkages in the ecosystem through the removal of both small pelagic fish species and wild bluefin tuna for capture-based aquaculture operations. An ECOPATH model of the Southern Catalan Sea (Western Mediterranean) was modified to include a bluefin tuna farm supplied entirely from fish captured in the area modeled (Coll et al, 2006). Six scenarios were developed to simulate possible changes to the system using ECOSIM, including the continued growth of aquaculture operations, as well as changes to the total allowable catch for bluefin tuna as set by ICCAT. The current level of aquaculture production of bluefin tuna in the Catalan Sea does not produce detectable effects in the ecosystem. Simulation scenarios that include the level of production already present in a similar ecosystem to the south, in the Murcia region, resulted in large fluctuations of both bluefin tuna biomass and yield, as well as for many of the species in the modeled ecosystem. Increases in biomass of lower trophic level functional groups were observed along with reductions in biomass from higher trophic level predators. Jellyfish and benthopelagic fish exhibited an increase in biomass, the largest being 8.76% for jellyfish and 69.76% for benthopelagic fish, while wild bluefin tuna biomass decreased by 87.26%. Atlantic bonito and swordfish showed similar rates of decline in biomass levels. Some of these effects are caused by the shift of bluefin tuna prey species introduced by the caging of wild fish. Bluefin tuna eat a greater diversity of prey in the wild in comparison than in the cages. These outcomes stress that removal of biomass at top and intermediate trophic levels can have unforeseen outcomes on the structure of the ecosystem, due to the complexity of the food web. Results suggest that, in the case of the Western Mediterranean Sea, increasing bluefin tuna farming activities will likely contribute towards further degradation of an already highly exploited marine ecosystem.

HABITAT PREFERENCES OF JUVENILE BLUEFIN TUNA IN THE NW ATLANTIC

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Between 2005 and 2010, we deployed 132 implanted archival tags and 74 X-Tags on juvenile Atlantic bluefin tuna (ABFT) off the northeastern U.S. To date we've recovered data records from 26 pop-up tags as well as a single implanted tag. A major objective of this work is to increase understanding of their dispersal routes, rates and depth behavior, which are not well known, and to support development of fishery independent approaches to population assessment.

Tagged juvenile ABFT primarily aggregated on the shelf break between Cape Hatteras and Cape Cod during summer and were more broadly dispersed in the South Atlantic Bight and Gulf Stream during winter. ABFT core use areas shifted from south to north throughout the summer months and were consistent with bluefin recreational fleet locations off the Eastern Shore of Virginia, Eastern Long Island and southeast of Cape Cod. Mean summer depths of juveniles were shallower than in winter (e.g., 5.3 m, August, 58.4 m, February) when tagged ABFT occupied the upper layer of the thermocline. Their environmental temperature associations were 5°C (mean) warmer in summer than winter, but the standard deviations in winter months indicated greater use of the overall water column. These differences are likely attributable to seasonable changes in prey availability across their migratory range on the continental shelf and Gulf Stream margins.

The single implanted archival tag was recovered in Sept. 2010 and contained 30 months (Sept. 2005 – Feb. 2008) of light, internal and external temperature and depth data recorded at one-minute intervals. This ABFT was estimated to be two years old at the time of tagging and grew from 79cm to 180cm (CFL) over 5 years, yielding an average growth rate of 20cm y⁻¹. These data represent the first archival records of a juvenile ABFT in the western Atlantic in this size class, and are consistent with patterns returned from X-tagged juveniles. Our results also indicate that during summer months, juvenile ABFT should be highly detectable via aerial surveys and sonar.

THE IMPROVEMENT OF POSITION ACCURACY THROUGH INTEGRATION OF MAGNETIC SENSING

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At the 61st Annual Tuna Conference we explained how the new technologies we are developing would help increase position accuracy, tagging capabilities, and sample size. However, this talk unfortunately did not have any data from “on animal” tagging yet.

Therefore, here at the 62nd Annual Tuna Conference we would like to present our initial tagging discoveries (re: position accuracy) as well as how we have advanced the tagging capabilities. Such as defining parameters on how to use the 3-axis accelerometer to gauge changes in animal velocity. The poster will present initial data from loggerhead tagging in mid-summer 2010 as well as additional acquired magnetic latitude positioning for Alaska, Galapagos/Ecuador, and Australia to name a few.

**RESTRICTED VERTICAL AND CROSS-SHELF MOVEMENTS OF LONGTAIL TUNA
(*THUNNUS TONGGOL*) IN AUSTRALIAN WATERS AS DETERMINED BY POP-UP
ARCHIVAL TAGS**

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Nine longtail tuna (*Thunnus tonggol*) were tagged with miniature pop-up archival tags ('miniPAT', Wildlife Computers) between 6 August 2009 - 28 April 2010 within the neritic regime along Australia's eastern coast. Tags collected data for a total of 324 days (2.5-84 d). Fish primarily utilised depths of 0-15m with maximum recorded depth of 79 m. Water temperature preference differed with fish size with small (85-95 cm FL) and large (>100 cm FL) preferring 24-28 °C and 18-22 °C, respectively. Geolocation from raw light data revealed fish exclusively utilised the neritic zone restricted to depths of less than ~200m. In contrast to commercial and recreational fisheries catch data and anecdotal evidence that suggests fish move south during summer and autumn with the southward expanding East Australia Current, all nine fish moved north for linear distances of up to 650 km. Two fish tagged moved 450 km and 650 km north to a common area inside the Great Barrier Reef at times where spawning has been previously documented (Oct-Mar). When these fish arrived at the reef they displayed possible spawning behaviour consisting of continual 'bounce' diving between 5-75m for 2 and 6.5 days, respectively. This study has highlighted the marked differences in habitat preferences and behaviour of longtail tuna in comparison to other *Thunnus* species. Their habitat preferences are likely to be related to physiology and restricted dives may explain the loss of a swim bladder in this species.

MEASURING THE IMPACT OF LEATHERBACK TURTLE CONSERVATION REGULATION ON WEST COAST DRIFT GILLNET FISHERY ATTRITION

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Since its inception in the late 1970s, the California-Oregon drift gillnet (DGN) fishery for swordfish and thresher shark has been heavily subject to scrutiny over conservation concerns. Though drift gillnet gear is intended for commercially targeting swordfish and thresher shark, concerns about non-target species bycatch have been a problem for the fishery since its inception.

This research focuses on the measuring the impact on attrition from DGN fishery participation due to the establishment of the Pacific Leatherback Conservation Area (PLCA) closure, which effectively closed the DGN fishery north of Point Conception between August 15 and November 15 in each year beginning August 15, 2001 in order to reduce interactions with endangered leatherback sea turtles. The effect of this policy on attrition is of particular interest as the closure eliminates the possibility of fishing in a highly productive area during the peak season. A key analytical challenge to measuring the impact of establishing the PLCA is to account for exogenous factors which contribute to attrition from the DGN fishery. The results of our empirical analysis regarding the impacts of past fishery regulation should provide valuable information about the effects of conservation regulation on the operation of commercial fisheries.

HABITAT MAPPING OF EASTERN PACIFIC TUNA SPECIES FROM SATELLITE IMAGERY AND ITS APPLICATION TO THE FISHERY

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This presentation will be of an ongoing study to develop the means to use real-time satellite data products in support of tuna-fisheries management in the eastern Pacific Ocean. Purse-seine vessels principally target skipjack and yellowfin tuna. Bigeye tuna are also taken by these vessels. Management of these fisheries has focused, in part, on reducing the capture of bigeye by purse seine vessels. This is made more difficult by the fact that bigeye are most often taken in association with skipjack, and most often on sets targeted using fish-aggregating devices (FADs). At one point in the development of these fisheries, the focus of management action was on yellowfin tuna. During those years, a management action would be adopted and based on data received during the fishing year, there could occur increases in the allowable catch. More recently the development of the fishery on FADs has caused a need for management actions to reduce catches of small bigeye tuna and non-target species.

This study is incorporating into a GIS framework [PHAM] information from the fisheries, satellite-derived estimates of oceanographic parameters and dynamics, and others from such as Argo drifters and ocean general circulation models (OCGMs). Our first objective is to describe the distribution and dynamics of ocean conditions in which these species are taken. Assuming success, at least for now, our next objective is to estimate the annual distributions of fishing effort that would yield the greatest catch of yellowfin and skipjack and a constrained catch of bigeye tuna. Assuming successful completion of the second objective (perhaps by the time of this conference!), we will examine the feasibility of using satellite-derived data and habitat characterization to identify those oceanographic conditions and distributions in real-time, thus opening opportunities for management action that maximizes yield of skipjack and yellowfin while reducing catch of other species.

DATA FROM DOUBLE-TAGGED ANIMALS ELUCIDATES THE IMPACT OF FADS ON BEHAVIOR AND FEEDING ECOLOGY OF YELLOWFIN TUNA

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Double tagging of yellowfin tuna with implanted acoustic pingers and archival tags reveals the behavior of these fish both when they are associated with FADs and when they are not. The acoustic data positively identify when the fish are associated with FADs, thereby allowing interpretation of data from the archival tags in terms of on-FAD and off-FAD segments. In particular, this technique elucidates whether or not yellowfin tuna alter their vertical behavior when associated with FADs. This, in turn, can be used to explain the differences (or not) in feeding success of associated and unassociated animals and the differences between yellowfin and bigeye tuna feeding success when associated with FADs. Here we present novel results from six recaptured double-tagged animals. Illustration and analysis of these data were greatly facilitated by the availability of newly developed visualization and analysis software.

TUNA MANAGEMENT AT SUB-REGIONAL SCALES: SCIENTIFIC, ECOLOGICAL AND SOCIO-ECONOMIC ASPECTS OF AN OLD DEBATE

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Tuna and tuna-like fishes share many common traits but two main categories can be considered. The temperate water albacore and three bluefin species are often described by the overused and often abused “*highly migratory*” term, but do exhibit ocean basin scale movements at specific life stages and between juvenile feeding areas and tropical spawning habitat. Skipjack and yellowfin are considered tropical tunas that can spawn, recruit and live within a single warm-water region exhibiting more restricted lifetime movements. Bigeye tuna seem to share life history traits from both groups.

How these life history traits play out is of critical interest to countries and areas that wish to develop or maintain their domestic (within zone) tuna fisheries and are of particular interest to higher latitude or geographically isolated areas such as Japan, Hawaii, Australia and New Zealand. Large-scale tagging experiments have been conducted by the Secretariat of the Pacific Community since the late 1970s to examine movement patterns, interaction issues and exploitation rates of tropical tuna in the core of the WCPO tuna fishery. These projects provide essential data to inform management on general stock condition and the large-scale fisheries but have largely failed to address issues relevant to higher latitudes and at smaller scales.

A suite of projects using a variety of marking techniques have been supported by the Pelagic Fisheries Research Program to examine tuna movement, behavior, exploitation and interaction in Hawaii and the central Pacific. Information from completed and ongoing tagging experiments (conventional, acoustic, archival and PAT tags) will be discussed in relation to novel data using chemical signatures retained in sagittal otoliths to examine the natal origin of yellowfin and bigeye tuna. The degree to which tuna move (or not), size-dependent natural mortality, reproductive biology and life history traits are essential inputs to management that have been determined by PFRP projects. These basic parameters tempered with social and economic considerations will be discussed in relation to different scales of management.

LATEST STRATEGIES IN BLUEFIN RANCHING

Rex Ito

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Traditional methods of Bluefin tuna ranching have been based on the purse-seine capture of wild bluefin and the live transfer to floating cages which are towed to the culture site. Once stabilized and transfers between pens are made to adjust size classes and densities, the tuna are fed dead or frozen bait over a period of 3-6 months—feedlot style, to fatten the tuna and build “toro,” to be harvested and sent to Japan, U.S., or other high-end markets.

Taking into account the reduction of catch quotas, improved farming techniques, scientific advances, changing market realities, sustainability and profitability models, some successful bluefin ranches of today practice “long cycle” culture of 1-4 years. Implemented to the extreme, this method can convert initial capture biomass of 100 tons to 1,000 tons at harvest, maximizing both utilization of the species and profitability of this precious fishery resource.

FAST-TRACK MONITORING OF U.S. LONGLINE BIGEYE TUNA CATCHES IN THE WESTERN-CENTRAL PACIFIC OCEAN

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Bigeye tuna (*Thunnus obesus*) is the largest component of the catch and the most valuable species landed by the U.S. longline fishery in the Western-central Pacific Ocean. In 2008, the Western and Central Pacific Fisheries Commission (WCPFC) Scientific Committee recognized that there was a high probability that the bigeye tuna stock in the Western and Central Pacific Ocean was subject to overfishing and reductions in fishing mortality were required in order to reduce risks that this stock would become overfished. The WCPFC then developed a number of Conservation and Management Measures (CMM) to mitigate overfishing of bigeye tuna. With the adoption of the WCPFC's CMM 2008-1, the U.S. longline fishery was limited to 3,763 mt for the years 2009, 2010, and 2011. In response, the PIFSC developed and implemented a fast-track monitoring system whereby the data from longline logbooks are processed in an accelerated manner in order to generate timely estimates of cumulative bigeye tuna catches. A forecast model that uses catches from the fast-track system estimates a projected date when the limit will be reached. Fishery Administrators then implement a regulation with a closing date to prohibit longline bigeye tuna catches after this projected date in order for this fishery to stay within the WCPFC's CMM's limit. This presentation covers the fast-track system used to monitor U.S. longline bigeye tuna catches, including the algorithms employed, issues affecting the accuracy of the catch estimates, and possible refinements under consideration for future improvements to this system.

OPTIMIZING TAGGING EXPERIMENTAL DESIGN: APPLICATION TO PACIFIC BLUEFIN TUNA

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A design of tagging experiment for estimation of natural and fishing mortality coefficients for 0-age Pacific Bluefin Tuna (*Thunnus orientalis*, PBF) is considered, using artificial data generated by a simulation model (data generation model).

PBF is a highly migratory species which moves long distance (e.g. trans-pacific movement from Japanese coastal waters to the waters off west coast of North America). Fishing mortality and recapture reporting rates could be different among the areas. In the past time, tagging experiments were intermittently conducted by Japan and IATTC for 0-age PBF for about 20 years. However, because of quite limited recaptures from the eastern Pacific Ocean, simple estimation model without spatial structure was applied, although spatially structured estimation model is desirable in theory.

In this summer of 2011, tagging experiment with larger number of fish released will be resumed. By this experiment, the expected number of recaptures will increase and its increasing may provide a good indication for simple estimation model. Therefore we want to know, in advance, the minimum number of fish to be released which enable to reliably estimate fishing and natural mortality coefficients. In order to design tagging experiment, artificial data are generated by a data generation model given “True (in a simulation world)” fishing and natural mortality coefficients with spatially structured components. Then, parameters such as fishing and natural mortality coefficients are estimated with the estimation model used in the past study, using the generated data. By comparing estimated parameters with ‘true’ values assumed in the data generation model, validity of our estimation model is assessed. In addition, effects of number of fish released on estimation of parameters are studied. Especially, we focus on the two possible major issues; differences in fishing mortality and in reporting rates between areas.

VALIDATION OF THE PERIODICITY OF GROWTH-MARK FORMATION IN CROSS SECTIONS OF THE FOURTH DORSAL FIN SPINE IN THE BLUE MARLIN *MAKAIRA NIGRICANS*

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Age estimation is a core element in every investigation focused on the rational exploitation of fishing resources. Although there are a number of studies that have estimated age in the blue marlin *Makaira nigricans*, the periodicity of annual growth-mark formation has not been assessed to validate such age estimates. Without this validation, age data cannot be reliably used for stock assessment. This investigation aims at validating the periodicity of annual growth-mark formation through semi-direct validation, one of the most widely used validation methods. For this purpose, observations and measurements were made in cross sections of the fourth dorsal fin spine in the blue marlin obtained from fish landed in 2005 and 2006 by the sport fishing fleet operating off Cabo San Lucas, Baja California Sur, Mexico. The analysis of the monthly percentage of opaque and translucent edges, as well as the marginal increase index, suggests that the formation of growth-marks (one opaque band followed by a translucent band) displays an annual periodicity and is related to sea surface temperature. A growth mark starts with the formation of an opaque band at the beginning of the year until August-September; in October, the translucent band starts to grow up to the beginning of the next year. Two additional biological indices are used to supplement our interpretation criteria.

USE OF SIMULATION ANALYSES TO INVESTIGATE YELLOWFIN TUNA (*THUNNUS ALBACARES*) GROWTH MODELS IN THE ATLANTIC OCEAN INCORPORATING GEAR SELECTIVITY

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The growth rate of a fish is a fundamental component used in stock assessments to help determine the population size and the fishery pressure affecting the species. There has been recent debate within the stock assessment community regarding which type of growth model best represents the true growth rate of yellowfin tuna (*Thunnus albacares*) in the Atlantic Ocean; specifically, whether assessments done by the International Convention for the Conservation of Atlantic Tunas (ICCAT) should use a traditional von Bertalaffy growth curve or a so-called “two-stanza” growth curve, which has one growth rate for smaller individual tuna and another for larger sizes. Currently, ICCAT uses an age-structured virtual population analysis (VPA) for the stock assessment and assumes a two-stanza growth curve. Using a simulated population based on known biological parameters obtained by ICCAT from the stock in the Atlantic Ocean, and the Stock Synthesis 3 program available through the National Oceanic and Atmospheric Administration (NOAA), the simulated yellowfin tuna population is compared within each model in order to determine the merits of each growth rate assumption. In addition, gear selectivity during fishing operations often affects the length composition data from fisheries dependent sources, namely commercial fishermen. The simulated population is therefore also used to determine the effects of different gear selectivity on the growth rates within each of the growth models. Pelagic longline will be used for one gear type and purse seine and bait boat will be used for a second gear type.

THE EXTRA-OCULAR MUSCLES AS A POSSIBLE HEAT SOURCE FOR CRANIAL ENDOTHERMY IN LAMNID SHARKS

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Sharks of the family Lamnidae are considered to be cranial endotherms because that they have the ability to elevate brain and eye temperatures above ambient water temperature. To do so, these sharks must have a heat source and a method for retaining that heat. *Retia mirabilia* (vascular counter-current heat exchangers) in the orbital sinus conserve metabolic heat. Warm blood from the locomotor red muscle transported to the orbital *retia* contributes heat, but an additional heat source is needed to maintain cranial temperatures at levels that have been reported in lamnid sharks. We hypothesized that one or more of the extra-ocular muscles serve as a heat source for cranial endothermy in the shortfin mako shark (*Isurus oxyrinchus*). To test this hypothesis, eyes with the extra-ocular muscles attached were obtained by dissection from sharks captured by long-lining during National Marine Fisheries 2008 and 2009 juvenile shark abundance surveys. The mass (g) and specific activity of the mitochondrial enzyme citrate synthase (CS units g⁻¹) were measured for each of the six extra-ocular muscles as an index of heat production capacity in *I. oxyrinchus*, and compared to values in the ectothermic blue shark (*Prionace glauca*). In *I. oxyrinchus*, the medial and lateral rectus muscles were larger than the other extra-ocular muscles, but CS activity did not differ significantly among the six muscles. The CS activity of only the medial rectus muscle was significantly greater in *I. oxyrinchus* than in *P. glauca*. As a percentage of total eye mass, all six extra-ocular muscles were larger in *I. oxyrinchus* than in *P. glauca*. These results suggest that contraction of all six extra-ocular muscles may generate heat for cranial endothermy in *I. oxyrinchus*, with the medial and lateral rectus contributing a greater proportion of that heat. Muscle mass contributes more than CS activity to interspecific differences in heat production capacity.

THE DISTRIBUTION OF FADS AND ITS INFLUENCE ON SKIPJACK TUNA MOVEMENT IN THE WESTERN AND CENTRAL PACIFIC OCEAN

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This study estimates the distribution of fish aggregating device (FAD) and analyzes the influence of FAD distribution on movement of skipjack tuna (*Katsuwonus pelamis*). Nearly half of the world tuna catch is made from schools associated with FAD as a result of the widespread increase in FAD use. However, little is known about how FADs modify movement behavior of tuna because of spatial variability of FADs. In our study, we estimated FAD distribution by applying ocean current velocity fields from an Ocean General Circulation Model, and its effect on skipjack movement was estimated using the advection-diffusion reaction model (ADRM). In the model, the density of FADs control the movement of tuna by two ways; inhibit the movement by reducing diffusivity and attract toward the density gradient of FADs. The model is applied to the SPC Pacific Tuna Tagging Project (PTTP) skipjack tagging data.

DIET AND MERCURY CONTAMINATION OF HIGHLY MIGRATORY FISHES IN THE NORTHWEST ATLANTIC

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Top pelagic predators are of great ecological and commercial importance in the Northwest Atlantic. Though most species of tuna have been historic seasonal migrants to the Northwest Atlantic, dolphinfish is a more recent invader as its range expands pole-ward. Species such as yellowfin (*Thunnus albacares*), albacore (*T. alalunga*) and bluefin (*T. thynnus*) tuna, shortfin mako (*Isurus oxyrinchus*) and common thresher (*Alopias vulpinus*) sharks, and common dolphinfish (*Coryphaena hippurus*) are notoriously difficult species to study. Up to date and accurate information about their feeding habits and life histories is lacking due to their wide geographic ranges and highly migratory behavior. A current and comprehensive understanding of the trophic ecology of these species is necessary to understand if the increasing presence of dolphinfish, an opportunistic epi-pelagic feeder, is affecting the trophic niche of top predators in the Northwest Atlantic. Rising concern about mercury (Hg) contamination of these popular food fishes further emphasizes a need for current information regarding dietary composition of these predators to discover sources and paths of contamination.

A comparative analysis of predator diets is presented here as a prelude to mercury analysis of these pelagic fishes and their primary prey. Stomachs and tissues were collected at recreational fishing tournaments on the northeast coastal United States and a charter fishing vessel out of Hyannis, MA over four summer sampling seasons. This ongoing project has faced multiple challenges. Low sample size of certain predator species and high yearly variation in total samples collected has required innovation to increase statistical power from few samples and a high frequency of empty stomachs in some species. National Marine Fisheries Service trawl surveys proved an inadequate source for collection of prey items described in the literature. Individuals commonly found in diets are most often juvenile and larval stages of prey species; these could not be collected using standard trawl gear. In order to determine accurate mercury contamination of each predator's prey base, individuals of appropriate size were retrieved from predator stomachs when digestion was minimal and specimens intact. Mercury analysis of collected tissue and prey samples is scheduled for the spring.

Preliminary results have revealed striking similarities in the diets of yellowfin tuna and common dolphinfish, with almost identical percent composition of teleost, cephalopod and crustacean prey. An index of relative importance was used to determine primary prey of each predator. Shortfin squid has been identified as the most important prey to the tunas and dolphinfish, while bluefish, butterfish and saury compose the majority of shark diets. These and other key prey species have been prepared for mercury analysis to reveal bioaccumulation trends with diet, size and growth rate of top pelagic predators in the Northwest Atlantic.

A BAGGED CLASSIFICATION TREE APPROACH FOR PREDICTING FISH DIET COMPOSITION

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The feeding behaviour of top marine predators like yellowfin tuna (*Thunnus albacares*) is important for understanding complex food web dynamics and how these might change under increasing exploitation and environmental pressures.

To investigate complex feeding relationships, we extend on the classification tree methodology to provide a modeling framework for analysing diet composition using yellowfin tuna as a case study. The method is both exploratory and predictive and uses a spatial bootstrap approach to provide standard errors around the predicted prey composition and identify the most likely prey that was eaten. Variable importance measures highlight important variables used in the partitioning, while partial dependence plots were created from the bootstrap samples to explore the relationships between the explanatory variables and predicted prey composition.

Results indicate that yellowfin tuna in the Australasian region were diverse in their feeding behaviour, consuming a variety of prey types, mainly dominated by different fish taxa. Among the fish taxa, some prey were more prevalent than others depending on the location and size of yellowfin that were sampled. The most important variables were sea-surface temperature, latitude and yellowfin size (fork length).

The methodology presented here has the capacity to replace existing approaches for analyzing fish diet composition, which tend to be more exploratory and require the use of different multivariate methods to arrive at a similar conclusion. The approach has implications for research into ecosystem-level trophic dynamics, as it can easily incorporate large datasets comprising multiple predators to explore differences in the feeding relationships of a community under different environmental conditions.

INTEGRATED MANAGEMENT AND VISUALIZATION OF ELECTRONIC TAG DATA WITH TAGBASE

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Electronic tags have been used widely for more than a decade in studies of diverse marine species. However, despite significant investment in tagging programs and hardware, data management aspects have received insufficient attention leaving researchers without a generalized and well-rounded toolset to manage their data easily. The growing volume of these data holdings, the large diversity of tag types and data formats, and the general lack of data management resources are not only complicating integration and synthesis of electronic tagging data in support of resource management applications but potentially threatening the integrity and longer-term access to these valuable datasets.

To address this critical gap, Tagbase has been developed as a comprehensive yet accessible data management solution for electronic tagging applications. It is based on a unified relational model that accommodates a suite of manufacturer tag data formats in addition to deployment metadata and reprocessed geolocations. Tagbase includes an integrated set of tools for importing tag datasets into the system effortlessly, and provides reporting utilities to interactively view standard outputs in graphical and tabular form. Data from the system can be easily exported or dynamically coupled to GIS or other analysis packages. Tagbase is scalable and has been ported to a range of database management systems to support the needs of the tagging community, from individual investigators to large scale tagging programs. Initially released in 2006, Tagbase represents a mature initiative with numerous users at diverse institutions involved in electronic fish tagging research.

CHALLENGES FOR MONITORING ALLOWABLE CATCH LIMITS OF U.S.-ASSOCIATED PELAGIC LONGLINE FISHERIES IN THE WESTERN-CENTRAL PACIFIC

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U.S.-associated pelagic longline fisheries in the western and central Pacific currently include 126-128 active Hawaii vessels/permits annually, 27 from American Samoa (including 11-12 dual permitted vessels that also fish out of Hawaii), and 3 from the Commonwealth of the Northern Mariana Islands. They fish over a wide expanse of the North, central and South Pacific Ocean. Primary data challenges for monitoring their allowable catch limits (ACLs) include the vast distances involved, lack of real time reporting capabilities, and differences between the units of vessel reporting (fish numbers) versus ACLs (metric tons). Sampling regimes with limited funding attempt to address the need to estimate whole weight of the catch, based on dressed and processed weights at market settings ranging from canneries and roadside stands to warehouses and high-end sashimi markets.

ACLs for bigeye (*Thunnus obesus*), and to a lesser extent yellowfin tuna (*Thunnus albacares*), by the Regional Fisheries Management Organisation (RFMO) currently drive management of these fishery's 60-70 harvested species, based on an invisible line in the ocean at 150° west longitude. Boundaries for marine protected areas, based on depth or distance from shore, are even harder for fishermen to track at sea. Longline vessel captains are required to report begin and end of set and haul coordinates, but natural laws govern set and drift. Only trip-level (not set-level) landings are registered at the market, so that estimating ACLs by RFMO is always a challenge.

During the past two years, the Hawaii longline catch of bigeye tuna has threatened to exceed established annual catch limits in the western and central Pacific, leading to closure of the fishery in the middle of the prime season for sashimi fish (November through January). The potential for lost revenue, and repercussions of under- or overestimating the weight of landings, place additional importance on the reliability of fast track logbook monitoring, getting weight estimates from the markets, and forecasting when ACLs will be reached. All this must be done with adequate lead time to meet federal review and publication requirements if a closure is necessary. Regional differences in reporting requirements and monitoring support for commercial versus noncommercial landings add additional challenges to providing information vital to sustainable management. These challenges will be faced in an expanding universe of ACL requirements within this decade.

COMBINING AERIAL AND ACOUSTIC METHODS TO DEVELOP FISHERY INDEPENDENT ASSESSMENTS OF ATLANTIC BLUEFIN TUNA IN THE NW ATLANTIC

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Development of fishery-independent approaches for improving stock assessments is a key research recommendation of tuna RFMO's and Kobe Reports, but few of these approaches have been implemented. Atlantic bluefin tuna (ABFT) spend the majority of their time on summer foraging grounds at shallow depths, where direct detection is feasible. In 2008-09, we undertook a pilot study combining sonar and aerial mapping techniques to determine biomass and size composition of juvenile ABFT schools off Cape Cod, MA. Our team included experienced bluefin fishermen and spotter pilots who located schools and estimated fish size and school biomass. We tested 200 kHz SM2000 (2008) and 400 kHz Reson 7125 (2009) multibeam sonars, while the spotter pilots conducted simultaneous aerial observation and documentation with a digital camera, GPS and an attitude sensor attached to the camera. From sonar, we obtained vertical slices of schools, images of individual tuna, and aerial photographs of surface layers of fish. School packing density, height, area and fish size were evaluated from sonar and aerial images with custom MATLAB software. We seek to optimize the combination of sonar and aerial imagery methods that would allow efficient, cost effective surveys to be conducted. By integrating sonar and aerial findings with electronic tracking, tagging and biophysical modeling results, there is great potential to develop new fishery independent assessments and better indices of abundance for ABFT.

TISSUE TURNOVER RATES AND TROPHIC ENRICHMENT FACTOR OF $\delta^{13}\text{C}$ AND $\delta^{15}\text{N}$ IN PACIFIC BLUEFIN TUNA, *THUNNUS ORIENTALIS*

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Stable isotope analysis (SIA) of carbon and nitrogen isotope ratios ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) has proven to be useful in the study of the ecology of marine species. This technique is of particular interest in the study of migratory pelagic species due to the difficulty of studying the life history of these animals. However, stable isotope values should be interpreted within the context of species- and tissue-specific stable isotope dynamics. Obtaining such information is especially difficult in large pelagic fish which are difficult to keep in captivity. Pacific bluefin tuna (*Thunnus orientalis*) have been successfully maintained in the Tuna Research and Conservation Center (TRCC; Hopkins Marine Station, Pacific Grove, CA) for over ten years. PBFT are fed a controlled, stable diet of sardine (*Sardinops sagax*) and market squid (*Doryteuthis opalescens*), and over time their tissues should come to stable isotopic equilibrium with this diet. Upon arrival to the TRCC, initial values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in muscle and liver tissues of small (62-75 cm CFL) wild PBFT are lower than TRCC feed. Thus these captive tunas provide semi-controlled conditions to ascertain tissue turnover rates of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in PBFT white muscle (WM) and liver, as well as trophic enrichment factor (TEF), or the difference in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values between tuna tissues and prey. White muscle and liver tissues were harvested from 71 Pacific bluefin tuna with time in captivity ranging from 2 to 2914 days. Stable isotope values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in captive PBFT WM and liver changed until equilibrium was reached between tissues and captive diet. Here we report the first estimates of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ turnover rates and TEF in captive PBFT muscle and liver tissues. We apply these values to SIA of wild PBFT in the Eastern Pacific Ocean to inform our understanding of migratory history of tunas sampled in the California Current System. In particular we estimated whether tuna sampled in the Southern California Bight have migrated northward from southern Baja, CA or eastward from Japan.

STUDIES OF YELLOWFIN TUNA EARLY LIFE HISTORY CONDUCTED AT THE IATTC'S ACHOTINES LABORATORY, 2010-2011

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The Inter-American Tropical Tuna Commission (IATTC) conducts research on the reproductive biology and early life history of yellowfin tuna at the Achotines Laboratory, Republic of Panama. Yellowfin broodstock have been spawning at near-daily intervals since 1996, and the resulting eggs, larvae and early-juveniles are studied in experimental investigations.

During 2010-2011, several ongoing investigations of yellowfin early life history were continued or completed. The results of a collaborative nutritional study with Texas A&M University were published. The study included an analysis of digestive enzyme activities and amino acid composition of both egg and early juvenile stages of yellowfin. The research was undertaken to examine stage-specific changes with respect to the development of digestive capacity, biochemical composition and amino acid profiles during yellowfin early life history. In general, the results support the hypothesis of precocious digestive capacity for yellowfin larvae and early juveniles which facilitates an early transition from a microzooplankton diet to a macrozooplankton/piscivorous diet.

The results of a multi-year study on the tolerance of yellowfin eggs and larvae to limiting levels of water temperature and dissolved oxygen were published. The study was designed to gain a better understanding of the physical factors that control the spatial and temporal distribution of yellowfin eggs and larvae in oceanic habitats. Lethal temperature limits were estimated for both eggs ($< 20^{\circ}$ and $\geq 34^{\circ}$ C) and early larvae ($< 21^{\circ}$ and $> 33^{\circ}$ C). An estimate of the optimal range of temperatures for rapid growth and moderate to high survival in first-feeding larvae ranged from $26 - 31^{\circ}$ C. A lethal dissolved oxygen limit for early larvae was estimated at $< 34\%$ oxygen saturation. The results are reviewed and discussed.

Results from a multi-year study on the effects of microturbulence on yellowfin larval survival were completed and a manuscript is in review. Earlier analyses had estimated the optimal range of microturbulence for yellowfin larval survival during the first week of feeding in the laboratory. The analysis was expanded to estimate optimal wind speeds for yellowfin larval survival in mixed-layer habitats in the ocean. A 20-year period (1987-2007) of wind speeds in the eastern Pacific Ocean (EPO) was examined to investigate correlations between optimal wind speeds and yellowfin recruitment in selected $2^{\circ} \times 2^{\circ}$ areas of the EPO. Those results are discussed.

Additional joint studies at the Achotines Laboratory will commence during 2011. A collaborative experimental study, funded by the Pelagic Fisheries Research Program (PFRP) and conducted with the Secretariat of the Pacific Community (SPC), will investigate the potential effects of ocean acidification on yellowfin early life stages. In mid-2011, a 5-year joint study will begin at the Achotines Laboratory and in Japan to conduct comparative studies of the early life history of Pacific bluefin and yellowfin tuna. The studies will be conducted jointly with Kinki University and the Autoridad de los Recursos Acuáticos de Panama, and will be funded by the Japan International Cooperation Agency (JICA) and the Japan Science and Technology Agency (JST).

HABITAT UTILIZATION AND MOVEMENT PATTERNS OF JUVENILE PORBEAGLE SHARKS (*LAMNA NASUS*) IN THE NORTHWEST ATLANTIC

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Porbeagle sharks (*Lamna nasus*) are members of the Family Lamnidae, a group of fish known for their highly migratory behavior and the ability to sustain regional endothermy. The elevated body temperature of porbeagles is an unusual quality in fishes, and may allow these sharks to inhabit cold waters at high latitudes. The migratory patterns of this species in the northwest Atlantic have been inferred from both commercial catch data and conventional tagging. Technological advancements have spurred development of the archiving satellite tag, which can be used to develop a better understanding about the porbeagle's spatial and temporal movements, as well as the potential ecological forces driving its migratory behavior. Satellite tags pose a unique opportunity for researchers to gather actual swimming pattern data from fish without having to infer such behavior from fishery-dependent information. In late November 2006, twenty pop-up archival transmitting (PAT) tags were deployed on porbeagle sharks in George's Bank, off the coast of Cape Cod. Porbeagles in this study were all immature males and females of similar size (127.8-154 centimeter fork length). Tags were programmed to release and transmit at four, eight, and twelve-month intervals. Trends in vertical movements were analyzed using generalized estimating equations (GEE), and horizontal movements were determined by using the filtering program "trackit" in statistical software program R. Data analysis thus far has reveal two different uses of the water column. Some porbeagles, referred to as "divers", move into deep waters in the winter months, down to 1400 meters, and remain diving in these deep waters for the season, rarely coming to surface waters. The second group, "non-divers", frequent the surface waters in the winter months and rarely penetrate below 200 meters. GEE analysis reveals a significant effect of location, season, and time of day on vertical movement patterns. The sample size of fish and data revealed by this study offer a robust, fisheries-independent, assessment of the seasonal migration patterns of juvenile porbeagle sharks.

MODELING POPULATION PROCESSES FOR TUNA STOCK ASSESSMENT: WHAT ASSESSMENT SCIENTISTS NEED FROM BIOLOGISTS

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Tunas comprise some of the most valuable commercial fisheries in the world, yet the assessments of their stock status are uncertain. There are vast quantities of detailed data such as catch, effort, and length composition collected on a routine basis from the commercial fisheries. High tech methods are used to collect interesting information of the horizontal and vertical movement of tunas. However, basic information such as growth, natural mortality, maturity and fecundity, the stock-recruitment relationship, and reliable indices of abundance are lacking. We explain and illustrate how these population processes influence stock assessments and management advice, and present the current state of knowledge about these processes for tunas in the eastern Pacific Ocean. Finally, we provide recommendations on where research and funding should be focused.

TROPHIC DYNAMICS AND ECOSYSTEM CHANGES WITHIN THE SE FLORIDA COASTAL PELAGIC FISH COMMUNITY

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The waters off the southeast coast of Florida are home to a unique pelagic and coastal pelagic ecosystem. The geography and physical oceanographic characteristics of this area form a condensed ecosystem where multiple apex predators are present. The big game fish, particularly scombrids such as tunas and wahoo, can be harvested within these coastal pelagic waters and are primarily targeted by recreational anglers. Presently there is a shortage of available data concerning fishes of the coastal pelagic ecosystem.

The objective of this research project is to investigate and achieve a greater understanding of coastal pelagic fishes, with an emphasis on the higher order species that inhabit the mid-range coastal pelagic to true pelagic waters, and the ecological role they play within the community ecology of the pelagic ecosystem. The selected fish species includes King Mackerel (*Scomberomorus cavalla*), Spanish Mackerel (*S. maculatus*), Cero (*S. regalis*), Blackfin Tuna (*Thunnus atlanticus*), Yellowfin Tuna (*T. albacares*), Skipjack Tuna (*Katsuwonus pelamis*), Atlantic Bonito (*Sarda sarda*), Little Tunny (*Euthynnus alletteratus*) Wahoo (*Acanthocybium solandri*), Greater Amberjack (*Seriola dumerili*), and Dolphinfin (*Coryphaena hippurus*). These species were selected based on their position as upper trophic level predators in the marine ecosystem food web and their general habitat distribution in the coastal pelagic zone. In a one year period between March 2010 and March 2011, a total of 239 fish from the 11 species have been sampled. The samples were collected opportunistically from recreational tournament anglers in the south Florida area between West Palm Beach and the Florida Keys. From each fish specimen sampled the stomach, gonads, blood, muscle tissue, and liver tissue was collected for further analysis. Morphometric data for each specimen was also recorded.

A stable isotope analysis was performed with the muscle tissue and blood samples using carbon $\delta^{13}\text{C}$ and nitrogen $\delta^{15}\text{N}$ for trophic analysis. A gut content analysis was performed with the frequency of occurrence and percent composition by weight approaches used for quantitative description of the analysis. The gut content analysis is performed and compared to the stable isotope analysis to further understand the trophic interactions and trophic position among the coastal pelagic community. The preliminary results of the stomach content and stable isotope analysis from year 1 of sampling is being presented.

This research project began in 2010 and is planned to continue 2012, in an effort to collect data over 2-3 generations. The completion of this research project will achieve a greater understanding of the community ecology of these HMS coastal pelagic fishes and illustrate of the ecological roles/linkages between the coastal pelagic and pelagic ecosystems. The ecosystem and trophic data obtained from this study will also assist with the development of ecosystem based models and sustainable fisheries for the Florida East Coast HMS fishery.

POTENTIAL BENEFITS OF VISCERAL ENDOTHERMY IN THE SHORTFIN MAKO SHARK, *ISURUS OXYRINCHUS*

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Lamnoid sharks, including the shortfin mako (*Isurus oxyrinchus*), maintain digestive tract temperatures elevated above ambient water temperature (visceral endothermy). These sharks have evolved a vascular counter-current heat exchanger, the suprahepatic *rete*, which conserves metabolic heat produced by digestion and assimilation. It is thought that visceral endothermy results in higher food-processing rates in lamnoid sharks. We tested the hypothesis that visceral endothermy results in higher digestive enzyme activities in lamnoid sharks, by comparing *Isurus oxyrinchus* to two sharks that cannot elevate visceral temperatures, the thresher, *Alopias vulpinus*, and the blue, *Prionace glauca*. Sharks were collected by longline during National Marine Fisheries Service juvenile shark abundance surveys, 2007-2010. Stomach and pancreas tissue samples were dissected from mortalities, frozen in liquid nitrogen, and stored at -80°C until assays were performed. Tissue samples were homogenized in a 10-fold dilution of 50 mM Tris HCl buffer using a chilled ground glass homogenizer. The homogenate was centrifuged at 0°C for 10 min at 12,000 g, and the supernatant was stored on ice until the appropriate assay for pepsin, trypsin, or lipase was run. The digestive enzymes were activated, when necessary, then incubated in triplicate at 15°C and 25°C with the appropriate substrate at saturating concentrations (as determined by preliminary assays). The digestive enzyme specific activity, which was proportional to the change in absorbance at a specific wavelength over time, was expressed as μmol of substrate converted to product per minute (unit, U) per gram tissue wet weight (U g^{-1}). At the elevated digestive tract temperature of *I. oxyrinchus*, stomach pepsin activity was significantly greater than in both *A. vulpinus* and *P. glauca*. Preliminary results also indicate that pancreatic trypsin activity was significantly greater in *I. oxyrinchus* than in *P. glauca*, whereas pancreatic lipase activity did not differ significantly between these two species. The protease data support the hypothesis that maintaining higher digestive enzyme activities was a selective advantage of visceral endothermy in lamnoid sharks. We plan to collect additional specimens of *A. vulpinus* and also to measure pancreatic trypsin and lipase activities in more individuals of all three species.

POPULATION GENETIC STRUCTURE OF THE SPINETAIL MOBULA (*MOBULA JAPANICA*) IN THE PACIFIC AND INDIAN OCEAN BASINS

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The Pacific and Indian Ocean basins are home to 8 of the 12 species of manta ray (family Mobulidae, genera *Manta* and *Mobula*). Manta rays are regularly subject of directed and by-catch fisheries mortality in artisanal and large scale purse-seine fisheries. Tagging data show that some manta rays aggregate in areas with high prey densities that coincide with the distribution of that of yellowfin tuna and Eastern Pacific tuna purse seine fisheries. This results in manta ray bycatch in tuna purse seine fisheries – the primary target of the purse seine fisheries. A first step in evaluating the potential impact of this bycatch on manta ray populations is an analysis of their population structure. In this study we focus on *Mobula japanica*, a pelagic pan-tropical species that has been documented in bycatch data. We characterize microsatellites (12 loci) and mitochondrial DNA (2 genes: ND5 and CO1) variation within and between putative populations of this species from 6 locations across the Pacific and Indian Ocean basins. Discordance in observed patterns of variation across samples based on different classes of molecular markers are used to look for evidence of sex biased dispersal, and coalescent based approaches are used to elucidate the role dispersal may have in shaping the distribution of *M. japanica*. Our data suggest that *M. japanica* has little population structure and appears to be panmictic across sampled ocean basins, potentially decreasing the potential for local impact to *M. japanica* populations due to tuna purse seine activities.

COMPOUND SPECIFIC NITROGEN ISOTOPE ANALYSIS OF AMINO ACIDS: A NEW TOOL FOR STUDYING THE TROPHIC ECOLOGY OF MARINE ANIMALS

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Evidence increasingly demonstrates that selective removal of marine life can induce restructuring of marine food webs. Trophic structure is the central component of trophic mass balance models, tools widely used to evaluate fisheries in an ecosystem context and for inputs leading to decision support tools for future resource management. Recent management efforts guided by these ecosystem-based models have shown promise for reestablishing natural marine ecosystems and restoring fisheries. These mass-balance models represent trophic linkages among biomass pools based on diet however there has been no reliable independent method to validate the depiction of trophic structure in these models. We are testing and apply a new stable isotopic approach, amino acid compound specific nitrogen isotope analyses, that can provide efficient, time-integrated and unbiased assessments of the trophic status of organisms across marine ecosystems.

The bulk nitrogen isotopic composition of a consumer's tissue has been used extensively to investigate trophic linkages within marine food webs. However, there are a number of assumptions that must be met in order to satisfactorily interpret bulk tissue nitrogen isotope values in terms of trophic position, including knowing the isotopic composition of plants at the base of the food web and the expected nitrogen isotope enrichment at each trophic step. Compound specific nitrogen isotope analysis of amino acids can alleviate some of the challenges associated with interpretation of bulk tissue nitrogen isotopic values. In samples of consumer tissues some amino acids, such as phenylalanine, appear to retain the isotopic composition of nitrogen sources at the base of the food web, whereas other amino acids, such as glutamic acid, are significantly enriched in ^{15}N as they move through the food web. Our research is testing the assumption that the nitrogen isotopic composition of specific amino acids provides an unambiguous and integrated measure of fractional trophic position across multiple phyla, regardless of an animal's physiological condition or of the biogeochemical cycling at the base of the food web, which influences the isotopic composition of all members of the food web. We hope to determine if amino acid compound-specific isotopic analyses will allow rigorous testing of the efficacy of trophic position estimates based on ecosystem-based models and promote the evolution of these models into valuable decision-support tools. The application and pitfalls of this technique to marine organisms including zooplankton, reef and pelagic fishes, rays and sharks will be discussed.

FEEDING HABITS OF THE BROADBILL SWORDFISH (*Xiphias gladius*) SAMPLED FROM THE CALIFORNIA-BASED DRIFT GILLNET FISHERY, 2007-2010

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Broadbill swordfish (*Xiphias gladius*) are widely distributed in all tropical and temperate oceans, from roughly 50°N to 50°S latitude. They are typically found in areas of high productivity near current boundaries and frontal zones. Along the west coast of the U.S. and Baja California, Mexico, swordfish are seasonally abundant in the highly productive California Current. Electronic tagging data demonstrate that within the California Current, swordfish typically remain close to the surface at night, and when not basking, spend daytime hours at depths of up to 400 m. Characterization of their diet from various regions, as well as tagging data and the presence of specialized tissues that warm the brain and eyes suggest that these predators forage at great depths in cold, dark waters below the thermocline. The available diet data reveal a broad range of prey types depending upon the area, highlighting the need for regional studies. To date there have been few studies on swordfish foraging ecology in the California Current. Predator-prey information is particularly important for ecosystem-based management.

To quantify the foraging ecology of swordfish within the Southern California Bight (SCB), stomach content analyses were performed on stomachs collected from the California-based pelagic drift gillnet (CDGN) fishery over four fishing seasons, 2007-2010. One hundred-fifteen stomachs were collected by fishery observers from August through December within the U.S. Exclusive Economic Zone between the U.S./Mexico border and Point Piedras Blancas, California. Food was present in 97% of the stomachs representing at least 35 taxa. The five top prey as determined by the Geometric Index of Importance (GII) were cephalopods. The most important prey was jumbo squid (*Dosidicus gigas*), which was present in 79% of stomachs followed by the boreopacific gonate squid (*Gonatopsis borealis*) that was in 72% of stomachs. The most important teleosts were Paralepididae (Barracudinas) followed by Scopelarchidae (Pearleyes). The majority of the most important prey species are associated with the deep scattering layer, although epipelagic fish also occurred in their diets.

In comparing swordfish to other large pelagic fish that forage in the same productive waters of the SCB there are both similarities and differences. For swordfish, mako and blue sharks, cephalopods are the most important prey taxa, with jumbo squid being one of the dominant prey for all three species. Similar to bigeye thresher sharks, swordfish target both prey associated with the deep scattering layer in addition to small epipelagic fish, indicating that they can forage broadly throughout the water column. The behaviors of swordfish and bigeye thresher sharks are characterized by similar diel vertical migrations that are likely linked to the movements of the deep scattering layer. Common thresher sharks feed mostly on coastal small schooling fish that are a minimal component of the swordfish diet. The occasional remains of marine mammals, elasmobranchs and birds have also been found in the stomachs of mako and blue sharks, prey not yet observed in swordfish.

The large number of prey taxa found in the swordfish diet in this and other studies suggests that these vagile fish are generalists and capable of exploiting a range of prey in a variety of habitats. Generalist predators will be less susceptible to variability in the composition of the prey base that may result from natural or human impacts. The apparent habitat overlap between swordfish and many of the non-target fish species taken in the CDGN fishery, including the shark species listed above, presents a challenge to fishery managers aiming to minimize bycatch. More detailed quantitative analysis of diet studies such as this coupled with analyses of the distribution of swordfish and vulnerable non-target species will help to identify where habitat separation exists among species and to develop appropriate management options. These efforts are currently underway.

OCEAN SCALE HYPOXIA-BASED HABITAT COMPRESSION OF ATLANTIC ISTIOPHORID BILLFISHES

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Oxygen minimum zones (OMZs) below near-surface optimums in the eastern tropical seas are among the largest contiguous areas of naturally occurring hypoxia in the world oceans and are predicted to expand and shoal with global warming. In the eastern tropical Pacific (ETP), the surface mixed layer is defined by a shallow thermocline above a barrier of cold hypoxic water, where dissolved oxygen levels are $\leq 3.5 \text{ mL L}^{-1}$. This thermocline (~25-50 m) constitutes a lower hypoxic habitat boundary for high oxygen demand tropical pelagic billfish and tunas (i.e., habitat compression). To evaluate similar oceanographic conditions found in the eastern tropical Atlantic (ETA), we compared vertical habitat use of 32 sailfish (*Istiophorus platypterus*) and 47 blue marlin (*Makaira nigricans*) monitored with pop-up satellite archival tags in the ETA and western North Atlantic (WNA). Both species spent significantly greater proportions of their time in near-surface waters when inside the ETA compared to those in the WNA. We contend that the near surface density of billfish and tunas increases as a consequence of the ETA OMZ, therefore increasing their vulnerability to overexploitation by surface gears. Since the ETA OMZ encompasses nearly all Atlantic equatorial waters, the potential impacts of overexploitation are a concern. Because of the obvious differences in catchability inside and outside the compression zones, it seems essential to standardize these catch rates separately in order to minimize inaccuracies in stock assessments for these species. This is especially true in light of global warming which will likely exacerbate future compression impacts.

TUNA IN FREE-SWIMMING SCHOOLS ARE IN BETTER CONDITION THAN THOSE ASSOCIATED WITH NATURAL FLOATING OBJECTS: WHY DO THEY ASSOCIATE WITH FLOATING OBJECTS?

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Although the adaptive values of the associative behaviour of tuna with floating objects are not clear, this behaviour is believed to have evolved to provide certain advantages. However, the deployment of thousands of Fish Aggregating Devices (FADs) by fishers over the last decades, modifying the habitat, questions this previously beneficial associative behaviour (ecological trap hypothesis). Hence, within an area of natural occurring logs (and free of FADs), we tested the hypothesis that the health condition of tuna associated with logs would be similar or superior to that of tuna in free-swimming schools. Our results reject this hypothesis, showing that skipjack tuna associated with logs naturally exhibit poorer conditions than those in free-swimming schools for both morphometric (TG-FL linear relationship) and physiological indices (PA). Such a result prevents from interpreting differences in condition as an evidence of ecological trap. More, our results suggest that the reason for why tuna developed this associative behaviour with floating objects would not be directly related to trophic benefits but that logs could rather play a social role. This study provides new insights into the associative behaviour of tuna and furthers our knowledge of alternative habitat selections in anthropogenically modified environments.

DOES THE SPECIES AND SIZE COMPOSITION OF TUNAS CAPTURED UNDER FADS DEPEND ON TIME SINCE DEPLOYMENT?

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Tuna caught associated with fish aggregating devices (FADs) is an important component of the purse seine fishery of the EPO. The three major tuna species caught in FAD sets are yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*), and bigeye tuna (*T. obesus*). We analyzed the data available for all the sets made on FADs that were seeded during the same trip, for the period 2005 – 2010, from the IATTC observer database. The relative abundance of these 3 tuna species, as well as their size composition is analyzed as a function of the number of days spent drifting after the FAD seeding. Seasonal and spatial analyses of these trends were also developed for the major tuna species.

ANALYSIS OF FOOD SELECTIVITY AND FEEDING BEHAVIOR OF YELLOWFIN TUNA LARVAE, *THUNNUS ALBACARES*, DURING THE FIRST THREE WEEKS OF AGE

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Several experiments designed to investigate the feeding behavior of yellowfin tuna larvae were conducted at the Inter-American Tropical Tuna Commission's (IATTC) Achotines Laboratory in Panama. This paper will summarize the preliminary results from three experiments testing food selection behavior, two experiments studying diel feeding patterns, and one trial investigating feeding behavior in relation to light intensity level.

Previous experimental results published by our group in 2001 indicate that yellowfin tuna larvae are selective feeders, exhibiting strong patterns of prey selection during the first week of feeding. Three experiments during the 1997 and 2002 experimental seasons were conducted. The age range of the yellowfin tested was one to three weeks of age. Prey items offered included cultured *Artemia* and post-yolk-sac yellowfin larvae as well as wild zooplankton and cultured rotifers. The wild zooplankton was collected in net tows near the Frailes Islands, not far from the coast of Achotines Bay. Fish larvae were introduced as prey to test the widely-held hypothesis that older tuna larvae selectively feed on smaller fish larvae as a feeding strategy. Prey types comprising the majority of the diet over all three experiments were *Artemia*, calanoid, cyclopoid, and harpacticoid copepods, copepod nauplii, rotifers and yellowfin larvae. The larvae were found to show strong patterns of prey selection, demonstrating the strongest preference for fish larval prey when they were available.

Two diel feeding experiments were conducted, the first in 2000 and the second in 2001. The experiments were designed to estimate minimum light intensity thresholds for feeding in yellowfin larvae and gut clearance rates with development. During 2000, first-feeding yellowfin tuna larvae were sampled at approximately hourly time intervals for 33 hours, beginning at midnight of the morning of first feeding until 1000 hours on day two of feeding, and again from midnight on the sixth day of feeding until 2000 hours on the seventh day of feeding. In 2001, a similar experimental design was used to examine older larvae, and began at 1530 hours on the 17th day of feeding and ended at 1115 hours on the 18th day of feeding. Yellowfin were fed cultured rotifers in the first experiment and a mix of *Artemia* and fish larvae in the second. Light level measurements and gut samples were taken concurrently at set time intervals. Larvae at all stages of development exhibited a diel pattern of feeding. The minimum light intensity threshold for feeding decreased from $8.15 \mu\text{mol s}^{-1}\text{m}^{-2}$ for first-feeding larvae to $0.025\text{-}0.11 \mu\text{mol s}^{-1}\text{m}^{-2}$ for late-larvae. Gut clearance times increased from about 1.0-1.5 hrs in first-feeding larvae to 3.0-5.0 hrs in late-larvae. Larvae at all stages of development showed no evidence of feeding during dark cycles.

The light intensity experiment in 2002 examined the feeding behavior of yellowfin larvae at a low, medium, and high light intensity, with replication. The experiment was designed to determine the optimal level of light intensity for feeding of yellowfin larvae in mixed layer habitats as well as the optimal level for rearing of yellowfin larvae. The experiment began on the first day of feeding and was terminated after ten days of feeding. Results of feeding, growth and survival in relation to light intensity will be presented.

EVALUATING THE EFFECTS OF TRAILING GEAR IN THE CALIFORNIA RECREATIONAL THRESHER SHARK FISHERY

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The common thresher shark (*Alopias vulpinus*) is the target of a popular recreational fishery in Southern California. One of the primary techniques employed in this fishery entails trolling lead-headed lures (0.5 kg) with large J-type hooks. Since thresher sharks utilize their elongate caudal fin to stun prey, the majority of sharks are hooked by the tail in this fishery. The large size of many of the sharks within the Southern California Bight (>100 kg) is often sufficient for them to break free during the fight raising concerns over trailing gear in this fishery. Trailing gear refers to the terminal tackle that is left embedded in a free-swimming shark that was hooked but not landed. This research tests the hypothesis that tail-hooked common thresher sharks survive the acute effects of trailing fishing gear in the Southern California recreational fishery. Survivorship was determined using pop-off satellite archival tags (PSATs) deployed on common thresher sharks ranging in size from 132 to 175 cm FL. Tag deployments were scheduled for 60 days during which time depth, temperature, and light levels were sampled every minute. To date, PSATs have been deployed on five common thresher sharks captured using fishery standard techniques and released with trailing gear. Of the five sharks, three displayed immediate mortality (within 31 hours of release), one shark survived the effects of trailing gear, and one of the PSATs did not report any information. The results of this study, in combination with results of a published study on the survivorship of tail-hooked thresher sharks released without trailing gear, will be used to estimate the survival rates of thresher sharks released from the recreational fishery. Collectively, these data will be incorporated into the stock assessments for this species. Concurrent investigations on the effectiveness of degradable links and alternative fishing techniques were also performed to reduce overall post-release mortality in the recreational fishery. We will report information on additional deployments as well as findings related to reducing post release mortality in this recreational fishery as they become available.

RECRUITMENT HABITAT OF PACIFIC TUNAS AND BILLFISH: META-ANALYSIS, PREDICTIONS AND NEEDS

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Understanding of billfish and tuna recruitment dynamics lags far behind knowledge of adult dynamics of these heavily exploited fish. This critical gap in basic biological understanding has important implications for management and conservation. Direct observations of wild spawning and conditions it occurs in are rare. However, information about reproduction in the field can be derived from larval surveys and sampling adult gonad condition. Concurrent documentation of environmental parameters during sampling is critical to understanding exogenous factors underpinning reproduction. These kinds of data are accessible within the primary literature, but much more lies in the grey literature. When coupled with oceanographic databases, it is possible to construct habitat maps, build habitat suitability indices (HSI), and identify areas of interest for additional sampling effort. We summarize data from the literature to construct an overview of environmental conditions associated with reproduction of Pacific billfish (striped and blue marlin) and tunas (yellowfin, bigeye, skipjack, albacore, bluefin). Analytical approaches to deriving HSI and identifying focal areas for new sampling efforts are considered. We provisionally refer to this as 'recruitment' habitat, as opposed to 'spawning' or 'larval' habitat, because multiple sources of reproductive information are considered. Additionally, improving understanding of how the environment affects recruitment and overall population dynamics of these species is the main goal of this project.

FORAGING ECOLOGY AND OCCURRENCE OF OPAH, *LAMPRIS GUTTATUS*, IN THE SOUTHERN CALIFORNIA BIGHT

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The opah (*Lampris guttatus*) is a large, mid-water pelagic fish that is encountered in temperate and tropical oceans throughout the world. Caught incidentally in the California drift gillnet fishery (CDGN) that targets swordfish, opah are a highly valued food fish and can be purchased fresh or frozen at fish markets globally. Known to occur seasonally in the Southern California Bight (SCB) and off the coast of Mexico, opah are also occasionally caught during the summer and fall months by recreational fishermen targeting albacore, yellowfin, and bluefin tuna. Despite their value to commercial and recreational fishermen, opah have been largely ignored and little research on their ecology or patterns in abundance has been conducted, especially in the SCB. Recent genetic analysis confirmed two distinct species exist in the North Pacific characterized by the relative size of the eye. Fish samples in the SCB have been identified as “small-eye” opah and a description of the species is currently in preparation.

Based on a preliminary analysis of the CDGN observer database, covering the years from 1990 to 2009, catch rates averaged 2.31 opah per set. Peak catch rates were observed during 1997 (4.44), 2007 (3.41), and 2009 (4.4) which correlates with El Niño oceanographic conditions. This is similar to reports for the 1982-83 El Niño events when increases in US West Coast(?) opah landings were documented. Overall it appears opah catch rates are relatively constant over the past two decades with increases during El Niño events. This suggests that opah occurrence could be impacted by changing environmental conditions with increases in temperate waters during warming trends.

In 2009 and 2010, during the NOAA SWFSC’s annual juvenile shark abundance survey, 24 opah were caught using long-line gear baited with Pacific mackerel. This compares to only one opah caught in the 19 years of the survey prior to 2009. Stomachs collected in 2009 (n=1) and 2010 (n=8) are being processed and prey identified to the lowest possible taxonomic level. Preliminary results show a range of fish and squid including hake, barracudinas, and octopodoteuthis. These species are associated with the mesopelagic waters and indicate that opah are foraging in the midwater. A previous study in the central North Pacific found that prey species associated with the mesopelagic dominated opah diet composition. A comparison with diets of tunas and swordfish also from the SCB indicate greater niche overlap with swordfish than with tunas.

FACTORS INFLUENCING SWORDFISH DISTRIBUTION AND ABUNDANCE OFF THE U.S. WEST COAST

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Swordfish are an important fishery resource off the U.S. West Coast where they are commercially targeted by the Drift Gillnet (DGN) fishery. However, their co-occurrence with a number of protected and/or managed species has caused concern over the incidental take of these species in the DGN fishery. A number of approaches have been instituted to reduce bycatch of marine mammals, sea turtles, and other non-target species including time-area closures and mandates to modify fishing practices and gear. Although these approaches have successfully reduced bycatch, they have had negative effects on the swordfish fishery which has seen reductions in vessel number and catch. Moreover, several non-target species, such as pelagic sharks, are still caught in large numbers, compromising the sustainability of the fishery. The primary objective of this study is to identify environmental factors that influence the distribution and abundance of swordfish off the U.S. West Coast. Knowledge of these factors would allow for more effective management by targeting fishing efforts to those areas and time periods where the catch of swordfish is expected to be high and the catch of non-target species low. Using a novel statistical approach known as boosted regression trees, we modeled the relationship between swordfish catch and environmental factors in the DGN fishery. Preliminary results suggest that swordfish catch rate is correlated with both biotic (primary production, zooplankton abundance) and oceanographic (SST, currents, depth) factors. If combined with data on location (i.e., lat/long) and time of year (i.e., month), these factors can be used to predict swordfish catch rates with impressive accuracy (e.g., cross-validated R^2 values around 0.70). However, effectively avoiding bycatch will require that non-target species respond differently to the same set of factors (thereby allowing discrimination of preferred 'habitat' for management purposes). As a next step, similar modeling approaches will be conducted to characterize the occurrence of blue sharks and leatherback sea turtles.

RESEARCH EFFORTS ON THE BIOLOGY AND FISHERIES FOR THE COMMON THRESHER SHARK (*ALOPIAS VULPINUS*) ALONG THE U.S. WEST COAST

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Common thresher sharks, *Alopias vulpinus* (threshers), are thought to be moderately long-lived and slow growing sharks that inhabit coastal and pelagic temperate waters throughout the World's oceans. As the most economically valuable pelagic shark species caught off California, threshers are targeted and landed in commercial and recreational fisheries. Similar to most elasmobranchs, the life history characteristics of threshers make them highly vulnerable to overfishing. The NOAA Southwest Fisheries Science Center (SWFSC) has been conducting research on thresher sharks for more than twenty years to learn about their biology, distribution and abundance in the Northeast Pacific Ocean in support of fisheries management. We present an overview of ongoing data gathering efforts for threshers and review current and past research available for stock status assessment needs. We characterize thresher catch, present preliminary population trends and identify areas where data gaps exist and future research is needed for a complete and thorough stock status analysis.

Examples of preliminary results from the ongoing fishery data analysis and research efforts are mentioned below and others will be presented. Commercial landings records show that U.S. west coast thresher landings were highest during the early years of the California drift gillnet fishery (~ 1977-1983) peaking at approximately 1800 metric tons (mt) in 1982. Catch decreased sharply through 1987 and has since stabilized at roughly 200-300 mt annually. Nominal catch per unit of effort (CPUE), calculated as the number of threshers caught per set in the drift gillnet fishery, also declined dramatically in the early years of the fishery. This suggests an overfishing effect; however, regulatory changes imposed to protect pupping threshers during the spring months and other protected species, as well as changes in fishing practices in the drift gillnet fishery (i.e., a switch in target species from threshers to higher valued swordfish), have resulted in decreased effort on threshers. Nominal CPUE has been increasing since the early 1990s.

In addition to the CPUE analyses, tagging, foraging, and growth studies have provided vital information for stock assessment and management. For example, over 1400 threshers have been tagged off California and data from 90 recovered tags demonstrate movements of up to 426 nautical miles (nm) within the west coast Exclusive Economic Zones (EEZs) of the U.S. and Mexico. Foraging ecology studies of threshers off the coasts of California and Oregon have been ongoing since 2002 and show that northern anchovy (*Engraulis mordax*) is the highest ranked prey followed by the Pacific sardine (*Sardinops sagax*). Size frequency data and vertebral band counts have been used to develop a growth curve for threshers in the eastern Pacific Ocean.

Results from the SWFSC research program, as well as from other organizations, point toward a relatively confined population of threshers off the west coast of the U.S. and Baja California, Mexico. Thus, the SWFSC is working in cooperation with partners in Mexico to effectively monitor and manage threshers in the Northeast Pacific Ocean. Efforts are currently underway to conduct a regional stock assessment using data from both Mexico and the U.S. that will be used for management purposes. The research being conducted by the SWFSC will provide essential fishery and life history information for this assessment.

THE CHALLENGES TO COLLECTING FORAGING ECOLOGY DATA FROM FISH LANDED AT RECREATIONAL FISHING TOURNAMENTS

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Tunas, marlin, wahoo, and dolphinfish are top predators in pelagic marine ecosystems with the potential to shape food-web dynamics. They are also highly valued as commercial and recreational fisheries. Despite their importance, trophic relationships among many of these species are poorly understood. Logistical difficulties have mainly precluded studies of large pelagic fishes. For example, species aggregations in offshore environments are patchy, distributed over large spatial scales, and fluctuate widely in occurrence over temporal (e.g., seasonal) periods. Hence, they are difficult to access and sample comprehensively. Much of what we do know is derived from fishery-dependent sampling. The authors of the present study work almost exclusively with recreational anglers and at fishing tournaments. Although angler participation has been exemplary, the body sizes of fishes targeted at recreational fishing tournaments are skewed towards large individuals, and precise information on where and when individual fish were caught is often unavailable. Results and conclusions are therefore limited to a subset of the populations in question; however, this is often the portion of the population most influenced by fishing pressure and, thus is still of high value.

Fishes landed at recreational fishing tournaments were sampled throughout Massachusetts, New Jersey, North and South Carolina during 2007 – 2010 with the objective of collecting data for diet and stable isotope analyses. Stomachs and muscle tissue were collected from 145 yellowfin (*Thunnus albacares*), albacore, (*T. alalunga*), bigeye (*T. obesus*), and blackfin (*T. atlanticus*) tunas as well as 212 dolphinfish (*Coryphaena hippurus*), 75 wahoo (*Acanthocybium solanderi*), and 30 white marlin (*Tetrapturus albidus*) and roundscale spearfish (*T. georgii*). Stomach content analysis found that fish prey occurred most frequently and contributed the greatest proportion by mass to the diets of all predators landed in the Carolinas and New Jersey. Alternatively, cephalopods were of primary importance to the diets of fishes landed in northern waters off of Massachusetts. Bullet tuna (*Auxis* sp.) and shortfin squid (*Illex illecebrosus*) were primary prey shared by multiple predators. Stable isotope analysis revealed that white marlin had the highest $\delta^{15}\text{N}$ (11.5‰) values and hence were feeding at the highest trophic level among all predators examined. In the South Atlantic Bight, yellowfin and blackfin tuna muscles exhibited higher $\delta^{15}\text{N}$ values (10.8 and 10.7‰, respectively) than wahoo (9.9‰) or dolphinfish (9.5‰). However, the muscle of yellowfin (10.4‰) and albacore (10.6‰) tunas exhibited lower $\delta^{15}\text{N}$ values than dolphinfish (10.9‰) collected in waters off of Massachusetts. $\delta^{15}\text{N}$ values in dolphinfish exhibited a 1.4‰ increase between southern and northern waters suggesting a regional shift in foraging habits and an increase of approximately 0.5 trophic levels. We hypothesize this shift is a reflection of a diet comprised of higher amounts of larger-sized squid (46% by mass) in northern waters compared to a more piscivorous diet (94% fish by mass) diet composed of smaller-sized prey in southern waters. Since squid is a primary prey to tunas in all regions, our findings suggest there is increased competition between dolphinfish and tunas in northern habits. Results provide insight into shared resource use by these predators and will be discussed in relation to regional food habits and seasonal migration patterns.

AN EFFICIENCY APPROACH TO OPTIMIZING THE LEVEL OF OBSERVER COVERAGE

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The US Magnuson-Stevens Fishery Conservation and Management Act (MSA) authorizes the use of onboard observers to monitor commercial fisheries catch and bycatch. Observers are trained biologists who are paid to travel on board commercial fishing vessels to identify and record the amounts, characteristics and disposition of catch and bycatch for all species which are caught. Within some fishery management contexts, at-sea observers are regarded as the most reliable method to identify and determine total catch and disposition of catch (and bycatch) of different species subject to management. However, observer programs also pose drawbacks, including the direct cost of placing observers on commercial fishing trips and indirect costs such as disruption of normal vessel operations, burdening fishers with the need to accommodate observers, logistical difficulties with placing observers on long trips, and safety (PFMC 2003).

A key question of concern in implementing an observer program is that of the appropriate level of observer coverage. Current practice varies by fishery; for example, the California-Oregon drift gillnet (DGN) fishery for swordfish and thresher shark has employed an observer coverage level near 20 percent of effort since the program's inception in 1990, while the Hawaii shallow-set longline fishery currently requires a 100 percent coverage level to implement a sea turtle quota with a shut-down provision which requires in-season fishing effort to end once either sixteen leatherback turtle or seventeen loggerhead turtle interactions have been observed. Other federally managed US fisheries with little bycatch do not have observer programs.

We propose an efficiency approach to the question of what percent observer coverage level is optimal. Following Segerson (2007), we assume that bycatch occurs as a stochastic process whose mean level is conditionally dependent on nominal fishing effort. We further assume bycatch regulation through a quota with a shut-down provision which ends in-season fishing effort once the quota is reached with a specified probability. Assuming a fixed cost per observed set of fishing effort, we develop and illustrate an efficiency criterion for identifying the level of observer coverage to optimally balance the cost of a higher coverage level against the benefit of reducing uncertainty about whether the quota has been exceeded.

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VERTICALLY MIGRATING MESOPELAGIC MICRONEKTON IN THE WESTERN CENTRAL PACIFIC

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Mesopelagic micronekton (fishes, cephalopods and crustaceans in the size range ~ 1-15 cm) plays a significant role in trophic ecology of tunas and other pelagic predators. Information on micronekton taxonomic composition, biomass and distribution can be used to predict tuna abundance, refine our knowledge of tuna trophic ecology and provide a better foundation for modeling oceanic food webs. During March-April 2010 we investigated assemblages of vertically migrating micronekton and macrozooplankton around Guam and closely situated Northern Mariana Islands. Based on oceanographic observations, the study area was located entirely within the oligotrophic North Equatorial Current (NEC). However, southern stations of the survey were situated close to the northern boundary of the more productive North Equatorial Counter-Current (NECC), where we observed highest biomass, abundance, species richness and diversity of micronektonic organisms. Overall, we recorded significant pelagic fish diversity (85 species from 20 families) of mostly mesopelagic representatives in the area, with lanternfishes (Myctophidae - 40 species) and dragonfishes (Stomiidae -18) being the most taxonomically diverse groups. Three genera of mesopelagic shrimps – *Sergestes*, *Janicella* and *Sergia* dominated the crustacean component of resident micronekton community numerically and by biomass, while contribution from cephalopods was relatively minor. Assemblages of major micronekton/macrozooplankton groups based on biomass and abundance corresponded to predominant latitudinal changes observed along three meridional transects. However, the classification and ordination analysis based on taxonomically resolved taxa (fishes and decapod shrimps) indicated additional zonal variation, with areas east and west of the island chain showing different community structure. Mean total micronekton biomass for the area near productive boundary region between NEC and NECC was 5.8 mg/m³, with mean biomass 1.2 mg/m³ obtained for stations in the oligotrophic NEC area. Corresponding biomass of mesopelagic fishes was 0.88 mg/m³ and 0.24 mg/m³ for these two areas, respectively. In this presentation we also review and compare the available information on quantitative distribution of midwater fish biomass in the western tropical Pacific and outline major patterns of variation in the equatorial Pacific in general.

FISHERIES BYCATCH RESEARCH AND FISHERIES MANAGEMENT....IS THERE A CLEAR LINK?

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Incidental capture of discarded species in artisanal and commercial fishing operations can result in population-level impacts on threatened and endangered marine species, most notably sea turtles. In the past decade, NOAA Fisheries has played a pivotal role in domestic and international collaborative research aimed to improving our understanding of these fisheries dynamics. One major goal has been to develop tools for fisheries managers to help improve fishing selectivity for target species with minimal collateral damage, such as discards. It is clear that collaborative studies have enhanced our understanding of sea turtle and fish ecology, biomechanics, and sensory systems. In this overview of our of sea turtle bycatch research, we illustrate some of our results successes and discuss our failures in identifying means to improve the ecological sustainability of fisheries, with a focus on conservation of sea turtles. Specifically, we will trace the evolution of circle hooks as a successful bycatch reduction tool in pelagic fisheries. In addition, we will discuss experiments investigating the use of visual cues to deter sea turtles from coastal gillnets and implications for their future implementation. We also aim to identify direct links between fisheries bycatch mitigation research and federal and international regulations aimed to protect non-target species.

ENVIRONMENTAL INFLUENCES ON ATLANTIC BLUEFIN TUNA CATCH RATES IN THE SOUTHERN GULF OF ST. LAWRENCE

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Standardised catch per unit effort (CPUE) estimates for Atlantic bluefin tuna in the southern Gulf of St. Lawrence reveal an increasing trend in recent years that contrasts with a low and stable CPUE in southwest Nova Scotia and a decreasing CPUE in the U.S.A fishery. Although such estimates are typically standardised for several factors known to influence catch rate, the influence of environmental variables remains uncertain. The main objective of this study is to determine how environmental factors such as the Cold Intermediate Layer (CIL) may contribute to the standardisation of bluefin tuna catch rates in the southern Gulf of St. Lawrence.

Nominal bluefin tuna catch rates were standardised using a delta lognormal model and environmental variation was included in the modeling. Data from an annual multi-species survey conducted in September by Fisheries and Oceans Canada were used to quantify water mass characteristics in the southern Gulf of St. Lawrence over the period 1981 through 2009. As some fishing locations were either missing or incorrect (e.g. tuna reportedly caught on land), kernel methods were used to estimate the 95% utilisation distribution (areal estimates) of the fishery each year. The median of the annual 95% utilisation distributions was then used to randomly assign coordinates and associated water mass characteristics representing the missing fishing locations.

Analyses revealed considerable interannual spatial variation in water mass characteristics in the southern Gulf of St. Lawrence as well as indications of increasing depth to the CIL, decreasing thickness of the CIL, and an increase in the amount of habitat (defined by the upper 3°C isotherm of the CIL) available to the bluefin tuna. Preliminary standardisation models indicated that none of sea-surface temperature, bottom depth, minimum temperature of the CIL, or distance to the CIL contributed to the explained variation in catch rate. There was a negative and significant relation between catch rate and the depth to the CIL; indicating a possible relation between available habitat and catch rate. The thickness of the CIL also provided a significant contribution to explained deviance for the model of the probability of catching a bluefin tuna in the delta lognormal standardisation process. In summary, some characteristics of the CIL may be a factor in determining the amount of available habitat for bluefin tuna and thereby makes a significant contribution to the standardisation of catch rates in the southern Gulf of St. Lawrence.

THE EFFECTS ON THE HEALTH AND BEHAVIOR OF AN ADULT SHORTFIN MAKU, *ISURUS OXYRINCHUS*, FOLLOWING PROLONGED ENTANGLEMENT IN FISHING GEAR

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Fishes that are captured and remain entangled in fishing gear post release are subject to continued stress and injury. During a pelagic shark tagging project, a mature male shortfin mako, *Isurus oxyrinchus* (211 cm FL), was attracted to our fishing vessel with a three-strand twisted natural fiber rope wrapped around the body just posterior to the chondrocranium. The wear of the rope caused deep abrasions at various locations around its trunk, with the largest open wound running left to right across the dorsal musculature. Approximately 50 pelagic barnacles (ranging from juveniles to adults) from four species were observed fouling on the rope. Assuming larval settlement occurred following entanglement, barnacle growth-rate data suggest the rope had been on the shark for at least 100 days. However, the build up of scar tissue along either side of the large wound in the dorsal musculature and the sclerosis of the back (likely linked to the added drag induced by the barnacles) indicates that this rope may have been in place much longer. In addition, the shark appeared underweight (likely associated with decreased mobility and possibly with difficulty in processing large prey items) and maintained a large mouth gape indicating deficient oxygen uptake (the rope appeared to pinch shut 1-2 gill slits on either side of the head). Following a series of underwater photographs, the shark was captured using rod and reel (approximate fight time: 20 minutes), the rope was removed, and the animal was tagged with a mini pop-off satellite tag (Microwave X tag, recording duration set at 90 days). The tag popped off prematurely after 60 days. Despite its injuries associated with prolonged entanglement in fishing gear, the shark appears to have survived. This study compares the behavioral patterns of the injured mako with those determined for other pelagic sharks in order to assess post-release health.

AGE AND GROWTH OF NORTH PACIFIC ALBACORE (*THUNNUS ALALUNGA*)

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Age and growth of North Pacific albacore (*Thunnus alalunga*) were assessed by examining annual growth increments in sagittal otoliths from 338 fish collected throughout the North Pacific Ocean. A wide size range of albacore (53-128 cm fork length, FL) was collected in the western, central and eastern Pacific Ocean in attempt to incorporate size-at-age information over juvenile, sub-adult, and adult life history stages. Overall, ages ranged from 1 to 15 years with the majority of fish between 2 to 4 years of age. Growth models fit otolith-based size-at-age well and a bias-corrected form of Akaike's Information Criterion indicated that the specialized von Bertalanffy (VB) model provided the best fit. Biological parameters of the specialized VB model included $L_{\infty}=120.0$, $K=0.184$, and $t_0=-1.945$. Daily ages of several age-1 fish (55-61 cm FL) were also determined and confirmed correct annual age class assignments with daily ages ranging from 378 to 505 days. In addition to otolith-based techniques, dorsal fin spines and length frequency (LF) analysis were used to generate estimates of size-at-age. In general, fin spine ages matched otolith-derived ages (85% of samples) and results of the VB growth model generated from LF analysis provided similar size-at-age for the first five age classes, but estimated smaller sizes for fish ages 6 to 9 which may be a product of the limited size distribution from fishery dependent data. Results from this preliminary age and growth research suggest North Pacific albacore are a relatively long lived tuna species and provides updated biological parameters that may be useful to future stock assessment models incorporating age-specific life history information.

OTOLITH CHEMISTRY OF ALBACORE (*THUNNUS ALALUNGA*) IN THE EASTERN PACIFIC OCEAN

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North Pacific albacore tuna (*Thunnus alalunga*) support the most lucrative fishery for a highly migratory species on the U.S. West Coast, and currently are assessed and managed as one stock. Population structure of North Pacific albacore, however, may be more complex than the current single stock hypothesis, given the apparent regional differences in growth rates and movement patterns in the eastern Pacific Ocean (EPO). Accurately characterizing population structure and stock mixing is critical to effective management. Otolith chemistry is one approach to investigate population structure of tunas and other fish. The principal assumption is that the otolith acts as a natural tag because the chemical composition of the otolith is related to the physicochemical conditions of the water mass inhabited. As such, the purpose of this study is to examine otolith stable isotopes of carbon ($\delta^{13}\text{C}$) and oxygen ($\delta^{18}\text{O}$) in addition to several trace elements in whole otoliths of albacore collected in two regions of the EPO that have shown limited mixing: northern region (offshore Oregon and Washington, $> 40^\circ\text{N}$) and southern region (offshore southern California and northern Baja Mexico, $< 40^\circ\text{N}$). Samples from three age classes (ages 2-4) were collected from each region through recreational and commercial fishing vessels from July to October of 2010. Significant differences existed in otolith chemistry from fish collected between the two regions ($P < 0.05$) and overall cross-validated classification success to respective collection region was 100% with age-specific comparisons exceeding 90% success. Otolith $\delta^{18}\text{O}$ was significantly enriched by an average 0.31‰ in the southern region relative to the northern region, similar to reported seawater $\delta^{18}\text{O}$ differences. In addition, significantly higher concentrations of Na and Mg combined with lower P in otoliths from fish collected in the southern region appears consistent with regional physicochemical conditions (i.e. salinity, temperature, phosphate). Our preliminary findings support previous studies that have shown limited regional mixing of albacore in the EPO and provide life history information useful for sustainable management of North Pacific albacore.

A DISCRETE CHOICE APPROACH TO ANALYZING MOVEMENT PATTERNS BASED ON LIGHT AND GPS TAG DATA FOR BROADBILL SWORDFISH

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Regulatory frameworks for fisheries are changing due to increasing management of fisheries and external pressures such as the designation of marine reserves. Design of efficient management measures in this changing environment often requires descriptions of the distribution of target and nontarget species and understanding the factors driving these distributions is becoming increasingly critical.

Electronic tagging remains one of the few methods for collecting fisheries independent data for pelagic species. However, for many species the data available from the current technology is not easy to analyze. For instance, broadbill swordfish dive on dawn and ascend on dusk, degrading the light signal that is commonly used to estimate location on electronic tags.

Here we present a new method for analyzing light and GPS data from the satellite archival tags recently developed by Wildlife Computers. We take a different approach from most analyses, treating the data as a set of sequentially independent decisions instead of constructing a track. This allows us to concentrate on the analysis of covariates describing the movement instead of estimating a model describing the full path of the animal. We conduct this analysis in a statistically rigorous framework, which incorporates uncertainty in location. We present preliminary results for the effects of bathymetric and oceanographic features on decision-making by the fish. We suggest that this analysis approach may be more useful in cases where there are large temporal gaps in the data relative to the scale of movement of the animal.

**DIDYMOZOID GILL PARASITES OF AGE-0 PACIFIC BLUEFIN TUNA *Thunnus orientalis*
FROM THE WESTERN NORTH PACIFIC OCEAN AND THEIR USE AS BIOLOGICAL TAGS
FOR ESTIMATION OF THE HOST'S NATAL ORIGIN**

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Parasites have been used as biological tags to estimate the migration route or to discriminate fish stocks (Mackenzie, 1983) including tuna and tuna-like species, such as skipjack tuna *Katsuwonus pelamis* (Lester et al., 1985), Atlantic bluefin tuna *Thunnus thynnus* (Rodríguez-Marín et al., 2008) and albacore *T. alalunga* (Jones, 1991; Mele et al., 2010). For Pacific bluefin tuna *T. orientalis*, there was a study that pointed out the possibility of the gill-infecting didymozoids (Digenea: Didymozoidae) of young fish migrating around Japan (Kobayashi, 2004), but no further investigation was conducted. We studied the occurrence of didymozoids on the gills for age-0 *T. orientalis* from Japanese waters in order to examine their suitability as biological tags to study the migration ecology and natal origin of this fish species.

We collected fish specimens (19-59 cm in fork length) caught by coastal fishery in the North Pacific (PO) (n=169) and the Sea of Japan (SOJ) (n=183) off the Japanese main island (Honshu) from February to December 2008. In the laboratory, gills were removed from each fish. Cysts of the didymozoid parasites were counted separately for the gill rakers, gill arches, and gill filaments. Following Kobayashi (2004), four species of parasites (*Didymocystis wedli*, *D. soleiformis*, *D. semiglobularis*, *Wedlia reniformis*) were targeted. Prevalence (no. of infected fish/no. of fish examined) and mean intensity (mean number of cysts per infected fish) were compared by catch area and size group of fish.

Fifty-three percent of fish was infected with at least one of the four parasite species. There were some marked differences in infection level between SOJ and PO. For three species except *D. wedli*, both prevalence and mean intensity of infection were significantly higher in PO than those in SOJ. For *D. wedli*, prevalence was almost the same between SOJ and PO, but mean intensity was significantly higher in SOJ. Furthermore, 94% of fish infected with *D. soleiformis* were caught in SOJ. The didymozoids are semi-permanent type parasites because they occur in the host for a relatively long period (Lester et al., 1985). They also need intermediate hosts to develop before infecting tunas (Nikolaeva, 1981) and do not transfer between fish hosts. Then, the didymozoids we found in this study can be used as an effective tool to examine the natal origin of age-0 Pacific bluefin tuna, if infection data are used together with the result of otolith day-age analysis or microchemistry.

OUT WITH THE OLD AND IN WITH THE NEW: ESTIMATING RECREATIONAL CATCH AND EFFORT FOR THE SPECIALIZED PELAGIC SPORTFISH FISHERY OFF EASTERN AUSTRALIA

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Recreational fishing is a popular sport and social activity worldwide. There has been increasing participation in specialized fisheries (e.g. game fishing, deep-water fishing) in response to the increased affordability of new fishing technologies (e.g. electric reels, sonar) and transfer of knowledge between fishers (e.g. internet forums). These specialized fisheries often target large apex predators, and can exert considerable fishing pressure on many pelagic species. The complex offshore multi-species pelagic sport fishery off eastern Australia is one such fishery, where fishing effort and subsequent catch is largely dependent on the seasonally dynamic East Australian Current. Fishers comprising this fishery represent a “hard-to-reach” population since they are rare within the wider community, and cannot be cost-effectively located due to an absence of a complete list frame (e.g. fishing license). Therefore, a complemented approach was used to assess the fishing effort and catch of this fishery, using a traditional access point survey (APS) combined with an innovative method known as Time-Location Sampling (TLS). Through combining both methods, we were able to: i) assess the efficacy of each method for use in specialized fisheries, ii) obtain independent estimates of catch and effort for pelagic sportfish species, iii) adjust for some of the inherent biases associated with each method, and iv) obtain an estimate of the total population size of specialized sport fishers. Both survey types estimated values for the 2010 calendar year using stratified random sampling within a sampling universe of a 200km radius around Brisbane, Queensland. Mackerels (*Scomberomorus* spp.), tunas (*Thunnus* spp.) wahoo (*Acanthocybium solandri*), and black marlin (*Makaira indica*) were the main target species in this fishery, with fishing methods and catch highly variable with season. APS was an expensive and labour-intensive method that underestimated the total annual catch and effort for the majority of these species, due to the low intercept rate of these rare specialized fishers. However, APS was useful for providing high resolution species-specific catch and length information. In contrast, TLS using a 12-month recall survey represented a cost-effective way to estimate recreational catch of memorable captures (e.g. large pelagic species) in this specialized fishery, however overestimated effort due to the long recall period. Through conducting multiple TLS recall surveys, mark-recapture methods were used to estimate the size of the sport fisher population, allowing catch estimates from APS and TLS to be extrapolated to the total fishery. Estimated catch for many pelagic species caught in this fishery comprise significant proportions of the total catch in the region and need inclusion in stock assessments. Further method development is required for use in specialized recreational fisheries that extend across large jurisdictional or stock boundaries, such as for Southern Bluefin Tuna.

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