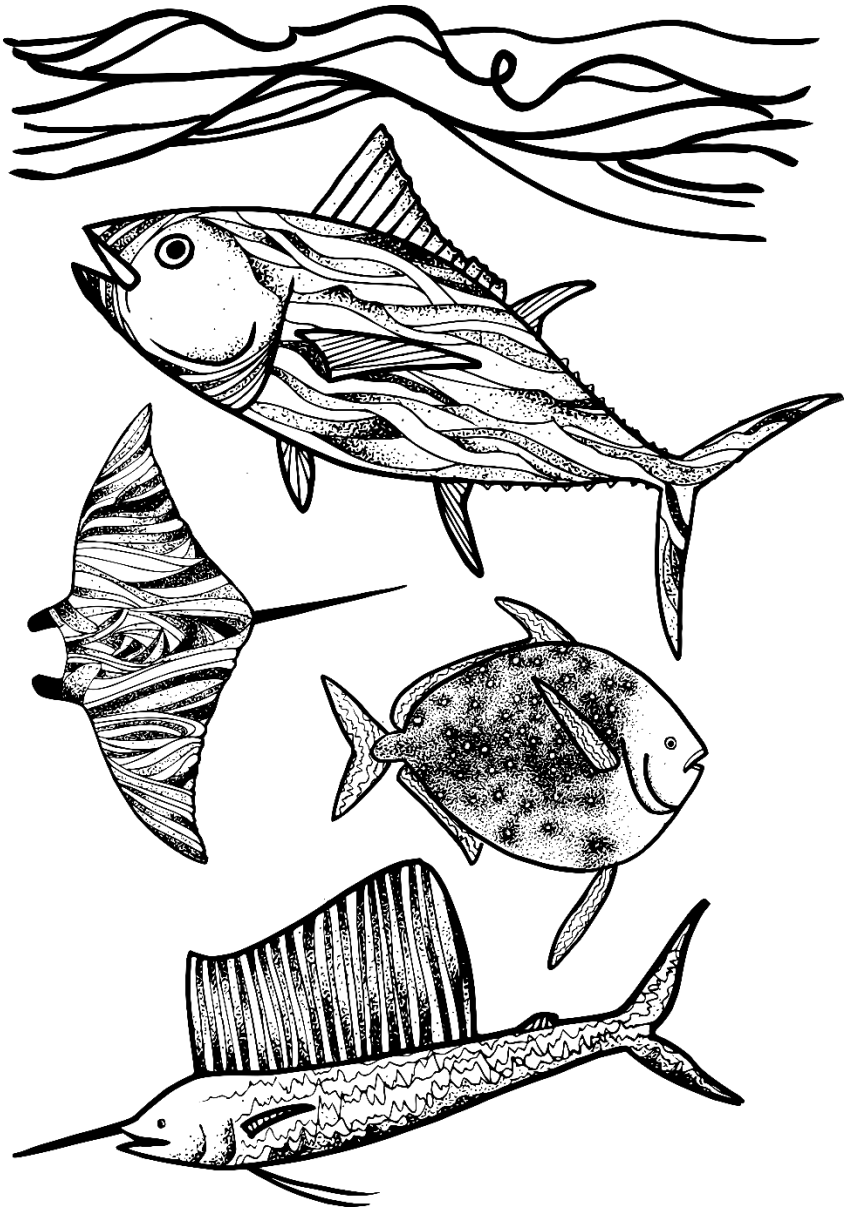
Proceedings of the 69th Annual Tuna Conference

Climate variability and ecosystem considerations in management of large pelagics



Lake Arrowhead, California, USA

May 21st – 24th, 2018

PROCEEDINGS OF THE 69th ANNUAL TUNA CONFERENCE

Lake Arrowhead, California,
May 21st – 24th 2018

Barbara Muhling and Desiree Tommasi – Chairs
Stephanie Flores and Freddie Logan – Coordinators

PREFACE

Welcome to the 69th Annual Tuna Conference. The goal of the Tuna Conference is to provide an open and informal forum for scientists, engineers, managers, fishermen, non-governmental organizations and other interested parties 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 key to the Conference's success.

The theme for this year's Tuna Conference is "**Climate variability and ecosystem considerations in management of large pelagics.**" Variability in the ocean environment drives changes in the distribution, feeding behavior and reproduction of pelagic fishes. This can result in altered stock productivity and availability to fishing fleets, with subsequent impacts on fishing communities. Climate variability and long-term change can therefore challenge traditional assessment and management frameworks. To maintain resilience of populations of large pelagics and limit socioeconomic impacts, future fishery management advice needs to be robust to climate-driven biological responses. This will require improved understanding of species ecology across life stages, of the structure and function of the ecosystems they rely on, and of methods for including these factors in assessment and management.

Many of the oral and poster presentations at this year's conference directly relate to the theme and, as always, there is a diverse and interesting series of presentations on the agenda. Over the course of the next four days, there will be 49 oral presentations across 6 sessions. We also have an additional 15 presentations in the poster session. Special thanks to this year's session moderators: Andre Boustany, Daniel Fuller, Sean Tracey, Carolina Minte-Vera, Stephanie Brodie, Shane Griffiths and Kurt Schaefer. We sincerely appreciate their efforts to keep sessions running smoothly.

The abstracts for the oral and poster presentations contained in the Proceedings are listed in alphabetical order of the author giving the presentation (shown in bold lettering; abstracts are combined for oral and poster presentations). 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. No abstract should be cited without prior consent from the author(s).

This year there were many excellent applications for student scholarships and ranking the candidates was a very difficult task. Many thanks to Nick Wegner, Carolina Minte-Vera, Shane Griffiths, Matt Craig, and Leanne Duffy for helping to review the student application packages. Thanks to the generosity of our donors, we are very pleased to announce that funds were available to support 7 student scholarships this year. The *Tuna Conference Scholarship* was awarded to Zahirah Dhurmeea for her talk titled "Spatial variation in fatty acid trophic markers and stable isotopes in albacore tuna (*Thunnus alalunga*) in the western Indian Ocean." The *Margarita Tomlinson Scholarship* was awarded to Blanca Orúe for her talk titled "Spatiotemporal distribution of tuna and non-tuna species associated with drifting fish aggregating devices (DFADS) in the Indian ocean, ascertained through fishery-independent data." Daniel Coffey received the *Wildlife Computers Scholarship* for his talk titled "Assessing blue shark habitat preferences under a changing climate." Christina Hernandez received the *American Fishermen's Research Foundation Scholarship* for her talk titled "Larval habitat suitability for Atlantic bluefin tuna spawned in the Slope Sea." Molly Morse received the *ADMB Award* for her talk titled "How do stock assessments perform for mixed Atlantic bluefin tuna stocks?" Maite Erauskin-Extramiana was awarded the *Monterey Bay Aquarium Scholarship* for her talk titled "Climate change impact in past and future distribution of six tuna species." Floriaan Devloo Delva received the *Big Data Scholarship* for his talk titled "How genomics can identify sampling bias, common breeding grounds and sex-determination markers in school sharks." Additional support for three students was provided from the *Manuel Caboz memorial scholarship* fund, and additional travel support for the 7 award winners was graciously provided by the International Seafood Sustainability Foundation.

In addition to support for student scholarships and travel, the Tuna Conference benefits from generous donations to support the various "social" functions such as the Sushi Social/Poster Session, the Tuna Barbecue, Campfire and Tavern get-togethers. We thank Rex Ito and Prime Time Seafood Inc. for donating the sashimi-grade tuna for the poster Sushi Social/Poster Session and Wildlife Computers Inc. and CLS America for providing refreshments. We gratefully acknowledge all our donors from the Automatic Differentiation Model Builder Foundation (ADMB), American Fishermen's Research Foundation, American Tuna Boat Association, CLS America, International Seafood Sustainability Foundation (ISSF), Lotek Wireless Inc., Monterey Bay Aquarium, Oceanographic In-situ Interoperability Project (OIIP), Patrick Tomlinson, Prime Time Seafood Inc., and Wildlife Computers Inc.

We would like to thank also Scott Aalbers, Daniel Fuller, Craig Heberer, Kim Holland, John Hyde, David Itano, Jeff Muir, Kurt Schaefer, Chugey Sepulveda, and Owyn Snodgrass for volunteering to be our gracious team of sashimi and poke cutters. We are appreciative of Kat Dale (www.kaemdale.com/art) for contributing her beautiful artwork to our cover page design. Chris Patnode provided invaluable help with sending out announcements, and updating the Tuna Conference website, and Joydelee Marrow contributed her time and expertise to answer all our questions regarding anything Tuna Conference! A special thanks to the UCLA Conference Center personnel for accommodating our numerous requests. We are also very grateful to the team of SWFSC and IATTC staff members, too numerous to be named here, for general assistance with preparation for the conference, as well as the transportation of supplies and conference participants.

In closing, we would like to thank you all for participating. It is the quality of your presentations and enthusiastic discussions that make the Tuna Conference such a great event. We hope you have a productive and enjoyable time and we look forward to seeing you back next year at the 70th Tuna Conference!

Barbara Muhling
69h Tuna Conference Chair

Desiree Tommasi
69th Tuna Conference Chair

Stephanie Flores
69th Tuna Conference Coordinator

Freddie Logan
69th Tuna Conference Coordinator

69th TUNA CONFERENCE AGENDA

Monday, 21 May 2018

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

13:00 **Welcome and Introduction (Pineview)**

SESSION 1: Insights on movement and ecology from tagging studies (Moderator: Dan Fuller, IATTC)

13:20 Leveraging datasets: a mechanistic approach to estimating catchability **– Stephanie Snyder**, Suzanne Kohin and John Childers

13:40 Movement, habitat preferences and behaviour of swordfish satellite tagged at the southern extent of their known range in Australia **– Sean R. Tracey**, Julian G. Pepperell and Samuel M. Williams

14:00 Swordfish tagging, migration patterns and fishery development off the U.S. west coast **– Chugey A. Sepulveda** and Scott Aalbers

14:20 **Coffee Break (20 minutes)**

14:40 Complex dispersal of adult yellowfin tuna from the Main Hawaiian Islands **–** Molly Lutcavage, Clayward Tam and **Chi Hin Lam**

15:00 Post-landing survival of large swordfish caught using recreational day-time deep dropping methods **– Sean R. Tracey** and Julian Pepperell

15:20 Overview of Recent and Future Planning of SPC Tagging Efforts in the WPO/WCPO - **Jeff Muir**, Bruno Leroy, Neville Smith, John Hampton

15:40 Movement patterns and habitat use of the common thresher shark (*Alopias vulpinus*) in the western North Atlantic Ocean – **Diego Bernal**, G. Skomal, L. Natanson, B. Gervelis, N. Kohler, J. White and J. Kneebone

16:00 **Coffee Break (20 minutes)**

16:20 Measuring ocean variability in near-real time with help from fish-borne sensors **– Kim Holland**

16:40 What have we learned? An overview of 15 years of albacore archival tagging **– Stephanie Snyder**, Suzanne Kohin and John Childers

17:00 Assessing blue shark habitat preferences under a changing climate – **Daniel Coffey** and Melanie Hutchison

* Wildlife Computers Scholarship winner / International Seafood Sustainability Foundation Travel Award winner

17:20 Illuminating detailed behavioral characteristics and migration context of pelagics in a dynamic environment by utilizing new sensing capabilities in pop-up satellite tags **– Marco Flagg**

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

Tuesday, 22 May 2018

8:00 Breakfast

SESSION 2: Fisheries assessment, management and socioeconomics (Moderators: Carolina Minte-Vera, IATTC (morning), Sean Tracey (afternoon))

9:00 Using historical catch records to document the history of western Atlantic bluefin tuna fisheries - **Andre Boustany**, Loren McClenachan, John Walter and Kyle Van Houtan

9:20 The ecosystem science behind the management of the largest tuna fishery in the world: facing climate change the Pacific way - **Valerie Allain**, Neville Smith, John Hampton, Peter Williams, Graham Pilling, Heidi Pethybridge, Anne Lorrain, Tim Park, Bruno Leroy, Francois Roupsard, Sylvain Caillot, Deirdre Brogan, Siosifa Fukofuka, Elodie Vourey, Thomas Peatman, Caroline Sanchez, Aurore Receveur and Malo Hosken

9:40 Credit systems for bycatch and target catch management in international fisheries – **Dale Squires**

10:00 Building economics into management strategy evaluation: A guide for setting sea turtle interaction limits - **Jonathan R. Sweeney**

10:20 Coffee Break (20 minutes)

10:40 A bootstrap analysis of fishery operation under protected species hard caps **– Stephen M. Stohs**

11:00 Decision making in a mixed commercial-recreational fishery for Atlantic bluefin tuna **– William M. Goldsmith**, Andrew M. Scheld and John E. Graves

11:20 The impact of the leatherback turtle conservation area closure on swordfish productivity: A difference-in-differences application **– James Hilger** and Kristin Helen Roll

11:40 Evaluating alternative management strategies for North Pacific albacore tuna **– Desiree Tommasi**, Steve Teo, Barbara Muhling and Gerard DiNardo

12:00 Lunch

13:00 How do stock assessments perform for mixed Atlantic bluefin tuna stocks? - **Molly Morse**, Lisa Kerr, and Steven Cadrin

* ADMB Foundation Scholarship winner / International Seafood Sustainability Foundation Travel Award winner

13:20 Estimation of the abundance of yellowfin tuna in the eastern Pacific Ocean using fisheries-dependent data **- Carolina Minte-Vera**, Mark Maunder and Alexandre Aires-da-Silva

13:40 Maximum economic yield and bioeconomics **– Dale Squires**

14:00 Estimating the population impacts from the global tortoiseshell trade 1844-1992 **– Emily A. Miller**, Y. Uni, G. Phocas, M. E. Hagemann, L. McClenachan, and K. S. Van Houtan

14:20 Coffee Break (20 minutes)

14:40 Shark bycatch and post release survivorship in tuna longline fisheries **– Melanie Hutchison** and Felipe Carvalho

SESSION 3: Eastern Pacific Ocean Tuna Fisheries (Moderator: Stephanie Brodie, UC Santa Cruz and NOAA SWFSC)

15:00 Electronic monitoring of small tuna purse-seine vessel fishing activities and catches – **Marlon H. Roman**, Cleridy Lennert-Cody and Enrique Ureña

15:20 Can we predict vulnerability of bycatch species in eastern Pacific Ocean tuna fisheries using environmental drivers and life history? **– Leanne Duffy**, Shane Griffiths and Cleridy Lennert-Cody

15:40 A flexible spatially-explicit ecological risk assessment approach for quantifying the cumulative impact of tuna fisheries on data-poor bycatch species in eastern Pacific Ocean – **Shane P. Griffiths**, Leanne Duffy and Marlon Roman

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

16:30 Assessing post-release survivorship and movement patterns of bigeye thresher sharks caught on deep-set buoy gear off southern California – **Scott Aalbers**, Charles Villafana and Chugey Sepulveda

California commercial passenger fishing vessel landings of highly migratory species taken in US and Mexican waters, 1998–2017 **- Travis Buck**

A Comparison of Circle and J Hooks within the Coastal Pelagic Longline Fishery in Grenada – **Anthony G. Burns** and David W. Kerstetter

Movements and site fidelity of giant trevally (*Caranx ignobilis*) in the South China Sea - Wei Chuan (Riyar) Chiang, **Ching-Tsun Chang**, Hsiang Chun Sun, Chen Hen Liao, Shian Jhong Lin, Michael K. Musyl, Te Yu Liao and Ker Yea Soong

Seasonal and size variations in feeding habits of sharptail mola (*Masturus lanceolatus*) in eastern Taiwan - **Ching-Tsun Chang**, Wei-Chuan Chiang, Chia-Hsu Chih, Fu-Yuan Tsai, Hung-Hung Hsu and Yuan-Hsing Ho

Pop-up satellite tag recoveries using the Argos Goniometer and Thorium X tablet – **Thomas Gray**, Rick Goetz and Andy Jasonowicz

Recent trends in hook and line landings of tropical and North Pacific tunas into California Ports (1998 – 2018) - **Morgan Ivens-Duran**

A retrospective analysis of San Diego commercial fishery catch and landings in the lifetime of a millennial **- Elizabeth Hellmers**, Sarah Shoffler and Stephen Stohs

The physiological effects of capture stress and their impact on post-release survival of Pacific bluefin tuna (*Thunnus orientalis*) caught on rod and reel – **Jeff Kneebone**, Scott Aalbers, Diego Bernal and Chugey Sepulveda

Challenges in monitoring the southern California North Pacific Bluefin Tuna commercial fishery – **Leeanne Laughlin**

Reproductive biology of roosterfish (*Nematistius pectoralis*) in waters of Baja California Sur, Mexico **- Sofía Ortega-García**, Chugey Sepulveda, Scott Aalbers, Nurenskaya Vélez-Arellano, Ulianov Jakes-Cota and Rubén Rodríguez-Sánchez

Trophic ecology of roosterfish (*Nematistius pectoralis*) in the eastern Pacific Ocean - **Sofía Ortega-García**, Arturo Tripp-Valdez, Chugey Sepulveda, Scott Aalbers and Ulianov Jakes-Cota

Upper trophic level opportunistic research **- Brian Overcash**

Projections of climate driven changes in tuna vertical habitat based on species-specific differences in blood oxygen affinity – **Allison Smith**, Curtis A. Deutsch, Richard W. Brill, John P. Dunne and Jorge L. Sarmiento

Ontogenetic changes in cutaneous and branchial ionocytes and morphology in yellowfin tuna (*Thunnus albacares*) larvae - Garfield T. Kwan, Jeanne B. Wexler, **Nicholas C. Wegner**, Martin Tresguerres

18:30 Dinner

Wednesday, 23 May 2018

8:00 Breakfast

9:00 Preliminary performance evaluation of normal versus shallow depth non-entangling FADS in the equatorial eastern Pacific tuna purse-seine fishery **– Kurt M. Schaefer** and Daniel W. Fuller

9:20 The spatiotemporal dynamics of yellowfin tuna (*Thunnus albacares*) in the Eastern Pacific Ocean **– Haikun Xu**, Cleridy Lennert-Cody, Mark Maunder and Carolina Minte-Vera

SESSION 4: Environmental drivers of distribution in large pelagics (Moderator: Andre Boustany, Monterey Bay Aquarium)

9:40 Seasonal and decadal forecast development for a multi-species pelagic longline fishery – **Jason R. Hartog**, Alistair Hobday, Paige Eveson, Claire Spillman, Kylie Scales, Toby Patterson, Xuebin Zhang, Richard Matear, Don Bromhead, Simon Nicol, John Hampton, John Annala, Robert Campbell and Sean Tracey

10:00 Integrating dynamic subsurface habitat metrics into species distribution models - **Stephanie Brodie**, Michael G. Jacox, Steven J. Bograd, Heather Welch, Heidi Dewar, Kylie L. Scales, Sara M. Maxwell, Dana M. Briscoe, Christopher A. Edwards, Larry B. Crowder, Rebecca L. Lewison and Elliott L. Hazen

10:20 Coffee Break (20 minutes)

10:40 Climate change impact in past and future distribution of six tuna species - **Maite Erauskin-Extramiana**, Guillem Chust, Haritz Arrizabalaga, Paula Alvarez, Leire Ibaibarriaga, Anna Cabré, Igor Arregui, Alistair Hobday
* Monterey Bay Aquarium / Manuel Caboz Scholarship winner / International Seafood Sustainability Foundation Travel Award winner

11:00 Spatiotemporal distribution of tuna and non-tuna species associated with drifting fish aggregating devices (DFADS) in the Indian ocean, ascertained through fishery-independent data **- Blanca Orúe**, Maria Grazia Pennino, Jon Lopez, Gala Moreno, Josu Santiago, Maria Soto, Hilario Murua
* Margarita Tomlinson Memorial Scholarship winner / International Seafood Sustainability Foundation Travel Award winner

11:20 Environmental associations of Pacific bluefin tuna (*Thunnus orientalis*) catch in the California Current system **- Rosa M. Runcie**, Barbara Muhling, Elliott Hazen, Steven J. Bograd, Toby Garfield, Gerard DiNardo

11:40 Interannual variability of north Pacific albacore distribution in the California current ecosystem – **Barbara Muhling**, Desiree Tommasi and John Childers

12:00 Lunch

13:00 Habitat preferences of blue marlin (*Makaira nigricans*) and black marlin (*Istiompax indica*) in the Eastern Pacific Ocean **- Nima Farchadi**, Michael G. Hinton, Andrew Thompson and Zhi-Yong Yin

13:20 Effect of climate change on the habitat distribution of *Mobula mobular* in Baja California **– Nerea Lezama-Ochoa**, M. Hall, H. Murua, K. Newton, D. Croll and J. Stewart

13:40 Modelling the oceanic habitats of silky shark (*Carcharhinus falciformis*) in the tropical Atlantic Ocean, implications for conservation and management **- Jon Lopez**, Diego Alvarez-Berastegui, Maria Soto and Hilario Murua

SESSION 5: Biological and fisheries oceanography (Moderator: Shane Griffiths, IATTC)

14:00 Spatiotemporal variability of two North Pacific fronts and their effects on micronekton **– Reka Domokos**

14:20 Coffee Break (20 minutes)

14:40 Larval habitat suitability for Atlantic bluefin tuna spawned in the Slope Sea - **Christina M. Hernandez**, David Richardson, Irina Rypina, Ke Chen, Larry Pratt, Joel Llopiz
* American Fishermen's Research Foundation / Manuel Caboz Scholarship winner / International Seafood Sustainability Foundation Travel Award winner

15:00 ENSO drives near-surface dissolved oxygen and hypoxia-induced vertical habitat space variability in the tropical pacific **– Shirley Leung**, K.A.S. Mislan and LuAnne Thompson

15:20 The Oceanographic In-situ data Interoperability Project (OIIP): Status and Progress One Year On **– Vardis Tsontos**, Chi Hin Lam, Sean Arms, Nga Quach and Charles Thompson

SESSION 6: Laboratory, genomic, isotope, and otolith data to improve understanding of population biology (Moderator: Kurt Schaefer, IATTC)

15:40 Updated comparative analysis of the laboratory growth of yellowfin tuna (*Thunnus albacares*) and Pacific bluefin tuna (*Thunnus orientalis*) larvae, and growth of early-juvenile yellowfin reared in land based tanks and a sea cage - **Enrique Mauser**, Dan Margulies, Jeanne Wexler, Maria Stein, Vernon Scholey, Susana Cusatti, Tomoki Honryo, Ryo Katagiri, Michio Kurata, Yasuo Agawa, Yoshifumi Sawada

16:00 Spawning ecology of captive Yellowfin tuna (*Thunnus albacares*) broodstock inferred by the use of mitochondrial DNA sequencing analysis **- Susana Cusatti**, Vernon Scholey, Yasuo Agawa, Daniel Margulies, Jeanne Wexler and Yoshifumi Sawada

16:20 Coffee Break (20 minutes)

'Big data' Mini-Workshop (Moderator: Chi Hin (Tim) Lam)

16:40 Web-based Tools and Data Standards for Electronic Tagging and I*n situ* Datasets: An Interactive & Consultative Workshop – **Vardis Tsontos**, Chi Hin Lam, Sean Arms, Nga Quach, and Charles Thompson

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

Thursday, 24 May 2018

8:00 Breakfast

9:00 Age and growth of yellowfin tuna in the eastern Pacific Ocean – **Daniel W. Fuller** and Kurt M. Schaefer

9:20 Age, growth, and reproduction of yellowfin tuna (*Thunnus albacares*) in the Gulf of Mexico **- Ashley Pacicco**, Robert Allman, Debra Murie, Hope Lyon

9:40 Spatial variation in fatty acid trophic markers and stable isotopes in albacore tuna (*Thunnus alalunga*) in the western Indian ocean **- Zahirah Dhurmeea**, Heidi Pethybridge, Chandani Appadoo and Nathalie Bodin
* Tuna conference scholarship winner / International Seafood Sustainability Foundation Travel Award winner

10:00 How genomics can identify sampling bias, common breeding grounds and sex-determination markers in school sharks - **Floriaan Devloo-Delva**, Gregory E. Maes, Sebastián I. Hernández, Jaime D. Mcallister, Rasanthi M. Gunasekera, Peter M. Grewe, Robin B. Thomson and Pierre Feutry
* Big Data / Manuel Caboz Scholarship winner / International Seafood Sustainability Foundation Travel Award winner

10:20 Age and growth of roosterfish (*Nematistius pectoralis*) in Baja California Sur - Rafael Chavez-Arrellano, Sofía Ortega-García, **Ulianov Jakes-Cota,** Chugey Sepulveda, Scott Aalbers and Rubén Rodríguez-Sánchez

10:40 Coffee Break (20 minutes)

11:00 Business Meeting

12:00 Meeting close and lunch

Abstracts

ASSESSING POST-RELEASE SURVIVORSHIP AND MOVEMENT PATTERNS OF BIGEYE THRESHER SHARKS CAUGHT ON DEEP-SET BUOY GEAR OFF SOUTHERN CALIFORNIA

Scott Aalbers[1], Charles Villafana[2] and Chugey Sepulveda[1]

1. Pfleger Institute of Environmental Research, PIER, Oceanside CA
2. National Marine Fisheries Service, West Coast Region Observer Program, Long Beach, CA

Recent NOAA-supported research has resulted in the development of Deep-set Buoy Gear (DSBG), an artisanal gear type that targets swordfish below the thermocline during the day. Research and exempted trials of DSBG have resulted in high selectivity for swordfish (~80-90% of total catch) and the occasional (5-8% of total catch) interaction with one other pelagic predator, the bigeye thresher (BET) shark (*Alopias supercilliosus*). Although frequently encountered in other west coast fisheries, BET are poorly studied, with little information existing on their general biology, movement patterns or current stock status in the eastern Pacific. Despite a small domestic market, cooperative fishers released approximately 66% of BET caught during exempted DSBG trials to reserve valuable hold space for swordfish. This study focused on assessing post-release survivorship and documenting depth distribution to determine if deep-set configurations can be modified to further reduce fishery interactions with BET. Working with cooperative DSBG fishers during the 2016-17 and 2017-18 swordfish seasons, 12 pop-up satellite tags (Wildlife Computers sPATs and miniPATs) were deployed on BET sharks following capture on deep-set gear. Overall, eleven BET (92%) survived the acute effects of capture and handling, with one mortality following a 110-min struggle on the line. Tagged BET travelled a mean distance of 1,220 km (730-1,660 km) to the south (162-219° heading) over the 30-day deployment period, with most tags popping off within a relatively narrow geographic area centered around 23°N and 123°W. Tagged BET dove to depths up to 964 m with a mean (±SD) daytime depth of 376 m (±59) and mean temperature of 7.9°C (±0.9) (range 4.6-11.7°C). Depth records from additional tag reports will be evaluated to determine if gear modification can be used to further reduce interactions with this species. This work will also develop a fishery manual to provide fishers with details on how to maximize survivorship of released BET.

THE ECOSYSTEM SCIENCE BEHIND THE MANAGEMENT OF THE LARGEST TUNA FISHERY IN THE WORLD: FACING CLIMATE CHANGE THE PACIFIC WAY

Valerie Allain[1], Neville Smith[1], John Hampton[1], Peter Williams[1], Graham Pilling[1], Heidi Pethybridge[2], Anne Lorrain[3], Tim Park[1], Bruno Leroy[1], Francois Roupsard[1], Sylvain Caillot[1], Deirdre Brogan[1], Siosifa Fukofuka[1], Elodie Vourey[1], Thomas Peatman[1], Caroline Sanchez[1], Aurore Receveur[1], Malo Hosken[1]

[1]Pacific Community (SPC)-OFP,
[2] CSIRO Oceans & Atmosphere, [3]IRD-LEMAR

Pacific Community (SPC), BP D5, 98800, Noumea, New Caledonia

Tuna production in the western and central Pacific represented 56% of the world's tuna catches in 2016. The exploitation of tuna delivers important economic benefits to small developing Pacific Island Countries and Territories through the sale of fishing access rights and the profits and employment generated by the fishing and fish processing industries; it also has a vital role in regional food security. Science is needed to support the development of conservation and management measures of these fisheries at the regional, sub-regional and national levels. To understand the variability in tuna abundance and distribution, and the impacts of fishing and climate change on the tuna ecosystem, monitoring of the fisheries and the ecosystem has been implemented in the western and central Pacific Ocean (WCPO) over several decades. Fisheries data on effort and catch of the target species have been collected since the 1950's. Since the 1990's fisheries observers of Pacific Island countries, which now operate under a regional standardized framework, also collect data on bycatch. This network of over 800 observers also collect biological samples (e.g. stomachs, otoliths, tissue) that are incorporated into a biological tissue bank of tuna and tuna-like fish (> 95 000 samples available to scientists). In parallel, tuna tagging programmes have been implemented since the 1970's to monitor fishing pressure and study tuna movements and growth as well as collecting biological samples. Fishing-independent data have also been collected during scientific cruises to monitor the pelagic ecosystem from the base of the food web (particulate organic matter, phytoplankton), to the intermediate trophic levels (zooplankton, micronekton). In the context of climate change impact assessment, experiments have also been conducted to analyze the impact of ocean acidification on tuna larvae survival and development. The data derived from these fisheries and ecosystem monitoring activities are incorporated into various models. For example, results were included in a recent global spatial and temporal analysis of tuna carbon and nitrogen isotopes conducted by the international CLIOTOP Marine Predator Isotope Task Team. These analyses reflect spatial gradients and temporal shifts in oceanic food web dynamics with a complex set of environmental and biological drivers. Population and ecosystem models (MULTIFAN, SEAPODYM, ECOPATH with ECOSIM) are also developed to provide, among other things, estimates of target species biomass and distribution, estimates of bycatch quantities, simulations of the impact of management measures, of environmental variability and climate change, and a better understanding of the ecosystem functioning. The results of these models are used to inform policy positions of Pacific Island governments and to support the design of management measures for WCPO tuna fisheries. The studies also highlight the critical need to establishing and maintain long-term collection of data and samples to contribute to our understanding of the impacts of fisheries and climate change on the marine ecosystems, and for the implementation of appropriate management measures for sustainable use of the resources.

USING HISTORICAL CATCH RECORDS TO DOCUMENT THE HISTORY OF WESTERN ATLANTIC BLUEFIN TUNA FISHERIES

Andre Boustany[1,2], Loren McClenachan[3], John Walter[4], Kyle Van Houtan[1,2]

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Managing the Western Atlantic stock of bluefin tuna (*Thunnus thynnus*) has long been a contentious process, with much debate over basic life history and population parameters. Even after almost 20 years of a rebuilding plan the stock remains at low levels (14% of SSB_0), with additional population declines projected under current quotas. The Virtual Population Analysis stock assessment used by ICCAT over the last two decades only assesses back to 1974, due to low availability of catch-at-size and catch-at-age data prior to this period. As most of the population decline in the Western Atlantic bluefin tuna population happened prior to 1974, our inability to assess the stock through the period of decline limits our ability to estimate stock productivity and spawner-recruit dynamics. Here we describe a project to locate landings and catch-at-size data from historical time periods. Documents were accessed at three locations; The Woods Hole Oceanographic Institution Library and Data Archive, The NMFS Southeast Fisheries Science Center, and NMFS Southwest Fisheries Science Center. The WHOI archive was particularly useful as it contained the Manuscript Collection of Frank Mather, who was actively involved in bluefin tuna science at WHOI from the 40's to 70's. Documents from the three sources were accessed, digitally photographed, cataloged, and formatted for use in stock assessment models, with the aim of improving estimates of unfished biomass, spawner-recruitment dynamics, and stock productivity.

INTEGRATING DYNAMIC SUBSURFACE HABITAT METRICS INTO SPECIES DISTRIBUTION MODELS

Stephanie Brodie[1,2], Michael G. Jacox[1,2], Steven J. Bograd[1,2], Heather Welch[1,2], Heidi Dewar[3], Kylie L. Scales[4], Sara M. Maxwell[5], Dana M. Briscoe[1], Christopher A. Edwards[1], Larry B. Crowder[6], Rebecca L. Lewison[7], Elliott L. Hazen[1,2].

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Species distribution models (SDMs) have become key tools for describing and predicting species habitats. In the marine domain, environmental data used in modelling species distributions are often remotely sensed, and as such have limited capacity for interpreting the vertical structure of the water column, or are sampled *in situ*, offering minimal spatial and temporal coverage. Advances in ocean models have improved our capacity to explore subsurface ocean features, yet there has been limited integration of such features in SDMs. Using output from a data-assimilative configuration of the Regional Ocean Modeling System, we examine the effect of including dynamic subsurface variables in SDMs to describe the habitats of four pelagic predators in the California Current System (swordfish *Xiphias gladius*, blue sharks *Prionace glauca*, common thresher sharks *Alopias vulpinus*, and shortfin mako sharks *Isurus oxyrinchus*). Species data were obtained from the California Drift Gillnet observer program (1997-2017). We used boosted regression trees to explore the incremental improvement enabled by dynamic subsurface variables that quantify the structure and stability of the water column, isothermal layer depth and bulk buoyancy frequency. The inclusion of these dynamic subsurface variables significantly improved model explanatory power (range 1-4% improvement, $p<0.0001$) for all species. Model predictive performance also significantly improved ($p<0.0001$), but only for species that had strong affiliations with dynamic variables (swordfish and shortfin mako sharks) rather than static variables (blue sharks and common thresher sharks). These results highlight the utility of including dynamic subsurface variables in SDM development and support the continuing ecological use of biophysical output from ocean. Geospatial predictions for all species showed the integration of isothermal layer depth and bulk buoyancy frequency contributed value at the mesoscale level (<100 km), and varied spatially throughout the study domain. We further explored the influence of environmental variability on pelagic predators in the California Current by temporally decomposing model covariates to determine how different scales of environmental variability relate to species distributions. Identifying which scales of variability impact the distribution of top pelagic predators has implications for seasonal forecasts and climate projections designed to aid marine resources management.

CALIFORNIA COMMERCIAL PASSENGER FISHING VESSEL LANDINGS OF HIGHLY MIGRATORY SPECIES TAKEN IN US AND MEXICAN WATERS, 1998 - 2017

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The California Department of Fish and Wildlife (CDFW) has required Commercial Passenger Fishing Vessels (CPFVs; also known as Party Boats or charter vessels) to submit logbooks detailing fishing activity and catch since 1936. Catch information includes the species encountered, as well as the number of individual fish retained. Fishing location is also collected, and 10 minute x 10 minute "fishing blocks" are used to specify where fish were caught. Data garnered from CPFV logbooks are stored in CDFW's Marine Logs System (MLS). CDFW staff can search MLS for historical CPFV logbook data by species code so that all records of CPFV catch for a given species are returned. California's CPFV fleet fishes in both U.S. and Mexican waters, and landings of Highly Migratory Species (HMS) have been highly variable from 1998 to 2017. North Pacific Albacore tuna dominated the landings of HMS species for much of that period, but there was a transition to Yellowfin tuna beginning in 2008. Pacific Bluefin tuna, Skipjack tuna, and Dolphinfish were also landed from 1998-2017, but to a lesser extent than North Pacific Albacore and Yellowfin tuna. Pacific Bluefin tuna landings have experienced two distinct periods of relatively high landings and peaked in 2013, actually outnumbering all other landings of HMS that year. Shortfin Mako shark and Common Thresher shark were also landed, but to a much lesser extent than the tunas and Dolphinfish. Striped Marlin and Broadbill Swordfish were rarely seen in California CPFV landings.

A COMPARISON OF CIRCLE AND J HOOKS WITHIN THE COASTAL PELAGIC LONGLINE FISHERY IN GRENADA

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In recent years, the impact of pelagic longline (PLL) gear on bycatch species has gained attention, with particular focus on vulnerable and charismatic species including sharks, sea turtles, and billfish. As a result, fishing mortality has been identified as a significant source of mortality for many bycatch species, leading to potential stock and ecosystem decline. To mitigate the effects of PLL gear interaction with bycatch species, developing or adapting gear technologies to local fisheries has become a common management-oriented research strategy. Circle hooks are promoted as a measure to increase survival of some bycatch and target species. Reduced ecological impacts of PLL on non-target species such as turtles and billfishes via reduced mortality at haulback and increased probability of post-release survival are proposed. Additionally, economic gains to the fishery are also proposed via increased catch rate of target species and reduction of mortality in target species. Prior to this study however, circle hooks have not been implemented by domestic commercial longline vessels in Grenada. To further assess the performance of circle hooks, size 16/0 circle hooks and size 7/0 J-style hooks were alternated over 20 sets between January 2018 and March 2018 in the Grenadian pelagic longline fishery. Hooking location, catch rates, catch composition, mortality, and grade of marketed fish were monitored. This presentation describes the results of the preliminary sets to evaluate the performance of circle hooks in the Grenadian PLL fishery and how these results may further promote circle hooks as a recovery tool for vulnerable species impacted by these fisheries.

SEASONAL AND SIZE VARIATIONS IN FEEDING HABITS OF SHARPTAIL MOLA (*MASTURUS LANCEOLATUS*) IN EASTERN TAIWAN

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Sharptail mola, *Masturus lanceolatus*, belongs to family Molidae inhabiting tropical and temperate ocean regions with seasonal migration. Their feeding habits may be influenced by the environment or/and body size since the seasonal variation of resource distribution and habitat utilization. Feeding habit of sharptail mola was assessed by stomach content analysis (SCA) at Shingang fish market, eastern Taiwan from January 2016 to January 2018. A total of 187 individuals of sharptail mola were investigated, and 40 stomachs (54-160 cm SL) were collected. There are 44 diet species were found in the collected stomachs and most of them were jellyfishes (FO% = 85%), followed by salps (FO% = 27.5%) and pteropods (FO% = 12.5%). The diet species composition of sharptail mola presented variations among seasons and size. They fed mainly on jellyfish throughout the year (FO%: spring = 100%, n = 8; summer = 81.3%, n = 16; autumn = 83.3%, n = 6; winter = 80%, n = 10), and consumed various species such as salps, pteropods, crustacean and mollusks in summer, autumn and winter. The diet shifts on body size was discovered in this study that the small individuals (<140 cm TL, n = 35) consumed both plankton (FO% = 88.6%) and benthic species (FO% = 28.6%), and large individuals, occurring in summer, autumn and winter, (>140 cm TL, n = 5) consumed only plankton species (FO% = 100%). Preliminary results suggested the heterogeneous diets of sharptail mola, and the shifts were possibly determined by their body size and season. Furthermore to improve understanding the trophic level and diet change of sharptail mola, we will use the combination of SCA and stable isotope analysis (SIA) to analyze the feeding habit in the future.

ASSESSING BLUE SHARK HABITAT PREFERENCES UNDER A CHANGING CLIMATE

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Blue sharks (*Prionace glauca*) make up the largest component of elasmobranch bycatch in longline fisheries targeting tuna (*Thunnus* spp.) and swordfish (*Xiphias gladius*) worldwide. In Hawai‘i-based pelagic longline fisheries, blue sharks are caught in 90% of the sets, make up >13% of the total catch, and compose >80% of the total elasmobranch bycatch. Retention of blue sharks in this fishery is low and most are discarded at sea. In this study, blue sharks were tagged with pop-up satellite archival tags by fishery observers in the pelagic longline fishery and using traditional ika-shibi fishing methods off west Hawai‘i to reveal the movements and habitat use of discarded sharks. All surviving sharks were highly migratory and demonstrated marked diel vertical movements, diving to deep, cold waters (>200 m, 12-15°C) during the day and occupying a narrow, warm vertical range (0-80 m, 20-27°C) at night. Some blue sharks orientated to high-productivity frontal zones and vertical habitat-use indicates a temporal and spatial overlap with Hawaii-based pelagic longline fisheries, particularly in the shallow-set sector targeting swordfish at night. Understanding patterns of space-use, thermal preferences and diel vertical behavior of blue sharks within areas of high fishing effort will inform conservation strategies and climate change impacts for this vulnerable shark species.

AGE AND GROWTH OF ROOSTERFISH (*NEMATISTIUS PECTORALIS*) IN BAJA CALIFORNIA SUR

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The roosterfish *Nematistius pectoralis* is a large coastal pelagic that inhabits shallow waters of the Eastern Pacific Ocean. Age and individual growth parameters are key for the evaluation of fishery resources, however, there is only one parameters estimate published for the species. From 2010 to 2015, 563 organisms were sampled in Cabo San Lucas, La Paz and San Carlos, B.C.S., of which were registered the furcal length (LF), weight, sex and collected the dorsal fin, sagittae otoliths and scales. The size range sampled was from 5.2 to 133 cm LF, organisms of 40 to 80 cm predominated (59% of the total number of specimens). The length-weight relationship indicated a negative allometric growth (b = 2.73) without significant differences between sexes ($p > 0.05$). Taking the highest R2 value (R2 = 0.95) of the linear relationship between the radius of the hard structures (Rt) and LF, as well as the value of the lowest coefficient of variation (CV = 5.67), of the three hard structures analyzed, the otoliths were the most suitable for estimating age. The validation of the annual formation of otoliths increment was established by the regularity of the deposition of the hyaline and opaque rings in the edge of the otoliths. This allowed the determination of the formation of an annual hyaline in June and an opaque ring in September-October. The age groups disembarked in Baja California Sur were 9 (0 - 8), groups 1 and 2 being the most abundant. To the data of size-age, three models of individual growth were adjusted (von Bertalanffy, Gompertz and Logistic), according to the values of the Akaike information criterion, the von Bertalanffy model is that better describes the individual growth of the species ($L\infty = 132.98$, $k = 0.34$, $t0 = -0.17$).

SPAWNING ECOLOGY OF CAPTIVE YELLOWFIN TUNA *(THUNNUS ALBACARES)* BROODSTOCK INFERRED BY THE USE OF MITOCHONDRIAL DNA SEQUENCING ANALYSIS

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In 1994, IATTC scientists at the Achotines Laboratory in Los Santos Province, Republic of Panama, began a study to rear and spawn yellowfin tuna (*Thunnus albacares*) in land-based facilities, and since October 1996, regular spawning of captive yellowfin tuna has occurred in this facility. In aquaculture, knowledge about broodstock structure and spawning dynamics is very helpful. The genetic monitoring of captive spawning populations using mitochondrial DNA (mtDNA) markers, targeting the mtDNA D-loop region, has been used to identify reproductively active females due to the exclusively maternal mode of inheritance. A previous study (Niwa, et al., 2003) was conducted at the Achotines Laboratory by targeting the mtDNA D-loop region but using restriction fragment length polymorphism (RFLP) analysis. In the present study, we used much quicker DNA extraction and PCR amplification methods, targeting a shorter DNA fragment (457 bp) from the mtDNA-D-loop region using different primers (Alvarado Bremer, 1994) and DNA sequencing analyses, a method of higher resolution. The main objectives of the study were to monitor the spawning and genetic patterns of captive broodstock yellowfin tuna at the Achotines Laboratory, assess the number of females that contribute to single spawning events and identify them, and estimate their spawning periodicity and frequency. We have sequenced a fragment of the the D-loop region of 50 broodstock fish with tag identification numbers that were in the tank at any time during the 2011-2014 period, and compared these mtDNA haplotypes with those of their offspring, 555 egg samples corresponding to 37 individuals spawning events that occurred during that period. We obtained single mtDNA haplotypes for the 50 individual broodstock fish. There were a total of 27 females and 23 males in the tank during the period 2011-2014. Sex identification was made by reviewing the gonads after death. Among 405 eggs analyzed, 8 unique haplotypes were detected during the period 2011-2013 (2014 analyses are ongoing), which match perfectly with the mtDNA haplotypes of 8 identified broodstock females. During 2011 there were 10 females in the tank and we found 6 unique mtDNA haplotypes in the spawning analysis. Thus, more than half of the females in the tank were reproductively active at some point. In each analyzed spawning event, 2 or more haplotypes were detected indicating that more than 2 females participated in spawning. One haplotype was present in all analyzed spawning events throughout the year and also had the highest frequency, which suggests that this female was more reproductively active than the other females in captivity and capable of spawning for extended periods. The six haplotypes identified were all detected in a single spawning event in August 2011, confirming that all six female parents were reproductively active in August. During 2012 there were 10 females in the tank and we found 6 mtDNA haplotypes of which 5 were old haplotypes detected in 2011 and a new haplotype was found. Again, one haplotype was present in all analyzed spawning events throughout the year and had the highest frequency. In 2 spawning events, just one haplotype was detected. In 2013 there were 12 females in the tank and there were only 3 months of spawning. We found 3 mtDNA haplotypes in 2013 of which 2 were old haplotypes detected in 2011/2012 as well as a new haplotype. It is likely that the number of spawning females was underestimated in our genetic analysis due to the conservative sampling frequency and sample sizes due to sampling and cost limitations. Future studies should consider the possibility of adding nuclear markers suitable to identify male parents also. Analyses of the study results for 2014 are ongoing, but in the presentation we will present preliminary results obtained to date.

HOW GENOMICS CAN IDENTIFY SAMPLING BIAS, COMMON BREEDING GROUNDS AND SEX-DETERMINATION MARKERS IN SCHOOL SHARKS

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Fishing represents a major problem for conservation of chondrichthyans, with a quarter of all species being overexploited. School sharks are targeted by commercial fisheries in Australia and New Zealand; with the Australian stock severely depleted (<20% of its virgin biomass). Individuals are known to move between both countries, but it is disputed whether the stocks are reproductively linked. New, unbiased knowledge about movement and biology of this species is crucial to inform effective management. Novel genome-scanning techniques can define kinship, population structure and sex-determination systems at a higher resolution. In this study, we assess the influence of non-random kin sampling on population structure analysis of Australian and New Zealand school sharks, using genome-wide single nucleotide polymorphisms (SNPs). Additionally, we detect SNPs located within sex-determining regions. Between 2009 and 2013, 88 neonate and juvenile individuals from Tasmanian and New Zealand nurseries were collected and genotyped. Neutral loci were analyzed to detect signals of fine-scale reproductive connectivity. Results indicate complete genetic connectivity and common breeding grounds (FST=0.0001, p=0.3319). Seven full sibling groups were identified as drivers for biased results. Moreover, 17 Y-linked and 14 X-linked SNP markers were found, indicating an XY sex-determination system in school sharks. These markers were successful at assigning sex to a holdout dataset and showed that 18% of the individuals were mis-sexed at the time of sampling. In conclusion, we show a significant effect of non-random sampling of kin and identify fine-scale reproductive connectivity with the presence common breeding grounds. Consequently, we argue for international management of this Vulnerable and commercially important species. Finally, findings concerning kin-biased sampling and sex-determination markers are relevant to other fish species.

SPATIAL VARIATION IN FATTY ACID TROPHIC MARKERS AND STABLE ISOTOPES IN ALBACORE TUNA (THUNNUS ALALUNGA) IN THE WESTERN INDIAN OCEAN

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The trophic ecology of albacore tuna, *Thunnus alalunga*, sampled in the western Indian Ocean from 2013 to 2015, was investigated through neutral fatty acids (NFAs) and stable isotopes (SI) analysis of liver and muscle tissues. Generalized additive mixed models (GAMMs) were employed to understand spatiotemporal patterns and drivers of the three main NFA families (saturated, monounsaturated and polyunsaturated fatty acids), fish nutritional condition indices (NCI: ω3/ω6 and total fatty acid content), SI, and known fatty acid tracers (FAT) of primary producers. Several intrinsic and extrinsic variables were taken into consideration, including: fork-length, somatic-gutted weight (WG), fishing position, month, chlorophyll-a (Chla) and sea surface temperature (SST). For all the fatty acid parameters, the best model fit included SST, Chla and WG. WG was a strong predictor for δ13C and δ15N in muscle and liver tissues. GAMMs for the NFA families, FAT, NCI and SI were used to produce oceanographic spatial contour maps which clearly demonstrated geographical gradients in the region. Distinct regional differences in FAT, NCI, and the NFA were found between albacore from the northern tropical areas and the more southern, temperate zones. Multivariate analyses revealed the dominance of 22:6ω3 (DHA) in the tropical-caught albacore, which also had a higher DHA/20:5ω3 (EPA) ratio than the temperate-caught albacore, suggesting a more significant dinoflagellate contribution and/or a higher trophic position. Our analysis also indicated comparatively lower proportions of the NCI in the muscle of tropical samples, which suggests that increased SST as a result of climate change could negatively affect the dietary intake of albacore and marine predators in the region, as well as humans. In addition to spatial variation, trophic markers in the muscle were shown to vary between seasons: higher PUFA, diatom, algae and protist FAT occurred during the north-east monsoon while higher 13δC values and SFA were observed during the southwest monsoon. The capacity to identify the spatiotemporal patterns of these ecological aspects is essential for proper management of the population of this economically important species. This is particularly crucial in areas where oceanographic conditions and seawater temperatures are changing at a fast rate.

MOVEMENT PATTERNS AND HABITAT USE OF THE COMMON THRESHER SHARK (*ALOPIAS VULPINUS*) IN THE WESTERN NORTH ATLANTIC OCEAN

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The common thresher shark (*Alopias vulpinus*) occurs in the western North Atlantic (WNA) Ocean from Newfoundland to Cuba and is taken in commercial fisheries (e.g., pelagic longline, gillnet) and targeted by an extensive, and rapidly growing, recreational rod and reel fishery off the U.S. east coast (from Virginia to Maine). While there is some evidence that their abundance in the WNA has declined considerably during the last three decades, their true population status remains unknown. Problematically, there are currently no domestic or international quotas for this species in the Atlantic and little is known about their stock structure and general movement patterns in this area. Because there is a growing call to list this species as 'threatened' or 'endangered', there is a critical need to increase our understanding of their long term movement patterns and the regional spatial and temporal habitat use. To address this need, we worked in collaboration with commercial and recreational fishermen to deploy 27 pop-up satellite archival transmitting tags on common thresher sharks ranging in size from 81 – 215 cm fork length. Preliminary results from reporting tags indicate that common threshers are highly migratory in the WNA, exhibiting both north/south movements along the U.S. east coast, and east/west movements to international waters of the central Atlantic in association with the Gulf Stream. Vertical movements generally occurred between the surface and 250 m, but dives to >1,000 m were observed. Sharks also experienced a wide array of temperatures (2.3 – 24.5°C), with the coldest temperatures being experienced at greater depths. Collectively, our preliminary results indicate that this species is wide-ranging in the WNA and may require coordinated international management.

SPATIOTEMPORAL VARIABILITY OF TWO NORTH PACIFIC FRONTS AND THEIR EFFECTS ON MICRONEKTON

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Two fronts dominate the frontal zone where the cool, productive Subarctic Gyre waters sink below the warm, oligotrophic Subtropical Gyre waters: the physical Subtropical Front (STF) and the biological Transition Zone Chlorophyll Front (TZCF). This region aggregates economically important top predators and protected species by providing migratory routes and foraging grounds, although the biomass and distribution of their prey, predominantly micronekton, are not well understood. In this study, active multi-frequency acoustics were used along with in situ and satellite oceanographic data from the spring of 2009, 2011, and 2015 to examine the variability of these fronts and their effects on micronekton. Results of this work indicate that in general, the position of TZCF was north of the STF by .1°-4° along 158°W and exhibited spatial variability on scales from a few days to several years. In contrast, the position of the STF seemed to vary less and on a larger spatial scale, which corresponded to large-scale SST anomalies associated with the 2011 La Niña and the 2015 El Niño events. Changes in micronekton MVBS, NASC, and δSv were strongly associated with the position of the STF, with the position of the TZCF playing a weaker role. Interannual variability of overall survey area MVBS/NASC was associated with changes in SSTA, eddy activity, mixed layer depth, and subsurface chlorophyll maxima, all seemingly the effects of mesoscale variability superimposed on atmospheric and oceanic changes associated with La Niña and El Niño events.

CAN WE PREDICT VULNERABILITY OF BYCATCH SPECIES IN EASTERN PACIFIC OCEAN TUNA FISHERIES USING ENVIRONMENTAL DRIVERS AND LIFE HISTORY?

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Tuna fisheries operating within the eastern Pacific Ocean (EPO) interact with highly diverse species assemblages some of which include extreme differences in life history characteristics (*e.g.* fast-growing, short-lived small pelagic fishes to slow-growing, long-lived marine mammals). Most of these species are caught incidentally and infrequently as bycatch, are poorly documented (*e.g.* reported as generic taxonomic groups, "sharks"), and have little economic value. Furthermore, many of these species are data limited, and since basic biological data is lacking, robust quantitative assessments cannot be undertaken to determine the status of stocks. Because abundance of data-rich species (*e.g.* tunas) is known to be influenced by environmental factors (*e.g.* sea-surface temperature) while the ecological dynamics of bycatch species is less understood, we used catch data—reported to the Inter-American Tropical Tuna Commission (IATTC) by observers onboard large purse-seine vessels (> 363 mt carrying capacity)—to postulate potential drivers which may have influenced catches of nontarget species. Specifically, we analyzed catch trends of sharks along with those of the target tunas in relation to indices of variability in oceanographic conditions over the past two decades. We focused on the region of the Humboldt Current Ecosystem (HCE) because shark mortality in the purse-seine fishery for many of the species occurred in this highly-dynamic area. Our results showed increased catch peaks of both tunas and sharks following strong El Niño (EN) events. Following the EN of 1997-1998, we observed an increase in tuna catch-per-set (cps), followed by an increase in shark cps 2-5 years later depending on the species. Assuming catch may be considered a proxy for relative abundance, we can hypothesize that tuna recruitment to the fishery increased due to an increase in *e.g.* available spawning habitat and distribution and abundance of forage. Shark recruitment may lag behind the highly productive tunas because of their lower productivity life history characteristics (*e.g.* slow-growing, long-lived, low fecundity and long gestation periods). Therefore, it may be possible to better manage data-poor species if catches may be predicted in future years from effects of variability in oceanographic conditions. Monitoring catch is valuable for determining the magnitude of a species' vulnerability to fisheries impacts and for assessing ecological variability over time and space. Future work should include improved monitoring of species-specific bycatch in fisheries other than large purse seine and obtaining reliable biological information to develop spatio-temporal models that seek to improve our understanding of vulnerable nontarget species in relation to oceanographic changes and localized impacts of fishing.

CLIMATE CHANGE IMPACT IN PAST AND FUTURE DISTRIBUTION OF SIX TUNA SPECIES

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Future scenarios of fish stocks and the impacts of climate variability and change on fisheries are critical to anticipate and minimize potential economic losses in this sector. In this study, we assessed the impact of recent sea warming and future climate change on the main commercial tuna species mainly caught by industrial pelagic fisheries around the globe. The tuna species considered in this study are: Albacore (*Thunnus alalunga*), Atlantic bluefin (*Thunnus thynnus*), southern bluefin (*Thunnus maccoyii*), yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*) and skipjack (*Ktsuwonus pelamis*). Tuna species are highly migratory and play an important ecological role as top predators in many regions due to their top-down influence on ecosystem structure. We used General Additive Models to relate environmental and fishing variables with the presence and abundance of tuna. We reconstructed the yearly distribution of tuna species between 1965 and 2004 and estimated the center of gravity (as mean location of the individuals that compose the population). We analyzed trends and shifts of the tuna species distribution and to identify what triggers such changes, by testing climate change and fishing as potential factors. Tuna distribution models are projected under the IPCC5 RCP8.5 climate change scenario for the mid (2040-2059) and the end-of-the-21st-century (2080-2099) with the objective of quantifying changes in tuna populations distribution and abundance. Those changes were estimated as the subtraction of the future distribution (mid- and end-of-the-century) and the reference period distribution.

HABITAT PREFERENCES OF BLUE MARLIN (*MAKAIRA NIGRICANS*) AND BLACK MARLIN (*ISTIOMPAX INDICA*) IN THE EASTERN PACIFIC OCEAN

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Blue marlin (*Makaira nigricans*) and black marlin (*Istiompax indica*) are epipelagic species distributed in tropical and temperate waters across the Indo-Pacific Ocean. In the eastern Pacific Ocean (EPO), both are primarily harvested by commercial longline fisheries. They are also by-catch of the tuna purse-seine fishery in this region. Previous studies suggest that overexploitation and climate change can reduce the abundance and shift the spatial distribution of marine species. These changes can be especially difficult to detect in pelagic species, such as billfish, due to their wide-ranging and patchy distributions, which can further complicate fisheries management. Using 14 years (1997-2010) of Inter-American Tropical Tuna Commission (IATTC) data collected aboard tuna purse-seine vessels by observers, we modeled the dynamic habitat suitability of blue and black marlin in response to environmental variables within the EPO. Habitat modeling was conducted using a maximum entropy model with occurrence data (n=29,711) matched with high resolution remotely sensed oceanographic data. The spatial distribution of suitable habitat for blue and black marlin had seasonal and El Niño–Southern Oscillation (ENSO) variability, predominately driven by high chlorophyll-a concentrations and warm sea surface temperature waters. Seasonal suitable habitat shifted between coastal (winter and spring) and oceanic (summer and fall) waters. During La Niña events habitat suitability extended well offshore along the equator, whereas suitable habitat shifted near shore and expanded to the northern waters during El Niño events. Cluster analysis on the center of distribution of the models revealed that the strength of ENSO events can change the typical seasonal center of distribution of blue marlin. Our findings suggest that determining the habitat suitability of a mobile pelagic species can help describe their spatiotemporal patterns over a broad spatial scale, which in turn can be used in the management of these fish.

ILLUMINATING DETAILED BEHAVIORAL CHARACTERISTICS AND MIGRATION CONTEXT OF PELAGICS IN A DYNAMIC ENVIRONMENT BY UTILIZING NEW SENSING CAPABILITIES IN POP-UP SATELLITE TAGS

Marco Flagg

Desert Star Systems LLC

Pop-up satellite tags (PSAT) have long been a staple in the study of large pelagics and many other marine animals. Providing fisheries independent results via satellite reporting, the sensing of light, temperature and depth yields large scale migratory behavior, vertical habitat and temperature preferences and tolerance. Recent advances in PSAT, in particular in Desert Star's SeaTag line, are now illuminating other aspects of pelagic behavior and are supporting analysis on finer time and location scales. Accelerometer measurements for example have recently been applied to establish the diel activity cycle of sailfish. Magnetometer aided position tracking contextualizes pelagic migration with ocean weather phenomena on a fine location and time scale. This presentation reviews recently published and ongoing research enabled by new PSAT capabilities. It concludes with a preview of upcoming advances and opportunities for satellite tag based research to help understand the response of subject species to a changing environment.

AGE AND GROWTH OF YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN

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Age and growth information utilized in the current stock assessment for yellowfin tuna in the eastern Pacific Ocean (EPO) is based on counts of daily increments from sagittal otoliths collected over forty years ago. Results from tagging experiments have indicated apparent stock structure of yellowfin tuna in the EPO, therefore suggesting spatially structured stock assessments be considered. To address the need to reevaluate the growth model utilized in the current assessments and evaluate the possibility of spatial variability in growth and maturation of yellowfin tuna in the EPO, the Inter-American Tropical Tuna Commission initiated a spatially-stratified sampling program in 2009. The program utilized observers aboard purse-seine vessels, to collect sagittal otoliths and ovaries from female yellowfin tuna. Observers were instructed to sample yellowfin tuna, only when sea-surface temperatures were above 25°C, up to 5 fish per set within twelve 10 cm length strata between 40 and 160 cm fork length. Between 2009 and 2016 1,004 otoliths and 2,461 ovaries were collected from four distinct areas within the EPO. These four areas were defined as: (1) a northern area, north of 20°N, (2) a central offshore area 5°N - 15°N and west of 105°W, (3) a central nearshore area 5°N - 15°N and east of 100°W, and (4) a southern area south of 5°S. Sagittal otoliths were weighed and measured, placed in a mold, and encapsulated in epoxy resin. Once cured, the epoxy block was removed from the mold and molds were discarded. The otolith was then examined, through the epoxy under a stereo microscope, at which time the primordium and post-rostral tips were marked on the surface of the epoxy block. The epoxy block was then carefully positioned in a low speed diamond wafering saw and aligned to obtain a section containing both the primordium and the post-rostral tip. Sections were mounted on slides using a thermoplastic and polished to a thickness of approximately 5-15 µ. Daily increments were counted on those otolith sections using a compound microscope at 1000x magnification. To date, 246 otoliths have been read, 128 from the central offshore region and 118 from the central nearshore region. A general additive model (GAM) was used to investigate whether differences in growth exists between those two areas.

DECISION MAKING IN A MIXED COMMERCIAL-RECREATIONAL FISHERY FOR ATLANTIC BLUEFIN TUNA

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Individual fishermen are often categorized as belonging to either the recreational or commercial sector. However, vessel owners who obtain a Charter/Headboat (CHB) permit from the National Marine Fisheries Service's Highly Migratory Species Management Division are able to fish for Atlantic bluefin tuna either commercially or recreationally, and either privately or for-hire, on a trip-by-trip basis. Given the complex size- and sector-specific quota structure of the U.S. Atlantic bluefin tuna fishery, understanding how fishermen utilize this unique permit's flexibility is needed to prevent overages while maintaining equity within and among sectors. We applied a novel contingent sequential behavior survey approach to examine several factors that might influence trip type decisions. Respondents completed an online survey in which they were presented two fishing trip choice scenarios, each of which asked them to make multiple choices regarding fish disposition, with the recognition that each decision might impact future choice options on that trip. A random parameters logit model that allowed for correlation among random parameters was used to identify key trip-specific variables and individual factors governing disposition decisions, evaluate the impact of inertia (habit formation) versus opportunism, and examine preference heterogeneity across fishermen. Respondents who indicated that they primarily fished in a commercial manner were more likely to exhibit inertia than primarily recreational anglers, while fishermen in certain regions were significantly more likely to harvest opportunistically than those located elsewhere. Harvest probability distributions under different fishery scenarios were generated to improve the ability of managers to predict CHB permit holders' relative contributions to the different sub-components of the domestic Atlantic bluefin tuna fishery, thus maintaining overall landings within internationally prescribed limits.

POP-UP SATELLITE TAG RECOVERIES USING THE ARGOS GONIOMETER AND THORIUM X TABLET

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Pop-up satellite tags (PSAT or PAT) are used throughout the world on a variety of free-swimming fish (examples include bluefin tuna, billfish, dolphinfish, salmon, sablefish, blue sharks, and a number of other similar species). Pop-up satellite tags record various sensor data such as light, magnetics, depth, temperature, accelerometer, and other data. With onboard compression and near unlimited memory the issue is not a matter of storing gigabytes worth of data but rather getting that data back. The polar orbiting Argos satellites are not always overhead (approximate 1-2hr gap between satellites), and no pop-up satellite tags currently utilize the two-way functionality on two of the six current Argos equipped satellites. Therefore, all messages transmitted by the tag are usually transmitted multiple times, and in some cases there is not a satellite overhead to receive the message. The result is typically either an incomplete picture of the animals' behavior or a compressed model of specific behavior aspects (for example: depth histogram). Many, if not all, researchers place reward messages on the tags in hopes that someone will find the tag on a fish or washed ashore and return the tag. While this has been successful in some programs (we have anecdotally heard of several programs having 50% or higher return rates), it is not a reliable approach. Knowing the value of the data on the tag, CLS sought out to develop a radio direction finder (RDF) that had capabilities unique to the Argos system. Several years ago CLS began offering a clunky solution to find satellite tags in the field, and over the last few years introduced a more streamlined, hand-held unit, the "Argos Goniometer." Since 2016 the Argos Goniometer has been used by more than 75 researchers looking to recover or actively track Argos tagged animals or instrumentation. This presentation will demonstrate how the Argos Goniometer coupled with the Thorium X Argos integrated satellite tablet is used to recover Argos satellite tags in the field and show the value in recovering pop-up satellite tags.

A FLEXIBLE SPATIALLY-EXPLICIT ECOLOGICAL RISK ASSESSMENT APPROACH FOR QUANTIFYING THE CUMULATIVE IMPACT OF TUNA FISHERIES ON DATA-POOR BYCATCH SPECIES IN EASTERN PACIFIC OCEAN

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The eastern Pacific Ocean (EPO) supports some of the largest and most valuable tuna fisheries in the world. Some EPO fisheries, such as longline and purse seine sets on floating objects, have a significant bycatch comprising species with diverse life histories from sea turtles, seabirds, elasmobranchs to large mesopelagic fishes. The Inter-American Tropical Tuna Commission has adopted an ecosystem-based management approach for EPO tuna fisheries through its Antigua Convention to account for fishing impacts on non-target species. However, demonstrating the sustainability of all impacted species—many having little catch or biological data—is a significant challenge. Ecological Risk Assessment (ERA) approaches, such as the widely-used attribute-based Productivity-Susceptibility Analysis (PSA), have been a major advancement for fishery managers to identify potentially vulnerable species in data-limited settings. Unfortunately, PSA produces only a relative measure of risk, it cannot assess the cumulative impact of co-occurring fisheries, and does not easily account for interannual changes in species habitats or fishing effort. This paper introduces a new spatially explicit ecological risk assessment approach designed for data-poor species and fisheries that can assess the cumulative impact of multiple fisheries by producing a quantitative estimate of fishing mortality using a flexible susceptibility analysis. Fishing mortality is then compared against conventional biological reference points (e.g. F_{msy}, $F_{0.1}$) derived from a length-based per-recruit model to determine a species' status. Our approach allows fisheries managers to adapt analyses to changing species habitats and fishing effort patterns under a changing climate to more confidently identify vulnerable species in which to direct resources to either implement mitigation measures, or collect further data to inform more formal stock assessment approaches.

SEASONAL AND DECADAL FORECAST DEVELOPMENT FOR A MULTI-SPECIES PELAGIC LONGLINE FISHERY

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The abundance and distribution and hence availability of highly migratory tuna and billfish species to fisheries are known to be strongly influenced by oceanographic conditions. The five target species of the Australian east coast longline fishery (albacore, bigeye, yellowfin tuna, striped marlin, broadbill swordfish) have a wide distribution outside the Australian EEZ, but the influence of oceanographic factors within the fishery region and the surrounding south-west Pacific region is poorly understood, creating uncertainty in current management arrangements. The waters off the east coast of Australia are also experiencing rapid climate change, with range expansion already observed for many coastal and pelagic fish species. Changes in distribution over the 21st century are also projected for these five species in eastern Australia and the wider Pacific. The Australian longline management agency and the fishing industry are seeking insight into past, current and potential future oceanographic and environmental impacts upon (i) the spatial and temporal distribution and level of longline catches, catch rates, fishing effort and fish sizes, and (ii) the interactions between focal species in the domestic and international fisheries. In previous work we have developed habitat models and seasonal forecasting approaches for a range of species in Australia, including southern bluefin tuna, using the Bureau of Meteorology's POAMA model, which produces skillful seasonal forecasts of key variables at lead times of up to four months. This new three year project will provide insights into potential long term changes in the longline fishery that may result from climate change, and deliver forecasting capability on seasonal and decadal time scales for the five species targeted in the fishery. We will utilise new high resolution models for seasonal forecasting (ACCESS-S1) and our state- of-the-art decadal forecasting capability. This effort will support decision making by Australian and south-west Pacific managers and fishers, and build capability for operating in a rapidly changing region.

A RETROSPECTIVE ANALYSIS OF SAN DIEGO COMMERCIAL FISHERY CATCH AND LANDINGS IN THE LIFETIME OF A MILLENNIAL

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California has a long and rich history of commercial fishing along most of its coastline. Commercial fishing in the San Diego area, once highly productive and profitable, has declined dramatically over the years due to a myriad of biological, social and economic reasons. Despite this downward trend, the commercial fishing industry is still an important and viable component of San Diego's socioeconomic base, providing fresh locally caught seafood to an every-growing community of consumers wishing to make positive environmental and health choices, as well as supplying U.S. seafood exports. Two of the main port locations in San Diego Bay, Driscoll's and Tuna Harbor, are being considered as part of a larger redevelopment of San Diego's downtown waterfront areas. Fishing industry stakeholders are interested in empirical evidence that demonstrates the importance of the commercial fishery presence in this area, and which documents infrastructure needed to maintain or improve commercial fishery operations. In order to provide context, this study documents the landings and economic performance of commercial fishing activity in these ports over recent decades. Future infrastructure needs can be difficult to anticipate, given the unpredictable effect of climate fluctuations on species availability. To help inform these decisions, two approaches were used. Economic performance indicators for commercial landings to San Diego County were analyzed for the top species (by tonnage and value). Additionally, graphs of the spatial distribution of catch taken in Southern California waters but landed into Orange and Los Angeles counties (indicating catch which could have been landed to San Diego) were produced for top species in those locations (by tonnage and value). Landings information for the majority of species for the period from 1997 to 2016 was evaluated as it encompassed periods of unique environmental conditions and varying availability of some species (e.g. Pacific Bluefin Tuna), while also characterizing biological and ecological variation in San Diego commercial fisheries. In addition, North-Pacific Albacore landings were examined back to 1981 to better capture long-term fluctuations in local abundance, as the species was historically an important component of San Diego catch.

LARVAL HABITAT SUITABILITY FOR ATLANTIC BLUEFIN TUNA SPAWNED IN THE SLOPE SEA

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Atlantic bluefin tuna (ABT), a highly migratory species, is currently managed using two stocks, differentiated by their spawning locations in the Mediterranean Sea and the Gulf of Mexico. Recent evidence of a third spawning ground in the Slope Sea (Richardson et al 2016) raises important questions about the population dynamics of ABT. We are working to understand the distribution and suitability of larval habitat in the Slope Sea through both empirical and modeling techniques. Larval collections from 2013, 2016, and 2017 provide data on the distribution of ABT larvae in this region. In 2017, oceanographic drifters were released into a patch of ABT larvae in a warm core ring off the eastern edge of Georges Bank, providing information on the transport processes experienced by the larvae. Larval dispersal modeling using both current velocities and SSTs from the high-resolution MABGOM2 model provide insights on optimal spawning locations for retention of larvae in the Slope Sea region and in optimal temperatures for larval growth. Comparing model results from 2013 with data on distributions shows that these optimal areas are the ones where larvae have been collected. Larval growth rates from the Slope Sea will be presented and compared to larval growth rates from the Gulf of Mexico. Together, this body of data and numerical modeling will help determine the extent to which ABT larvae spawned in the Slope Sea contribute to stock productivity.

THE IMPACT OF THE LEATHERBACK TURTLE CONSERVATION AREA CLOSURE ON SWORDFISH PRODUCTIVITY: A DIFFERENCE-IN-DIFFERENCES APPLICATION

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Fishery management actions focused on the conservation of non-target species may impact the productivity of fisheries in terms of target species. This article studies California's drift gillnet swordfish (*Xiphias gladius*) fishery and investigates the impact of a recent regulatory measure aimed to protect leatherback turtles. A parametric approach is used for the primal characterization of the production technology in the California drift gillnet swordfish fishery controlling for fishing behaviors, equipment characteristics, stock abundance, and climate effects. The production model is subsequently framed in the context of the difference-in-differences estimator to investigate the effect of the introduction of a regulatory time-area closure on the fishery. Estimation results suggest the regulation has a statistically significant negative impact on swordfish productivity, and that production is impacted by effort, equipment, stock, and climate.

MEASURING OCEAN VARIABILITY IN NEAR-REAL TIME WITH HELP FROM FISH-BORNE SENSORS

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A key component of understanding changes in fish distribution due to changes in ocean conditions is to actually measure what those physical conditions are and obtain the data in near-real time and with appropriate geographical resolution and accuracy. Despite decades of advances in the technology for obtaining ocean profiles, much of the world's oceans are still not regularly measured or are not monitored frequently or widely enough to detect small or mesoscale phenomena or phenomena that are changing rapidly. This under-sampling is especially true marginal seas, coastal shelves, boundary currents, eddies and oceanic fronts – all of which are important fish habitats. One promising method of cost-effectively improving the 'density' of data from these important areas is to equip fishes with sensors that can collect and relay pertinent oceanographic data with appropriate measurement accuracy (both of location and ocean parameters). These data serve the dual purpose of obtaining physical oceanographic data and also elucidating movement patterns and habitat preferences of the animals carrying the tags. Here we describe successful preliminary experiments using a new type of electronic tag to obtain near-real time ocean temperature profiles from two species of sharks in Hawaiian waters and we discuss implications for fisheries oceanography in the future.

SHARK BYCATCH AND POST RELEASE SURVIVORSHIP IN TUNA LONGLINE FISHERIES

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The incidental capture of sharks in commercial fisheries targeting tuna and billfish is having a negative impact on pelagic shark populations. Recently, studies have shown that some shark species captured in longline and purse seine fisheries may sustain high levels of post release mortality due to injuries sustained during the fishing interaction. Researchers have identified the three main factors that lead to mortality in sharks; 1) the physiology of the species where some are more susceptible to the lethal effects of stress, 2) the duration of the interaction and 3) the methods used to release the animal. In this study and in collaboration with the Pacific Islands Regional Observer Program, we are quantifying post release mortality rates and assessing the effects that handling and discard practices (used in the Hawaii and American Samoa-permitted tuna longline fisheries) have on release condition and survivability of sharks using pop-off archival satellite tags. These new estimates of survivorship and total fishing mortality were then integrated into a stock assessment model for the north Pacific blue shark to assess population level effects.

RECENT TRENDS IN HOOK AND LINE LANDINGS OF TROPICAL AND NORTH PACIFIC TUNAS INTO CALIFORNIA PORTS (1998 – 2018)

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Commercial tuna landings into California ports are typically made with purse seine, longline, or hook and line gears. Historically, much of California's management attention has focused on purse seine landings (as they tend to comprise the majority of the catch volume and generally operate within the US West Coast Exclusive Economic Zone), and to a lesser degree on longline landings (which meaningfully contribute to overall landings but take place outside the US West Coast Exclusive Economic Zone). However the hook and line sector, which opportunistically targets tuna species when they are available in waters relatively close to shore, also merits attention. While the per-trip volume is generally smaller than purse seine or longline landings, when tunas are available hook and line gear can comprise a large number of individual landings. This likely plays an important role in supporting working commercial waterfronts, by providing a steady stream of business for commercial fish buyers and processors as well as affiliated shoreside supply industries (e.g. fuel, ice, and bait). The hook and line fishery can be a highly important sector in years where one or more tuna species are subject to restrictive commercial quotas and trip limits, which is a disincentive to participation by the purse seine fleet. Using commercial landing receipts (also known as "fish tickets") submitted to the California Department of Fish and Wildlife, this analysis examines twenty years of landings made by the hook and line fishery for key tropical and North Pacific tuna species, including Pacific Bluefin Tuna, North Pacific Albacore, and Yellowfin Tuna. Particular attention is paid to trends in catch composition, geography (both the general catch location and port of landing), and the number, volume, and Ex-Vessel Value of hook and line landings. Improving our understanding of this fishery is particularly timely, since the low 2018 catch limit for Pacific Bluefin Tuna and correspondingly low trip limits are likely to result in a fishery which is dominated by hook and line landings. Developing a more detailed understanding of hook and line fishing activity should assist with future international negotiations and domestic implementation of international resolutions.

THE PHYSIOLOGICAL EFFECTS OF CAPTURE STRESS AND THEIR IMPACT ON POST-RELEASE SURVIVAL OF PACIFIC BLUEFIN TUNA (*THUNNUS ORIENTALIS*) CAUGHT ON ROD AND REEL

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Recent stock projections for Pacific bluefin tuna (PBT) have led to reductions in U.S. daily and trip recreational retention limits, a scenario that can potentially lead to a larger number of individuals being released in the fishery. However, the efficacy of catch-and-release as a management tool for reducing PBT mortality is unknown due to the lack of post-release disposition data and the unknown extent to which physiological capture stress may influence survival. To address this data gap, this study coupled electronic tagging with biochemical analyses of blood to assess fish condition following capture in the Southern California recreational fishery. Survivorship pop-up archival tags (sPATs; Wildlife Computers) were deployed on 49 PBT ranging in size from 82–146 cm FL (11–61 kg). All PBT were caught using standardized recreational fishing gear following the protocols currently used by the Southern California fleet. Similarly, blood samples were obtained from an additional 50 PBT (80–170 cm FL) immediately after capture with similar angling techniques aboard local sportfishing vessels. Whole blood samples were processed immediately to evaluate acid base chemistry (pH, lactate) and hematocrit. Aliquots of whole blood were also centrifuged and plasma samples were snap frozen for future laboratory analysis of electrolytes and metabolites. Preliminary results suggest high post-release survivorship in PBT following capture on recreational fishing gear. From the tag data it was evident that only two of the 49 PBT died as a result of the angling event (estimates based on acute post-release mortality). One of the two mortalities was considered to be a predation event that occurred seven days after release. Preliminary results from the blood chemistry analyses suggest that PBT physiology was impacted by the capture process, with greater disruption generally occurring with increased fight time. Comparison of these results with our electronic tagging data suggest that PBT are capable of coping with and surviving the physiological stress of capture when handled correctly and time on the line is <60 minutes.

COMPLEX DISPERSAL OF ADULT YELLOWFIN TUNA FROM THE MAIN HAWAIIAN ISLANDS

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The local availability of yellowfin tuna is a key economic, dietary and cultural concern for MHI communities and fisheries. Interactions of inshore versus offshore fisheries and connectivity to yellowfin elsewhere remain important management questions. Local fisheries target adult "ahi" during the summer months, but subsequent movements, presumably away from the islands after reproduction ceases, remain undocumented. From 20014-2016, we partnered with local ahi fishermen to catch and release nineteen yellowfin tuna (estimated 90- 220 lbs) off Kauai, with PSAT tags programmed for one-year missions. Although data collection periods did not exceed 59 days due to tag hardware failures and two observed predation incidents, these short tracks revealed surprisingly diverse patterns: local residency for some individuals, and rapid, long distance (e.g., > 500 nmi) dispersals in multiple directions for others. These tantalizing patterns suggest that ahi frequenting the MHI have more complex movements than previously assumed. Attainment of one-year migration records will require a level of hardware performance not achieved by current tag manufacturers, but is prerequisite for greater understanding of yellowfin in the central north Pacific, and assessment of connectivity, impacts of climate change, and shifting ecosystems on MHI fisheries.

CHALLENGES IN MONITORING THE SOUTHERN CALIFORNIA NORTH PACIFIC BLUEFIN TUNA COMMERCIAL FISHERY

Leeanne Laughlin

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In 2014, North Pacific Bluefin Tuna (*Thunnus orientalis*) was determined to be overfished by the International Scientific Committee, which recommended international take reductions. In 2017, federal regulations limited the US portion of the commercial catch to 600 metric tons over two years, with no more than 425 metric tons in a single year, accompanied by a 25mt trip limit. The U.S. commercial fishery is primarily a San Pedro based coastal purse seine fishery, with smaller volumes being taken by hook and line and drift gillnet. The fishery presents challenges to monitoring due to the pulse nature of fishing activity, and reporting requirements and technology that do not account for "real time" data collection needs. In 2017, landings in the fishery were unique due exceptional effort by the purse seine fleet over a short period of days. Despite the trip limits of 25 mt and CDFW staff monitoring daily landings, fleet capacity allowed for purse seine vessels to land approximately half the annual catch limit over a few days. On August 18, 2017 CDFW determined the catch limit had been exceeded as landings of catch from the previous 24 hours were made. CDFW immediately notified NMFS and provided notice to fish receivers by phone and letter, in addition to coordinating with United States Coast Guard to issue a notice to mariners that the catch limit had been reached. On August 28, 2017, NMFS announced that the commercial PBF fishery was closed. (82 FR 40720). This 10-day lag, along with the lack of real-time catch data, demonstrates the challenges in current monitoring and management for small quotas. Based on the lessons learned, the 2018 quota will be managed with lower trip limits, increased outreach to fishery participants, and implementation of electronic landings reporting.

ENSO DRIVES NEAR-SURFACE DISSOLVED OXYGEN AND HYPOXIA-INDUCED VERTICAL HABITAT SPACE VARIABILITY IN THE TROPICAL PACIFIC

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The El Nino-Southern Oscillation (ENSO) is the main cause of observed variability in sea surface temperatures within the tropical Pacific Ocean. Using in situ measurements of temperature and dissolved oxygen (O_2) concentrations from World Ocean Database, we show that ENSO is also the primary driver of interannual variability in near-surface O_2 throughout the tropical Pacific. These variations in O_2 concentrations are driven by vertical shifts in thermo- and oxycline depth, which alternately elevate and suppress cold, hypoxic waters from below depending on the ENSO phase and location. ENSO-induced changes in near-surface O_2 in turn alter the amount of oxygenated vertical habitat space available to pelagic fish, especially in the western tropical Pacific, where catches of skipjack tuna, yellowfin tuna, and blue marlin are largest. Of the eight western tropical Pacific countries that together supply 50% of the world's skipjack tuna, waters belonging to Tuvalu and Nauru undergo the greatest variations in hypoxia-defined vertical habitat extent: ~55 m and ~43 m, respectively, between typical El Nino and La Nina phases. Extreme ENSO phases, which may become more common with future warming, cause especially large variations in vertical habitat extent throughout the tropical Pacific. These vertical habitat space changes can alter interactions between predator and prey as well as drive horizontal migrations and variations in the vulnerability of pelagic fish to surface fishing gears, with potential impacts on the tuna and other fisheries that many small Pacific island nations depend on.

MODELLING THE OCEANIC HABITATS OF SILKY SHARK (*CARCHARHINUS FALCIFORMIS*) IN THE TROPICAL ATLANTIC OCEAN, IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

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Investigating the relationship between abundance and environmental conditions is of primary importance for the correct management of marine species, especially highly migratory large pelagic species like silky sharks (*Carcharhinus falciformis*), a species that is currently ranked by the IUCN as near threatened or vulnerable, depending on the region. Tropical tuna purse seine vessels annually catch millions of tons of tuna worldwide. However, tuna fishing may have implications on certain sensitive by-catch species, along with other potential impacts on the ecosystem. This work aims to provide the first insights into the environmental preferences of silky sharks by modelling their abundance from observer data with a set of biotic and abiotic oceanographic factors, spatial-temporal terms and fishing operation variables. The study considers Spanish observer data (IEO and AZTI database) from 2003 to 2015, which comprises about 7500 fishing sets for the Atlantic Ocean. Oceanographic data (SST, SST gradient, salinity, SSH, CHL, CHL gradient, oxygen, and current information such as speed, direction and eddie kinetic energy) were downloaded and processed for the study period and area from the MyOcean-Copernicus EU consortium. Results provide information on the distribution dynamics and hotspots of silky shark as well as the most significant relationships with environmental processes. Models detected a significant relationship between permanent and seasonal upwelling events, mesoscale structures and shark abundance and suggested strong interaction between productive systems and the spatial-temporal dynamics of sharks. The model also highlighted certain persistent areas of shark occurrence off Gabon and Guinea. This information could be used to assist t-RFMOs in the conservation and management of this vulnerable non-target species.

UPDATED COMPARATIVE ANALYSIS OF THE LABORATORY GROWTH OF YELLOWFIN TUNA (*THUNNUS ALBACARES*) AND PACIFIC BLUEFIN TUNA (*THUNNUS ORIENTALIS*) LARVAE, AND GROWTH OF EARLY-JUVENILE YELLOWFIN REARED IN LAND BASED TANKS AND A SEA CAGE

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The IATTC has been conducting research on the early life history and biology of tropical tunas at the Achotines laboratory in the Republic of Panama since 1986. Spawning from a population of yellowfin tuna (YFT) has taken place almost daily in the laboratory's land-based tank since 1996. Eggs and larvae collected from the broodstock tank are used to conduct biological and physical experiments aimed at gathering ecological information on early life history stages. A comparison of the early life histories of YFT and Pacific bluefin tuna (PBF) has been conducted from 2011-2017 in collaboration with Kindai University of Japan. Work conducted on PBF at the Oshima Branch of Kindai University in Kushimoto, Japan, has allowed us to compare the effects of food density on larval growth with results obtained from the IATTC's work on YFT larvae at the Achotines Laboratory. Rearing both species independently but with identical feeding and physical tank conditions, we have compared larval growth dynamics of YFT and PBF from 2 to 13 days after hatch. An update on these comparative growth trials is presented here. Early-juvenile growth data of tunas from either *in situ* or laboratory studies are rare. Survivors from different groups of YFT larvae used for experiments at the Achotines laboratory often reach the transformation period into the early juvenile stage. These fish are reared as long as possible, with sampling occurring at intervals dictated by mortality. Early juvenile growth data have been compiled from studies conducted at the Achotines Laboratory, and from these studies we have obtained growth analyses examining the effects of food, life stage and rearing conditions on growth. Over a span of 18 years, the growth of 1,077 individual survivors that reached post-transformation stage from a total of 22 rearing trials was analyzed. Growth rates were described as part of an analysis of all transformation and juvenile individuals, classified by a minimum standard length of 16 millimeters. The growth pattern of an early juvenile group transferred to a sea cage will also be presented. The ongoing research on pre-recruit growth will help fill the knowledge gap about growth dynamics of YFT and PBF at these early life history stages.

ESTIMATING THE POPULATION IMPACTS FROM THE GLOBAL TORTOISESHELL TRADE 1844-1992

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Illegal, unreported, and unregulated (IUU) fishing is arguably the greatest challenge to achieving sustainable fisheries today. Recent studies have shown that IUU fishing is closely associated with human trafficking, as well as the illicit trade in wildlife, and other crimes. The hawksbill sea turtle (*Eretmochelys imbricata*) is among the least abundant of the globally-distributed sea turtle species. This species was heavily exploited over centuries for their prized shells rather than sustenance, yet no reliable estimates of historical depletion rates exist. In this study, we obtained, curated, and analyzed official records of hawksbill tortoiseshell trade from 1844-1992. In addition, we used strandings and archived specimens to calculate the ontogeny of scute growth and derive the morphometric relationship between turtle length and tortoiseshell mass. Next, we examined a seizure of 1,741 specimens confiscated in the 1980s to understand the demographics of the tortoiseshell trade. Using these data and relationships, and several likely harvest scenarios, we estimated the biological impact of the tortoiseshell trade over 150 years. We then examined local overexploitation and depletion from harvests, the spatial expansion of the trade, and then basin- and global-scale patterns. We discuss these results in the context of current patterns of IUU fishing data.

ESTIMATION OF THE ABUNDANCE OF YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN USING FISHERIES-DEPENDENT DATA

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The main goal of this research was to compare different methods of to estimate the abundance of yellowfin tuna in the eastern Pacific Ocean (EPO) using fisheries dependent data. The methods, all conditioned on the catches, included: (i) age-structured length-based statistical catch-at-age models (Stock Synthesis), (ii) the age-structured production models fit exclusively to the CPUE-based indices of relative abundance; (ii) catch-curve model using length composition of the catches (iv) in-season depletion models fit to CPUE-based indices of abundance. The consistency and differences of the results were assessed, so that the origin of the information about absolute abundance and/or trends in abundance could be traced to the different data components. Also, discrepancy in results were inspected to detect misspecifications in the integrated model.

HOW DO STOCK ASSESSMENTS PERFORM FOR MIXED ATLANTIC BLUEFIN TUNA STOCKS?

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Atlantic bluefin tuna (*Thunnus thynnus*) is currently assessed as two separate eastern and western fisheries by the International Commission for the Conservation of Atlantic Tunas (ICCAT). However, recent studies indicate that both fisheries harvest a mix of distinct eastern and western populations. Failure to account for mixed stocks in assessment and management of bluefin tuna could lead to an incomplete understanding of the two spawning populations and overexploitation of the more vulnerable population. Simulation testing of stock assessment models can be used to understand the implications of stock mixing and uncertainty in bluefin life history. We used a biologically realistic operating model conditioned on the 2017 Atlantic bluefin tuna stock assessment and a simulation testing framework to evaluate the performance of the virtual population analysis (VPA) used for the current and past several bluefin stock assessments, VPA-2BOX. Pseudodata of typical quantity and quality available for the bluefin stock assessment were generated using a spatially complex operating model that incorporates movement and mixing between stocks. To address areas of uncertainty in the parameterization of the 2017 stock assessment, alternative operating models accounting for different assumptions of natural mortality and spawner-recruit relationships were tested. Separate eastern and western stocks were assessed using VPA-2BOX as the estimation model, and model performance was assessed by comparing results across simulations and to the operating model. Preliminary results suggest that the estimation model is sensitive to structural error (i.e., stock mixing) and measurement error, biasing estimates of spawning stock biomass, recruitment, and harvest ratio. Although separate VPA-based assessments of eastern and western stocks may accurately reflect general stock and population trends, absolute estimates may be biased and may provide misleading management advice.

INTERANNUAL VARIABILITY OF NORTH PACIFIC ALBACORE DISTRIBUTION IN THE CALIFORNIA CURRENT ECOSYSTEM

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North Pacific albacore (*Thunnus alalunga*) migrate throughout much of the North Pacific, including the California Current Ecosystem (CCE). Their abundance in the CCE, and local availability to fishing fleets, has varied strongly historically, at both interannual and decadal-scales. In this study, we use species distribution models to show how albacore use migration corridors across the North Pacific, and link these to spatial availability of favorable metabolic and foraging habitats. We also relate albacore distribution to abundance of primary prey species in CCE foraging areas, and investigate how varying availability of forage fishes has driven "prey switching" behavior in time and space. Our results have relevance to the development of ecosystem models for the CCE, and for the assessment of future climate change impacts on the stock, and associated fisheries.

OVERVIEW OF RECENT AND FUTURE PLANNING OF SPC TAGGING EFFORTS IN THE WPO/WCPO

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Recent large scale tropical tuna (Skipjack-SKJ, Yellowfin-YFT, and Bigeye-BET) tagging efforts in the Western and Western Central Pacific Ocean conducted by The Pacific Community (SPC) have expanded from annual, targeted bigeye trips to alternating, biennial pole and line skipjack tagging and dangler/handline style bigeye tagging. With support of the Western and Central Pacific Fisheries Commission (WCPFC), ongoing support and funding is now committed for the near future for these campaigns in the WCPFC's jurisdiction. During 2016 on a 35 day tagging trip, 2,135 fish (73.7%BET, 17.4%YFT, 5.1%SKJ) were tagged primarily around drifting Fish Aggregation Devices a(FADs) supplied by Trimarine in the Marshall Islands, Federated States of Micronesia, Tuvalu, Solomon Islands, and Kiribati Exclusive Economic Zones (EEZ)s as well as International Waters. Of these 2,135 tagged fish, 234 were archival and/or sonic tagged. During 2017 on a 50 day tagging trip, 27,780 tuna (91.5%SKJ, 8.4%YFT .1%BET) were tagged on a combination of anchored FADs (56%), unnassociated schools (23%), dFADs (3%), seamounts (12%), whale sharks (2%) and logs (4%) in Papua New Guinea (23.9%) and Solomon Island (76.1%) EEZs. A bigeye tagging trip is planned for Jul-Aug 2018, departing from Majuro, Marshall Islands targeting dFADs and anchored TAO moorings along the 165E and 180 meridians. In 2019, a pole and line skipjack trip will be conducted in PNG and Solomon Islands waters, similar to the 2017 WP4 campaign. To date, 14.1% of fish tagged during CP12 have been recaptured, including 17 archival tags. Archival tag days at liberty range from 16-228d. Preliminary recapture data and validations from WP4 are still being collected, but 4.4% have been recaptured to date. For WP4, this rate is expected to increase over the next several months as fish are recaptured and recapture data are reported and validated.

EFFECT OF CLIMATE CHANGE ON THE HABITAT DISTRIBUTION OF *MOBULA JAPANICA* IN BAJA CALIFORNIA

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Manta or devil rays (pelagic rays of the family Mobulidae) have been identified to form an important component of the tropical tuna purse seine fishery bycatch, particularly in the eastern Pacific Ocean. Although a large and charismatic group with a potentially important role in the marine ecosystem, the distribution of their habitat and potential impact of fisheries and environmental change is poorly known.

Mobula japanica is one of the mobulid bycatch species most frequently caught in tropical purse seiners, so understanding their habitat use is crucial to develop sound and practical management solutions to assure their conservation. This research integrates bycatch data from the Eastern Tropical Pacific tuna purse seine fishery (2005-2015) and remotely sensed environmental data to study the potential habitat of *M. japanica* bycatch species in Baja California comparing and evaluating three different habitat models (Bioclim, Mahalanobis and MaxEnt). Results showed better (AUC: 0.91%) model performance for MaxEnt compared with the other models and, thus, this model was selected to study the possible impact of climate change on the distribution of this species. Projections showed that areas inside the Gulf of California were the main potential habitat for this species during early summer and the Pacific coast of the Baja Peninsula during fall. Depth, temperature and primary production were the most important environmental variables which contributed to explain the distribution of this species. Under an A2 climate change scenario, the MaxEnt model predicts that suitable *Mobula* habitat could be reduced by 22% and would shift outside of the Gulf of California, driven by predicted increases in temperature and the possible movement of their main prey Nictiphanes simplex to this area, by 2100. The inclusion of independent data (i.e. tagging) or other environmental variables could improve the performance and predictive value of the models.

REPRODUCTIVE BIOLOGY OF ROOSTERFISH (*NEMATISTIUS PECTORALIS*) IN WATERS OF BAJA CALIFORNIA SUR, MEXICO

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The roosterfish (*Nematistius pectoralis*) is the only species in the genus Nematistius and is distributed along the eastern Pacific coast from Northern Baja California, MX to Peru. Although this species is not subject to significant commercial exploitation, it is a resource of great importance for sportfishing, due to its large size and challenges involved in its capture. In Mexico, this species is reserved for sportfishing with commercial take prohibited within 50 nautical miles from the national coastline. Despite its importance to regional recreational fisheries, few studies have been conducted on the basic biology of the roosterfish. The aim of this study was to assess reproductive parameters and maturation schedule of roosterfish caught along the coast of Baja California Sur. Biological samples were collected from artisanal camps out of San Carlos and La Paz Bay, as well as from recreational fishers operating out of Cabo San Lucas from 2010-2017. Each organism was weighed, measured and sexed, prior to preserving the gonads in a Davidson's solution. In the laboratory, gonadosomatic indices (GSI) were estimated (n=324) and histological sections were examined to determine maturation stages (n=229). It was determined that 50% of sampled individuals reached maturity at 60.7 cm fork-length (L_{50}). Mean GSI values peaked in July and histological preparations confirmed that roosterfish reproduction occurs primarily during the summer (June-August) along southern Baja California. Given that there is little information on stock size, status and exploitation rates, future management efforts may consider using the data collected in this study to better manage fishing mortality.

TROPHIC ECOLOGY OF ROOSTERFISH (*NEMATISTIUS PECTORALIS*) IN THE EASTERN PACIFIC OCEAN

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The roosterfish (*Nematistius pectoralis*) is distributed in shallow waters along the eastern Pacific coast, where it is caught by artisanal and sportfishing fleets. Despite its importance in sportfishing operations, little is known regarding its interaction with other species and feeding habits. Stomach and muscle samples were collected during 2010-2017 in Baja California Sur (BCS), México and during 2015 in El Golfo Dulce, Costa Rica (CR). Quantitative analyses of roosterfish stomach contents were made using the prey specific index of relative importance (PSIRI) and Levin´s Index. Tests for differences between regions and sexes were also performed using an analysis of similarities test (ANOSIM test). To evaluate feeding habitats, stable isotope analyses were performed to calculate trophic level and isotopic niche. Stomach contents from 212 roosterfish captured along BCS revealed a diet consisting primarily of Carangid and Engraulid fishes with a relatively narrow niche breadth (Levin Index= <0.5). Similarly, stomachs from roosterfish sampled off CR (n=40) primarily contained fishes from the families Carangidae, Engraulidae and Clupeidae, and also revealed a narrow niche breadth (Levin Index=0.54). Ontogenic diet shifts were only detected in BCS, where larger roosterfish tended to display an increased prey diversity, with species such as scombrids commonly in their diet. No differences were detected between sexes in either region suggesting that both males and females feed in the same areas on similar prey. Isotopic analyses revealed a mean trophic level of 4.1 for CR and 4.4 for BCS. These values suggest that roosterfish feed closer to the coastline with a wider isotopic niche along CR than off BC. This study contributes to the ecological information available for this valuable game fish and provides some insight into the feeding ecology of this species.

SPATIOTEMPORAL DISTRIBUTION OF TUNA AND NON-TUNA SPECIES ASSOCIATED WITH DRIFTING FISH AGGREGATING DEVICES (DFADs) IN THE INDIAN OCEAN, ASCERTAINED THROUGH FISHERY-INDEPENDENT DATA

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Floating objects drifting in the surface of tropical oceans, also called drifting fish aggregating devices (DFADs), attract a great variety of marine species, including tunas and non-tuna species. In the Indian Ocean, purse-seine fishing on DFADs account for about 50% of the overall catch of tropical tunas. Due to the importance and value of this fishery, understanding the habitat characteristics of pelagic species aggregated under DFADs is key to improve fishery management and fishing practices. Hierarchical Bayesian spatial models were used to investigate tuna and non-tuna species spatiotemporal distribution, modelling the presence/absence of tuna through acoustic data derived from fishers' echo-sounder buoys and selected environmental variables (sea surface temperature, chlorophyll, salinity, eddie kinetic energy, oxygen concentration, sea surface height and current heading). These models have some advantages over traditional methods, as Bayesian statistical methods offer the possibility of using both the observed data and the model parameters as random variables, which provide a more realistic and accurate estimation of uncertainty. In addition, Bayesian statistics allow integrating all types of uncertainties using the probability as a metric. Results highlighted species-specific spatial and temporal distributions, suggesting that both tuna and non-tuna species may have different habitat preferences depending on the monsoon period. The new information provided by this study will contribute to the understanding of the ecology and behavior of target and non-target species and the sustainable fishery management of exploited resources.

UPPER TROPHIC LEVEL OPPORTUNISTIC RESEARCH

Bryan Overcash

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CalCOFI cruises present a unique opportunity to collect samples from upper trophic level fish species. The cruise pattern takes the ship and its crew far offshore where many highly migratory species (HMS) thrive. These offshore areas tend to be difficult to sample with regularity. The HMS group at the SWFSC is very interested in obtaining samples from these offshore specimens. CalCOFI cruises visit these offshore areas four times yearly. If utilized, sampling these areas would require no extra funding and could be performed on all annual CalCOFI cruises. Through much of CalCOFI's life fishing has been a part of the culture onboard every ship. It is high time we take advantage of the fish caught on CalCOFI cruises and use them for research.

AGE, GROWTH, AND REPRODUCTION OF YELLOWFIN TUNA *(THUNNUS ALBACARES)* IN THE GULF OF MEXICO

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Biological information derived from direct ageing methods and reproductive tissue analyses is limited for yellowfin tuna (*Thunnus albacares*) in the Gulf of Mexico (GOM). Yellowfin tuna otoliths (n=1300) and gonads (n=500) were sampled by the National Marine Fisheries Service (NMFS) Pelagic Observer Program which sampled commercial catches from the west Florida shelf and by NMFS port agents sampling recreational landings from Louisiana during 2011 to 2017. Yellowfin tuna sampled ranged from 673 -1810 mm straight fork length (SFL). Ages were determined by counting opaque zones in sectioned sagittal otoliths at 50x. Ages ranged from 1 to 18 years with ages 2 and 3 representing the majority of ages (68%), due to the large contribution from the recreational sector (71%). Von Bertalanffy growth curves were estimated for all observations and by sex. Results for the female model were $L\infty = 1548.095$, $k=0.448$, and $to= -0.448$ and for males $L\infty = 1659.53$, $k=0.414$ and $to=-0.315$. Male and female growth curves were significantly different ($p=2.65$ E-05), indicating that males obtain a greater size than females. Whole otoliths weight (g) plotted on age showed a strong linear relationship ($R^2=0.802$). Females with post ovulatory follicles (POFs) were seen as early as March and as late as December, indicating that yellowfin in the GOM may have a longer spawning season than previously documented. Peak spawning occurs from May to August. Length at 50% maturity (L_{50}) for females in the cortical alveolar stage was estimated at 970 mm FL, however a majority of females did not enter the spawning capable phase until they were much larger, around 1100 mm FL. Batch fecundity estimates using the hydrated-oocyte method showed an average of 2 million oocytes released per spawn.

ELECTRONIC MONITORING OF SMALL TUNA PURSE-SEINE VESSEL FISHING ACTIVITIES AND CATCHES

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For the IATTC to meet its scientific responsibilities for management under the Antigua Convention, quality data on vessel activities and on catch of target and non-target species are needed from all eastern Pacific Ocean (EPO) purse-seine fleets. The AIDCP onboard observer program provides detailed data for all Class-6 ("large"; carrying capacity > 363 t) vessel trips. However, trips by Class 1-5 ("small") vessels are rarely sampled by observer programs. Small vessels' logbooks provide basic catch information with respect to target species, but information on tuna discards is unavailable and catch of non-target species can be incomplete or unavailable. Thus, where fisheries management or assessment requires complete catch and bycatch information, other data collection tools are needed. Electronic monitoring systems offer the possibility of providing solutions for some of these challenges. The aim of this study is to evaluate the feasibility of installing and collecting EM data aboard EPO small purse-seine vessels, and the quantitative comparison of various types of EM data and observer data in order to define the implementation and data collection on electronic monitoring systems for small tuna purse-seine vessels.

ENVIRONMENTAL ASSOCIATIONS OF PACIFIC BLUEFIN TUNA (*THUNNUS ORIENTALIS*) CATCH IN THE CALIFORNIA CURRENT SYSTEM

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We investigate the impact of oceanographic variability on Pacific bluefin tuna (*Thunnus orientalis*: PBF) distributions in the California Current system (CCS) using remotely-sensed environmental data, and fishery dependent data from multiple fisheries in the CCS in a habitat modeling framework. We examined the effects of local oceanic conditions (sea surface temperature, surface chlorophyll, sea surface height, eddy kinetic energy), as well as large-scale oceanographic phenomena, such as El Niño, on PBF availability to commercial and recreational fishing fleets. Warmer temperatures generally increased PBF habitat suitability in the Southern California Bight (SCB) and off northern Baja California, and were associated with increased catches in the Commercial Passenger Fishing Vessel (CPFV) and purse seine fleets. These associations were particularly evident during a recent marine heatwave (the "Blob"). Monitoring and understanding changes in the availability of PBF, which are high level predators and important in commercial and recreational fisheries, provides information on their vulnerability to different fisheries and contributes to the implementation of ecosystem approaches to fishery management.

PRELIMINARY PERFORMANCE EVALUATION OF NORMAL VERSUS SHALLOW DEPTH NON-ENTANGLING FADS IN THE EQUATORIAL EASTERN PACIFIC TUNA PURSE-SEINE FISHERY

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Field experiments were designed to enable a statistical evaluation of the performance of normal versus shallow depth non-entangling drifting fish-aggregating devices (FADs) in the equatorial eastern Pacific Ocean (EEPO) purse-seine (PS) fishery; seeking a practical solution to reduce PS fishing mortality on undesirable sizes of bigeye tuna (BET). The experiments were undertaken in collaboration with Negocios Industriales Real S.A. (NIRSA), a vertically integrated large diverse seafood company located in Posorja, Ecuador, with a fleet of 11 tuna PS vessels. The first experiment began in June-July 2015 with deployments of 50 normal and 50 shallow depth FADs and concluded on 31 October 2016. The first experiment yielded catch information from seven different NIRSA PS vessels for sets on experimental FADs for which depths could be verified from IATTC observer records. The catch data obtained during the first experiment was deemed insufficient for conducting a valid statistical analyses to evaluate whether FAD depth is a significant factor with respect to BET catch composition while accounting for set location, month, and other factors. In order to increase the number of sets from normal and shallow depth FADs, a second experiment was undertaken in collaboration with NIRSA. The second experiment began in March-May 2017 with deployments of 100 shallow and 100 normal depth FADs and concluded on 31 December 2017. In both experiments the rafts for the normal and shallow depth FADs were similar construction materials and dimensions (1.2-1.5 m x 2-2.3 m). The appendages hanging beneath the normal depth FADs were approximately 37 m, and consisted of 2 coils of twisted and tied scrap tuna or sardine netting weighted with chain. The appendages hanging beneath the shallow depth non-entangling FADs were approximately 5 m, and consisted of 4 ropes (1-2" dia) with coconut palm fronds tightly laced, attached at the bottom to a split bamboo frame weighted with chain. Marine Instruments (MI) M3i echo-sounder buoys (50 kHz, 50 depth intervals of 3m/ea, 5 min sampling frequency) were attached to each of the FADs. Normal and shallow depth FADs were deployed by NIRSA PS vessels simultaneously in pairs along transects in the EEPO. Each deployment was recorded by the navigator on a data form created specifically for this project which included data fields for FAD type, deployment position and date, M3i buoy number and the NIRSA ID numbers assigned and painted on each buoy. In addition, the IATTC observers aboard monitored and recorded each of the deployments so as to independently verify the FAD type with each buoy ID number. A fishing activity form was provided to all 11 NIRSA PS vessels to be completed when conducting any fishing activities around the experimental FADs, including setting, checking, picking up, and/or redeploying. Results of a preliminary performance evaluation of normal versus shallow depth non-entangling FADs in the EEPO PS fishery, focused on tuna species catch composition, will be presented.

SWORDFISH TAGGING, MIGRATION PATTERNS AND FISHERY DEVELOPMENT OFF THE U.S. WEST COAST

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This work presents data on the coupling of fishery development trials for swordfish with tagging and genetic studies to assess regional movement patterns of swordfish in the Eastern North Pacific (FNA16NMF4270257). Within the study area, swordfish are currently managed as two independent stocks that vary in terms of productivity and current stock status[1]. Off California currently the swordfish resource is considered to be a component of the Western and Central North Pacific Ocean Stock (WCNP). The WCNP is the larger of the two stocks with recent projections suggesting that it is not overfished and that overfishing is not occurring[1]. To better understand migratory behaviors in relation to both the WCNP and neighboring Eastern Pacific Ocean Stock (EPO) boundaries, this work deployed a combination of electronic tags (Cefas G-5 data storage tags, Wildlife computers MR-PAT, Spot and mini-Pat tags) on swordfish during the 2016-2017 field seasons. Each swordfish sampled during the study period was outfitted with at least two electronic tags that were set to pop-off at different times of the year. Pop-off times were chosen to coincide with the spring spawning season and deployment duration ranged from 90 to 180d. Preliminary data from 47 individuals has yielded movement patterns that range from tags reporting proximal to deployment sites, to fish that moved as far as the Equator (0.8°N/132°W). The most common movement trend (47%) has been from Southern California to the south and east towards areas along Southern Baja California and Central Mexico. For 23% of the tagged individuals we observed movements to the west or southwest into the WCNP region, while 30% of tags were recovered or reported within close proximity (<100 km) of the original tagging location. This work has also yielded a relatively high recapture rate of 12% (n=13), with recovered individuals reported from Southern California (46%), within the EPO boundary off Mexico (46%), and within the WCNP boundary off Hawaii (8%). Movement patterns and trends observed throughout the deployments will be discussed in relation to current stock boundaries of the Eastern North Pacific.

[1] Western and Central Pacific Fisheries Commission (WCPFC) (2014) North Pacific swordfish (*Xiphiaus gladius*) stock assessment in 2014. International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, Billfish Working Group Paper WCPFC-SC10-2014/ SA-WP-13. https://www.wcpfc.int/system/files/SC10-SA-WP-13%20North%20Pacific%20Swordfish%20Assmt%20Report%202014.pdf

PROJECTIONS OF CLIMATE DRIVEN CHANGES IN TUNA VERTICAL HABITAT BASED ON SPECIES-SPECIFIC DIFFERENCES IN BLOOD OXYGEN AFFINITY

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Oxygen concentrations are hypothesized to decrease in many areas of the ocean as a result of anthropogenically-driven climate change, resulting in habitat compression for pelagic animals. The oxygen partial pressure, pO_2, at which blood is 50% saturated (P_{50}) is a measure of blood oxygen affinity and a gauge of the tolerance of animals for low ambient oxygen. Tuna species display a wide range of blood oxygen affinities (i.e., P_{50} values) and therefore may be differentially impacted by habitat compression as they make extensive vertical movements to forage on sub-daily time scales. To project the effects of end-of-the-century climate change on tuna habitat, we calculate tuna P_{50} depths (i.e., the vertical position in the water column at which ambient pO_2 is equal to species-specific blood P_{50} values) from 21st century Earth System Model (ESM) projections included in the fifth phase of the Climate Model Intercomparison Project (CMIP5). Overall, we project P_{50} depths to shoal, indicating likely habitat compression for tuna species due to climate change. Tunas that will be most impacted by shoaling are Pacific and southern bluefin tunas – habitat compression is projected for the entire geographic range of Pacific bluefin tuna and for the spawning region of southern bluefin tuna. Vertical shifts in P_{50} depths will potentially influence resource partitioning among Pacific bluefin, bigeye, yellowfin, and skipjack tunas in the northern subtropical and eastern tropical Pacific Ocean, the Arabian Sea, and the Bay of Bengal. By establishing linkages between tuna physiology and environmental conditions, we provide a mechanistic basis to project the effects of anthropogenic climate change on tuna habitats.

WHAT HAVE WE LEARNED? AN OVERVIEW OF 15 YEARS OF ALBACORE ARCHIVAL TAGGING

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The Albacore Archival Tagging Program (AATP) is a collaborative effort of the Southwest Fisheries Science Center and the American Fishermen's Research Foundation to electronically tag juvenile albacore along the U.S. West Coast. Over the last 15 years, the AATP has developed the tagging procedures, the dataset, the analytical infrastructure and the partnerships to provide biological insights into the stock structure, the movement patterns and the catchability of North Pacific albacore. AATP's dataset – with 37 tag recoveries and 42 annual migrations – contains fine scale environmental, physiological and behavioral information across broad spatial and temporal scales. The timing and routes associated with 6 different migration types have been recorded, with movements throughout the North Pacific. The development of new analytical techniques and expertise is just beginning to uncover the mechanistic underpinnings that drive observed albacore movement patterns – from environmental cues to ontogenetic shifts in behavior. Analysis of this dataset, that includes tracks of two and three year durations, has provided insights into how albacore use thermal fronts, documented ontogenetic movement across fisheries, and revealed physiological and behavioral responses to changes in environmental temperatures. The operation is now well-known with an extensive network of informed and engaged fishermen and scientists alike. The AATP provides a valuable long-term platform for research on albacore, a highly migratory species with broad international interest.

LEVERAGING DATASETS: A MECHANISTIC APPROACH TO ESTIMATING CATCHABILITY

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Oceanographic conditions are known to impact catchability – i.e., the probability of catching a fish. However, incorporating oceanographic data into stock assessments remains challenging due to both data limitations as well as available stock assessment models. Thus, catchability parameters are often estimated analytically rather than mechanistically. While tagging datasets can theoretically provide the link between habitat use and oceanographic conditions, they are often disregarded because they constitute a biased and a small sampling of the population. This study examines whether a catchability parameter generated by tagging data – courtesy of the Albacore Archival Tagging Program – can capture trends in the probability of catch given oceanographic conditions found in logbook data of the U.S. North Pacific juvenile albacore surface fishery. The Albacore Archival Tagging Program has recovered 37 fish over the course of the last 15 years with over 11,000 days of minute-by-minute information on depth, light, and temperature. Locations were derived using light-based geolocation. The tagging data from these individuals was used to generate a probability of an albacore being in range of surface fishing gear given a specific oceanographic condition – defined as a combination of sea surface temperature and chlorophyll. To examine whether this analysis of the tagging data provided a useful measure of catchability in terms of the surface fleet, the tag-derived catchability was compared with probability distributions of presence of catch in the logbook data given the same oceanographic conditions. Preliminary results show consistent patterns in surfacing of albacore under specific oceanographic conditions and an interesting comparison between the oceanographic signatures of the fishery effort and that of the tagging data.

MAXIMUM ECONOMIC YIELD AND BIOECONOMICS

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Maximum economic yield (MEY) in the standard bioeconomic model develops maximum economic yield in steady-state equilibrium but in the absence of technological change. BMEY > BMSY in this model, because leaving fish in the water lowers the costs of harvesting and hence increases discounted net economic returns. Adding technological change to the traditional bioeconomic model leads to BMEY < BMSY because fewer fish are required to remain in the water to lower search and harvesting costs and earlier catches and revenues are favored by discounting. Under open access, the new technology, when it is provided from outside of the sector such as electronics to find fish, can lead to the absence of the traditional open-access equilibrium. Simply put, new technology, such as FADs or electronics, finds the fish. Learning about new technology from other fishers (i.e. the diffusion and adoption of new technology) creates a network effect, so that the more that learn and adopt the new technology, the more the new technology is employed. These "knowledge spillovers" lead to continuously lower costs that in turn incentivize increased fishing (increasing returns to scale). Economically optimal BMEY < BMSY is reached even faster. Moreover, because with the basic fish finding technology supplied from the aerospace, information technology, and military sectors, incentives are created under open access to rapidly adopt new technology and there is not a steady-state equilibrium. This bioeconomic model with technological change and allowing for network effects and learning about new technology is illustrated with a simplified example from the northern albacore fishery.

CREDIT SYSTEMS FOR BYCATCH AND TARGET CATCH MANAGEMENT IN INTERNATIONAL FISHERIES

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Incentive-based systems to manage bycatch and target catch are increasingly adopted to add additional effectiveness to traditional approaches of "technological fixes" for gear, equipment, and operating procedures and to replace forms of direct regulation that have proven costly to implement and can be cumbersome and eventually, ineffective. Incentive-based systems in international fisheries present unique challenges that differ than national jurisdictions because of the need to manage within the RFMO system and under the Law of the Sea, notably issues of national sovereignty and RFMO governance. Allocation of permanent or long duration rights, such as transferable rights to catch, effort, capacity, or access, pose particularly thorny challenges due to the sovereignty of States, the self-enforcing voluntary nature of RFMO decision-making and enforcement, RFMO super-majority or consensus requirements, development aspirations of coastal and small island developing States, stocks within Exclusive Economic Zones and the Area Beyond National Jurisdiction (ABNJ), and Law of the Sea allowance for entry into a high seas fishery. Credit systems offer a promising alternative that is incentive-based and fits within the strictures of international fisheries. One type of credit system is a quota or limit, first allocated to CPCs and then to vessels, made flexible by allowance of trade or transfer among vessels of unused portions or carry-forward into the following time period. The quota or limit can be of varying duration, ranging from a single season to multiple seasons to accommodate the planning decisions of large-scale vessels. The CCSBT uses a simple version of this system for target catch and the Alaskan Pollock fishery uses another version for salmon bycatch to incentivize dynamic ocean management (real-time spatial management). A second type of credit system is a penalty-and-reward system (indirect subsidy and tax) that allocates credits of say additional days or areas to fish or penalties of fewer days or areas to fish if vessels meet their bycatch targets. This system, formerly used by the Scottish trawl fishery for cod, was superseded by the EU full retention program. One version is a deposit-refund system for drifting FADs. Both types of credits can be applied to either catch or effort. This talk discusses credit programs and their potential design and application to tropical tuna fisheries.

A BOOTSTRAP ANALYSIS OF FISHERY OPERATION UNDER PROTECTED SPECIES HARD CAPS

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Conservation impacts on protected sea turtles and marine mammals are a longstanding concern in U.S. swordfish fisheries, including the Hawaii shallow-set longline (SSLL) fishery and the west coast drift-gillnet (DGN) fishery. Observer records for these fisheries document a history of rare-event interactions with large cetaceans and endangered sea turtles. Since 2001, leatherback and loggerhead sea turtle interactions in the SSLL fishery have been limited by hard caps, or common-pool limits on the numbers of observed interactions which may occur before the fishery shuts down for the remainder of a season. More recently, in September 2016, the Pacific Fishery Management Council adopted hard caps to strictly limit annual DGN fishery interactions with a range of protected species including fin whale, humpback whale, sperm whale, leatherback turtle, loggerhead turtle, olive ridley turtle, green turtle, short-fin pilot whale, and bottlenose dolphin. Hard caps create a tradeoff between protected species conservation and potential fishery production. Caps set low enough to make closure early in the season a likely event may result in lost fishing effort and quasirents. Uncertainty over closure timing increases the risk to fishing livelihoods. A bootstrap analysis has been developed to simulate the conservation and economic effects of hard caps on DGN fishery operation. The methodology can be used to estimate the impacts of climate-driven changes in protected species distribution and associated interaction rates. Observer, logbook and landings databases and cost-and-earnings survey data are used to calibrate the analysis. Results suggest a substantial loss of economic viability with limited conservation benefits may occur if caps are set at levels which are likely to trigger early season closure.

BUILDING ECONOMICS INTO MANAGEMENT STRATEGY EVALUATION: A GUIDE FOR SETTING SEA TURTLE INTERACTION LIMITS

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As management strategy evaluation methods continue to develop, it is critical to build economics into the fishery management framework. Fishery regulations often create a trade-off between permissible fishing activity and protected species conservation impacts. Fishery managers are therefore tasked with balancing regulatory costs of lost fishing opportunity with marine conservation benefits to protected species populations. Although the direct goal of protected species interaction limits is to reduce the impacts of fishing on protected species conservation, setting optimal regulations requires managers consider the economic costs of these management decisions. I present a Bayesian decision analysis for sea turtle interaction limits applied to Hawaii's longline fishery. This work generates a guide for managers to optimally set sea turtle interaction limits conditional on the value of sea turtle bycatch. The approach is limited by the fact that protected species bycatch is not explicitly valued by society. To address this limitation, I assume managers optimized net social benefits when setting sea turtle regulations from 2004 to 2009 and uncover the implicit value of a sea turtle. Regulations over this period imply large social values for sea turtle bycatch, in the range of $5.1 million per leatherback, and $4.9 million per loggerhead caught. These estimates are intended to facilitate discussions between managers, fishery stakeholders, and the general public to arrive at a consensus value for sea turtle bycatch, serving as a starting point toward identifying optimal protected species conservation regulations. Integrating decision analysis into management strategy evaluation provides an opportunity to implement management rules that meet fishery management goals while optimally balancing the economic costs associated with fishery regulations.

EVALUATING ALTERNATIVE MANAGEMENT STRATEGIES FOR NORTH PACIFIC ALBACORE TUNA

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North Pacific albacore tuna (*Thunnus alalunga*) is a highly migratory species whose range expands the entire North Pacific. Spawning occurs in the tropical and sub-tropical waters of the western and central Pacific Ocean. Juvenile fish then undertake trans-Pacific migrations, with some moving from to the eastern Pacific Ocean to feed in the productive coastal waters of the California Current. This juvenile fish migration sustains lucrative U.S. commercial surface fisheries, in addition to recreational ones. By contrast, the U.S. longline fleet operating out of Hawaii largely catches adults. U.S. vessels account for 17% of North Pacific albacore catch, most (62%) is caught by Japan. The highly migratory nature of this stock and the large number of nations involved in its fisheries necessitates international cooperation via a regional fishery management body, the Western and Central Pacific Fisheries Commission (WCPFC), to ensure effective management. The WCPFC recently discussed the need to improve the current management framework for albacore by identifying formal harvest rules with appropriate limit and target reference points. Here we outline the management strategy evaluation (MSE) process and framework, developed in collaboration with international stakeholders and the WCPFC science advisory body, used to examine the performance of alternative harvest strategies and reference points for North Pacific albacore given uncertainty. Potential uncertainties in mortality, growth, recruitment, and movement (via time varying age-selectivity) were considered. Results presented will provide an overview of the effectiveness of each harvest strategy in achieving specific management objectives, and will highlight trade-offs among the objectives.

MOVEMENT, HABITAT PREFERENCES AND BEHAVIOUR OF SWORDFISH SATELLITE TAGGED AT THE SOUTHERN EXTENT OF THEIR KNOWN RANGE IN AUSTRALIA

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Swordfish (*Xiphius gladius*) are a globally ubiquitous species, found in all the major oceans of the world. Molecular evidence and electronic tagging studies suggest the presence of population structure in the Pacific Ocean, with a lack of trans-equatorial movements and limited connectivity between eastern and western parts of the southwest Pacific. Previous tagging of commercially caught Swordfish in the Australian EEZ have shown very limited evidence of fish migrating south of 40°S. The recent development of a recreational fishery targeting Swordfish off the east coast of Tasmania (40°S - 43°S), however, has shown that the fish do indeed inhabit the cooler waters off the southeast coast of Australia. The fish caught in this area by the recreational fishery have provided an unprecedented opportunity to satellite tag Swordfish caught at the southern extent of their range in Australia. To date, seven pop-up satellite archival tags (PSATs) have been deployed on swordfish off the east coast of Tasmania. The data received has provided novel insights into the broad ranging migrations of the species, with some fish traversing 25° of latitude in a matter of months as fish move north into tropical waters. Data from the tags also reveal a potential migratory path as the fish move north along the western edge of the Lord Howe Plateau. Some fish were also observed to embark on return migrations which generally occurred with the fish moving from the Coral Sea to the shelf break along Australia's east coast before moving south. One fish was observed to return to waters close to where it was tagged after 250 days at liberty, which may indicate the presence of philopatry, similar to that observed in istiophorid billfishes. The tag data also provided insight into the vertical habitat usage of the fish as they migrate from the cool temperate waters adjacent to Tasmania into the tropical waters of the Coral Sea.

POST-LANDING SURVIVAL OF LARGE SWORDFISH CAUGHT USING RECREATIONAL DAY-TIME DEEP DROPPING METHODS

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Swordfish (*Xiphius gladius*) are caught recreationally in some regions around the world, however, the development of the recreational fishery in Australia is very recent. Fishers in Australia target swordfish during the day in depths of approximately 400-600 m in the temperate clines south of 40°. The average size of fish caught is large, with an average weight of 177 kg and a maximum of 356 kg reported to date. As the fishery has developed there has been debate about whether the fishery should be promoted as a catch-and-release fishery, such as the recreational fisheries in Australia targeting istiophorid species. Little was known, however, regarding post-release survival of these large fish caught at depth to inform the debate. Here we assessed post-release survival using pop-up satellite archival transmitters. A total of 17 fish were caught as part of this research. A physiological assessment identified that 47% of fish were not in a condition to be released. Nine fish were released successfully with a satellite tag attached. Two fish died shortly after release. A post-release survival rate of 78% for fish that were identified by physiological assessment as suitable for release was estimated. Considering post-landing mortality combined with post-release mortality an overall survival rate of Swordfish landed was estimated at 41%. Severe barotrauma and deep hooking were identified as significant predictors of mortality. Angling duration was not a significant predictor of mortality. Circle hooks were identified as having a much lower probability of deep-hooking than rigs using J-hooks. A common-sense approach is required by fishers as to whether they should release a fish or retain it (if they are within fisheries management regulations) with consideration of the evidence-based evaluation presented here. We identify several factors that are significant predictors of mortality and these can easily be assessed by fishers. Large swordfish caught at depth during the day are not a good candidate to be promoted as a catch and release only species, and the decision to release should be carefully considered.

THE OCEANOGRAPHIC IN-SITU DATA INTEROPERABILITY PROJECT (OIIP): STATUS AND PROGRESS ONE YEAR ON

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The inherent heterogeneity of oceanographic in-situ datasets and their variable adherence to data standards poses a significant impediment to interoperability and long-term data stewardship. Last year we introduced a NASA-funded, technology development project called OIIP that is a collaboration between NASA/JPL, UCAR/Unidata and the Large Pelagics Research Center (UMASS-Boston). OIIP seeks to address these interoperability challenges with a focus on technology solutions for data from both conventional oceanographic sensors and electronic tags deployed on biological "glider" platforms. The project seeks to demonstrate and deliver a reusable and accessible set of web-based and open source tools to: 1) Mediate reconciliation of heterogeneous source data into a tractable number of standardized, archivable formats consistent with earth science data standards. 2) Develop and implement an improved metadata model for electronic tagging datasets. 3) Enhance the THREDDS server technology for support of point, profile, and trajectory spatial data types. 4) Demonstrate the added value of integrated data access via a range of available tools and services hosted at the PO.DAAC, including a web-based visualization tool for comprehensive mapping and charting of satellite and in-situ data. An innovative part of our project involves engagement with the stakeholder community along the data value chain (instrument manufacturers, data providers, data archives and earth observation standards authorities) to promote the adoption of appropriate data management frameworks. Here we return a year on to provide an update on progress with OIIP tool development efforts.

WEB-BASED TOOLS AND DATA STANDARDS FOR ELECTRONIC TAGGING AND IN-SITU DATASETS: AN INTERACTIVE & CONSULTATIVE WORKSHOP

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This session builds upon the oral presentation of the Oceanographic In-situ data Interoperability Project (OIIP) by showcasing and discussing in more detail the web-based and open source tools developed by the project. The objective of this session is to engage directly with stakeholders, soliciting community comment on OIIP capabilities demonstrated in an interactive workshop setting. Particular attention will focus on three specific areas: 1) integrated web-based visualization of in-situ and satellite remote sensing data, 2) use of ROSETTA to produce standards compliant data files from ASCII source files, 3) extensions of geospatial metadata standards developed during OIIP to support "rich", community specific metadata, such as those associated with electronic tagging datasets. Finally, eTUFF, a single, highly normalized ASCII file format capable of supporting the full range of electronic data representations will also be presented.

ONTOGENETIC CHANGES IN CUTANEOUS AND BRANCHIAL IONOCYTES AND MORPHOLOGY IN YELLOWFIN TUNA (*THUNNUS ALBACARES*) LARVAE

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The development of osmoregulatory and gas exchange organs was studied in larval yellowfin tuna (*Thunnus albacares*) from 2 to 25 days post-hatching (3-25 mm standard length, SL). Cutaneous and gill ionocytes were identified and examined using Na^+/K^+-ATPase immunostaining and scanning electron microscopy. Cutaneous ionocyte abundance significantly increased with SL, but a reduction in ionocyte size and density resulted in significant decreases in relative ionocyte area. Cutaneous ionocytes in preflexion larvae (~3.8 mm SL) had extended microvilli indicative of active ion excretion; however, microvilli retracted into their apical pits in flexion larvae (~6.5 mm SL). The pseudobranch and gills were first detected around ~3.3 mm SL, and both branchial structures had lamellae upon initial development. The nascent pseudobranch already had ionocytes, which were present on both its filaments and lamellae. Ionocytes appeared later on gill filaments (~4.2 mm SL) and interlamellar fusions (~24.5 mm SL), a structural adaptation in ram-ventilating fishes. Ionocytes on the pseudobranch and gills had extended apical microvilli throughout development. Altogether, these results support an osmoregulatory shift from cutaneous to branchial organs during yellowfin tuna early development. The appearance of lamellae before ionocytes in the gills indicates that the gill plays a role in gas exchange before osmoregulation. These results also suggest the pseudobranch is important in osmoregulation during early larval development. This study provides baseline knowledge for future environmental and aquaculture studies in yellowfin tuna, a species that supports multi-billion dollar fisheries worldwide.

THE SPATIOTEMPORAL DYNAMICS OF YELLOWFIN TUNA (*THUNNUS ALBACARES*) IN THE EASTERN PACIFIC OCEAN

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We applied a size-structured, spatiotemporal, delta-generalized linear mixed model to the size-structured catch rate of yellowfin tuna (*Thunnus albacares*) for the dolphin-associated purse-seine fishery in the Eastern Pacific Ocean. The spatiotemporal model can standardize the index of abundance for each size bin and estimate the correlations of spatial and spatiotemporal residuals among those size bins. We used the spatiotemporal model to predict the spatial distribution of yellowfin tuna for each size bin and examine the difference in the spatial distribution for various life stages, namely, the condition of size-segregation of available habitat. Preliminary results suggested that small yellowfin tuna tends to reside in warmer waters off Mexico and large yellowfin tuna tends to reside in cooler but more productive pelagic and equatorial waters. Pronounced size-segregation was also found in the spatiotemporal residuals of predicted catch rate, suggesting that small and large yellowfin tunas have differing habitat preferences. We then examined how environmental conditions affect the spatial distribution of yellowtail tuna at each life stage by evaluating the relationship between predicted catch rate and sea surface temperature for each size bin. Understanding how habitat preference changes over life stages is crucial to spatial fisheries management and predicting the hotspots for dolphin-associated fishery using real-time environmental observations.

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