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Report of 2013 NRIFSF Workshop on Biological Reference Points for Fisheries Management under Environmental Changes

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June 13-14, 2013
National Research Institute of Far Seas Fisheries (NRIFSF)
Shizuoka, Japan

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Executive Summary

National Research Institute of Far Seas Fisheries (NRIFSF) organized the workshop on biological reference points (BRPs) for fisheries management under environmental changes, supported by Fisheries Agency of Japan. The objectives of this workshop are to review various BRPs for fish stocks including tuna and other fish species and to discuss the appropriate BRPs for temperate tunas considering the characteristics of biology and fishery for these species, environmental and ecosystem, and socio-economic effects. The key points of twelve presentations are provided below plus a short summary of the discussion are as follows. Participants were not necessarily representing the positions of their affiliated organizations.

Japanese coastal fisheries have long history and some of them have never experienced the stock level of Bmsy. Bloss, which is the historically smallest biomass with enough RPS, is easier to be understood by fishermen, because fishermen know well from their experience that the stock biomass had fluctuated. Considering on the hardness to estimate MSY, for the stocks in North Pacific Ocean which had experienced various fishing intensity and had fluctuation of biomass, Bloss would have similar performance with Bmsy.

Bmsy and Fmsy are not used for the management of TAC stocks in Japanese coastal fisheries, because the density dependence in S-R relation is not clear and there is uncertainty in MSY estimates. Instead of Fmsy, Fmed and Frec are mainly used for setting TACs. Management strategy evaluation is one of the good ways to consider these uncertainties in assessment and population dynamics**.**

AnexII of the UNFSA does provide some important factors to consider when adopting reference points, but some of it is confusing. Limit reference points are primarily to protect the stock and should – at a minimum - be based around some low level of the spawning biomass that you wish to avoid. WCPFC has adopted for it's main tuna stocks a tiered approach for limit reference points that are not directly related to MSY quantities and consider fluctuations in productivity. There is no reason not to consider this approach for other stocks of temperate tunas and billfishes in the Pacific**.**

Inaccurate estimation of steepness can lead to overestimation of Fmsy, which in turn is associated with a high risk of recruitment overfishing and stock depletion. For this reason, it is not recommended to apply MSY-based LRPs such as Fmsy to temperate tuna stocks. Floss was robust to the overestimation of steepness. This means that Floss can be used for risk-averse and conservative fisheries management. For this reason, historically-based LRPs such as Floss would be appropriate for temperate tuna stocks such as PBF and ALB-N.

Defining precise MSY-related reference points is difficult for a range of fundamental reasons. In any case, target reference points need to reflect multi-criteria objectives, not just MSY-related ones. Importantly, MSY-related reference points do not naturally reflect a conservation objective such as avoiding recruitment impairment and are not natural candidates for limit reference points. It is important to distinguish if reference points are to be used directly as indicators to guide management action or as performance measures in management procedure evaluations. Use of MSY-related reference points as performance measures, calculated using operating models, is a valid approach. Use of MSY-related reference points directly as indicators is potentially problematic. It is important to note that reference points only have meaning and can only be considered in the context of defined management

procedures that specify how management should respond. It is also best to use both state (e.g. biomass) and pressure (e.g. exploitation rate) reference points to ensure effective management. In terms of environmental trends and change, it is best to choose these based on Management Procedure Evaluation (MPE) with suitable robustness testing; to use most recent, reliable information to inform control processes; and in management to include "meta rules" to determine when the use of Management Procedures (including reference points) remains valid **.**

Large uncertainty, in particular large unidirectional temporal variability and/or estimation biases, may result in inappropriate estimation and implementation of BRPs, leading to fisheries mismanagement. It is important to consider different types of uncertainty associated with BRPs. Management Strategy Evaluation (MSE) can be very helpful to evaluate the performance of BRPs; identify optimal BRPs for a given set of HCR; identify optimal HCR for a given set of BRPs**.**

More attention is needed for ecosystem services beyond areas of national jurisdiction. It is hard to identify which human activities should be regulated to provide effective conservation of ecosystem services (because land-based activities exist). Thus, designing legally binding instruments will not be easy. Economic based solutions, such as payment for the ecosystem services or any other mechanisms for providing incentives and peer-sanctions, would be useful under this situation **.**

For species which have been exposed to strong fishing pressure for a long period of time, Bmsy may be the ultimate target, but setting a modest target that can be achieved in a realistic schedule should be considered a practical approach. It is needed to avoid a collapse of the stock, to maintain viability of fisheries, and to rebuild the stock to a safer level. But it is essential to set a realistic goal that can be supported by fishermen**.**

Three periods were identified; a low recruitment period (1978-1987) and two high recruitment periods (1966-1977, 1988-2009). Climate indices were incorporated with the classical BH mode. NPI and PDO relatively increased accuracy of NPALB R estimates. Atmospheric-ocean conditions may impacts on NPALB Recruitment and this cannot be negligible. The understanding of the effect of environmental variability on recruitment could lead to better implementation of harvest control rules .

When the regime shift occurred, PBF and ALB change their recruitment level rapidly, without showing rapid change in spawning stock biomass. RPS of tropical tuna, especially SKJ, shows significant correlations with ENSO indexes. All of five tuna recruitments and/or RPS increased when the SST in and around the spawning area is higher than average**.**

When considering production and recruitment, among four competing hypotheses (Abundance, Regimes, Random and Mixed), Regimes Hypothesis explains about 40% of 219 stocks. Collapsed stocks tend to have their production driven by shifts in environment. Productivity depending on biomass is not well supported. It might be an issue given that most management are based upon the assumption of abundance and productivity being fishing driven. The challenge is to identify the recruitment regimes early enough for a good forecast and to find management robust to regime shifts**.**

It has been long believed that because the tunas are positioned at top, their biomass is relatively stable over time and subject to MSY management. However, variations in their biomass are fairly wide, with an intimate link with the regime change in the clupeoid species as their diet. In order to sustainably utilize them, studying natural laws that dominate variations in biomass of the resources may be essential **.**

Responsible fisheries may play roles of umbrella species, and give many data of utilized resources. Fishing efforts for "maximum sustainable ecosystem service" (MSES) are usually smaller than those for a maximum sustainable yield (MSY)**.**

In the general discussion of the workshop, the following two topics were discussed; (1) Ecosystem services, Socio-economic and BRPs and (2) Regime Shifts and BRPs and all the participants agreed that it is difficult to summarize or make a single recommendation about BRPs. Regarding the environmental conditions which can be influential to the stock abundance, at least, scientists should monitor fisheries as comprehensively as possible. And it's necessary to distinguish the environmental effect to the stock from exploitations.

Although scientists may not be able to decide target BRPs because it always depends on the relevant objectives, which should be decided by stakeholders, scientists can suggest limit BRPs to avoid the collapse of stocks or overfishing. It's also possible to show multiple BRPs and its performance with uncertainty and pros-&-cons for each scenario, and evaluate their performance via MSE. This would be helpful for decision making. Considering regime shifts, the use of the multiple BRPs were discussed. Further discussion is necessary to consider the biological characteristics of target species and flexibility of incorporating different BRPs in the face of changing environment.

1. Opening remarks & Background and objectives

Good morning everyone, and welcome to Shimizu. I am Hitoshi Honda, and I would like to express the welcome remarks on behalf of Mr. Jyoji Morishita, Director General of National Research Institute of Far Seas Fisheries, Fisheries Research Agency of Japan. On behalf of this institute, it is my great pleasure to have this workshop here in Shimizu. This workshop is entitled "Workshop on Biological Reference Points for Fisheries Management under Environmental Changes." The workshop has more than 40 prominent participants from United States, New Zealand, New Caledonia, and Japan. The main subject of this workshop is to make comprehensive discussions on the Biological Reference Points for management of tuna fisheries resources, in particular, for temperate tuna resources like Pacific bluefin tuna in the North Pacific Ocean in the region of the Western and Central Pacific Fisheries Commission. Now Shimizu is in the middle of rainy season, and plum and Japanese loquat fruits "Biwa" have been just ripened for harvest. The Japanese name of rainy season "Tsuyu" means actually the season of plum. This is not good for viewing Mount Fuji because high humidity prevents to see mountain clearly. Recently Mount Fuji has been nominated as a predominant candidate of the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site. Anyhow, I hope all of you enjoy your stay in Shimizu during this meeting, even if you are expected to work hard.

At this opportunity to open the workshop, I would like to talk about the background and objectives of this workshop briefly. As you know, the interest in stock status and fishery management for tuna stocks has been increasing domestically and internationally, that means wide range from coastal area to offshore and high sea area, with increasing global demand and catch of tuna species. Therefore, many of tuna related regional fisheries management organizations (RFMOs) are trying to use various kinds of biological reference points (BRPs) including the concept of traditional maximum sustainable yield (MSY) to manage the stock properly by conventional science-based approach. However, tuna species, especially temperate tuna species like Pacific bluefin tuna and albacore tuna are highly affected not only by human activities such as fishing, but also by natural conditions and environmental changes such as regime shift. So it is questionable whether traditional BRPs based on MSY are effective or not for such species.

This workshop aims to review various BRPs for fish stocks including tuna and other fish species and to discuss the appropriate and/or plausible BRPs for temperate tunas with considering the characteristics of biology and fishery for these species, environmental and ecosystem, and socio-economic effects.

In closing my speech, once again, I hope that you will have a fruitful workshop and also I hope that you will enjoy your stay in Shimizu to visit nice scenic places around and near here. Thank you.

Hitoshi Honda
Director of Project Management Division

2. Fisheries management and biological reference points

The estimation strategy of ABC and the management rule of TAC for Japanese coastal fishery stocks

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Considering the current status of scientific knowledge for the fishery target species in Japan, nearly MSY based management have been implemented for each stock by determining specific optimal yield in accordance with its fishery stock management policy. Also, the allowable biological catch (ABC) is estimated for important coastal fishery stocks. For this purpose, the threshold level of stock (B_{limit}: the minimum stock biomass to ensure an appropriate amount of recruitment) is defined for management and if the biomass is above Blimit, ABC is established based on one of several reference points which ensure sustainable yields. If the biomass is below B_{limit}, tighter ABC is set to recover the stock. If the stock biomass is extremely low (below B_{ban}), fishing moratorium or similar measure will be recommended. In the presentation, the reference point of biomass in Japanese coastal fishery stocks will be showed and the stock level for these target fisheries will be discussed.

Keywords
nearly MSY based management

Discussion

Main topic discussed was the possible performance of B_{loss} as B_{limit}. A participant expressed argument that B_{loss} doesn't perform similar with B_{MSY} as a biomass based BRP. Especially, in case the stock, which increase biomass in early period and then show continuous decline followed by stable trend, estimation of B_{loss} may be biased due to continues declining. The presenter stated that the temperate tuna fisheries have a long history and the stock fluctuated plural times. Under this situation, MSY can be ranged widely and the performance of B_{loss} as B_{limit} can be included inside the B_{msy} range. Every participants as well as the presenter understood the necessity to be careful using B_{loss}. The presenter showed a possibility to evaluate whether B_{loss} working similar to B_{msy}, by operating many simulations for different levels of F.

Another question was about a reason of the stock recovering from below B_{loss} level. The presenter answered that it would be caused either the recruiting of the dominant year class and the effect of tight TAC which was implemented according to the estimation strategy of ABC using the B_{loss} as the BRP. Including the effect of environmental condition into the calculation of ABC was also discussed by the floor member because the MSY might be different levels depend on the different levels of SST or something.

Biological reference points for TAC-regulated stocks in Japanese waters

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Major offshore fisheries in Japanese waters are regulated through a TAC (Total Allowable Catch) system. TACs are set based on ABC (Allowable Biological Catch) and socio-economic considerations. The ABC is determined by biological reference points and harvest control rules. In 12 out of 19 TAC-regulated stocks, ABCs are calculated using stock-recruitment relationships. A linear relationship between stock and recruitment is assumed in four stocks. Although a hockey stick relationship is assumed in six stocks, the upper limit of recruitment is set for convenience of calculation, not for considering the density dependence in the stock-recruitment relationship. Only two out of 12 stocks explicitly consider density dependence assuming a Ricker model (Pacific stock of spotted mackerel) and a hockey stick model (Tsushima stock of chub mackerel). When SSB (Spawning Stock Biomass) is above B_{limit} (Biomass limit reference point), the harvest strategy is maintaining present SSB using F_{med} (six stocks), or maintaining SSB above B_{limit} (allowing decrease of SSB, two stocks). When SSB is below B_{limit}, recovery of SSB is the harvest strategy (four stocks). The potential difficulties in biological reference points used in TAC-regulated stocks are also discussed.

Keywords
stock-recruitment relationship, density dependence, fishing mortality reference points

Discussion

The presenter introduced the methods to estimates ABCs of Japanese TAC-regulated stocks, and the participants questioned how to determine B_{limit}, which is the threshold to determine the harvest strategy. The presenter responded that it's not subjective but there are some methods to determine B_{limit} depending on the stock recruitment relationship of each stock. Some comments rose about the methods to rebuild overfished stocks, and the participants exchanged the information about those of each country. Concerning about Japanese TAC-regulated species, F_{med} is not considered appropriate to be used if the stock is lower than the B_{limit}. If the stock is upper than B_{limit}, F_{med} can be allowed as the target RP. To discuss among different countries, to see the relationship between the F_{med} and %SPR or something appropriate would be helpful.

WCPFC progress on limit reference points

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Modern fisheries management agreements highlight the importance of adopting target and limit reference points (LRPs). In WCPFC this process has been increasing in importance in recent years, driven partly by the Marine Stewardship Council (MSC) certification process which has been achieved for some skipjack and albacore fisheries. In this talk I will focus on the progress for three tropical tuna stocks bigeye, yellowfin, skipjack, and the temperate south Pacific albacore stock, through the adoption of a 'tiered' approach to determine what type of LRPs are appropriate, to the development and adoption by WCPFC of LRPs. Interestingly,

those adopted by WCPFC do not rely on MSY-quantities and take into account the variability that is observed in the stocks - therefore are dynamic in nature. Because of the lighter exploitation of these stocks, the adopted LRPs are generally at lower biomass levels than have been observed. I will also apply the same methods to determine the limit reference points that might be considered for Pacific bluefin and North Pacific albacore if a similar approach was adopted for these northern stocks. Finally I will outline the work ahead on LRPs, in particular the adopted of F-based LRPs and seeking guidance from the Commission on acceptable levels of risk.

Keywords
'tiered' approach, variability in the stocks, acceptable levels of risk

Discussion

It was clarified that the estimation of spawning biomass at FBS=0 was conducted by rerunning the model with no catch in the entire years. It was noted that the target reference point is better to be included in Kobe plot which has been widely used in the WCPFC. The author mentioned that they are trying to incorporate the limit or target reference points in the current Kobe matrix. It was further informed the tentative results of considering F-based and B-based reference points. It was also commented that it is important but difficult to understand the gap of reference points among scientists, stakeholders, and fishermen due to their wide backgrounds.

The Usefulness of a Historically-based Limit Reference Point: Application to Pacific tuna stocks

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The MSY-based reference point (RP) F_{MSY} to maximize sustainable yield and the historically-based RP F_{loss} to sustain a historically lowest observed spawning stock size were estimated and evaluated under various scenarios using the data of tropical tuna stocks such as yellowfin tuna and temperate tuna stocks such as Pacific bluefin tuna in the Pacific Ocean. Numerical simulations indicated that accuracy and precision of estimates for tropical tuna stocks were higher than those for temperate tuna stocks because the assessment for tropical tuna stocks started nearly from unfished stock size and gave enough information on SR relationship. For temperate tuna stocks, the performance of F_{loss} was better than that of F_{MSY} if the steepness and process errors were high. For tropical tuna stocks, the performance of both F_{loss} and F_{MSY} was good when steepness was high, regardless of the magnitude of process errors. These results suggest that F_{loss} would be preferable under high recruitment compensation, large process errors, and lack of contrast in spawning stock size.

Keywords
MSY-based RP, historically-based RP

Discussion

There were several comments and advises to this study. It was suggested to take the realistic range of steepness for tunas to avoid leading readers to misunderstanding about the characteristics of tunas, though the authors tended to show a general study. It was also suggested to consider setting the smaller natural mortality with the smaller steepness. It was commented that the results might be changed if the more historical data for the temperate tunas, where would include the exploiting period, were incorporated in this study. Discussions on the use of Floss were made. It was emphasized that Floss is sometimes used as a proxy of F_{crash}, thus the value should be carefully considered. There are various ways to calculate the value of Floss, and it was noted the necessity of clear declaration of the calculation method.

How can science best inform fisheries management? Procedural versus assessment approaches and the place of MSY-related reference points.

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MSY-related BRPs have a long history and have a central place in much of modern fisheries legislation, management and science. MSY, however, is more useful conceptually than in practice. MSY-related BRPs are often difficult to use in the real world which does not conform to the underlying assumptions required of the fundamental theory. Difficulties arise because real world systems are complex, non-linear and highly stochastic, displaying hard to interpret fluctuations and systematic variation. The assumptions required to estimate MSY-related BRPs are usually not well met and data availability is often a serious problem making inferences difficult. This talk will review a number of issues related to MSY-related BRPs and will look at approaches to management that provide a possible way forward to meet multiple objectives in the face of uncertainty. The talk will focus on the procedural, as opposed to assessment, approach to fisheries management and the importance of BRPs as indicators to be used within harvest control rules and as standards against which to measure performance related to objectives. While the talk will primarily be conceptual, some example cases will be considered.

Keywords
MSY-related BRPs, uncertainty, procedural approach, assessment approach

Discussion

Although almost all the participants understood how MSY are useful conceptually, the discussion is focused on how to practice with that (ie; for MSC consultation?, as a RP_{limit}/RP_{target}?). The presenter suggested that it can be used for the estimation of the risk level flexibility of overfishing, and this approach is not inconsistent with WCPFC. The presenter also explained the importance to monitor the recent recruitment for the practice. A question was focused that relationship between MSY-related BRPs as a target BRP and the fishermen's goals which are dependent on each fishery's background. The presenter answered that 1.)

Limit BRP should perform to avoid stock clash and 2). Target setting may involve multiple criteria, not just maximum yield depend on circumstance. A participant also raised an importance for taking into accounts many things such as socio-economic circumstance, the environmental condition when the stakeholders consider the management.

Uncertainty in biological reference points and its management implications

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Biological reference points (BPRs) play a critical role in quantifying management objectives and determining status of fisheries in a fishery management system. Together with stock assessment and harvest control rules, they help managers determine the status of fisheries and develop management regulations to avoid the target fishery being in an undesirable status (i.e., overfishing and/or overfished). Biological reference points are likely subject to large uncertainty as a result of temporal and spatial variability in the dynamics of ecosystem (e.g., changes in ecosystem productivity and critical habitats) and/or uncertainty associated with the way they are quantified (e.g., models and data used in the calculation). However, they are often considered as exact when they are used in fisheries management. Large uncertainty, in particular large unidirectional temporal variability and/or estimation biases, may result in inappropriate estimation and implementation of BRPs, leading to fisheries mismanagement. In my talk, I will give an overview of uncertainty associated with MSY-based or MSY-proxy-based BRPs and empirical or ad hoc BRPs and discuss quantification and implementation of uncertainty associated with BRPs in fisheries management. Using an invertebrate fishery and a tuna fishery as examples, I will evaluate potential impacts of uncertainty associated with BRPs on fisheries management, highlight factors contributing to the uncertainty in BRPs, and outline a general approach to identifying suitable BRPs. Potential consequences of lack of considering uncertainty in developing BRPs will be discussed. I will also discuss approaches such as management strategy evaluation (MSE) that can be used to evaluate the effectiveness of BRPs in achieving management objectives.

Keywords
uncertainty, MSY-based or MSY-proxy-based BRPs, empirical or ad hoc BRPs

Discussion

A question was raised that why F10% was used as the BRP for Lobster. The presenter answered that because of the size selectivity of this fishery F10% can secure the sustainability of this fishery. The reason of the Lobster stock rebuilding (the management result/environmental effect) was also asked to the presenter and he answered that the management would contribute mainly and the decreases of the predator abundance also support the Lobster stock rebuilding. The participants confirmed the effectiveness of MSE approach.

3. Management considering socio economics

Conservation and management tools including area-based management

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Area-based managements in fisheries are gaining attentions in various international bodies recently. Many of them are discussed in the context of marine protected areas. For instance, in 2010, COP 10 of Convention of Biological Diversity (CBD) adopted “Aichi target”, which provides “by 2020, at least ... 10 per cent of coastal and marine areas are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes. CBD at its COP 9 also established criteria for “Ecologically and Biologically Significant Areas” (EBSA). Food and Agriculture Organization (FAO) in 2008 also developed the Guidelines were developed owing to increased international concern regarding the management and potential impact of deep-sea fisheries on vulnerable marine ecosystems (VMEs) in the high seas. The United Nations holds General Assembly Ad Hoc Open-ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction in 2013.

Keywords
Area-based management in fishery, biological diversity, ecosystem services, marine protected areas

Discussion

In response to a question regarding the legally binding for TAC allocation in Japanese costal/offshore fisheries, the following information was provided; 1) there are no IQ systems; 2) there are several local government's laws, and the quotas for the each costal area are decided and distributed after the negotiation among the several local governments; 3) the quota for offshore fishermen is totally enforced and allocated through the offshore fishing operating association.

It was discussed the difficulty of extension of communicate-based management which is mainly conducted in local coastal area to species living in high sea area such as pacific bluefin tuna. For the management of pacific bluefin tuna, the situation is difficult because there are two sectors, one is the coastal fishery (e.g. troll) and second is the offshore and distant-water fishery (e.g. purse seine). Therefore, the presenter noted that the extension of communicate based management to high sea area is almost impossible. Other participant suggested the difficulty of the extension of ecosystem service management to high sea area. The presenter agreed that and mentioned the approach of the economic based solution by UN, world bank, and the other economic institute.

Practical application of reference points to the management of stocks which have been exposed to strong fishing pressure for a long period of time –a manager’s point of view-

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Pacific bluefin tuna (PBF) is probably one of the species that have the longest history of human exploitation in the world. The recent stock assessment done by International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) suggests that for a half century the PBF stock has fluctuated at a level much less than 20% of estimated pre-exploitation spawning biomass, which is considered to be Limit Reference Point for some other tuna species. ISC also estimates that the current (2010) spawning biomass is 3.6% of the pre-exploitation level. At the same time, the steepness of the species is considered to be very high (ISC estimates 0.99), which means that the stock can rebound anytime when the environmental condition is favorable. In fact, it is observed that PBF recovered strongly from a very low stock level in the early 1990's. Those information indicate that the stock has been harvested sustainably for a long period of time though it has likely been at very low stock level, which could be characterized as "overfished". Some studies suggest that fish stock with high steepness can produce pretty good yield even at very low stock level. ISC also projects that the stock will gradually recover if the management measures currently introduced by WCPFC and IATTC as well as voluntary measures by Japan be implemented properly. I try to explore how fisheries managers can apply management framework to PBF. In doing so, the very complex nature of PBF fisheries must be taken into account. Particular attention should be given to the facts that for some fisheries reward for their conservation efforts is expected to be very little (eg. Purse seine targeting juvenile) and that in other fisheries very large number of small scale vessels are involved. In this situation, introduction of radical measures in order to rebuild the stock to a relatively high level such as B_{msy} in a short term is not feasible. Rather, a gradual approach that can obtain supports from those fishermen involved is critical for the success of the measure. B_{msy} may be the ultimate target, but setting a modest target that can be achieved in a realistic schedule should be considered a practical approach. Japan has introduced various measures for the management of PBF, including licensing system for small scale trollers to be implemented next year, and those measures should reduce the risk of the increase of catch in the process of the recovery.

Keywords
radical measures, gradual approach, practical approach

Discussion

Some participants suggested the importance of national and international management policy for Pacific bluefin tuna stock. BRPs could notice the fisheries the reason and impact of the management policy. Regarding the importance of the target of rebuilding preference, the time period and generation number to achieve the 20%B0 were discussed. It is confirmed that the information of biological characteristics for maturity (size and age) is essential to consider the time periods of rebuilding, and recruitment should be monitored continuously because the strategy for rebuilt the stock depends on the recruitment. Presenter agreed and indicated that Japan has responsibility for rebuilt of this stock and should make decision seriously. The meeting discussed about the estimation process for B0 and the reason for the stability of recruitment. For the Pacific bluefin tuna stock assessment, B0 was simply calculated with SPR100% (SPR without fishing mortality) using biological parameters in the stock assessment model. It was also mentioned that B0 is the estimated and extrapolated one as it is not estimated by age-structured model. For the stability of the recruitment, the interpretation of this result still remains argument because of the difficulty of estimation. Regarding the environmental change, it was pointed out that a possibility of the century fluctuation of Pacific bluefin tuna stock as is observed in Atlantic bluefin tuna stock.

4. Management considering environment and ecosystem

Review on regime shift in North Pacific Ocean and stock-recruitment-environmental relationship for North Pacific albacore (*Thunnus alalunga*)

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Several recent researches on climate, physical, biological and ecosystem dynamics in North Pacific Ocean show some possibilities of decadal environmental variability, so called “regime shift”. Recruitment is also one of important process that drives population dynamics and complex process influenced by various environmental factors. Stock-recruitment-environmental relationship is then examined for North Pacific albacore (*Thuunus alalunga*) based on spawning biomass and recruitment estimated by stock assessment in 2011 and several possible environmental indices such as Pacific Decadal Oscillation Index (PDO). As results of North Pacific albacore stock assessment, three periods were identified; (a) a low recruitment period (1978-1987) and (b) two high recruitment periods (1966-1977, 1988-2009). These periods may reflect effects of changing environmental conditions on population dynamics. However, relationship between recruitment of North Pacific albacore and decadal environmental changes has not been fully understood. In this study, we analyze the effect of environmental variability on the recruitment or stock-recruitment relationship for North Pacific albacore. If the effect of environmental variability on recruitment can be explained in stock assessment, it could lead to not only improvement of our understanding of stock-recruitment-environmental relations but also of implementation of harvest control rules.

Keywords
Pacific decadal oscillation index (PDO), recruitment or stock-recruitment relationship, harvest control rules

Discussion

Several questions and comments were provided by the participants. A correlation between six climate variable was asked. Presenter noted that there is negative correlation between NPI values and PDO index. It was recommended to evaluate model performance with cross validation and checking residuals. Another question was about the timing and trend of "regime shift". Presenter explained that the timings of regime were detected by computer software named STARS (version 3.2) automatically, and the average values of each phase were calculated as the regime level.

Relation between changes in climatic/oceanographic conditions and tuna stocks

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This study examines the impacts of atmosphere-ocean variability on recruitment (R) fluctuations of tunas such as Pacific bluefin tuna (PBF), albacore (ALB), skipjack (SKJ), bigeye tuna (BET) and yellowfin tuna (YFT) in the Western and Central Pacific. PBF-R fluctuates with three peaks in the middle 1950s, the early 1970s and 1990s. ALB-R shows a similar fluctuation to PBF. When the regime shift occurred, PBF and ALB change their recruitment level rapidly, without showing rapid change in spawning stock biomass (SSB). Size of ALB (Body length mode of age-4 ALB) fluctuates out of phase with R but also shows a rapid change after the Climate Regime Shift. This means that climate changes have impacts on not only R but also biological quality. SKJ-R and RPS increase from the 1970s to 2000s with decadal oscillation, there are three peaks in the middle 1980s, the latter half of 1990s and middle 2000s. BET-R and RPS (recruitment per spawning stock biomass) show a long-term fluctuation with a period of 60 years or more. BET shows no typical change around the Climate Regime Shifts, but BET-R and RPS increase despite of SSB decreasing after 1976/77, when the major Regime Shift was occurred. YFT-R shows a decreasing trend with 30-year cycle oscillation. YFT-R and SSB show increasing or decreasing trends after Climate Regime Shift, although RPS was not so good until 1995. Significant correlations are noted between R of PBF, ALB, SKJ and/or BET and sea surface temperature (SST) in and around its spawning area. It suggests that period of high temperature in a spawning area corresponds with high recruitment years. RPS of SKJ, BET and/or YFT also corresponds with SST fluctuations in the eastern and central tropical Pacific, especially along the ITCS (Intertropical Convergence Zone) and SPCZ (South Pacific Convergence Zone) which are rainfall bands with SST maxima. R and RPS of PBF and/or ALB do not show significant correlations with climate indices, although correlations between SKJ and ENSO indices (*i.e.* SOI, NINO index), and/or between BET and/or YFT and NINO-WEST shows the significant relationship. The relations between tropical tunas and climate indices suggest climate change, especially ENSO events, affects to SST in spawning area and RPS and/or R. Temperate tuna does not show significant relationship with climate indices, but R was affected by SST in and around its spawning area. My interpretation is that climate changes affect to survival rates of tunas larvae in their breeding area through changes in food availability, growth rate and the period vulnerable to predation according to their ambient temperature changes.

Keywords
atmosphere-ocean variability, recruitment level, recruitment per spawning stock biomass

Discussion

The relationship between the stock recruitment and the environmental effect was asked and presenter clarified. Following first question, the existence of significant correlation between SSB and recruitment within the same regime was asked. Presenter mentioned that no statistical analysis have been conducted because of data noise.

Frequency and intensity of productivity regime shifts in marine fish stocks

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The relative importance of environmental conditions and stock abundance in determining the productivity of fish stocks has been a subject of an on-going debate. The controversy can be formulated as four competing hypotheses: 1) productivity is driven by fishing pressure, which affects abundance, subsequent recruitment; 2) productivity is regime-driven, with periods of good and bad productivity unrelated to abundance; 3) productivity is random from year to year and unrelated to abundance and is temporally uncorrelated; and 4) both stock abundance and regimes of good and bad conditions interact to affect productivity. The goals of this study are (1) to evaluate the support for each of these hypotheses by examining the productivity of marine species using a large number of stocks, and (2) to evaluate the same hypotheses with respect to recruitment. This project uses historic data from about 230 assessments from the RAM Legacy Database. Each of the four hypotheses will be formulated as alternative models, and the support for the hypotheses evaluated using model selection via AICc and AICc weights. The specific models are (1) a biomass-dynamic model relating surplus production to stock size, (2) a regime shift model accounting for temporal shifts in productivity; (3) a model that assumes productivity to be random and (4) a biomass-dynamics model that has regime changes in productivity parameters. Then a similar analysis was performed on recruitment. I found that when considering production the abundance Hypothesis best explains 18.3% of stocks, the Regimes Hypothesis 38.6%, the Mixed Hypothesis 30.5%, and the Random Hypothesis 12.6%. When considering recruitment, the stocks recruitment Hypothesis best explains 12% of stocks, the Regimes Hypothesis 39%, the Mixed Hypothesis 15% and the Random Hypothesis 34%. If the production of a stock is determined by periodic regimes and the assessment of the stock does not recognize the shift in regimes, then the management system with respect to sustainable yield is incorrect. I do not suggest that we should abandon the goal of maintaining fish stocks at high abundance. Rather I simply show that it is unlikely that such policies will assure high and sustained recruitment. Thus, future work should identify and evaluate management strategies that would be robust to irregular jumps in average productivity.

Keywords
Four competing hypotheses, Abundance, Regimes, Random and Mixed Hypothesis

Discussion

It was clarified that the regime shift model was conducted with one break point for one regime. It was also asked that how to apply this study to real fishery management. It was mentioned that the estimation of uncertainty.

Trophodynamics in marine ecosystems in terms of the regime shift in tuna assemblages

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Fish populations need to be utilized according to the natural laws: **regime shifts**. **Regime shift** is defined as "**shift** on a multidecadal timescale of the fundamental structure (**regime**) of earth surface system composed of atmosphere, oceans and marine ecosystems". **Food chain** connects **trophic levels (TLs)** in the ecosystem. Pathway of grazing food chain in marine ecosystems through which energy and material is transferred starts at photosynthesizing phytoplankton and ends in apex predators such as tunas. Here, I show **trophodynamics model** that could explain mechanisms underlying the regime shift. Patterns of interaction between atmosphere and oceans over the Pacific Ocean are well manifested by the Pacific Decadal Oscillation (**PDO)** pattern which switches from positive phase (or cool phase over the northwest Pacific) to negative phase (or warm phase) and back on an interdecadal basis. When the PDO is in positive phase, Aleutian Low tends to be well developed, which accelerates deep waters rich in nutrient to upwell. As the waters over the northwest Pacific become cooler, phytoplankton (TL=1), in turn zooplankton (TL=2), begins to rise in biomass and much energy and material is transferred at a higher rate to lower-TL **SP** (TL<3), small-sized pelagic fish, mostly sardine (**sardine regime**). In this phase transfer efficiency from the SP to **LP**, large-sized pelagic fish such as tunas (TL=4), is lower and biological energy is converged into the TL of SP. When the PDO phase changes to negative, the SP assemblage is switched from the sardine regime to **non-sardine regime** in which higher-TL SP (TL>3) such as anchovy, chub mackerel, jack mackerel and saury dominate, and the transfer efficiency from the SP to the LP becomes higher, leading to divergence of energy out of the SP. **The Japan Sea** is a semi-enclosed environment, where pattern of species replacement has been accentuated. As the PDO patterns had shifted, alternation at the TL of SP from the anchovy to the sardine was observed in the late 1970s and that in opposite direction in the late 1990s, while those at the TL of LP from bluefin tuna to yellowfin tuna and back were in progress in the early 1980s and in the early 2000s, with a **phase lag** of several years between timings of the species replacement at the TL of SP and that at the LP, showing time requisite for energy transfer from the SP to the LP, which is a clear evidence for the energy transfer between the two TLs. In its **overfished** state, normal pattern of regime shift for the stock is biased by strong fishing power. Excess fishing pressure, particularly on young fish before their first spawning, in the low-biomass phase of regime shift would be especially responsible for stock collapse. Variations in abundance or carrying capacity of the environment of fish stocks are subject to natural order of the regime shift and control of fishing for them shall be done in line with the natural laws, regime shift.

Reference

Kawasaki, T, 2013, Regime Shift - Fish and Climate Change-, Tohoku University Press, ISBN 978-4-86163-205-1

*phytoplankton (TL=1), zooplankton (TL=2), lower-small-sized pelagic fish such as sardine (lower-TL SP, TL<3), higher-small-sized pelagic fish such as anchovy, chub mackerel, jack mackerel and saury (higher-TL SP, TL>3), large-sized pelagic fish such as tunas (LP, TL=4)

Keywords
trophodynamics model, regime shift

Discussion

As the application to the actual fishery management under the regime shift, the presenter suggested that we must refrain from overfishing especially early stage of fish and do not stop their rhythm. It was also mentioned that it is important to pay attention to the high fishing pressure, such as by purse seine. The author presented that the regime shift is influenced by predator relationship. It was noted that bluefin tuna doesn’t have relationship between spawner and recruitment, but they have competitions between larvae versus other small fish such as sardine. In the presentation, it was shown that species competition between sardine and bluefin tuna regime and the bluefin tuna curve was different from the shift of sardines and tropical tunas. As for the reason of occurrence, it was mentioned that small pelagic fish occurs in 1970’s however tuna’s assemblage occurred several years later. The hypothesis was suggested that the transfer of energy from LP to SP needs to take some time.

Fisheries resource management that maximizes the value of ecosystem services

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The classic theory of fisheries management seeks a maximum sustainable yield (MSY) from a target species. There are several variations that include uncertainty (measurement errors in stock abundance), fluctuation (regime shift), and species interactions. The MSY from a single target species do not always guarantee persistence of other species. It is known that constant escapement policy is a solution of dynamic programming (DP) to maximize the long term yield under fluctuating environment. The maximum sustainable yield from the multiple resources is obtained from DP even with process errors and species interactions, but it is vulnerable for measurement errors. Feedback control in which fishing effort or acceptable biological catch depends on the recent stock abundance is robust against measurement errors and process errors, but it is vulnerable for species interaction. We investigate the effects of species interactions on the robustness of feedback control of the harvesting of prey species. We consider the consequences of feedback control of fishing effort. If a prey species is exploited, increasing fishing effort decreases predator abundance more than it does the prey abundance. Feedback control of fishing effort may cause the extinction of the predator, even if the prey population is well controlled. Even when fishing effort is controlled by predator density, it is difficult for the fishery and the predator to coexist, and, if they do so, the system exhibits complex dynamic behaviors. If the predator and fishery coexist, feedback control of fishing effort converges to a stable equilibrium, a synchronous cycle, or an asynchronous cycle. In the last case, the system undergoes more complex cycling with a longer period than that when the fishing effort is kept constant. These analyses suggest that there is no effective strategy that is robust against measurement errors, process errors and complex interactions in ecosystem dynamics. Ecosystems provide several categories of ecosystem services to human wellbeing: supporting, provisioning, regulating, and cultural services. Fishery yields belong to provisioning services. The existence of living marine resources may maintain these services,

and certainly a much larger contribution from regulating services than that from fishery yields. Therefore, we define an optimal fishing strategy that maximizes the total ecosystem service instead of a sustainable fishery yield. We call this the fishing policy for “maximum sustainable ecosystem service” (MSES). The regulating service likely depends on the standing biomass, while the provisioning service from fisheries depends on the catch amount. We obtain fishing policies for MSES in a single species model with and without uncertainties and in multiple species models. In any case, fishing efforts for MSES are usually smaller than those for a maximum sustainable yield (MSY).

Keywords
Ecosystem services, supporting, provisioning, regulating, and cultural services, maximum sustainable ecosystem service (MSES)

Discussion

Although the participants confirmed the concept of the maximum sustainable ecosystem service (MSES), they also wonder how MSES are instituted to the actual fishery management. The author responded that there is a gap between fishery scientist and conservation ecology scientist, and the author continued a study to bury this gap. Some scientists from mathematics can build a ecosystem model with caring a vulnerability for process and observation error, and Fisheries and socio-economic scientists also can support this. Since the presenter suggested the importance of the multi-species monitoring to monitor the ecosystem service, a question was raised about cost-performance of the monitoring. The author answered that a solution can be to ask about the local fishery condition and fishery-related matter to the fishermen.

5. General discussion

In the general discussion of the workshop, the following two topics were discussed; (1) Ecosystem services, Socio-economic and BRPs and (2) Regime Shifts and BRPs and all the participants agreed that it is difficult to summarize or make a single recommendation about BRPs. Regarding the environmental conditions which can be influential to the stock abundance, at least, scientists should monitor fisheries as comprehensively as possible. And it’s necessary to distinguish the environmental effect to the stock from exploitations.

Although scientists may not be able to decide target BRPs because it always depends on the relevant objectives, which should be decided by stakeholders, scientists can suggest limit BRPs to avoid the collapse of stocks or overfishing. It’s also possible to show multiple BRPs and its performance with uncertainty and pros-&-cons for each scenario, and evaluate their performance via MSE. This would be helpful for decision making. Considering regime shifts, the use of the multiple BRPs were discussed. Further discussion is necessary to consider the biological characteristics of target species and flexibility of incorporating different BRPs in the face of changing environment.

6. Closing Remarks and Adjournment

Dear participants, Ladies and Gentlemen. It is my pleasure to join you for the closing of this workshop on biological reference point and related matters. I would like to thank presenters, especially who came from abroad, taking a long trip and time for this workshop. Above all, I would like to thank all of you here for leading this workshop to success through your valuable contributions and active participation throughout the workshop and especially during the discussions. During the past 2 days, we had discussed the characteristics of biological reference points and related issues such as influence of environmental fluctuations and socio-economic back ground. We understand that the topics are complex and need more research and study. But our work does not end here. That is why I would like to think the next step based on the results of the workshop. We may plan part II of the workshop next year. We need to continue working together as we face these many challenges. Finally, I would also like to thank the staff of the National Research Institute of Far Seas Fisheries that has worked so hard to lead this workshop to success. I wish you enjoy the rest of your stay in Shimizu, unfortunately now is rainy season, but still there are lots of valuable to see, eat and experience. And I wish you have a safe trip back to home.

Thank you very much.

Hideki Nakano
Director of Bluefin Tuna Resources Division

Appendix 1. Program

1st day

June 13, 2013

9:00-9:10

1. Opening remarks & Background and objectives

Hitoshi Honda, National Research Institute of Far Seas Fisheries (NRIFSF)

2. Fisheries management and biological reference points

9:10-9:50

The estimation strategy of ABC and the management rule of TAC for Japanese coastal fishery stocks

Minoru Kanaiwa, Tokyo University of Agriculture

9:50-10:30

Biological reference points for TAC-regulated stocks in Japanese waters

Kazuhiko Hiramatsu, The University of Tokyo

10:30-10:45

Coffee break

10:45-11:30

WCPFC progress on limit reference points

Shelton Harley, Secretariat of Pacific Community (SPC)

11:30-12:10

The usefulness of historically-based limit reference points: Application to Pacific tuna stocks

Mikihiko Kai, NRIFSF

12:10-13:40

Lunch break

13:40-14:25

How can science best inform fisheries management? Procedural versus assessment approaches and the place of MSY-related reference points.

Kevin Stokes, STOKES.NET.NZ Ltd.

14:25-15:10

Uncertainty in biological reference points and its management implications

Yong Chen, University of Maine

15:10-15:25

Coffee break

3. Management considering socio economics

15:25-16:05

Conservation and management tools including area-based management

Nobuyuki Yagi, The University of Tokyo

16:05-16:45
Practical application of reference points to the management of stocks which have been exposed to strong fishing pressure for a long period of time –a manager's point of view-
Shuya Nakatsuka, Fisheries Agency of Japan

16:45-17:25
Review on regime shift in North Pacific Ocean and stock-recruitment-environmental relationship for North Pacific albacore (*Thunnus alalunga*)
Relation between changes in climatic/oceanographic conditions and tuna stocks
Hidetada Kiyofuji, NRIFSF
Denzo Inagake, National Research Institute of Fisheries Science

17:25-17:40
Wrap up

19:00-
Reception

2nd day
June 14, 2013.
4. Management considering environment and ecosystem
9:00-9:45
Frequency and intensity of productivity regime shifts in marine fish stocks
Katyana A. Vert-pre, University of Washington

9:45-10:30
Trophodynamics in marine ecosystems in terms of the regime shift in tuna assemblages
Tsuyoshi Kawasaki, Tohoku University

10:30-10:45
Coffee break

10:45-11:25
Fisheries resource management that maximizes the value of ecosystem services
Hiroyuki Matsuda, Yokohama National University

11:25-12:30
5. General discussion

12:30-14:30
Lunch break

14:30-15:00
6. Reporting

15:00
7. Concluding Remarks & Adjournment
Hideki Nakano, National Research Institute of Far Seas Fisheries (NRIFSF)

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