### PROCEEDINGS OF THE 74<sup>th</sup> Annual Tuna Conference

### Bridging and filling the gaps

Uniting stakeholders and science through dialogue for successful conservation and management strategies in pelagic fisheries



LAKE ARROWHEAD, CALIFORNIA MAY 20-23, 2024

### **PROCEEDINGS OF THE 74th ANNUAL TUNA CONFERENCE**

Lake Arrowhead, California, May 20<sup>th</sup> - 23<sup>rd</sup> 2024



#### Melanie Hutchinson - Chair

#### Peggy Loor and JoyDeLee Marrow - Coordinators

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



#### PREFACE

Welcome to the 74<sup>th</sup> 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-associated" species. The free and open exchange of ideas is what makes the Tuna Conference such a unique forum and has formed the basis for many successful collaborations, projects and careers!

The theme for this year's Tuna Conference is "Bridging and filling the gaps: Uniting stakeholders and science through dialogue for successful conservation and management strategies in pelagic fisheries." In an era where large amounts of data are newly available to address complex issues in large fisheries spanning whole ocean basins, how do we as a community of resource users, including managers and policy makers, scientists, fishers and industry personnel, communicate research priorities and what data gaps are preventing the implementation of meaningful management actions, and then work together to find solutions? This year, we want to focus on mechanisms that bridge the gaps between management, science, and industry by engaging personnel across disciplines and fisheries sectors in a productive conversation where we share ideas and success stories. Recognizing the need for multidisciplinary collaboration and greater inclusion of key stakeholders in fisheries science and management, we welcome presentations and posters that demonstrate how the integration of diverse perspectives has been instrumental in the development and implementation of conservation measures. 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 three days, there will be 46 oral presentations across 8 sessions. We also have an additional 7 presentations in the poster session. Special thanks to this year's session moderators: Dan Fuller, Joe O'Malley, Dan Ovando, John Hyde, Kim Holland, Suzy Kohin, Stephen Stohs, Leslie Roberson and Camille Pagnielo. We sincerely appreciate their efforts to keep sessions running smoothly.

The abstracts for the oral and poster presentations contained in the Proceedings are listed as presented. Bold lettering denotes the author giving the presentation. 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, John Hyde, Travis Richards, Leanne Fuller, Dan Crear, and Salvador Siu 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 11 student scholarships this year. The Tuna Conference Scholarship was awarded to Chloe Mikles for her talk titled, "Signals of neutral and adaptive divergence in Atlantic bluefin tuna revealed by whole genome sequencing". The Manuel Caboz scholarship was awarded to Ciara Willis for her talk, "Evaluating the contributions of mesopelagic prey to tunas and swordfish in the open ocean using compound-specific stable carbon isotope analysis". The David Linney Memorial Scholarship was awarded to Elena Fernández-Corredor for her presentation titled, "Environmental and human drivers shape the trophic ecology of a widespread marine predator". The Albacore Research Foundation (formerly known as American Fisherman's Research Foundation) Scholarship was awarded to Zurisaday Ramirez-Mendoza for her talk titled, "Mesoscale activity drives the habitat suitability of yellowfin tuna in the Gulf of Mexico: Seasonal and interannual predictions". The Wildlife Computers Scholarship was awarded to Roselyn Aquila for her talk titled, "Population structures of swordfish (Xiphias gladius) in the eastern Pacific Ocean based on genomic and satellite tagging data". This year we are extra grateful to the Sportfishing Association of California for sponsoring the following six student scholarships: Joseph Dello Russo for his talk titled, "Proposing the Fisheries Industrial Complex as a Critical Component to the Marine Fisheries Research Machine"; Blaise Jenner for his talk, "Cooperative research and stakeholder engagement reveals three substantial shifts in the foraging ecology for Atlantic bluefin tuna (Thunnus thynnus) in the Gulf of Maine"; Ryan Kueber for his talk, "Catch method, quality, and price formation in the Japanese swordfish fishery"; Rachel Willard for her talk, "Distribution of Southern Bluefin Tuna Larvae"; Pamela Pacheco Aldana for her talk, "Seasonal and ontogenic differences in the trophic spectrum of the striped marlin (Kajikia audax) in Cabo San Lucas, Baja California Sur"; and Jessica Henkens for her talk titled, "Diet and nutrition of wild and captive southern bluefin tuna (Thunnus maccovii) associated with changing population distributions in Southern Australia". We also want to



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acknowledge and thank the International Seafood Sustainability Foundation for sponsoring the travel costs for the top six student scholarship winners.

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 and other 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. for providing refreshments. We thank the Woods Hole Group for providing refreshments for the movie night. We gratefully acknowledge all our donors from the Albacore Research Foundation, International Seafood Sustainability Foundation, Sportfishing Association of California, Walter Golet and the David Linney Memorial Scholarship, The Woods Hole Group, Prime Time Seafood Inc., and Wildlife Computers Inc.

We would like to also thank Scott Aalbers, Dan Fuller, Craig Heberer, Kim Holland, John Hyde, David Itano, Chugey Sepulveda, Joe O'Malley, John O'Sullivan, Dan Ovando, Joshua Tucker and Owyn Snodgrass for volunteering to be our gracious team of sashimi and poke cutters. Thanks go Dave Itano and to Russell Ito *in absentia* for sharing their amazing poke recipes. Many thanks to Santiago Olivares for his time, sense of humor and AI image generation skills for playing with our ideas to create the artwork on the cover page. We are also grateful to Jorge Parraga and Salvador Siu for the inspiration. Our graphic designer Chris Patnode put her creativity and invaluable help to work on the logo and the Tuna Conference website. Special thanks to Peggy Loor for creating the nametags and for the beautifully designed and framed student certificates. 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.

This year we have a special evening documentary presentation from Shark Stewards. We want to thank David McGuire and Deron Verbeck for sharing their film and for inspiring a movie night where others can also share their wildlife videography.

Last but certainly not least, we want to thank all of you for being a part of the 74<sup>th</sup> Tuna Conference. After all, it is the quality of your presentations, collegial and productive discourse and camaraderie 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 75<sup>th</sup> Tuna Conference!

**Melanie Hutchinson** 74<sup>th</sup> Tuna Conference Chair **Peggy Loor** 74<sup>th</sup> Tuna Conference Co-Coordinator **JoyDeLee Marrow** 74<sup>th</sup> Tuna Conference Co-Coordinator



### 74th TUNA CONFERENCE AGENDA

#### Monday, 20 May 2024

**11:00** Registration opens in the Library (continued throughout the conference)

#### 13:00 Welcome and Introduction in Pineview

#### SESSION 1: Starting with Biology- diet and physiology (Moderator: Dan Fuller )

- **13:20** Foraging ecology, prey preference, and prey energetics of bigeye tuna (*Thunnus obesus*) in the northwest Atlantic Mackenzie O'Donnell, Riley Austin, Walter J. Golet
- 13:40 Diets of pacific bluefin tuna (*Thunnus orientalis*) in the southern California Bight from 2020-2023 Travis
  M. Richards, Antonella Preti, Owyn Snodgrass, Heidi Dewar, and Barbara Muhling
- 14:00 Diet and nutrition of wild and captive southern bluefin tuna (*Thunnus maccoyii*) associated with changing population distributions in southern Australia Jessica Henkens\*, Ryan Baring, Lauren Meyer, Charlie Huveneers, Kirsten Rough and Heidi Pethybridge
  \*Sportfishing Association of California Scholarship
- 14:20 Cooperative research and stakeholder engagement reveals three substantial shifts in the foraging ecology for Atlantic bluefin tuna (*Thunnus thynnus*) in the Gulf of Maine Blaise Jenner\*, John Logan, Lisa Kerr, Matthew Cieri, Walter J. Golet \*Sportfishing Association of California Scholarship

#### 14:40 Coffee Break (30 minutes)

15:10 Environmental and human drivers shape the trophic ecology of a widespread marine predator — Elena Fernández-Corredor\*, Alba Fuster-Alonso, Francisco Ramírez, Joan Giménez, Salvador García-Barcelona, David Macías, Marta Coll, Joan Navarro
 \*David Linney Memorial Scholarship / International Seafood Sustainability Foundation Travel Award winner

- 15:30 Seasonal and ontogenic differences in the trophic spectrum of the striped marlin *Kajikia audax* (Philippi, 1887) in Cabo San Lucas, Baja California sur Pamela Pacheco Aldana\*, Sofia Ortega-Garcia, Leonardo Andres Abitia-Cardenas, Ulianov Jakes-Cota, Arturo Tripp-Valdez, and Antonella Preti
  \*Sportfishing Association of California Scholarship
- 15:50 Evaluating the contributions of mesopelagic prey to tunas and swordfish in the open ocean using compound-specific stable carbon isotope analysis Ciara Willis\*, Kayla G. Gardner, Martin C. Arostegui, Camrin D. Braun, Walt Golet, Leah Houghton, Joel K. Llopiz, Simon R. Thorrold \*Manuel Caboz Scholarship / International Seafood Sustainability Foundation Travel Award winner
- 16:10 Insights into the ontogenetic development of yellowfin tuna (*Thunnus albacares*) from physiological energetics **Takaaki Hasegawa**, Marko Jusup, Kei Okamoto, and Keisuke Satoh Fisheries Research and Education Agency, Fisheries Resources Institute, Yokohama, Japan.
- **18:30** Dinner followed by 'Welcome Gathering' in Lakeview and movie night in Pineview Refreshments provided by the Woods Hole Group



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#### Tuesday, 21 May 2024

#### 8:00 Breakfast

#### SESSION 1 (continued): Starting with Biology - physiology, ageing and genomics (Moderator: Joe O'Malley)

- **9:00** Highly maintained heat production capacity contributes to the initial step of endothermal development in pacific bluefin tuna **Takaaki K. Abe**, Maho Fuke, Ko Fujioka, Takuji Noda, Takashi Kitagawa
- **9:20** Routine and postprandial oxygen consumption rates and swimming speeds in dolphinfish (*Coryphaena hippurus*) **Nicholas C. Wegner**, Heather Fenix, Zachary R. Skelton, Sofía Ortega-García, Rubén Rodríguez-Sánchez, John O'Sullivan
- 9:40 Determining the preferred structure for aging smalleye pacific opah (*Lampris incognitus*) María del Carmen Rodriguez-Medrano, Zurisaday Ramirez-Mendoza, Oscar Sosa-Nishizaki, Nicholas Wegner, John Hyde, Joseph O'Malley, Owyn Snodgrass, Heidi Dewar, Scott Aalbers, and Chugey Sepulveda
- 10:00 Signals of neutral and adaptive divergence in Atlantic bluefin tuna revealed by whole genome sequencing —
  Chloe S. Mikles\*, J. R. Rooker, Aurelio Ortega, Fernando de la Gándara, and Barbara A. Block
  \*Tuna Conference Scholarship / International Seafood Sustainability Foundation Travel Award winner

#### 10:20 Coffee Break (20 minutes)

10:40 Population structures of swordfish (*Xiphias gladius* l.) in the eastern Pacific Ocean based on genomic and satellite tagging data — Roselyn D. Aguila\*, Scott Aalbers, Chugey Sepulveda, Jaime R. Alvarado-Bremer \*Wildlife Computers Scholarship / International Seafood Sustainability Foundation Travel Award winner

#### SESSION 2: Engaging stakeholders to address complex fishery management issues (Moderator: Dan Ovando)

- 11:00 Uniting science and stakeholders for sustainable tuna management: a collaborative approach to developing harvest strategies in the western and central Pacific Ocean Nan Yao, Robert Scott, Finlay Scott, Paul Hamer, Graham Pilling
- 11:20 Collaborating with longline fishers to improve the post-release survival of mobula rays Jennifer Stahl, Melanie Hutchinson, Chelsey Young, Joshua Tucker, Forest O'Neil, and Emily Crigler
- 11:40 Fisheries development: where does it fit with conservation and management strategies for pelagic fisheries? David Itano

#### 12:00 Lunch

- **13:30** Integrating science and stakeholder input: an example from the north pacific albacore tuna management strategy evaluation and harvest strategy adoption processes **Steven L. H. Teo**, Celia Barroso, Valerie Post, and Desiree Tommasi
- 13:50 Over a decade of collaboration between the Sportfishing Association of California (SAC), NOAA Southwest Fisheries Science Center (SWFSC), and California Department of Fish and Wildlife (CDFW) Alayna Siddall, Ken Franke, Steve Crooke, Steve Williams, Gerard DiNardo, Dale Sweetnam, Heidi Dewar, Kelsey James, Owyn Snodgrass, Elizabeth Hellmers, Melissa Monk, Lyall Bellquist
- 14:10 Cooperative fisheries research on highly migratory species in the eastern Pacific Ocean Owyn Snodgrass and Heidi Dewar



14:30 Exploring variability among individual vessels to identify existing elasmobranch bycatch avoidance strategies — Leslie Roberson

#### 14:50 Coffee Break (20 minutes)

15:10 Proposing the fisheries industrial complex as a critical component to the marine fisheries research machine
 — Joseph Dello Russo\*, Andy Danylchuk, Lucas Griffin, Grace Casselberry, Walter Golet
 \*Sportfishing Association of California Scholarship / International Seafood Sustainability Foundation Travel Award winner

#### SESSION 3: Catch condition and quality (Moderator: John Hyde)

- 15:30 Assessing trends in indirect measurements of condition for Atlantic bluefin tuna in the western Atlantic John A. Carlucci, Dr. Walter Golet
- **15:50** A gem or a boot? Examining the quality of commercially caught rod and reel Atlantic bluefin tuna, *Thunnus thynnus*, from the perspective of anglers **Kaylyn Zipp**, Walter Golet
- 16:10 Catch method, quality, and price formation in the Japanese swordfish fishery Ryan Kueber\* and Nobuyuki Yagi
  \*Sportfishing Association of California Scholarship

16:30 Poster Session and Sushi Social in Lakeview – Sashimi donated by Prime-Time Seafood, Inc. and refreshments donated by Wildlife Computers

Electronic monitoring performance in a developing deep-set fishery for swordfish off California — **Scott Aalbers**, Mike Wang, Charles Villafana, Kate Kauer, Lyall Bellquist, and Chugey Sepulveda

Electronic Monitoring in Hawai'i Longline Fisheries — Chloe Moore, Andrew Lanza, Jennifer Stahl, Joshua Tucker, Keith Bigelow

Using multi-taxa marine isoscapes to assess potential provenance of dolphinfish captured off Cabo San Lucas, Mexico — Sergio A. Briones-Hernández, Ulianov Jakes-Cota, John M. Logan, John O'Sullivan, **Sofía Ortega-García** 

Mapping the distribution of the pelagic stingray in the eastern Pacific Ocean — Andrés Romero, Jon Lopez

Joining the dots; linking management, conservation, and broad phenological shifts of Atlantic bluefin tuna - a perspective from the Straits of Gibraltar — **Samantha Slisarenko**, Awantha Dissanayake

Investigating non-lethal deterrents to reduce interactions and mortality of oceanic whitetip sharks and other protected species around Hawai'i — **Thomas TinHan**, Molly Scott, Melanie Hutchinson

Together towards tomorrow: western stock Atlantic bluefin tuna, *Thunnus thynnus*, close-kin mark-recapture abundance estimation — Walter Golet, **Kaylyn Zipp**, Matthew Lauretta, John Walter, Peter Grewe, Mark Bravington, Robin Thomson, Shane Baylis, Alex Hanke, Dheeraj Busawon, Jan McDowell, Campbell Davies

#### 18:30 Dinner



#### Wednesday, 22 May 2024

#### 8:00 Breakfast

#### SESSION 4: Technological advancements in telemetry (Moderator: Kim Holland)

#### 9:00 ARGOS: Future constellation upgrades — Thomas Gray

**9:20** The potential of high-resolution geomagnetic and accelerometer equipped geolocators to enhance the understanding of the ecology and movement of migratory fish — **Takuji Noda**, Takuya Koizumi, Ko Fujioka

#### SESSION 5: Habitat use, movement behavior, predicting hotspots (Moderator: Suzy Kohin)

- 9:40 Atlantic bluefin tuna tagged off Norway show extensive annual migrations, high site-fidelity and dynamic behaviour in the Atlantic & Mediterranean Sea Camille M.L.S. Pagniello, Keno Ferter, Barbara A. Block, Otte Bjelland, Michael R. Castleton, Sean Tracey, Theodore J. Reimer, Andreas Sundelöf, Iñigo Onandia, Martin Wiech, Francisco Alemany, Leif Nøttestad
- 10:00 Seasonal site fidelity by salmon sharks demonstrates the influence of scale on identifying potential high-use areas and vulnerabilities Natalie S. Arnoldi, Aaron B. Carlisle, Samantha Andrzejaczek, Michael R. Castleton, Fiorenza Micheli, Robert J. Schallert, Timothy D. White, Barbara A. Block

#### 10:20 Coffee Break (20 minutes)

- 10:40 Illuminating the effects of the moon: ecological impacts of the lunar cycle on tuna, billfish, sharks and rays
   Samantha Andrzejaczek, Alexandra E. DiGiacomo, Chloe S. Mikles, Camille M. Pagniello, Theodore E.J. Reimer and Barbara A. Block
- 11:00 Mesoscale activity drives the habitat suitability of yellowfin tuna in the Gulf of Mexico: seasonal and interannual predictions Zurisaday Ramírez-Mendoza\*, Oscar Sosa-Nishizaki, Mario A. Pardo, Sharon Z. Herzka, R. J. David Wells, Jay R. Rooker, Brett J. Falterman, Michel J. Dreyfus-León
  \*Albacore Research Foundation Scholarship / International Seafood Sustainability Foundation Travel Award winner
- **11:20** Factors affecting catch rates in the Hawai'i shallow-set longline fishery **Justin J. Suca**, Johanna L.K. Wren, Robert Ahrens, Ryan R. Rykaczewski, Phoebe Woodworth-Jefcoats, and Donald Kobayashi
- 11:40 Distribution of Southern Bluefin Tuna Larvae Rachel Willard\* \*Sportfishing Association of California Scholarship
- 12:00 Lunch
- 13:30 Overlap between Atlantic fishing fleets and distributions of highly migratory pelagic species reveals hotspots of potential management interest Emilius Aalto, Jonathan Dale, Timothy White, Christian Jones, John Walter, and Barbara Block

#### SESSION 6: Improving fishery selectivity (Moderator: Steven Stohs)

13:50 Shark deterrent research in Hawaii — Kim Holland, Lauren Arnold, Edward Cardona, Kaylee Skidmore-Rossing and Carl Meyer



14:10 Deep-set fishery development research and exempted trials off the U.S. west coast — Chugey Sepulveda and Scott Aalbers

#### SESSION 7: Improvements to monitoring and management capacity (Moderator: Leslie Roberson)

14:30 The IATTC workplan for the implementation of an EMS in the EPO: Process and stakeholders — Marlon H Roman, Jon Lopez, Brad Wiley, Alexandre Aires-da-Silva, Jean-François Pulvenis

#### 14:50 Coffee Break (30 minutes)

- **15:20** Artificial intelligence (AI) models developed from electronic monitoring video provide an opportunity to automate detection of catch in the Hawai'i longline fisheries **Joshua Tucker**, Jennifer Stahl, Keith Bigelow
- **15:40** Combatting illegal, unreported, and unregulated fishing with Edge computation in the Eastern Tropical Pacific Vienna Saccomanno, Ben Gilmer, Alvaro Teran, and **Craig Heberer**.
- 16:00 TUN-AI: utilizing echo-sounder buoys as floating sampling stations to monitor tuna biomass Daniel Precioso, Manuel Navarro-García, Kathryn Gavira-O'Neill, Alberto Torres-Barrán, David Gordo, Víctor Gallego, David Gómez-Ullate
- 16:20 Exploring technologies for remote identification of FADs Jon Lopez, Marlon Roman, Jose Luis Beloso, Gonzalo Legorburu
- **16:40** Business Meeting (Everyone is welcome)
- 18:30 Dinner Tuna Barbeque
- 20:00 Karaoke night in Lakeview

#### Thursday, 23 May 2024

#### 8:00 Breakfast

#### SESSION 8: Putting it all together to improve assessment and management (Moderator: Camille Pagniello)

- 9:00 Informing the spatial management of silky shark *Carcharhinus falciformis* in the eastern Pacific Ocean Brendan S. Talwar, Brice X. Semmens, Alexandre Aires-Da-Silva, Darcy Bradley, Jenn Humberstone, Melanie Hutchinson, Jon Lopez, Carolina Minte-Vera, Dan Ovando, Salvador Siu, Lyall F. Bellquist
- 9:20 Predicting, assessing, and communicating the effects of spatial management in pelagic fisheries Dan Ovando
- **9:40** Climate-resilient fisheries: available tools and a proposed workplan for IATTC **Daniel Crear**, Jon Lopez, Leanne Fuller
- 10:00 Uniting stakeholders and science to assess the efficacy of potential conservation measures on the vulnerability status of the critically endangered east pacific leatherback turtle (*Dermochelys coriacea*) caught in pelagic fisheries Shane Griffiths, Bryan Wallace, Verónica Cáceres, Jon Lopez, and the East Pacific Leatherback Ad Hoc Joint Working Group



- 10:20 Coffee Break (30 minutes) Please check out of your room by 11:00 a.m.
- **10:50** Bayesian estimation of catch performance in novel fishing methods **Stephen M. Stohs,** Karter Harmon, and Lyall Bellquist

11:10 Sustainability of Global Tuna Fisheries According to the Seafood Watch Standard — Eva May, Santi Roberts, Sam Wilding, Andre Boustany

#### 11:30 Final remarks

- 12:00 Lunch
- 13:00 Drive safe and hope to see you next year!



# Abstracts



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#### ELECTRONIC MONITORING PERFORMANCE IN A DEVELOPING DEEP-SET FISHERY FOR SWORDFISH OFF CALIFORNIA

Scott Aalbers<sup>1</sup>; Mike Wang<sup>1</sup>; Charles Villafana<sup>2</sup>; Kate Kauer<sup>3</sup>; Lyall Bellquist<sup>3,4</sup> and Chugey Sepulveda<sup>1</sup>

<sup>1</sup>Pfleger Institute of Environmental Research <sup>2</sup>NOAA West Coast Regional Office <sup>3</sup>The Nature Conservancy, California <sup>4</sup>Scripps Institution of Oceanography

Electronic monitoring (EM) has been incorporated into data collection efforts for industrialized fisheries worldwide; however, use on smaller fishing vessels remains limited. We tested the performance of small-vessel EM systems to meet the reporting requirements in the California deep-set buoy gear fishery (DSBG) targeting swordfish (*Xiphias gladius*). Two EM service providers were contracted to develop monitoring platforms, which included both 1 and 2-camera systems. Initial testing was performed onboard the PIER research vessel to identify functional configurations and refine data collection procedures prior to testing on commercial fishing vessels. Commercial trials were performed onboard 4 vessels that participated in deep-set EFP trials during the 2021-22 fishing seasons. Fishery performance metrics from EM records collected during 126 monitored sets were compared between service providers, fisher logbooks, and NOAA-certified observer data. Catch comparisons with logbook and observer data yielded full agreement (100%) for both target (109/109) and incidental catch (9/9) using 2-camera EM system records. Whereas, records from a 1-camera system yielded 88% agreement (52/59) for target catch and 14% (1/7) for incidental catch. Unquantified catch events occurred outside the 1-camera field of view onboard larger vessels with independent hauling and catch-processing areas. Collectively, this study demonstrated that EM can be used to accurately document fishery catch statistics in the recently-authorized commercial DSBG fishery.



#### OVERLAP BETWEEN ATLANTIC FISHING FLEETS AND DISTRIBUTIONS OF HIGHLY MIGRATORY PELAGIC SPECIES REVEALS HOTSPOTS OF POTENTIAL MANAGEMENT INTEREST

Emilius Aalto<sup>1</sup>, Jonathan Dale<sup>1</sup>, Timothy White<sup>2</sup>, Christian Jones<sup>3</sup>, John Walter<sup>3</sup>, and Barbara Block<sup>1</sup>

<sup>1</sup>Stanford University <sup>2</sup>Global Fishing Watch <sup>3</sup>NOAA

Due to their large ecological niche and high commercial value, highly migratory pelagic species such as bluefin tuna and blue marlin are exposed to fishing pressure across the Atlantic. Although spatial catch and effort data are provided to the International Commission for the Conservation of Atlantic Tunas (ICCAT) under the organization's Task 2 program, the accuracy and representativeness of these statistics are difficult to verify. However, fleet behavior (e.g., vessel course and speed, deployment of fishing gear) can increasingly be monitored using data from ship detection technologies such as the Automatic Identification System (AIS) and a wide range of vessel monitoring systems. At the same time, electronic tagging has provided both direct daily location estimates for individuals of a species as well as broader insights into the suitable seasonal habitat they occupy. Here, we combined tagging-based species distribution maps with estimates of monthly pelagic longline effort derived from AIS data to identify times and regions of high overlap between species and fleet. By comparing these regions with the species-specific CPUEs reported to ICCAT (typically at 5°x5° resolution), we identified combinations of species, regions, months, and fleets that are of potential interest to management of the species. We examined regions where fleets are fishing and used presence data and habitat models to project the potential catch species, allowing us to estimate the accuracy of reported catch records. This approach may be useful to management enforcement agencies and may provide evidence of fleets that are under-reporting.



#### HIGHLY MAINTAINED HEAT PRODUCTION CAPACITY CONTRIBUTES TO THE INITIAL STEP OF ENDOTHERMAL DEVELOPMENT IN PACIFIC BLUEFIN TUNA

Takaaki K. Abe<sup>1, 2</sup>, Maho Fuke<sup>1</sup>, Ko Fujioka<sup>3</sup>, Takuji Noda<sup>4</sup>, Takashi Kitagawa<sup>1, 5</sup>

<sup>1</sup>Atmosphere and Ocean Research Institute, The University of Tokyo, Japan
 <sup>2</sup>College of Bioresource Science, Nihon University, Japan
 <sup>3</sup>Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Japan
 <sup>4</sup>Field Science Education and Research Center, Kyoto University, Japan
 <sup>5</sup>Graduate School of Frontier Sciences, The University of Tokyo, Japan

An important trait of Pacific bluefin tuna (PBT) is its ability to maintain body temperature through high metabolic heat and body insulation. PBT rapidly develops the thermo-conservation ability in 20-40 cm fork length (FL), which has been attributed to improved insulation. Meanwhile, how heat production capacity develops during ontogeny is not well understood. The aim of this study was to explore the ontogenetic change in metabolic heat and its to endothermic swim-tunnel respirometry and heat-budget model. Swimcontribution ability through tunnel respirometry was conducted on PBT, ranging from 19.4 to 27.5 cm FL (94-330 g, n = 16) in Kochi Prefecture, Japan, from August to September 2022 and 2023. The metabolic rate of each PBT was calculated as the standard metabolic rate  $(B_{SMR})$  at a swim speed of 0 cm/s and the minimum metabolic rate  $(B_{Umin})$  at a minimum swim speed of 44.3 cm/s. The scaling exponents of  $B_{\text{SMR}}$  and  $B_{\text{Umin}}$  were estimated at 1.03 and 0.93, respectively. Both scaling exponents were higher than those estimated in the species of tribe *Thunnini* above 300 g (0.5–0.6). Furthermore, the scaling exponents close to 1 imply that the heat-production rate ( $\dot{T}_m$  in °C/min) in heat-budget model does not decrease in this size range. To explore the ontogenetic change in the heat-production rate of PBT in nature, a heat-budget model was applied to bio-logging data collected from nine juveniles (size of analysis: 23-60 cm FL; 200–5272 g) with electronic archival tags inserted into their body cavities. The heat-production rates did not decrease until approximately 800 g and declined thereafter, supporting the respirometry results. In addition, we evaluated the effects of the heat production rate on the thermo-conservation ability and found that maintaining a high heat production rate mainly contributed to the initial step of the difference between body temperature and water temperature.



#### POPULATION STRUCTURES OF SWORDFISH (Xiphias gladius L.) IN THE EASTERN PACIFIC OCEAN BASED ON GENOMIC AND SATELLITE TAGGING DATA

Roselyn D. Aguila<sup>1</sup>, Scott Aalbers<sup>2</sup>, Chugey Sepulveda<sup>2</sup>, Jaime R. Alvarado-Bremer<sup>1</sup>

<sup>1</sup> Texas A&M University at Galveston, Texas, USA <sup>2</sup> Pfleger Institute of Environmental Research, California, USA

Pacific swordfish (Xiphias gladius L.) is a eurythermal apex predator found in most tropical and temperate oceanic waters, where it is subject to intense commercial fisheries using longlines, accounting for 40,994 mt which represents 42.5% of the swordfish global catches in 2021 (FAO FishStat, 2024). Despite its importance as a fishery resource, and as a top predator, the genetic population structure of swordfish is poorly understood. Fisheries data has been interpreted to support 1, 2, 3, or even 4 stocks; and currently, Eastern Pacific swordfish is managed as belonging to two stocks-the Western and Central North Pacific (WCNPO) and the Eastern Pacific Ocean (EPO). Several genetic studies have rejected a panmictic population of Pacific swordfish, but no clear delineation of stock structure has been advanced. Other highly migratory fishes that appear to lack genetic differentiation in the Pacific using allozymes and mitochondrial DNA are now known to display a strong signal of genetic structuring using genome-wide singlenucleotide polymorphisms (SNPs), including Pacific yellowfin tuna that displays discrete east and west stocks (Grewe et al., 2015) and striped marlin that displays four distinct stocks within the Pacific (Mamoozadeh et al., 2020). Evidence of population structuring in Pacific swordfish is supported by the results of electronic satellite tagging off Southern California, where horizontal displacements towards and from the southern eastern Pacific Ocean and the Central North Pacific Ocean, suggest that this region does not constitute a single unit (Sepulveda et al., 2020). In this study, we seek to characterize 48 of these satellite-tagged swordfish with SNP data obtained through ddRAD sequencing to test whether they belong to two genetically discrete populations that share the feeding grounds off Southern California. We also test alternative hypotheses of stock structure for eastern Pacific swordfish, including the Brodziak & Ishikawa (2008) three-stock model that is currently adopted by the International Scientific Committee (ISC) for Tuna and Tuna-Like Species in the North Pacific Ocean.



#### ILLUMINATING THE EFFECTS OF THE MOON: ECOLOGICAL IMPACTS OF THE LUNAR CYCLE ON TUNA, BILLFISH, SHARKS AND RAYS

## Samantha Andrzejaczek<sup>1</sup>, Alexandra E. DiGiacomo<sup>1</sup>, Chloe S. Mikles<sup>1</sup>, Camille M. Pagniello<sup>1</sup>, Theodore E.J. Reimer<sup>1</sup> and Barbara A. Block<sup>1</sup>

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The moon's influence on marine ecosystems is a popular subject of discourse among scientists, fishing communities, and the public. As the moon orbits the earth across an approximate 29.5-day cycle, it influences marine ecosystems by altering nighttime light availability and shaping the strength and timing of tides. Numerous studies have documented the effects of the lunar cycle on large epipelagic fishes (here referring to tuna, billfish, sharks and rays), however, there has been no concerted effort to systematically compare these patterns across studies. Here, we review a total of 190 studies documenting the effects of the lunar cycle on the ecology of large epipelagic fishes and discuss the potential underlying factors that contribute to the observed patterns. Most studies focused on fisheries science and movement ecology, examining metrics such as catch rate and depth of tagged individuals respectively. A smaller proportion of studies delved into foraging behaviors and behavioral patterns. The effects observed varied among study types and taxa, yet vertical movement patterns consistently indicated a trend of deeper movements with increasing lunar illumination. Many factors likely contribute to this variation, including study specific methods (both field and analytical), local site variation (such as local oceanography and prey distribution), species specific traits (such as distribution and foraging strategy) and individual traits (such as ontogenetic stage and body condition). We conclude by proposing a framework for future studies on lunar effects, aimed at addressing this variation and promoting comparative analyses.



#### SEASONAL SITE FIDELITY BY SALMON SHARKS DEMONSTRATES THE INFLUENCE OF SCALE ON IDENTIFYING POTENTIAL HIGH-USE AREAS AND VULNERABILITIES

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Considering habitat use throughout highly mobile marine species' whole range is necessary to understand life history, identify vulnerabilities, and inform effective management. We used satellite tagging data from 128 adult female salmon sharks to identify seasonal hotspots of activity in an extended California Current region (ECCR; encompassing the California Current Large Marine Ecosystem); an area far away from their well-described primary habitat in the Alaska Downwelling Region (ADR) where they have been documented, but whose utility has been poorly understood. Tag track durations had a mean of  $447.7 \pm 381$  days and 88 sharks (68.8%) visited the ECCR, comprising 33.6% of 28,019 total daily Argos detections. Tracking data revealed that the timing and duration of migrations to the ECCR varied, but salmon shark distribution within the ECCR displayed consistent latitudinal shifts in accordance with regional oceanographic seasons. High site fidelity across multi-year tracks to high productivity features, such as sea banks, and previously published knowledge of salmon shark life-history suggest that the ECCR provides important foraging habitat which may be linked to reproductive success. The data reveal high overlap of salmon shark distribution with cumulative fishing effort collected by Global Fishing Watch for 2012-2019, particularly around seasonal hotspots, suggesting that female salmon sharks might be at risk of fisheries encounters. Collectively, our findings emphasize the importance of the ECCR in salmon shark life history and demonstrate the influence of spatial and temporal scale on interpretation of large movement datasets and identification of critical habitat outside of well-studied regions.



#### ASSESSING TRENDS IN INDIRECT MEASUREMENTS OF CONDITION FOR ATLANTIC BLUEFIN TUNA IN THE WESTERN ATLANTIC

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The Atlantic bluefin tuna (ABFT), *Thunnus thynnus*, commercial fishery in the western Atlantic is a comparatively 'new' fishery having only been exploited as a source of commerce for 70-80 years. During this time, there have been well documented changes in ABFT abundance, shifts in their foraging ecology, and now uncertainties regarding the structure/mixing of the overall ABFT population in the Atlantic. All these factors can result in changes to key biological reference points like weight-length relationships, which are crucial parameters used in stock assessments. As drivers of biological change continue to be identified and questions remain about the life history of ABFT, understanding long-term changes in somatic condition can provide a glimpse into the overall health and trajectory of the population while providing insight into foraging conditions. Several studies have been conducted to explore temporal trends in the somatic condition of ABFT, however, due to costs/accessibility of equipment which directly measures somatic condition (lipid content analysis) these results are often based on qualitative grade data from dealers. Although ABFT dealer grades have been used as a proxy for condition, these grades can be subject to the bias of the grader/dealer with no standardized protocols for grading. This is a preliminary study utilizing Fulton's K as a standardized, quasi-quantitative metric to assess ABFT condition over the past 42 years. Using data from the National Marine Fisheries Service landings database, values of Fulton's K have been calculated for nearly 90,000 individuals landed in the US rod and reel fishery from 1980-2022. To capture the most representative rod and reel data, areas included in this analysis extend from the US border with Canada to Cape Hatteras, North Carolina (USA). This area covers the most aggregated fishing effort while avoiding any condition bias caused by spawning activity in the Gulf of Mexico fishing areas.



### CLIMATE-RESILIENT FISHERIES: AVAILABLE TOOLS AND A PROPOSED WORKPLAN FOR IATTC

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At IATTC's 101<sup>st</sup> annual meeting in August 2023 a resolution on climate change was adopted. The resolution recognizes the impacts climate change is having on target and non-target species, as well as the fisheries, and that these impacts could affect the long-term conservation and sustainability of fish stocks covered by the Antigua Convention. Given the adoption of this resolution, IATTC staff have reviewed various tools and frameworks, many of which are participatory in nature, that other countries and international organizations have developed to promote climate-resilient fisheries. These tools and frameworks have been used to (1) understand climate change impacts on marine species, ecosystems, fisheries, and communities, (2) develop and implement more adaptive management actions, and (3) monitor progress as changes continue to occur. We used this review to inform a proposed workplan that aims to integrate input from a diverse group of stakeholders and lead to climate-resilient fisheries within IATTC. This work will allow us to better understand, account for, and prepare for the impacts climate change will likely have on fisheries, their target species, non-target species, and the eastern Pacific Ocean ecosystem.



### PROPOSING THE FISHERIES INDUSTRIAL COMPLEX AS A CRITICAL COMPONENT TO THE MARINE FISHERIES RESEARCH MACHINE

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The use of scientific inquiry to answer questions pertinent to fishery management relies on the acquisition of a representative sample of the population or system in question. Methods of data collection have evolved, but consultation of local knowledge and techniques from user groups is persistent. User groups are defined as those that interact with or within the study system and have been identified as fishers, processors, and seafood buyers and dealers, among other examples. Though the aid these communities provide is project specific, the contributions are significant and deserving of formalized credit within fisheries science. Here we present a case study approach to explore the quantified contributions of fishery user groups to a diverse set of projects from two academic labs focused on applied research. The Pelagic Fisheries Lab at the University of Maine studies highly migratory species with the goal of filling life history knowledge gaps to reduce stock assessment uncertainties. The Danylchuk lab at the University of Massachusetts, Amherst works to understand the natural and anthropogenic influences on aquatic organism life history and population dynamics. While both groups necessitate stakeholder engagement for project success, they specialize in pelagic commercial and coastal recreational fisheries respectively, offering a comprehensive view of user group inclusivity. The Pelagic Fisheries Lab leveraged buyer/processor connections to biologically sample 14,954 commercial sized Atlantic bluefin tuna for stock assessment use while the Danylchuk lab taps the recreational angler community to build decade-long relationships which resulted in formative catch and release science. We quantify the contributions of each group through sample collection and assess the impact through publication, managerial, and dissemination records. We demonstrate how fishery science often lags the capacity for industry to provide pathways for sample collection and stand these collaborators up as equal and opposite to fisheries scientists and administrators within fishery management governance structure.



#### ENVIRONMENTAL AND HUMAN DRIVERS SHAPE THE TROPHIC ECOLOGY OF A WIDESPREAD MARINE PREDATOR

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Developing ecosystem monitoring tools for the dynamic management of marine resources, species, and ecosystems is becoming increasingly important. Integrative approaches that consider diet-environment relationships may also provide the necessary means for exploring and predicting changes in food-web dynamics under contrasting scenarios of climate change and human impacts. In particular, investigating the trophic ecology of top predators provides a unique opportunity to unravel the relationship between environmental factors, predator-prey dynamics, and the influence of human activities. However, few studies have analyzed the relationship between environmental factors and trophic interactions, and none of them have considered additionally other human stressors such as fisheries. Here, we investigated the diet of swordfish (Xiphias gladius), the most widely distributed billfish, in response to environmental patterns and fishing pressure. We used Bayesian Stable Isotope Mixing Models (BSIMM) to estimate the diet of swordfish based on stable isotope values ( $\delta$ 15N and  $\delta$ 13C) from muscle samples collected in the western Mediterranean Sea and the adjacent Atlantic waters. We then fitted Generalized Additive Models (GAM) to evaluate the relationships among diet estimates and biological, environmental, and anthropogenic drivers. The best-fitted GAMs were used to produce spatial predictions of each prey consumption. As a prospective exercise, GAMs were also used to predict changes in prey consumption under two different climate change scenarios. We found that fish consumption was relatively homogeneous throughout the sampling area. In contrast, squid had a higher contribution to the diet of swordfish around the Canary Islands and the western Mediterranean Sea, while gelatinous organisms were more consumed around the Gulf of Cadiz. Overall, we found that swordfish diet may vary spatially and temporally as a likely response to changing environmental conditions, particularly associated with key oceanographic factors such as sea surface temperature (SST), dissolved oxygen (DO) and chlorophyll-a concentration (Chl); as well as to fishing pressure. Fish consumption was higher at higher SST, and decreased with increasing DO levels. Squid were more consumed at lower SST and by swordfish of intermediate lengths. The consumption of gelatinous organisms was higher in areas with lower productivity, higher SST and intermediate DO levels. Accordingly, we observed an increase in gelatinous prey and fish consumption under both climate change scenarios, while squid were expected to decrease their abundance in the swordfish diet. We aimed to model swordfish dietary responses to environmental and anthropogenic drivers and our estimates offer a tool to understand the potential effects of global environmental change, and how it can reflect ecosystem responses as a monitoring species. We provide, for the first time, quantitative evidence on how large-scale, spatial-temporal patterns in fishing pressure and environmental conditions can shape the diet of swordfish. Relying on stable isotope analysis to monitor the diet of these predators reduces the time between science outputs and their translation into policies, providing a first step towards adaptive management of this commercially important resource.



#### TUN-AI: UTILIZING ECHO-SOUNDER BUOYS AS FLOATING SAMPLING STATIONS TO MONITOR TUNA BIOMASS

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The use of dFADs by tuna purse-seine fisheries is widespread across oceans, and the echo-sounder buoys attached to these dFADs provide fishermen with estimates of fish biomass aggregated to them. This information has traditionally been difficult to process and use, given variability in buoy configuration, and oceanographic conditions around the buoys. TUN-AI combines dFAD logbook data, oceanographic data and echo-sounder buoy data to establish a machine-learning pipeline for processing echosounder buoy data and estimating tuna biomass (in metric tons, t) at various levels of complexity: binary classification, ternary classification and regression. Of all the models evaluated, the best performing one uses a 3-day window of echo-sounder data, oceanographic data and position/time derived features. This model is able to estimate if tuna biomass was higher than 10 t or lower than 10 t with an F1-score of 0.925. When directly estimating tuna biomass, the best model (Gradient Boosting) has an error (MAE) of 21.6 t and a relative error (SMAPE) of 29.5%, when evaluated over sets. All models tested improved when enriched with oceanographic and position-derived features, highlighting the importance of these features when using echo-sounder buoy data. By applying TUN-AI to data gathered by echo-sounder buoys attached to dFADs across all tropical oceans, we examined the temporal trends of tuna-school associations with drifting objects both in comparison to previous studies, and in the context of the 'ecological trap' theory. By using the binary output, metrics typically used in the literature have been adapted to consider the entire tuna aggregation under the dFAD. The median time it took tuna to colonize the dFADs for the first time varied between 25 and 43 d, depending on the ocean, and the longest soak and colonization times were registered in the Pacific Ocean. Continuous residence times of tuna schools were found to be generally shorter than continuous absence times (median values: 5-7 and 9-11 d, respectively). Using a regression output, 2 novel metrics, namely aggregation time and disaggregation time, have been estimated to obtain further insight into the symmetry of the aggregation process. Across all oceans, the time it took for tuna aggregations to depart from individual dFADs was not significantly longer than the time it took for the aggregations to form. This does not align with what would be expected if the association were 'strong and long-lasting' as proposed by one of the aspects of the 'ecological trap' theory.



#### **ARGOS: FUTURE CONSTELLATION UPGRADES**

Thomas Gray

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For over 40 years, the Argos satellite telemetry system has emerged as the backbone of marine science research, serving environmental agencies, NGOs, foundations, charities, parks, reserves, and the broader scientific community worldwide. Since its inception, Argos has played a pivotal role in our understanding of how pelagic fisheries utilize our shared resource - Earth. Currently the Argos satellite system is made up nine space-agency funded satellites. By the end of 2024, the constellation will be expanded to over 30. With a new constellation comes new features and capabilities, and this presentation will discuss those. We will also highlight an Argos tool that is used to recover popup satellite tags. The Argos Goniometer has been used to recover tens if not hundreds of pop-up satellite tags at sea (and can be used to actively track tagged animals). We will share some of those experiences from researchers.



The ideas presented in any given abstract may not be fully developed, and therefore no abstract should be cited without prior consent from the author(s).

### TOGETHER TOWARDS TOMORROW: WESTERN STOCK ATLANTIC BLUEFIN TUNA, *Thunnus thynnus*, CLOSE-KIN MARK-RECAPTURE ABUNDANCE ESTIMATION

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The ongoing Western Atlantic Bluefin Tuna Close-kin Mark-Recapture Abundance Estimation project aims to estimate the absolute abundance of Western Atlantic Bluefin Tuna, Thunnus thynnus, (ABFT) spawners by utilizing existing field sampling programs. Close-Kin Mark Recapture (CKMR) is a genetic approach that measures population demographic parameters, such as absolute abundance and survival of the reproductive population, through the occurrence of closely related individuals. The project was initiated due to limitations in conventional tagging methods for Western ABFT and the inability of recent assessments to estimate biomass-based reference points. Additionally, uncertainty arises from stock mixing between western (Gulf of Mexico) and eastern (Mediterranean Sea) origin fish in North Atlantic feeding aggregations, prompting the investigation of innovative techniques. The success of CKMR in estimating abundance for other species like Southern bluefin tuna, white sharks, brook trout, and thornback rays has motivated its exploration for Western Atlantic Bluefin Tuna. Implementing CKMR for ABFT requires collecting several thousand samples over multiple years, including adult and juvenile specimens, necessitating collaboration among existing sampling programs. This poster summarizes the sampling and preliminary results of the collaborative Western Atlantic Bluefin Tuna Close-kin Mark-Recapture Abundance Estimation project, focusing primarily on local stakeholder participation fostered by one of the many contributors, the Pelagic Fisheries Lab at the University of Maine, and their field sampling programs. Through partnerships with commercial industry professionals, tournaments, local anglers, and Genetics for Giants, an angler fin clip collection program, ~12,300 samples have been contributed. Through these collective efforts and contributions of other participating institutions both domestically and abroad, parent-offspring pairs, POPs, have been identified, and critical questions about the use of larvae and the impact of sibship on CKMR population modeling have been identified (McDowall et al., 2023). The work demonstrates that diverse stakeholder engagement, interdisciplinary teams, and existing sampling programs can coalesce to fulfill fisheries management needs.



#### UNITING STAKEHOLDERS AND SCIENCE TO ASSESS THE EFFICACY OF POTENTIAL CONSERVATION MEASURES ON THE VULNERABILITY STATUS OF THE CRITICALLY ENDANGERED EAST PACIFIC LEATHERBACK TURTLE (*Dermochelys coriacea*) CAUGHT IN PELAGIC FISHERIES

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Industrial and small-scale coastal (i.e., 'artisanal') pelagic fisheries in the eastern Pacific Ocean (EPO) are multispecies fisheries that also interact with the Critically Endangered East Pacific (EP) stock of leatherback turtle (Dermochelys coriacea). EPO tuna fisheries have been mandated since 2008 to ensure the safe handling and release of captured sea turtles. A revised resolution on sea turtles entered into force in 2021 that requires EPO tuna fisheries to implement measures to reduce sea turtle bycatch, in particular the use of circle hooks and finfish baits in shallow longline sets. The low encounter rates of sea turtles by fishing vessels make these 'rare event' data difficult to utilize in conventional population assessments. Consequently, alternative means are needed to assess vulnerability status and better understand the potential efficacy of conservation and management measures (CMMs) to improve sea turtle conservation. One such approach is the Ecological Assessment for the Sustainable Impacts of Fisheries (EASI-Fish) methodology, developed by Inter-American Tropical Tuna Commission (IATTC) staff to quantify the vulnerability of bycatch species in data-limited settings. This paper describes a highly collaborative research project conducted by a working group of participants from the IATTC, the Inter-American Convention on the Protection and Conservation of Sea Turtles (IAC), and international sea turtle experts where EASI-Fish was used to explore the changes in the vulnerability status of the EP leatherback turtle stock under 70 different hypothetical CMM scenarios simulated for EPO industrial (purse-seine and longline) and artisanal (longline and gillnet) fisheries for 2019. CMMs involved decreasing bycatch rates (i.e., "contact selectivity" in EASI-Fish) and post-capture mortality (PCM), implementing the use of circle hooks and/or finfish bait in longline fisheries, illuminated gillnets, best practices for safe handling and release of leatherbacks, and combinations of CMMs. The "status quo" scenario revealed the stock was classified as "most vulnerable". Of the 70 scenarios, 42 resulted in significant reductions in vulnerability. Although use of circle hooks, finfish bait, and to a lesser extent best handling and release practices were each predicted to decrease vulnerability when examined individually, by far the most effective scenarios involved using these three measures in concert, followed by using circle hooks with either finfish bait or best practices. However, predicted benefits for CMM scenarios assume 1) 100% compliance with CMM implementation in each relevant fishery, and 2) that CMMs achieve the prescribed levels of efficacy reflected in the model inputs. This modelling exercise provided detailed results that enable evaluation of the potential efficacy of CMMs established in in IATTC Resolution C-19-04 in reducing impacts of fisheries bycatch on EP leatherbacks and can inform development of fisheries-specific strategies to implement the CMMs described.



#### INSIGHTS INTO THE ONTOGENETIC DEVELOPMENT OF YELLOWFIN TUNA (*Thunnus albacares*) FROM PHYSIOLOGICAL ENERGETICS

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Tunas, dubbed "Energy Speculators", have evolved numerous adaptations for a lifestyle that requires large amounts of energy consumption. Different tuna species, however, exhibit different ecophysiological characteristics, including those in the contexts of energetics and heterothermy. Understanding these characteristics for each species not only elucidates the eco-evolutionary backgrounds of tunas but also helps predict the effects of environmental change on their performance. Dynamic Energy Budget (DEB) theory quantifies the processes by which an organism acquires and allocates energy for survival, growth, maturation, and reproduction. This, in turn, provides a general framework for quantitatively comparing energetic characteristics among species. Here, we present the development of a DEB model for the yellowfin tuna (*Thunnus albacares*) covering its entire life cycle, from an egg to a spawning adult and its eggs. Using a comprehensive dataset for the life-history traits of this species, we successfully estimated model parameters with a high goodness of fit. The DEB theory is unique in capturing the metabolic processes of an organism throughout its entire life cycle as a function of temperature and food abundance. To validate the performance of our model, we attempted to reproduce the growth trajectory of captive yellowfin tuna using temperature and feeding data from a dedicated experiment in captivity. By comparing the model parameters with those for bluefin tuna and skipjack, we discuss the energetic characteristics of yellowfin tuna and tuna species in general.



## DIET AND NUTRITION OF WILD AND CAPTIVE SOUTHERN BLUEFIN TUNA (*Thunnus maccoyii*) ASSOCIATED WITH CHANGING POPULATION DISTRIBUTIONS IN SOUTHERN AUSTRALIA

Jessica Henkens, Ryan Baring, Lauren Meyer, Charlie Huveneers, Kirsten Rough and Heidi Pethybridge

Flinders University

Southern bluefin tuna (*Thunnus maccoyii*; SBT) hold significant ecological, nutritional, and economic importance, particularly in South Australia where tuna ranching takes place. Each year SBT undertake seasonal migrations through the Indian Ocean to their feeding grounds in the Great Australian Bight, South Australia, where juveniles reside during the Austral summer months for multiple years. However, shifts in SBT distribution have been observed by the commercial and recreational fishing community over the past decade. Since 2012, SBT have not yet returned to their historic feeding grounds and instead are found further east, towards Victor Harbor and Kangaroo Island, but with an inconsistent distribution. To date, we know little about their habitat preference and what they feed upon during their stay in South Australian waters but also how this compares with captive individuals that are fed a consistent diet. This project aimed to determine the diet and nutritional value of wild and captive SBT in southern Australia using biochemical approaches (i.e., stable isotopes and fatty acids). Results indicate that wild SBT diet is highly variable across their distribution in South Australia, with notable differences in fatty acids across years (2022 and 2023), most likely due to recent shifts in their distribution. Fatty acids of captive SBT in Port Lincoln ranching pens were distinct from wild caught locations, indicating some step-changes of SBT response to ranching processes. Additionally, important fatty acids for human health such as 20:5n3cis (EPA) and 22:6n-3cis (DHA) were detected in higher overall concentrations in wild SBT. These results further contribute to our understanding of SBT diet in South Australia where they migrate annually to forage and highlights the role of the tuna ranching industry from a human nutrition perspective.



#### SHARK DETERRENT RESEARCH IN HAWAII

#### Kim Holland, Lauren Arnold, Edward Cardona, Kaylee Skidmore-Rossing and Carl Meyer

Hawaii Institute of Marine Biology

Longline tuna and swordfish fisheries are among those that are significantly impacted by shark bycatch and shark depredation (sharks eating target species after they are hooked). Other fisheries impacted are demersal longline and artisanal and commercial bottom fish ("snapper") fisheries. Although rare, shark attacks on humans are traumatic and occasionally tragic. These circumstances have given rise to multiple attempts to devise shark deterrents - devices or stimuli which deter sharks from biting – and there is currently high interest in this topic. Many previous studies have suffered from insufficient sample size and/or inappropriate controls that would normally allow rigorous statistical testing. There is also a building body of evidence to suggest that there are significant inter-specific differences in responsiveness to putative shark deterrents. The Shark Research Group at the Hawaii Institute of Marine Biology has recently received significant funding to investigate putative deterrents at a level which will allow exhaustive and rigorous testing on a variety of species – including those involved in depredation and in attacks on humans. This talk will outline the experimental approaches that are being pursued and present some preliminary results.



#### FISHERIES DEVELOPMENT: WHERE DOES IT FIT WITH CONSERVATION AND MANAGEMENT STRATEGIES FOR PELAGIC FISHERIES?

#### **David Itano**

#### Hawaii Institute of Marine Biology

Fisheries development programs of the 1950s and 1960s were based on the age-old proverb: Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime. Motorized artisanal fishing craft were introduced to developing countries with basic training in troll and dropline techniques. The introduction of novel and efficient fishing gears and techniques produced an abundance of fish but stable fisheries were often undermined by targeting inappropriate species and short-lived subsidies for vessels, fuel and gear that fed boom and bust cycles. In the worst case, the subsidies attracted opportunists that took advantage of the easy money but got out when the benefits dried up, leaving a depleted resource for the "real" fishermen. Subsequent fishery development programs have adopted a more holistic approach that includes training on catch handling and conservation, post-harvest processing and marketing. Ideally, responsible programs should benefit members of a coastal community without risk to the long-term sustainability of the targeted resource. Many programs have concentrated effort on fast growing pelagic species aggregated to anchored Fish Aggregation Devices. Unfortunately, the development of stable and sustained small-scale fisheries has been more the exception than the rule. Too often, the same mistakes have been repeated country by country as aid organizations become trapped in endless cycles of training and more training without the development of a self-sustaining fishery. Ultimately, the big question must be addressed: is fisheries development a defensible activity in this day and age given the high levels of exploitation facing fish stocks in all oceans? Recent experiences in fisheries development in the Pacific and Africa are described here in order to showcase the strengths and weaknesses of fisheries development initiatives that also face a variety of institutional and practical roadblocks to success.



#### COOPERATIVE RESEARCH AND STAKEHOLDER ENGAGEMENT REVEALS THREE SUBSTANTIAL SHIFTS IN THE FORAGING ECOLOGY FOR ATLANTIC BLUEFIN TUNA (*Thunnus thynnus*) IN THE GULF OF MAINE

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For more than three decades the diet of Atlantic bluefin tuna (Thunnus thynnus, ABFT) in the Gulf of Maine has consistently been dominated by Atlantic herring (*Clupea harengus*). In just under five years, the main forage species has changed three times indicating substantial shifts in the abundance or availability of forage for Atlantic bluefin tuna. These shifts included Atlantic herring to shortfin squid (Illex illicebrosus), and finally Atlantic menhaden (Brevoortia tyrannus). Through collaborations with commercial fishers and dealers, as well as fishing tournaments from June – October of 2022 and 2023 the stomachs (n=239) of commercially harvested (> 185 cm curved fork length CFL) ABFT were collected. Stomach content analysis (SCA) determined that Atlantic menhaden is now the predominant prey species for ABFT in the Gulf of Maine, both by percent presence (50.5%, 59.7%, %O) and percent weight (41.5%, 77.1%, %W) for 2022(n=95) and 2023(n=144) respectively. During this sampling period, Atlantic herring made up a relatively small contribution of ABFT diet, with a %O of 15.8% and 18.8%, and %W of 3.6% 2.2% for each year sampled. Shortfin squid which in previous sampling (2018 and 2019) represented the predominant prey species, was observed to be a decreasing portion of diet, %O (22.1%, 4.2%) and %W (3%, 0.2%) over the current study period. ABFT are known to regularly consume Atlantic menhaden along the Mid-Atlantic Bight, but these results represent the first time they have made up the majority of ABFT diet in the Gulf of Maine. This shift in ABFT diet corresponds to trends in the spawning stock biomass of Atlantic menhaden (increasing) and Atlantic herring (decreasing) that has been observed in the Gulf of Maine in the most recent stock assessments for both species. These results suggest a substantial shift in ABFT forage in the Gulf of Maine that has changed AFBT distribution and could influence condition of ABFT in the Gulf of Maine.



## CATCH METHOD, QUALITY, AND PRICE FORMATION IN THE JAPANESE SWORDFISH FISHERY

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Globally, swordfish (Xiphias gladius) are a high-value commercial species and caught using multiple types of fishing gear. Within Japan, swordfish are caught in both distant and offshore waters using primarily 4 catch methods: longline, driftnet, harpoon and buoy gear. While fishermen themselves say there exists a quality difference between swordfish caught by different methods, this topic has received little coverage in the literature. This study aims to take a more objective look at the role of fishing gear in swordfish quality and price formation. If swordfish quality is dependent on catch method to a high degree, then fishery regulations on capture gear affect the consumer market through the quality of fish supplied, as well as the value generated from managed fisheries. We aim to estimate the influence of the catch method on various swordfish quality characteristics and the role of those quality characteristics in the price formation of swordfish at auction. To do this, we use data on fish freshness, size, weight, shape, muscle characteristics and price obtained from swordfish sold at auction in the Kesennuma City Fish Market; the largest auction for swordfish in Japan. Data was collected via monthly visits to the auction site where the authors were given access to the fish on the auction floor. Data collection is currently ongoing and expected to finish in fall 2025. Preliminary results show that there is a price premium for swordfish caught using harpoon and buoy gear over those caught on gillnet and longline. We hope that the results of this study will be of value to fishery stakeholders on both the supply and demand sides of the market by highlighting unexploited opportunities to arbitrage the price-quality relationship by increasing the utilization of fishing gears that deliver high quality swordfish to market.



#### **EXPLORING TECHNOLOGIES FOR REMOTE IDENTIFICATION OF FADs**

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Fishers have taken advantage of the aggregative behavior of tunas to fish around floating objects for decades. Their use has significantly expanded ever since, and FAD fishing rapidly became the predominant way to capture tuna in the purse-seine fishery of the EPO. Quantification of the impacts of the FAD fishery requires efficient collection methods for high-quality data, including accurate tracking and monitoring methods for individual FADs throughout their lifetime. Currently, FADs are identified using satellite-buoy identifiers and accurately obtaining buoys' alphanumeric serial numbers has traditionally been difficult for observers, and not possible with current electronic monitoring (EM) capabilities. However, this information is key to merge and connect different IATTC databases and support scientific research on FAD-related activities. Thus, an electronic system to automatically and remotely detect and identify individual FADs would improve the value and utility of all types of data. Therefore, this collaborative study evaluates the suitability of different technologies to remotely and electronically identify individual FADs by testing, comparing and measuring the efficiency of different technologies to remotely and electronically identify individual satellite-linked echo-sounder buoys used by the fleet to monitor FADs in "real" conditions. We investigated the suitability of these technologies to be incorporated into electronic monitoring sensors and equipment, as well as into other devices (i.e. satellite buoys, hand-held sensors for observers) with the idea of improving data collection and traceability of FADs. In conjunction with technological partners, a possible plan of action for the in the near future has also been discussed.



#### Sustainability of Global Tuna Fisheries According to the Seafood Watch Standard

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The Monterey Bay Aquarium's Seafood Watch Program, now entering its  $25^{\text{th}}$  year, reviews and rates fisheries and aquaculture production systems for sustainability practices across a number of criteria. For fisheries, these four criteria include impacts on the fish stock under assessment, impacts of the fishery on other species, management effectiveness, and fishery impacts on the physical environment. Our assessments of tuna fisheries reach back to 2009 and provide a view of the sustainability of global tuna fisheries. We are currently updating our tuna assessments, which gives us an opportunity to identify patterns that have driven the sustainability scores and potentials for improvement. Prior to this update, our tuna assessments were last updated and released in 2020 and 2021, respectively. Across all commercial tuna fisheries, the majority (~59%) are red-rated (lowest environmental performance relative to our standards) with ~29% having a yellow rating and only ~12% having a green rating.

Gear type and fishing method were main drivers in sustainability, with troll, handline, and non-FAD purse seine fisheries mainly scoring higher (50% or more fisheries are yellow or green, or a combination of the two) than other gear types for sustainability across all ocean basins. FAD-set purse seine fisheries generally scored poorly, with all resulting in a red rating. Longline fisheries showed more variability in ratings, with fleets having more stringent bycatch management and mitigation measures scoring better than other fleets, though the majority of longline fisheries still had red ratings.

Drivers of red ratings are most often bycatch impacts and bycatch management. More successful bycatch management measures can drive the difference between a red rating and a yellow rating in fisheries with inherent bycatch issues due to the fishing method used. Despite long-term acknowledged bycatch and ecosystem issues in high seas pelagic fisheries, many RFMOs still lack adequate protection and mitigation measures. In this presentation, we also highlight how to engage with the Seafood Watch assessment and standard revision processes, both of which encourage collaboration and input from multiple stakeholder groups.



#### SIGNALS OF NEUTRAL AND ADAPTIVE DIVERGENCE IN ATLANTIC BLUEFIN TUNA REVEALED BY WHOLE GENOME SEQUENCING

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Atlantic bluefin tuna are currently managed by ICCAT as two separate stocks based primarily on spatially separate spawning grounds in the Gulf of Mexico (GOM) and Mediterranean Sea (MED). The differentiation of these stocks has been previously investigated using diverse genetic markers such as allozymes, mitochondrial DNA, microsatellite loci, an single nucleotide polymorphism (SNP) loci, though many questions remain regarding the population structure and evolutionary adaptive capacity of bluefin tuna. We sequenced the whole genomes (mean coverage 10.24X) of 92 Atlantic bluefin tuna from the GOM (n=45) and MED (n=47) populations to evaluate the role of neutral and adaptive evolutionary processes in driving population divergence. We included 44 fin clips from electronictagged individuals spatially assigned to either GOM or MED stocks and 48 larvae collected from their respective spawning grounds. We obtained 13,241,151 SNPs, a dataset of unprecedented size and resolution, with coverage across the entire genome allowing for increased power in analyses of population structure, patterns of selection, and demographic history between the two recognized stocks. We estimated basic descriptive statistics, including individual mean heterozygosity, which was similar for both GOM (mean= $0.20\pm0.04$ ) and MED (mean= $0.19\pm0.02$ ) populations. To infer genome-wide population structure, we ran a principal component analysis (PCA), which found subtle, but significant, differentiation across both principal component axes, as well as among comparisons of putatively adaptive versus neutral loci. We are currently evaluating the role of selection in shaping population differentiation in Atlantic bluefin tuna by identifying putatively adaptive SNPs under selection. Our leverage of highresolution whole genome data will characterize and account for adaptive variation that can be highly relevant for management issues, and critical for preserving locally adapted populations.



#### **ELECTRONIC MONITORING IN HAWAI'I LONGLINE FISHERIES**

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Through collaborative research with fishers in the Hawai'i longline fisheries, the Pacific Islands Fisheries Science Center is conducting electronic monitoring (EM) research to modernize data collection of catch and bycatch (discarded) species while saving money and time with potential benefits to fishers. The EM systems deployed on 20 volunteer longline vessels consist of two video cameras to record activities both on deck and in the water next to the vessel. This research has demonstrated that from EM systems both retained and discarded catch can be detected with high accuracy. In addition, protected species such as cetaceans and sea turtles can be detected, providing data on the handling and condition of the animal upon interaction and the amount of attached fishing gear at release. Research is ongoing into the integration of Artificial Intelligence (AI) to automatically detect catch events, which has the potential to provide efficient and economical processing of large quantities of EM video data. AI models are trained using an annotated image library created by drawing bounding boxes around the catch and bycatch or other desired objects from EM video. This image library currently consists of fish, sea turtles, and cetaceans and additional annotations are being added of elasmobranchs, rare protected species, and objects often falsely detected as targets by preliminarily trained AI models (e.g., floats are detected as sea turtles). EM paired with AI and human review provides the opportunity to expand coverage to fishing fleets across the world's oceans with limited or no monitoring and to supplement human observer coverage. These data can allow for management of sustainable fisheries through more accurate population assessments and document impacts on bycatch and protected species.



#### THE POTENTIAL OF HIGH-RESOLUTION GEOMAGNETIC AND ACCELEROMETER EQUIPPED GEOLOCATORS TO ENHANCE THE UNDERSTANDING OF THE ECOLOGY AND MOVEMENT OF MIGRATORY FISH

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Geolocators using light intensity have been a crucial method for tracking the migration of pelagic fish. Accelerometers and geomagnetic sensors, on the other hand, have been shown to effectively monitor short-term behaviors, activity levels, biomechanics, and three-dimensional trajectories of animals. Accelerometers, particularly in recent years, have been employed in pop-up tags, becoming an essential method for providing activity indicators alongside geolocation. Recently, geomagnetism has also shown potential for use in geolocation. However, there is still no available small-sized, intraperitoneal-implantable logger that can simultaneously acquire geomagnetic and accelerometer data along with geolocation functionality. High-resolution geomagnetic and accelerometer-equipped intraperitoneal-implantable loggers, while capturing traditional geolocation data through light intensity, depth, and temperature, can contribute to a more detailed understanding of the ecology and movement of pelagic fish behavior due to their ability to measure high-resolution, body-attached movements. This presentation reviews what can be understood by adding high-resolution geomagnetic and accelerometer data based on preliminary experimental data from Pacific bluefin tuna *Thunnus orientalis* kept in a fish pen and discusses the potential of small geolocators capable of simultaneously acquiring geomagnetic and accelerometer data over yearly cycles. We seek collaborators for the multi-point deployment of this novel logger.


# FORAGING ECOLOGY, PREY PREFERENCE, AND PREY ENERGETICS OF BIGEYE TUNA (*Thunnus obesus*) IN THE NORTHWEST ATLANTIC

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Evaluating foraging ecology for highly migratory pelagic predators, like bigeye tuna, Thunnus obesus, provides information on important marine food web linkages, and the potential impacts of variable ocean conditions on food attainment. Outside of a basic understanding of energetic linkages, it is important to identify patterns in forage composition for the highly valued bigeye tuna, as the potential exists for the development or expansion of commercial fisheries that target deeper, highly abundant, ocean resources. This was and continues to be seen for species like Atlantic bluefin tuna (Thunnus thynnus) whose main prey are subject to commercial exploitation. We hypothesize that many of these top predators, including bigeye tuna, prey on abundant forage species that maximize caloric return due to their high energy densities. Stomachs were collected from 91 bigeye tunas captured in commercial longline and recreational rod and reel fisheries from 2018-2020 with 19, 45, and 27 stomachs, respectively. Stomach content analysis was completed to understand how prey species and energetic content influence forage choice and trophic levels of bigeye tuna in the northwest Atlantic. Prey items of whole individuals, hard parts (i.e., otoliths and beaks), and partial individuals were identified with morphological and genetic techniques to the lowest taxonomic level, and the energetics of prey were identified through literature review. Across all years, *Illex illecebrosus* contributed to the largest percentage by weight and presence (56.66% Prey Item Mass (%PIM) and 32.98% Prey Item Presence (%PIP)), Paralepididae followed with 26.60% PIP, and Themisto spp. had the highest average abundance of 11 individuals. The high percentage of weight and presence of I. illecebrosus suggests an important predator-prey linkage, which is consistent with documented higher energetic values when compared to other prey items of bigeye tuna, and therefore, energetically favorable. Although uptake for ecosystem-based fishery management has been slow within our governance structure, the foraging ecology of commercially viable species, such as bigeye tuna, has utility when considering a holistic assessment of fisheries.



# USING MULTI-TAXA MARINE ISOSCAPES TO ASSESS POTENTIAL PROVENANCE OF DOLPHINFISH CAPTURED OFF CABO SAN LUCAS, MEXICO

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The use of stable isotope analysis for feeding habit studies is a well stablished practice in modern ecology. However, the potential use of stable isotope (SI) data to assess movement of marine organisms through the description of their isotopic niches (isoscapes) is a growing field and it is known to have important limitations due to the availability of data, especially in oceanic environments. Recent availability of stable isotope data has allowed the description of robust isoscapes of marine consumers in different "trophic bins" in the North Pacific Ocean. To represent their isoscapes along the different Longhurst provinces (CCAL, PNEC, CAMR, NPTG, PEQD), available literature on carbon and nitrogen SI data of marine consumers categorized as trophic bin 4 was used. Each of the Longhurst provinces isoscapes were compared to measured muscle SI values of adult and juvenile dolphinfish captured off Cabo San Lucas (CSL) from July to December 2018-2021. This was done to infer the provenance probability (Pp) through the Bayesian overlap probability of the ellipses in the SIBER package in R. Further, to estimate expected carbon and nitrogen SI values of a consumer such as dolphinfish, that feeds in CSL area (*Residencesi*) SI available data of prev species of the dolphinfish in the Longhurst provinces off CSL were used. The Residence<sub>SI</sub> value was calculated using the weighted average of the SI values of carbon and nitrogen on the prey species consumed by the dolphinfish inferred through stomach content analysis plus a trophic discrimination factor. The average of the prey species was weighed according to the proportion of importance of the Prey-specific index of relative importance (%PSIRI). Residencess values for dolphinfish for our study area were  $\delta^{13}C = -16.7\%$  and  $\delta^{15}N = 16.5\%$  while measured stable isotope values (mean±SD) for juvenile dolphinfish were -16.4  $\pm$  0.6 and 16.0  $\pm$  1.5% for  $\delta^{13}$ C and  $\delta^{15}$ N, respectively. For adults, measured isotope values were -16.8  $\pm$  0.4 and 13.5  $\pm$  1.2‰ for  $\delta^{13}$ C and  $\delta^{15}$ N, respectively. Isotopic niches of each of the analyzed Longhurst provinces were successfully separated in \delta-space and differences were observed in the distribution of juvenile and adult dolphinfish samples in  $\delta$ -space. Juveniles had similar provenance probability values (Pp = 0.4) for CAMR, CCAL, and PNEC, while this probability was lower for PEQD and NPTG. The isotopic niche for adults showed similar Pp values for every province, with the highest value for PEQD (Pp = 0.3). This approach to study the provenance of dolphinfish supports previous hypotheses regarding the differences in habitat use between juvenile and adult dolphinfish where juveniles tend to show SI values in steady state with local isoscapes in the region where they were captured while adults tend to show more variation in their SI values. Adult dolphinfish showed isotopic niches in between the distribution of the Longhurst isoscapes in  $\delta$ -space which might be an insight into the movement capabilities of the species, as it appears to show an average of those provinces as if those animals were constantly feeding across isoscapes without reaching a stable isotope steady state with local isoscapes in their muscle tissue. This is an experimental approach on trying to infer the provenance of oceanic species using available isoscapes in the Northern Pacific Ocean and potential biases due oversimplification of processes that might influence our observations. However, we considered this as a potential tool to further improve our application of isotopic methods in movement ecology of marine predators.



# PREDICTING, ASSESSING, AND COMMUNICATING THE EFFECTS OF SPATIAL MANAGEMENT IN PELAGIC FISHERIES

# **Dan Ovando**

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Pelagic fisheries are often characterized by highly mobile species, dynamic habitats, and a diverse set of fishing interests. Given the spatial scales at play, management of these fisheries has historically relied mostly on restrictions on effort, fishing practices, and total catch. However, spatial closures such as Marine Protected Areas (MPAs) or Other Effective Conservation Measures (OECMs) are increasingly being proposed for use in pelagic ecosystems, most notably in the form of the "Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction", also known as the "BBNJ" Agreement. Among other things, BBNJ provides a framework for the establishment of things like MPAs and OECMs in areas beyond national jurisdiction and is closely tied to the broader efforts to protect 30% of the oceans by 2030. In this talk, I will discuss challenges and opportunities in predicting, assessing, and communicating the effects of spatial management in pelagic fisheries. I will specifically dive into the ways that conflicting methods, language, and objectives can lead to confusion and disagreement between different stakeholders, and provide thoughts on solutions to these issues that can help spatial management measure be more effective and equitable.



# SEASONAL AND ONTOGENIC DIFFERENCES IN THE TROPHIC SPECTRUM OF THE STRIPED MARLIN *Kajikia audax* (PHILIPPI, 1887) IN CABO SAN LUCAS, BAJA CALIFORNIA SUR

# Pamela Pacheco Aldana, Sofia Ortega-Garcia, Leonardo Andres Abitia-Cardenas, Ulianov Jakes-Cota, Arturo Tripp-Valdez, and Antonella Preti

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Striped marlin (Kajikia audax) is important for recreational fishing in Cabo San Lucas, B.C.S., Mexico. Previous studies have described trophic ecology with analysis of stomach contents or stable isotope analysis. This study aims to apply both methods with the ultimate goal of characterizing changes due to sex, ontogenetic development (young and adults), and season (warm and cold). To achieve this goal, a total of 519 stomachs collected from the Cabo San Lucas sport fishing fleet will be processed from 2019 to 2022. To date, 239 stomachs have been successfully analyzed, of which 83% contained prey. The total length of the organisms ranges between 140 cm and 242 cm in general. Currently, there are 82 prev items reflected in the diet. To date, the Prev Specific Index of Importance (%PSIRI) has yielded preliminary results. Across all categories, cephalopods dominate the diet with fishes closely following in importance. In general, the Humboldt squid Dosidicus gigas (46%), Pacific Mackerel Scomber japonicus (17%), Auxis spp. (8.7%), Sardinops sagax (4.4%), and Argonauta spp. (4.3%) were the most important species. Female striped marlin mainly consumed D. gigas (43%), S. japonicus (25.9%), S. sagax (5.6%), Auxis spp. (4.9%), and Argonauta spp. (4.1%). Males primarily consumed D. gigas (46%), S. japonicus (13%), Auxis spp. (10%), Lagocephalus lagocephalus (5.3%), and Argonauta spp. (4.3%). The juvenile males (lengths  $\leq$  188 cm) and juvenile females (lengths  $\leq$  197 cm) principally consumed D. gigas (33%), Argonauta spp. (25%), Balistes polylepis (11%), Auxis spp. (7%), S. japonicus (5.3%), Adult males (lengths > 189 cm) and adult females (lengths > 198 cm) principally consumed D. gigas (36%), Argonauta spp. (26%), S. japonicus (20%), S. sagax (3%), L. lagocephalus (2.5%). Diet in the warm season consisted of D. gigas (36%), B. polylepis, (16%), Argonauta spp. (14%), Auxis spp. (7.7%), L. lagocephalus (5.3%). Diet in the cool season consisted of Argonauta spp. (38%), S. japonicus (31%), D. gigas (16%), S. sagax (10%), Auxis spp. (0.5%). Diet differences in the warm and cold season were found (R = 0.103, p = 0.01). The other categories were not found to have differences. These preliminary results suggest the following preliminary conclusions. The striped marlin tends to pursue similar cephalopod and fish species when they are available regardless of sex and maturity. The diet may change between cool and warm seasons due to prey item migrations in response to environmental conditions. Future work entails preparation of approximately 110 muscle samples for stable isotope analysis. The prepared samples will be sent for analysis at University of California Davis and results will be expected in late May or early June for further statistical analysis and interpretation.



# ATLANTIC BLUEFIN TUNA TAGGED OFF NORWAY SHOW EXTENSIVE ANNUAL MIGRATIONS, HIGH SITE-FIDELITY AND DYNAMIC BEHAVIOUR IN THE ATLANTIC & MEDITERRANEAN SEA

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Atlantic bluefin tuna (ABFT; *Thunnus thynnus*) is a highly migratory species. To investigate the migrations and vertical behaviours of ABFT migrating to Nordic waters, we deployed pop-up satellite archival transmitting tags on 25 ABFT off Norway (Curved Fork Length: 228-292 cm). We obtained 16 full-year migrations, and physically recovered 13 tags which provided 4,762 days of archival depth and temperature data. ABFT occupied waters from the Arctic Circle to as far south as Cabo Verde, Africa, and occupied depths down to 1190 m and temperatures from 0.5 to 27.8 °C. During their annual feeding migrations, ABFT spent, on average, 68 days in Norwegian waters, 65 days in the Newfoundland Basin, 35 days around the Canary Islands and 33 days in the West European Basin. Most ABFT entered the Mediterranean Sea, visiting known spawning grounds, with a mean entry date of May 13th. After staying, on average, 44 days in the Mediterranean Sea, these ABFT migrated rapidly (average: 40 days) back to Norwegian waters. ABFT displayed high site-fidelity and dynamic vertical diving behaviours that varied between hotspots and seasons. These spatiotemporal data provide important ecological knowledge for sustainable management and the conservation of the recently recovered eastern ABFT stock.



# MESOSCALE ACTIVITY DRIVES THE HABITAT SUITABILITY OF YELLOWFIN TUNA IN THE GULF OF MEXICO: SEASONAL AND INTERANNUAL PREDICTIONS

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Yellowfin tuna, *Thunnus albacares*, represents an important component of commercial and recreational fisheries in the Gulf of Mexico (GoM). We investigated the influence of environmental conditions on the spatiotemporal distribution of this species using fisheries' catch data spanning 2012-2019 within Mexican waters. We implemented hierarchical Bayesian regression models with spatial and temporal random effects, and fixed effects of several environmental covariates to predict habitat suitability (HS) for the species. The best model included spatial (ADT<sub>SA</sub>) and interannual (ADT<sub>IA</sub>) anomalies of the absolute dynamic topography of the ocean surface, bottom depth, and a seasonal random effect. High catches occur mainly towards anticyclonic features with bottom depths > 1000 m. The spatial extent of HS was higher in years with positive ADT<sub>IA</sub>, which implies more anticyclonic activity. The highest values of HS (> 0.7) generally occurred at positive ADT<sub>SA</sub> in the oceanic waters of the central and northern GoM. However, during summer, high HS values (> 0.6) were observed in the southern GoM, in waters with cyclonic activity. Our results highlight the importance of mesoscale features for the spatiotemporal distribution of yellowfin tunas and could help to develop dynamic fisheries management strategies in Mexico and the U.S. for this valuable resource.



# DIETS OF PACIFIC BLUEFIN TUNA (*Thunnus orientalis*) IN THE SOUTHERN CALIFORNIA BIGHT FROM 2020-2023

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Pacific bluefin tuna (Thunnus orientalis) utilize the California Current Large Marine Ecosystem as a key foraging ground and, in turn, are the focus of a lucrative recreational and commercial fishery. Bluefin are highly active and mobile predators capable of feeding on a wide variety of prey and have been shown to undergo diet shifts in response to rapidly changing prey availability. Since 2008, scientists with NOAA SWFSC and the University of California Santa Cruz have worked collaboratively with local recreational fishers and fish processors to collect stomach and tissue samples from bluefin caught in the southern California Bight to support ecosystem-based monitoring efforts. Here, we present novel stomach content data from the most recent years of the bluefin diet time series. Specifically, we examined the stomach contents of > 300 bluefin collected from the southern California Bight during 2020 - 2023. Similar to previous studies, no size-related patterns in diet were identified, with smaller bluefin (<100 cm FL) found to feed on similar types of prey of a similar size (<10 cm) relative to larger bluefin (>100 cm FL). Across the years examined, northern anchovy (Engraulis mordax) was the dominant prey item by number (>70% of prey items by number across all stomachs), with several coastal pelagic and mesopelagic fishes and cephalopods representing < 10% of prey by number during any given year. Patterns in the frequency of occurrence of prey differed slightly from percent number, with anchovy appearing in >65% of stomachs examined in 2020 - 2022 before declining in frequency to 30.8% in 2023. In the absence of more frequent consumption of anchovy in 2023, the frequency of occurrence of lanternfishes, market squid, and tunicates increased. Additionally, in 2023, the average number of prey items per stomach and the average weight of stomach contents decreased relative to 2020-2022. When viewed in the context of the greater Pacific Bluefin Tuna diet time-series, the data we present support the conclusion that bluefin are capable of taking advantage of a range of available taxa. Additional analyses comparing nutritional condition of bluefin across sampling years are underway to further explore the physiological implications of changing prey composition and lower prey number and prey weight in 2023.



# EXPLORING VARIABILITY AMONG INDIVIDUAL VESSELS TO IDENTIFY EXISTING ELASMOBRANCH BYCATCH AVOIDANCE STRATEGIES

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Bycatch of non-target species remains one of the most pervasive challenges for improving sustainability of fisheries globally. Bycatch is typically managed with fleet-level controls, such as technology requirements, fleet-wide bycatch quotas, or time-area closures. These approaches have successfully reduced bycatch of some threatened or protected species in certain cases. While some of the more straightforward bycatch problems have been resolved, fisheries are now grappling with the more complex challenges. For instance, certain species and fisheries remain extremely problematic for fisheries managers, such as oceanic sharks in tuna fisheries. The remaining challenges urgently need to be addressed without overburdening fishers and managers or imposing too many additional costs on industry. One largely untapped source of innovation is the fishers themselves. Exploration of a variety of gear types and non-target species in Australia indicated that certain operators maintain high catch rates while having low bycatch rates across a range of fisheries. Managers and practitioners have long understood there is variability among fishing operators, but this concept has rarely been translated into individual-directed management measures. We explore this concept in additional fisheries outside Australia, including industrial tuna purse seine and longline fleets in the Pacific, to test the systemic nature of this pattern of variation in efficiency (bycatch/catch ratio). Here we focus on pelagic elasmobranch species that remain a key bycatch challenge for tuna fisheries globally. We find that this variability is consistent across different contexts, implying that some fishers have already developed effective bycatch reduction strategies, even for problematic species. Additionally, we explore the effect of the operating company and find evidence that this influences the bycatch performance of individual vessels. This suggests there is opportunity to help tackle bycatch problems that have been difficult and expensive to address with current approaches by investigating the practices of the efficient operators and culture of the operating companies in a fleet.



# MAPPING THE DISTRIBUTION OF THE PELAGIC STINGRAY IN THE EASTERN PACIFIC OCEAN

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Results from a sensitivity analysis using boosted regression trees to model the distribution of the pelagic sting ray in the Eastern Pacific Ocean showed that salinity, temperature at 100 meters depth, chlorophyll *a* and mixed layer depth were the most important in describing the habitat of this species. It was also shown that using different presence/absence ratios had an effect in model performance with models with a 50:50 and 25:75 ratio having the best performance and explaining around 37% of the deviance. The next step is to develop maps of the predicted probability of occurrence and to visualize the effects of different presence/absence ratios on these predictions which are the objectives of this investigation. Time-matched environmental data fields with a resolution of 0.25° will be used to generate prediction maps on different time scales.



# DETERMINING THE PREFERRED STRUCTURE FOR AGING SMALLEYE PACIFIC OPAH (*Lampris incognitus*)

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This work is an international collaboration between CICESE (Ensenada Center for Scientific Research and Higher Education), NOAA Southwest Fisheries Science Center (SWFSC), NOAA Pacific Islands Fisheries Science Center (PIFSC), and PIER (Pfleger Institute of Environmental Research) that is focused on refining and comparing the methods used to estimate age and growth in the smalleye Pacific opah (Lampris incognitus), a poorly studied pelagic resource of the North Pacific Ocean. Information on age and growth is critical for population analyses and stock assessments of marine resources. For most fish species, age estimation is accomplished by the visual examination of concentric rings deposited on hard and bony structures during growth. The otolith (i.e., inner ear bone) continues to be the most common structure used to estimate age across taxa. However, several species have been successfully aged using different sectioning methods and structures, including dorsal fin spines/rays, vertebrae, and scales. For this study we collected smalleye opah (n=6) across a size range (89-111cm FL) from both US and Mexican commercial fishing vessels operating in the eastern North Pacific. Three initial dissections were performed to assess the suitability and practicality of extracting and visualizing rings from the otolith(s), vertebrae, and dorsal fin rays. Current efforts are focused on embedding, sectioning, and comparing the legibility of the different structures and their potential utility for estimating age. Initial dissections revealed visible growth rings on the otolith(s), vertebrae, and dorsal fin rays. Preliminary results suggest that rings are best visualized on vertebrae; however, obtaining vertebrae in the field is difficult as it requires a complete dissection of the fish. The fin rays also show good visualization of the growth rings and can be easily obtained in the field, while maintaining marketability. Otolith extraction is time consuming and the structures are extremely fragile which may impact feasibility of use in future aging studies. Current efforts are focused on comparing the three structures to assess legibility across different sized individuals as well as feasibility for use in future aging efforts.



# THE IATTC WORKPLAN FOR THE IMPLEMENTATION OF AN EMS IN THE EPO: PROCESS AND STAKEHOLDERS

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The process to implement an EMS for the tuna fisheries of the eastern Pacific Ocean (EPO) commenced in May 2020. Since then, six EMS workshops have been held to address all the primary components of EMS, along with two *Ad Hoc* working groups focused on refining the implementation strategy for EPO-EMS. A crucial aspect of these efforts has been the development of EMS standards, especially those related to data collection and analysis and reporting standards. The recommendations proposed for these standards have been shaped significantly by the findings from EM trials on purse-seine and longline vessels, facilitated by the support of IATTC country members, NGOs, and participating vessel companies. The trials have yielded valuable insights into which fishing activities can be reliably collected by EM systems and which areas still require improvements, potentially achievable with current technology advancements. This presentation summarizes the IATTC EMS work plan in the EPO, including the workshops, working groups, pilot projects, stakeholder engagement, and the current state of play of this process.



# COMBATTING ILLEGAL, UNREPORTED, AND UNREGULATED FISHING WITH EDGE COMPUTATION IN THE EASTERN TROPICAL PACIFIC

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<sup>1</sup>The Nature Conservancy

Large-scale fishing provides seafood that one in seven people around the world rely on for protein and supports millions of livelihoods. However, it is estimated that over a third of the world's fish stocks are overfished. Catch reporting is a requirement in most global fisheries, but without independent monitoring this self-reporting is unverifiable, creating conditions for many licensed fishing vessels to conduct widespread illegal, unreported, and unregulated (IUU) fishing activities. Electronic monitoring (EM) systems have significant potential to improve monitoring and inform management of target and bycatch species, but the cost and logistics of data review have hindered expansion to entire fleets. Fisheries managers and supply chain partners need better technology to rapidly flag risky activity in EM footage and focus the sector's limited monitoring and surveillance resources on the vessels that are likely misreporting their activities, or otherwise engaging in IUU activity. The Nature Conservancy and our partners are conducting research and development in the Eastern Tropical Pacific on risk-based assessments of fishing activity in near-real-time using edge technology, a form of AI that makes processing data more efficient by analyzing it close to the data source, in this case aboard fishing vessels. In partnership with INCOPESCA and individual captains, we have installed EM systems and Nvidia Jetson series edge devices on three mid-scale tuna longliners. Our edge computation approach takes siloed components of fisheries operations – e.g., EM footage, GPS data, and electronic logbooks (i.e., self-reported catch data from the vessel)- and combines them with machine learning catch count models in near real-time to establish a new system that is greater than the sum of its parts. Initial results suggest that edge assessments can reliably produce an overall IUU risk assessment for a vessel's trip to guide prioritization of human EM data review within a trip, and between vessels. Our preliminary conclusions are that implementation of edge-based AI-assisted EM review can potentially transform the status quo of the footage review process into a strategic and streamlined workflow to quickly identify IUU fishing activities before products enter global supply chains.



# DEEP-SET FISHERY DEVELOPMENT RESEARCH AND EXEMPTED TRIALS OFF THE U.S. WEST COAST

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#### Pfleger Institute of Environmental Research (PIER), Oceanside, CA

This study reports on the progression of deep-set fishery development research performed by the Pfleger Institute of Environmental Research since 2010. All gear experiments were designed using fine-scale depth distribution data from swordfish tagged along the California coast. Gear configurations were tailored to avoid surface-oriented bycatch, with daytime fishing depths ranging between 250-350m. Fishery development efforts have been performed in three distinct phases: Phase I - Deep-set Buoy Gear (DSBG) was initially developed in 2010 and has proven to be highly selective and complementary to ongoing swordfish operations off Southern California. Phase II - Linked Buoy Gear (LBG) incorporated DSBG bycatch mitigation attributes in a configuration that allowed for more hooks to be deployed at target depth over the same horizontal footprint as DSBG. This configuration resulted in slightly higher swordfish catch rates and similar catch composition as DSBG. Following eight years of EFP trials, both DSBG and LBG were authorized by the Pacific Fisheries Management Council and National Marine Fisheries Service for use in the West Coast Fishery Management Plan for highly migratory species (HMS FMP). Phase III - Expanded linked buoy gear (XLBG) builds upon the LBG configuration to meet the needs of larger vessels that fish farther from port. This presentation will discuss gear development process, results from exempted fishing trials and proposed work plans moving forward.



# OVER A DECADE OF COLLABORATION BETWEEN THE SPORTFISHING ASSOCIATION OF CALIFORNIA (SAC), NOAA SOUTHWEST FISHERIES SCIENCE CENTER (SWFSC), AND CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE (CDFW)

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California marine recreational fisheries support vibrant coastal communities and economies, depend on productive and biodiverse marine resources, and are managed in highly dynamic ocean ecosystems. The value and complexity of California recreational fisheries necessitate a broad portfolio of management tools and strategies, science-based decisions, stakeholder engagement opportunities, and industry-agency collaborations. In recognition of this, the Sportfishing Association of California (SAC), which was founded in 1972 as the non-profit organization that represents the Commercial Passenger Fishing Vessel (CPFV) fleet in southern California, collaboratively manages several fisheries data collection programs with both state and federal fisheries managers. Industry-led data collection efforts began at SAC as individual projects designed to inform specific management needs, such as determining fillet length regulations for nearshore species with CDFW, establishing at-sea fillet regulations for all local tunas with NOAA, and estimating post-release mortality of rockfishes with descending devices. As science and management needs grew, our strong collaborative industry-agency relationships led to the development of the SAC Fisheries Sampling Program. Under this program, SAC worked directly with CDFW to test electronic logbooks, train CPFV captains, and distribute eLogs to the recreational CPFV fleet, which was the first fishery in California to receive eLogs. Most SAC member vessels now report recreational landings electronically, which has reduced the management lags that are conventionally associated with paper-based catch logs. The SAC Fisheries Sampling Program also collaborated with the NOAA SWFSC to design and implement an at-sea data collection program to obtain size structure data for all tuna species caught by recreational anglers aboard SAC vessels. Using a randomized sampling design that was created and vetted by both NOAA and CDFW, crews aboard SAC fishing vessels were trained to follow a specific protocol to measure total lengths of four species of tuna (Pacific bluefin, yellowfin, bigeye, and skipjack). The dataset is maintained by an independent contractor who sends the data to science staff at the NOAA SWFSC and the Inter-American Tropical Tuna Commission (IATTC). This is now a highly successful and collaborative program with a 9-year time series of size structure for all four tuna species, which was recently analyzed in parallel with NOAA-led length data collection, and is scheduled for use in upcoming tuna stock assessments. The success of the tuna sampling model also informed the expansion of SAC-led data collection efforts to include nearshore species, particularly coastal rockfishes, with randomly sampled copper and quillback rockfishes being sent to the NOAA SWFSC for otolith processing to inform stock assessments. Finally, SAC has supported the California Collaborative Fisheries Research Program (CCFRP), which is a consortium of six California universities that work directly with the recreational fishing fleet to collect fishery independent data for evaluating effectiveness of the statewide network of marine protected areas. SAC support provides management agencies complex and timely data on a range of recreational species that is integral to stock assessments and management decisions. Our unique relationship provides a highly successful model for industry-academic-government cooperation, which is critical when all hands-on deck are needed for sustainable fisheries management in a dynamic ocean.



# 'JOINING THE DOTS'; LINKING MANAGEMENT, CONSERVATION, AND BROAD PHENOLOGICAL SHIFTS OF ATLANTIC BLUEFIN TUNA - A PERSPECTIVE FROM THE STRAITS OF GIBRALTAR"

#### Samantha Slisarenko, Awantha Dissanayake

#### University of Gibraltar

Understanding the adaptive responses of key species like Atlantic bluefin tuna is imperative for devising effective conservation and management strategies in the context of global climate change's profound impacts on marine ecosystems. Climate variability, driven in part by atmospheric oscillations, can significantly alter oceanographic conditions, closely linked to biological processes and environmental variables, including nutrient distribution, prev abundance, and the timing of biological events. Such understanding is crucial for predicting ecological responses to climate change and managing marine resources sustainably. Our study delves into the dynamics of Atlantic bluefin tuna within the critical habitat of the Straits of Gibraltar, a strategic migratory corridor essential for assessing ecological behaviours. Within Gibraltar's waters, bluefin tuna is fished seasonally under a managed quota system. In the absence of a commercial capture fishery (compared with regional neighbouring countries), this study 'joins the dots', bringing stakeholders, scientists, and policymakers together with a view of sustainable conservation and management strategies in an important local fishery. Through a multimethod approach integrating recreational anglersourced observations and emerging technologies such as environmental DNA analysis, we delve into bluefin tuna's seasonal dynamics and behavioural adaptations amidst shifting environmental conditions. By 'ground-truthing' data from anglers with eDNA analysis, we hope to improve our grasp of bluefin tuna ecology, particularly in response to climate variability. An initial multivariate analysis of diet markers elucidates a potential connection between these markers and climate variability. We aim to explore how this relationship influences foraging ground selection and the identification of potential hotspots for bluefin tuna. The present preliminary findings report on the possibility of an 'over-wintering' behaviour and are expected to feed into local policy decisions, guide the development of targeted conservation measures, and enhance fisheries sustainability, ultimately fostering the resilience of marine ecosystems against the backdrop of climate change.



# COOPERATIVE FISHERIES RESEARCH ON HIGHLY MIGRATORY SPECIES IN THE EASTERN PACIFIC OCEAN

# Owyn Snodgrass and Heidi Dewar<sup>+</sup>

#### NMFS NOAA Southwest Fisheries Science Center + Retired

In 2007, NOAA's Southwest Fisheries Science Center (SWFSC) began a partnership with the Sportfishing Association of California (SAC) to improve our understanding of the biology and ecology of Highly Migratory Species (HMS) of commercial and recreational fishery importance in waters off the southwest coast of the United States. Biological samples from HMS are needed to fill data gaps identified in management efforts. SWFSC biologists were given permission by SAC to take part in Commercial Passenger Fishing Vessel (CPFV) trips targeting HMS. The initial focus was on collecting otoliths and stomachs from Pacific bluefin tuna (Thunnus orientalis) and Pacific albacore tuna (Thunnus alalunga) carcasses donated by recreational fishers at sea aboard CPFV's. To expand and improve the quality and sample size of biological collections, SWFSC biologists began working with recreational fish processors and private boaters at the docks in San Diego, California, USA, to collect tuna carcasses. To date, over 7,000 tuna have been sampled, and the data generated have been used to support stock assessments, further ecosystem-based management efforts, and produce 24 peer-reviewed publications on movement, foraging ecology, age and growth, and reproductive biology of HMS. In addition to working directly with recreational fishermen and the fishing industry, the SWFSC participates in local and regional outreach such as attending fishing trade shows, posting on online fishing forums, giving news interviews, appearing on podcasts, and co-authoring magazine articles. Through these outreach opportunities, the SWFSC has further increased the volume of HMS samples donated by fishers while also sharing the scientific results publicly. This cooperative research and outreach approach have fostered trust and understanding between the scientific community, recreational fishermen, and recreational fisheries. The result has been the ongoing production of a transparent, robust biological sample archive and relevant data on HMS that informs assessments and management of HMS in the eastern Pacific Ocean. The success of this program is a direct consequence of strong professional and personal relationships that have been built and maintained between SWFSC biologists, SAC, recreational fishermen, and the fishing industry.



# COLLABORATING WITH LONGLINE FISHERS TO IMPROVE THE POST-RELEASE SURVIVAL OF MOBULA RAYS

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Developing conservation strategies for the threatened giant manta ray (*Mobula birostris*) and other mobulid rays (devil and reef manta rays) captured in U.S. longline fisheries is hindered by a lack of data on species specific catch, fisher handling and release practices, and survival rates post-interaction. To better understand the catch dynamics for mobulid species interacting with the Hawai'i-based tuna longline fishery, a multi-pronged approach was used to generate species specific catch data, record handling and release practices, and to quantitatively assess post-release survival rates through a satellite tagging telemetry program. A species identification guide was developed to facilitate accurate identification by fishers, observers, and researchers, and genetic samples were collected on observed trips by the Pacific Islands Region Observer Program. Electronic monitoring (EM) video, collected from volunteer vessels as part of research conducted by the Pacific Islands Fisheries Science Center, was also evaluated for potential identification on trips with mobulid interactions. To quantify the post-release survival of mobula rays interacting with the Hawai'i longline fisheries, fishers were trained to tag incidentally caught mobulid rays with satellite tags and to collect video and data on the interaction. This project is still in progress; at present, six mobula rays of five different species have been tagged with five animals surviving to at least 60 days after the interaction. This unique project demonstrates the benefits of collaborations across fishery stakeholder groups to fill data gaps and address bycatch issues from different perspectives.



# **BAYESIAN ESTIMATION OF CATCH PERFORMANCE IN NOVEL FISHING METHODS**

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Many fisheries around the world have benefited from innovative fishing methods that sustainably catch target species while minimizing bycatch. Identifying new gears that reduce bycatch without compromising economic viability is of interest to industry participants, managers, conservationists, and other stakeholders. However, analysis of new gear types during their development is often challenged by limited data and the rare, random nature of bycatch events, making it difficult to obtain precise estimates of catch and bycatch rates. Additional complications arise if different data sets are available to characterize the performance of alternative fishing methods. In this paper we present a case study of the U.S. West Coast swordfish fishery, which recently has undertaken testing of deep-set buoy gear as a lowbycatch method of targeting swordfish. We extend previous Bayesian analyses of swordfish fishing methods to new metrics that allow us to differentiate catch and bycatch performance between multiple fishing gear configurations, while considering statistical uncertainty due to limited and skewed data. We present a novel metric for comparing expected target species catch rates to bycatch rates of nonmarket and protected species. This metric quantifies the level of uncertainty in the predictions, and allows comparison of two different deep-set buoy gear configurations despite a large discrepancy in data availability between the two methods. We close with a discussion of the results, considerations for continued research, and possible extensions to other fisheries or non-fishery natural resource contexts. Preliminary findings indicate a higher marketable species share and lower unmarketable and protected species shares of catch for linked buoy gear than standard buoy gear, though with greater statistical uncertainty for linked buoy gear due to a smaller sample size.



# FACTORS AFFECTING CATCH RATES IN THE HAWAI'I SHALLOW-SET LONGLINE FISHERY

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The Hawai'i shallow-set longline fishery targets swordfish around the North Pacific Transition Zone, predominantly in the 4<sup>th</sup> and 1<sup>st</sup> quarters of the year between 180°W and 124°W. While swordfish are targeted largely for export to the continental United States, the fishery catches an array of species including secondary target species (e.g., mahimahi, bigeye tuna, albacore), bycatch (e.g., blue shark, lancetfish, pelagic stingray), and occasionally protected species (e.g., loggerhead sea turtles and albatrosses). We use ensemble boosted regression trees to estimate the occurrence (presence/absence) and catch rate (fish/1000 hooks) for 27 species in the Hawai'i shallow-set longline fishery from 2005–2022 based primarily on oceanographic conditions. Results indicate clear patterns in catch rate driven by gear and captain effects. Catchability for species with diel vertical migratory behavior is impacted by the lunar cycle. For the majority of taxa, catch rate is partitioned by the North Pacific Transition Zone, with unique secondary target and bycatch patterns on each side of the front. Proximity to seamounts and islands, including within what is now Papahānaumokuākea, and teleconnections such as ENSO have important roles in the catch rate of select taxa. These models provide baselines for how oceanography drives catch rate, allowing us to move toward projections of shifts in occurrence and catch rate of these taxa in the face of climate change.



# INFORMING THE SPATIAL MANAGEMENT OF SILKY SHARK *Carcharhinus falciformis* IN THE EASTERN PACIFIC OCEAN

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Fisheries management often relies on stock assessments, which benefit from a thorough understanding of spatial population structure. This understanding has been lacking for silky shark (*Carcharhinus falciformis*) in the Pacific Ocean, where silky shark stock assessments have failed to produce reliable results. We holistically considered the available literature on silky shark population genetic structure and horizontal movements across the Pacific Ocean, used male size at maturity to evaluate possible population units in the Eastern Pacific Ocean, and interrogated size structure and sex ratios across multiple fisheries in the region. Multiple data sources indicated that up to three silky shark stocks – southern, central, and northern – may occur within the Eastern Pacific Ocean. Silky shark length as measured by fisheries observers varied with latitude, where larger sharks were more common at higher latitudes within the silky shark's range. Sex ratios favored females in oceanic and equatorial zones and were more balanced or male-dominated nearer the subtropics close to the continental shelf. Given significant declines in silky shark abundance in recent decades, these data may inform future stock assessments that lead to the improved management and conservation of this common bycatch species in the world's largest tuna fisheries.



# INTEGRATING SCIENCE AND STAKEHOLDER INPUT: AN EXAMPLE FROM THE NORTH PACIFIC ALBACORE TUNA MANAGEMENT STRATEGY EVALUATION AND HARVEST STRATEGY ADOPTION PROCESSES

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The scientific literature on the management strategy evaluation (MSE) process typically focuses on the technical aspects of MSE. How MSE results are then translated into a real world harvest strategy is often not discussed or is assumed to be a logical extension of model results. However, our experiences with north Pacific albacore tuna suggests that the journey from initiating an MSE to adopting a harvest strategy at a tuna regional fisheries management organization (tRFMO) can be more of a long and winding road with last minute roadblocks and unexpected side tracks. Here, we present the history, processes, and lessons learned from the initiation of the MSE process to the adoption of harvest strategies for north Pacific albacore tuna at the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC). North Pacific albacore tuna is a temperate tuna stock that is assessed by the International Scientific Committee of Tuna and Tuna-like Species in the North Pacific Ocean (ISC), with fisheries that are managed by the IATTC and WCPFC. Although the stock was considered to be in a healthy status, prior to the initiation of the MSE, the fisheries management approach for this stock lacked a formal harvest strategy and target reference points. Several fisheries for north Pacific albacore obtained Marine Stewardship Council (MSC) certification, which likely improved marketability for albacore tuna from these fisheries. However, new MSC standards required an established harvest strategy with biological reference points for stocks managed by RFMOs. Subsequently, the WCPFC's Northern Committee directed the ISC to develop and lead a MSE for the stock, with the objective of establishing a harvest strategy and biological reference points, based on the MSE results. We were involved from the initiation of the MSE process in April 2015 through the adoption of a harvest strategy at IATTC and WCPFC in 2023. We learned that overcoming obstacles in this journey often hinged upon, not the output of computer models, but rather human-human communications between scientists, managers, and stakeholders. For example, one critical aspect of these communications is the building of trust between scientists, managers, and stakeholders but building trust requires time and effort, as well as consistency in the participants throughout the process. There were some aspects of the process that could be handled by the scientists but others required clear and regular interactions with the managers and stakeholders.



# INVESTIGATING NON-LETHAL DETERRENTS TO REDUCE INTERACTIONS AND MORTALITY OF OCEANIC WHITETIP SHARKS AND OTHER PROTECTED SPECIES AROUND HAWAI'I

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In Hawaii, oceanic whitetip sharks (Carcharinus longimanus: OCS) commonly associate with floating objects such as fish aggregating devices (FADs). As a result, there are high interaction rates between OCS and local small-boat tuna and bottomfish fishers that often lead to injury or mortality for the sharks. A common method fishers use to deter sharks from an area is jugging. Jugging is where fishers add a float, normally a plastic bottle, to a hooked animal and set it free. Depending on the configuration of the jugged line, some sharks are unable to free themselves and this often leads to mortality. To maintain resilience and geographic representation of OCS in the Western and Central Pacific region where the population status is most impacted, it is crucial to reduce these negative interactions between OCS and fishers. Partnering with local fishers, we tested two types of non-lethal deterrents; 1) galvanic links in jug rigs and 2) magnetic deterrents on baited lines. First, nine sharks were tagged with survival pop-off archival tags (SPATs) and quick release (2-5 hour) galvanic links on a jugging apparatus to determine if they could effectively and nonlethally deter sharks from an area. Second, we conducted paired trials to test Sharkbanz magnetic deterrents in the local bottomfish fishery, comparing depredation rates on a control rig and a treatment rig with Sharkbanz magnets. Of the 9 tags deployed on sharks jugged with a galvanic jugging apparatus, one tag did not report and the others (n=8)showed the animal surviving until the tags came off between 11-60 days post release. Although overall depredation rates in trials of magnetic deterrents in the bottom fish fishery (n=127) were low (<5% of drops), we found no significant effect of Sharkbanz magnets upon depredation rates (p=0.94). Our results indicate that more work is required to mitigate shark interactions with fishers in the Hawaii based small boat fisheries.



# ARTIFICIAL INTELLIGENCE (AI) MODELS DEVELOPED FROM ELECTRONIC MONITORING VIDEO PROVIDE AN OPPORTUNITY TO AUTOMATE DETECTION OF CATCH IN THE HAWAI'I LONGLINE FISHERIES

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Artificial Intelligence (AI) models have the potential to save cost and time for video review of electronic monitoring (EM) data through the automatic detection of fishing vessel catch events. Research is ongoing in the Hawai'i longline fisheries to automatically detect catch events including bycatch released from fishing gear without being brought on board the vessel. To train AI models, a library of annotated images of fish, sharks, and protected species (sea turtle and cetaceans) is being built. EM video is currently collected from 20 volunteer vessels, and images of catch on both the deck and in the water are extracted. Annotations are created by drawing bounding boxes around catch using VIAME dive desktop software. These annotations and their associated images are incorporated into a YoloV5 object detection algorithm for training, utilizing the computing power of virtual machines and Google cloud. A successful AI model has been developed that detects fish on deck, sea turtles on deck and in the water, and cetaceans in the water using 198,412 annotations. Model performance metrics and tests from running raw video footage through model algorithms indicate good accuracy and confidence with minimal false positives. The ability of AI models to detect protected species will help inform how to best design an EM program that incorporates AI with human reviewers.



# ROUTINE AND POSTPRANDIAL OXYGEN CONSUMPTION RATES AND SWIMMING SPEEDS IN DOLPHINFISH (*Coryphaena hippurus*)

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Routine and postprandial oxygen consumption rates of dolphinfish (*Coryphaena hippurus*) were assessed over a wide size range (4.30 – 18.50 kg) and variable temperatures (21.0-24.5 °C) at preferred swimming velocities using a large 8850 l static respirometer. Post-meal oxygen consumption was determined following feedings of 3-13% body mass, with meals of variable caloric value of either sardine or squid to examine the magnitude of specific dynamic action. Postprandial oxygen consumption was elevated for up to 41 hours post ingestion and was linearly correlated with meal size and caloric value, resulting in a maximum 3.1X increase in metabolic rate with the largest meals. These trends mirror those observed in other teleost fishes, and postprandial oxygen consumption was similar in magnitude to that of tunas (family Scombridae). In addition to metabolic data, video recordings from the trials were collated to examine routine and post-meal swimming speeds and behavior. Some individuals exhibited a tilted swimming posture, which may provide some hydrostatic lift and consequent energy savings. Future research efforts should seek to link lab-based energetic estimates and observations with field-based movements and behavior to accurately gauge true energetic costs in the wild. The emergence of accelerometers capable of measuring tilt, speed, acceleration, and tailbeat frequency, along with environmental parameters such as temperature, can further refine such energetic cost estimates.



# DISTRIBUTION OF SOUTHERN BLUEFIN TUNA LARVAE

Preliminary results from the Bloofinz-IO Project (NSF-1851395) – Environmental factors impacting the larval distribution of Southern Bluefin Tuna (*Thunnus maccoyii*) https://storymaps.arcgis.com/stories/4a7fbab3e05d45a4b42a0384605c6395

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Southern bluefin tuna (SBT) (*Thunnus maccoyii*) are a widespread species of commercially valuable fish found throughout much of the southern hemisphere's oceans. SBT share a singular spawning ground in the Indian Ocean between Indonesia and northwestern Australia. This study investigates the relationship between larval SBT abundance and zooplankton (prey) abundance and explores additional correlations with environmental parameters and impacts of marine protected zones. Geospatial software (ArcGIS) was utilized to interpolate environmental data and analyze larval SBT relationships. A weak, negative correlation (r = -0.34) was found between larval SBT abundance and prey abundance. This finding may indicate that SBT larvae are facing high feeding competition with low prey availability. These preliminary results from the BLOOFINZ Project highlight the dynamic roles the ecosystem has on the distribution, behavior, and success of larval SBT.



# EVALUATING THE CONTRIBUTIONS OF MESOPELAGIC PREY TO TUNAS AND SWORDFISH IN THE OPEN OCEAN USING COMPOUND-SPECIFIC STABLE CARBON ISOTOPE ANALYSIS

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The ocean's twilight zone is a vast area of the global ocean that lies between the sunlit surface waters and perpetually dark midnight zones, covering depths from c. 200 to 1000 meters. While marine science has historically focused on shallow and nearshore regions, recent work in the twilight (or mesopelagic) zone has revealed unexpected biomass and diversity that may not only challenge scientific understanding of marine systems but also provide a new and largely untapped resource for fisheries harvest. One of the key knowledge gaps in our understanding of the mesopelagic is how its food webs support unquantified foraging activity by commercially valuable, highly migratory top predators. Here, we trace the flow of carbon through pelagic ecosystems in the northwest Atlantic to three predators - bigeye tuna (Thunnus obesus), swordfish (Xiphias gladius), and yellowfin tuna (Thunnus albacares) via compound-specific stable carbon isotope ratio ( $\delta^{13}$ C) analyses using a sample collection made possible by collaboration with a commercial longlining vessel and a recreational fishing charter. Mesopelagic-associated carbon was estimated to have contributed greatly to predator biomass with overall mean contributions by species of 63%, 33%, and 51%, respectively. At the individual level, mesopelagic carbon contributions to predators ranged from 8% to 92%. Additionally, we describe the seasonally shifting carbon sources of predators as they move between temperate and tropical waters by contrasting tissues (liver, muscle) and season of sampling (summer, fall). This work informs the motivations of deep diving in large marine predators, and provides key estimates of food web linkages to inform multi-species pelagic fisheries management of both mesopelagic prey and migratory predators.



# UNITING SCIENCE AND STAKEHOLDERS FOR SUSTAINABLE TUNA MANAGEMENT: A COLLABORATIVE APPROACH TO DEVELOPING HARVEST STRATEGIES IN THE WESTERN AND CENTRAL PACIFIC OCEAN

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The Western and Central Pacific Ocean (WCPO) accounts for over half of the world's tuna catch. Recognizing the critical need for sustainable management of tuna fisheries, the members of the Western and Central Pacific Fisheries Commission (WCPFC) agreed to a workplan for the adoption of harvest strategies for WCPO skipjack, bigeye, yellowfin and South Pacific albacore tuna in 2015. Central to this initiative is a comprehensive stakeholder engagement programme. The Pacific Community (SPC) plays a pivotal role in organising and facilitating capacity building and stakeholder engagement workshops at the regional, sub-regional and national level. Focussing on the national level, by facilitating 18 workshops across 12 Pacific Island Countries and Territories (PICTs) since 2018, the SPC has trained over 400 participants, laying the groundwork for informed decision-making. This collaborative effort was essential for the adoption of the interim skipjack management procedure (MP) at the WCPFC meeting in December 2022, marking a significant milestone as the implementation of a harvest strategy for the world's largest tuna fishery. Drawing from this experience, we outline the critical elements of stakeholder engagement in the WCPFC harvest strategy development process. These components have not only enabled stakeholders to drive the development process but also provided a framework for directing and implementing harvest strategies to meet management objectives. Our findings highlight the importance of stakeholder-driven approaches in achieving sustainable fisheries management and offer insights for tuna fisheries in other RFMOs.



# A GEM OR A BOOT? EXAMINING THE QUALITY OF COMMERCIALLY CAUGHT ROD AND REEL ATLANTIC BLUEFIN TUNA, *Thunnus thynnus*, FROM THE PERSPECTIVE OF ANGLERS

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Scientists, managers, and commercial anglers have raised concerns that the commercial ABFT rod and reel fishery suffers from overcapitalization due to market oversaturation driving down ABFT prices. ABFT are individually examined and graded for four quality variables that impact their market value: freshness, fat, color, and shape. In New England, anglers commonly believe that ABFT measuring between 72 and 90 inches are the highest quality fish. In tournaments for commercial-sized ABFT, anglers are not incentivized to catch high-quality fish. Instead, they can earn substantial prizes by landing large fish during each tournament day. The primary objectives of this study are to 1) Determine temporal breakpoints in ABFT quality to evaluate how the relative quality composition has changed in the rod and reel fishery overall and in New England, 2) Examine the notion that ABFT between 72 and 90 inches have high-grade quality ratings, 3) Determine the potential quality of contemporary tournament sized ABFT. Structural Break analysis was performed on Permit Category rod and reel PECAT data and dealer-supplied grades from 1996-2022 to determine compositional breakpoints. Statistical analysis of "gems," ABFT with very high-quality grades, and "boots," ABFT with very low-quality grades, was conducted to determine if the central tendency fell within the 72 to 90-inch bounds. The tournament ABFT size range was determined by calculating the quartile range of fish lengths observed in three tournaments from 2021 to 2023. Statistical analysis was repeated using these boundaries to ascertain whether tournament-sized fish represented the typical central tendency. Preliminary results show punctuated changes in the composition of ABFT quality grades over time. Quality grades from New England states demonstrated varying temporal changes in composition. Findings corroborate the supposition that 72 - 90-inch ABFT have increased potential for high-grade quality and show that contemporary tournament-sized ABFT qualities vary spatially and temporally with higher variability in quality grades.



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