Bluefin Futures Symposium

Meeting Report • January 18-20, 2016

BLUEFIN FUTURES SYMPOSIUM MEETING REPORT

January 18-20, 2016

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INTRODUCTION

The Monterey Bay Aquarium and Stanford University, with the help of many sponsors, organized the "Bluefin Futures Symposium," held January 18-20, 2016 in Monterey, California. The Symposium brought together many of the world's leading bluefin tuna experts from diverse fields, including research, policy, industry and conservation, to discuss and share the latest information on issues affecting the status and future of bluefin tunas in our global ocean.

The objectives of the Symposium were to present the latest scientific research and information on Atlantic, Pacific and southern bluefin tunas, to encourage dialogue among experts and participants, and to identify goals and solutions that will build a sustainable future for all three species. In particular, the Symposium sought to clearly identify the research and population status of each species, share perspectives on management approaches used by different regional management bodies, share lessons learned, open new dialogues on cross-cutting issues that face all bluefin tunas, and stimulate discussion about challenges and potential solutions to achieve sustainability.

The Bluefin Futures Steering Committee (Appendix 2) designed the program with input from sponsors (Appendix 1) and a range of experts. The program (Appendix 4) was divided into 11 sessions by topic: the latest scientific knowledge for all three species (Atlantic, Pacific and southern bluefin tunas); stock assessments; fishery management tools; management challenges and opportunities; best practices in providing scientific advice; the economics of the bluefin tuna industry; the role of aquaculture; and the impacts of climate change. Sessions featured a mixture of presentations, moderated panel discussions, keynote speakers, and opportunities for engagement by participants. Participants (Appendix 3) were encouraged to submit questions and comments during each session's discussion to facilitate a robust dialogue from different perspectives. At the end of each day, session moderators offered a brief summary of the day's discussions as a recap for participants.

The Symposium was conducted under Chatham House Rule to encourage open dialogue and participation. Accordingly, the descriptions and accounts of the Symposium within this meeting report do not associate specific comments with any individual or with their affiliation. The exceptions are invited speakers identified in presentation summaries and keynote speakers that were listed in the official symposium program. Participants attended the Symposium based on their individual qualifications and their comments do not necessarily reflect the position of their affiliation.

The Bluefin Futures Symposium was a first step in what is envisioned as a continuing, multi-year dialogue to support international collaborations on science and management that promote the recovery and sustainability of bluefin tunas globally.

OPENING

Ms. Julie Packard opened the meeting and welcomed participants from around the world to Monterey for the Bluefin Futures Symposium. Ms. Packard recognized and thanked the sponsors of the Symposium, as well as a number of official dignitaries. She offered remarks on the need for collaboration among all participants to recover and sustain bluefin tunas globally, and her hope that the Symposium would stimulate new dialogue and partnerships.

Ms. Maria Damanaki provided a keynote address to share her historical perspective on Atlantic bluefin tuna from her experience as Former European Commissioner for Maritime Affairs and Fisheries. Ms. Damanaki identified the

value of bluefin tunas, the current overfished population status of each species, governance and management challenges within the Regional Fisheries Management Organizations (RFMOs), and her experience in implementing major policy changes for eastern Atlantic bluefin tuna. She offered five recommendations to support the strongest possible recovery of bluefin tunas globally: partner with fishermen and fishing communities; use science to set management targets; make policy reform through government partnerships; encourage private sector partnerships and investments; and pioneer new technologies and access to markets.

Dr. Barbara Block offered a keynote address to welcome the Symposium participants on behalf of Stanford University and echoed Ms. Packard's thanks to the sponsors that made the event possible. Dr. Block outlined her perspective on bluefin tunas globally, including the need for additional investments in research to address key knowledge gaps, the need for more comprehensive modeling approaches to inform stock assessments, and stronger scientific review processes and technical capacity within the RFMOs.

Note: Abstracts for all presentations are included in Appendix 5.

DAY 1: THE LATEST RESEARCH ON BLUEFIN TUNAS

PURPOSE: The purpose of Sessions 1-3 was to highlight current knowledge and discuss science gaps for Atlantic, Pacific and southern bluefin tunas. Experts studying various aspects of the life history, stock structure, habitat and migrations of bluefin tuna discussed the most recent advances to support science-based management decisions. Future research needs were also identified. The presentations addressed advances in electronic tags, molecular tools, modeling, statistics, spatial dynamics and life history research.

SESSION 1 WHAT SCIENCE IS NEEDED FOR "SCIENCE-BASED" MANAGEMENT OF ATLANTIC BLUEFIN TUNA (ABFT)?

MODERATOR: Dr. Clay Porch, NOAA

PRESENTATIONS:

Dr. Andre Boustany, Duke University. Migration patterns and population structure of Atlantic bluefin tuna (*Thunnus thynnus*).

Dr. Haritz Arrizabalaga, AZTI. Life history and migrations of Mediterranean bluefin populations.

Dr. Fausto Tinti, University of Bologna. Back to the future: What population genomics and paleogenomics reveal on spatio-temporal stock structure, connectivity and adaptation in the Atlantic bluefin tuna.

Dr. Jay Rooker, Texas A&M University. Origin and population connectivity of Atlantic bluefin tuna: Insights from natural markers in otoliths.

Dr. Barbara Muhling, Princeton University. Predicting Atlantic bluefin tuna larval habitat in the western Atlantic.

Dr. Antonio Di Natale, ICCAT. Improving the scientific understanding of Atlantic bluefin tuna: The ICCAT GBYP research program.

Dr. Andre Boustany discussed migration patterns and population structure of ABFT primarily in the western Atlantic. He presented the history and results for 1300 archival and pop up satellite tag deployments in the western Atlantic, recoveries and days at liberty from 1996-2015. He described the evidence from tagging for assigning origin to a population, mixing between populations on the feeding grounds and the capacity for electronic tagging in combination with genetics to inform ABFT movements, origin, maturation and life history. He described information useful to management that has been revealed by tagging efforts including bulk transfer

movement and mixing rates, duration on site, age and size of returning fish, regional fidelity patterns and genetic structure.

Dr. Haritz Arrizabalaga presented information on the life history and migrations of ABFT from the Mediterranean populations, identifying population structure, population mixing and components of reproduction (maturity, fecundity, sex ratio, and patterns of fish not spawning in any one season if conditions are not optimal) as critical information needs. He described more recent views on ABFT population structure that offer different hypotheses regarding multiple populations versus the single eastern Atlantic and Mediterranean Sea population from earlier work. Using genetics, tagging and otoliths microchemistry he presented several population structure hypotheses for the Mediterranean (i.e. single population, several populations and several contingents) and the scientific evidence to support them. He noted that new methodologies indicate more populations or contingents might exist in the Mediterranean Sea than previously thought. He summarized the information presented by saying that there is great connectivity throughout the Atlantic and Mediterranean but substantially more research is needed to resolve the Mediterranean population structure.

Dr. Fausto Tinti presented on population genomics and paleogenomics as tools to look at stock structure (spatial and temporal), connectivity and adaptation in the ABFT. He described sampling of larvae, young of year (YOY) and adults, obtaining genetic sequences for work on single nucleotide polymorphisms (SNPs) as a technique for assigning fish origin (western Atlantic or Mediterranean). Researchers found high average probability of correctly assigning origin using this technique (83% larvae/YOY and 82.2% adults). He also presented paleogenomics work that revealed clear genetic structure between the northwest Atlantic and Mediterranean populations, but no evidence of genetic structuring within the Mediterranean Sea.

Dr. Jay Rooker described a number of tools available to look at population connectivity, such as genetics, tagging, biophysical modeling and natural tracers in hard parts. He then focused in on how natural tracers in hard parts of bluefin tunas, particularly the otoliths, can be analyzed to better understand population exchange and factors that influence connectivity among ABFT stocks. Otoliths are ear “stones” found in the inner ear that are made up primarily of calcium carbonate and accrete material continually as the fish grows, incorporating substances found in their environment. Dr. Rooker explained that this makes otoliths a convenient “natural tag” because isotopes and trace elements found in otoliths can be used by researchers as chemical tracers to determine where fish have traveled. Isotopes are variations in the number of subatomic particles (neutrons) in the nucleus of an element (e.g., Carbon-14), and stable isotopes of an element do not decay into other elements, thus leaving a “signature” where they accumulate that can be detected by researchers. He described his work developing a research and analytical approach to use these tracers in hard parts and then his key findings to guide researchers in using it for assessing age-specific movements.

Dr. Barbara Muhling began her presentation by noting that although adult distribution of ABFT is the largest among tunas, their known spawning habitats are very restricted. She noted that larval sampling has been done in the Gulf of Mexico for over 30 years, but that fish distributions can vary annually based on environmental conditions within the spawning area. She described work on predictive habitat models to see if environmental conditions were restricting ABFT spawning habitats in the Gulf of Mexico. She presented some common findings from the different habitat models her team has tested. Temperature and surface chlorophyll were important indicators, suggesting adaption to an oligotrophic environment—in other words, fish were selecting for habitats with low nutrients and limited phytoplankton growth and this information could be useful for predicting where spawning is likely to occur in Gulf of Mexico. She also described exploratory cruises that sampled areas outside the Gulf or Mexico and US-EEZ that found ABFT larvae in the Caribbean and north of the Bahamas. Dr. Muhling also

presented larval ecology studies, explaining their importance for understanding environmental influences on distribution.

Dr. Antonio Di Natale presented on the International Commission for Conservation of Atlantic Tunas (ICCAT) Atlantic–wide research program for ABFT, the Grande Bluefin Tuna Year Program (GBYP) that includes a list of priority research actions supported by cooperation among multiple countries, institutions and individual scientists. These actions fall into five broad categories that he detailed in his presentation: data mining and recovery, aerial surveys, biological and genetic sampling and analyses, tagging, and modelling. Ongoing and future work includes recovery of more data and biological samples, extension of aerial survey coverage, change in tagging emphasis from conventional to electronic, improved tag recovery and reporting, improved linking of biological data, and development of generic software tools to implement Management Strategy Evaluation (MSE), including developing the best approaches for using fishery independent data and better quantifying uncertainties.

DISCUSSION

The panelists and participants in this session generally agreed that understanding ABFT population structure and the life history within populations is essential to making improvements in current management models. The panelists identified critical information gaps including: population structure, life history traits (such as natural mortality for these populations), larval distributions and survival, spawning behaviors, locations, movement patterns, connectivity between spawning grounds, age at maturity, mixing, inter-annual variation in many of these factors and potential climate impacts. Panelists suggested that genetics and electronic tagging will play an important role in gathering these data in conjunction with conventional tagging techniques, and it was noted that long-term tag data (e.g., 5 year archival tags) will be essential to understand the connections between populations in the Mediterranean Sea and in the western Atlantic.

The panel discussed the limitations of traditional research techniques in addressing key population model uncertainties, including understanding larval distributions and the difficulties of adequately sampling different age classes. Panelists suggested that new molecular-based techniques (e.g., next generation sequencing, chemical markers) will be instrumental in evaluating distribution and age structure. One participant noted the importance of prioritizing data collection and analyses, and ensuring that the information is delivered at predictable time intervals to inform stock assessments and management decisions (e.g., quality and availability of catch data, length/age, and catch rates), including assessing the effectiveness of harvest strategies and other management actions. The continuing problem of limited resources for unmet research needs in this context was acknowledged. Participants and panelists also recognized that many management questions require a very sophisticated, data-driven research approach, highlighting the need for sustained funding sources for robust, long-term research projects necessary for ABFT management.

The panel discussed possible solutions to fill ABFT science gaps. Many panelists highlighted the need to better understand bluefin tuna population structure in the Atlantic. Panelists and participants discussed the possibility of a meeting among relevant scientists and stock assessment modelers that could create an overall sampling design to answer key questions and coordinate among scientists who are tagging fish, e.g., to clarify whether the tagged population is well mixed with untagged populations. In addition, to obtain information on spawning adults, a participant suggested tagging adults in Morocco and Ireland. Panelists and participants discussed the potential value of a genetics workshop to establish a multinational plan for validation of samples, and an additional workshop to compare and evaluate techniques (e-tags, population genetic tags, and otoliths) towards achieving consistency among participating scientists (e.g., academic, government and others). Members of the panel noted that knowledge gaps could be reduced if “official biological samples” (i.e. an internationally agreed upon list of

samples, including protocols on how they are collected) were taken routinely and representatively by each country for all major fisheries. A panelist also recommended that the current stock assessment models should be improved to include better estimates of mixing, such as through inclusion of biological data (e.g. genetics, otolith microchemistry and electronic tagging studies).

SESSION 2 WHAT SCIENCE IS NEEDED FOR "SCIENCE-BASED" MANAGEMENT OF SOUTHERN BLUEFIN TUNA (SBT)?

MODERATOR: Dr. Jim Ianelli, NOAA

PRESENTATIONS:

Ms. Jessica Farley, CSIRO. Advances in biology and life history of southern bluefin tuna.

Dr. Toby Patterson, CSIRO. Spatial dynamics of southern bluefin tuna – an overview and implications for management.

Ms. Ann Preece, CSIRO. Long term recruitment monitoring data for the SBT management procedure and stock assessment models.

Dr. Mark Bravington, CSIRO. Close-kin mark-recapture for southern bluefin tuna.

Ms. Jessica Farley presented information on the long term data and sample collection efforts for understanding southern bluefin tuna life history. This included data on SBT adults on the spawning grounds in Indonesia, and juveniles on feeding grounds across their range. She described analyses on age, growth and reproduction, and noted important milestones, including identification of increases in growth rates of juveniles, changes in the length and age distribution of adults on the spawning ground, and size related trends in reproductive parameters. Ms. Farley presented the current state of knowledge based on work spanning more than 20 years, as well as priorities for future research to fill information gaps, highlighting the importance of long-term data collection and international research collaboration.

Dr. Toby Patterson described research into the spatial dynamics (i.e., distribution, movement rates and migration paths/cycles) of SBT. Specifically, he described how electronic tagging has informed our understanding of SBT biology and provides important contextual information for stock assessment and management. A combined analysis of conventional and electronic tagging data has improved the estimates of juvenile mortality. Advances in geolocation and estimation of movement paths have provided higher resolution of timing and scale of movements between fishing areas such as the Great Australian Bight and the Eastern Tasman Sea. He hypothesized that the lack of movement to spawning grounds in data sets from some fish may be due to "skip spawning" behavior that suggests that reproductive age fish may not spawn every year. There are also indications of different timing of spawning depending on tagging area – which may indicate that timing of spawning is influenced by the choice of winter foraging areas. Considerably more data, collected over a longer period, are required to determine whether this hypothesis has support. Dr. Patterson concluded that well designed electronic tagging programs can provide highly informative data on fish movements, behavior and distributions.

Ms. Ann Preece began her presentation with a discussion of the SBT management procedure[1] (MP) and how scientific research programs provide data used in the MP to recommend the total global catch. She discussed the importance of recruitment monitoring data in the SBT MP to allow rapid responses that enable rebuilding of the stock. She noted that SBT strategic scientific research programs have prioritized collection of reliable fisheries data,

[1] Management procedures (MPs) are commonly known as "harvest strategies". In this report, we generally use the term harvest strategies, although MP is used in the context of SBT/CCSBT.

fishery independent data and the establishment of cost-effective, long term monitoring projects. She described the history of collaborative SBT research programs, developed by the Commission for the Conservation of Southern Bluefin Tunas (CCSBT) members and the Commonwealth Science and Industrial Research Organization (CSIRO) that included conventional tagging for estimates of fishing and natural mortality, age and growth studies, and aerial surveys for juvenile abundance. Data from these programs are included in the SBT operating models for assessment of stock status. Ms. Preece also discussed a new research project using gene tagging to estimate the absolute abundance of juvenile SBT, emphasizing the importance of thorough research program design and review processes.

Dr. Mark Bravington described the use of Close-Kin Mark-Recapture (CKMR) to estimate absolute abundance for adult SBT, without needing Catch per Unit Effort (CPUE) or total catch data. CKMR is a relatively new technique that uses modern genetics to identify pairs of close relatives among large samples, and then examines the number and arrangement of pairs found using an extended mark-recapture framework, to allow estimation of absolute abundance as well as other demographic parameters. The mark-recapture analogy is that each sampled juvenile "tags" its two parents, which may or may not be recaptured among the sampled adults. Dr. Bravington described the application to SBT, where 5000 adults and 8000 juveniles from catches were sampled between 2006--2010, yielding 45 Parent-Offspring Pairs (POPs). In conjunction with length and age composition data from the spawning-ground fishery (but without catch or effort data), it was possible to estimate a time-series of adult abundance between 2002--2010, as well as true fecundity-at-size, selectivity, and total mortality rate. The fit was good, the per capita reproductive contribution of bigger adults was considerably more than previously assumed, and the abundance estimates were substantially higher than speculations based on untestable assumptions about the extent of under-reported catches. The CKMR data has now been incorporated into the main CCSBT stock assessment, and is being considered for direct use in future MPs; CCSBT has funded the ongoing collection of samples. Dr. Bravington noted that the SBT case happens to be tractable just using POPs, because of particular circumstances around biology and sampling, and extensive prior research on histology and reproductive dynamics. For other species, though, a truly CPUE-free CKMR model that estimates mortality and selectivity usually also requires more distant (and harder-to-detect) kin--- specifically, Half-Sibling Pairs (HSPs). Happily, this has recently become possible thanks to technological advances--- specifically, the advent of Next-Generation Sequencing (NGS). Dr. Bravington commented that great care is still needed to choose the right variant of NGS--- not all are cheap or reliable enough for finding HSPs. However, with the right NGS method and about 2000 well-chosen SNPs, HSPs can be found reliably, and CSIRO is now changing over to NGS for SBT. For other tunas, a naive misapplication of an unchanged SBT-like CKMR model would fail in the presence of stock structure, but Dr. Bravington noted that the underlying equations can be adapted to allow for (and indeed infer) stock structure given adequate sampling coverage. While CKMR requires a lot of care and thought to get right, its potential as an inexpensive, robust, and CPUE-free way of monitoring the spawning stock is compellingly attractive for bluefin tunas in particular.

DISCUSSION

SBT is a single stock that has been severely depleted (8-12% of unfished spawning stock biomass (SSB_0)) and is harvested by a complex international fishery. However, the CCSBT has had success in addressing a number of specific science and management challenges. Panelists noted that there has been cooperation between industry, government, and research agencies over many decades to create multi-national and multi-disciplinary research programs and integration of catch, biological data, mortality and abundance estimates into the SBT stock assessment and management procedure. Validated age, growth and reproductive dynamics provide key data for model estimates of changes in population size. Electronic and conventional tag data have been integrated and translated for managers through mathematical models to show movement and use of different ocean locations. The panel discussed general population trends in SBT, noting that recruitment has increased in recent years and

this offers hope for population rebuilding in the coming years. The panel discussed potential areas for continued investment in SBT science including fishery-independent monitoring of recruitment (gene-tagging for absolute abundance estimates of juveniles), and fishery-independent monitoring of adult abundance (through close-kin mark recapture); these activities provide data that, along with key biological parameters, are critical to the management procedure for setting global total allowable catch (TAC) and monitoring the rebuilding of the spawning component of the stock.

Since 2011, SBT management has been based on a management procedure developed using MSE. Several panelists and participants described the MP and MSE approach, which projects a model of the SBT fishery into the future under various scenarios to test the effectiveness of alternative MPs. The MSE is a useful tool because it tests management strategies against biologically plausible scenarios and uncertainty. Importantly, it specifically addresses the short and long-term performance of MPs against stated management objectives, is transparent and involves all stakeholders. Specific discussion centered on how specified monitoring data is used in the selected MP, and the importance of pre- determined, timely mechanisms to respond to unanticipated changes that are outside the range of the scenarios the MP was tested under. For example, the SBT management procedure is codified in the Harvest Control Rules (HCR) to respond to a situation where monitoring data indicates levels of low recruitment, by reducing the recommended TAC. In addition, if recruitments, or other indicators, are outside the range tested in the MSE then the pre-agreed Meta-Rules process requires the scientific committee to provide decision makers with advice on how to respond appropriately to the unforeseen circumstances.

Panelists highlighted the ability of existing and new research techniques, including electronic tags, aerial surveys, CKMR and gene tagging, to provide important information on fish migration and residency and fishery-independent indices of abundance A panelist noted reproductive biology was important to address knowledge gaps on SBT spawning cycles for use in CKMR abundance estimates, but that CKMR could be further supplemented by electronic tagging and biological sampling to understand other critical research questions.

The panel discussed what lessons from the SBT CKMR work could be applied to Pacific bluefin tuna (PBF) and ABFT. For ABFT, a panelist suggested that picking the right molecular technique for genotyping is critical for reliable CKMR results because ABFT has complex stock structure issues requiring precise origin data and sampling design. Another panelist commented that applying CKMR to PBF also has some complexity due to uncertainties related to migration and population structure.

Participants and panelists discussed traditional and alternative tagging techniques. A panelist pointed out that the difficulties of implementing a conventional tagging program are well known (such as estimation of tag loss and reporting rates) and that gene-tagging circumvents the need to control for these as the tags are invisible and permanent. Electronic tagging requires many of the same design considerations as other tagging projects, but does have the capacity to provide important behavioral information. In the case of SBT, further information on the behavior on the spawning ground would assist in addressing current assumptions of CKMR method.

SESSION 3 WHAT SCIENCE IS NEEDED FOR "SCIENCE-BASED" MANAGEMENT OF PACIFIC BLUEFIN TUNA (PBF)?

MODERATOR: Dr. Toshihide Kitakado, Tokyo University of Marine Science and Technology

PRESENTATIONS:

Dr. Tamaki Shimose, Seikai National Fisheries Research Institute, Japan Fisheries Research Agency. Life history of Pacific bluefin tuna.

Dr. Takashi Kitagawa, University of Tokyo. Electronic tagging applications and migrations of Pacific bluefin tuna in the western Pacific Ocean.

Dr. Rebecca Whitlock, Tuna Research and Conservation Center. Electronic tagging applications for Pacific bluefin tuna in the eastern Pacific Ocean: Migrations, fisheries and foraging.

Dr. Nobuaki Suzuki, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency. Genetics of Pacific bluefin tuna: Introduction of close-kin project with NGS approaches by Fisheries Research Agency, Japan.

Dr. Daniel Madigan, Harvard University. Pacific bluefin tuna migration: Filling in knowledge gaps with chemical tracers.

Dr. Tamaki Shimose began his presentation with an explanation of the term "life history" and a diagram of fish life stages (egg, larva, juvenile, adult) with transitions between these life stages (growth, migration, reproduction). He explained that knowledge of the transitions is fundamental to stock assessment efforts. Dr. Shimose presented results of recent research designed to improve understanding of these fundamental biological attributes for PBF. He described otolith research that is advancing knowledge on age and growth, and some of the significant findings from otoliths comparing ABFT, PBF, SBT and other tuna species. Dr. Shimose also explained migration, detailing tagging research on habitat use that demonstrated different patterns of use as fish changed from juveniles to spawning adults. On reproduction, he described research on spawning in Sea of Japan and around Okinawa that indicated a difference in age composition between samples from the Sea of Japan (3-10yrs, 110-200cm fork length) and samples collected off of Okinawa (8 -20yrs, 200-250cm fork length). The relationship between the spawning grounds was not clarified. He noted that to date, no genetic isolation has been found in PBF, and there is no evidence of multiple populations. In concluding remarks Dr. Shimose revisited the life history cycle diagram to emphasize unanswered questions and ongoing research.

Dr. Takashi Kitagawa presented research from the western Pacific and application of electronic tagging techniques to studies of PBF migrations. He noted that over 800 archival tags had been released that included measures of ambient light intensity, pressure and internal temperature to establish the geolocation of PBF in water column and whether they were feeding. He presented location data that showed trans-Pacific migrations from the west to the east, averaging 2 months in duration, and he noted that the timing for the start of the migration depends on the wintering location. The tagging data also revealed that fish made frequent dives during day time and changed their behavior according to oceanographic conditions. This information is important to understand and predict habitat use and movements. Dr. Kitagawa outlined future goals for electronic tagging research, including describing the entire PBF life history and stock structure.

Dr. Rebecca Whitlock described electronic tagging studies of PBF in the eastern Pacific Ocean, including research on migrations, fisheries and foraging strategies. She started by identifying knowledge gaps and management challenges, noting that the stock is severely depleted, and that the assessment model has key areas that need to be improved. In particular, Dr. Whitlock noted that the model is highly sensitive to values for natural mortality and the stock-recruitment curve steepness, and there is considerable uncertainty regarding values for model parameters and lack of understanding of spatial structure in the population. She described archival tags as "biologgers", capable of recording temperature (ambient, visceral), light, pressure and time and noted that these tags are informative for managers because of their high return rate, long deployment, and delivery of positon and mortality data. In addition, data on PBF energy intake and metabolic rates derived from laboratory experiments can be applied to wild fish, improving our understanding of migration, life history and mortality.

Dr. Nobuaki Suzuki introduced a CKMR, NGS project for PBF to look at mitochondrial phylogeny, the genetic relationships among tuna species based on mitochondrial DNA. He noted that a complete genome for PBF has

been sequenced and evolutionary level changes were observed in multiple visual pigment genes. Dr. Suzuki explained that based on the success of the CKMR project for SBT, attempts are being made to incorporate CKMR for PBF by developing a sampling framework, molecular markers and modeling. Sampling began in 2015 and he described some of the results leading to future plans for a population dynamics model by 2018, and calculation of a rough independent estimate of spawning stock biomass by 2020.

Dr. Daniel Madigan provided a history of the state of knowledge of migrations for PBF, and outlined the benefits of using chemical tracers, specifically stable isotope analysis, as a retrospective tool to better understand recent migrations. He explained that specific chemical tracers are found in different age classes of PBF that correspond to specific ecosystems in different regions of the Pacific. Therefore, stable isotope analysis of PBF can help understand recent migrations and ecosystem connectivity. Dr. Madigan summarized stable isotope research results, noting that this type of research can provide a range of information, including movements from different regions to spawning grounds, diet information and life history. He outlined the importance of sampling design, emphasizing broad geographic coverage, incorporation of multiple life stages/sizes of fish and large sample sizes as important elements in future PBF stable isotope studies.

DISCUSSION

Panel discussions in this session highlighted the need for enhanced life history data to improve PBF stock assessments. Panelists identified several priority research needs, including information on natural mortality, recruitment curve steepness, spatial movement patterns, connectivity between spawning grounds, age at maturity in the two spawning areas, the location and timing of spawning, connections with the eastern Pacific Ocean and inter-annual variation in all these parameters. A panelist noted that the current stock assessment is particularly sensitive to natural mortality and steepness values. Both of those parameters are highly uncertain and current estimates must be improved. Some participants and panelists noted that reliable catch data incorporating age information remains a very important need. The panel also highlighted the importance of understanding uncertainty in data and its impacts on the assessment, and cautioned not to forget how valuable data mining can be, especially in a resource strapped environment that may preclude other more resource intensive types of research (e.g., at–sea tagging).

The importance of new tools and techniques was highlighted, including electronic tagging, molecular techniques, and chemical markers to help clarify fish origin and migration patterns. A panelist observed that studies need to be designed to maximize the effectiveness of those tools for providing essential information relevant to the stock assessment and management. Some panelists and participants suggested that more electronic tags need to be released, while also recognizing that it is important to quantify the expected return on investment (i.e., how investment in additional tags will improve understanding of life history questions, such as the exact location of spawning grounds). Others suggested that the cost of tagging studies remains very high, and more economical archival tags must be developed if tagging experiments are to be used more broadly. The panel discussed obstacles to using electronic tagging data in stock assessment processes because of the lack of ability to incorporate spatial structure, uncertainty and mortality into assessment models. A panelist proposed that experts need to be brought together to create balanced sampling designs that achieve appropriate coverage of life stages and geography, particularly for electronic tagging, and that coordination of multiple researchers in different locations is necessary.

CKMR for Pacific bluefin tuna is still in early stages of development, and panelists noted that the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) is developing a joint research project among the relevant nations to begin collecting samples for analysis. Early results may be available as soon as 2020. Panelists recommended that CKMR should be assessed for its best possible use in filling specific data gaps

for Pacific bluefin tuna. A key question identified in the session is: What data and information can CKMR efforts provide that will assist with science-based management?

Panelists discussed the continued need to incorporate aging into models and correlate age with oceanographic factors and catch, but this remains a challenge while basic information on stock structure is still missing. A panelist proposed that researchers should collaborate to explore whether acoustic receivers could be useful in filling natural mortality data gaps.

SESSION 4 PANEL DISCUSSION OF SCIENTIFIC KNOWLEDGE GAPS, THE MANAGEMENT CHALLENGES THEY CREATE AND PATHWAYS TO ADDRESS PRIORITY RESEARCH QUESTIONS

PURPOSE: Session 4 was designed to engage an expert group of tuna scientists in a panel discussion on the knowledge gaps across all three bluefin tuna species, the challenges those gaps create for fishery managers and pathways to address those gaps through targeted, prioritized research projects. Summary points from Sessions 1, 2 and 3 were presented to stimulate debate and identify potential pathways to address key research questions.

MODERATOR: Dr. Fabio Hazin, Universidade Federal Rural de Pernambuco, Chair, UN-FAO Committee on Fisheries

PANELISTS:

Dr. Barbara Block, Stanford University

Dr. Sylvain Bonhommeau, Ifremer

Dr. Mark Bravington, CSIRO

Dr. Craig Brown, NOAA

Dr. Heidi Dewar, NOAA

Dr. John Gunn, AIMS

Dr. Takashi Kitagawa, University of Tokyo

The panel identified several potential pathways to address knowledge gaps including: forming new international collaborations among governments and academics that could help address key knowledge gaps more quickly; a stable, perennial funding mechanism for basic data collection that is essential for effective assessment and management; increased MSE capacity; research designed to ensure results that can be integrated into the tactical needs of assessment now and in the future; strategic investments into essential basic information on life history, maturity, fecundity, growth, and other essential biological information that is still incomplete. A panelist noted that unilateral actions by countries are unlikely to be successful. Additional research collaboration is essential.

The panel discussed electronic tagging from the perspective of coordination and strategic planning among scientists so that resources are leveraged toward the most critical research questions. This is important because limited money, vessel time, and the inaccessibility of the fish remain challenges. In addition, electronic tagging applications need to focus on addressing basic science and management needs. The discussion identified results from recently completed studies (e.g., movement patterns, mixing, fishing mortality) that can inform the design of future studies, and provide important insights for management.

A panelist noted that another way to determine how to spend resources is to look at indices used in assessments on which management plans and operating models are based to determine which aspects of data collection are more important for effective fishery management. A participant recommended that funding should prioritize research on biological or harvesting-based factors that will help with development of appropriate science-based management measures.

The panel discussed efforts to use genetics to address key research gaps for bluefin tunas. Panelists discussed the importance of incorporating aging into models, but noted that basic information on stock structure is still missing. One panelist noted that genetic "tagging" through CKMR is evolving rapidly and may provide more precise population estimates (relative to measures of absolute abundance) as compared to current assessments that rely on relative abundance estimates. Panelists discussed whether genetics and genomics may be able to address some of the complexity of estimating bluefin tuna age at maturity and fecundity, two critical biological data gaps that are important to improve stock assessments. A panelist discussed recent research that demonstrated salmon maturity can be influenced by environmental or genetic cues, highlighting the importance of collecting molecular and environmental data to improve stock assessments.

The panel discussed the precautionary approach in relation to current management. A panelist noted that MSE is considered a critical tool for managers to insure against overestimating a population's productivity, providing a powerful framework for effective management. However, another panelist suggested that the effectiveness of MSE is dependent upon the quality of available data.

DAY 2: SCIENCE-BASED MANAGEMENT OF BLUEFIN TUNAS

KEYNOTE: PROF. GLENN HURRY, MRAG ASIA-PACIFIC; INTERNATIONAL BLUEFIN MANAGEMENT… DOES IT DELIVER? LEGACY AND LESSONS OF THE LAST 20 YEARS

Prof. Glenn Hurry provided an address on challenges and recommendations to improve international fisheries management at the RFMOs. Prof. Hurry suggested that the structure of the RFMOs is strong, but member nations often fail to act in a timely and responsible fashion. Further, he noted the lack of adequate funding, transparency and experience among delegates and chairs of subcommittees as key factors limiting the ability of RFMOs to achieve sustainable utilization of bluefin tunas. Prof. Hurry offered several recommendations to improve RFMO effectiveness: member nations must be willing to pay the cost of RFMOs and support long-term research investments, with a focus on addressing uncertainty; concentrate on building trust among the members and include industry and non-government organizations in the process; the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC) must immediately convene dedicated meetings to address the decline of Pacific bluefin tuna; members must be accountable, including independent chairs that must be provided with adequate resources to fulfill their mandates; and members must adopt improved codes of conduct to build trust among all parties, stakeholders and the Secretariat.

SESSION 5 CURRENT STOCK STATUS AND CHALLENGES FOR ASSESSMENT

PURPOSE: This session was designed to articulate the current stock status of each bluefin population and to specify strengths and weaknesses of the methodologies and models that are being used in each assessment. The presentations also highlighted the types of reference points used, as well as key biological assumptions factored into the assessments, such as for natural mortality, maturity and recruitment. The session sought to identify specific research that should be prioritized to improve assessments, as well as the associated resources required. The session also described improvements, in progress or planned, to enhance the current stock assessments.

MODERATOR: Dr. Joe Powers, Louisiana State University

PRESENTATIONS:

Dr. Guillermo Diaz, NOAA. Western Atlantic bluefin tuna.

Dr. Sylvain Bonhommeau, Ifremer. Atlantic bluefin tuna: A Mediterranean perspective.

Dr. Hideki Nakano, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency. Stock status and challenges for assessment of Pacific bluefin tuna.

Ms. Ann Preece, CSIRO. Integrating past, present and future into a scientifically evaluated rebuilding plan for southern bluefin tuna.

Dr. Guillermo Diaz and Dr. Sylvain Bonhommeau presented on the stock status of Atlantic bluefin tuna, focusing on the western and eastern (including Mediterranean) populations, respectively. Both Atlantic stocks are currently assessed using virtual population analysis. There is considerable debate over the status of the western stock that is heavily dependent on assumptions about future recruitment potential (low-recruitment vs high-recruitment scenarios). The eastern assessment indicates considerable recent stock growth, with full recovery anticipated by the 2022 rebuilding deadline, if not before. Dr. Bonhommeau urged patience in light of the assessment's uncertainty and advocated for better science and more transparency and sharing in the data collection and modeling process. He discussed efforts underway to improve Atlantic bluefin tuna assessments, including expanded tagging and biological sampling programs, development of new abundance indices, consideration of alternative biological reference points and new modeling approaches that account for stock mixing.

Dr. Hideki Nakano presented the 2012 Pacific bluefin tuna assessment that found the stock to be near its historically lowest level, with overfishing continuing to occur. Dr. Nakano noted that improvements are being made to the assessment model as well as to input data, including CPUEs, size composition and seasonal growth, in advance of the 2016 stock assessment.

Ms. Ann Preece discussed the development of the SBT operating model and management procedure that resulted from evidence of catch levels that were too high (undermining stock rebuilding), unreported catches, uncertainty in primary CPUE data, and failures in the stock assessment and consensus-based management processes that allowed continued declines in spawning biomass. The management procedure was developed and tested in an MSE approach, which included development of operating models that characterize the full range of uncertainties, including key parameters steepness and natural mortality. It has been used since 2011 to recommend total global catches. Ms. Preece noted that the operating models require long-term data sets from cost-effective monitoring programs. The operating models were updated to include highly informative close-kin mark–recapture data for the 2014 stock assessment. As part of the MP implementation, stock status is assessed every three years, and that timeline is intentionally offset from the schedule for adjusting the MP. The most recent assessment, completed in 2014, estimates current spawning stock biomass is 8-12% of initial levels (SSB_0).

DISCUSSION

Panelists identified the current stock status of each species, as well as modeling techniques and approaches. Panelists and participants discussed the unique challenges of stock assessment for each species, including different population structure hypotheses, different types and resolution of data, different assumptions about key parameters, and varying levels of monitoring. Panelists noted that a number of factors have a significant influence in the models and assessment results, including population structure (where it exists), temporal and spatial distribution, fisheries and natural mortality estimates, and life history characteristics, including age-at-maturity and stock recruitment relationship parameters. A participant noted that the availability of fishery dependent data may also influence our understanding of important biological factors, such as recruitment. For example, the participant noted that there has been no fishing effort targeting juvenile Atlantic bluefin tuna recently, and questioned how to improve recruitment estimates without this fishery dependent information.

Participants questioned the current (2014) Pacific bluefin tuna assessment, particularly assumptions regarding PBF age at maturity and what had caused the stock to be overfished prior to the 1950s (the earliest years included in the ISC stock assessment). A panelist noted that gonad data and studies of PBF in captivity were the basis of the current age-at-maturity assumption, and responded that stock abundance may fluctuate or have a cycle that includes low abundance, but this is unknown.

Many panelists and participants discussed key challenges related to characterizing and minimizing uncertainty and risk. A panelist noted that assessment results are often communicated through decision tables, narratives, and sensitivity analyses, but that these may not be comprehensible to decision makers. The panelist suggested that using common MSE performance statistics (i.e., the probability of stock rebuilding, inter-annual variability in catch, mean catch) would help to characterize long term risk in a consistent manner. Another panelist suggested that MSEs in general are important tools to help delineate objectives, costs, and constraints that could define risk and provide a possible mechanism to meet assessment challenges. A participant suggested standardizing approaches to characterizing risk across all of the tuna RMFOs.

Panelists and participants debated the costs and benefits of using fishery independent surveys, including CKMR, to inform stock assessments. A panelist suggested that fishery independent surveys are key to solving assessment challenges, but other participants noted that fishery independent surveys are expensive and logistically complicated to conduct for highly migratory species like tuna. Panelists and participants discussed possible next steps to collect new types of fishery independent data, noting the need for thorough design studies.

Several panelists and participants commented on the resources needed to improve assessments including, funding, time and capacity for research and methodological development. Panelists noted the need to improve the quality of the indices (fishery independent indices, catch, and size composition) and resolve some key life history uncertainties. Panelists discussed several data collection tools that have not been utilized to study bluefin tunas (e.g., drones, autonomous underwater vehicles, satellites and citizen science), as well as other new tools, such as CKMR, that are in use (SBT) or in development (PBF) and may have other applications to aid stock assessments. However, a participant noted that new methods like CKMR, while important, are not a panacea, and recommended that existing methodologies still have a role to play.

Other panelists highlighted the importance of utilizing all of the available existing information (e.g., via data-mining initiatives) to improve stock assessments. High quality, accurate and timely catch data is central to ensure robust assessments of the impact of fisheries on a stock. However, ongoing reliance on fishery dependent CPUE in stock assessments is unlikely to provide robust advice over time due to the uncertainty in the relationship between CPUE and abundance, which will be exacerbated by the declining size and coverage of longline fleets. This increases the priority for developing robust methods for monitoring abundance.

Participants acknowledged that all the tuna RFMOs are facing similar challenges related to assessments and characterization of risk, so collaborative problem solving and enlisting the expertise of independent, interdisciplinary experts is an option worth exploring

SESSION 6 MODERNIZING SCIENCE-BASED FISHERIES MANAGEMENT TOOLS

PURPOSE: This session's presentations and discussion were intended to survey current and emerging management tools, including the challenges and opportunities presented by each tool; the resources needed to fully utilize each tool; their potential to increase accountability and compliance; their potential to address conservation needs; and to improve profitability. In addition, this session sought to identify why different tools have been adopted for different bluefin species, how these tools can work independently or together to improve the likelihood of

achieving sustainable management objectives and how to prioritize the application of these tools (or other tools not covered) for each species.

MODERATOR: Dr. Victor Restrepo, International Seafood Sustainability Foundation

PRESENTATIONS:

Dr. Nathan Taylor, Fisheries and Oceans Canada. Spatial temporal assessments in modernizing fisheries management tools.

Mr. Alejandro Anganuzzi, Food and Agriculture Organization of the United Nations. Reference points.

Dr. Campbell Davies, CSIRO. Harvest strategies, MSE and the precautionary approach in the management of bluefin tuna fisheries.

Dr. Tom Carruthers, University of British Columbia. Towards a management strategy evaluation framework for Atlantic bluefin tunas.

Mr. Shuya Nakatsuka, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency. A harvest control rule for Pacific bluefin tuna based on recruitment indices.

Dr. Nathan Taylor outlined spatial and temporal assessment modelling methods that are intended to capture all of the available information (all sources of data, area-specific fishing mortality and uncertainty) and predict stock-specific movements to better inform management. This approach has been applied to ABFT, and it offers great promise as a more accurate representation of the complex mixing that occurs between Atlantic stocks. In addition, these spatial and temporal assessment approaches could be used as a potential operating model in the MSE process. However, further improvements are needed to address key assumptions and integrate data that may have overlapping temporal information (i.e., challenges related to reconstructing time series to attribute tags and removals to stocks and to commercial fishing CPUE).

Mr. Alejandro Anganuzzi presented on the evolution of reference points, from initial concept to inclusion in the U.N. Fish Stocks Agreement, and more recently, as an integral part of the implementation of a precautionary approach to management. He explained that target reference points have evolved to articulate the management objective with an associated level of acceptable uncertainty, whereas limit reference points specify an unacceptable risk of the stock being below a biologically based threshold, factoring in uncertainty. Reference points are a key component and trigger for action in HCR – a proactive management approach that is being incorporated by many RFMOs. Mr. Anganuzzi noted that the principles and structure of reference points can also be helpful to advance ecosystem-based management and improve communication between the scientific community, decision makers and stakeholders.

Dr. Campbell Davies outlined the process of identifying potential harvest strategies and testing various alternatives through MSE to facilitate selection of a harvest strategy that will best achieve the management objectives. Dr. Davies contrasted the role of stock assessment for providing the best scientific advice on stock status and productivity, and the MSE approach, which is aimed at selecting a harvest strategy to provide robust advice for management decisions (e.g. setting catch or effort limits). He suggested that management advice based on short-term stock assessment projections tends to result in reactionary management decision making and often leads to "gridlock" in international fisheries management forums. The advantage of the MSE approach is that it focuses science-management-policy discussions on identifying practical strategies to achieve the management objectives in the short and long-term, as well as the trade-offs in tangible performance measures, such as short and long-term average catch, CPUE and risk of depletion below established limit reference points. The MSE process involves the creation of an operating model to incorporate the relevant information into a "virtual fishery", which can be

complex or simple, depending on the context of the application, the needs of the stakeholders and knowledge of the fishery. The "virtual fishery" is used to test potential alternative harvest strategies, and each harvest strategy includes the full specification of the harvest control rule, data inputs, any data analyses/methods, and metarules. Dr. Davies provided a case study of the specification of the SBT management procedure (harvest strategy) through the MSE process and how it assisted in reducing the focus on contested assessments to the selection and implementation of an agreed management procedure for setting the global TAC. He noted that the adoption of a MP has not replaced the need for periodic review of stock status and the assumptions underlying the MSE - these reviews continued at regular intervals. However, the focus was on stock status and the impact of new information on understanding of stock and fishery dynamics instead of providing management advice on levels of fishing. This provided a strong basis for identifying key uncertainties and priorities for future research that were directly relevant to management and stock assessment.

Dr. Tom Carruthers described the potential for MSE to better inform the science and management of Atlantic bluefin tuna. He identified a number of areas where the MSE process offers potential improvements over the current Atlantic bluefin tuna stock assessment process, including incorporating multiple sources of information, ranking operating approaches, more clearly articulating tradeoffs, improving transparency and increasing dialogue between scientists and managers. Potential weaknesses include the availability and complexity of key data sets, the technical challenges of developing the operating model, and the need for agreement on performance measures. Dr. Carruthers advised that considerable progress has been made in the technical development of a MSE for Atlantic bluefin tuna.

Mr. Shuya Nakatsuka outlined a new HCR concept for management of Pacific bluefin tuna based on regulating catch of juvenile fish. He discussed the challenges with using a conventional HCR for PBF because so many are caught as young juveniles before they can be counted in the assessment. Therefore, Mr. Nakatsuka presented a HCR concept that uses recruitment indices specific to each cohort to set a TAC for juvenile Pacific bluefin tuna to achieve a range of target spawning stock biomass levels. However, Mr. Nakatsuka also identified a few challenges, including the accuracy of the recruitment indices and complexity of implementing an age-specific TAC divided among the eastern and western Pacific.

DISCUSSION

Panelists outlined several current and emerging tools for assessing and managing bluefin tunas. The presentations illustrated that some of the tools applied relatively universally across all three bluefin species, whereas others may only apply to one species or were in the early stages of development.

Various aspects of MSE were discussed by panelists and participants. A panelist noted that MSE holds an advantage over other management tools because it specifies short to long-term objectives and identifies the candidate harvest strategy most likely to achieve these objectives, reducing the tendency for highly political, short-term negotiations. Harvest strategies (including reference points) are in development for all bluefin species, but only CCSBT has a harvest strategy in place that has also been tested with MSE.

Panelists noted that MSE adds value because it fosters intensive communication on key issues (data needs, model uncertainties) that are of greatest concern for managers, scientists and stakeholders. A panelist noted that the SBT MSE and other successful MSE applications may not translate to other tunas, and cautioned that the process is intensive and requires significant quantitative capacity and resources to conduct the necessary stakeholder engagement, however, less resources are required once the harvest strategy is implemented.

Panelists and participants also discussed the potential for MSE to assist in setting research and data collection priorities. A panelist recommended that research investments should prioritize and target specific types of data that can improve the accuracy and precision of the operating models that form the basis of the harvest strategies. A participant asked whether MSE could be used to help select and prioritize those data collection targets. A panelist responded that as managers consider different harvest strategies, MSE simulations could be used to set data collection priorities by evaluating how different types of data may change harvest strategy performance.

Panelists also discussed harvest strategies and pointed out that they are an effective tool because they can quickly incorporate new information and feed into the management process, fostering intensive communication on key issues (data needs, model uncertainties) that are of greatest concern for managers, scientists and stakeholders. While much of the discussion was on how to develop and adopt a harvest strategy, a panelist noted that the SBT harvest strategy and other successful harvest strategies may not translate to other tunas, and cautioned that the process is intensive and requires significant quantitative capacity and resources to conduct the necessary stakeholder outreach and science-manager iterative interactions. In addition, many panelists discussed the need to address differing objectives about rebuilding targets for bluefin tunas (e.g., some RFMOs use a rebuilding target of 20% SSB_0 (unfished spawning stock biomass), while others are comfortable with the risk of maintaining stocks as low as 6% SSB_0). Nevertheless, many panelists and participants envision that it is feasible for harvest strategies to be in place for all bluefin tunas within 5 years.

Allocation processes in RFMOs were discussed by the panelists and participants. Several panelists expressed the view that it is important to make allocation decisions in advance of the MSE process to facilitate adoption of an optimal harvest strategy, while others noted this was not necessary to make progress. A panelist provided an example illustrating the benefit of establishing allocations before the MSE process where an Atlantic swordfish fishery set a TAC in accordance with scientific advice, but the sum of all allocations was higher than the TAC, creating a situation with the potential for all parties to be in compliance individually while their collective actions could cause non-compliance. A panelist noted that if allocation decisions are done in advance of the MSE process, a contingency could be built into the harvest strategy that would provide managers some flexibility to mitigate for unforeseen events, such as accommodating a new participant in the fishery or environmental crisis, without compromising overall objectives. Other panelists commented that the MSE process can be used to focus on harvest strategies that would effectively manage total harvest, using a harvest control such as a quota. In this case, the MSE process would focus solely on the form of harvest strategy that would meet the stock conservation and catch objectives, with allocation decisions negotiated among members based on their preferences. Provided that the total harvest remained within that specified by the agreed harvest strategy, then this was likely to be more effective than ad hoc advice and negotiation and would progress development and understanding.

Participants debated the challenges of stakeholder engagement in stock assessments. A participant noted the difficulty of achieving scientific agreement on uncertainty for various model parameters, and questioned whether increased transparency in the stock assessment process would produce more robust results. A participant commented that non-government organization representatives are important partners that are sometimes excluded from the stock assessment process, but they play a role in establishing oversight and transparency that can be as important to the process as the technical details. Another participant noted that a smaller group of experts may be needed for certain aspects, and that not every process produces better results with everyone involved, especially if the process is highly technical.

SESSION 7 WORKING TOWARD SUSTAINABLE BLUEFIN TUNA FISHERIES: RFMO SOLUTIONS

PURPOSE: This session's panelists participated in a moderated panel discussion on RFMO challenges and opportunities to achieve sustainability for bluefin tunas globally.

MODERATOR: Prof. Glenn Hurry, MRAG Asia-Pacific

PANELISTS:

Dr. Pablo Roberto Arenas Fuentes, National Fisheries Institute (INAPESCA), Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), Mexico

Mr. Stefaan Depypere, European Commission Directorate General for Maritime Affairs and Fisheries

Dr. James Findlay, Australian Fisheries Management Authority

Dr. Fabio Hazin, Universidade Federal Rural de Pernambuco and UN-FAO Committee on Fisheries

Mr. Masa Miyahara, Japan Fisheries Research Agency

Ms. Amanda Nickson, Global Tuna Conservation, The Pew Charitable Trusts

Mr. Russell Smith, National Oceanic and Atmospheric Administration, United States Department of Commerce

Mr. Miyahara opened the session with a brief presentation on Atlantic and Pacific bluefin tuna population trends and management responses (see Appendix 6 for the presentation).

Panelists and participants discussed a number of elements needed to achieve sustainable management for bluefin tunas at RFMOs and highlighted examples from other types of successful fishery management models. Panelists generally agreed with the concept of "good data informs good management", and the importance of investments in science to drive successful management outcomes. Several panelists also noted the importance of following scientific advice, including ensuring active participation by a range of technical experts and delegates in RFMO scientific meetings as well as the need to build scientific capacity in developing nations. A panelist mentioned that a key feature of the successful U.S. fisheries management system was the use of quality science to guide management decisions, including clear standards and guidelines for managers on how to adhere to the scientific advice and incorporate new data.

Panelists highlighted the importance of communication and outreach among scientists, managers, and stakeholders. A panelist commented that RFMOs cannot take any shortcuts – delegates need to work hard to build consensus with their stakeholders, and it can be time consuming. Panelists outlined the need for strong communications to build trust and ensure compliance and accountability.

The panel discussed whether data from performance reviews can help drive changes in management by RFMOs. A panelist provided an example from a 2008 ICCAT performance review that demonstrated how the review pushed governments to set more ambitious rebuilding targets. A participant questioned whether a performance review would help accelerate recovery of Pacific bluefin tuna. One panelist responded that an independent review would likely conclude that the two RFMOs (WCPFC and IATTC) need to enhance collaboration and set more ambitious conservation and management measures to rebuild the population more quickly. Another panelist noted that the ISC has recently completed a performance review, and suggested that the bigger challenge for PBF is to bring the two RFMOs and the four main nations (Japan, U.S., Mexico, and Korea) together. Panelists discussed the need to revive the Kobe process to strengthen RFMO collaboration and enhance the utility of performance reviews. In particular, one panelist recommended that the Kobe process should focus on technical topics, and ensure that it

does not become politicized. The "Kobe process" was established through a series of international meetings with the purpose of coordinating the activities of the five tuna RFMOs under a common set of principles and practices.

As with Session 6, several panelists identified harvest strategies as a tool to advance sustainable management for bluefin tunas as part of a precautionary approach. There was optimism that several RFMOs were already considering harvest strategies for bluefin tuna management, and that they could be implemented within a few years if there was the necessary political will.

The lack of reliable catch statistics was identified by the panel as an ongoing problem and a fundamental data gap. One panelist mentioned that many countries lack coherent sampling plans and fundamental catch composition data, while another suggested that more cost-effective solutions are needed. A panelist suggested that one solution could be to adopt a rule similar to ICCAT where a nation would only be able to fish if it had fully complied with reporting requirements in the prior year ("no data, no fish"). Another panelist suggested that supporting better dialogue between scientists and managers could improve availability of catch statistics, as could technological tools like Vessel Monitoring Systems. A panelist concluded that incentives are just as important as requirements when considering ways to collect fundamental catch data.

The panelists debated the merits of RFMOs versus other legal and governance regimes (e.g., Convention on International Trade in Endangered Species (CITES)) for managing bluefin tunas, but many supported strengthening the existing RFMO system and building capacity for fisheries science, management and enforcement as the most effective means to achieve sustainability for bluefin tunas. Several participants and panelists noted that the threat of external drivers to catch more fish will continue, so action is needed to end overfishing as soon as possible, improve compliance, establish trust, increase transparency and build consensus.

SESSION 8 ADVANCING BEST PRACTICES IN PROVIDING SCIENTIFIC ADVICE

PURPOSE: This session featured a moderated panel discussion designed to stimulate discussion on how scientific advice is developed and communicated at RFMOs, including identification of best practices, progress that has been made in recent years and opportunities to enhance stock status advice and future projections.

MODERATOR: Dr. Gerald Scott, International Seafood Sustainability Foundation

PANELISTS:

Mr. Alejandro Anganuzzi, Food and Agriculture Organization of the United Nations

Dr. Doug Butterworth, University of Cape Town

Dr. Campbell Davies, CSIRO

Dr. David Die, University of Miami

Ms. Shana Miller, The Ocean Foundation

Dr. Hideki Nakano, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency

In advance of Session 8, Dr. Scott prepared and circulated a handout (see Appendix 6) to familiarize participants with efforts to date to improve and align procedures for providing scientific advice among the RFMOs. He opened the panel with a brief history on the Kobe process that established clear goals, needs and best practices for scientific advice and data collection in global tuna fisheries.

Panelists described how the Kobe criteria and best practices have been incorporated in an inconsistent manner and have not been universally adopted by the different RFMOs. Panelists identified a number of barriers preventing broad implementation, including insufficient transparency in the development of scientific advice, a

lack of clarity in defining assumptions and misinterpretation of uncertainty, and lack of confidence in the quality of science provided by some RFMOs.

Panelists identified a lack of sufficient scientific capability as a key challenge with respect to achieving the Kobe best practices. Panelists noted that all parties involved in the RFMO process, as well as the Secretariats, need to enhance their scientific capacity and invest in resources (including time) necessary to train additional scientists. In addition, new scientists need to be cognizant and knowledgeable on past and current stock assessment methods and practices.

Panelists recognized that each RFMO has different processes and providers of scientific advice, and data practices vary widely. Several panelists suggested that additional transparency is needed, and they recommended that RFMOs provide more information on the data and processes that are being used to inform the scientific advice. This could include an explanation of the data and the underlying assumptions, similar to the reports of the International Whaling Commission. Other panelists suggested that each RFMO identify key data gaps (i.e., in compliance, operational level data, or instances of no data reported) and prioritize how they will fill those gaps. Several panelists identified the need for all countries to provide and share operational level catch and effort data in addition to aggregate data at the RFMOs. A panelist suggested that any possible proprietary concerns relating to provision of operational level data could be addressed through a confidentiality clause.

Panelists and participants discussed the need to improve communications between scientists and managers. The panel identified a number of challenges, including a lack of robust dialog between scientists and managers, either party asking the wrong questions and the absence of a consistent forum for exchange. A participant suggested that often scientists do not know what information managers need, so scientists need to better anticipate the scientific advice desired by managers (in content and interpretation). Several panelists and participants supported more engagement and inclusiveness in the process, and suggested that it would enhance the understanding of the output (the scientific advice). A panelist suggested that standardizing how scientific advice is communicated across the RFMOs could address some of these communications challenges. It was pointed out that the intent of the Kobe chart and the Kobe II Strategy Matrix was, in fact, to enhance communication between scientists and managers by standardizing how advice on stock status and future prospects is communicated.

Panelists discussed interpretation of scientific advice and the need to communicate more clearly on uncertainty and risk associated with management alternatives (quotas) and Kobe strategy matrices. A panelist suggested that quota recommendations should always include a range of probabilities of success, and that best practice should be a probability of success above 50%, and perhaps as high as 75%. Other panelists noted that this issue raises questions over who is making the decisions- scientists or managers- and the fact that the underlying management objectives may not provide clear guidance. In the case of SBT, the Kobe plots are not used, so this issue does not apply universally across all RFMOs. A panelist identified harvest strategies and MSE as potential solutions to address challenges associated with uncertainty and risk.

Panelists offered several other suggestions to improve the provision of scientific advice, including: enhancing the understanding of Kobe II Strategy Matrix; all RFMOs adopting consistent data and fisheries statistics standards; developing simpler tools and better reports; increasing the specificity of scientific advice; making RFMO reports available in a timely fashion; and including observers in all scientific meetings.

During the session, participants were asked if they could support the values agreed upon by the ICCAT Scientific Committee and endorsed by ICCAT:

- ✓ INTEGRITY: apply the highest ethical standards to scientific work

- ✓ INDEPENDENCE: Provide advice that is objective and based on the best scientific information available and not unduly influenced by stakeholders, ideological or political pressure groups or by economic or financial interests
- ✓ COOPERATION: Value and encourage the participation of scientists from all CPCs, acting through scientific collaboration to cultivate a diverse set of expertise to promote best available scientific practices.
- ✓ COMMITMENT: Committed to provide the best scientific advice in support of the Commission's objective of implementing science-based fishery management.
- ✓ ABILITY: Strive to ensure work conforms to the highest scientific standards and state of the art methodologies, constantly improving the foundation of knowledge to support the mandate, and
- ✓ TRANSPARENCY: Conduct work in open sessions and encourage participation of national scientists and external experts; information, analyses and decision-making process are well documented and easily accessible to all interested parties.

A high proportion of the participants in the Symposium responded to the anonymous survey and there was near universal agreement that the Values identified represent best practices for provision of scientific advice at the RFMOs. In addition, most participants in the survey agreed that they should be generally applicable across all of the tuna RFMOs.

DAY 3: EMERGING OPPORTUNITIES AND CHALLENGES FOR BLUEFIN TUNA SUSTAINABILITY

KEYNOTE: DR. YOSHIFUMI SAWADA, KINDAI UNIVERSITY; CHALLENGES OF RAISING BLUEFIN TUNA

Dr. Yoshifumi Sawada presented a keynote address describing his experience with aquaculture of PBF at Kindai University. Dr. Sawada shared the history of bringing PBF into a closed loop life cycle and discussed the many challenges and successes of doing so including: larval survivorship and causes of mortality; food conversion ratio and incorporating soybean meal into feeds; selective breeding resulting in higher growth rates, greater disease resistance and better taste; and the successful business venture - marketing of fish at the Kindai University restaurants and supplying juvenile seedlings to farmers. He emphasized that the role of a successful aquaculture enterprise is to contribute to natural resource sustainability. Dr. Sawada explained that bluefin tuna aquaculture production will continue increasing while wild fisheries production has peaked, advocating for a reduction in fishing pressure and for developing aquaculture techniques and associated human resources to allow for increases in aquaculture production. In addition, studies of early life history for aquaculture and associated research on tuna biology in captivity increases our understanding of wild populations whose broad dispersal of tiny eggs and larvae makes field study challenging. Dr. Sawada described a successful joint research effort (supported by IATTC) on yellowfin tuna in Panama and stressed the importance of cooperation between tuna research scientists and tuna aquaculture scientists. He invited all participants to work together toward a future stable supply of high quality food.

SESSION 9 ROLE OF AQUACULTURE AND FARMING IN THE FUTURE OF BLUEFIN TUNAS

PURPOSE: Aquaculture is expected to be an important part of the bluefin tuna sustainability equation in the future. Given their life history, successful culture of bluefin tuna was initially elusive, but great strides are now being made in captive culture of all three species. This session's presentations and discussions highlighted advances in bluefin tuna aquaculture and what it potentially means for the resource and the marketplace.

MODERATOR: Dr. Barbara Block, Stanford University

PRESENTATIONS:

Mr. Chuck Farwell, Monterey Bay Aquarium. History and challenges of working with Pacific bluefin tuna, *Thunnus orientalis*, in captivity.

Dr. Christopher Bridges, Universität Düsseldorf. Progress in the domestication of *Thunnus thynnus* (DOTT) – Perspectives for Atlantic bluefin tuna aquaculture in the Mediterranean.

Dr. Aurelio Ortega Garcia, Spanish Institute of Oceanography. Progress in Spanish aquaculture.

Dr. Josh Silverman, Calysta Inc. The potential role of biofeeds in aquaculture of salmon and tuna.

Dr. Dane Klinger, Princeton University. Resource and environmental intensity of tuna aquaculture.

Mr. Chuck Farwell gave a presentation on the challenges and successes of keeping Pacific bluefin tuna in captivity for research and display purposes. The first successful display was at Tokyo SeaLife Park with juvenile fish. Displays at Aquamarine Fukushima and Monterey Bay Aquarium followed. He described the laboratory studies of the Tuna Research and Conservation Center and provided examples for how studies on captive fish can help interpret findings from wild bluefin tuna. For example, establishing metabolic rate and the heat increment of feeding in the lab resulted in algorithms with archival tags that now allow one to collect information from internal temperature tags that enables documentation of feeding events both in captivity and in the wild. This then provides the opportunity to measure energetics and caloric intake both in captivity and in the wild. Many organizations and individuals working together have resulted in these successes.

Dr. Christopher Bridges presented on a variety of European Union (EU) Domestication of Bluefin Tuna *Thunnus thynnus* (DOTT) programs that are solving problems in aquaculture of Atlantic bluefin tuna. He described several successful studies, including a determination of the ideal temperature range for spawning; the creation of a tool for simultaneous underwater tissue biopsy, spawning induction and facilitated tagging of broodstock; assembling an effective egg collection system; DNA tagging of eggs; hatching and larval rearing including determining the most effective larval food source. Using these developments, various EU aquaculture researchers are now discussing the potential to release eggs and larvae from captive broodstock and hatchery operations into the ocean to enhance wild populations. Released eggs and larvae could be "tagged" with a DNA marker at the egg stage enabling researchers to subsequently sample adults at the Tokyo fish market to assess success of releases and how the effort may contribute to bluefin tuna sustainability and the global market. A commercial propagation and restocking facility is under construction in the Mediterranean that will vastly increase larval production and hatchery capacity. The DOTT work is a result of 10 years of work by a multitude of European scientists with extensive funding from the European Union and collaboration with other scientists worldwide.

Dr. Aurelio Ortega presented improvements in Spanish aquaculture of Atlantic bluefin tuna including larval rearing, juvenile transport, growth and feeding successes. Overcoming feeding and growth challenges using the copepod *Acartia* as a primary food source has improved larval rearing techniques and survivorship, resulting in larger cohorts for grow out. The mortality rate remains high until fish reach 0.5kg. Closing the life cycle, where fish are bred in captivity and grow up to spawn in captivity, producing multiple generations, remains a priority for aquaculture of ABFT. A new facility at the Spanish Institute of Oceanography (IEO) is underway that will greatly expand bluefin tuna egg production capacity and improve broodstock maintenance.

Dr. Josh Silverman provided a presentation about Calysta's FeedKind™, a biofeed product produced by microorganisms that metabolize methane into a nutritious high protein biomass for feed, rather than fishmeal or soy. This food source has high-value mineral content, high vitamin content and contains highly saturated, short-

chain lipids as well as key amino acids. When compared to fishmeal, Dr. Silverman noted that feed efficiency, protein retention and digestibility are improved in farmed salmon over soy-based feeds. He concluded that this product supplies a sustainable source of protein with minimal land and water impacts compared to agricultural products, and reduces the demand for fishmeal.

Dr. Dane Klinger presented on the resource and environmental intensity of tuna aquaculture. Bluefin tuna is a small but important component of global aquaculture production. He noted that their unique physiology and high trophic level make them less efficient than other farmed species. He emphasized that bluefin aquaculture still relies heavily on wild stocks both for adult broodstock and juveniles for grow out. However, selective breeding in captivity could enhance farmed productivity, including increased growth rates and better food efficiency, but these benefits can't be realized until the life cycle is closed. Bluefin tuna require high quality protein and fat for growth thereby requiring significant sources of wild resources as feed. Characteristics of bluefin tuna and their high resource requirements put them in a category with other luxury consumer items.

DISCUSSION

The panel and participants engaged in a dialogue about feed improvements for bluefin tuna aquaculture, and many comments recognized feed improvements as one of the most important factors for its future viability and success. A panelist recommended that non-moist, vegetarian-based feeds are an important potential alternative to traditional feeds (moist fish pellets) because they can be distributed automatically (reduced labor), and they may be more efficient as a feeding strategy (based on the amount of feed converted to tuna weight, or feed conversion ratio (FCR)). A participant suggested that it may be challenging to produce bluefin tuna on a largely "vegetarian" diet because their digestive systems evolved for carnivory. However, a panelist responded that it may be viable in the future due to selection experiments in which tunas that can digest plant based diets are bred for this trait. A panelist commented that the FCR for vegetarian-based diets is improving, and the industry has succeeded in developing feeds that include 80% replacement of fish with soybean meal. A panelist also noted that applying enzyme pre-treatments to the feed prior to feeding can improve digestibility.

The panel and participants discussed the pros and cons of aquaculture for bluefin tunas. On the con side, a participant suggested that the same concerns expressed during the rise of salmon farming may also apply to bluefin tunas, such as farmed fish escapees diluting the gene pool of wild fish populations. One panelist suggested releasing aquaculture-produced fish into the ocean for restocking purposes, and this led to a discussion over the potential for aquaculture to enhance wild populations. A participant remarked that if the concerns expressed for salmon aquaculture are found to be true for bluefin tuna, then bluefin tuna aquaculture could be a source of additional pressure on bluefin tuna populations rather than a solution (e.g. escapees diluting the wild population gene pool through interbreeding, creating offspring that are less fit to thrive in the wild, ultimately leading to population level effects). A panelist clarified that the same potential problems identified for salmon aquaculture would actually not be an issue for bluefin tuna aquaculture under current practices because only eggs derived from wild fish are being used to produce larvae for release into the wild. Therefore, the genes are the same and no dilution of the gene pool could occur. In addition, efforts to enhance wild populations with aquaculture could be closely monitored through new technologies that allow scientists to follow releases and evaluate the impacts of restocking on wild populations. For example, scientists could "mark" the eggs/larvae being released into the ocean through gene tagging, and then they can be "recaptured" in fish flesh at the Tokyo market. This could provide information on movement, age and growth, fitness, and fishing mortality, and it could be combined with other fishery dependent and independent data to allow researchers to compare hatchery and wild stocks, and also evaluate potential effects on the wild population.

One participant suggested that the economics and cost-benefit ratio may indicate that it is better to stop harvesting young bluefin tuna rather than investing in trying to raise a luxury food. Another participant questioned whether aquaculture will really reduce market demand or simply create a new bluefin tuna product on the market. A panelist clarified that it is unlikely that bluefin tuna aquaculture production will ever fully replace the market for wild-caught fish, but it will remain as an important part of the supply. The panelist also suggested that the increasing seafood consumption rate by humans will continue to put pressure on wild stocks (demand is going up, with or without aquaculture), and consequently the continued investment in aquaculture as an option to reduce some of that market pressure remains important. One panelist summarized that economically successful farming operations of the future will rely on effective long term stock management, increased investment in FCR, accelerated uptake of new technologies and operations, greater international cooperation, integration of supply chains and increased offshore operations.

KEYNOTE: MR. BRIAN JEFFRIESS, AUSTRALIAN SOUTHERN BLUEFIN TUNA INDUSTRY ASSOCIATION; BLUEFIN RANCHING ECONOMICS – MANAGING THE RESOURCES AND THE FARM

Mr. Brian Jeffriess presented a keynote address and presented his perspective on bluefin tuna economics and the ranching industry. Mr. Jeffriess noted that since ranching is capital intensive and requires a supply of wild fish, its economic success depends on having sustainable wild stocks to reduce the business risk. He stressed that reducing that capital risk requires a precautionary approach to management of bluefin stocks, noting the strong Australian industry support for implementation of harvest control rules as an example. He mentioned many improvements in the ranching industry, but there are many more gains and efficiencies still to be made, including in feeds. Mr. Jeffriess described economic factors and costs at play among the three major producers of ranched bluefin (Japan, Australia and Mexico), and noted that prices are the lowest since ranching began. He suggested that future prices will depend on the Japanese yen, feed prices, and whether Pacific bluefin or other key tuna species (bigeye) continue to decline. In the longer-term, Mr. Jeffriess suggested that China will play an increasing role in catching and consumption of bluefin tuna.

SESSION 10 BLUEFIN TUNA ECONOMICS

PURPOSE: This session explored economic aspects of the bluefin tuna trade, including market conditions, trends, expectations, the influence of Japan on markets and management impacts.

MODERATOR: Mr. Brian Jeffriess, Australian Southern Bluefin Tuna Industry Association

PRESENTATIONS:

Mr. David Schalit, American Bluefin Tuna Association. West Atlantic bluefin tuna: Some challenges and solutions in balancing economics and conservation.

Dr. Yasuhiro Sanada, Waseda University. Pacific bluefin tuna fisheries and regulations in Japan.

Ms. Alayna Siddall, Sportfishing Association of California. Economic importance of access to Pacific bluefin tuna by eastern Pacific recreational anglers.

Mr. David Schalit began his presentation with a summary of the participants in the ABFT fishery, from the traditional hand held harpoon fishery in the western Atlantic to the pelagic longline fleets that have significant capacity and have the potential to exceed the available quotas if not managed carefully. He noted that since 1998 when ICCAT began the rebuilding program for western ABFT, the SSB has increased by 70%, resulting in the first quota increase in 2014. Mr. Schalit pointed out that the U.S. has established strict rules within its EEZ to protect ABFT, including during spawning, but other nations have not adopted similar measures.

Dr. Yasuhiro Sanada described the economics of bluefin tuna markets in Japan and explored contributions of the different fisheries for PBF. He presented 15 years of market data on prices for bluefin tuna at the Tokyo fish market and 2013 wholesale prices and catch statistics for PBF in Japan's ports. He also described data on PBF catch by gear type and port over a span of 10 years. Dr. Sanada also presented 2014 data on Japan's imports of bluefin from key exporting nations.

Ms. Alayna Siddall provided participants with a recreational perspective of the southern California bluefin tuna fishery. She described the recreational fleet's 100-year history in California, noting that approximately 151 vessels currently participate in the recreational fishery for PBF under a strict regulatory framework that includes monitoring and extensive data collection. She highlighted the strong conservation measures adopted by the recreational fleet, including a decreased bag limit for PBF from 10 fish to 2 fish per person per day – a regulation that complies with management measures adopted by IATTC in 2014. Ms. Siddall pointed to the recreational fleet's use of hook and line as a highly selective fishing gear, and the considerable efforts of the fleet to support and participate in voluntary data collection programs to advance PBF research and management. She noted that the opportunity to fish for PBF offers a significant marketing advantage over other recreationally-caught species because bluefin tuna are very popular with anglers, and recreational fishing supports a large number of local businesses. In summary, Ms. Siddall emphasized the value of recreational fishery to the Southern California economy, and the importance of research, compliance and stewardship of the PBF resource.

DISCUSSION

Panelists discussed the influence of aquaculture on market economics, as an increasing amount of the global bluefin tuna supply is expected to come from farmed product in the future. However, several key factors continue to impact profitability and viability of farming operations, including over-capitalization, falling prices, increasing feed costs, and the changing dynamics of supply and demand. A recommendation emerged from the discussion advising that RFMOs should increase capacity by adding expertise that can support management issues related to farming. Panelists noted that the future viability of farming is linked to sound management and harvest strategies, increased investment in feeds, new technology and efficiencies (including offshore operations), integration of supply chains and international cooperation.

Panelists discussed economic benefits and drawbacks of a global quota trading system for wild caught bluefin tunas. A panelist stated that, in general, a global trading system is highly desirable from an economic and behavioral standpoint, but compliance of some countries could pose significant future challenges, especially for SBT. Another panelist outlined potential compliance concerns if countries do not have capacity to stop fishing effort after quota has been traded or sold to another country/party. Participants also discussed concerns related to fishing fleets switching their effort from one species to another, and how that may impact the viability of dedicated bluefin tuna fisheries, as well as stock sustainability. Another panelist suggested that these are really multispecies problems, and that distant water fleets fishing for multiple species may not be economically viable in the future depending on fuel and other costs.

The panel discussed the economic drivers in the Mediterranean, including a suggestion by a panelist that farming operations may be increasing fishing pressure on smaller bluefin tunas. A panelist explained that the Mediterranean farming operations are responding to Japanese sashimi market demand, using smaller fish for grow out operations that are more suited to the sashimi markets. The panelist noted an additional concern over the growing demand in China for fish in small packages. The panelist suggested that as a result, market penetration is restricted to these smaller fish and cannot diversify. This in turn increases demand for small wild-caught bluefin tuna to stock the farms, and poses a threat to the population's sustainability.

The panel discussed ways to encourage industry investments in research. A panelist suggested that additional investments in research can easily be demonstrated as worth the cost, whereas another panelist noted that some RFMOs already collect industry funds and have processes in place to support research. A panelist suggested that decisions must be made within the context of each RFMO.

The panel discussed the unique economic considerations of recreational fisheries for bluefin tunas, including their economic impact and opportunities they present for expanded research and data collection that have not been fully utilized by RFMOs.

KEYNOTE: DR. ROBERT DUNBAR, STANFORD UNIVERSITY; BLUEFIN TUNA IN A WARMING WORLD: THE SCIENCE OF OCEANIC CLIMATE CHANGE AND ACIDIFICATION

Dr. Robert Dunbar presented a keynote address on the science of oceanic climate change and acidification, and what this might look like for the future of bluefin tunas. Dr. Dunbar stressed the importance of integrating climate science into studies of ocean ecology and the blue economy, and covered multiple aspects of what changes might be important to bluefin tunas. Bluefin tunas have evolved fairly recently; he hypothesized they diverged from closely related other *Thunnus* species in the ice age and have experienced many changes in oceanic conditions in the last 10,000 years. Their evolution occurred in more alkaline, more oxygenated and colder seas. In the next 100-200 years, bluefin tunas will see equivalent changes to what they experienced in the last 10,000 years, including greater temperatures, changing salinity and resulting stratification of polar and subpolar water columns, reduced rates of deep and bottom water production, and reduced circulation and reduced oxygen levels in the ocean interior will restrict their range. Dr. Dunbar hypothesized that acidification could be a bigger problem than temperature change, but he noted that increases in both will have food web impacts. Physiological sensitivities such as acidosis (too much acid in body fluids), reductions in metabolic rates, reduced oxygen uptake, and reduced reproductive success are to be expected. Dr. Dunbar pointed out the need to better understand the resilience of bluefin tunas (their biology) and their ecosystem to be able to better characterize potential risks.

SESSION 11 BLUEFIN IN A WARMING WORLD

PURPOSE: The purpose of this session was to review how climate change and environmental variability are impacting bluefin tuna fisheries globally and to examine how climate change science may be able to generate predictable models of the impact of ocean change on bluefin tuna. Speakers presented the science of climate change in relationship to bluefin tuna fisheries, including modeling habitat utilization patterns in a changing sea, interaction with other human impacts on habitats, and the challenges for managers in incorporating potential impacts.

MODERATOR: Dr. Cisco Werner, NOAA

PRESENTATIONS:

Dr. Alistair Hobday, CSIRO. Habitat modeling, climate change and fishery applications.

Dr. Elliott Hazen, NOAA. Examining the influence of climate variability and human impacts on northern bluefin tuna.

Dr. Francisco Chavez, Monterey Bay Aquarium Research Institute. The influence of climate variability and change on Pacific tuna

Dr. Cisco Werner opened the session with a brief presentation on past trends in oceanic conditions, including data on sea surface temperature (SST), examples of anomalous biological events such as changes in the feeding environment, harmful algal blooms and shifts in normal species distributions on unprecedented time scales. He

noted that varied stomach contents of PBF reflect the changing composition of forage species (e.g., in 2015, bluefin tuna off southern California fed almost exclusively on pelagic red crabs (*Pleuroncodes*)). Dr. Werner also highlighted a variety of studies documenting changes in ocean temperatures.

Dr. Alistair Hobday explained the importance of habitat models and stock assessments that incorporate climate variations into the scenarios thus being able to make fully informed choices in fisheries management. He noted that managers can control either inputs (e.g., fishing effort), where habitat modeling is needed and/or outputs (e.g., catch) where stock assessment information is needed. He emphasized that managers need integrated management advice from scientists that includes both habitat models and stock assessment. He explained that habitat modelling has been used for spatial planning (closed areas) but much less for quota management and bycatch reduction, and even less for seasonal forecasting (dynamic ocean management) or climate scale projections. Dr. Hobday reviewed the different types of habitat mapping/modeling including environmental niche models, boosted classification trees and mechanistic models, noting that they are based on different assumptions and differ in how they handle unexpected results and future predictions. He suggested that environmental niche models may work best and that future work needs to focus on producing better projections of future habitat conditions over both short (immediate decision making needs) and longer time scales.

Dr. Elliott Hazen focused his talk on two species of tuna, ABFT and PBF, and how oceanography can be used to improve species knowledge. As an example he described how environmental modelling was used to predict Atlantic bluefin tunas' use of Gulf of Mexico spawning habitats after the Deepwater Horizon Oil Spill. First, they created a switching state space movement model to describe bluefin tuna use of spawning habitats. Next, they modeled the habitat for its physical oceanographic characteristics specifically in relation to bluefin tuna movement and spawning obtained from electronic tags, and identified the spatial distribution of the oil spill layers. Those results were then used to quantify and predict bluefin tuna spawning habitat in relation to the distribution of oil layers. The combination of models (physical habitat characteristics and fish movements) can inform bluefin tuna management by providing information on habitat use (could be used for fishing effort controls), and can inform predictions of the stock's reproductive capacity (spawning and recruitment). Similarly, he demonstrated how sea surface temperature and chlorophyll-a (as a measure of phytoplankton) can be used to predict biodiversity patterns in the Pacific, allowing prediction of where core habitats will be located for multiple predatory species, including bluefin tuna, as ocean conditions change.

Dr. Francisco Chavez discussed the impact of El Niño on spatial dynamics of tuna and other fish species in the Pacific and how sea surface temperature and phytoplankton can be used to make predictions on fish production (biomass) for some species. He noted that the exact relationship is not yet clear for PBF. Dr. Chavez showed a graph of the range of sea surface temperature over 100 years in relation to PBF biomass for El Niño and Pacific Decadal Oscillation, and it revealed that PBF biomass fluctuated over multiple decades, not decadally as previously thought. This underscores the complexity of environmental forecasting and the difficulty of predicting the impacts of climate variation on fish production. He concluded by pressing for more observations of climate and biological variables over different time scales, more predictive models and more work on how these predictions can be used for management.

DISCUSSION

The scale of current climate forecasts in terms of usefulness for management advice was discussed by panelists and participants. One participant noted that managers need reference points to make decisions, and since climate scale forecasts are large, 20 years or more over regime shift time periods, they pose challenges for developing management advice. A panelist explained that it is difficult to effectively average out phenomena that can have a big impact on factors like temperature and oceanic conditions (e.g., volcanic eruptions) at a temporal and spatial scale that would be needed for incorporation into models of fish production. Therefore, predicting annual oceanic

fisheries production regimes with climate forecasting models is difficult. The panelist mentioned efforts to improve decadal scale models to solve these problems.

Panelists and participants described the rapidly evolving science around climate and fish habitat modeling, and many provided observations on their usefulness for incorporating climate variability into bluefin tuna management decisions. The panel discussed the importance of model validation and one panelist noted that a suite of methods offer quantitative validation measures.

The panel then turned to the question of options to mitigate the potential impacts of climate change on wild populations of bluefin tunas. Because bluefin spawning locations are restricted by their specific requirements, climate change is expected to affect them more than other highly migratory species. Some solutions noted by panelists were the potential for aquaculture, as discussed earlier, to replace some of the market demand for wild fish or to provide eggs/larvae for release in enhancement programs. Another suggestion from the panel was to increase the resilience of the natural populations by reducing harvest rates.

CLOSING

Ms. Margaret Spring offered closing remarks on behalf of Monterey Bay Aquarium. She thanked all speakers and participants, and she acknowledged the importance of convening experts from many disciplines outside of the RFMO context to address key issues and identify solutions. She noted the need for enhanced communications, transparency, coordination and a unified strategy for global bluefin recovery.

Ms. Spring identified a number of areas for continued advancement and collaboration, including stronger conservation commitments by Members of RFMOs, development and implementation of new assessment and compliance tools, implementation of harvest strategies and MSE, increased efforts to collect basic catch and effort data, and adoption of greater scientific transparency. She thanked all of the sponsors for their support of the Symposium, and asked participants to consider continuing this type of dialogue in the future.

Dr. Barbara Block offered closing remarks on behalf of Stanford University. Dr. Block recognized the importance of the open and supportive exchange of information on challenging topics that span science and management, and the value of gathering scientific experts, managers and policy makers together. Dr. Block noted that all parties must follow up from this Symposium to tackle some of the most challenging issues facing bluefin tunas globally, and suggested that NGOs and academics can play an important role in supporting advances in scientific research and modeling, including encouraging adoption of similar approaches across RFMOs.

Dr. Block highlighted the importance of developing new fishery-independent estimates, the evolution of bluefin tuna aquaculture and MSE, the contribution of electronic tagging to understanding movement dynamics, and some of the challenges and new ideas presented during the Symposium for improving stock assessments. She thanked the sponsors and staff who contributed to the Symposium, and announced plans for a proceedings volume, with details to follow.

Several participants offered thanks to the Symposium hosts and contributors, and indicated their desire to convene another symposium to continue this dialogue and collaboration in the future.

Ms. Julie Packard offered her thanks to all sponsors and participants and closed the meeting.

BLUEFIN FUTURES SYMPOSIUM MEETING REPORT APPENDICES

APPENDIX 1: LIST OF SPONSORS

The Monterey Bay Aquarium and Stanford University would like to thank the following organizations and individuals:

Bluefin USA

Calysta, Inc.

Center for Ocean Solutions

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Fondation Bertarelli

Guy Harvey

Hopkins Marine Station

Japan Fisheries Research Agency

Randall E. Kochevar

Laurie K. Allen Consulting

Lotek Wireless, Inc.

Monterey Bay Aquarium Research Institute

National Oceanic and Atmospheric Administration, U.S. Department of Commerce (NOAA)

Stanford Woods Institute for the Environment

Tag-A-Giant

The David and Lucile Packard Foundation

The Ocean Foundation

The Pew Charitable Trusts

Tuna Research and Conservation Center

Wildlife Computers

APPENDIX 2: LIST OF STEERING COMMITTEE MEMERS

Bluefin Futures Steering Committee

Dr. Barbara Block

Dr. Campbell Davies

Mr. Charles Farwell

Ms. Sue Lisin

Mr. Josh Madeira

Ms. Shana Miller

APPENDIX 3: LIST OF PARTICIPANTS

Bluefin Futures Symosium Participant List

Monterey, CA, January 18-20, 2016

Name	Affiliation	Name	Affiliation
Lisa Ailloud	Virginia Institute of Marine Science	Elizabeth Hellmers Mendoza	California Department of Fish and Wildlife
Yujiro Akatsuka	Fisheries Agency of Japan	Richard Herrmann	Silverback Films
Laurie Allen	Laurie K Allen Consulting	Rich Hillary	CSIRO
Robert Allman	NOAA Fisheries	Alistair Hobday	CSIRO
Alejandro Anganuzzi	UN - FAO	Sarah Hogan	The David and Lucile Packard Foundation
Pablo Roberto Arenas F.	INAPESCA / SAGARPA, Mexico	Melinda Holland	Wildlife Computers
Haritz Arrizabalaga	FUNDACION AZTI	Rachel Hopkins	The Pew Charitable Trusts
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Steven Bograd	NOAA SWFSC	Yutaka Ishikawa	Nippon Suisan Kaisha, Ltd.
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Kristi Booseman	Center for Ocean Solutions, Stanford University	Brian Jeffriess	Australian Southern Bluefin Tuna Industry Assn.
Andre Boustany	Duke University	Sal Jorgensen	Monterey Bay Aquarium
Mark Bravington	CSIRO	Toshio Katsukawa	Tokyo University of Fisheries & Marine Tech
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Doug Butterworth	University of Cape Town	Toshihide Kitakado	Tokyo University of Marine Science & Tech
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Charles Cook	The Nature Conservancy	Kelly Lipscomb	Documentary filmaker
Athena Copenhaver	Monterey Bay Aquarium	Sue Lisin	Monterey Bay Aquarium
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Campbell Davies	CSIRO	Mark Maunder	IATTC

Bluefin Futures Symposium Participant List – continued

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Rob Dunbar	Stanford University	Shuya Nakatsuka	National Research Institute of Far Seas Fisheries
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Kip Evans	Documentary Filmmaker	Sarah O'Brien	Environmental Defense Fund
Manny Ezcurra	Monterey Bay Aquarium	Eri Oki	The David and Lucile Packard Foundation
Jess Farley	CSIRO	Rachel O'Malley	NMFS
Chuck Farwell	Monterey Bay Aquarium	Aurelio Ortega	Spanish Institute of Oceanography (IEO)
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Santi Roberts	Monterey Bay Aquarium	Isao Sakaguchi	Gakushuin University

Bluefin Futures Symposium Participant List – continued

Name	Affiliation
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Benito Sarmiento	Baja Aqua Farms
Yoshifumi Sawada	Kindai University
Chikako Sawada	
David Schalit	American Bluefin Tuna Association
Robbie Schallert	Tag-A-Giant/TRCC
Kathryn Schleit	Ecology Action Centre
Chris Scholin	Monterey Bay Aquarium Research Institute
Margo Schulze-Haugen	NOAA NMFS
Chrissy Schwinn	The Nature Conservancy
Jerry Scott	International Seafood Sustainability Foundation
George Shillinger	The Leatherback Trust
Tamaki Shimose	Fisheries Research Agency
Alayna Siddall	Sportfishing Association of California
Josh Silverman	Calysta Inc.
Russell Smith	NOAA
Margaret Spring	Monterey Bay Aquarium
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Paige Welsh	Center for Ocean Solutions, Stanford University
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Tim White	Stanford University - Hopkins Marine Station
Becky Whitlock	Tuna Research and Conservation Center
Steve Wilson	Tuna Research and Conservation Center
Aiko Yamauchi	WWF Japan
Hideaki Yukawa	Company
Mark Zimring	The Nature Conservancy

APPENDIX 4: PROGRAM

Bluefin Futures Symposium, Monterey, CA USA

Program Sessions and Symposium Schedule

MONDAY, JANUARY 18

Day 1: The latest research on bluefin tunas (Atlantic, Pacific and southern)

TOPIC	TIME	SESSION
Opening	8:30 - 9:00	**Welcome and Introduction – Ms. Julie Packard**, Executive Director, Monterey Bay Aquarium
	9:00 - 9:30	**Keynote – Ms. Maria Damanaki**, Former European Union Commissioner for Maritime Affairs and Fisheries, and Global Managing Director for Oceans, The Nature Conservancy: **Bluefin tuna can be saved: A history of hope from the Mediterranean**
	9:30 - 10:00	**Keynote – Dr. Barbara Block**, Stanford University: **Sushi and satellites: The importance of science for assuring bluefin futures**
	10:30 – 12:00	**SESSION 1 - Moderator: Dr. Clay Porch**, NOAA
What science is needed for "science-based management" of Atlantic bluefin tuna?		Migration patterns and population structure of Atlantic bluefin tuna (*Thunnus thynnus*) – **Dr. Andre Boustany**, Duke University, Dr. Carol Reeb, Stanford University, et al.
		Life history and migrations of Mediterranean bluefin populations – **Dr. Haritz Arrizabalaga**, AZTI, et al.
		Back to the future: What population genomics and paleogenomics reveal on spatio-temporal stock structure, connectivity and adaptation in the Atlantic bluefin tuna – **Dr. Fausto Tinti**, University of Bologna, Dr. G.N. Puncher, Ghent University, et al.
		Origin and population connectivity of Atlantic bluefin tuna: Insights from natural markers in otoliths – **Dr. Jay Rooker**, Texas A&M University, Dr. Haritz Arrizabalaga, AZTI , et al.
		Predicting Atlantic bluefin tuna larval habitat in the western Atlantic – **Dr. Barbara Muhling**, Princeton University, Dr. John Lamkin, NOAA, et al.
		Improving the scientific understanding of Atlantic bluefin tuna: The ICCAT GBYP research program – **Dr. Antonio Di Natale**, ICCAT and Dr. David Die, University of Miami
		Session 1 Panel Discussion – What knowledge gaps do we need to address in order to advance Atlantic bluefin tuna management?
	13:30 – 15:00	**SESSION 2 - Moderator: Dr. Jim Ianelli,** NOAA
What science is needed for "science-based management" of southern bluefin tuna?		Advances in biology and life history of southern bluefin tuna – **Ms. Jessica Farley**, CSIRO, Ms. Paige Eveson, CSIRO, et al.
		Spatial dynamics of southern bluefin tuna – an overview and implications for management – **Dr**. **Toby Patterson**, CSIRO, Ms. Paige Eveson, CSIRO, et al.
		Long term recruitment monitoring data for the SBT management procedure and stock assessment models – **Ms. Ann Preece**, CSIRO, Ms. Paige Eveson, CSIRO, et al.
		Close-kin mark-recapture for southern bluefin tuna – **Dr. Mark Bravington**, CSIRO, Dr. Peter Grewe, CSIRO, et al.
		Session 2 Panel Discussion – What knowledge gaps do we need to address in order to advance southern bluefin tuna management?

	15:30 – 17:00	**SESSION 3 - Moderator: Dr. Toshihide Kitakado**, Tokyo University of Marine Science and Technology
What science is needed for "science-based management" of Pacific bluefin tuna?		Life history of Pacific bluefin tuna – **Dr. Tamaki Shimose**, Seikai National Fisheries Research Institute, Japan Fisheries Research Agency
		Electronic tagging applications and migrations of Pacific bluefin tuna in the western Pacific Ocean – **Dr. Takashi Kitagawa**, University of Tokyo and Dr. Ko Fujioka, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency
		Electronic tagging applications for Pacific bluefin tuna in the eastern Pacific Ocean: Migrations, fisheries and foraging – **Dr**. **Rebecca Whitlock**, Tuna Research and Conservation Center, Mr. Charles Farwell, Monterey Bay Aquarium, et al.
		Genetics of Pacific bluefin tuna: Introduction of close-kin project with NGS approaches by Fisheries Research Agency, Japan - **Dr. Nobuaki Suzuki**, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency
		The influence of uncertainty in biological and fishing processes on Pacific bluefin tuna stock assessment - **Dr. Mark Maunder**, IATTC, Dr. Kevin Piner, NOAA, et al.
		Session 3 Panel Discussion – What knowledge gaps do we need to address in order to advance Pacific bluefin tuna management?
	17:00 – 18:00	**SESSION 4 Moderated Panel Discussion – Moderator: Dr. Fabio Hazin**, Universidade Federal Rural de Pernambuco and Chair, UN-FAO Committee on Fisheries
Discussion of scientific knowledge gaps, the management challenges they create & pathways to address priority research questions		**Dr. John Gunn**, AIMS
		Dr. Mark Bravington, CSIRO
		Dr. Sylvain Bonhommeau, Ifremer
		Dr. Barbara Block, Stanford University
		Dr. Craig Brown, NOAA
		Dr. Heidi Dewar, NOAA
		Dr. Takashi Kitagawa, University of Tokyo

TUESDAY, JANUARY 19

Day 2: Science-based management of bluefin tunas

TOPIC	TIME	SESSION
	8:30 – 9:00	**Keynote – Prof. Glenn Hurry**, MRAG Asia-Pacific: **International bluefin management… does it deliver? Legacy and lessons of the last 20 years**
	9:00 – 10:30	**SESSION 5 - Moderator: Dr. Joe Powers**, Louisiana State University
Current stock status and		Western Atlantic bluefin tuna – **Dr. Guillermo Diaz,** NOAA, Dr. Matthew Lauretta, NOAA, et al.
		Atlantic bluefin tuna: A Mediterranean perspective - **Dr. Sylvain Bonhommeau**, Ifremer
		Stock status and challenges for assessment of Pacific bluefin tuna – **Dr. Hideki Nakano**, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency and Dr.

challenges for assessment		Hiromu Fukuda, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency
		Integrating past, present and future into a scientifically evaluated rebuilding plan for southern bluefin tuna – Dr. Richard Hillary, CSIRO, **Ms. Ann Preece**, CSIRO, and Dr. Campbell Davies, CSIRO
		Session 5 Panel Discussion – Stock status and challenges for assessment of all bluefin tunas
	11:00 – 12:30	**SESSION 6 - Moderator: Dr. Victor Restrepo**, International Seafood Sustainability Foundation
Modernizing science-based fisheries management tools		Spatial temporal assessments in modernizing fisheries management tools – **Dr. Nathan Taylor**, Fisheries and Oceans Canada, Dr. Murdoch McAllister, University of British Columbia, et al.
		Reference points – **Mr. Alejandro Anganuzzi**, Food and Agriculture Organization of the United Nations
		Harvest strategies, MSE and the precautionary approach in the management of bluefin tuna fisheries – **Dr. Campbell Davies**, CSIRO, Dr. Keith Sainsbury, University of Tasmania, et al.
		Towards a management strategy evaluation framework for Atlantic bluefin tunas – **Dr. Tom Carruthers**, University of British Columbia
		A harvest control rule for Pacific bluefin tuna based on recruitment indices – **Mr. Shuya Nakatsuka**, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency
		Session 6 Panel Discussion – Achieving sustainability goals through science-based management tools
	14:00 – 15:30	**SESSION 7 Moderated Panel Discussion – Moderator: Prof. Glenn Hurry**, MRAG Asia-Pacific
Working toward sustainable bluefin tuna fisheries: RFMO solutions		**Mr. Masa Miyahara**, President, Japan Fisheries Research Agency
		Mr. Russell Smith, Deputy Assistant Secretary for International Fisheries, National Oceanic and Atmospheric Administration, United States Department of Commerce
		Mr. Stefaan Depypere, Director of International Affairs and Markets, European Commission Directorate General for Maritime Affairs and Fisheries
		Dr. Pablo Roberto Arenas Fuentes, Director General, National Fisheries Institute (INAPESCA), Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), Mexico
		Dr. James Findlay, Chief Executive Officer, Australian Fisheries Management Authority
		Ms. Amanda Nickson, Director, Global Tuna Conservation, The Pew Charitable Trusts
		Dr. Fabio Hazin, Universidade Federal Rural de Pernambuco and Chair, UN-FAO Committee on Fisheries
	16:00 – 17:00	**SESSION 8 - Moderated Panel Discussion – Moderator: Dr. Jerry Scott**, International Seafood Sustainability Foundation
Advancing best practices in		**Dr. Doug Butterworth**, University of Cape Town
		Dr. Campbell Davies, CSIRO
		Mr. Alejandro Anganuzzi, Food and Agriculture Organization of the United Nations

providing scientific advice		**Dr. Hideki Nakano**, National Research Institute of Far Seas Fisheries, Japan Fisheries Research Agency
		Ms. Shana Miller, The Ocean Foundation
		Dr. David Die, University of Miami
	17:00 – 17:30	**Day 2 Summary**

WEDNESDAY, JANUARY 20

Day 3: Emerging opportunities and challenges for bluefin tuna sustainability

TOPIC	TIME	SESSION
	8:30 – 9:00	**Keynote – Dr. Yoshifumi Sawada**, Kindai University: **Challenges of raising bluefin tuna**
	9:00 – 10:30	**SESSION 9 - Moderator: Dr. Barbara Block**, Stanford University
Role of aquaculture and farming in the future of bluefin tunas		History and challenges of working with Pacific bluefin tuna, *Thunnus orientalis*, in captivity – **Mr. Chuck Farwell**, Monterey Bay Aquarium
		Progress in the domestication of *Thunnus thynnus* (DOTT) – Perspectives for Atlantic bluefin tuna aquaculture in the Mediterranean – **Dr. Christopher Bridges**, Universität Düsseldorf, Dr. Hillel Gordin, NCM-IOLR, et al.
		Progress in Spanish aquaculture – **Dr. Aurelio Ortega Garcia**, Spanish Institute of Oceanography (IEO) and Dr. Fernando de la Gándara, IEO
		Status of Mexican ranching – **Mr. Benito Sarmiento**, Baja Aqua Farms
		The potential role of biofeeds in aquaculture of salmon and tuna – **Dr. Josh Silverman**, Calysta Inc.
		Resource and environmental intensity of tuna aquaculture – **Dr. Dane Klinger**, Princeton University
		Session 9 Panel Discussion – What is the role of aquaculture and farming in the future of bluefin tunas?
	11:00 – 11:30	**Keynote – Mr. Brian Jeffriess**, Australian Southern Bluefin Tuna Industry Association: **Bluefin ranching economics – Managing the resource and the farm**
	11:30 – 12:30	**SESSION 10 - Moderator: Mr. Brian Jeffriess**, Australian Southern Bluefin Tuna Industry Association
Bluefin tuna economics		West Atlantic bluefin tuna: Some challenges and solutions in balancing economics and conservation – **Mr. David Schalit**, American Bluefin Tuna Association
		Pacific bluefin tuna fisheries and regulations in Japan – **Dr. Yasuhiro Sanada**, Waseda University
		Economic importance of access to Pacific bluefin tuna by eastern Pacific recreational anglers – **Ms. Alayna Siddall**, Sportfishing Association of California
		Session 10 Panel Discussion – Economic challenges and opportunities for future sustainability

	14:00 – 14:30	**Keynote – Dr. Robert B. Dunbar**, Stanford University: **Bluefin tuna in a warming world: the science of oceanic climate change and acidification**
	14:30 – 15:30	**SESSION 11 – Moderator: Dr. Cisco Werner**, NOAA
Bluefin in a warming world		Habitat modeling, climate change and fishery applications – **Dr. Alistair Hobday**, CSIRO, et al.
		Examining the influence of climate variability and human impacts on northern bluefin tuna – **Dr. Elliott Hazen**, NOAA
		The influence of climate variability and change on Pacific tuna – **Dr. Francisco Chavez**, Monterey Bay Aquarium Research Institute and Dr. Barbara Block, Stanford University
		Session 11 Panel Discussion – How will bluefin fisheries management incorporate a changing climate?
Closing	16:00 – 17:30	**Closing Remarks on Bluefin Futures**

BLUEFIN TUNA CAN BE SAVED: A HISTORY OF HOPE FROM THE MEDITERRANEAN

Maria Damanaki

Keynote, 18/1/16 @ 0900 hrs

This keynote will discuss the current state of bluefin tuna and offer a suggested approach for reversing the disastrous decline of the world's most sought after commodity. Drawing on her expertise and experience as the EU commissioner of Maritime and Fisheries, Ms. Damanaki offers a story of hope, but a hope that is grounded in reality. In order to change the dangerous trajectory of the global decline of bluefin, we must focus on the following: global governance, state of the art technology, and public opinion. Presenting a blueprint for action based on her work in the Mediterranean, Maria Damanaki will offer examples of international cooperation, bilateral and trilateral initiatives, clear enforcement and control, and why a strong education campaign will be critically important to a successful effort. A decade after the establishment of the Bluefin Tuna Recovery Plan and the implementation of a variety of governance mechanisms, the situation in the Mediterranean has been somewhat improved. But there is much work still to be done: establishment of further monitoring and controlling mechanisms against IUU bluefin tuna fishing as well as stricter regulations against bluefin tuna overfishing in the eastern Atlantic and broader Mediterranean. In addition, we must address the need for a stricter framework for non-compliance with regulations and the need for strengthening ICCAT regulations in order to address the current challenges.

Contact: M. Damanaki, Former European Union Commissioner for Maritime Affairs and Fisheries, and Global Managing Director for Oceans, The Nature Conservancy, maria.damanaki@tnc.org

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SUSHI AND SATELLITES: THE IMPORTANCE OF SCIENCE FOR ASSURING BLUEFIN FUTURES

Barbara Block

Keynote, 18/1/16 @ 0930 hrs

Bluefin tunas are highly migratory apex predators that are among the largest perciform fish on the planet. These fish are highly prized by fishers throughout the globe for their power, strength, speed and commercial value as food. Throughout human history they have been difficult to study which has led to major gaps in knowledge about their life history and population structure. However, in the past two decades pelagic fish science has rapidly advanced with new technological breakthroughs in electronic tagging, genetics, genomics, microconstituent, isotopic, analyses and aquaculture. This has led to a suite of new data and techniques that provide novel information that can help to delineate bluefin tuna population structure, spatial and temporal uses of habitat, spawning and foraging behaviors, trans-oceanic migrations and maturity schedules. Such vital life history data are essential for properly informing stock assessment models and assuring that bluefin biodiversity, severely depleted in the twentieth century, can rebuild in our lifetimes. To make advances in fisheries models, fisheries managers, decision makers, and funding agencies must

work together internationally to assure that significant investments in the new science continues at a pace required to inform fisheries models, and enable science advances to properly inform management models and decisions. New efforts at international collaborations across bluefin species will rapidly advance the science, and collaborations among academic and RFMO scientists as well as managers can assure rapid transfer of knowledge that will assure bluefin futures.

Contact: B. Block, Professor, Hopkins Marine Station, Stanford University, USA, bblock@stanford.edu

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MIGRATION PATTERNS AND POPULATION STRUCTURE OF ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*)

Andre Boustany, Carol Reeb, Michael Castleton, Robert Schallert,

Michael Stokesbury, and Barbara Block

Session 1, Talk 1, 18/1/16 @ 1030 hrs

Recent advances in electronic tagging and molecular genetic technologies have shed light on the population structure and movements of bluefin tuna globally. In the Atlantic Ocean and adjacent seas, bluefin tuna (*Thunnus thynnus*) spawn in the Mediterranean Sea in the east and the Gulf of Mexico/Caribbean Sea/Straits of Florida in the west. Genetic differentiation and repeat migrations to specific spawning grounds observed in electronic tracked fish support the theory of natal homing among isolated spawning populations. Young of the year western spawned fish travel north through the Straits of Florida where they feed for up to a decade or more along the East Coast of North America and throughout the North Atlantic Ocean, with movements varying with season and ontogeny. At ages 10-16, these fish begin to return to the western spawning grounds during the winter and spring months. In the Mediterranean Sea, bluefin depart though the Strait of Gibraltar during the first year of life, although a sizable portion of fish remain within the Mediterranean where they may form resident populations. Eastern fish range throughout the North Atlantic, with major feeding grounds being found in the Bay of Biscay, along the northern edge of the Gulf Stream and off the East Coast of North America. It is in this latter foraging area where bluefin of eastern and western origin mix most extensively, with some size classes being equal parts eastern and western in origin.

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LIFE HISTORY AND MIGRATIONS OF MEDITERRANEAN BLUEFIN POPULATIONS

Haritz Arrizabalaga, I. Arregi, A. Medina, N. Rodriquez Ezpeleta,

J.M. Fromentin, I. Fraile

Session 1, Talk 2, 18/1/16 @ 1030 hrs

The largest proportion of bluefin individuals living in the Atlantic and adjacent seas are born in the Mediterranean Sea. The life history and migrations of Mediterranean Bluefin tuna are complex.

Many new studies have been conducted in recent years, but in many cases, far from solving the original uncertainties, they allowed to discover extra levels of complexity that require additional research. The complexity of Mediterranean bluefin tuna biology, and the imperfect and sometimes controversial scientific knowledge, impacts the ability to assess stock status and the successful management. In this presentation, current knowledge on life history and migrations is reviewed, focusing on the controversial biological topics, their management implications, and the research that would be needed to address them and allow a better "science-based management". The main topics reviewed include population structure, migrations and mixing, reproduction, age structure, productivity and recruitment.

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BACK TO THE FUTURE: WHAT POPULATION GENOMICS AND PALEOGENOMICS REVEAL ON SPATIO-TEMPORAL STOCK STRUCTURE, CONNECTIVITY AND ADAPTATION IN THE ATLANTIC BLUEFIN TUNA

Fausto Tinti, Gregory N. Puncher, ICCAT GBYP Project Consortium,

ICCAT GBYP Data Recovery Project Consortium,

ATGC-TUNA Project Consortium and Alessia Cariani

Session 1, Talk 3, 18/1/16 @ 1030 hrs

A genotyping-by-sequencing approach was used to discover SNPs throughout the Atlantic Bluefin tuna genome while simultaneously analyzing population structure in the Gulf of Mexico, Atlantic and Mediterranean, including several previously uncharacterized sites. Genotyping revealed temporally persistent differentiation among baseline, early life stage samples from the western Atlantic and Mediterranean using panels of 80 and 25 SNPs (F_{ST} = 0.0091, $p<0.001$ and F_{ST} = 0.028, $p<0.001$, respectively) and an average self-assignment success rate of 83.8%. No clear pattern of structuring was detected among Mediterranean samples. The assignment (overall probability 82.2%) and mixture analyses of mixed feeding aggregations in the Atlantic Ocean and Mediterranean revealed an extensive mixing in the Atlantic Ocean, particularly in the Gulf of St. Lawrence, as well as a poleward shift in the distribution of eastern migrants in the Western Atlantic and ontogeny-dependent migratory behavior.

Parallel ongoing researches are also exploiting Bluefin paleogenomic resources retrieved from Atlantic, Mediterranean and Marmara-Black Sea historical remains from late Iron Age, Ancient Roman, Byzantine and modern eras. Significant differences in geographic and temporal SNP allele frequencies are revealed at several functional genes. By comparing the contemporary and historical genetic codes we are making efforts to shed light on the evolution of the species genome in response to nearly two millennia of fisheries pressure, a changing climate and pollution of the sea.

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ORIGIN AND POPULATION CONNECTIVITY OF ATLANTIC BLUEFIN TUNA: INSIGHTS FROM NATURAL MARKERS IN OTOLITHS

Jay Rooker, Haritz Arrizabalaga, David Secor, Igaratza Fraile, Anna Traina, and Jessica Lee

Session 1, Talk 4, 18/1/16 @ 1030 hrs

The productivity and dynamics of bluefin tuna populations are influenced by patterns of movement during the life of an individual, and the degree of trans-Atlantic movement and connectivity between eastern and western populations remains unresolved. We investigated migratory patterns, stock mixing, and homing behaviors of bluefin tuna from several regions of the North Atlantic Ocean using natural, chemical markers—stable isotopes and trace elements—in otoliths (ear stones). Otoliths of young bluefin tuna were first used to develop natal signatures or "birth certificates" for members of eastern and western populations. Using our baseline sample, we then examined migratory behaviors of larger, older bluefin tuna, which indicated that trans-Atlantic and trans-boundary movements occur for individuals from both populations. In fact, adolescent bluefin tuna in the western fishery (U.S. waters) often originate from the eastern spawning area (Mediterranean Sea). Despite the fact that both populations commonly cross the 45°W management boundary in the Central North Atlantic Ocean, we found that giant bluefin tuna collected from western (Gulf of Mexico) or eastern (Mediterranean Sea) spawning areas were nearly all (~100%) from the same area, demonstrating that bluefin tuna display natal homing.

Contact: J. Rooker, Texas A&M University, USA, rookerj@tamug.edu

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PREDICTING ATLANTIC BLUEFIN TUNA LARVAL HABITAT IN THE WESTERN ATLANTIC

Barbara A. Muhling, John T. Lamkin, Mitchell A. Roffer, Frank Muller-Karger, Estrella Malca, Ricardo Domingues, David Lindo, Joseph Quattro, G. Walter Ingram Jr., Redwood Nero, Sang-Ki Lee, and Yanyun Liu

Session 1, Talk 5, 18/1/16 @ 1030 hrs

Atlantic bluefin tuna spawning activity is concentrated in two sub-tropical semi-enclosed seas: the Gulf of Mexico and Mediterranean Sea. United States waters in the Gulf of Mexico are historically well-sampled for larval bluefin, with annual cruises completed during the spring spawning season since the late 1970s. Analyses of catch data have shown that larvae are associated with specific oceanographic conditions, which largely reflect known adult habitat use. Across the >30 years of sampling, larval bluefin tuna were collected most often in offshore waters where surface temperatures were warm (~24-28°C), and surface chlorophyll was low. Exploratory cruises completed since 2009 have targeted adjacent areas in the western central Atlantic with similar environmental characteristics to the northern Gulf of Mexico spawning area. Low numbers of bluefin tuna larvae were collected in the western Caribbean Sea, southern Gulf of Mexico and Bahamas, however the contribution of these areas to total spawning activity remains uncertain.

Recent advances in larval ecology suggest general adaptation to oligotrophic environments, and potential links between oceanographic conditions and larval survival. As drivers of recruitment are better studied and understood, the potential impacts of climate change can be assessed, as well as the influence of spawning ground conditions on future stock sustainability.

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IMPROVING THE SCIENTIFIC UNDERSTANDING OF ATLANTIC BLUEFIN TUNA: THE ICCAT GBYP RESEARCH PROGRAM

Antonio Di Natale and David J. Die

Session 1, Talk 6, 18/1/16 @ 1030 hrs

Despite a long history of research, many aspects of the Atlantic bluefin tuna fishery, biology and ecology are still poorly known. For this reason, in 2008, ICCAT decided to start the Atlantic-wide research program for bluefin tuna (GBYP). This broad and ambitious research program includes data mining and recovery of historical fishery and biological information, aerial survey for spawning aggregations, conventional and electronic tagging, biological collection of samples for ageing, micro-chemistry, genetics and otoliths shape analysis and finally, development of new population modelling approaches. The first five GBYP Phases covered the period 2010-2016 and produced many interesting results, along with hundreds of papers and reports. Several scientific methods have been tested for the first time on bluefin tuna, and others have been done at a scale never attempted before for the species. Many of the research results have clearly improved the knowledge of this species and its fisheries. The fishery data sets now available for Atlantic bluefin tuna contain the longest time series for a marine species, going from 1512 to 2015. Genetic material obtained from very ancient samples (II century b.c.) is now also available. By involving research entities from 23 different countries, and hundreds of scientists and technicians, this program has demonstrated the importance of working together for a common objective: improving the knowledge about Atlantic bluefin tuna and its fishery to support management decisions.

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ADVANCES IN BIOLOGY AND LIFE HISTORY OF SOUTHERN BLUEFIN TUNA

Jessica Farley, Paige Eveson and Naomi Clear

Session 2, Talk 1, 18/1/16 @ 1330 hrs

Our understanding of the population biology and life-history of southern bluefin tuna (SBT) (*Thunnus maccoyii*) has increased substantially over the past two decades through the collection of high quality, multi-sourced data on the age, growth and reproduction. The collection of these data, using a combination of targeted research and collaborative long-term monitoring work, was driven by the need for this information for quantitative population assessment and effective management of the highly depleted species. Here we provide a

synthesis of the data and resulting information obtained, and highlight its use in models to assess population abundance and stock status.

Growth rates of juvenile SBT increased between the 1960s and 1990s, possibly as the result of population decline, but appear to have stabilized since. After 10 years of age, males grow faster than females, which may account for the bias observed in the sex ratio of SBT whereby males become progressively more dominant above ~170 cm. A comparison of the length-at-age of fish caught on and off the spawning ground suggests that size may be the primary determining factor in timing of maturation for both males and females. Although the maturity schedule for SBT remains poorly defined, size related trends in other reproductive parameters such as batch fecundity, spawning frequency and the duration of spawning and non-spawning episodes are available. These biological data and parameter estimates have been central to the development and refinement of the CCSBT Operating Model used for assessing the status and productivity of the stock and evaluating alternative management procedures, as well as to the construction of models for close-kin abundance estimation. Priorities for future research include targeted sampling and analysis to improve estimates of size and age at maturity (and senescence) and of duration on the spawning ground, and continued monitoring of growth rates through the rebuilding period.

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SPATIAL DYNAMICS OF SOUTHERN BLUEFIN TUNA –

AN OVERVIEW AND IMPLICATIONS FOR MANAGEMENT

Toby Patterson, Paige Eveson, Jason Hartog, Karen Evans,

Alistair Hobday, and Campbell R. Davies

Session 2, Talk 2, 18/1/16 @ 1330 hrs

The southern bluefin tuna is a highly migratory and depleted species targeted by a multi-national fishery across three oceans. We present results from electronic tagging conducted by CSIRO since the late 1990s, largely of juveniles tagged in their summer aggregation area in the Great Australian Bight (GAB). This area is the location of the Australian purse seine fishery and is a staging ground prior to the east or westward feeding migrations of juveniles for the Austral autumn and winter. We provide an overview of the juvenile summer residency in the GAB, annual migration timing and summarise available observations of sub-adult and adult SBT moving from the Tasman sea toward the Indonesian spawning grounds. We discuss, also, the implications of the timing and the associated uncertainty in movement rates (both from geolocation error and individual variability) for interpretation of abundance indices based on catch data and approaches for more explicitly incorporating movement information into analysis and population dynamics models of this highly migratory species.

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LONG TERM RECRUITMENT MONITORING DATA FOR THE SBT MANAGEMENT PROCEDURE AND STOCK ASSESSMENT MODELS

Ann Preece, Paige Eveson, Jessica Farley, Mark Bravington and Campbell R. Davies

Session 2, Talk 3, 18/1/16 @ 1330 hrs

In response to concerns about parental biomass decline, uncertainty in recruitment and the information time-lag between recruitment and adults due to the late maturity population dynamics of SBT, research has been undertaken on reliable techniques for long-term recruitment monitoring, fishery independent indices of juvenile abundance and key biological processes. The scientific aerial survey, developed in the early 1990s, provides an index of relative abundance of juveniles and is a key input to the CCSBT Management Procedure used to set the global TAC. Large conventional and electronic tagging programs, age and growth research, and trolling and acoustic surveys have provided direct age data, time varying growth estimates, tagging data and natural mortality estimates for use in SBT population dynamics models. These models are used to assess stock status and evaluate performance of management procedures.

Most recently, a gene-tagging program has been initiated. It takes advantage of recent advances in genetics and statistical methods to provide absolute abundance estimates of juveniles. The SBT gene-tagging data will be used in a new management procedure that will supersede the current one. Gene-tagging is similar to conventional tagging but uses the genetic fingerprint of a fish in place of physical tags. The key advantages are that the tag is invisible, there is no shedding, no reward costs, and perhaps most importantly, it overcomes the uncertainty in reporting rates. Through simulation tests using the adopted SBT management procedure, the value of this fishery independent recruitment data has been demonstrated to be essential for management of the SBT fishery.

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CLOSE-KIN MARK-RECAPTURE FOR SOUTHERN BLUEFIN TUNA

Mark V. Bravington, Peter M. Grewe and Campbell R. Davies

Session 2, Talk 4, 18/1/16 @ 1330 hrs

Close-Kin Mark-Recapture (CKMR) is a new way to estimate absolute abundance, survival, and other demographic parameters. Modern genetics is used to find pairs of close kin (parents, offspring, siblings) amongst large numbers of tissue samples; the number and pattern of pairs found are used to fit a modified mark-recapture model, based on the simple idea that each animal "marks" its two parents. Unlike conventional mark-recapture, there is no need to "put animals back alive"--- samples can come directly from dead catches. And unlike conventional stock assessment, there is no need to use any catch-rate (or even catch) data to estimate abundance; this makes CKMR very appealing for tuna, where the interpretation of CPUE is notoriously problematic. In this talk I will briefly cover: the ideas behind CKMR; how we applied it to SBT; and plans for ongoing use of CKMR as a cheap, transparent, and fishery-independent way

to monitor the SBT adult stock size while--- we hope--- it rebuilds. I will also briefly comment on CKMR's data requirements and potential applicability to other species.

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LIFE HISTORY OF PACIFIC BLUEFIN TUNA

Tamaki Shimose

Session 3, Talk 1, 18/1/16 @ 1530 hrs

Pacific bluefin tuna *Thunnus orientalis* occurs in tropical to temperate waters in the Pacific Ocean, and main distribution range is in the North Pacific. Ontogenetic habitat shift and seasonal movement of the species are reviewed with the information of size (fork length), age (Shimose et al. 2009), and gonadal maturation (Ashida et al. 2015, Okochi et al. 2016 etc.) which was determined by using specimens of Japanese commercial catch. A ge-0 bluefin (ca. <60 cm) occur in coastal areas of Japan from July to next spring. After reaching age-1 (ca. >60 cm), core distribution area moves northward in summer and southward in winter, and some of age-1 bluefin migrate to the eastern North Pacific feeding ground. Spawning was confirmed from age-3 (ca. 110 cm) in the Sea of Japan spawning ground during mid-June to early-August, and nearly 100% of bluefin in this specific region were mature at age-4 (ca. 130 cm). Adult bluefin also migrate to another main spawning ground located from around Okinawa (southernmost islands in Japan) to off Philippines only during the spawning season mid-April to early-July. The first occurrence of maturity in this region is age-6 (ca. 170 cm), but main component is age-8–20 (ca. 200–250 cm). During non-spawning season, some adults occur around the waters off northern Japan and some probably migrate to other areas. Growth rate decreases after age-10. Average asymptotic length, body weight, and maximum life span are estimated to be ca. 250 cm, 300 kg, and 28 years, respectively.

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ELECTRONIC TAGGING APPLICATIONS AND MIGRATIONS OF

PACIFIC BLUEFIN TUNA IN THE WESTERN PACIFIC OCEAN

Takashi Kitagawa and Ko Fujioka

Session 3, Talk 2, 18/1/16 @ 1530 hrs

Investigations of the migration and distribution of Pacific bluefin tuna (PBT) in the Pacific Ocean have used fisheries data analysis and/or conventional tagging experiments mainly in the 20th century, but these previous studies could not follow the detailed behavior of individuals at a higher resolution. The electronic tags that were developed and applied to fish species at the end of the last century allowed the measurement of environmental and physiological variables by recording

raw or processed data in their memory. The tags used for PBT research allow a rough estimation of fish geolocation using a light sensor. To date, more than 800 PBT tuna tagged with the electronic tags have been released in the western Pacific Ocean (WPO). Analyses of the retrieved tag data have shown that the vertical distributions and movements of immature PBT are affected by spatial and seasonal changes in the vertical temperature structure. They make brief dives to depths below the thermocline for foraging and maintaining body temperature. The data indicate they aggregate in the Kuroshio-Oyashio transition region where they spent much more time at the surface feeding than in the other areas in the WPO. The timing of their trans-Pacific migrations from the transition region to the Eastern Pacific appears to depend on their wintering areas. We also suggest directions of future research for investigating PBT migratory characteristics in the WPO.

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ELECTRONIC TAGGING APPLICATIONS FOR PACIFIC BLUEFIN TUNA

IN THE EASTERN PACIFIC OCEAN:

MIGRATIONS, FISHERIES AND FORAGING

Rebecca Whitlock, Charles Farwell, Elliott Hazen, Andreas Walli,
Murdoch McAllister, Andre Boustany, Robert Schallert,
Mike Castleton, James Ganong, Steven Bograd, and Barbara Block

Session 3, Talk 3, 18/1/16 @ 1530 hrs

Biologging using electronic tags has paved the way for major advances in our understanding of the ecology and population dynamics of bluefin tunas in the past two decades. The Pacific bluefin tuna population is severely depleted and urgent management action is needed for rebuilding. In the eastern Pacific Ocean, returns of archival tags deployed on over 750 Pacific bluefin (~50% return rate), have provided important information about natural mortality rates, year class specific harvest rates, and seasonal patterns of migration in the California Current. Trans-oceanic migrations from the eastern Pacific to the western Pacific Ocean offer an insight into the age at first spawning for migratory Pacific bluefin tuna.

Peritoneally-implanted archival data storage tags have also revealed when and where juvenile Pacific bluefin feed, by applying a laboratory validated model to estimate energy intake from visceral warming measured in wild fish in the California Current. These estimates allow identification of foraging hotspots, areas of high feeding success and potentially high aggregation, that together with oceanographic correlates of feeding success can help predict environment-driven changes in distribution. Making use of the information about life-history (natural mortality and age at maturity), spatio-temporal patterns of habitat use, and interactions with fisheries from electronic tagging data is key in contributing to more biologically realistic models and formulating management advice for stock rebuilding.

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GENETICS OF PACIFIC BLUEFIN TUNA:

INTRODUCTION OF CLOSE-KIN PROJECT WITH NGS APPROACHES BY FISHERIES RESEARCH AGENCY, JAPAN

Nobuaki Suzuki

Session 3, Talk 4, 18/1/16 @ 1530 hrs

In recent, Next-Generation-Sequencing (NGS) analyses are widely spread for a variety of wild organisms. However, for bluefin tuna species, there is less applications of NGS especially in the field of ecology. What kind of genetic information do we need for science-based management of Pacific bluefin tuna (PBF)? As one of the answers, we started preliminary attempt to implement Close-kin genetics for estimating PBF spawning biomass by using NGS approaches since 2014. In our presentation, we will introduce steady progress in the Japanese Close-kin project. A huge number (> 6,000) of single nucleotide polymorphic markers (SNPs) have been screened from 50 individuals of wild PBF through Restriction-site Associated DNA (RAD) sequencing. Given a level of allelic variability for SNPs based on the result of RAD sequencing, computational simulations have been performed to illustrate how many SNPs should be analyzed to identify parent-offspring pairs exactly on the assumption of an ideal reproductive process. We also started modeling work to import Close-kin information into population dynamics. In the near future, we expect that these genomic data generated by NGS could be integrated with stock assessment of PBF.

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THE INFLUENCE OF UNCERTAINTY IN BIOLOGICAL AND FISHING PROCESSES ON PACIFIC BLUEFIN TUNA STOCK ASSESSMENT

Mark N. Maunder, Kevin R. Piner, Alexandre Aires-da-Silva, Steve Teo, Hui-Hua Lee, and Paul Crone

Session 3, Talk 5, 18/1/16 @ 1530 hrs

Management advice from fisheries stock assessments is dependent on various assumptions about biological and fishing processes. Unfortunately, our understanding of these processes and the best way to model them is much poorer than most scientists and managers realize or care to admit. The recent stock assessment of Pacific bluefin tuna in 2014 is a prime example of uncertainties about biological and fishing processes. Despite wide acceptance of the highly depleted nature of the stock and the need for drastic management action (which has been implemented), the

stock assessment's inability to reconcile standard data types (e.g. catch, CPUE based indices of abundance and length composition) are indicative of our lack of biological and fishery understanding. Parameter uncertainty, model structure uncertainty, and unmodelled temporal variation in biological (e.g. growth, mortality, and movement) and fishery processes (e.g. selectivity and catchability) results in poor fits to data and potentially biased estimates of the historical dynamics. The estimates of future stock trends are influenced by bias in the historical dynamics as well as additional uncertainty in the stock-recruitment relationship. At the current highly depleted stock level, future projections may be hyper sensitive to assumptions about the stock-recruitment relationship even when the recreation of the historical dynamics is not. It is critical to know which processes are most important to improve the understanding of stock status and probable future trends so that research efforts can focus on those most likely to improve management advice.

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INTERNATIONAL BLUEFIN MANAGEMENT….. DOES IT DELIVER?

LEGACY AND LESSONS OF THE LAST 20 YEARS

Glenn Hurry

Keynote, 19/1/16 @ 0830 hrs

This presentation focuses on the challenges faced over the past 20 years in delivering sustainability to bluefin through the current RFMO management framework. The presenter looks at sustainability by considering the performance of the different participant groups, industry, government officials and negotiators, scientists and NGOs over the last 20 years. He then looks at the lessons that can be drawn from this legacy for the future management of bluefin.

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CURRENT STOCK STATUS AND CHALLENGES FOR ASSESSMENT:

WESTERN ATLANTIC BLUEFIN TUNA

Guillermo Diaz, Matthew Lauretta and Clay Porch

Session 5, Talk 1, 19/1/16 @ 0900 hrs

The International Commission for the Conservation of Atlantic Tunas (ICCAT) manages Atlantic bluefin tuna as two separate stocks: Western Atlantic, and Eastern Atlantic and Mediterranean separated by the 45° West Longitude meridian. The western Atlantic stock was last assessed in 2014 using a Virtual Population Analysis (VPA) assessment model and stock status was determined relative to MSY-related benchmarks. A key factor in estimating these benchmarks is the highest

level of recruitment that can be achieved in the long term. Assuming that average recruitment cannot reach the high levels estimated to have occurred in the early 1970s (low recruitment potential scenario), $F_{2010\text{-}13}$ / F_{MSY} = 0.36 and SSB_{2013}/SSB_{MSY}=2.25. In contrast, estimates of stock status are more pessimistic under a high recruitment potential scenario with $F_{2010\text{-}13}$ / F_{MSY} = 0.88 and SSB_{2013}/SSB_{MSY}=0.48. ICCAT's Standing Committee on Research and Statistics cautioned that the conclusions of the assessment do not capture the full degree of uncertainty in the assessment. Some of the main unquantified uncertainties include mixing rates between the two stocks (the stock assessment was conducted assuming no mixing between stocks), recruitment levels (both recent and potential future levels), age of maturity, and age determination from length samples. The ICCAT Atlantic-wide Bluefin Tuna Research Program is addressing many of these deficiencies.

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ATLANTIC BLUEFIN TUNA: A MEDITERRANEAN PERSPECTIVE

Sylvain Bonhommeau

Session 5, Talk 2, 19/1/16 @ 0900 hrs

Over the last six years, the status of the Eastern stock of Atlantic bluefin tuna has changed from overexploited/overfished to not overexploited and not overfished. This is the result of strong regulations, in particular, the rebuilding plan enforced since 2007/2009. This plan includes Total Allowable Catch, a minimum size, fishing seasons, and catch/effort controls. While these management regulations have proved their efficacy, they have led to major changes in fisheries strategies which have substantial impacts on the stock assessment inputs such as the abundance indices derived from catch and effort data. For example, the estimated spawning stock biomass has increased by ~four-fold over the last ten years: is this a management success or is this an indication of an unreliable stock assessment model? This presentation will show the evolution of the Eastern Atlantic stock status and the related uncertainties. I will discuss the next challenge for scientists to improve our knowledge of the biology and ecology of this species and to integrate this new information into modeling tools. Substantial efforts remain to be achieved in assessing socio-economic impacts and understanding how scientific knowledge and advice are currently used and understood by managers to make their decisions.

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STOCK STATUS AND CHALLENGES FOR ASSESSMENT OF PACIFIC BLUEFIN TUNA

Hideki Nakano and Hiromu Fukuda

Session 5, Talk 3, 19/1/16 @ 0900 hrs

The Pacific bluefin tuna (PBF) has been exploited by several countries using many kinds of fishing gears which catch PBF of different ages since more than a century ago. The latest stock assessment of this species was carried out by the PBF Working Group of the International Scientific

Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC PBFWG) in 2014 using data up to 2013. The input data for the stock assessment covers catch amount and size composition data of most of the major fisheries. It also includes representative indices of adult abundance and recruitment strength. Given those data rich situation especially recent 20 years, PBFWG conducted the assessment using an integrated statistical length based age-structured model (Stock synthesis 3). Although there are still uncertainties in the model associated with the data and assumptions, the model results generally suggested that spawning stock biomass (SSB) largely fluctuated throughout the assessment period (1952-2012), and the SSB has been declining for more than a decade. The current (2012) SSB level is near historic low levels and the current F (2009-2011 average) is above all target and limit biological reference points commonly used for management. The stricter management for this stock has started in 2015 through the catch and effort control, and the stock projections in 2014 assessments suggested that those measures would contribute to the stock recovery. The next stock assessment, which will accompany the improved data and assumptions with less uncertainty, is scheduled in March 2016.

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INTEGRATING PAST, PRESENT AND FUTURE INTO A SCIENTIFICALLY EVALUATED

REBUILDING PLAN FOR SOUTHERN BLUEFIN TUNA

Richard Hillary, Ann Preece and Campbell Davies

Session 5, Talk 4, 19/1/16 @ 0900 hrs

In 2006, the status of southern bluefin tuna (SBT) was estimated to be low (ca. 3-5% of the unfished state). Revelations of large unreported catches, at that time, generated unquantifiable uncertainty in the primary abundance index (longline CPUE) used in the operating model, which meant the recently adopted Management Procedure (MP) was not implemented. Since then, the CCSBT has done a number of important things: (i) acted to verify member catch and effort data, (ii) transitioned from negotiated annual advice on global TAC, based on stock assessments, to adopting and implementing a fully evaluated Management Procedure (2011), and (iii) supported and adopted novel methods for monitoring abundance that do not rely on fisheries dependent CPUE. In this talk we outline how the historical dynamics, data and outcomes shaped the present management regime for SBT; why current changes across all bluefin fisheries will likely mean we have to adapt to using alternative data and management approaches in the near term; and, for SBT, how we are developing a long-term monitoring and management regime to provide the basis to measure the effectiveness of the rebuilding plan.

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SPATIAL TEMPORAL ASSESSMENTS IN MODERNIZING FISHERIES MANAGEMENT TOOLS

Nathan G. Taylor, Murdoch K. McAllister, Gareth L. Lawson,

Tom Carruthers, and Barbara A. Block

Session 6, Talk 1, 19/1/16 @ 1100 hrs

Spatial-temporal assessment methods capture alternative population dynamics of bluefin tunas but also expose new analytical and management challenges. We briefly review some current spatial assessment methods. We describe the motivation for the Multistock Age Structured Tag integrated assessment model (MAST) that was developed for Atlantic bluefin tuna stock assessment. It originated as a 5 area, quarterly time step, two stock model that uses otolith microchemistry, catch, commercial catch per unit effort, conventional, and electronic tagging data. While the absolute values MAST's biomass estimates differ from its single stock single area counterparts, some of the broad stock trends are similar. However predictions of policy performance differ significantly between single and two stock models: Importantly, MAST illustrates that the western stock recovery depends on the harvest policies applied to the eastern stock. The modeling exercise also illustrates some key data gaps, notably: the limitations of conventional mark-recapture data; the need for a clear resolution to the maturity ogive; and the need for mark-recapture data to be assigned to specific stocks. Finally we discuss the use of spatial temporal assessment methods in modernizing science-based fisheries management as operating models in the Management Strategy Evaluation context.

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REFERENCE POINTS

Alejandro Anganuzzi

Session 6, Talk 2, 19/1/16 @ 1100 hrs

Abstract not available.

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HARVEST STRATEGIES, MSE AND THE PRECAUTIONARY APPROACH IN THE MANAGEMENT OF BLUEFIN TUNA FISHERIES

Campbell R. Davies, Rich Hillary, Ana Parma, Ann Preece,

Victor Restrepo and Keith Sainsbury

Session 6, Talk 3, 19/1/16 @ 1100 hrs

The value, international nature, population dynamics and depleted state of bluefin tunas have often placed them at the forefront of contention with respect to conservation and sustainable use, and scientific approaches to formulating management advice in the face of uncertainty about stock status and productivity. Formal Harvest Strategies (*aka*, Management Procedures) and the application of Management Strategy Evaluation(MSE) to test their performance and robustness have been advocated for bluefin since the early 1990's; although adoption of the approach has been mixed. Central to this approach are:

i. Recognition that the various forms of uncertainty (*sensu* Francis and Shotton, 1996) inherent in the monitoring, assessment, decision-making and management action (collectively = harvest strategy) must be propagated though the evaluation process;
ii. That the purpose of the process (i.e. selecting a strategy that is likely to meet the stated management objectives and be robust to important uncertainties) is not an optimisation problem, *alla* conventional stock assessment, but one of trade-offs among conflicting objectives (e.g. catch, profit/efficiency and conservation status); and
iii. While it may be possible to determine general classes of harvest strategy suitable (and not) for different fisheries, the specific circumstances of each fishery will require bespoke applications that reflect the nature of the available monitoring, assessment methods and management.

We make two general observations:

i. The substantial observation and process errors associated with common data series for bluefin tunas mean that empirical/simple statistical harvest strategies are likely to a) perform better and b) be less sensitive to important uncertainties, than those which incorporate more complex stock assessment models as part of the harvest control rule and,
ii. The scientific tasks of providing advice on a) stock status (i.e. via a full stock assessment) and b) appropriate catch or effort levels can be addressed as two parallel processes within the scientific committee and commission.

The focus of the former should be to determine the range of most plausible trends in stock sizes relative to reference points, identify the sources of information that would reduce the uncertainty in stock status to the greatest degree and recommend suitable research and monitoring. The focus of the latter should be the development and implementation of a tested harvest strategy that provides confidence, transparency and robustness in the scientific advice to the commission on future allowable catches.

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TOWARDS A MANAGEMENT STRATEGY EVALUATION FRAMEWORK FOR ATLANTIC BLUEFIN TUNAS

Tom Carruthers

Session 6, Talk 4, 19/1/16 @ 1100 hrs

In many ways Atlantic bluefin tuna represents an ideal candidate for management strategy evaluation. There are numerous hypotheses for fishery dynamics that are plausible, for example regarding stock structure and mixing. The management setting is complex due to a wide variety

of stakeholders with particular interests that are likely to generate performance trade-offs. There are also a wide range of data that may be used to inform decision making and therefore a diverse variety of candidate management procedures that can be considered. We describe the core opportunities and challenges of an MSE for Atlantic bluefin tuna, the lessons learned from other MSEs and approaches we are taking to solve new problems.

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A HARVEST CONTROL RULE FOR PACIFIC BLUEFIN TUNA BASED ON RECRUITMENT INDICES

Shuya Nakatsuka

Session 6, Talk 5, 19/1/16 @ 1100 hrs

Discussions on the long-term management strategy of Pacific bluefin tuna have only recently started. The unique situation of Pacific bluefin tuna needs to be taken into account in the development of a harvest control rule (HCR) for Pacific bluefin tuna such that (i) Pacific bluefin tuna has been harvested mainly by targeting juveniles and as a result the stock has remained at a low level for a long time but has sustained. (ii) Pacific bluefin tuna is being caught by many different types of fishery and the size range of the catch by each fishery is generally limited. (iii) At least age 0-2 fish are always being caught before their status is evaluated through stock assessments, which makes it difficult to apply a conventional HCR based on assessment results to the fish of those ages. However, it also has a strength in having a lot of operational information, including recruitment indices. In this presentation, we propose an HCR to set a TAC for juvenile Pacific bluefin tuna that secures any given target spawning stock biomass based on recruitment estimates of the cohorts available to fisheries derived from recruitment information from the monitoring results in addition to the assessment results.

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CHALLENGES OF RAISING BLUEFIN TUNA

Yoshifumi Sawada

Keynote, 20/1/16 @ 0830 hrs

In 2002, the life cycle of Pacific bluefin tuna (PBF) was closed under aquaculture condition in Kindai University, 32 years after the start of our tuna aquaculture project. That was the world's first success for large tuna species accomplished by advanced technology at that time. Since then PBF aquaculture technology has further developed in Kindai University, and in recent years, the number of produced PBF juveniles has been increased to more than 200,000 which are distributed to the domestic tuna farmers. This means the industrialization of the PBF hatchery technology. In

addition, the fourth generation of PBF was produced in 2012 by generation succession to improve PBF breed aiming future production with better efficiency. Although the present survival of artificially hatched PBF juveniles till they grow up to adults is still poor of approximately 5%, rearing technology continues developing day by day and it will be the same level as other cultured fishes. Therefore, in the near future, the supply of fingerlings in the present capture-based tuna aquaculture will be surely substituted by that of artificially hatched ones. However, due to the difficulties in finding appropriate farming sites and limited feed fish supply in the future, the complete substitution of bluefin tuna market supply by aquaculture cannot be the realistic solution for its sustainable market supply. Both the whole life cycle aquaculture and well-managed fisheries will be the solution, and only the further research and development enables it.

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HISTORY AND CHALLENGES OF WORKING WITH PACIFIC BLUEFIN TUNA, *THUNNUS ORIENTALIS*, IN CAPTIVITY

Chuck Farwell

Session 9, Talk 1, 20/1/16 @ 0900 hrs

Pacific bluefin tuna have been considered difficult if not impossible to work with both at sea and to keep in captivity for display or research. Tokyo Sea Life Park included this species on their display list for their new aquarium's 1989 opening. Their collection efforts started several years before opening and focused on 0-age class PBF. On their grand opening, their premier exhibit, Ocean Voyagers, featured several hundred young bluefin. The technology used in collecting, transportation and care of this difficult species was shared with Monterey Bay Aquarium through participation with the Tokyo Sea Life Park's collection staff over two different seasons. Our collections of this species followed the Japanese efforts in style and process. The second major Japanese aquarium to display Pacific bluefin was Aquamarine Fukushima Aquarium led by the same person who brought tuna to Tokyo, Director Yoshitaka Abe.

Our first collections of bluefin started in 1994 for display in the Monterey Bay Aquarium's new "Outer Bay Exhibit". This first time opportunity to keep this species in controlled experimental conditions in captivity in the U.S. allowed new research in science to be done in collaboration with Hopkins Marine Station. Topics covered today will include observations made on Pacific bluefin tuna at the Tuna Research conservation Center: The effects of swimming speed and temperature on metabolic rate; Specific dynamic action and the heat increment of feeding and heart rates associated with feeding.

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PROGRESS IN THE DOMESTICATION OF *THUNNUS THYNNUS* (DOTT):

PERSPECTIVES FOR ATLANTIC BLUEFIN TUNA AQUACULTURE IN THE MEDITERRANEAN

Christopher Bridges, Hillel Gordin, Robert Vassallo Agius, Matthew Spagnol, Ellul, Angus Sharman, Bill Koven, Grethe Rosenlund, Karl Sveinsvoll, Stephan Schulz, Florian Borutta, Jan Giebichenstein, Dimitra Nousdili, Dubi Helman, Roni Mor, Patricio Urrutia, Bent Urup and Michele Deflorio

Session 9, Talk 2, 20/1/16 @ 0900 hrs

In numerous domestication projects funded by the European Commission under the DOTT logo, European scientists have been striving to domesticate the Atlantic bluefin tuna since the turn of the century. From initial discussions and symposia over the last 15 years from DOTT, through REPRODOTT, SELFDOTT and finally TRANSDOTT, many of the initial goals have been reached such as spawning in captive brood stocks, "eggs on demand", and the development of new and innovative techniques for both the monitoring of the broodstock and assessing breeding efficiency and egg collection. Within the hatcheries themselves the introduction of new feeding strategies with both live feed and dry food have enabled some of the previous bottlenecks to be overcome with fish still surviving after 3 years or more. The time is now ripe for commercialisation of a number of activities and global investors have been found who believe that sustainable aquaculture is possible. This is still a long-term process but it is an essential part of an overall strategy for the future of the bluefin tuna in the Mediterranean. Through "full-circle" aquaculture some of the present pressure felt by natural populations can be alleviated and restocking scenarios and "farm to fork" traceability are additional spin-offs from these processes.

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PROGRESS IN SPANISH AQUACULTURE

Aurelio Ortega and Fernando de la Gándara

Session 9, Talk 3, 20/1/16 @ 0900 hrs

Since 2000 the Spanish Institute of Oceanography (IEO) is participating in several European research projects (DOTT, REPRODOTT, SELFDOTT) on Atlantic bluefin tuna (ABFT) culture with the aim of contributing of the Domestication of this species, for improving the productive process and reducing the pressure on the wild stock as it has already happened with other full cycle cultured species. Greatest efforts are being developed from 2011 in collaboration with the companies Caladeros del Mediterraneo and Fortuna Mare (FM). As a result of that, between 3 and 15 thousand tunas have been produced in the IEO experimental hatchery and transported every year to offshore cages placed in El Gorguel (Cartagena, SE Spain) and the Fortuna Mare company has nowadays some thousands of tunas belonging to 0+ to 4+ age classes. It is expected that oldest tunas start to spawn from next summer, closing by the first time the life cycle of ABFT in captivity.

Results have been improved the last season, and more than 15.000 fingerlings 35-40 days old (average weight of 3 gr) have been produced in July-August by the IEO. They have been moved to three 25 m diameter cages (FM property) and some of them have been moved to a new IEO land based facility named ICRA (Infraestructure for the Control of the Reproduction of Atlantic bluefin tuna). The target of the ICRA is to hold a broodstock to control the reproduction in indoor big tanks, and some large tunas will be move in the upcoming months.

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STATUS OF MEXICAN RANCHING

Benito Sarmiento

Session 9, Talk 4, 20/1/16 @ 0900 hrs

Abstract not available.

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THE POTENTIAL ROLE OF BIOFEEDS IN AQUACULTURE OF SALMON AND TUNA

Josh Silverman

Session 9, Talk 5, 20/1/16 @ 0900 hrs

By 2050, 9.6 billion people will demand 60% more protein than is currently available. Further, arable land and water are finite resources and while crop yields continue to increase, new sources of protein will be required to meet this growing demand. Aquaculture represents an attractive approach to improving the food supply while protecting natural resources, but feeds for carnivorous species such as salmon and tuna will require high quality protein which currently is sourced from fish meal derived from wild forage fish. Calysta has developed the world's only commercially validated gas fermentation platform using specialized microorganisms (methanotrophs) which efficiently convert methane to high quality protein (FeedKind) with properties similar to fish meal. Methane is a highly sustainable feedstock, with a greenhouse gas impact approximately 34x worse than CO2. Methane does not compete with the human or native ocean food chain and Calysta's process has minimal impacts on land and water usage. Feedkind has been used extensively in salmon diets and provides increases in growth rates and animal health relative to fish meal or other alternate protein sources. These effects are potentially also applicable to tuna, and Calysta is working to develop an optimized feed formulation to support tuna aquaculture that uses zero marine-sourced ingredients.

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RESOURCE AND ENVIRONMENTAL INTENSITY OF TUNA AQUACULTURE

Dane Klinger

Session 9, Talk 6, 20/1/16 @ 0900 hrs

The high trophic level and unique physiology of bluefin tunas mean that they are energetically expensive to culture relative to other current aquaculture species. As a result, the resource and environmental intensity of bluefin production greatly exceeds that of other types of seafood. At the same time, the bluefin tuna's physiology provides many of the characteristics that define their meat as a luxury good and incentivizes fisheries and aquaculture production. This presentation will review the major bottlenecks, challenges, and opportunities that bluefin aquaculture faces in reducing its resource and environmental intensity. These attributes will be placed in the context of other aquaculture systems and species, as well as other luxury goods. While bluefin farming may not be able to achieve the high environmental or resource performance possible in other aquaculture sectors, bluefin's status as a luxury good means that bluefin fishermen and farmers can have an outsized role in fostering innovation and improvement in the seafood industry as a whole.

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BLUEFIN RANCHING ECONOMICS – MANAGING THE RESOURCE AND THE FARM

Brian Jeffriess

Keynote, 20/1/16 @ 1100 hrs

The economic future of wild bluefin ranching depends on having sustainable wild stocks. Ranching requires major capital investment. This capital risk leads to ranching requiring a more precautionary approach to management of bluefin stocks. For example, Australian industry strongly supports the CCSBT harvest control rules. Science has been the basis of the large current increases in catch quotas for Atlantic and Southern bluefins. Possibly, the hard decisions are still to be made on the Pacific bluefin stock. Bluefin ranching innovation is a relocation of tuna from a low productivity wild environment with relatively high mortality and Feed Conversion Ratio (FCR) to a generally much higher productivity farm environment with lower mortality and FCR. It is generally a much more effective utilisation of a natural resource. However, innovation eventually results in price pressure – and global ranched bluefin prices are at their lowest ever level. Is this just the cyclical trough or a structural change? Even if the market price recovers, the global bluefin ranching industry has fundamental economic challenges other than wild stocks. First, is the over-dependence on Japan and the Yen. Second, the world feed prices will average much higher. Third, is that the high profitability up to recent years has been capitalised into high expectations and over-investment in some parts of the supply chain. Fourth, is the challenge from salmon and other foods. Global bluefin ranching in 2020 needs to look very different from now to be

economically viable – the question is whether it will come from game-changers, or just significant incremental improvements.

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WEST ATLANTIC BLUEFIN TUNA: SOME CHALLENGES AND SOLUTIONS IN BALANCING ECONOMICS AND CONSERVATION

David Schalit

Session 10, Talk 1, 20/1/16 @ 1130 hrs

Demand for bluefin is a constant. Bluefin fleets have "built-up" over decades to meet this seemingly unlimited demand. Now, it is the responsibility of fishery managers to control catch in order to address the negative effects on these fish stocks from decades of overharvesting. This already difficult process is made even more problematic by the fact that these fleets are highly industrialized, very expensive to own and operate and have harvesting capacity that, in certain cases, greatly exceed the present allowed fishing quota. Fleets can be expected to bring tremendous pressure to bear on their fishery managers to forestall or, at the very least, slow down this process. We take a look at the industrialization of our bluefin fisheries and ask if the present composition of these fleets will meet our conservation needs for the long term.

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PACIFIC BLUEFIN TUNA FISHERIES AND REGULATIONS IN JAPAN

Yasuhiro Sanada

Session 10, Talk 2, 20/1/16 @ 1130 hrs

In this presentation, we will take up tuna fisheries and regulations in Japan and associated issues. First, after briefly touching upon the tuna fisheries in Japan, we will deal with purse seine Pacific bluefin tuna (PBF) fishing in the Sea of Japan and Sakaiminato, the largest landing port of PBF fisheries in Japan. In doing this, we will point out that one of the reasons of the development of PBF fisheries in Sakaiminato was the resource depletion of sardine and mackerel caused by overexploitation of these species and the need for alternative fish species for commercial harvesting, and second, development of PBF purse seine fisheries caused resource depletion of this species. Third, we will take a look at the effects which may be caused by massive overexploitation by touching on the situation of pole and line and longline PBF fisheries. Fourth, we will discuss international and domestic regulatory measures and show that they are not sufficient for the conservation and restoration of this species, as most of them merely let current fisheries remain untouched except for the reduction of catches of juvenile tuna. The lack of sufficient regulations is reinforced by "regulatory capture," in which the authorities concerned have cozy

relations with large-scale fishing industry representatives who tend to prefer regulatory measures to be as lax as possible. We will conclude by stressing the importance of substantial strengthening of conservation measures by the WCPFC or trade restriction though the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Contact: Y. Sanada, Visiting Assistant Professor, Waseda University, Japan, sanappie@wd6.so-net.ne.jp

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ECONOMIC IMPORTANCE OF ACCESS TO PACIFIC BLUEFIN TUNA BY EASTERN PACIFIC RECREATIONAL ANGLERS

Alayna Siddall

Session 10, Talk 3, 20/1/16 @ 1130 hrs

The Commercial Passenger Fishing Vessel (CPFV) fleet in southern California is the largest of its kind in the world, with over a 100-year history. Since 2014, the recreational fishery for bluefin has experienced significant management changes in the form of individual daily bag limit reductions (10 fish to 2 fish per person per day) in US waters and a complete (but temporary) moratorium in Mexican waters, which were the result of the species stock assessment produced in 2014. To understand the potential economic impacts of bag limit reductions,the Sportfishing Association of California (SAC) surveyed approximately 1200 bluefin tuna anglers in 2014, and results were presented at the Pacific Fishery Management Council. During this time, the bluefin fishery was exceptionally productive in US waters with anglers landing fish across all size classes (1-4 year old fish) within state and federal waters, producing catches that had not been seen previously. Determining the economic impacts of the recent management changes on the fishery is difficult given the atypical fishing conditions for bluefin during the 2015 season, likely due to the El Niño and associated oceanographic conditions. However, the bluefin fishery continues to be an extremely important component of recreational fishing in California, which is valued at $2.8 billion annually by the National Marine Fisheries Service. Additionally, the fleet continues to ensure accountability with the recent transition into the new electronic fishing log book system, and is now actively engaged in two voluntary projects being led by SAC to collect length/frequency and length/weight data, which will help to produce more informed stock assessments for the species in the future.

Contact: A. Siddall, Director of Science and Communications, Sportfishing Association of California, San Diego, USA, alaynasiddallsac@gmail.com

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BLUEFIN TUNA IN A WARMING WORLD:

THE SCIENCE OF OCEANIC CLIMATE CHANGE AND ACIDIFICATION

Robert B. Dunbar

Keynote, 20/1/16 @ 1400 hrs

Our oceans are warming at rates that are unprecedented in the last 10,000 years and to temperatures that may soon be unprecedented over the past 3 to 4 million years. More importantly for marine taxa, our oceans are also rapidly acidifying and will soon experience chemical conditions not seen for over 25 millions of years ago. In this talk, I will briefly review what is known about tropical and subtropical ocean temperatures over the past century to several thousand years and also examine ocean climate evolution over the evolutionary timescales of tuna. I will delve into the most fascinating features of the carbon system in seawater as a prelude to describing what we know about modern ocean acidification (OA) as well as past major OA events and their impacts. I'll also provide information about follow-on impacts of oceanic climate change - dissolved oxygen levels, stratification, nutrient supplies, and productivity. Many larger and long-lived organisms like bluefin tuna have, until recently, lived in an ocean environment set to a cooler and more stable thermostat and chemostat. The changing ocean environment will present a new challenge to many of these species.

Contact: R. Dunbar, Professor, Stanford University, USA, dunbar@stanford.edu

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HABITAT MODELING, CLIMATE CHANGE AND FISHERY APPLICATIONS

Alistair Hobday, Jason Hartog, and Paige Eveson

Session 11, Talk 1, 20/1/16 @ 1430 hrs

Information on the environmental associations of southern bluefin tuna from fishery and electronic tag data have supported development of habitat models for several life stages. These habitat models have been used to project distribution at a range of time scales, from realtime to seasonal to century-scale. These models have been used to deliver information for use by managers and fishers in eastern and southern Australia. The developmental process will be described, along with the validation and delivery approach. Decision time scales are critical in developing fishery applications. These lessons are relevant to the future understanding of distribution and abundance of the bluefin tunas, and illustrate an important engagement pathway that returns benefits to the fishery managers and participants. This pathway is important to develop as the challenges under climate change will lead to some dramatic changes in the distribution of tunas and the fisheries that exploit them.

Contact: A. Hobday, CSIRO Marine Laboratories, Australia, Alistair.Hobday@csiro.au

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EXAMINING THE INFLUENCE OF CLIMATE VARIABILITY AND HUMAN IMPACTS ON NORTHERN BLUEFIN TUNA

Elliott Hazen

Session 11, Talk 2, 20/1/16 @ 1430 hrs

Bluefin tuna are one of the most highly valued fish in the world, which has led to high exploitation rates in the world's oceans. Here we explore how oceanographic covariates of habitat can be used to assess how anthropogenically-induced risks may affect Atlantic and Pacific bluefin tuna stocks. In the Pacific, bluefin tuna spawn in the western Pacific but use the eastern Pacific as key foraging grounds. We used ocean-habitat relationships and climate projections to predict how bluefin tuna distribution is likely to change in the future. In the Atlantic, bluefin tuna use foraging grounds in the northwest Atlantic but spawn in the Gulf of Mexico, near their upper thermal tolerance. Between April-August of 2010, the Deep Water Horizon oil spill released an estimated 4.4 million barrels of oil into the Gulf, with severe ecosystem and economic impacts. We again used ocean-habitat relationships this time combined with ERMA oil spill data to quantify the impact of oil exposure on the spawning and foraging grounds of bluefin tuna. Acute oil exposure has been shown to lead to mortality of bluefin tuna eggs and larvae while chronic effects on adults are less understood. Understanding impacts of multiple stressors including climate variability and anthropogenic stressors on bluefin tuna is important to ensure sustainable populations in the future.

Contact: E. Hazen, NOAA SWFSC, USA, Elliott.hazen@noaa.gov

THE INFLUENCE OF CLIMATE VARIABILITY AND CHANGE ON PACIFIC TUNA

Francisco Chavez and Barbara Block

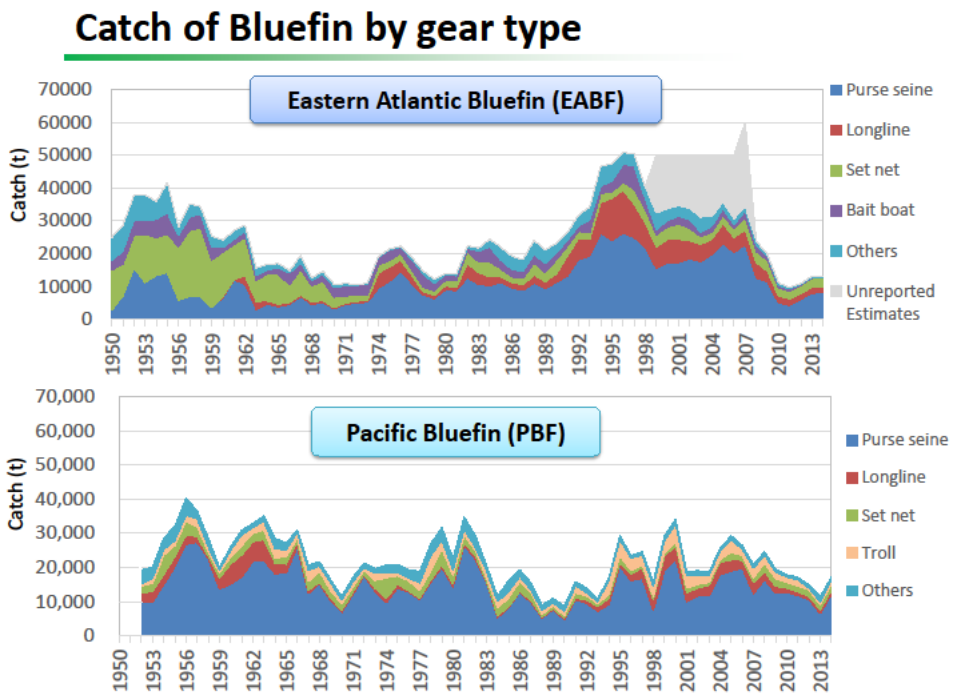
Session 11, Talk 3, 20/1/16 @ 1430 hrs

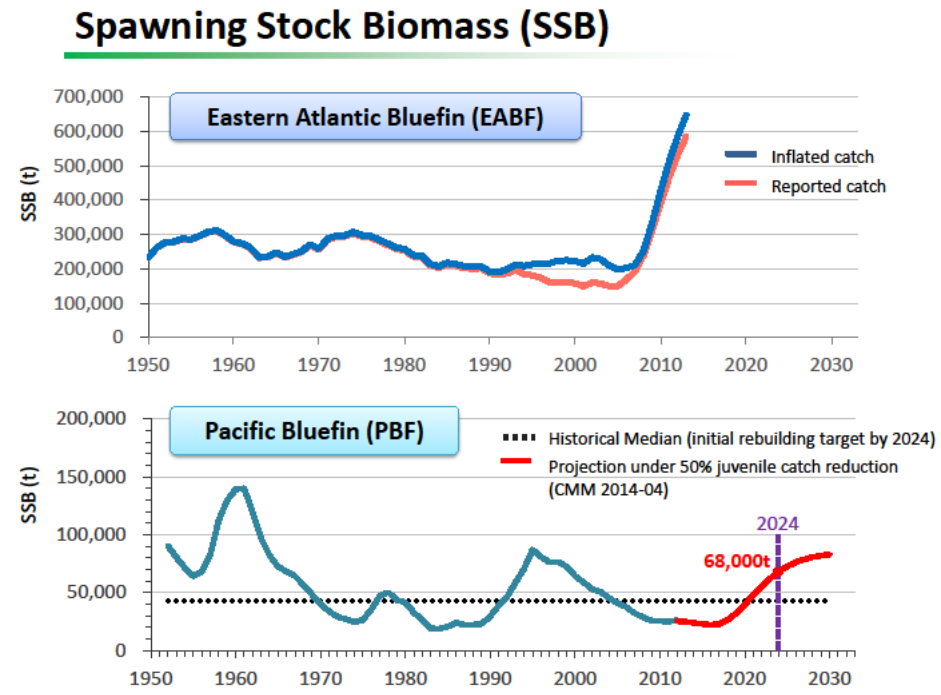
A multitude of factors control the abundance and distribution of marine populations. These factors can be biotic, such as competition and predation, or abiotic such as environmental variability. Early ecological studies focused on biotic interactions, but it is now well known that environmental fluctuations occur on many scales, both spatial and temporal, and strongly affect ecological systems. Over the past three decades, study of environmental fluctuation in relation to ecology has blossomed around interannual (El Niño) to mutidecadal (PDO) climate variability and global warming. The 1982-1983 El Niño galvanized interest in climate change. Over an 18-month period strong climate fluctuations occurred globally over short time scales. Because El Niño changes global climate on a scale of months, the concern arose that human-induced accumulation of CO_2 in the atmosphere could also impact climate on similar scales. The discovery of natural variations on decadal, multi-decadal and centennial scales has further complicated the attribution of ecosystem changes. Here we review large-scale variations in the marine environment over the past century with an emphasis on the Pacific. Examples of how these variations impact tuna populations are provided.

Contact: F. Chavez, Monterey Bay Aquarium Research Institute, chfr@mbari.org

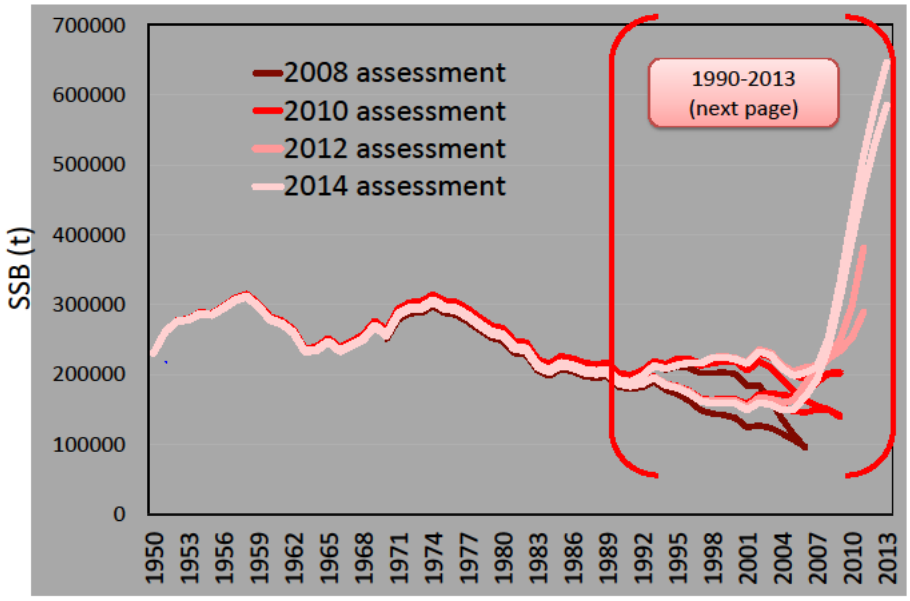
APPENDIX 6: PRESENTATIONS REQUESTED FOR INCLUSION IN MEETING REPORT

SESSION 7: Mr. Masa Miyahara

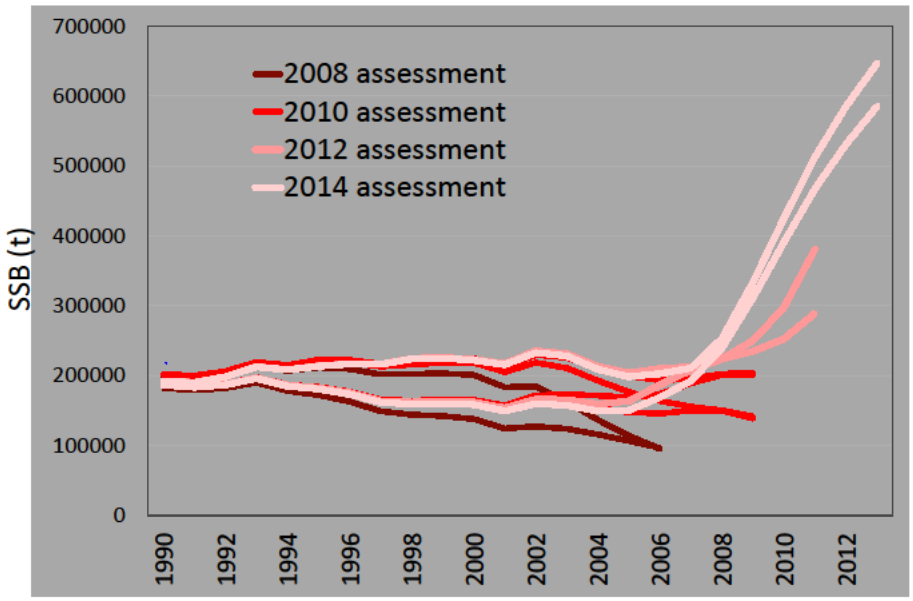




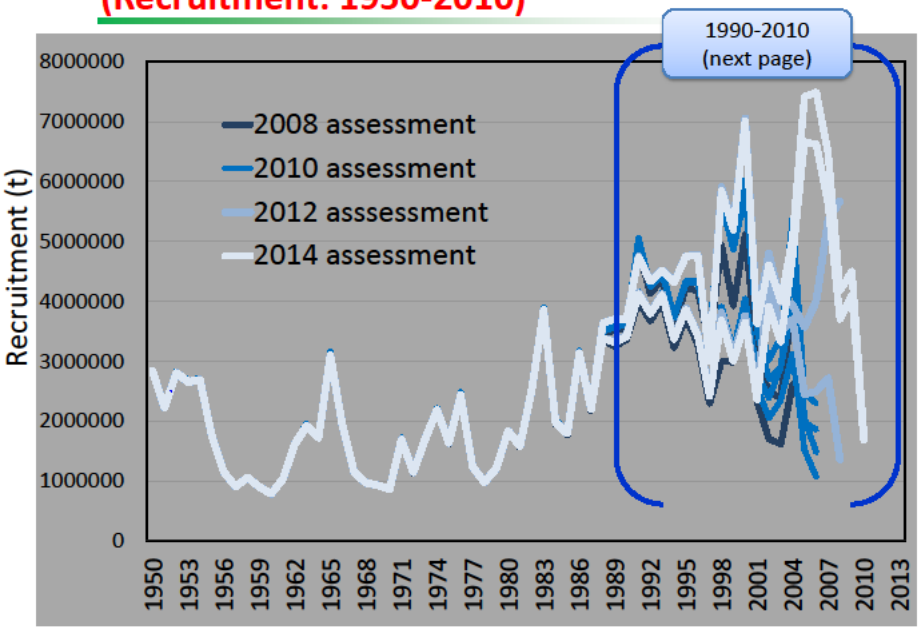
Comparison of EABF Stock Assessments
(SSB: 1950-2013)



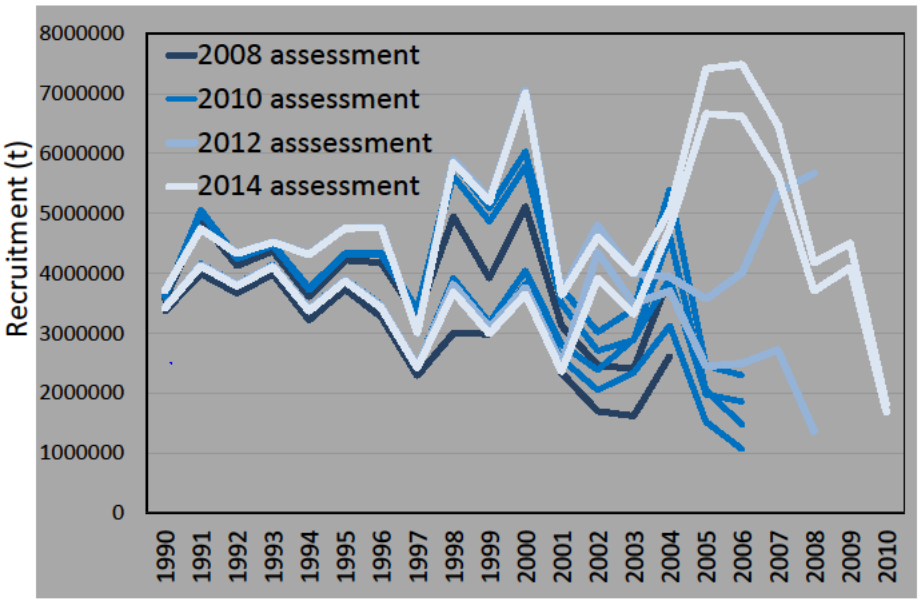
Comparison of EABF Stock Assessments
(SSB: 1990-2013)



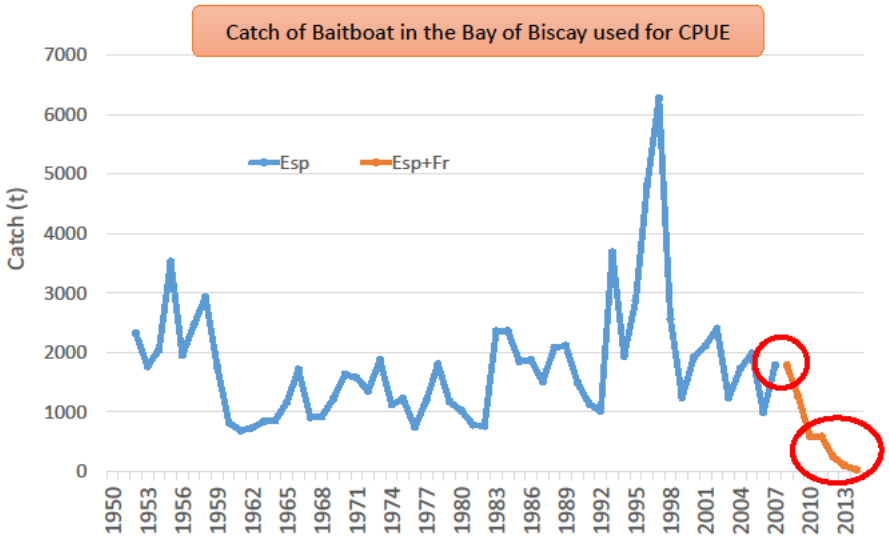
Comparison of EABF Stock Assessments
(Recruitment: 1950-2010)



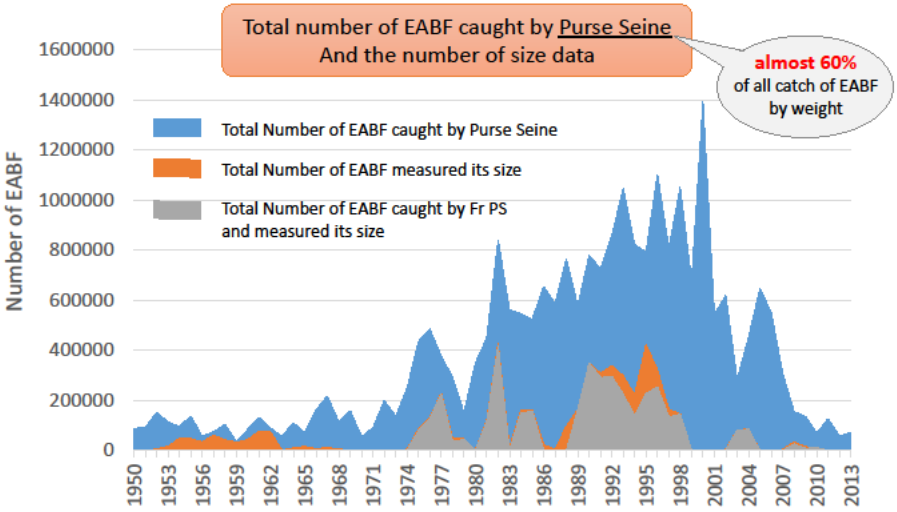
Comparison of EABF Stock Assessments
(Recruitment: 1990-2010)



Monitoring of Recruitment (EABF)

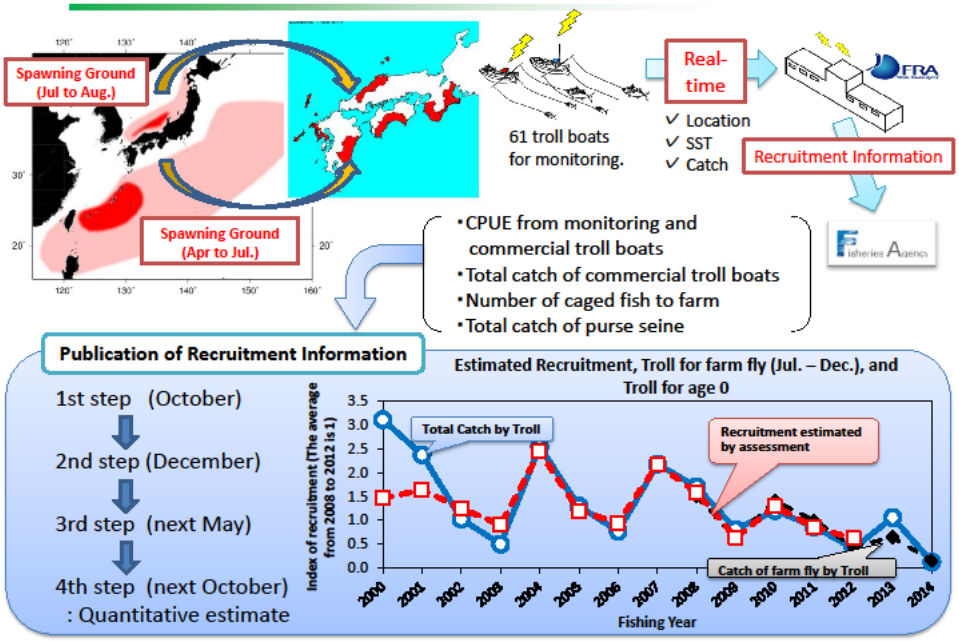


Monitoring of Size Data (EABF)

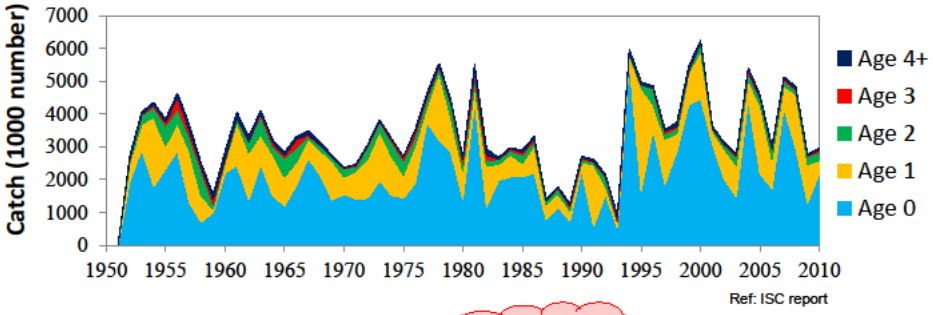


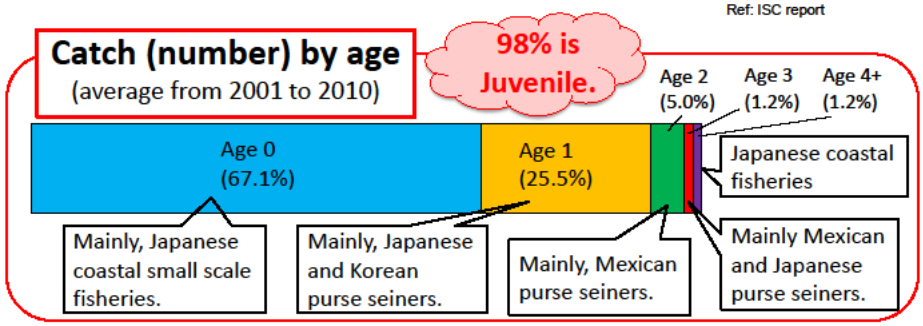
Source: ICCAT Task II

Monitoring of Recruitment (PBF)

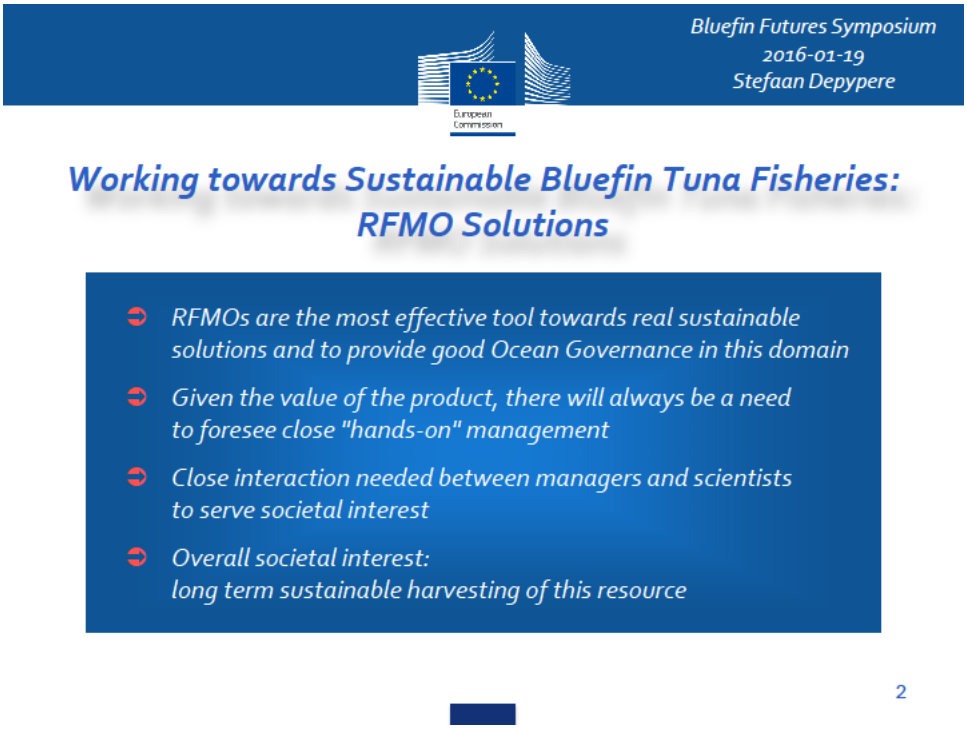


Catch Characteristics of PBF





SESSION 7: Mr. Stefaan Depypere



Working towards Sustainable Bluefin Tuna Fisheries: RFMO Solutions

- Societal interest simplified technically:
  steer rapidly into and remain in green quadrant of KOBE plot
  (harvest < Fmsy; stock > Bmsy)
- Develop conditions for long term stability
  (LT harvest strategies, HCR)
- Integrate "ecosystem" dimension
- Catch words: science based measures
  enforcement - compliance

3

Bluefin Futures Symposium
2016-01-19
Stefaan Depypere

Working towards Sustainable Bluefin Tuna Fisheries: RFMO Solutions

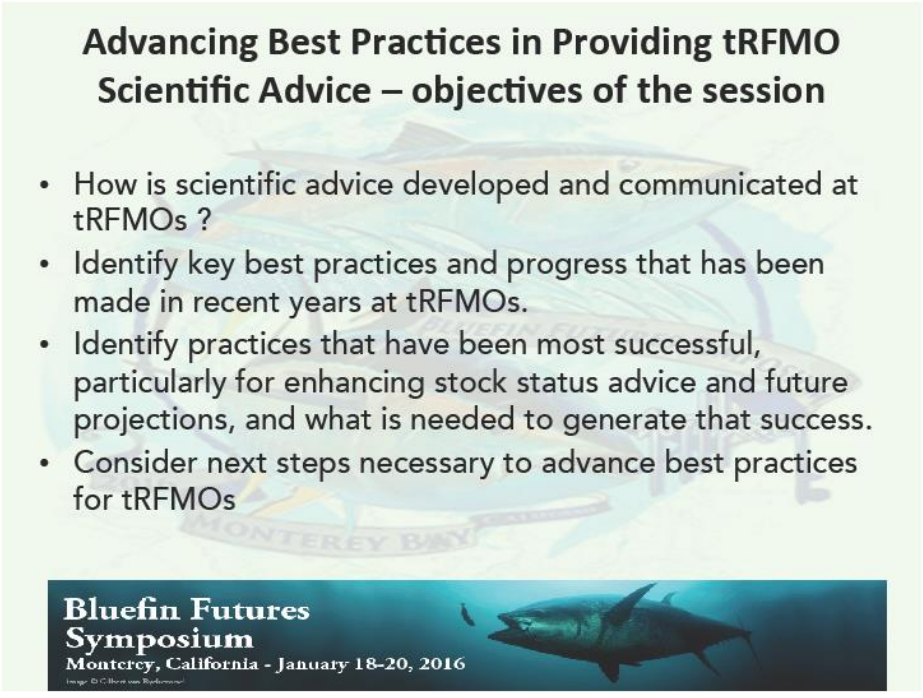
Conditions for good science based measures:
cooperation managers – scientists

- Managers
  - create political, operational, financial and moral support
    (incl. data collection, etc.)
  - formulate appropriate questions
  - "design" measures, enforce, monitor, etc. [recovery mgt plans]
  - organize proper dialogue with scientific community
- Scientists
  - make proper analysis
  - provide answers and "interpretation guidance"
    (uncertainties, error margins, etc.)
  - suggest appropriate options regarding measures

4


Bluefin Futures Symposium
2016-01-19
Stefaan Depypere
Working towards
Sustainable Bluefin Tuna Fisheries:
RFMO Solutions
Comments?
Suggestions?
Questions?
Thank you!

SESSION 8: Dr. Jerry Scott




Report of the Joint Meeting of Tuna RFMOs
January 22 – 26, 2007
Recommended Best Practices for
Regional Fisheries
Management Organizations
Report of an independent
panel to develop a
mandate for improved governance
by Regional Fisheries
Management Organizations
CHATHAM HOUSE
REPORT OF THE JOINT TUNA RFMOS MEETING OF EXPERTS
TO SHARE BEST PRACTICES ON THE PROVISION OF SCIENTIFIC ADVICE
CHAIR'S REPORT OF THE THIRD JOINT MEETING OF THE
TUNA REGIONAL FISHERIES MANAGEMENT ORGANIZATIONS (RFMOS III)
Some
Background Materials
Technical eXperts Overseeing
Third country eXpertise
FINAL PROJECT REPORT
Coordination and Support Action
From 1/04/2008 to 30/09/2011
Bluefin Futures
Symposium
Monterey, California - January 18-20, 2016

"Kobe Criteria" – RE: Provision of Scientific Advice

- Kobe I emphasized actions needed to improve tRFMO performance on the use of the best scientific evidence and advice available and communicating that advice through the so-called Kobe diagram.
- Kobe II, building upon KI, recommended mechanisms to better articulate risk and uncertainty in scientific advice through the so-called K2SM.
- Kobe III, again, building on KI&II, recommended improvement in information sharing across tRFMOs, and decision-making guidelines taking uncertainty in scientific advice into account
- Kobe II and III emphasized the importance of uncertainty and risk in decision-making, and the need for science advice to relflect that advice.
- tRFMO Joint Meeting of Experts on Best Practices for Provision of Scientific Advice, recommended a number of elements regarding data collection and sharing, stock assessment, communication, and biological research to address the actions regarding these Kobe Criteria.

"Kobe Criteria" Best Practice – Data

After All, Data are an Important Component for Providing Advice

- **R**outine collection by year on catch, effort and sizes;
- **T**imely provision of high quality data;
- **R**educe lags in fishery data submission;
- **H**armonize basic data formats;
- **M**ake data used in stock assessment available via the websites or other means;
- **M**ake the fine scale operational data available;
- **A**ddress confidentiality concerns through rules and procedures for access;
- **E**nsure adequate sampling for catch, effort and size composition across all fleets;
- **C**ooperate with other tRFMOs to improve the quality of data:
  - species and size composition of PS caught tunas
  - catch and size of farmed tunas;
- **R**outine validation of statistics reported by Parties and estimate catches from non-reporting fleets using alternative sources (e.g. observer and cannery data)

"Kobe Criteria" Best Practice –Scientific Advice

Science Advisory Bodies Should ...

- Produce best scientific advice relevant to the fish stocks and other living marine resources under tRFMO, as well as to the effects of fishing on the marine environment ;
- Stock assessment:
  - Promote peer reviews of stock assessments
  - Use multiple stock assessment models and avoid the use of assumption-rich models in data-poor situations.
  - Develop checklists and minimum standards for stock assessments with other tRFMOs
- Develop methods to quantify uncertainty and reflect it in risk assessment;
- Clearly articulate risk and uncertainty to decision-makers;
- Contribute to function of the joint Technical WG on Management Strategy Evaluation;

"Kobe Criteria" Best Practice – Scientific Advice

Science Advisory Bodies Should ...

- Conduct Research:
  - Develop regular large scale tagging programs;
  - Undertake archival tagging as an ongoing activity;
  - Apply high-resolution spatial modeling frameworks.
- Enhance Communication:
  - Standardize Executive Summaries for all tuna RFMOs
  - Expand K2SM application to stocks for which sufficient information exists
  - Develop mechanisms to deliver timely and adequate information on their scientific outcomes to the public.
  - All documents, data and assumptions related to past assessments undertaken by tuna RFMOs should be made available in order to allow evaluation by any interested stakeholder.
- Enhance Cooperation among tRFMO Science Bodies
  - Chairs of Scientific Committees should establish an annotated list of common issues that should be addressed jointly by tRFMOs
  - Active cooperation with programs integrating ecosystem and socio-economic approaches to support the conservation of multi-species resources.

Questions to Panelists & for Discussion

- Have we been able to achieve these 'Best Practices' for provision of scientific advice?
- What best practices have been most effective to enhance advice on stock status and future projections?
- Who are the main targeted audiences for scientific advice? Commissioners, peers, stakeholders, the public at large?
- Are managers receiving the scientific advice they need to confidently make management decisions? Are uncertainty and risk adequately represented in the scientific advice?
- Can we advance on these 'Best Practices' to make our advice more robust, more useful, and/or more understandable?
- Where is the line between scientific advice and management decisions (i.e., acceptable levels of risk)?
- What are the best strategies to improve communications among scientists and managers? And stakeholders?

A bonus question for consideration:

Should the Values Adopted at 1 tRFMO For Provision of Scientific Advice Generally Apply?

- ✓ **INTEGRITY:** apply the highest ethical standards to scientific work.
- ✓ **INDEPENDENCE:** Provide advice that is objective and based on the best scientific information available and not unduly influenced by stakeholders, ideological or political pressure groups or by economic or financial interests.
- ✓ **COOPERATION:** Value and encourage the participation of scientists from all CPCs, acting through scientific collaboration and cooperation to cultivate a diverse set of expertise and to promote best available scientific practices.
- ✓ **COMMITMENT:** Committed to provide the best scientific advice in support of the Commission's objective of implementing science-based fishery management.
- ✓ **ABILITY:** Strive to ensure work conforms to the highest scientific standards and state of the art methodologies, constantly improving the foundation of knowledge to support the mandate.
- ✓ **TRANSPARENCY:** Conduct work in open sessions and encourage participation of national scientists and external experts; information, analyses and decision-making process are well- documented and easily accessible to all interested parties.