Proceedings of the 65th Annual Tuna Conference

Lake Arrowhead, CA
May 19-22, 2014

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Nicholas C. Wegner – Chair
Stephanie Flores – Coordinator

Southwest Fisheries Science Center
8901 La Jolla Shores Drive
La Jolla, CA 92037

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

Welcome to the 65th Annual 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 **"How do large pelagics work and what do they want?"** Fish movements, growth, reproduction, and ultimately stock biomass and population structure are dependent on how organisms interact with their environment. Examining the response of different species to biological and physiological variables at different developmental stages provides insight into both the behavior and life-history of an organism and can be used to better understand requirements for fish survival and consequently where fish are likely to be found in space and time. The theme for this year's Tuna Conference will thus focus on what tunas, billfishes, and sharks "want" and how their basic needs influence behavior and ultimately shape management decisions.

A total of 44 presentations and 10 posters touching on various aspects related to this theme and other topics on large pelagic fishes will be presented over the course of four days.

Four student scholarships were awarded this year. The Tuna Conference Scholarship was awarded to Ching-Ping Lu for her talk titled "Population structure study of genetic informative data differentiation in Pacific swordfish (*Xiphias gladius*) using high resolution melting analysis (HRMA)." The Manuel Caboz Memorial Scholarship was awarded to Jon Lopez for his talk titled "Diel behaviour of by-catch and tuna species at drifting fish aggregating devices (DFADs) in the Western Indian Ocean as assessed by fishers' echo-sounder buoys." In addition, our industry partners graciously sponsored two scholarships. The Wildlife Computers Scholarship was awarded to Scott Lynch for his talk titled "Do pop-up satellite tags affect the swimming energetics and kinematics of juvenile sharks?" The Desert Star Systems Scholarship was awarded to Nerea Lezama-Ochoa for her talk titled "Study of biodiversity in the by-catch communities of the pelagic ecosystem and the use of Maxent species distribution model to predict the potential habitat suitability under future scenarios of climate change in the Eastern Pacific Ocean." Travel for the four award winners as well as three other students (Emily Loose, Wessley Merten, and Matt Siskey) was further supported by the International Seafood Sustainability Foundation. All of these students presented impressive scientific work, research goals, and progress. We wish them continued success in their graduate and post-graduate careers.

We wish to thank a suite of volunteers for assisting with the Tuna Conference. We are especially gratefully for JoyDeLee Marrow, long-time Tuna Conference Coordinator for IATTC, who provided invaluable advice and detailed instructions on how to organize and coordinate the Conference. We also thank Dan Fuller, John Hyde, Carolina Minte-Vera, Catherine Purcell, and Michael Scott for reviewing the student scholarship applications and Dan Fuller, Kim Holland, Dave Itano, Stephen Stohs, Pedro Afonso, John Hyde, Owyn Snodgrass, Kurt Schaefer, and Bruce Collette for moderating the scientific sessions. Christine Patnode created the cover for

this year's program and updated the Tuna Conference website. We thank Rex Ito and Prime Time Seafood for donating the sashimi-grade tuna for the poster session and Dave Itano for kindly picking up the tuna for the barbecue and sushi social. 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 SWFSC and IATTC 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 Fishermen's Research Foundation, American Tuna Boat Association, Desert Star Systems LLC, International Seafood Sustainability Foundation, Lotek Wireless Inc., Monterey Bay Aquarium Foundation, and Prime Time Seafood Inc.

We are sad to report that Witek Klawe and Tom Calkins, both long-time attendees of the Tuna Conference and employees of IATTC passed away this past year. Their obituaries are contained on pages 66-67.

The abstracts contained in the Proceedings are listed in alphabetical order under their respective presentation type (either Oral or Poster). All abstracts 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 have a productive and enjoyable time and look forward to seeing you back next year at the 66th Tuna Conference!

Nicholas C. Wegner
65th Tuna Conference Chair

Stephanie Flores
65th Tuna Conference Coordinator

65th TUNA CONFERENCE AGENDA

Monday, 19 May 2014

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

13:30 Welcome and Introduction (Pineview)

SESSION 1: Pelagics and Their Environment (Moderator: Dan Fuller)

13:40 Influence of subtropical fronts on the spatial distribution of albacore tuna (*Thunnus alalunga*) in the Northeast Pacific over the past 30 years (1982-2011) – **Yi Xu**, Karen Nieto, Steven Teo, Sam McClatchie, and John Holmes

14:00 Study of biodiversity in the by-catch communities of the pelagic ecosystem and the use of Maxent species distribution model to predict the potential habitat suitability under future scenarios of climate change in the eastern Pacific Ocean – **Nerea Lezama-Ochoa*** Hilario Murua, Martin Hall, Emiel Van Loon, Guillem Chust, Jon Ruiz, and Nick Vogel
*Desert Star Student Scholarship / International Seafood Sustainability Foundation Travel Award winner

14:20 Spatial and temporal variations of primary productivity and recruitment of skipjack tuna (*Katsuwonus pelamis*) in the western and central Pacific Ocean – **Kuo-Wei Yen** and Hsueh-Jung Lu

14:40 Effects of environmental characteristics on tuna larvae distribution in the northern Gulf of Mexico – **Maëlle Cornic** and Jay R. Rooker

15:00 Break (30-minutes)

15:30 Distribution and abundance of the bluntnose flyingfish (*Prognichthys occidentalis*) in the northern Gulf of Mexico across mesoscale features – **Landes L. Randall** and Jay R. Rooker

15:50 Assessing the trophic ecology of large pelagic fishes in the U.S. South Atlantic using diet and stable isotope analysis – **Stephen J. Poland,** Frederick S. Scharf, and Michelle D. Staudinger

16:10 Spatial patterns of modern pollutants in tuna: A global assessment – **Lindsay Bonito**, Sacha Nicklisch, Amro Hamdoun, and Stuart Sandin

16:30 Listening to what they want – improving data throughput in pelagic fish telemetry – **Kim Holland**

18:30 Dinner followed by 'Welcome Gathering' in the Tavern

Tuesday, 20 May 2014

8:00 Breakfast

SESSION 2: Fish Movements (Moderator: Kim Holland)

9:00 Deep diving in large pelagic fishes – **Pedro Afonso**, Frederic Vandeperre, Jorge Fontes, and Simon Thorrold

9:20 Describing the vertical behavior of yellowfin and bigeye tuna using multivariate-normal hidden Markov models – **Joe Scutt Phillips**, Toby A. Patterson, Bruno Leroy, Graham M. Pilling, Jason Noble, and Simon Nicol

9:40 Movements of bigeye tuna (*Thunnus obesus*) tagged and released in the equatorial central Pacific, with conventional and archival tags – **Kurt Schaefer**, Daniel Fuller, John Hampton, Sylvain Caillot, Bruno Leroy, and David Itano

10:00 Transatlantic movements of juvenile Atlantic bluefin tuna inferred from analyses of organochlorine tracers – **John E. Graves** and Andrew S. Wozniak

10:20 Coffee Break (30-minutes)

10:50 Archival and pop-off tagging of albacore in the northeastern Pacific - **Suzy Kohin**, John Childers, David Wells, John LaGrange, Geof Walker, James Wraith, Steve Teo, Stephanie Snyder, Helena Aryafar, Ashley Williams, and David Itano

11:10 Diel behaviour of by-catch and tuna species at drifting fish aggregating devices (DFADs) in the western Indian Ocean as assessed by fishers' echo-sounder buoys – **Jon Lopez***, Gala Moreno, Leire Ibaibarriaga, and Laurent Dagorn
*Manuel Caboz Student Scholarship / International Seafood Sustainability Foundation Travel Award winner

11:30 Horizontal and vertical movements of satellite tagged shortfin mako sharks in the northeastern Pacific – **Nicole Nasby-Lucas**, Suzy Kohin, Heidi Dewar, James Wraith, Owyn Snodgrass, Dave Holts, Oscar Sosa-Nishizaki, and Russ Vetter

12:00 Lunch

SESSION 3: Swordfish (Moderator: Dave Itano)

13:10 Did regulation of West Coast Pacific swordfish fisheries reduce sea turtle bycatch? A nonparametric bootstrap analysis of regulatory effectiveness – **Stephen Stohs** and Valerie Chan

13:30 Regulatory impacts on exit from the California drift gillnet swordfish fishery: A treatment-control duration model – **James Hilger** and Stephen Stohs

13:50 Investigating swordfish movements and testing alternative deep-set gear above Point Conception, CA – **C. Sepulveda**, S.A. Aalbers, C. Heberer, H. Dewar, and S. Kohin

14:10 Population structure study of genetic informative data differentiation in Pacific swordfish (*Xiphias gladius*) using high resolution melting analysis (HRMA) – **Ching-Ping Lu***, Brad L. Smith, Michael G. Hinton, Robert L. Humphreys Jr. and Jaime R. Alvarado Bremer

*Tuna Conference Student Scholarship / International Seafood Sustainability Foundation Travel Award winner

14:30 Coffee Break (30 minutes)

SESSION 4: Fisheries and Management I (Moderator: Stephen Stohs)

15:00 Long-term dynamics of trophy-sized pelagic fishes based on a new California recreational fisheries database (1966-2013) – **Lyall Bellquist**, Brice Semmens, and Jeffrey B. Graham

15:20 Stakeholder opinions on management options for future conservation measures for North Pacific striped marlin **– Valerie Chan** and Richard Ambrose

15:40 Bycatch sharks from Chinese longline fishery in the east Pacific Ocean based on port investigations in 2012-2013 – **Yan Chen**, Zhenhua Wang, Xiaojie Dai and Jiangfeng Zhu

16:00 Red listing tunas and billfishes – **Bruce B. Collette**

POSTER SESSION (with sushi) – Sashimi donated by Prime Time Seafood, Inc.

16:30 Evaluating seasonal swordfish movement patterns in the eastern Pacific – **Scott A. Aalbers**, Chi H. Lam, Justin E. Stopa, and Chugey A. Sepulveda

Tracking movements of swordfish, *Xiphias gladius,* using Empirical Orthogonal Function analysis of temperature by depth profiles. **Kathryn Carmody**, Arthur Mariano, and David Kerstetter

Status review of the northeastern Pacific population of white sharks (*Carcharodon carcharias*) under the Endangered Species Act – **Heidi Dewar**, Tomoharu Eguchi, John Hyde, Doug Kinzey, Suzanne Kohin, Jeff Moore, Barbara L. Taylor, and Russ Vetter

Habitat utilization and vertical movements of the pelagic stingray *Pteroplatytrygon violacea* (Bonaparte, 1832) in the western North Atlantic Ocean using short-duration pop-up archival satellite tags – Tiffany Weidner, Charles F. Cotton, and **David W. Kerstetter**

Predicting habitat utilization of sailfish (*Istiophorus platypterus*) to reduce bycatch within the purse-seine fishery in the eastern Pacific Ocean – Raúl O. Martínez-Rincón, **Sofía Ortega-García**, Juan G. Vaca-Rodríguez, and Shane Griffiths

Insights into the life history and ecology of a record shortfin mako shark (*Isurus oxyrinchus*) caught in the Southern California Bight – **Antonella Preti**, Kady Lyons, Heidi Dewar, Kate Spivey, Mary Blasius, Suzanne Kohin, Jeff Harris, Ken MacKenzie, Owyn Snodgrass, Natalie Spear, and Christopher G. Lowe

From migrants to mossbacks: SIA-inferred habitat shifts in the California yellowtail *Seriola lalandi* – Daniel J Madigan, **Owyn E. Snodgrass**, and Heidi Dewar

Thermal dependence of aerobic muscle function in a deep-diving shark, *Alopias superciliosus,* and teleost, *Xiphias gladius* – **Ashley A. Stoehr**, Jeanine M. Donley, Scott A. Aalbers, Douglas A. Syme, Chugey A. Sepulveda, and Diego Bernal

Early life history research at the Achotines Laboratory – Daniel Margulies, **Vernon Scholey**, **Jeanne Wexler**, and Maria Stein

Coastal upwelling fronts: A key habitat for albacore tuna (*Thunnus alalunga*) in the northeast Pacific Ocean – Karen Nieto, **Yi Xu**, Steven Teo, Sam McClatchie, and John Holmes

Wednesday, 21 May 2014

8:00 Breakfast

SESSION 5: Physiology and Morphology I (Moderator: Pedro Afonso)

9:00 Bioenergetics of captive Pacific bluefin tuna (*Thunnus orientalis*): A fifteen-year study – **Ethan Estess**, Danny Coffey, Tamaki Shimose, Andrew C. Seitz, Luis Rodriguez, Alex Norton, Barbara Block, and Charles Farwell

9:20 Temperature dependent postprandial behavioral responses in juvenile Pacific bluefin tuna (*Thunnus orientalis*) – **Adrian Gleiss**, Jonathan Dale, Dane Klinger, Ethan Estess, Chuck Farewell, and Barbara Block

9:40 The effect of temperature on postprandial metabolism of yellowfin tuna (*Thunnus albacares*) **– Dane H. Klinger**, Tyler Brandt, Jonathan J. Dale, Ethan E. Estess, Adrian Gleiss, Benjamin Machado, Luis Rodriguez, James Stiltner, Charles Farwell, and Barbara A. Block

10:00 Structural features of the olfactory system in tunas **– Ralph R. Mana** and Gunzo Kawamura

10:20 Coffee Break (30-minutes)

SESSION 6: Genetics (Moderator: John Hyde)

10:50 Assigning bluefin tuna (*Thunnus thynnus*) to spawning areas: are we there yet? – **Jan R. McDowell**, Heidi L. Brightman, and John E. Graves

11:10 Genetic structure and dispersal capabilities of dolphinfish (*Coryphaena hippurus*); implications for stock-based fishery management in the western central Atlantic – **Wessley Merten***, Nikolaos Schizas, Matthew Craig, and Richard Appeldoorn
***International Seafood Sustainability Foundation Travel Award winner

11:30 Developing genetic resources to guide broodstock selection and culture practices for California yellowtail, *Seriola lalandi* – **Catherine Purcell** and John Hyde

12:00 Lunch

SESSION 7: Physiology and Morphology II (Moderator: Owyn Snodgrass)

13:10 Do pop-up satellite tags affect the swimming energetics and kinematics of juvenile sharks? – **Scott Lynch***, Heather Marshall, Peter Bushnell, Richard Brill, and Diego Bernal
*Wildlife Computers Student Scholarship / International Seafood Sustainability Foundation Travel Award winner

13:30 Comparative scale morphology of roundscale spearfish (*Tetrapturus georgii*) and white marlin (*Kajikia albida*) – **Emily Loose***
***** International Seafood Sustainability Foundation Travel Award winner

13:50 Evaluating post-release mortality of white marlin (*Kajikia albida*) caught in the recreational fishery: Biochemical and physiological indicators of lethal stress – **Lela S. Schlenker**, Robert J. Latour, Richard W. Brill, and John E. Graves

14:10 Capture stress and post-release survival of southern bluefin tuna from recreational fishing **– Sean Tracey**, Klaas Hartmann, and Melanie Leef

14:30 Reflex impairment as a measure of delayed mortality in grey triggerfish (*Balistes capriscus*) – **Francesca Forrestal**

14:50 Coffee Break (30-Minutes)

SESSION 8: Life History (Moderator: Kurt Schaefer)

15:20 Factors affecting spawning patterns of captive yellowfin tuna *Thunnus albacares* – **Vernon Scholey**, Jeanne Wexler, Daniel Margulies, and Maria Stein

15:40 Minimum food requirements for survival and growth of yellowfin tuna (*Thunnus albacares*) and pacific bluefin tuna (*Thunnus orientalis*) larvae – **Jeanne Wexler**, Daniel Margulies, Maria Stein, Yang-Su Kim, Tsukasa Sasaki, Vernon Scholey, Tomoki Honryo, Angel Guillen, and Yoshifumi Sawada

16:00 Age structure of Atlantic bluefin tuna from the North Carolina winter fishery **– Matt Siskey*** and David Secor
***International Seafood Sustainability Foundation Travel Award winner

16:20 Resilience of bluefin tuna in the western Atlantic Ocean: The storage effect – **D.H. Secor**, J.R. Rooker, B.I. Gahagan, M.R. Siskey, and R.W. Wingate

16:40 Break (10 mins)

16:50 Video Documentary by Wessley Merten "A Journey Pelagic" (22 minutes)

18:30 Dinner – Tuna Barbeque sponsored by the American Fishermen's Research Foundation, American Tuna Boat Association, Lotek Wireless Inc., and Prime Time Seafood Inc.

Frontier Village – Campfire and Social

Thursday, 22 May 2014

8:00 Breakfast

SESSION 9: Fisheries and Management II (Moderator: Bruce Collette)

9:00 Catch per unit effort spatial metric for pelagic longline catch and effort data from the western north Atlantic tuna fishery – **Max H. Appelman,** Brian K. Walker and David W. Kerstetter

9:20 California CPFV skipper logbook trip type classification: 1995-2012 – **James Hilger** and Jonathan Sweeney

9:40 Difference between the deep-set and shallow-set sectors of the Hawaii-based longline fishery **– Russell Ito**

10:00 Mobulid bycatches in the tuna purse seine fishery and mitigation approaches – **Marlon H Roman** and Martin Hall

10:20 Where do large pelagics fishermen work and what do they want? Endogenous location choice and the attenuation of the abundance-CPUE relationship – **Stephen Stohs**, Yi Xu, Steven Teo

10:40 Coffee Break (20 mins)

11:00 Tuna Conference Business Meeting

12:00 Lunch

Oral Presentation Abstracts (In order of presenting author last name):

DEEP DIVING IN LARGE PELAGIC FISHES

Pedro Afonso, Frederic Vandeperre, Jorge Fontes and Simon Thorrold

IMAR - University of the Azores
Dpt. Oceanography & Fisheries, 9901-862 Horta, Azores, Portugal

Biotelemetry - tracking animals with electronic devices - is showing us that deep diving between shallow and deeper ocean layers is a much more widespread phenomenon than anticipated among large pelagic fishes, encompassing evolutionarily distant species such as teleost fishes, sharks and rays. This behavior contradicts our notion that the shallow open ocean holds the largest biological production and less physiological and sensory challenges than the deep ocean. The central question thus remains 'Why do large (epi)pelagic fishes dive into the deep ocean'? Deep diving behavior of LPFs has generally been interpreted as an adaptive response to the availability of pelagic prey but there is surprisingly little direct evidence for this hypothesis. Deep diving could also provide other benefits to LPFs including escape from predators or reduced energetic costs. This work reviews current our knowledge and presents some new findings of extreme, bathyal diving in sharks and rays, to discuss the occurrence and adaptive significance of deep diving in such a variable set of animals. Understanding if the deep ocean layers are fundamental for the survival of LPFs can be critical in the conservation of these, nowadays, mostly threatened species.

CATCH PER UNIT EFFORT SPATIAL METRIC FOR PELAGIC LONGLINE CATCH AND EFFORT DATA FROM THE WESTERN NORTH ATLANTIC TUNA FISHERY

Max H. Appelman, Brian K. Walker, and David W. Kerstetter

Nova Southeastern University Oceanographic Center
8000 North Ocean Drive
Dania Beach, FL 33004

Catch per unit effort (CPUE) is a quantitative method used to describe fisheries worldwide. CPUE can be presented as number of fish per 1000 hooks, number of fish per amount of fishing time, or with any unit of effort that best describes the fishery (i.e., search time, hooks per hour, number of trawls, etc.). CPUE is commonly used as an index to estimate relative abundance and is then applied within stock assessments so that fisheries managers can make justified decisions for how to manage a particular stock or fishery using measures such as catch quotas, catch limits, and gear or license restrictions. For commercial pelagic longline fisheries, onboard observer data are considered the only reliable data available due to the large-scale migratory behavior of highly migratory species and because of the high costs associated with fisheries-independent surveys. Unfortunately, fishery-dependent data can be biased in favor of the target species and the subsequent CPUE frequently overestimates relative abundance. The spatial distribution of fish and fishing effort is essential for understanding the proportionality between CPUE and stock abundance. A spatial metric for PLL CPUE can increase the accuracy of relative abundance estimates by utilizing small-scale area specific CPUE rather than a CPUE that does not incorporate geographic data, which will in turn increase the accuracy of stock assessments and provide fisheries managers with the best information possible. This research utilizes a comprehensive eight-year (2003-2010) observer catch and effort dataset from the western North Atlantic U.S. PLL fleet targeting yellowfin tuna, swordfish, and bigeye tuna. Utilizing latitude and longitude coordinates recorded at the set and haul of each deployed section buoy, a spatial metric was created specific to the distribution of fishing effort from the longline fleet. Areas with increased habitat utilization of target and bycatch species such as bluefin tuna, marine mammals, sharks, and sea turtles, are highlighted using ArcGIS and R programming.

LONG-TERM DYNAMICS OF TROPHY-SIZED PELAGIC FISHES BASED ON A NEW CALIFORNIA RECREATIONAL FISHERIES DATABASE (1966-2013)

Lyall Bellquist, Brice Semmens, and Jeffrey B. Graham

Scripps Institution of Oceanography
8750 Biological Grade, Hubbs Hall 3370, La Jolla, CA 92037

Historical fisheries declines have been documented throughout the world, and the impacts of size-selective fishing are well studied. However, the dynamics of the largest size classes of fishes, i.e. “trophy” fishes, are often difficult to document because historical fisheries datasets do not frequently include size structure information, and data specific to trophy-sized fishes are even rarer. We introduce a new historical fisheries database that specifically focuses on trophy-sizes of most marine fishes that are targeted recreationally (and some commercially) in California from 1966-2013. While the database includes 94 species of both benthic and pelagic fishes, we focus exclusively on pelagic species for this analysis. Temporal analyses show that trophy sizes of pelagic species in California are highly variable over time, with dynamics more closely correlated with oceanographic processes than recreational fishing effort. Coastal pelagic species, however, tend to show variable or increasing trends in mean size over time, possibly due to changes in regulatory policies and fishing gear type. Oceanographic indices, such as the ENSO, PDO, NPGO, and coastal upwelling show varying degrees of correlation, depending on the species. Only one species, yellowfin tuna (*T. albacares*), showed a sustained decrease in mean trophy size during the 48-year study period. The southern California recreational fishing fleet consists of thousands of private vessels and hundreds of Commercial Passenger Fishing Vessels (CPFVs) that collectively have focused intense fishing effort in coastal and offshore waters for over half a century. Despite this fishing effort, trends in the size of trophy fishes do not appear to show long-term declines.

SPATIAL PATTERNS OF MODERN POLLUTANTS IN TUNA: A GLOBAL ASSESSMENT

Lindsay Bonito, Sacha Nicklisch, Amro Hamdoun and Stuart Sandin

Scripps Institution of Oceanography
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La Jolla, CA 92093-0202

It has been well documented that the oceans have become a repository for global pollutants, especially for organic compounds known as persistent organic pollutants (POPs). Resistant to environmental degradation, these toxins can be transported over long distances, contaminating seafood throughout the globe. Seafood consumption is the major pathway to human exposure for these contaminants. This study is the first to document the spatial distribution and concentrations of target POPs at a global scale. We are investigating organochlorine pesticides, mercury and polychlorinated biphenyls within yellowfin tuna (*Thunnus albacares*), one of the most commercially and recreationally important scombrids. Yellowfin often exhibit site fidelity, occupying regions (10-100kms) with distinct chemical concentrations for sufficient periods of time to note regional differences within the tissue. Previous analyses of yellowfin are limited to mercury, with no insight into modern chemicals, especially at a global scale. We found strong spatial patterns between population density and increased levels of POPs across ocean basins. Additionally, data reveal strong correlations between chemical congeners across sites. These results show the far-reaching implications of legacy and modern pollutants on important fisheries resources.

STAKEHOLDER OPINIONS ON MANAGEMENT OPTIONS FOR FUTURE CONSERVATION MEASURES FOR NORTH PACIFIC STRIPED MARLIN

Valerie Chan[1,2], Richard Ambrose[2]

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[2] University of California, Los Angeles, Los Angeles, CA

In 2010, the Western and Central Pacific Fisheries Commission (WCPFC) adopted a conservation and management measure (CMM) for north Pacific striped marlin that included a provision directing the commission to revise the measure if information from the new stock assessment warranted changes. Although a new stock assessment was completed in 2012, no revisions to the current CMM have been proposed or made to date. This study examined stakeholder preferences in the event a revised CMM were to be developed for north Pacific striped marlin. The study assessed the factors considered important by various stakeholders, preferred management options, whether these preferences were similar or different between stakeholder groups, and opinions on application of management options across gear types and other billfish. To investigate these preferences, we employed Analytical Hierarchy Process (AHP) and a few short answer questions to discern criteria important for decision making as well as which of six management alternatives were viewed as more or less favorable.

Forty respondents, primarily individuals from government agencies and the fishing industry, participated in the study. In general, there were similarities overall, and between government and fishing industry respondents, in the weightings of the various factors with biological factors outweighing economic, social and political factors when considering management options for north Pacific striped marlin. Greater variability was observed between government and fishing industry respondents in the ratings for management options, and management options with the highest ratings were circle hooks and catch limits while the lowest ratings were for a retention ban. Participants had a broad range of opinions on the need to limit catch of striped marlin, and some participants indicated they would be willing to support the need for management if there was more scientific support or information available on its efficacy.

BYCATCH SHARKS FROM CHINESE LONGLINE FISHERY IN THE EAST PACIFIC OCEAN BASED ON PORT INVESTIGATIONS IN 2012-2013

Yan Chen[1,2,3], Zhenhua Wang[1,2,3], Xiaojie Dai[1,2,3], Jiangfeng Zhu[1,2,3]

[1]College of Marine Sciences, Shanghai Ocean University, Shanghai 201306, China

[2]Key Laboratory of Shanghai Education Commission for Oceanic Fisheries Resources Exploitation, Shanghai Ocean University, Shanghai 201306, China

[3]Key Laboratory of Sustainable Exploitation of Oceanic Fisheries Resources, Ministry of Education, Shanghai 201306, China

Conservation and effective management of the world's exploited shark populations have become issues of considerable concern on an international scale as a result of greatly expanded commercial fishing efforts over the past decades. Three port investigations were conducted in March 2012, January 2013 and April 2013 on the catch of Chinese Longline Fishery from the east Pacific Ocean at the longitude N0°~10° and latitude W120°~150°. Totally seven shark species were recorded, silky shark (*Carcharhinus falciformis*) and blue shark (*Prionace glauca*) were the most abundant in numbers, bigeye thresher (*Alopias superciliosus*) and pelagic thresher (*Alopias pelagicus*) were moderate in number, whereas oceanic whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead (*Sphyrna lewini*) and Shortfin mako (*Isurus oxyrinchus*) were relatively low in number. Individuals from each species were randomly selected and measured in their body length, size compositions were then presented. Size frequency information of various shark species in the east Pacific Ocean provided in the present study would be important for us to understand shark populations within this area.

RED LISTING TUNAS AND BILLFISHES

Bruce B. Collette

Chair, IUCN Tuna and Billfish Specialist Group and
National Marine Fisheries Service Systematics Laboratory,
National Museum of Natural History, Washington, D.C., 20560

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 is there a 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 evaluated as Least Concern and be able to be managed sustainably, although at a much lower level than in the original situation. However, in the cases of the three species of bluefin tunas which have restricted spawning sites, population reduction by overfishing has been severe enough that these populations may not be able to recover.

EFFECTS OF ENVIRONMENTAL CHARACTERISTICS ON TUNA LARVAE DISTRIBUTION IN THE NORTHERN GULF OF MEXICO

Maëlle Cornic[1] and Jay R. Rooker[1,2]

[1]Department of Marine Biology, Texas A&M University at Galveston, Texas, USA

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Summer ichtyoplankton surveys were conducted in the northern Gulf of Mexico (GoM) from 2007-2011, and catch data were used to characterize patterns of distribution and abundance of tuna larvae (*Thunnus* spp.) within this region. High resolution melting analysis was performed on a subset of 5,930 samples to determine the species composition of *Thunnus* larvae in our collections and four different species were observed: blackfin tuna *Thunnus atlanticus*, yellowfin tuna *T. albacares*, bluefin tuna *T. thynnus*, and bigeye *T. obsesus*. Overall, 14,128 larvae in the genus *Thunnus* were collected and mean density and percent frequency of occurrence of larvae was 10.5 larvae 1000 m^{-3} and 94%, respectively. Interseasonal variability and interannual variability in catch numbers of tuna larvae were observed with the highest density present in June (12 larvae 1000 m^{-3}) and in 2010 (6.4 larvae 1000 m^{-3}), the summer following the Deepwater Horizon oil spill. Ocean influences on catch numbers of tuna larvae occurred and our results indicate that mesoscale features and physicals characteristics of water masses may impact the abundance and distribution of tuna larvae. Response plots from generalized additive models (GAMs) indicated that mesoscale features and physicals characteristics of water masses may impact catch numbers of tuna larvae occurred and the abundance and distribution of tuna larvae.

BIOENERGETICS OF CAPTIVE PACIFIC BLUEFIN TUNA (*THUNNUS ORIENTALIS*): A FIFTEEN-YEAR STUDY

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Holding highly migratory marine species in captive scenarios offers a unique opportunity to quantify growth and bioenergetic parameters of otherwise difficult-to-study organisms. The Tuna Research and Conservation Center of Stanford University and the Monterey Bay Aquarium (TRCC) began collecting Pacific bluefin tunas *Thunnus orientalis* for research purposes in 1998, maintaining captive tunas in 20^{O}C holding tanks for up to 10 years in some instances. Captive bluefin were fed 3 times per week with a diet of sardine, squid, and gelatin-vitamin mixture. Length and mass records from a 15-year study period were used to estimate a von Bertalanffy growth equation and length-weight regression for this species. We conducted proximate analyses of individual tunas post-mortem to quantify tissue energy values. Metabolic costs (eliminated waste, routine metabolic rate, specific dynamic action, and increased activity level) and food energy values were integrated to quantify daily growth increments and food conversion ratios. Captive growth rates are compared with data on growth rates for wild bluefin tunas. These findings have application to bluefin tuna aquaculture operations and inform our understanding of tuna physiology and ecology.

REFLEX IMPAIRMENT AS A MEASURE OF DELAYED MORTALITY IN GREY TRIGGERFISH (*BALISTES CAPRISCUS*)

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The use of fish aggregation devices (FADs) in tropical tuna fisheries can lead to inadvertent capture of several teleost species, including several members of the family Balistidae, that are released as discards from fishing vessels. To reduce ecosystem effects of fishing, managers aim to minimize mortality of these discards. Measurements of blood plasma parameters are often used to estimate delayed mortality in discard species but this method can have inconsistent results. By contrast, reflex impairment as a measure of fish condition, has been used to predict delayed mortality in several fish species. *Balistes capriscus*, a commonly discarded species in the tropical tuna purse seine fishery, was collected in near-shore Miami waters and held at the UM Experimental Hatchery. Baseline reflexes were measured and fish were exposed to air in 4 minute intervals to simulate stress experienced during capture. Reflexes were quantified immediately following stress treatments and fish were held for 7 days to observe if delayed mortality occurred. Significant reflex impairment was observed after 4, 12, and 16 min of air exposure. Delayed mortality was recorded after 8 and 16 minutes of air exposure. Predicted mortality amounts were found using a binomial generalized linear model. Data are being used to construct a Reflex Action Mortality Predictor (RAMP) curve to determine delayed mortality of triggerfish.

TEMPERATURE DEPENDENT POSTPRANDIAL BEHAVIOURAL RESPONSES IN JUVENILE PACIFIC BLUEFIN TUNA (*THUNNUS ORIENTALIS*)

Adrian Gleiss, Jonathan Dale, Dane Klinger, Ethan Estess, Chuck Farewell, and Barbara Block

Bluefin tunas are the most endothermic among all tunas and permit these fish high levels of aerobic performance at cold temperatures. Specific Dynamic Action, the metabolic response of digestion, has been shown to increase metabolic rate in blue fin by 1.5-2.3x Routine Metabolic Rate, the increase in metabolic rate is accompanied by a marked increase in visceral temperature of 2-5 °C. Here we use novel acceleration data-logging technology to elucidate the behavioral responses that accompany SDA. Our data confirm that SDA results in a significant metabolic challenge and at 24°C, tuna show a marked increase in tail-beat frequency over the same duration as the increase in visceral temperature, whereas at 17°C no discernable increase in activity was evident. Detailed analysis of activity tail-beat frequency during each SDA event at 24°C revealed that greater thermal excess during digestion was accompanied by greater activity. We suggest that the increase in activity is a ventilatory response to the increasing metabolic demands of digestion. Higher Standard Metabolic Rates and lower dissolved oxygen concentrations at higher temperatures may result in insufficient oxygen uptake at the gills, making an increase in swimming speed a necessity to prevent the development of an oxygen deficit.

TRANSATLANTIC MOVEMENTS OF JUVENILE ATLANTIC BLUEFIN TUNA INFERRED FROM ANALYSES OF ORGANOCHLORINE TRACERS

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Analyses of organochlorine pollutant ratios were used to investigate trans-Atlantic movements of juvenile Atlantic bluefin tuna (*Thunnus thynnus*). Specifically, we evaluated temporal variation of organochlorine ratios in baseline samples of young-of-the-year (YOY) bluefin spawned in the Gulf of Mexico and Mediterranean Sea, as well as the incidence of recent migrant juvenile bluefin in the U.S. mid-Atlantic and Bay of Biscay fisheries. Limited inter-annual variation of organochlorine pollutant ratios was detected among baseline samples of western and eastern YOY bluefin, and highly significant differences were observed between eastern and western baseline samples each year and for all years combined. Organochlorine analyses demonstrated a substantial influx of juvenile eastern bluefin tuna to the west with recent (< 1 year) eastern migrants comprising approximately 20 – 30% of western Atlantic juveniles at age-2, age-3, and age-4. Recent migrants from the western Atlantic were found to comprise a much smaller percentage of the eastern Atlantic Bay of Biscay fishery; however, the ability to detect these migrants was limited due to an increase in organochlorine ratios for all age-1 eastern juvenile bluefin, and the much larger size of the eastern stock. The organochlorine data are consistent with those from otolith stable isotope analyses, demonstrating a large influx of eastern juvenile bluefin tuna into the western Atlantic fisheries. Future research into the timing and nature of subsequent movements of eastern origin bluefin in the western Atlantic is critical to our understanding of stock dynamics.

REGULATORY IMPACTS ON EXIT FROM THE CALIFORNIA DRIFT GILLNET SWORDFISH FISHERY: A TREATMENT-CONTROL DURATION MODEL

James Hilger and Stephen Stohs

NOAA Fisheries, SWFSC, FRD

This paper reports an estimate of the impact of fishery regulations on vessel exit rates and fleet size. It provides a study of the duration of initial participation from entrance to exit of US fishing vessels engaged in the commercial California drift gillnet swordfish fishery between 1989 and 2010. The impact of the regulation is estimated using a treatment-control approach. Patterns of entry and exit across multiple strata of the fishery are documented. Multiple duration-modeling approaches are discussed and investigated. The Gompertz parametric hazard model is selected as the model of best fit based on statistical tests and graphical analysis. An approach for modeling the counterfactual fleet size is developed. Counterfactual hazard rate and fleet size estimates are produced for the counterfactual state of non-implementation of a time-area closure regulation initiated beginning with the 2001 season. Empirical results suggest that the regulation had a significant impact on exit rates and fleet size. These findings are consistent with the hypothesis that increased regulatory policies impact fleet participation rates and led to larger exit rates and smaller fleet size.

CALIFORNIA CPFV SKIPPER LOGBOOK TRIP TYPE CLASSIFICATION: 1995-2012

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We present a characterization of the trip-length variable classification for over half a million trips provide over 10 million angler-days between 1995 and 2012 by the California Commercial Passenger Fishing Vessel (CPFV) fleet. CA CPFV logbook records were classified into trips by trip-length type categories following a methodology based on California Department of Fish and Wildlife (CDFW) documentation. Trip-length type was assigned as a function of the following variables: departure time, return time, and hours fished. Analysis illustrates that the distribution of trip length type is heterogeneous across CDFW districts. Additionally, species specific catch rate, passenger load, and fishing location vary annually and over trip-length type. These differences may represent diversity in the species availability and operating conditions facing the CA CPFV fleet.

LISTENING TO WHAT THEY WANT – IMPROVING DATA THROUGHPUT IN PELAGIC FISH TELEMETRY

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Knowledge of the environment (depth, temperature, oxygen concentration, etc.) experienced by free swimming fishes is important for advancing our understanding of their physiological ecology and habitat preferences. However, obtaining these data in a timely manner (for example, in near real time) and with sufficient precision, detail and geographic accuracy presents significant challenges because these species come to the surface infrequently and/or for short periods of time. This situation is exacerbated in areas with minimal satellite coverage because of the limitations on the amount of data that can be uploaded. For instance in Hawaii, Argos satellite coverage is only approximately 20% of any 24 hour period. One new avenue of inquiry is whether land based receivers can significantly augment the data being acquired via satellite transmissions. We are testing this concept in Hawaii. This presentation will briefly review the progress being made in these various lines of investigation.

DIFFERENCE BETWEEN THE DEEP-SET AND SHALLOW-SET SECTORS OF THE HAWAII-BASED LONGLINE FISHERY

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The Hawaii-based longline fishery is composed of two distinct sectors; the deep-set longline fishery that targets large tunas that began in the early 1900's and the shallow-set longline fishery targeting swordfish which was first introduced in 1988. There were differences in gear and technology, area of operation, effort, and catch between these two sectors of the longline fishery. The deep-set sector fishes during the day and with the effort widespread around the Hawaiian Islands whereas the shallow-set sector sets and soaks its gear during the night with its main fishing grounds north of Hawaii. The composition of the catch for the deep-set sector was diverse while the catch of the shallow-set sector was composed predominantly of swordfish and blue sharks. The size of target species were smaller for the deep-set sector when compared to the shallow-set sector of the Hawaii-based longline fishery.

THE EFFECT OF TEMPERATURE ON POSTPRANDIAL METABOLISM OF YELLOWFIN TUNA (*THUNNUS ALBACRES*)

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Specific dynamic action (SDA) represents a substantial portion of fish energy budgets and is highly influenced by temperature. The effect of temperature on aerobic metabolism and the energetic cost of SDA was measured in yellowfin tuna (*Thunnus albacares*) at 20 and 24°C. First, routine oxygen consumption of individual fasted tuna was assessed in an intermittent-flow, swim tunnel respirometer. Next, fish were fed a known quantity of food and returned to the respirometer to measure post-prandial oxygen consumption. The energetic cost and duration of SDA were calculated by comparing routine and post-prandial oxygen consumption rates. Results are discussed relative to measurements of SDA for bluefin tuna and other teleosts.

ARCHIVAL AND POP-OFF TAGGING OF ALBACORE IN THE NORTHEASTERN PACIFIC

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The Southwest Fisheries Science Center initiated an archival tagging program with the U.S. albacore surface fleet in 2001 to study the migration patterns and stock structure of juvenile albacore in the North Pacific. Since 2001, a total of 878 archival tags have been deployed along the U.S. West Coast and off northern Baja California, Mexico. Twenty-six archival tagged fish (62-90 cm fork length [FL] at tagging) have been recaptured with deployment durations of 63-753 days. Results based on the first 20 fish were published in 2011 and demonstrated a broad range of horizontal and vertical movements of juvenile albacore. Juvenile albacore tagged in the north off the Columbia River tended to travel greater distances, into North Pacific Transition Zone waters, than those tagged off Southern California and Northern Baja California, many of which remained along the Baja Peninsula throughout the year. We will report on the latest 6 recoveries which includes two fish that were captured close to the coast of Japan in the western Pacific. We also initiated a collaborative pilot pop-off tagging study on albacore caught in the handline fishery off the island of Hawaii to test the use of new attachment anchors on albacore and gather information on the horizontal and vertical movements of adult albacore. In 2012 and 2013, four adult albacore (102-114 cm FL) were caught and tagged with mini pop-off satellite archival tags (PSATs). Three of the PSATs reported with deployment durations of 8-13 days. Although the tags popped off early, the results were promising, particularly when using a monofilament loop through the dorsal musculature below the second dorsal fin to anchor the tag. The daytime swimming behavior of the adult fish differed from that of the juveniles with fewer excursions to surface waters and more time spent at greater depths. Further deployments of both archival tags and PSATs are planned for the 2014 season.

STUDY OF BIODIVERSITY IN THE BY-CATCH COMMUNITIES OF THE PELAGIC ECOSYSTEM AND THE USE OF MAXENT SPECIES DISTRIBUTION MODEL TO PREDICT THE POTENTIAL HABITAT SUITABILITY UNDER FUTURE SCENARIOS OF CLIMATE CHANGE IN THE EASTERN PACIFIC OCEAN

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Few studies have been conducted to understand the biodiversity in marine ecosystem, and its changes through time when a fishery develops in a region With the aim to describe and analyze diversity patterns of the pelagic by-catch communities in the tropical tuna purse seiner fishery in the Eastern Pacific Ocean, data from observer programs carried out between 1993 until 2011 with 100% of coverage on IATTC purse seiner fleets was analyzed in sets of tuna associated with floating objects (log sets or FAD sets) and on school of tunas not associated. Alpha diversity (rarefaction curves and log abundance curves), Beta diversity (differences in species composition) and some heterogeneity indexes, such as Simpson and Shannon, were analyzed by areas. Furthermore, Maxent species distribution model was used to generate the potential habitat suitability for *Carcharhinus falciformis* and *Canthidermis maculata* by-catch species exploring present and future conditions under A2 IPPC scenario of climate change. Results showed that by-catch communities in FAD sets, formed by large and permanent species were more diverse in general than in Non-associated sets, formed by few but dominant/migratory species. Alpha, Beta and diversity indexes were explained by sampling effort and fishing strategy in each area. The highest number of species and evenness was found in a tropical area situated between -5/5º N and -80/-150º W for both fishing modes. Differences in species composition and diversity patterns were found between equatorial and upwelling zones. The equatorial areas showed the highest diversity and similar species composition whereas the upwelling areas showed highest dominance values. Maxent model showed that primary production and the sea surface temperature contributed most to explain the species distribution and predicted a habitat loss in a future scenario near the equator and the Peru coastal upwelling area and a gain in the north close to the California upwelling area. Differences in currents circulation, distribution of fishing effort, productivity and stability of systems between both zones (equator and upwelling areas) determined the diversity of the by-catch communities and their changes by climate effects.

COMPARATIVE SCALE MORPHOLOGY OF ROUNDSCALE SPEARFISH (*TETRAPTURUS GEORGII*) AND WHITE MARLIN (*KAJIKIA ALBIDA*)

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Scale shape is one of several characteristics used to differentiate between two morphologically similar istiophorids: roundscale spearfish (*Tetrapturus georgii*) and white marlin (*Kajikia albida*). Past studies have characterized the scales of white marlin and roundscale spearfish as being morphologically very distinct, but there has been little effort to describe variation within an individual or species. The objective of this study is to describe and photographically document the morphological variation in scales and squamation patterns of distinct body regions of these two istiophorids. Individual scales were collected from 11 specific regions of each specimen of white marlin and roundscale spearfish brought into marlin tournament weigh stations in the Mid-Atlantic Bight during 2012 and 2013. These scales, in addition to scale patches, were later photographed and described. Scale patches were cleared and stained to examine the separation distance between scales within the skin of the fish, as well as the overall squamation pattern, which was compared between regions within each species and between the two species. Scale morphology was found to vary greatly within each of the two species, with scales varying in size, number of points, and other characteristics. Although vast morphological variation is inherent in the scales of both species, white marlin scales generally have fewer posterior points, and the scales are much more heavily imbricated, while roundscale spearfish scales can be rounded, but often have many posterior points and are farther separated within the skin. Detailed scale descriptions allow for a more accurate characterization of the differences between these two species, and could potentially be a valuable tool for investigating istiophorid systematics.

DIEL BEHAVIOUR OF BY-CATCH AND TUNA SPECIES AT DRIFTING FISH AGGREGATING DEVICES (DFADS) IN THE WESTERN INDIAN OCEAN AS ASSESSED BY FISHERS' ECHO-SOUNDER BUOYS

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Several tuna and non-tuna species are known to associate with floating objects drifting in the surface of the ocean. Taking advantage of this associative behaviour, tropical tuna purse seines deploy thousands of man-made fish aggregating devices (also called FADs) to facilitate the catch of tuna. Although the exploitation level of target species is really high through this fishing technique (today almost half of the world tuna catch is taken on FADs) little is known on the reasons driving this associative behaviour, the impacts of these floating structures on the ecology of fish, or the species-specific behaviour when associated. Because FADs are temporary in time and space, they are difficultly studied by conventional scientific means. In the present study, we use fishers' instrumented buoys (i.e. satellite linked GPS buoys equipped with echo-sounders) to continuously collect acoustic samples around remote FADs and investigate the diel cyclical behaviour patterns of FAD associated fauna (i.e. non-tuna species, small tuna and large tuna). For that purpose, we modelled fish biomass during a 24 hour period using GAMs (generalized additive models), which was relative to social factors such as the presence or the amount of conspecifics or allospecifics. Results showed a strong correlation between the presence of non-tuna species and tuna species, and between small tuna and larger individuals, suggesting a likely domino/call effect. In addition, diel biomass dynamics were variable and species/area-specific, implying adaptive behaviour patterns, which allow scientists looking for biological conservation measures such as reducing the non-tuna/tuna catch ratio or minimizing small tuna catch. In fact, the time of the day in which the maximum biomass was recorded varied for each fish group. Comparisons between results observed through echo-sounder buoys and conventional acoustic tags are offered as well.

POPULATION STRUCTURE STUDY OF GENETIC INFORMATIVE DATA DIFFERENTIATION IN PACIFIC SWORDFISH (*XIPHIAS GLADIUS*) USING HIGH RESOLUTION MELTING ANALYSIS (HRMA)

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There are several working hypotheses for Pacific swordfish population structure, including two, three, or four stocks based on genetic and fisheries data. Through the analysis of multi-locus nuclear DNA data, we seek to clarify the population structure of Pacific swordfish. A total of 891 individuals, including adults and early-life stages, from sixteen localities sampled in tropical and anti-tropical regions of the Pacific Ocean were characterized genetically at 10 single-copy nuclear loci as follows: Seven using High Resolution Melting Analysis (HRMA) targeting single nucleotide polymorphisms (SNPs), another SNP as a Restriction Fragment Length Polymorphism (RFLP), and two loci as size polymorphisms of short sequence repeats (SSR). The results of the Bayesian analyses of 20 informative SNPs and two SSR using STRUCTURE indicate genetic heterogeneity among Pacific localities, with a pattern of differentiation separating tropical from anti-tropical regions. No genetic differentiation was detected among the northern and southern Pacific anti-tropical sampling localities. In addition, the tropical sampling localities of Taiwan, Hawaiian larvae (HawLa), Central South Juveniles (CenSJu), and Ecuador were different with respect to some tropical localities. The spatial analysis of genetic data using GENELAND suggests a very complex pattern of genetic differentiation in the Pacific swordfish with no clear geographic boundaries, as those that separate swordfish populations elsewhere (e.g., North and South Atlantic and Mediterranean), although this may be a function of sampling gaps. The genetic characterization of additional sampling localities in both tropical and anti-tropical localities is needed to be able to better define boundary areas for fishery management purposes.

DO POP-UP SATELLITE TAGS AFFECT THE SWIMMING ENERGETICS AND KINEMATICS OF JUVENILE SHARKS?

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During the last decade pop-up satellite archival tags (PSATs) have gained many uses (e.g., determination of the horizontal and vertical movement patterns of fish, quantification of post-release survival). In recent years there have been growing concerns that the PSAT deployment itself may affect the fish by adding extra drag and increasing the cost of locomotion, a scenario reported in swimming eels. Although researchers commonly established a lower (albeit subjective) size limit for PSAT deployment on small fish, no data exist on how PSATs may alter the swimming energetics of small sharks. This experiment investigated the effects of satellite tags on the metabolic rates of juvenile sandbar sharks (*Carcharhinus plumbeus*) and quantified the potential effects PSATs may have on swimming kinematics. The metabolic rate of sharks (n=9; 69±11 cm FL) was calculated with and without PSATs by measuring their rate of oxygen consumption in a circular respirometer. There was no significant difference in the metabolic rates between untagged (157±50 mgO_2/kg/hr) and tagged (172±47 mgO_2/kg/hr) sharks. There was no significant difference between the tailbeat amplitude for untagged (15.1±3.8 %FL) and tagged (14.3±2.98 %FL) sharks. Tailbeat frequency did not change significantly between untagged (1.2±0.5 Hz) and tagged (1.1±0.4 Hz) sharks, and there was no significant difference in the stride length between untagged (74.5±15.2 %FL/tailbeat) and tagged (75.3±12.4) sharks. These results suggest that unlike the published data for eels, PSATs do not have a negative impact on the swimming energetics and kinematics of juvenile sandbar sharks larger than 69 cm FL.

STRUCTURAL FEATURES OF THE OLFACTORY SYSTEM IN TUNAS

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Previous studies have provided evidence that olfactory system plays a vital role in fish behavior. In pelagic fish, little tuna and yellowfin tuna were attracted to chemical attractants; yellowfin tuna also formed a chemical search image in procurement of food as a convenient system that enables the species to switch to a major food source while ignoring food source of little abundance. In continuation of our work on pelagic fish olfaction, we investigated the olfactory organs of yellowfin tuna, bigeye tuna and albacore tuna. Gross morphologic examination showed that the olfactory chamber that houses the round olfactory rosette in 3 tunas is covered by a thick epidermal tissue with an anterior nasal inlet and a posterior slit-like outlet. Olfactory ventilation sac is well-developed in all species. Sensory epithelia are found intermingled as islets within the non-sensory epithelia, which may be regarded as a manifestation of specialization in fast-swimming pelagic fish. Three cell types were observed; olfactory receptor neurons (ORN), sustentacular and mucus cells. Density/mm^2 of the olfactory receptor neurons ranged from 43000 – 58 000. Of the 2 types of ORNs, ciliated olfactory receptor neuron is the most abundant while microvillous olfactory receptor neuron is rarely present on observed samples. Ciliated nonsensory cells are either rare or absent in all the lamellae observed. Epidermal cells forming microridge patterns are the primary cells of the non-sensory epithelium. The results indicated that the 3 tuna species have a functional olfactory system best evolved for pelagic way of life.

ASSIGNING BLUEFIN TUNA (*THUNNUS THYNNUS*) TO SPAWNING AREAS: ARE WE THERE YET?

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Previous genetic studies of Atlantic bluefin tuna have found small but statistically significant differences between samples of YOY and spawning adults from the Gulf of Mexico and the Mediterranean Sea. This suggests that it may be feasible to use the genetic profiles of western Atlantic and eastern Atlantic baseline samples to assign juvenile bluefin tuna caught off the U.S. mid-Atlantic coast to western or eastern Atlantic spawning areas. However, sample size and the number of genetic markers available have limited the power of these studies. To this end, we produced two reduced representation libraries, one from adult bluefin tuna captured on the spawning grounds in the Gulf of Mexico and one from young-of the-year samples from the Mediterranean Sea. Libraries were sequenced on a single flow cell of an Illumina GaIIx. A total of 16,259,628 reads were generated from the Gulf of Mexico samples and 14,864,434 reads were generated from the Mediterranean Sea samples after discarding low quality reads. Reads were assembled and high-throughput single nucleotide polymorphism assays were developed based on these assemblies. Preliminary results based on these assays will be presented.

GENETIC STRUCTURE AND DISPERSAL CAPABILITIES OF DOLPHINFISH (*CORYPHAENA HIPPURUS*); IMPLICATIONS FOR STOCK-BASED FISHERY MANAGEMENT IN THE WESTERN CENTRAL ATLANTIC

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The common dolphinfish (*Coryphaena hippurus*) is of significant recreational and commercial importance around Puerto Rico and the western central Atlantic, yet its population/stock structure in the region is uncertain. The mitochondrial NADH dehydrogenase subunit 1 (ND1; 972 bp) gene was used at two spatial scales to investigate the genetic population structure of dolphinfish. From 183 specimens of *C. hippurus* compared between the north and south coasts of Puerto Rico over 4 consecutive years, no genetic differentiation was detected (F_{ST}= -0.00214, P=0.64027). At the scale of the western central Atlantic, patterns of genetic variation of ND1 were compared among samples collected from the southeastern U.S.A. (n=90), Puerto Rico/Northeastern Caribbean (n=183), eastern Caribbean Sea (n=43), and central north Atlantic (n=8), where 199 haplotypes were identified. Potential high levels of gene flow were supported by conventional mark and recapture movements, which showed all regions to be linked by fish movements. While, statistical significance of population subdivision between all sampled regions was detected (F_{ST}=0.008, P=0.019), the absolute differences were only slight indicating little population differentiation of *C. hippurus* around the western central Atlantic. However, because low levels of genetic differentiation around the western central Atlantic were detected, variability in space and time of peak abundances of *C. hippurus* between sampling regions (Northeastern Caribbean Sea versus Eastern Caribbean Sea) could be the result of a northern and southern migration circuit which would merit management based as a multi-stock fishery throughout the region.

HORIZONTAL AND VERTICAL MOVEMENTS OF SATELLITE TAGGED SHORTFIN MAKO SHARKS IN THE NORTHEASTERN PACIFIC

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Between 2002 and 2013, 109 shortfin mako sharks (*Isurus oxyrinchus*), ranging from 114 to 298 cm total length, were tagged with SPOT and/or PAT satellite tags. Most all tags were deployed in the southern California Bight in the months of June, July or August and consisted of 89 SPOT tags and 71 PAT tags with 52 double tagged sharks. Data were analyzed from 85 SPOT tags with deployment durations of 3 to 1025 days and 56 PAT tags with durations of 18 to 227 days, including data from 40 double tagged sharks. Vertical movements for tagged sharks ranged from the surface to more than 600 m, with the majority of time spent in the top 100 m. The range of horizontal movements of tagged sharks spanned along the coast of North America from the northern coast of Washington, USA to just south of Puerto Vallarta, Mexico and out to the Hawaiian Islands. Two sharks travelled as far south as 4˚N but did not cross the equator. Sharks showed seasonal movements travelling out of the Bight in the fall and winter and returning in the spring and summer. Sharks with multi-year tracks returned to the same general locations in subsequent years showing a preference for certain areas rather than random movements. Overall, sharks over the size range tagged remained in the Eastern Pacific with no movement West of Hawaii or South of the Equator. We will report on observations of horizontal and vertical movements by season, sex and size.

DESCRIBING THE VERTICAL BEHAVIOUR OF YELLOWFIN AND BIGEYE TUNA USING MULTIVARIATE-NORMAL HIDDEN MARKOV MODELS

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Describing the behavioural time-series obtained from archival tagging experiments is non-trivial, and factors such as temporal autocorrelation, varying time-scales of behaviour, noise and underlying motivation must be considered when drawing conclusions about these data. To examine the potential population level effects of smaller scale behaviours such as foraging or FAD-association, we have developed a method of quantitatively and objectively describing vertical movement in tropical tuna using hidden Markov modelling for time-series (HMM). These models assume that the observed patterns in vertical movement data are generated by an unseen Markov process, which switches between an observation model of several different multivariate-normal distributions. Our approach includes processing time series from tuna tagging experiments by compressing them into summary metrics that capture variation in patterns of diving behaviour and form a multivariate time-series. Each observation was associated with covariate information incorporating factors such as day or night or estimated length during time-at-liberty. HMM parameters are estimated to describe the distributions associated with each behavioural state, the probabilities of switching between these states, and a probabilistic classification of occupying each state at each time-step.

We have estimated HMMs for a subsample of 60 yellowfin and bigeye individuals from the Western and Central Pacific Tuna Tagging Project archival database, under a number of different behavioural assumptions. In all cases, HMMs estimated two distinct behavioural states, predicting a shallow warm state, which was similar across all individuals, and a deep colder state, which was more variable, with some individuals exhibiting less persistent intermediary states. Marked diurnal behavioural switching was predicted, consistent with many previous empirical studies on tuna, and a deepening of cold states was seen with increased length.
While this research is on-going, we expect the quantitative outputs on vertical behaviour from this approach to be used to examine and compare animal behaviour directly, as well as eventually inform models of population dynamics in management contexts.

ASSESSING THE TROPHIC ECOLOGY OF LARGE PELAGIC FISHES IN THE U.S. SOUTH ATLANTIC USING DIET AND STABLE ISOTOPE ANALYSIS

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Sustainable management of marine fishery resources requires an understanding of the ecological relationships that contribute to community structure and population dynamics. In pelagic ecosystems, the functional role played by large pelagic predators is poorly understood, yet this knowledge is essential to the application of ecosystem based approaches to fisheries management.

To assess the trophic structure of the pelagic community in the US South Atlantic, stomachs and muscle tissue samples were collected from blue marlin (*Makaira nigricans*), wahoo (*Acanthocybium solandri*), dolphinfish (*Coryphaena hippurus*), yellowfin (*Thunnus albacares*) and blackfin tuna (*T. atlanticus*) through participation in organized fishing tournaments and cooperation with charter fishing fleets operating in the offshore waters of North and South Carolina from spring 2010 through fall 2013. Diet items were removed from stomachs, identified to lowest possible taxon, and sizes reconstructed when possible. Indices of relative prey mass and occurrence were used to describe the diets and to evaluate the potential for resource competition among predators. Analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopes was performed on muscle and liver samples from predators as well as muscle samples and whole body samples of prey to elucidate the trophic structure of the community and identify important predator and prey guilds.

Stomach contents revealed fishes as the most important prey by mass for all predators during all seasons. Fishes of the family Scombridae contributed the most to mass diet indices for all predators. Invertebrates were as equally important in the diets of blackfin tuna and yellowfin tuna with the most dominant prey being Ommastrephidae squid and amphipods. Schoener's index calculated from prey mass and frequency of occurrence showed high diet overlap between dolphinfish-blackfin tuna ($\alpha = 0.649$) and wahoo-yellowfin tuna ($\alpha = 0.770$) suggesting direct competition for prey resources between the predators. Stable isotopic analysis indicated seasonal shifts in primary prey use and trophic position by only blackfin tuna. Measures of isotopic niche overlap also suggested the potential for competition between dolphinfish-blackfin tuna (SEA = 0.691) and wahoo-yellowfin tuna (SEA = 0.515). Clustering of the bivariate isotopic data revealed a trophic hierarchy in which larger predators occupied the highest trophic positions within the community while most prey species were grouped in the lowest levels. Results to date suggest that all predator species forage in similar habitats and rely on a few dominant prey items. Further work is need to describe the abundance and dynamics of these dominant prey species before ecosystem approaches can be implemented within the US South Atlantic.

DEVELOPING GENETIC RESOURCES TO GUIDE BROODSTOCK SELECTION AND CULTURE PRACTICES FOR CALIFORNIA YELLOWTAIL*, Seriola lalandi.*

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Aquaculture of yellowtail (*Seriola* spp.) is well established globally with an estimated annual value of $1.3 billion. In the Pacific, the yellowtail, *Seriola lalandi*, is a strong candidate for future development of offshore commercial aquaculture in southern California. Unfortunately, larval rearing methods for this and other *Seriola* species are still unreliable, resulting in highly variable survival rates and prevalence of physical malformations that impact commercial aquaculture by reducing the market value of fish. Genetic resources have been developed and used extensively in agriculture and livestock breeding for decades, improving product quality and quantity. Advances in genetics have also been used to improve aquaculture practices for a handful of valuable marine species. However, few of these resources have been developed for *S. lalandi*. To address this gap, we are developing genetic resources and tools for *Seriola lalandi*, thereby working to improve sustainable aquaculture production for this and other economically important *Seriola* species. The approach is multifaceted and includes: analyzing global and regional genetic population structure, examining spawning dynamics through parentage/kin analyses, assembling a draft yellowtail genome, and exploring early developmental gene expression. Analyses of genetic structure are important for evaluating impacts on wild populations from translocations of brood- and seed-stock, which are likely to become more frequent as aquaculture grows for *S. lalandi*. Spawning group dynamics are key for the selection and maintenance of broodstock populations; this includes determining reproductive output of individual brood fish, parental contribution to deformity prevalence or growth variation, and maintenance of genetic diversity. The assembled genome is an extremely valuable tool for examining regions (genes) of interest, and looking for candidates for marker selection and development. Importantly, the genome will be used as a launching point for a range of studies. Lastly, the gene expression analyses are important to understanding physiological changes that occur in early development. These analyses may help identify particularly vulnerable developmental stages, and reveal important variation between larvae of low and high levels of fitness. The results to date and updates on the different projects will be presented.

DISTRIBUTION AND ABUNDANCE OF THE BLUNTNOSE FLYINGFISH (*PROGNICHTHYS OCCIDENTALIS*) IN THE NORTHERN GULF OF MEXICO ACROSS MESOSCALE FEATURES

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The aim of the present study is to characterize the distribution and abundance of larval *P. occidentalis* (family Exocoetidae) in the northern Gulf of Mexico. Flyingfishes are an essential component of pelagic food webs, serving as both predator and prey. Many pelagic fishes (billfishes, dolphinfishes, and tunas) consume large quantities of flyingfish, and several studies have documented their importance as prey for apex predators residing in coastal and offshore environments. Here, we report on summer ichthyoplankton cruises conducted in the northern Gulf of Mexico (NGoM) from 2009 to 2011. Samples were collected using neuston nets towed through the upper meter of the water column in the outer shelf and slope waters of the NGoM. Over the three year sampling period, a total of 9,533 bluntnose flyingfish larvae were collected representing 77% of the total flyingfish catch collected. Interannual variation was detected with densities of *P. occidentalis* larvae higher in 2009 and 2010 (11.3 and 7.9 larvae $1000m^{-2}$, respectively) than 2011 (1.9 larvae $1000m^{-2}$). *P. occidentalis* larvae were present in each month and year sampled, and percent frequency of occurrence ranged from 40% in July 2011 to 100% in June 2010, suggesting that bluntnose flyingfish represent a common and important component of the ichthyoplankton assemblage in the NGoM. Generalized additive models were used to evaluate the influence of oceanographic conditions on the density of *P. occidentalis.* Several environmental variables (month, year, sea surface height anomaly, distance to Loop Current, and salinity) were found to significantly influence *P. occidentalis* distribution and retained in the final GAM model. Abundance of *P. occidentalis* larvae increased in waters associated with higher salinities and negative sea surface height, corresponding to cyclonic features in the NGoM. These areas typically have higher productivity because of upwelling, which may provide the larvae with more feeding opportunities.

MOBULID BYCATCHES IN THE TUNA PURSE SEINE FISHERY AND MITIGATION APPROACHES

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Manta or devil rays, Mobulidae, are a component of the bycatch of the tuna purse seine fishery in the eastern Pacific Ocean. IATTC observers have been collecting bycatch data on mobulids at the family level since 1993. In 2002, bycatch data collection began at the species level. Five species are reported in the IATTC data base: *Manta birostris*, *Mobula japanica*, *M. munkiana*, *M. thurstoni* and *M. tarapacana*, and they were captured in all three set types made by the tuna purse seine fishery. The highest mobulid bycatches were reported in sets on unassociated schools of tunas, followed by sets on tunas associated with dolphins and sets on tunas associated with floating objects, respectively. Spatial patterns of distribution were similar among species. Aggregations of mobulids were concentrated in areas with high indices of biological productivity. Compared with boney fishes, mobulids have a small litter size, long reproductive cycle, late maturity, etc., which makes them particularly susceptible to over-exploitation. Some approaches for the live release from tuna purse-seines are mentioned in an effort to mitigate the bycatch of mobulids in tuna fisheries.

MOVEMENTS OF BIGEYE TUNA (*THUNNUS OBESUS*) TAGGED AND RELEASED IN THE EQUATORIAL CENTRAL PACIFIC, WITH CONVENTIONAL AND ARCHIVAL TAGS

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Information on the movement patterns and population structure of any species of tuna is necessary for stock assessments and management. The objectives of this investigation are to describe the movements and dispersion of bigeye tagged and released in the equatorial central Pacific Ocean (CPO), and to estimate the amount of mixing with fish in adjacent areas.

A total of 31,242 bigeye tuna was captured, tagged, and released, 30,793 with dart tags (DTs) and 449 with geolocating archival tags (ATs), in the equatorial CPO at 140°W, 155°W, 170°W, and 180°, during 2008 through 2012, of which 9,822 (31.9%) and 73 (16.3%), of the tags were returned. A subset of high-confidence filtered DT data was retained for 5,415 fish at liberty for 30 d or more, for evaluating linear displacements from release to recapture positions. For the filtered DT data, days at liberty ranged from 30 to 1,565 d (median = 197 d). Linear displacements ranged from 1 to 5,372 nmi (median = 1,013 nmi), with 71% eastward and 29% westward, and 95% within 3,677 nmi of their release positions.

An unscented Kalman filter model with sea-surface temperature measurements integrated (UKFsst) was used to process 48 AT data sets from bigeye at liberty for 30 d or longer, in order to obtain most probable tracks, improved estimates of geographic positions, and movement parameters. The most probable tracks from bigeye releases at the 140°W, 155°W, 170°W, and 180°, show substantial overlap.

The linear displacements and most probable tracks obtained from these tagging data demonstrate constrained latitudinal dispersion, regional fidelity, extensive longitudinal dispersion, and mixing of bigeye between release locations. The amount of mixing of bigeye between these release locations in the equatorial CPO, with those in adjacent areas of the equatorial eastern and western Pacific, is dependent on distances between locations, with, in general, the greatest mixing occurring between the areas that are closest to one another.

EVALUATING POST-RELEASE MORTALITY OF WHITE MARLIN (*KAJIKIA ALBIDA*) CAUGHT IN THE RECREATIONAL FISHERY: BIOCHEMICAL AND PHYSIOLOGICAL INDICATORS OF LETHAL STRESS

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White marlin (*Kajikia albida*) are a highly migratory species that occur throughout temperate and tropical regions of the Atlantic and are the basis of a large sport fishery along the U.S. Atlantic coast. The single, Atlantic-wide stock is considered to be well below the target for maximum sustainable yield with less than half the spawning biomass that is estimated to be necessary. Billfish management measures adopted by the International Commission for the Conservation of Atlantic Tunas (ICCAT) and implemented in the United States by the National Marine Fisheries Service (NMFS), as well as increasing angler awareness of conservation, have resulted in the vast majority of white marlin being released after capture. In 2003 it was estimated that more than 99% of the 4,000-8,000 white marlin captured each year in the United States recreational fishery are released alive.

Not much information is available regarding the fate of released fishes; however, recent research aimed at estimating post-release mortality in marine and freshwater fishes suggests that mortality may vary with hook type, hook location, fight time, the amount of time the fish is exposed to air, relative temperature change, and the size of the animal. Stress resulting from an angling event may also have sublethal effects and stimulate physiological change at the organismal level, thereby impacting growth rates, reproductive output or investments, ability to evade predators, and disease resistance.

Circle hooks have been recognized by anglers as an important conservation tool and most U.S. Atlantic offshore anglers have adopted their use following research that showed that circle hooks have significantly lower post-release mortality, have a higher probability of catching in the corner of the jaw, and cause lower incidences of bleeding in white marlin than do J-hooks. This large-scale acceptance has allowed us to design a study that controls both for hook type and hooking location and examine the stress response due to angling.

We are examining post-release mortality and post-angling physiological stress with a two-part study collecting physiological data and deploying pop-up satellite archival tags (PSATs) on recreationally angled white marlin. Over two years we sampled blood from 68 recreationally caught white marlin of which 22 were additionally tagged with PSATs to follow survival. Physiological data demonstrated that plasma glucose, sodium, potassium, and cortisol had a significantly relationship with fight time and plasma lactate and chloride increased significantly with fight time and water temperature. We inferred 3 mortalities (17%) from PSAT data and models demonstrated that plasma potassium was a significant predictor of mortality. Our results indicate that increased angling times and warmer water result in physiological stress in white marlin; however, post-release mortality was not related to fight time and was marked by elevated potassium levels.

FACTORS AFFECTING SPAWNING PATTERNS OF CAPTIVE YELLOWFIN TUNA *THUNNUS ALBACARES*

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Achotines Laboratory is the only research facility in the world with captive broodstock tuna that have been spawning on a near daily basis for over 17 years. Yellowfin tuna captured with hook-and-line from the wild at 1 year of age and held in a 1,300 m^3 in-ground concrete tank were reared to reproductive size in 6-9 months. Age at first spawning for female yellowfin in captivity was estimated at 1.3 to 2.8 years, averaging slightly less than 2.0 years.

Studies based on histological analyses of gonads of fish sampled at sea have estimated spawning seasons, spawning intervals, fecundities, and energetic costs of spawning for yellowfin tuna. The development of the spawning population of yellowfin tuna at the Achotines Laboratory allowed the study of daily spawning dynamics of yellowfin over multiple years. Since 1996 the courtship and spawning behaviors of the captive yellowfin, their spawning periodicity, and the influence of physical and biological factors on spawning and hatching have been observed and described confirming the veracity of the aforementioned field studies. Water temperature appears to be the main exogenous factor controlling the occurrence and timing of spawning with the fish spawning as long as they receive adequate daily food rations and water temperature is above 23.5°C.

While the captive yellowfin tuna broodstock have spawned on a near daily basis since late 1996, there have been periods of no spawning activity. Daily spawning has occurred about 90% of the time over the past 17 years when water temperatures were conducive to spawning. There were cessations in spawning lasting more than a week for about 10% of that same period. Extensive data collected on broodstock tank water quality, size distribution of captive tuna, and sex ratios in the broodstock tank since 1996 was analyzed to look for possible factors to explain these periods of no spawning. Preliminary results will be presented.

The tuna broodstock and spawning component, including objectives of genetic work on captive yellowfin tuna, of a joint 5-year Kinki University-Inter-American Tropical Tuna Commission-Autoridad de los Recursos Acuáticos de Panama research project being conducted under the SATREPS (Science and Technology Research Partnership for Sustainable Development) program will be presented and discussed.

RESILIENCE OF BLUEFIN TUNA IN THE WESTERN ATLANTIC OCEAN: THE STORAGE EFFECT

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Atlantic bluefin tuna (*Thunnus thynnus*), like other marine fish populations, are known to transition between stationary demographic states. Their persistence within a given state depends on structuring agencies that distributes climate, fishing, and other environmental influences across population cohorts and segments. Long-term depressed abundance in the western stock of Atlantic bluefin tuna followed a period of intense overfishing in the 1970s and has been attributed to several causes: (1) during the past 30 years the ecosystem has not supported strong years of juvenile production, (2) the stock mixes with the more highly exploited eastern stock (fisheries in the Northeast Atlantic Ocean and Mediterranean Sea), and (3) the population underwent a regime shift. Analysis of age and stable isotopes in otoliths (ear-stones) from a North Carolina fishery confirmed recent years of relatively high juvenile production in 2003, 2005, and 2006 and low levels of mixing during the recent period. In support of a historical transition in demographic states, substantial age truncation was observed for adults sampled in 1996-2007 (mean age=13.4±3.8 SD; skewness=1.3) in comparison to 1975-1981 (mean age=20.1±3.7 SD; skewness= -0.3). Half of the historical sample exceeded 20 years in age; less than 5% did so in the recent period. Loss of age structure is consistent with changes in selectivity in western bluefin tuna fisheries and retrospective trends in the stock assessment used for management. This retrospective analysis supports the view that fishing as a forcing variable brought about a phase shift in the western stock towards lower biomass and production. An abbreviated reproductive life span directly compromised the storage effect by reducing the capacity of adults to sample conditions favorable for offspring survival over decadal time scales. Because recruitment dynamics by the western stock exhibits threshold dynamics, returning it to a higher production state will entail greater fishing controls.

INVESTIGATING SWORDFISH MOVEMENTS AND TESTING ALTERNATIVE DEEP-SET GEAR ABOVE POINT CONCEPTION, CA

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Within the exclusive economic zone (EEZ) off the coast of California, swordfish are primarily landed using drift gillnet (DGN) gear and to a lesser extent with traditional harpoon techniques. DGN interactions with bycatch species of concern (e.g., marine mammals, sea turtles), although relatively uncommon, have spurred numerous restrictions that have directly affected fishers through time and area closures [including a roughly 200,000 sq. mile Pacific Leatherback Closure Area (PLCA)] and mandated gear modifications. The restrictions in place since 2001 prohibit DGN operations within the most productive waters off California during the season when swordfish are most abundant. Given the current underutilization of the swordfish resource along the U.S. West Coast the present study was undertaken to (1) quantify swordfish depth distribution within the PLCA, (2) compare swordfish vertical distribution with non-target species of concern (i.e., leatherback sea turtles) and (3) conduct experimental deep-set buoy gear trials. Wildlife Computers PSAT (11) and WC-SPOT tags (2) were deployed on basking swordfish using harpoon methods in 2012 and 2013. Short-term (2-20d) and extended deployments (i.e., 150d) offer both fine and course scale depth and temperature information for swordfish within the region of concern. Findings from the movement patterns of 13 swordfish (80 to 200 kg) tagged within the PLCA, gear trials and future directions will be discussed.

AGE STRUCTURE OF ATLANTIC BLUEFIN TUNA FROM THE NORTH CAROLINA WINTER FISHERY

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Among large pelagics population growth and resilience depends on periodic production of strong year-classes. For the diminished western stock of Atlantic bluefin tuna, length data showed evidence of a strong year-class occurring in 2003, following >20 years of poor recruitments. The North Carolina winter recreational fishery presented the opportunity to collect a range of sizes that should include the abundant 2003 year class. Here, direct age estimates were used to test for the presence of this strong year-class in a representative sample (2011-2013; N=337; >30% sampling rate). Age estimates were determined from sectioned otoliths based on standardized methods developed by an international team of bluefin tuna scientists. Ageing methods included protocols related to section type, image enhancement and annotation, consistent interpretation of the first annulus, and calibration based on a reference set of images. Ages ranged from 4 to 18 years, with the majority (99.1%) of individuals between 4 and 11 years, and confirmed a strong 2003 year-class as well as two other strong year-classes in 2005 and 2006. The largest individual (267 cm CFL), an angling category state record, was estimated to be 18 years. Mean sizes at age were similar to those predicted from the currently accepted ICCAT western stock growth model. Improved stock assessments for Atlantic bluefin tuna through explicit consideration of mixing and differential stock production rely heavily on age structure, which is currently inferred exclusively from length data. Recent initiatives by ICCAT states have resulted in otoliths collected from thousands of Atlantic bluefin tuna throughout the North Atlantic and Mediterranean Sea in support of improved age-structured assessment and simulation modeling.

DID REGULATION OF WEST COAST PACIFIC SWORDFISH FISHERIES REDUCE SEA TURTLE BYCATCH? A NONPARAMETRIC BOOTSTRAP ANALYSIS OF REGULATORY EFFECTIVENESS

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From 1990 through 2000, the primary commercial swordfish fisheries with landings to West Coast ports were the shallow-set longline fishery which operated on the high seas between the West Coast and Hawaii, and the California drift gillnet fishery. Though the California-based harpoon fishery also landed swordfish to the West Coast, landed weight and revenues were relatively small fractions of production in comparison to the two other methods.

Concerns over levels of endangered leatherback and loggerhead sea turtle bycatch led to regulation in 2001 of both of the primary west coast swordfish fisheries under the Endangered Species Act (ESA). The portion of the shallow-set longline swordfish fishery operating out of Hawaii was shut down over the period from 2001-2004, primarily due to concerns over levels of loggerhead sea turtle interactions, although the longline fishery was still permitted to make landings to the West Coast over this period. Observed leatherback sea turtle interactions led to the establishment in all seasons since 2001 of a time and area closure of the drift gillnet swordfish fishery over a large area to the north of Pt. Sur during the period from August 15 through November 15.

Two further regulatory measures took effect in 2004 which drastically altered the operation of the fishery: The Hawaii-permitted shallow-set longline fleet was allowed to resume operations, under requirements to use circle hooks and mackerel type bait with 100% observer coverage to monitor catch and bycatch. The federal Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species went into effect in 2004 without authorizing shallow-set (swordfish) longline as a permissible gear, while Hawaii shallow-set longline vessel landings to the West Coast were permitted.

This paper addresses the question of whether ESA regulations in the early-2000s were effective to reduce leatherback and loggerhead sea turtle bycatch in the two primary west coast commercial swordfish fisheries. Data which is representative of the periods before and after ESA regulation in each fishery are used to estimate sea turtle bycatch and mortality rates per unit of swordfish production before and after ESA regulation. A nonparametric bootstrap approach is used to quantify uncertainty in the pre- and post-regulation estimates and to test the null hypothesis that ESA regulation had no effect on leatherback sea turtle bycatch rates per unit of swordfish production against the one-tailed alternative hypothesis that sea turtle bycatch rates significantly decreased after regulation. The results will be discussed in the context of a cost-benefit analysis of proposed legislation to ban drift gillnet and shallow-set longline landings of swordfish to the West Coast.

WHERE DO LARGE PELAGICS FISHERMEN WORK AND WHAT DO THEY WANT? ENDOGENOUS LOCATION CHOICE AND THE ATTENUATION OF THE ABUNDANCE-CPUE RELATIONSHIP

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The CPUE-abundance relationship is confounded by the endogenous choice of where and when to fish. Besides spatial-temporal variation in target species density, the fisherman's location choice is impacted by economic variables such as the relative cost of prosecuting effort at different locations. If catch rates are insufficient at distant locations to fully offset the added cost of accessing them, the economically optimal fishing location may be located closer to port, even if areas of greater target species density with potentially higher catch rates are located in distant waters.

We develop a model of location-dependent variable fishing profits to explain potential selectivity bias in CPUE estimates. The model is used to estimate the endogenous dependence of commercial albacore fishing location choice on the economic viability of fishing effort. Albacore troll-and-pole logbook data and economic data are used to calibrate the equilibrium conditions of the model. The analysis considers whether high fuel costs in the recent years explain the location shift of U.S. albacore troll and pole fishing effort from outside the U.S. EEZ in the pre-2000 period to almost entirely inside the U.S. EEZ in the post-2000 period. Sensitivity analyses are used to study changes in potential profits based on alternative scenarios. We consider potential implications for interpreting fishery-dependent CPUE data as an index of abundance for assessments.

CAPTURE STRESS AND POST-RELEASE SURVIVAL OF SOUTHERN BLUEFIN TUNA FROM RECREATIONAL FISHING

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Southern Bluefin tuna are an iconic large pelagic species that demands one of the highest prices for seafood per kilogram on international markets. The high demand for this species led to significant commercial overfishing in the past. More recently international management efforts have led to a slow but recovering trend in southern Bluefin tuna stocks. Australia currently holds the largest quota share of southern Bluefin tuna with the species found in relative abundance off the western, southern and southeastern coastline of the continent. At certain times of the year schools of fish migrate along the coast of Australia within range of recreational fishing boats. In recent years the popularity of the recreational fishery for southern Bluefin tuna has increased significantly due in part to the affordability of vessels suitable to fish offshore waters as well as an increased technological capacity to find fish with high quality GPS and depth sounders. Given this increase in fishing effort and the stringent international management of this species gaining an understanding of the Australian recreational fishery is seen as filling a crucial knowledge gap. This study explored capture stress and post-release survival of southern Bluefin tuna caught using recreational fishing techniques. For 56 fish we assessed factors such as fight time and hooking damage against physiological stress indicators including glucose, lactate, pH, cortisol and osmolality levels in blood plasma. We then assessed survival post-release for a sub-set of these fish (n = 45) by attaching pop-up satellite archival tags to monitor the fish's behavior and movement for up to 180 days post-release. The results will be used to develop a scientifically robust code of practice for the handling of southern Bluefin tuna that are intended for catch and release to maximize survival opportunity. Furthermore, the post-release survival rates will be available in conjunction with planned surveys to estimate the national recreational harvest of southern Bluefin tuna to provide a robust assessment that will be available for integration into the international stock assessment for this species.

MINIMUM FOOD REQUIREMENTS FOR SURVIVAL AND GROWTH OF YELLOWFIN TUNA (*THUNNUS ALBACARES*) AND PACIFIC BLUEFIN TUNA (*THUNNUS ORIENTALIS*) LARVAE

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Comparative growth studies of yellowfin tuna (*Thunnus albacares*) (YFT) and Pacific bluefin (*Thunnus orientalis*) (PBT) larvae were conducted between 2011 and 2013 at the IATTC's Achotines Laboratory in Panama and the Kinki University Fishery Laboratory in Japan as part of a 5-year research project of the SATREPS Program (Science and Technology Research Partnership for Sustainable Development) funded by JICA (Japan International Cooperation Agency) and JST (Japan Science and Technology Agency).

YFT and PBT exhibit very different modes of reproduction but both have high fecundities and both are pelagic, broadcast spawners. The egg and larval-stage durations are temperature dependent in both species, but PBT larvae are, on average, larger than YFT larvae at the onset of first feeding. Prey availability has a large influence on vital rates (i.e. growth and mortality) of tuna larvae especially during the first week of feeding when larvae may encounter suboptimal feeding conditions. We will present results from laboratory experiments that compared the survival and growth potential between YFT and PBT larvae after exposure to a gradient of relatively low and high food levels and their growth and survival responses to a two-day delay in feeding of optimal prey levels at similar water rearing temperatures.

Additionally, we also conducted experiments to estimate rates of starvation of PBT larvae reared at different water temperatures. Mean starvation durations (hours until 100% mortality without feeding) were 65.5, 59.25, 58.5, and 37 hours at 24°C, 26°C, 27°C and 29°C, respectively. Experiments will be conducted later this year at the Achotines Laboratory to estimate starvation rates of YFT larvae. The growth and survival characteristics of both species will be integrated into models that may be used to predict pre-recruit survival based on measureable physical and biological processes.

INFLUENCE OF SUBTROPICAL FRONTS ON THE SPATIAL DISTRIBUTION OF ALBACORE TUNA (*THUNNUS ALALUNGA*) IN THE NORTHEAST PACIFIC OVER THE PAST 30 YEARS (1982-2011)

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Relationships between albacore tuna distribution and subtropical fronts in the Northeast Pacific were examined on seasonal and interannual scales from 1982 to 2011. Spatial analyses were performed on commercial logbook data from US and Canadian troll and pole-and-line fisheries targeting albacore tuna that were matched with corresponding satellite images from the Advanced Very High Resolution Radiometer (AVHRR). Subtropical fronts were detected by deriving sea surface temperature (SST) gradients on large basin-scales and by using an improved version of the Cayula-Cornillon frontal detection algorithm. Our results suggest that areas with high albacore catch-per-unit-effort (CPUE) tend to occur in regions with high SST gradients, such as the North Pacific Transition Zone (NPTZ) and the North American coast. Approaching the North American coast along the NPTZ, SST gradients drop off substantially around 130°W before increasing rapidly near the coast, which corresponded to a similar pattern in albacore CPUE. In the NPTZ, the centroid of albacore CPUE showed a seasonal shift northwards in summer and southwards in fall, which coincided with seasonal spatial shifts of areas with high SST gradients. A similar pattern was found on an interannual scale, with the exception of several years with limited fishery data in the NPTZ due to changes in fishery operations. A fine-scale analysis of frontal locations suggested that areas with high albacore CPUE are associated with oceanic fronts, with the highest albacore CPUE being observed within 100km of the nearest front. In addition, albacore distribution is related to frontal strength, with the highest CPUE being found near fronts with high SST gradient values of 0.12-0.16°C km^{-1}. These results will likely improve the standardized abundance indices used in North Pacific albacore stock assessments by integrating the influence of frontal areas into the standardization model.

SPATIAL AND TEMPORAL VARIATIONS OF PRIMARY PRODUCTIVITY AND RECRUITMENT OF SKIPJACK TUNA (*KATSUWONUS PELAMIS*) IN THE WESTERN AND CENTRAL PACIFIC OCEAN

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The western and central Pacific Ocean (WCPO), characterized by high sea surface temperature and an oligotrophic environment, is the largest fishing ground of skipjack (*Katsuwonus pelamis*) in the world. The spatial and temporal features of primary productivity in the WCPO may affect the distribution of skipjack stock. In this study, we used 3 types of high-resolution remote sensing data (4 km × 4 km spatial resolution), including sea surface temperature (SST), chlorophyll-*a* (Chl-*a*) and photosynthetically active radiation (PAR). Throughout the study, the vertically generalized production model (VGPM) was utilized to establish euphotic depth-integrated primary productivity (IPP). The modeling IPP was used to find the relationship between IPP and the assessment amount of skipjack tuna stock. During 2003-2010, CPUE data from a Taiwanese purse seiner fishery was utilized for accurate analysis. The major results of the analysis are as follows: In the WCPO, IPP near islands is higher, but most of the high IPP spots are still from the eastern Pacific Areas with high IPP altered by ENSO episodes. Areas where IPP significantly correlated with ENSO are mainly located along the equatorial band (2°N-2°S), with the highest value at between 160 ~ 165°E. We found that high recruitment of skipjack occurred in the 24 and 48 months after an IPP bloom. The time lags imply that the increase in primary productivity led to a boost in the larvae survival rate and affected the recruitment of skipjack broodstock. This study attempts to obtain the result by connecting recruitment, primary productivity and climate variability, in addition to verifying the impact of climate variability on fish resources. The study also highlights the diverse impact of primary productivity on tuna resources caused by climate variability.

Poster Presentation Abstracts (In order of presenting author last name):

EVALUATING SEASONAL SWORDFISH MOVEMENT PATTERNS IN THE EASTERN PACIFIC

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Management strategies to reduce bycatch interactions require spatial and temporal information on swordfish (*Xiphius gladius*) movements relative to other species of concern. To address the need for selective fishery options and support adaptive management efforts, tagging studies were conducted to identify regional variations in swordfish depth distribution throughout the eastern Pacific. We report on the seasonal movement patterns of a mature swordfish (~175 kg) tagged and recaptured off the coast of southern California. Smoothed sunrise and sunset curves were estimated from fine-scale time (60 s) and depth data over the 16-month track period, based on assumptions of consistent crepuscular dive patterns of swordfish in the Pacific. Daily geolocation projections were generated from estimated time of dawn and dusk in conjunction with mean daily sea-surface temperature (SSTs) and bathymetry data. Mean daily SSTs increased steadily from 15.0 to 27.4°C during February and March of 2013, as the swordfish migrated approximately 3,600 km to the southwest from near 30N/119W to 7N/143W. Sea-surface temperature peaked at 30°C during the spawning season (April-May), while minimum temperatures at depth reached 2.5°C below 1200m during a northerly migration back towards the Southern California Bight in June. Regional dive patterns were evident during seasonal migrations between foraging and spawning areas.

TRACKING MOVEMENTS OF SWORDFISH, *XIPHIAS GLADIUS*, USING EMPIRICAL ORTHOGONAL FUNCTION ANALYSIS OF TEMPERATURE BY DEPTH PROFILES

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The application of satellite tags for tracking purposes has shown success in tracking certain large pelagic species. However, the diel movements of swordfish prevent light-based geolocation from effectively locating their position. Advances in geolocation methods have allowed coordinate estimates of swordfish to be within 0.3° longitude and 0.7° latitude. To produce more accurate tracks of swordfish, a mathematical model was created to analyze temperature and pressure data recorded by archival tags rather than light data. This model applies empirical orthogonal function analysis to project the most probable movement between the initial location of release and the location of the tag pop-off. Data from three pop-off satellite archival tags (Microwave Telemetry) attached to swordfish and blue marlin, *Makaira nigricans*, was used to generate daily coordinate estimations. The blue marlin data provided enough light information to create accurate geolocation estimates using the 'TrackIt' model. Comparison analyses of the two models results in lower root mean square error than error estimated from the most precise geolocation methods. This demonstrates an improvement in accuracy using our analysis. This study shows the feasibility of using temperature and depth data instead of light levels to allow effective tracking of swordfish.

STATUS REVIEW OF THE NORTHEASTERN PACIFIC POPULATION OF WHITE SHARKS (*CARCHARODON CARCHARIAS*) UNDER THE ENDANGERED SPECIES ACT

Heidi Dewar, Tomoharu Eguchi, John Hyde, Doug Kinzey, Suzanne Kohin, Jeff Moore, Barbara L. Taylor, and Russ Vetter

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In 2012 the National Marine Fisheries Service (NMFS) received two petitions requesting that the northeastern Pacific (NEP) population of white sharks (*Carcharodon carcharias*) be listed as endangered or threatened under the Endangered Species Act (ESA). NMFS formed a Biological Review Team (BRT) made up of NMFS scientists having diverse backgrounds. The BRT considered a variety of scientific and technical information and conducted an independent analysis. Given the limited data available for some topics and the associated uncertainty the team used Structured Expert Decision Making.

- The BRT examined the discreteness of the NEP population. An examination of the behavioral and genetic data suggests that the NEP white shark population is markedly separated from other white shark populations.
- The team examined potential threats to the population, e.g. fisheries, pollution, global warming, and a diminished prey base. The greatest threat was considered to be from near-shore fisheries in the U.S. and Mexico. A current catch estimates for the last 10 years in the U.S. net based fisheries are ~28 young-of-the-year (YOY) and juvenile white sharks per year, of which ~50% are presumed mortalities. The estimated annual white shark landings for Baja California Norte in 2011 were ~185 individuals, all of which are assumed to be mortalities.
- The BRT looked at direct and indirect evidence of population trends in the NEP. There were several examples including catch per unit effort data, marine mammal attack information, and the photo ID data from Guadalupe Island that all suggested increasing trends. There were no examples that suggested declining trends.
- The team concluded that the estimated number of 339 provided by the petitioners significantly underestimated the population of all adults and sub-adult white sharks in the NEP. This conclusion is based on the potential sampling biases at the two study sites upon which the number is based, the haplotypic diversity, the YOY mortality rates and the demographics documented at the two sites where the majority of sharks are mature males. The BRT concluded that there was a high probability that the number of mature females alone was >200. The focus of analyses was on the abundance of mature females given their key role in population growth rates.
- The BRT conducted a population viability analyses to characterize the probability that fisheries mortality could lead to future population decline, especially to levels below certain thresholds reflecting extinction risk within relevant time periods. The BRT considered 20 modeling scenarios combining different levels of fisheries mortality and female abundance. Model results revealed that at adult female populations levels >200 the risk of extinction was low to very low.

Taking into consideration a broad range of factors, including the threats, the population status and trends, the haplotypic diversity and the model results, the BRT concluded that the NEP white shark population was most likely at a low to very low risk of extinction. Ultimately, NMFS Southwest Regional Office decided that an endangered or threatened listing for NEP white sharks under the ESA was not warranted.

HABITAT UTILIZATION AND VERTICAL MOVEMENTS OF THE PELAGIC STINGRAY *PTEROPLATYTRYGON VIOLACEA* (BONAPARTE, 1832) IN THE WESTERN NORTH ATLANTIC OCEAN USING SHORT-DURATION POP-UP ARCHIVAL SATELLITE TAGS

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The pelagic stingray *Pteroplatytrygon violacea* (Bonaparte, 1832) is commonly encountered as bycatch in the pelagic longline fishery targeting swordfish and tunas. However, very little is known about its habitat utilization and whether depth or temperature differences between the pelagic stingray and pelagic longline fishing gear could be used to develop fisheries bycatch mitigation techniques. Four pop-up satellite archival tags (PSATs) with 13-day deployment durations were attached to pelagic stingrays in 2010 and 2011 in both the South Atlantic Bight (n=2) and the northern Gulf of Mexico (n=2). Analysis of the minimum straight-line distances from the first transmission locations showed that pelagic stingrays moved between 151-258 kilometers (km) from where each stingray was released (11.6-19.8 km/day). PSAT data indicate significant diel difference in behavior, with all four animals utilizing deeper depth during daylight periods. All four stingrays appeared to follow a temperature regime above all other variables. All four animals also displayed frequent short-duration (*ca.* 5-minute lengths) movements of more than 50 m from the baseline depth of the diel period and a thermal range of approximately 8°C over 24-hour periods. Applying the known habitat utilization and behavior of less economically important species will help fisheries managers better understand both overall interactions with more economically valuable target species and the overall pelagic ecosystem.

PREDICTING HABITAT UTILIZATION OF SAILFISH (*ISTIOPHORUS PLATYPTERUS*) TO REDUCE BYCATCH WITHIN THE PURSE-SEINE FISHERY IN THE EASTERN PACIFIC OCEAN

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Indo-Pacific sailfish (*Istiophorus platypterus*) is an important apex predator in neritic and oceanic pelagic ecosystems. The species is also a primary target of valuable catch and release sport fisheries in many developing countries that sustain local economies. However, commercial purse-seine fisheries that target tunas in the Eastern Pacific Ocean (EPO) incidentally catch and discard large numbers of sailfish raising concern over their long-term sustainability and potential impacts on local sport fisheries and the ecosystem function. Sailfish bycatch data recorded by scientific observers in the Mexican tuna purse-seine fleet in the EPO between1998-2007 was used in Generalized Additive Models (GAMs), to predict environmental and spatial preferences that may be used as a fisheries management tool to reduce sailfish bycatch in the EPO. The model predicted the highest sailfish catches in coastal waters during El Niño events with warm temperatures (> 26 °C) and low sea surface chlorophyll-a concentration (<0.25 mg m^3). GAM predictions showed that the catch probability of sailfish increased 1.8 fold during El Niño events in coastal waters and 1.5 fold under La Niña conditions. However, the spatial distribution of sailfish remained largely unchanged during these three scenarios.

INSIGHTS INTO THE LIFE HISTORY AND ECOLOGY OF A RECORD SHORTFIN MAKO SHARK (*ISURUS OXYRINCHUS*) CAUGHT IN THE SOUTHERN CALIFORNIA BIGHT

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Predatory sharks are typically difficult to study, especially for the larger size classes which are only occasionally encountered in commercial and recreational fisheries. In the Northeastern Pacific Ocean, shortfin mako sharks (*Isurus oxyrinchus*) are important predators, and while data are increasing for smaller size classes, there is a paucity of data on large adults. On 3 June 2013, a record-breaking female shortfin mako shark (total length = 373 cm, mass = 600.11 kg) was captured by a recreational angler off Huntington Beach, California, and was subsequently donated to research. Samples of various tissue types were collected and analyzed to gain more information about the shark's anatomy, physiology, ecology, and life history. The shortfin mako shark was found to have an approximately three-year old female sea lion carcass in its stomach. This confirms the presence of pinnipeds in the diet of larger shortfin makos, which are available prey items year round in southern California. The spiral valve contents included two species of cestode parasite: 20 specimens of the tetraphyllidean *Ceratobothrium xanthocephalum* and two of the trypanorhynch *Nybelinia* sp. Two damaged specimens of a nematode *Capillaria* sp. were also found, but as this genus is not known to parasitize sharks, and they were likely ingested with their teleost prey. Twenty-six and 27 band pairs were counted in the vertebrae using thin sectioning with microscopy and x-ray imaging, respectively. Given that shortfin mako sharks in the Northeast Pacific deposit two band pairs in vertebrae per year through age 5, and the uncertainty in band pair deposition rates in older specimens, the estimated age range of this shark was 13-22 years old. Organic contaminants and total mercury were measured in the liver and muscle tissue of the shark and were found to be substantially greater than most animals previously measured in southern California (total DDTs: 0.2 mg/g wet weight; total PCBs: 0.03 mg/g wet weight); however, the potential implications of this contaminant burden are unknown. Mercury levels were much higher than FDA recommendations for human consumption. This rare opportunity allowed for the collection of important data and contributes to our knowledge about the life history characteristics of large shortfin mako sharks.

FROM MIGRANTS TO MOSSBACKS: SIA-INFERRED HABITAT SHIFTS IN THE CALIFORNIA YELLOWTAIL *SERIOLA LALANDI*

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The California yellowtail (YT; *Seriola lalandi*) is found in both coastal and pelagic regions of the southern California Current Large Marine Ecosystem. Targeted by recreational anglers, YT are known for their strength and high quality as table fare. Despite their importance in southern California's recreational fishery,YT are not landed in large numbers commercially, and little is known about their population dynamics or migration patterns. Historical tagging data suggest that YT migrate seasonally; they travel north from Baja California, Mexico into southern California during spring and summer months, spawn in pelagic waters, and return south during fall and winter. Data on size distributions suggest that these migrations may reflect an ontogenetic shift in habitat use, with smaller individuals traveling long distances in pelagic water offshore before settling into near shore coastal regions. Large numbers of smaller YT (50-80 cm, 'migrants') are observed in pelagic waters, while larger YT (>81-130 cm, 'mossbacks'), while also observed offshore, are thought to structure oriented and reside predominantly in coastal waters. We used stable isotope analysis (SIA) of carbon and nitrogen ($\delta^{13}C$ and $\delta^{15}N$) to determine the extent to which offshore- and inshore-caught YT resemble their environment of capture, and to ascertain the size(s) over which the potential shift from pelagic to coastal waters takes place. $\delta^{13}C$ and $\delta^{15}N$ values were used to group YT into 'inshore' or 'offshore' using discriminant analysis, with $\delta^{13}C$ and $\delta^{15}N$ values of a pelagic predator (yellowfin, *Thunnus albacares*) and a coastal predator (white sea bass, *Atractoscion nobilis*) serving as training data. We also used two separate Bayesian mixing model approaches to determine the extent to which inshore- and offshore-YT reflect (1) pelagic and offshore prey inputs, and (2) their similarity to the predators above. We found a shift in habitat use, based on changes in $\delta^{13}C$ and $\delta^{15}N$, between the sizes of 81 and 96 cm SFL. Mixing models confirmed that smaller, offshore YT largely reflected pelagic prey resources and were similar to yellowfin tuna SIA values. In contrast, larger, inshore YT reflected higher input from inshore resources and were similar to white seabass, though there was significant contribution (25-45%) of offshore prey to diet of inshore YT. Our results show that once YT reach 96 cm, they rely heavily on prey input from coastal ecosystems. Preliminary conventional tagging data suggests that YT movements in coastal waters are restricted. One fish remained at liberty for 18 months and was recaptured during the winter season within 7 miles of release location. Although spawning has never been documented in the coastal waters off southern California, yellowtail caught inshore in the spring appear to be in spawning condition. Documented catches of larger YT in southern California during winter months combined with our SIA results suggest the possibility for local, residential populations of YT in areas that aggregate preferred prey sources, such as coastal islands, kelp beds, and other types of near shore structure. It has been hypothesized that recruitment of YT from Mexico fuel the southern California recreational fishery. Our study provides valuable information that could aid in the development of a management plan for this species. The spawning contribution from large, female CA-residential 'mossback' YT to future generations of YT may be more important than previously hypothesized.

THERMAL DEPENDENCE OF AEROBIC MUSCLE FUNCTION IN A DEEP-DIVING SHARK, *ALOPIAS SUPERCILIOSUS*, AND TELEOST, *XIPHIAS GLADIUS*

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Temperature is a key regulator of physiological processes, and in the marine environment exposure to disparate thermal regimes could have marked consequences on the contractile function of the muscle. Despite this, vertical movement patterns of bigeye thresher sharks (*Alopias supercilious)* and swordfish (*Xiphias gladius)* showcase their ability to make routine, long duration dives that stem from the surface (18-20˚C) to well beneath the thermocline (5-10˚C). During dives, bigeye threshers must experience drastic changes in locomotor operating temperature since they do not possess the internalized aerobic, red muscle and complex vasculature, which is characteristic of regional endothermy in the closely related common thresher shark (*A. vulpinus*), as well as lamnid sharks and tunas. By contrast, swordfish possess internalized red muscle, but rudimentary vasculature may not permit prolonged elevation of body temperatures, and may only serve to modify heat transfer rates. Whether the aerobic power output and contractile kinetics of the red, locomotor muscle in related, but morphologically different bigeye thresher sharks or unrelated, but morphologically similar swordfish are significantly impaired at cool temperatures, as is the red muscle of the common thresher shark, has yet to be determined.

This study used the work loop technique to examine optimized aerobic power output during contraction-relaxation cycling in red muscle preparations from bigeye threshers and swordfish at 8, 16, and 24˚C. Work was optimized at each test temperature by altering cycle frequency, stimulus phase, and stimulus duration during sinusoidal strain (±10%). Relative power was calculated as the product of work and cycle frequency, and then standardized to the power output at 24C and 1Hz for each preparation. Peak power production in both bigeye threshers and swordfish varied with cycle frequency and temperature. The cycle frequency producing peak power increased in both species as temperature increased from 8C to 24C, moving from 0.25Hz to 0.5Hz in bigeye threshers and from 0.5Hz to 1.5Hz in swordfish. Overall, aerobic power production was relatively insensitive to thermal changes in bigeye threshers, but increased with temperature in swordfish. The red muscle of swordfish, however, appeared comparatively less temperature sensitive relative to endothermic, common thresher sharks, due to the ability of swordfish red muscle to produce greater power at the lowest temperatures. Although preliminary, this result further supports trends concerning anatomical complexity, which were previously observed between common thresher sharks and lamnid sharks (i.e. less complexity = less temperature sensitivity). Understanding what specialized mechanisms, be it thermal insensitivity or none at all, permit expansion of bigeye thresher sharks and swordfish, into habitats inhospitable to most active fishes, is integral to the future management of high performance, commercial species.

EARLY LIFE HISTORY RESEARCH AT THE ACHOTINES LABORATORY

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The Inter-American Tropical Tuna Commission (IATTC), the body responsible for the assessment and management of the tuna stocks of the eastern Pacific Ocean (EPO), operates the Achotines Laboratory in the Republic of Panama, where captive yellowfin tuna (*Thunnus albacares*) have been spawning almost daily since 1996. The Laboratory is the only facility in the world with nearly year-round availability of tuna eggs and larvae for research purposes. The research, carried out by the Early Life History (ELH) Research Group of the IATTC, focuses on areas of tuna ecology and biology that provide important information for the IATTC in fulfilling its research responsibilities. Researchers from other institutions at local, national, and international levels also carry out investigations at Achotines Laboratory, often in collaboration with ELH scientists. A summary of research findings from studies conducted at the Achotines Laboratory is presented.

COASTAL UPWELLING FRONTS: A KEY HABITAT FOR ALBACORE TUNA (*THUNNUS ALALUNGA*) IN THE NORTHEAST PACIFIC OCEAN

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We used satellite sea surface temperature (SST) data to characterize coastal fronts in an automatic way and then tested the effects of the fronts and other environmental variables on the distribution of the albacore tuna (Thunnus alalunga) catches in the coastal areas (from the coast to 200 nm offshore) of the Northeast Pacific Ocean. A boosted regression tree (BRT) model was used to explain the spatial and temporal patterns in albacore tuna catch per unit effort (CPUE) (1988-2011), using frontal features (distance to the front and temperature gradient), and other environmental variables like SST, surface chlorophyll concentration), and gesotrophic currents as explanatory variables. Based on over two decades of higher resolution data, the modeled results confirmed the previous findings that albacore CPUE distribution is strongly influenced by S S T and chlorophyll at fishing locations, albeit with substantial seasonal and interannual variation. Albacore CPUEs were higher near warm, low chlorophyll oceanic waters, and near SST fronts. We performed sequential leave-one-year-out cross-validations for all years and found that the relationships in the BRT models were robust for the entire study period. Spatial distributions of model-predicted albacore CPUE were similar to observations, but the model was unable to predict very high CPUEs in some areas. These results help to explain previously observed variability in albacore CPUE and will likely help improve international fisheries management in the face of environmental changes.

OBITUARIES

THOMAS P. CALKINS, 1931-2014

Tom Calkins, a long-time employee of the IATTC, passed away at his home in San Diego. California, on February 7, 2014.

Tom was born in Seattle, Washington, on June 12, 1931, and graduated from the University of Washington in June 1953. After two years of military service, he worked for more than four years for the Fisheries Research Institute of the University of Washington on Alaska salmon. He was hired by the IATTC in November 1959, and continued as an IATTC staff member until he retired in June 1996. His service for the IATTC included two periods in Ecuador, one in 1960 and the other in 1963. Aside from those, he was stationed in La Jolla.

Tom was quite productive. He was author or co-author of 11 Bulletins, 9 on yellowfin and/or skipjack and 1 each on bigeye and bluefin. All of these were put to good use by the people who performed stock assessments. In addition, he was author of a species synopsis on bigeye for IATTC Special Report 2 and co-author of one on black skipjack for FAO Fisheries Report, Vol. 6, No. 2. He was a quiet and modest person; he never sought recognition for his work, but he was very conscientious, and everyone recognized the high quality of his work.

He was a voracious reader, particularly about history and current events, and he seemed to be able to remember clearly most of what he had read.

He is survived by his wife, Flerida, three sons, and three grandchildren. All who knew him will miss him greatly.

WITOLD L. KLAWE, 1923-2013

Mr. Witold L. Klawe, an IATTC scientist from 1955 to 1999, passed away at his home in La Jolla, California, USA, on 7 June 2013.

Witek was born in Piotrkow Trybunalski, Poland, on 9 June 1923. After World War II he emigrated from Poland to Canada, where he earned his B.A. and M.A. degrees at the University of Toronto in 1953 and 1955, respectively. His master's thesis was on the **biology of the bloodworm, *Glycera dibranchiate*, of the Maritime Provinces of Canada. Later, in 1991, he was awarded the degree of** Doctor Honoris Causa by the Academy of Agriculture in Szczecin, Poland.

Witek joined the staff of the IATTC in 1955. His first assignment was to study larval tunas. He was very good at that, and soon became recognized worldwide as an authority on that subject. He was a prolific writer. He is probably best known for the book, Tuna and Billfish—Fish without a Country, by James Joseph, Witold Klawe, and Pat Murphy, and the Spanish version of it, Atunes y Peces Espada—los Peces sin Patria, and for his paper, What is a tuna?, published in Marine Fisheries Review, Vol. 39, No. 11, and reproduced in FINS [Fishing Industry News Service, Department of Fisheries and Wildlife, Western Australia], Vol. 11, No. 2. His other works include 3 IATTC Bulletins, 2 IATTC Data Reports, about 50 papers in outside journals, and 20 translations, mostly from Russian to English.

He was interested in almost everything—botany, gardening, marine invertebrates, birds, philately, languages, the Southern California desert, and other subjects too numerous to mention. Most importantly, he was interested in other people. He was a generous host, and whenever scientists or students from other countries visited the Tuna Commission for periods of work or study, Witek and his wife Barbara welcomed them, inviting them to fine restaurants, visits to the many attractions of San Diego, and trips to the desert. Some visitors spent many months with the Klawes in their home in La Jolla.

Witek and Barbara travelled extensively, particularly to Hawaii and Europe. He had extensive contacts with Polish scientists, and in 1988 he was awarded the Gold Insignia of the Order of Merit, Polish People's Republic, for his many contributions to Polish science.

Witek is survived by his wife Barbara, son David, and daughter-in-law Lisa. Everyone who knew him will miss him greatly.

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