SBT Recruitment Monitoring Review Workshop:

The role and constraints of scientific monitoring for stock management – brain storming using southern bluefin tuna experiences as an example.

15-17 December 2004

National Research Institute of Fisheries Science
Yokohama, Japan

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The role and constraints of scientific monitoring for stock management
– Brain storming using southern bluefin tuna experiences as an example

みなみまぐろ加入量モニタリング国際レビューワークショップ：
資源管理における科学的モニタリングの役割と限界
--ミナミマグロ加入量モニタリングをモデルケースとして

The above-mentioned Workshop will be hosted by the Fisheries Research Agency of Japan in collaboration with CSIRO Marine Laboratory, Hobart, Australia. Importance of fishery-independent scientific stock indicators including those obtained from line-transect type survey has been repeatedly emphasized. Still, it is relatively rare that those indicators are used as key inputs to stock assessment and management. The Workshop will seek guidance toward establishing long-term reliable stock indicators thorough reviewing past experiences from various standpoints. We are anticipating for participation and frank opinions from wide areas covering survey design, survey techniques to utilization of indicators.

水産総合研究センターでは、オーストラリアの CSIRO と共同で上記のワークショップを開催します。ライントランセクトを始めとした科学的資源量モニタリング調査の重要性はいつも指摘されますが、資源評価・資源管理に活用されているケースは必ずしも多くないようです。ワークショップでは調査実施とモニタリング指標活用の両面から、長期的な信頼度の高い資源モニタリング指標を確立するにはどうしたらいいかを探ります。調査から資源管理に至るまで、あらゆる分野の方々からの率直なインプットを期待しています。

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VANUE: National Research Institute of Fisheries Science, Fisheries Research Agency
水産総合研究センター、中央水産研究所国際会議場　（横浜）
Yokohama, JAPAN

DATE: 15-17 December 2004 (10:00 – 18:00)
2004 年 12 月 15-17 日　(10~18 時)

OBJECTIVES:

1) To identify and review advantages and limitations of fishery-independent stock monitoring and their causes,
漁業とは独立した資源指数の利点の問題点･限界を検討し､その要因を探る

2) To explore how stock indices can be used if certain levels of accuracy are achieved,
資源指数の正確さに応じた指数の利用方法を探る

3) To develop general rules when developing effective fishery-independent stock monitoring surveys, and
効率的な資源モニタリング調査であるための一般的な条件を探る

4) To develop a specific recommendation for the SBT case.
ミナミマグロ調査への勧告作成

Overall structures of Workshop:

The Workshop will be open to the public. A limited source of funds may be available for key speakers and/or coordinators traveling from outside Japan. English and Japanese will be used and simultaneous translation will be available.

Each session will have a keynote presentation by an appointed coordinator, presentation of called papers, general discussion, and summary notes by a coordinator. Agenda Item 4 is considered as a final wrap-up session with panel discussion followed by open-floor discussion. Then, panel members are requested to develop a summary conclusion and recommendations arising from the Workshop.

All speakers including coordinators are requested to submit an abstract either in English or

Japanese no later than 5 December 2004. Documents submitted, summary notes by coordinators, records of discussion, and summary conclusion and recommendation will be printed after review for distribution. Possibility of group submission to scientific journals is also under consideration.

PROGRAM:

1. **What we learnt from historical experiences of SBT Recruitment Monitoring Program? – Review of survey and results, pros and cons, technical limitation, logistic limitation, and impacts of environmental factors:**

1) Aerial survey
2) Acoustic survey
3) Tagging
4) Troll survey

現在までのミナミマグロ加入量モニタリングの手法と成果の再整理。特にモニタリング指標の信頼性と手法･調査デザインの問題点とを整理

Coordinator: John GUNN, Sachiko TSUJI

Presentations:

Alistair HOBDAY: Summary review of aerial survey. (航空機目視調査の総括)

Jessica FARLEY: Summary review of SAPUE. (SAPUE 調査の総括)

Yoshimi TAKAO: Review of acoustic studies conducted in RMP sonar survey. (加入量モニタリング調査で行われてきた水産音響試験のレビュー)

Tomoyuki ITOH: Review of the acoustic survey using sonar to monitor recruitment level of age one southern bluefin tuna. –Analysis of data for eight years. (ミナミマグロ 1 歳魚の加入レベルをモニターするためのソナーを用いた音響調査のレビュー－8 年間のデータ解析)

Tom POLACHECK, Norio TAKAHASHI: Summary review of conventional tagging.

John GUNN: Archival tags – windows to the migrations, behaviour and physiology of SBT recruits. （アーカイバルタグ-ミナミマグロ加入魚の回遊・行動・生理学への窓）

Tomoyuki ITOH: Review of the recruitment monitoring survey for southern bluefin tuna by trolling. (曳縄漁獲調査によるミナミマグロ加入モニタリングのレビュー)

2. **Evaluation of accuracy and precision of historical recruitment indices:**

1) Review of available information on SBT recruitments:
   ① Recruitment fluctuation obtained from stock analyses
   ② Direct observation of recruitment fluctuation – LL CPUE and surface catches, data extracted from direct aging
   ③ Information obtained from tagging
2) Consistencies and discrepancies among indices and evaluation of historical SBT recruitment indices.
3) Impacts of oceanographic conditions on recruitment and uncertainties of monitoring indices

ミナミマグロ加入量変動に関する情報の整理。特に資源評価結果、標識放流事業の結果、直接年齢査定情報から得られる情報等を再整理する。その上で各加入量モニタリング指標精度と正確さを評価する

Coordinator: John KALISH

Presentations:

John GUNN: An application of statistical analyses of archival tag data on the diving behaviour and fine scale movements of Southern Bluefin Tuna (*Thunnus maccoyii*) to an estimation of abundance based on aerial surveys of surface orientated schools. (アーカイバルタグで得られたミナミマグロ（*Thunnus maccoyii*）の潜水行動･詳細な移動データ統計解析の航空機目視による表層魚群量推定への応用)

Alistair HOBDAY: Influences of environment on aerial and acoustic survey indices. (航空機目視指標、音響指標への環境の影響)

Ryo KAWABE: Automated monitoring of juvenile SBT migration in southern Western Australia and implication for the design of Acoustic Sonar survey. (西オーストラリア州南におけるミナミマグロ幼魚の自動モニタリングと音響調査計画への応用)

Kazushi MIYASHITA: Analysis of fish schools migration direction and migration velocity from scanning sonar. (スキャニングソナーからの魚群移動方向・移動速度の解析)

Sachiko TSUJI: Comparison of various recruitment information for southern bluefin tuna. (ミナミマグロ各種加入量情報の比較)

Denzo INAGAKE: Preliminary results of study on the relation between southern bluefin tuna resources and atmospheric-oceanic variability. (ミナミマグロ資源と気象･海況変動との関係に関する予備的研究)

Akihiko YATSU: Outline of prerecrutiment survey of Japanese sardine and chub mackerel in the Kuroshio/Oyashio Transition Zone: a challenge for forecasting recruitment levels and early survival processes. (黒潮／親潮遷移ゾーンでのマイワシとマサバに関する加入前調査の概要：加入量水準および初期生存過程を予測する)

3. **How can recruitment indices be used in stock assessment and management, depending on level of accuracy and precision of indices? -- Quality requirement of recruitment indices useful for stock assessment and management points:**

1) Need for recruitment indices, and minimum requirements for usable index
2) Priority between accuracy and precision from assessment and management view points
3) How can indices be used if indices satisfy XX? – Consideration of feasible

scenarios

資源評価の立場から要求される加入量情報の精度と、現状のモニタリング手法の限界との関係の整理

Coordinator: John Kalish

Presentations:

Yasushi NAKAZATO: Evaluation of the current SBT recruitment monitoring survey and future effective investigation- Question and proposal from executive official -. (現行の SBT 加入量モニタリング調査の評価と今後の効果的な調査のあり方について－行政官からの質問・提言－)

Tom POLACHECK: Requirement from stock assessment points

Andy BODSWORTH: Role of recruitment indices in management decisions.

Norio TAKAHASHI: Where do large-scale monitoring surveys go? - from a cost-performance view point (大規模モニタリング調査はどこへ行く？－コストパフォーマンスの視点から)

４． Overall conclusion and recommendation for future SBT Recruitment Monitoring Program (Panel Discussion)

1) Keys in establishing long-term recruitment monitoring system (inc. balance between accuracy and precision of indices and required cost)

長期モニタリングに必要な条件の整理、具体的な提案･勧告の作成、及び今後の研究協力体制の確立

Coordinator: John GUNN, Sachiko TSUJI

INTRODUCTION:

1. Opening Remarks:

Yoshio ISHIZUKA (National Research Institute of Far Seas Fisheries, Fishery Research Agency)
石塚　吉生 (水産総合研究センター　遠洋水産研究所)

皆さん、おはようございます。ご紹介いただきました遠洋水産研究所所長の石塚です。本日はこの WS のために国内だけでなく、海外からも多くの方々に参加していただき、大変ありがとうございます。また中央水研からは、この立派な会議室を提供していただきました。改めて御礼申し上げます。

さて、このミナミマグロ加入量モニタリングプログラムは私にとって大変思い出深いものです。私は 1990 年から約 5 年間、今の辻さんと同じ立場でいました。そのとき今ここにいる John Gunn さんや Tom Polacheck さんといっしょにこの仕事を始めたことがあります。当時のミナミマグロ親魚資源量は減少の一途をたどっており、一方若齢魚では若干いい兆候も見えていたところです。こういう悲観的な状況と楽観的な状況とが混在する中で、資源評価、あるいは将来予測で、各国の科学者の見解が大きく分かれておりました。しかし資源評価の厳しい議論の中でも、皆さんが共通して認識していたのは、今後のミナミマグロ資源の方向を大きく左右するのは加入量であり、それをタイムリーかつ精度良く推定することが、もっとも大切であると、皆さん、認識していたと思います。加入量を精度良く推定できれば、資源評価あるいは将来予測の不確実性が減少し、資源枯渇の危険性が減少し、そして持続的な資源利用につながる、という認識でした。そこでどういう調査を行ったらいいか、みんなで検討しました。その結果、航空機によるライントランゼクト調査、船舶による調査、あるいは acoustic survey、それに加えてタギングが開始されました。また観測データを正しく評価するためや、環境による魚群分布や行動への影響を把握するため、アーカイバルタグなどの補足調査も実施されました。幸い、各国の行政部局のご理解、財政的なバックアップもあって、その後長期間の精力的な RMP が行われ、ミナミマグロの加入量、分布生態、及びこれらと環境との関係等、多くの科学的知見が得られました。そして、これらの成果は資源評価に取り入れられ、評価精度の向上の貢献してきたものと思っております。

さて、今回のワークショップは、このような経過で行われてきた RMP をレビューし、さらに効果的な RMP を見出すことが目的だと思っております。これまでの知見を用いて、コストパフォーマンスのいい資源評価のための加入量調査、解析方法を検討していただきたいと思っております。また議論を通じて、新しい調査研究の方向が見出されるかもしれないと期待しております。これまでミナミマグロで行ってきた、RMP の先進的な調査研究手法・成果は、他のまぐろ類及びその他の資源の加入量調査研究にとっても、大変参考になるものと思います。また今回のワークショップによってこれまでの成果がとりまとめられることから、さらに有効な情報が発信できるものと確信しております。それでは 17 日まで

の 3 日間のワークショップが実りあるものとなるよう、皆様の活発な議論をお願いして、ご挨拶とさせていただきます。ありがとうございました。

2. Background and objective of the Workshop -- 1:

Sachiko TSUJI (National Research Institute of Far Seas Fisheries, Fishery Research Agency)
辻　祥子 (水産総合研究センター　遠洋水産研究所)

3. Background and objective of the Workshop -- 2:

John GUNN (CSIRO Marine Laboratory)

SESSION 1 – Review of Recruitment Monitoring Program:

1. Summary review of aerial survey
航空機目視調査の総括

Alistair HOBDAY (CSIRO Marine Laboratory)

Summary:

A review of the line transect aerial survey of juvenile southern bluefin tuna (SBT) in the Great Australian Bight (GAB) was presented. A full scientific aerial survey was conducted annually from 1993 until 2000, and the data formed the basis of a fishery-independent index of juvenile SBT abundance. The methods of the survey were presented including logistical problems encountered in the latter years regarding the unavailability of trained spotters. In 2001, the survey was suspended to allow for extensive analysis of the existing data. Since then, a large amount of effort has been directed at improving the index by incorporating information from the supporting projects. The re-analysis of the 1993-2000 data by Bravington (2003) concluded that the aerial survey does provide a suitable relative index of juvenile SBT abundance in the GAB with CVs of around 30-40%, and could in principle be improved with more data. It has also been recognized that the level of uncertainty is similar to that found in other fishery-independent surveys carried out around the world. With a 30-40% CV, you would expect to detect a 50% change in juvenile abundance over a 5-10 year period.

In 2002-2004, the full line transect survey was scaled down while analysis of the existing data occurred; it particular to examine key assumptions and the uncertainty in the index. A reduced line transect survey occurred in the interim (2002-2004). The reduced survey relied on the volunteer participation of commercial spotters and planes when not required for commercial spotting, which meant that it was both reduced and ad-hoc in terms of the timing, location and number of transects flown. This, together with the high variability in abundance estimates resulting from reduced effort (CV ~45-154%), suggests that an ad-hoc reduced survey will not provide a reliable indicator of juvenile SBT abundance.

Recent work comparing the 1993-2000 aerial survey index with the Stock Assessment for SBT

found no evidence for inconsistency between the two time series such as might be caused by variations in the proportion of juveniles entering the GAB. However, the approach could not discount low levels of inter-annual variation.

Discussion:

The ways in which we could present the reliability and usefulness of indices to the managers were discussed. The 95 % confidence intervals were very high as the standard used in the decision making on fishery management and so that the result only based on this value could be unduly pessimistic. At the same time, it was noted that the uncertainties in the stock assessment context would be reduced when multiple information was used together. However, the portion of the presentation showing that the aerial survey with 30% CV indicated to be able to detect a 50% change in abundance of juveniles over a 5-10 year was emphasized as very useful way for fishery managers to understand the meaning of the real uncertainties of index and to help in making decisions.

It was explained that the full scale aerial survey would be run in the Australia this summer with inexperienced trainees and trained spotters sitting on the same plane. The index would be estimated by only using the data collected by experienced spotters, although the data could be used to test for the effect of inexperienced spotters.

2. Summary review of SAPUE (SAPUE 調査の総括

SAPUE 調査の総括

Jessica FARLEY (CSIRO Marine Laboratory)

Summary:

A review of SBT sightings data collected by commercial tuna spotters between 2002-2004 in the GAB was presented. The data was collected by experienced tuna spotters while engaged in commercial fishing activities in the eastern GAB, and formed the basis of nominal and standardised indices of surface abundance per unit of effort (SAPUE). Unfortunately, data were only obtained for a small area where concentrated commercial fishing occurred. Since nothing is known about the abundance of SBT in areas not searched, the SAPUE indices obtained are difficult to interpret and suffer from similar problems to those associated with longline CPUE. Further, it was suggested that the standardised SAPUE results are sensitive to analysis assumptions and should be treated with caution. However, the commercial spotting data has potential to be used to calibrate between spotters (eg school size measurements and their ability to detect schools), and improved estimation of the effects of environmental factors on sightability.

Discussion:

The question was raised on usefulness and utility of this sort of work, collection of data from commercial activities, for the next five to ten years; especially in a term of comparison with transect type systematic scientific survey. The meeting noted it important to include industry

data when understanding what is going on in the stock, although recognizing the difficulty of interpretation and potential bias caused from commercial nature operating in a restricted area. For example, when population was contracted into small area and commercial activities only focus in that area, relying only on fishery dependent data would give a very biased view on what was going on in the stock.

It was recognized that the commercial spotting data or SAPUE will be only potentially meaningful index of fish abundance that can be obtained from commercial fishing activities in the GAB, far better than simple CPUE of pole and line and purse seine operations. Also, it was noted that the required cost to collect these data was relatively low and even going down each year. Then, the meeting considered that this should be endorsed as the data to be collected routinely in the long term.

Relative utility and reliability between fishery dependent and fishery independent indices were discussed a little bit but major discussion was deferred for the later opportunity.

Regarding the utility of the commercial spotting data for calibration purposes, it was cautioned to use these data for calibration of detestability, because the detestability very much varied according to search behaviors and it would not be proper to take difference in commercial search including back and forth checking behaviors and in line transect survey as difference in spotting ability by spotters. However, the usefulness of these data for calibration of spotters' ability in estimating school size was noted when able to be sure the data come from the same school.

3. Review of acoustic studies conducted in RMP sonar survey

加入量モニタリング調査で行われてきた水産音響試験のレビュー

Yoshimi TAKAO (NRI Fishery Engineering, FRA)
高尾　芳三 (水産総合研究センター　水産工学研究所)

Summary:

Sonar survey in Western Australia has been conducted to obtain juvenile Southern Bluefin Tuna (SBT) recruitment index from 1996. Omni-directional sonar is operated by experienced sonar specialists to scan wide area and track fish schools. Sonar specialists estimate both species and biomass of fish school from sonar image. Acoustic studies have been conducted to improve the accuracy and precision of sonar survey. It is important to know the performance of sonar and the acoustic properties of target animal. The following studies are reviewed.

Sonar technology to estimate SBT biomass

- History of hardware specifications of sonar used in RMP survey
- Affect of oceanographic factors' change on sampling volume
- Sonar calibration with standard target
- Inter-calibration of sonar specialists
- Trial of biomass estimation from sonar image

Acoustic scattering properties of juvenile SBT and other species

- Target strength measurement of live fish in cage
- Sound propagation speed of muscular tissue of SBT
- Target strength of SBT calculated by acoustic scattering model
- Target strength measurement of Aussie mackerel controlled tilt angle

Discussion:

The role of sonar specialists was questioned. It was explained that the role of sonar specialists was as much like the role of spotters in the aerial survey, identifying species and making estimation of biomass of schools based on long years' experience. In both cases, subjectivities were included in their judgment. It was noted that the current research effort was trying to develop a method in identifying species and estimating school biomass in an objective, automatic and mechanic way.

4. Review of the acoustic survey using sonar to monitor recruitment level of age one southern bluefin tuna. –Analysis of data for eight years

ミナミマグロ1歳魚の加入レベルをモニターするためのソナーを用いた音響調査のレビュー－8年間のデータ解析

Tomoyuki ITOH (NRI Far Seas Fishery, FRA)
伊藤　智幸 (水産総合研究センター　遠洋水産研究所)

Summary:

As the research surveys to obtain recruitment abundance indices of age one southern bluefin tuna (SBT) in the framework of the Southern Bluefin Tuna Recruitment Monitoring Program, the acoustic monitoring has been carried out, followed by the trolling monitoring survey which had been conducted for five years. After two years feasibility surveys, the acoustic survey has been carried out every year since 1996 (1995/96 season) to 2002 and provide recruitment indices. In this review, the acoustic surveys for eight years are overviewed. Then, examine how adequate the survey method to obtain index that reflects the abundance of age one SBT using the eight years data and other available data.

In the acoustic survey, fish schools were searched while cruising zigzag transect lines which scientifically designed within the pre-fixed survey area off the southern coast of Western Australia. On-board sonar specialists estimated species and biomass of schools found. Fish were caught by trolling to confirm the species of the school and to estimate age composition of SBT within the survey area. The index is calculated as a biomass of age one SBT within the survey area considering the area transected incorporate effective wide of sonar searching and duration of transected. The indices were sharply declined and stable at low level since 2000.

Various things, such as research season, area, species identification and biomass estimation by sonar specialists, age composition of SBT, and the number of line transected, were examined. Australian fishery data were helpful. As a result, no serious problem that could explain the large decline of the index since 2000 has found in the survey methods. However, it should be

noted on uncertainties of the distribution and migration dynamics of age one SBT and biomass estimations of sonar specialists.

Discussion:

It was noted that although some changes were also made in acoustic equipments used, all of those changes had actually improved the detectability of fish schools and could not explain the observed drastic decline of indices in recent years.

The presentation concluded that the current survey design worked reasonably well as least to an extent to satisfy the original intention to monitor majority of one-year-old abundance migrating through the Western Australia survey region, as long as fish migrated into the region in the similar way in history, and that they could not find specific factors that would possibly explain the observed decline of SBT indices. It was pointed that the review efforts did not cover whether the survey is an adequate way to approach getting relative abundance index over long time of monitoring in a quantitative sense.

Although there were still some unresolved issues, the meeting participants were encouraged to provide specific proposal of improvement and to move things forwards.

5-1. Summary review of conventional tagging – (1)

通常標識放流調査のレビュー (1)

Tom POLACHECK (CSIRO Marine Laboratory)

Summary :

A summary of the conventional tagging under the Recruitment Monitoring Program (RMP) was presented. The primary objective of the conventional tagging program was to estimate juvenile fishing mortality rates (F) by age and year through a multi-year, multiple cohort tagging program and with these estimates combined with catch data to provide estimates of recruitment for each cohort tagged. Conventional tagging of juvenile SBT was conducted from 1990/91 through 1996/97 fishing seasons. Tagging was then suspended because after 1997, a lack of observers in longline fisheries meant there was no information for estimating reporting rates from these fisheries. Altogether 67,937 tags were released during this period up to 1997. Most of the tags were released from pole and line captured fish but 848 fish were released by observers on commercial longliners. This was the first large-scale release of tags using longline-caught fish and the recovery rates were similar to surface released fish. In addition, an additional 2771 tags were subsequently released in the 2000-01 summer under the RMP as a precursor to the CCSBT Scientific Research Program (SRP) conventional tagging program. Under the RMP, extensive publicity and liaison work was conducted to promote the return of tags from recapture fish.

The key outcomes of the RMP conventional tagging program were:

- Year/age specific juvenile fishing mortality estimates.

- Fishing mortality increasing in the 1990s
- Average juvenile natural mortality rates were ~0.35. This was substantially higher then previously assumed
- Juvenile growth rates in the 1990 appear similar but higher to those in 1980.
- Validation of direct aging methods.

The conventional tagging program provided valuable developed effective approach and an understanding of the prerequisite for design and implementation of tagging experiments for recruitment monitoring of SBT. These included:

- Effective mechanisms for recovering tags from the various SBT fisheries
- Estimating reporting rates essential from the different fishery components (observers and tag seeding)
- Reliable catch data by size for all fishery components.
- Spreading of tags to ensure mixing (tagging from longliners)
- Effective training of taggers to ensure low tag shedding rates.
- Estimation of shedding rates - double tagging
- Resource/time needed to be devoted to analyses of results.

The RMP conventional tagging program has resulted in a large number of follow-up and spin-off research projects and results including the incorporation of conventional tagging as one of the priority components of the CCSBT Scientific Research Program; part of the impetus for scientific observer program in SRP; high seas longline tagging (conventional, archival, PSAT), development of tag seeding programs for reporting rates from farms; development of new analytical methods and a commitment from the CCSBT to direct-age estimation of the SBT catch. The results from the RMP conventional tagging program yielded the following overall conclusions:

- Tagging provides an effective mechanism to monitor SBT recruitment;
- Effective implementation is critical (collaboration on reporting rates, proper training, experimental design)
- large number of additional benefits exists (estimation of growth, movements, natural mortality, etc)
- the results suggests increasing fishing mortality rates on juveniles in the 1990s and possibly decreasing recruitment and
- substantial scope exists for improving current analyses and future experiments

Discussion:

The estimation of reporting rate was noted as one of the key problem in determining the success of the conventional tagging program. In fact, it was explained that one of the factors leading to stop the RMP tagging in 1997 was related to that the observer program in Australian zone was terminated in 1998 essentially because no longline fisher in zone. Without the information on reporting rate, it would not possible to separate non-mixing or partial-mixing issues from non-reporting and lead to biased estimate of abundance. It was noted that the current SRP tagging program picked up by the CCSBT was also developed in conjunction with development of the scientific observer program monitoring the longline fisheries.

Corresponding to the question on which of indices presented was actually incorporated into stock assessment, it was explained that the indices obtained from the conventional tagging program is not used in the same way as the indices obtained from the Recruitment Monitoring Program. The approach that the CCSBT generally uses is to integrate raw tagging data into assessment as an additional source of information together with CPUE, catch at age data and so on to determine about recruitment trends. This approach was considered as more robust in technically and statistically especially in the case of tagging data due to an interaction with catch at age data.

5-2. Summary review of conventional tagging -2

通常標識放流調査のレビュー (2)

Norio TAKAHASHI (NRI Far Seas Fishery, FRA)
高橋　紀夫 (水産総合研究センター　遠洋水産研究所)

Summary:

As additional information to this review of the conventional tagging program, some results from Japanese longline tagging off Cape Town (South Africa) were briefly presented. SBT movement revealed by returned archival and conventional tags suggests a possibility that fish do not mix uniformly between South Africa and Australian waters, with some separation between east and west. This might affect parameter estimates using tagging data.

Discussion:

Although the partial mixing had been recognized as an important issue of tagging data, several points of caution were raised against a simple comparison between the data obtained from the western and southern Australia release and those obtained from the west Indian Ocean tagging, which included the age difference; ages 1-3 from the GAB release versus age 3-4 in the west Indian Ocean release, the substantial difference in number of fish tagged and released between two projects, and the inclusion of data recaptured within six month after release, the period with high potential of non-mixing, in the west Indian Ocean tag data. It was noted that no combined comparative analysis of those two data sets had not been made and recognized as one area for future collaboration between Australia and Japan.

It was noted that there were some level of site fidelity. It was important for the all Recruitment Monitoring components to understand the behaviors of juveniles around South Africa and their impacts on estimation of recruitment indices. It is still uncertain if a consistent proportion of juveniles occur off southern Africa and in the GAB each summer.

It was noted that the pattern of fishing activity has to be considered when analysing conventional tagging data. In that context, the importance of reliable data on catch location and composition by fleets together with tag recapture data was emphasized.

6. Archival tags – windows to the migrations, behaviour and physiology of SBT recruits

アーカイバルタグ-ミナミマグロ加入魚の回遊・行動・生理学への窓

John GUNN (CSIRO Marine Laboratory)

Summary:

CSIRO scientists and Australian electronic engineers developed archival (data storage) tags for use on tuna were developed in the early 1990's for use in studying the patterns and processes of migration in oceanic pelagic fishes and to overcome the significant gaps in our knowledge between the fine-scale data we'd collected using ultrasonic telemetry and coarse-scale data derived from conventional tag-and-recapture experiments. The technology has now been used successfully throughout the world on three species of bluefin tuna, and recently also on bigeye tuna. In all cases, the data collected have provided a quantum leap forward in our understanding of the biology and ecology of species.

Since 1994 we have used archival tags to examine the movements of juvenile SBT. The results from recoveries have challenged the conceptual models based on conventional tag data. We have found that large-scale, cyclic migrations, associated with major changes in habitat and feeding behaviour, are common. The data from archival tags indicate that our previous understanding of migratory behaviour was significantly biased by the behaviour/co-operation of fishermen.

Archival tags have shown us the nature of variation in behaviour over daily, weekly, lunar and seasonal time periods. For example, diving patterns vary on lunar cycles when fish are in oceanic waters, but not when they are in coastal waters. Fish sun-bake in the upper 2 metres of the water column during summer afternoons, but in the winter prefer to spend most of the day at depth sin excess of 200 metres. At some times of the year fish are restricted to depths above the thermocline, while at others this provides no barrier to movement. Although explanations for the variability are difficult to determine, we believe the majority are related to shifts in feeding behaviour.

The internal thermistor of the archival tag has allowed us to examine variation in visceral temperature. As Carey found for Atlantic bluefin in the 1970's, visceral temperature in SBT increases as digestion begins and remains above basal core temperature throughout the digestion process. Using thermodynamics models, we have been able to examine when, how often and where fish are feeding. These data show that fish frequently go for many days to a week or so

without feeding; the longest period of “starvation” is 42 days. We are currently examining the relationship between the amount of heat produced and ration/calorific to determine whether we can also estimate the amount of food eaten over a given period.

The presentation will provide an overview of the new information provided by archival tags with particular focus on the use of these data for the monitoring of recruitment in SBT.

Discussion:

Correspondence between fish location estimated from archival tags and fishing area by Japanese and Taiwanese longline vessels in the eastern Indian Ocean was discussed. During summer, October to February, the Japanese fleet do not operate in the area of off Cape where two archival tagged fish stayed, although there was historical record of catch of small individuals in that area. Taiwanese vessel might be operating in the area.

Reliability and possible systematic bias in geo-location estimates of archival tags were questioned. The latitude estimation in this work estimation has been obtained from oceanographic data, i.e. sea surface temperature and there can be error of around one to two degrees. This was considered at least without seasonal bias because the spread of isotherm does not show a large inter-seasonal variation within the area southern blufin tuna migrate. The longitude position is estimated from the archival tag light data. It was convinced that the longitude can be estimated within plus or minus half degree through light, through experiments with fish in cages or mooring experiments. Especially when estimated points gather into one point like a cloud, actual fish location should be within one degree band around the point at any time of year at any part of world.

It was noted that the archival tag data and conventional tag data gave quite different picture. From archival tags, it seemed that the majority of SBT released from the Great Australian Bight appear to undertake a cyclic migration out into the Indian Ocean in winter, and back to Australia for summer and that very few individuals move into the western part of the Indian Ocean. When focusing on returns of archival tags from Japanese longline vessels, only 2 returns were from the western Indian Ocean, whilst around 10% of total archival tag returns were made by the Japanese vessels and majority of those were from Tasman Sea, or eastern Indian Ocean. On the other hand, about one third of conventional tags reported from Japanese longline vessels were returned from the western Indian Ocean. Though various factors including differentiate reporting rates by fleets or by tags would need to be consider to interpret these information, the need in getting better information especially from the western Indian was recognized to understand global migration and mixing of bluefin tuna. It was also noted that the issue of mixing was critical for how we interpret information getting out the RMP.

7. Review of the recruitment monitoring survey for southern bluefin tuna by trolling

曳縄漁獲調査によるミナミマグロ加入モニタリングのレビュー

Tomoyuki ITOH (NRI Far Seas Fishery, FRA)

伊藤　智幸 (水産総合研究センター　遠洋水産研究所)

Summary:

For five years, since 1988/89 to 1992/93, a monitoring program for southern bluefin tuna (SBT) based on trolling operation had been conducted. Trolling operations had done off the west and south coasts of Western Australia by 3-4 chartered Australian vessels to obtain a recruitment index. When SBT were caught, pole & line was also conducted by the vessels to obtain data of school sizes. Two types of transects had done; 1) survey on lines lay systematically at parallel, east-west or north-south, and 2) survey on spots where SBT usually distributed intensively. Survey off the west coast was finished after the first two years because of little number of SBT caught.

As the results of the surveys, it was found that SBT distributed intensively at so-called “hot spot” where located on special geographic feature or at the edge of continental shelf, i.e. geographical distribution of SBT vary largely. Therefore, confidence interval of the indices became quite large for the survey on lines lay systematically, though less for the other type of survey. In addition, the monitoring based on trolling catch is inherent in uncertainty of influence on selectivity of fishing gears, fish activity of feeding, and absence of information on school size. Then, the trolling monitoring survey was finished and the development of acoustic monitoring method has started.

However, trolling is so powerful for monitoring on maneuverable, cost efficiency, and no necessity of special expensive devises that it would be valuable as a supplemental survey on which provide a rough abundance index from wide time-and-area. Analysis of the trolling catch data in the acoustic monitoring surveys shows roughly.

Discussion:

Higher catchability, higher gear efficiency, was proposed as one potential explanation for relatively high catch by trolling despite of low acoustic index in 2003, since the field technician onboard in 2003 was very keen and good for catching fish with trolling gear. At the same time, it was reported that neither systematic changes in catchability nor gear configuration were observed during this survey period. This problem suggested the difficulty to deal with consistency in efforts or effectiveness in efforts that would be influenced by uncontrollable factors. This was noted as a common problem for any survey.

Although having multiple sources of information was obviously valuable, caution was raised on drawing conclusion about utility of trolling survey without having rigorous statistical analysis including variances, biases, and process errors. Since the following sessions were expected to deal with the relative utility of each component of the Recruitment Monitoring Program, the further discussion was deferred.

It was questioned whether the commercial trolling data accumulated for 30-40 years could be used together with the information obtained from the survey to provide any meaningful measure of recruitments. Difference in operational patterns and catchability between commercial and

survey operations were noted.

It was sought an example using troll survey data as an index of abundance in the world. Although the troll gear was commonly used for albacore in the South Pacific and North Pacific, those data were not used as an abundance index. In Japan, the other pelagic gears, drift gillnet for salmon and pelagic trawl for sardines and mackerels, had been increasingly utilized to monitor stock abundance. Although it was difficult to theoretically evaluate the representativeness of values obtained with pelagic gears, some of survey results were considered to reflect the actual stock fluctuation relatively well judging from their experiences. Gear saturation and difficulty in distinguishing sampling individuals and sampling schools were further identified as possible problems of pelagic gears.

8. Wrap-up discussion

まとめ

Coordinators: John GUNN, Sachiko TSUJI

Conventional and Archival Tagging

Conventional tagging would provide a powerful way to estimate cohort strength, fishing mortality and natural mortality with a good understandings on statistical and theoretical aspects. The Recruitment Monitoring Program had contributed substantially to the improvement of tag implementation procedures and parameter estimations. Even knowing the ideal tagging procedures, it would be hard to implement them in reality partly due to shortage of resources and strong will. The conventional tagging program has been now shifted to the CCSBT SRP. Although some discussion was made on the importance of tag seeding over the entire known range of juvenile distribution, the importance of reporting rate estimation, and the use of observers both for obtaining reporting rate estimation and putting tags on fish, those issues were considered more relevant to the discussion at the CCSBT level.

Aerial Survey

The aerial survey had developed a statistically robust sampling design to cover essentially the whole of the distribution of age 2-4 juveniles in the Great Australian Bight during summer. The latest review by Bravington et al. (2003) provided a good summary of source of uncertainties, estimate of the level of uncertainty around the current index, and way to improve. The level of uncertainty was considered to be within the bounds providing good additional information into the stock assessment on the aggregated relative abundance for ages 2-4. The availability of experienced spotters continued to be a problem and the calibration experiments would be the critical part of the survey. As long as there were trained spotters and calibration of spotters could be done properly then it could provide a relative index that could be used in the CCSBT stock assessment process. Consideration should be given to the transition from a research phase to more routine phase, although it was recognized that a high level of involvement of scientists would be needed even after shifting to the routine phase. The reduced line transect was not considered to be suitable. The level of cost for conducting the full scale aerial survey was about

the same magnitude of the on-going cost of the conventional tagging program by the CCSBT SRP.

Acoustic Survey

Good progress was made in understanding the strength and weakness of the acoustic survey from the technical and instrumental prospects as well as from the survey design and analytical point through the review process occurred during the last two years. The capability to monitor a relative abundance of one year old, i.e. one age class at the earliest possible stage, was considered as the strongest point of this survey. On the other hand, the non-linear relationship between the index and fish abundance, the problem relating with detectability, and the involvement of potentially large process errors were recognized as the weak aspects.

Quite lengthy and intensive discussion was held regarding to the current status of the survey. Some considered that the survey was still at the developmental phase and needed more research work on statistical properties of data, general fish behaviors and their annual and seasonal variability before accepting as the informative index. The others, especially for those actually had participated in the survey, considered that the survey technique and design had been already adequately proven to provide reasonable reliable estimates of relative abundance of one year old juveniles within the survey area and that it would be time to re-design the survey to fit for the longer-term monitoring purpose. There was a general agreement that the acoustic survey would be more suitable for extracting very rough measure of abundance like a presence/absence measures to be used as an early warning signal.

Both aerial and acoustic surveys relied on the subjective judgment by specialists of school detection, species identification, and school abundance estimation and the potential to develop more automated objective methods were argued. The previous intensive work had proven that it was very difficult to replicate the experience in interpreting images or schools from the air. However, in the case of acoustic survey, the efforts toward the automated sonar system had been already initiated in various areas and there was some prospect that the automated quantitative sonar would be manufactured in near future under the current rapid development of both hardware and software relating to the acoustics. Currently, all acoustic records were kept in digital raw form, which could be re-analyzed when the appropriate processing software would become available in the future. Corresponding to the suggestion to introduce the more powerful device, it was confirmed that the current survey was using the most advanced and most powerful acoustic system in the world.

Troll survey

Troll survey would certainly provide a source of information of relative abundance of one year old when conducting in conjunction with the acoustic survey or conventional tagging work as an ancillary indicator.

SESSION 2 – Evaluation of historical recruitment indices:

1. An application of statistical analyses of archival tag data on the diving behaviour and fine scale movements of Southern Bluefin Tuna (*Thunnus maccoyii*) to an estimation of abundance based on aerial surveys of surface orientated schools

アーカイバルタグで得られたミナミマグロ（*Thunnus maccoyii*）の潜水行動･詳細な移動データ統計解析の航空機目視による表層魚群量推定への応用

John GUNN (CSIRO Marine Laboratory)

Summary:

Since 1994, archival tags have been used to study the migrations, behaviour and aspects of the physiology of juvenile southern bluefin tuna (SBT) in the southern Pacific, Indian and Atlantic Oceans. In this investigation we used depth and location information from tags deployed and recovered in the Great Australian Bight (GAB) to investigate the relationship between surfacing, and hence detectibility in an aerial survey, and environmental conditions. The objective of the work was to allow for standardization of aerial survey effort under a range of environmental conditions – in effect to account for the probability of seeing a fish on the surface.

Several methods for classifying depth information into behavioural definitions related to surfacing were considered for four time-scales, in different areas of the GAB. Generalized linear models were developed to explore the relationship between the surfacing measure (response) and environmental (covariates) variables in each of three areas covered by the aerial survey. The surface-oriented behavioural definition and the whole-day time-scale were chosen for final model selection based on preliminary analysis of the data. The timing and extent of surface-orientated behaviour and its environmental covariates varied significantly among areas within the GAB, and our final models explained between 26.9% and 51.2% of the null deviance. The inability of the analyses and models to account for more than 50% of the observed responses is discussed from a umber of perspectives, including variation in behaviour among individuals, the constraints imposed by the accuracy of geolocation estimates from archival tags, and the challenges of linking tag-based observations with those from satellites or model-derived oceanographic data.

Discussion:

Corresponding to the question about the difference in behavior depending on ages, it was noted that only 3 year-old fish have been tagged in the Great Australian Bight so it is not possible to determine whether the behaviour observed is age dependant. However, one year old fish tagged in the Western Australia showed radically different behavior to those observed in the South Australia, and they were more surface orientated and spending more than 90 percent of time in the top 20m of water column.

There was some discussion on the consistency between results obtained in this study and fishermen's observation of fish behaviors. Though the fishermen's recognition on fish behaviors varied significantly, some fishermen predicted very well the types of fish responses observed with archival tags. It was noted that although fish stayed majority of time in the surface depth,

they were not necessarily in the rippling or shining status that fish became visible from the boats. It had not been totally resolved through the consultation with the industry what was the real likelihood of fish to be seen by spotters when staying within the top 20 m depth and whether there was difference in the likelihood depending on behavioral types.

There was also some discussion about how individual fish behaviour related to an overall school behaviour. Some anecdotes supported that the types of behaviors classified here could be observed in fish schools at sea. It was noted the benefit in utilizing sonar watching overall school behavior and their biomass together with archival tagged fish to better understand behaviour of fish schools.

2. Influences of environment on aerial and acoustic survey indices

航空機目視指標、音響指標への環境の影響

Alistair HOBDAY (CSIRO Marine Laboratory)

Summary :

The apparent abundance of fish is influenced by uncertainty in observation error and process error. One contribution to process error is the response of fish to environmental influences. These influences can impact the precision possible in recruitment indices. Two of these indices have been developed under the RMP, and the influence of the environment has been investigated in both index regions.

Aerial Survey Region and Index

Improvements to the 1993-2000 aerial index and reduction of index uncertainty were attempted by including environmental variables that may influence the abundance or detection of SBT in the aerial survey region. Juvenile SBT are surface-orientated and non-randomly distributed in the GAB during the austral summer. In particular, SBT are clustered around the shelf break and inshore reefs, islands and rises, collectively known as lumps. Because of the greater detection frequency at these locations, the presence of SBT observed during the aerial survey was analysed with regard to the topographic characters of these features and local environmental variables. The focus on the regions of highest SBT abundance increased the “signal to noise ratio” and the goal was to identify environmental variables that could be included in future indices covering the whole survey region. Generalised linear models indicated non-linear relationships between the presence of SBT at topographic features and environmental and topographic variables, and models incorporating topography and the environment explained 40% and 28% of the deviance at the lumps and shelf break respectively. The significant environmental variables differed between locations; at the shelf they were wind speed, swell, air temperature, and sea surface temperature (SST), while at the lumps they were wind speed and SST. Chlorophyll was important in some preliminary models, but insufficient temporal coverage for this variable prevented it being considered in the final models. Overall there is a moderate influence of the environment on distribution of SBT at the time and space scales considered on the distribution within the

GAB. Environmental variables are now included in the aerial survey indices.

Acoustic Survey

Over the history of the RMP a number of projects have attempted to explore the influence of the environment on the distribution and abundance of age-1 fish in southern Western Australia. The most recent efforts, in 2003-04 have been focused on exploring the decline in the Recruitment Monitoring Program (RMP) acoustic survey recruitment index for age-1 southern bluefin tuna (SBT) that occurred in 2000 and remained low in subsequent years. A similar decrease in commercial SBT catches in the Great Australian Bight was not observed, indicating that the age-1 recruitment index did not reflect subsequent SBT recruitment at older age classes (2-5 year olds). This possibility that a change in environmental conditions was responsible for the decrease in the index by causing juvenile SBT to avoid the survey area during the period on which the index is based (January to March) was investigated by acquiring and analyzing a large number of environmental datasets. These consisted of satellite datasets, environmental models, *in situ* observations, archival tags and biological samples. Consultation between scientists from Japan and Australia at two early project meetings generated a variety of hypotheses for investigation. Various analyses were used to investigate the datasets including yearly anomalies, anomalies along the Leeuwin current trajectory, habitat suitability indices, Leeuwin current characterisation and temporal diet content analysis. Where possible and applicable these analyses were conducted in three key locations – (i) an upstream area to the west, (ii) the area from which the acoustic index is constructed and (iii) a downstream area to the east. Comparison between these areas should reveal if there has been a spatial shift in the location of suitable environmental conditions. This project did not reveal any environmental variables that are temporally consistent with the change in the index nor are there spatial differences that suggest a shift in suitable habitat. There are some aspects that would benefit from further attention, primarily the characterisation of the Leeuwin current. This is a difficult problem with potential impacts on SBT and in which further investigation would be beneficial. The effect of a combination of environmental variables is also worthy of investigation, however, the limited temporal period of the abundance index makes such analyses problematic. It seems overall that the distribution of age-1 juvenile SBT is not strongly linked to environmental variables at the spatial and time scales investigated to date. Including environmental variables in the Acoustic Survey Index is not recommended at this stage.

Discussion :

The question was raised on whether one year old fish were passing through the acoustic survey area or they were resident in one place for some time and it was pointed that both hypotheses should be kept when analyzing data until the time that this question would be solved. The analysis of short recaptures from the conventional tagging conducted in the 1960's and 1980's in the Western Australia was suggested as one possible way to address this question. In fact, many efforts had been made to address this question including analysis of conventional tag data, and archival and sonic tag data and it was explained that this work on environmental factors also tried to determine the fish movement by looking at three different areas, i.e. upstream and

downstream area as well as acoustic survey area. It was noted that the recent work with sonic tags and detailed analysis of sonar information revealed that fish tended to stay in the region longer than originally assumed when the acoustic survey was designed.

It was pointed that the temporal scale of available data varied significantly and this had confounded the analysis. It was also pointed that the impacts of fish moving to an extent of hundreds of kilometers per day should be taken into account when interpreting temporal and spatial relationship between fish abundance, or location of fish and environmental factors.

In the GAB there seemed to be a greater aggregation of fish along the shelf break than on the lumps and possible reasons of this were asked. In fact, some analysis on the archival tag data had been conducted to examine in difference in feeding habitat whether fish were on the shelf or along the shelf break. As one possibility, it was explained that the fishing activity in this area might be acting as a FAD. Though the aerial survey data suggested consistent decline of fish abundance in the Bight over the period of 1993 to 2000, the abundance within the small box of aggregated fishing activities showed increased. So, there might be a major effect of behavior of fish without changes in natural environmental conditions.

It was noted that the value of this work was in reducing uncertainties around some of those recruitment indices and making us more focused on the fact really relating with recruitments.

3. Automated monitoring of juvenile SBT migration in southern Western Australia and implication for the design of Acoustic Sonar survey

西オーストラリア州南におけるミナミマグロ幼魚の自動モニタリングと音響調査計画への応用

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河邊　玲 (長崎大学　水産学部)

Summary:

The acoustic (sonar) survey under the Recruitment Monitoring Program has been established to monitor the relative abundance of 1-year old SBT based on a line transect survey using omni scanning sonar. The acoustic survey area was set in the area between off Albany and Esperance, where the width of continental shelf becomes narrow, with the assumption that most 1-year old SBT (and 2-year old) will pass through along the southern western coast of Australia during summer. The acoustic survey has been conducted using a consistent protocol since 1995/96 season. However, the abundance indices obtained from the survey has showed a drastic decline in 2000 and have stayed at extremely low levels since. It has been suggested that the juvenile SBT are moving inshore of the Acoustic Survey Area (ASA), or are not moving through the area during the period of the survey. Thus, there is an urgent need to investigate the main causes of decline in indices in relation to the SBT migration timing, pathway and migratory speed. Recent advances in acoustic tagging technology have made available low-cost, submersible receivers that can automatically detect and identify passing fish, such as cod and tuna. The object of this experiment was to evaluate the design of acoustic (sonar) survey using the data obtained during the summer migration of juvenile SBT population in 2002/03 and 2003/04 seasons.

Tagging experiment was also successful and a substantial fraction (33.0 % in 2002/03, 45.7 % in 2003/04) of the tagged fish was also detected. This experiment was designed to assess the migration path and position within/out of ASA at which mainly 1-years SBT migrated along the coast of southern Western Australia, and the results have important implications for the assessment of the distribution of juvenile SBT. The present result indicated that more fish detected migrated in ASA than in 2002/03 season. The result suggested that juvenile SBT might change in the migration path through ASA, yearly. It is not possible to explain the reasons of fluctuation, although the distribution of juvenile SBT in summer might be explained in relation to oceanographic conditions (eg. the strength of Leewin Current, the presence of eddy in the shelf break and upwelling inshore).

Discussion:

It was noted that the fraction of fish actually detected were 33% for 2002/2003 and 46% for 2003/2004. The survey was designed to detect around 45% of fish with sonic tags passing through the line, by setting a distance as 1,500m between listening stations with a detection range of 350-400m for each. The presenters reported to estimate that between 70 and 100% of fish crossed the line were detected in this study by using some re-sampling technique like a boot-strapping sense, even though there were still possibility that some tagged fish move outside the survey range. It was reported that the 2004/2005 survey would use tags with higher power to improve detection rate as well as increase to three lines to enable more detailed analysis of fine-scale behaviors of fish in the area.

There were several ways to define residence time, e.g. the longest time of one fish staying in the area, the average time for fish between the first detection and the last detection, as well as the absolute time from the first fish detected to the very last fish detected. This study used the last definition. The caution was raised on a property of a type of statistics such as the maximum time of being detection and it was pointed that this sort of statistics was very hard to interpret and the current work could not conclude a large difference in residency time between years.

Three archival tags released from the survey area in this study were recaptured. It would be possible to calculate how long these animals were resident in this region from those three archival tags data. Question was raised about a comparison of residency time estimates obtained in this study and those from archival tags and potential benefits and flaws. Since no one worked out this from archival tags, no answer was made.

Mortality of tagged fish was briefly discussed. Conventional tagging was also conducted at the same time of sonic tagging and recapture rate of those fish in the subsequent years in the GAB had been very high also, around 20%. From the comparison of the percentage of fish that were detected and recaptured and percentage of that were not detected and recaptured, together with high detection rates, the mortality of sonic tagged fish was considered to be low. It was also reported that preliminary analysis did not show difference in residency time nor survivorship between when fish were tagged individually and tagged as a part of a school.

4. Analysis of fish schools migration direction and migration velocity from scanning sonar

スキャニングソナーからの魚群移動方向・移動速度の解析

Kazushi MIYASHITA (Hokkaido University)
宮下　和士 (北海道大学北方生物圏フィールド科学センター)

Summary:

Purpose

In recent years, inside and outside the country, monitoring survey of fish schools using scanning sonar have been conducted, and survey about measurement of action of fish schools such as migration and escape from the reaction record has been made. However, the measuring method is not yet established and an immediate action is desired. This study examined the method of presuming migration velocity and migration direction of fish schools from the scanning sonar picture information acquired by the acoustic survey on juvenile Southern bluefin tuna (SBT) recruitment in Australian southwest ocean. Furthermore, we actually applied this method about the sonar picture information in 1998, 2000 and 2001 in that acoustic survey to attempt to understand the migration velocity and the tendency of migration direction of fish schools in that ocean space.

Material and method

We used the sonar picture information in 1998, 2000, and 2001 obtained by juvenile SBT recruitment monitoring survey in Australian southwest ocean for analysis object. The migration velocity of the fish schools and the measurement method of the migration direction are as follows. We acquire the center of gravity position of the reaction of fish schools on the sonar picture as school fish location in local coordinates which starting point is vessel.

In order to obtain reliable values, we choose what is continuing catching the reaction of fish schools more than 50 seconds. We calculate position coordinates of the fish schools in the obtained partial coordinate system, the position of the vessel from GPS information, the migration direction of the vessel, the migration direction vector and velocity vector of fish schools in the coordinate system absolutely from the posture angle of the beam. We identify fish schools for the Southern bluefin tuna (SBT) and bait (BAI) using sonar specialists' information, and try to grasp the tendency of migration direction and migration velocity.

Result and consideration

The fish schools reactions which we acquired coordinates more than 50 seconds were 228 groups, among those SBT were 93 groups and BAI were 135 groups. The average of migration velocity for SBT was 1.16 ± 0.968 m s-1 (Mean ± S.D., n=93), and for BAI was 1.06 ± 0.797 m s-1 (n=135). The number of SBT was a little greater than that of BAI. Also, as we calculate the average migration velocity facing each east and west using the migration direction vector, the average migration velocity facing west for SBT was 1.30 ± 1.10 m s-1(n=40), facing east for SBT was 1.04 ± 0.846 m s-1 (n=53), the average migration velocity facing west for BAI was 1.22 ± 0.931 m s-1(n=59), and facing east for BAI was 0.955 ± 0.656 m s-1 (n=76). Both SBT and BAI average migration velocity facing west was greater, and almost the same tendency is shown in the comparison in past few years. Also in the estimate of the migration velocity of

juvenile SBT in this ocean using acoustic tag, since west migration velocity was significantly larger than that of facing east, it is considered that these results were appropriate. On the other hand, the swimming velocity and direction obtained by this survey varied significantly, and it is judged that more measurement of fish school will be necessary for improvement in measurement accuracy.

Discussion:

It was questioned whether there were any observations indicating that the survey vessel itself had a reaction of animals, i.e. the differences in behaviors of animals depending on the direction of boat and the distance from the animals. It was reported that there was no particular evidence of this such as quick change of moving direction. Figures showing the movement vectors of animals relative to the vessel position were suggested as one way to visualize the difference of animal responses with survey vessel.

Following to the question, it was explained that the analysis did not separate data collected during daytime and those collected during nighttime. However, the future analysis might include day/night compassion if adequate number of schools data could be retrieved from the historical data set.

5. Comparison of various recruitment information for southern bluefin tuna

ミナミマグロ各種加入量情報の比較

Sachiko TSUJI (NRI Far Seas Fishery, FRA)
辻　祥子 (水産総合研究センター　遠洋水産研究所)

Summary:

Various indices for southern bluefin tuna recruitment are compared using the recruitment trend obtained through assessment model as a common scale. The objective is to identify indices that represent overall recruitment trend most effectively as well as those that detect strong signals such as strong cohort or recruitment failure. Indices examined include overall longline CPUE for young age classes, longline juvenile CPUE from a given area and time with high juvenile occurrence, surface fishery CPUE, and aerial and acoustic recruitment indices.

Fishery dependent indices indicate strong influence by environmental factors with higher co-relation among different age classes within a year than co-relation among different years within the same cohort. The CPUE from a limited time and area show especially strongly with signals by years (not by cohorts), and caution is needed for interpretation. In general, fishery dependent indices based on the whole fleet tend to represent overall recruitment trend relatively well.

Fishery independent indices obtained through the Recruitment Monitoring Program, aerial, acoustic, and troll indices, generally show good correspondence with recruitment trend obtained from assessment model. Since aerial survey only covers the period that recruitment did not show strong trend, it is difficult to evaluate a reliability of this indices with current method.

Acoustic indices and troll catch information show a good correspondence with model-estimated recruitment fluctuation with a different level of exaggeration, which suggest a prospect of these indices as recruitment monitoring index as well as a need for some correction function to make them representative for actual level of recruitment fluctuation.

Discussion:

It was pointed that the graphical presentation of various lines would be hard to interpret and might be misleading especially because the associated uncertainties, in both precision and accuracy, around each line differed substantially. The use of traffic light approach, just indicating red, amber, and green, was suggested one way in presenting semi-quantitative or qualitative things, especially for presentation to the managers. In this case, the associated confidence level might be able to illustrate in the radius of traffic lights.

It was also pointed that the assessment results had some inherent correlation with some of information examined including age-specific CPUEs and tagging results, because many of these indices heavily used and depended on the catch data. Therefore, it must be careful when assessing the value of indices based on the assessment results.

It was noted that there was the trade-off between having multiple indices and having few indices with high precision. For instance, the relative merit of five different indices with CVs of 30-40% versus three indices with CVs of 20% should be considered seriously, especially under the condition where only limited amount of resources were available. This topic would be discussed in the following section as well as at the final wrap up session, in more detail.

6. Preliminary results of study on the relation between southern bluefin tuna resources and atmospheric-oceanic variability

ミナミマグロ資源と気象･海況変動との関係に関する予備的研究

Denzo INAGAKE (NRI Far Seas Fishery, FRA)
稲掛　伝三 (水産総合研究センター　遠洋水産研究所)

Summary:

In this study, we want to show fluctuations of southern bluefin tuna (SBT) resources in related to atmospheric-oceanic variability. Fluctuations in the recruitment (R) and the ratio of recruitment per spawning stock biomass (RPS) have significant correlation with some of climate variability indices, that is, Indian Ocean Dipole Mode Index, Antarctic Oscillation, North Pacific teleconnection pattern indices connected with ENSO. The most significant index in North Pacific teleconnection pattern is west pacific pattern (WP), that is near their spawning area in the north-eastern Indian Ocean. Some of indices increased its correlation coefficient with time lag of several years. We considered that climate variability should impact to spawning stock, and hence the recruitment of SBT fluctuates in related with atmospheric-oceanic variability. When SST in their spawning grounds was warmer than monthly mean SST, recruitment of SBT increased. On the other hands, when SST at the fishing area southern Indian Ocean (around 40 degree S) was colder, the recruitment and RPS

increased. We have now two hypotheses. First one is “cold SST in fishing area effect to the spawning stock for quality and quantity of their eggs. Second one is “warm regime in the spawning grounds might be good condition for larvae’s survival through its growth rate and activity”.

Discussion:

Responding to the clarification question, it was explained that the estimates for recruitment and spawning stock of southern bluefin tuna were taken form the version of Operating Model results developed for the CCSBT 2nd Management Strategy Workshop held in April, 2004.

Question was raised on the potential impacts of the Indonesian Through-flow and Leeuwin current to the southern bluefin tuna recruitment. No direct analysis was made due to lack of established index directly corresponding with the Indonesian Through-flow. Judging from the correlation map, there seemed to be positive correlation between sea surface temperature of Leeuwin current area and recruitment.

7. Outline of prerecrutiment survey of Japanese sardine and chub mackerel in the Kuroshio/Oyashio Transition Zone: a challenge for forecasting recruitment levels and early survival processes

黒潮／親潮移行域でのマイワシとマサバに関する加入前調査の概要：加入量水準および初期生残過程を予測する

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Summary:

Biomass of the Pacific stock of Japanese sardine *Sardinops melanostictus* decreased from ca.14-19 million tons during 1980’s to less than 0.2 million tons in recent years. This decline was mainly caused from successive recruitment failures during 1988-1991 corresponded to weak Oyashio intrusion and positive anomalies of winter sea surface temperature in the Kuroshio Extension southern area. Biomass of the Pacific stock of chub mackerel *Scomber japonicus* also decreased from ca.3-4 million tons since the 1970’s to less than 0.2 million tons in recent years. Reproductive success of chub mackerel is affected by winter sea surface temperature in the Izu area (central Honshu) which is their major spawning grounds. In contrast, Japanese anchovy *Engraulis japonicus* stock recovered since the early 1990's.

Larvae and juveniles of sardine, chub mackerel and anchovy share common nursery grounds in the Kuroshio/Oyashio Transition Zone (KOTZ) during spring. They recruit to purse seine fisheries in the northern Honshu at age of 6-10 months. In years of low stock abundance, yearly fluctuation of recruitment affects seriously fisheries and stock management plans. In order to forecast recruitment levels, a mid-water trawl survey has been carried out in spring since 1996 in KOTZ. Recruitment abundance index from the pre-recruitment survey of sardine and chub mackerel had a fairly good correlation with VPA-derived recruitment numbers (for anchovy, reliable recruitment abundance is not available).

We also estimated early somatic growth rates of sardine and anchovy obtained from the pre-recruitment survey using otolith daily increments. The annual mean growth rates of sardine juveniles was positively correlated with early survival rates and negatively correlated with growth rates of anchovy. The optimum temperature range for early growth rates of sardine was 2-3 ºC cooler than those of anchovy. These findings suggest that temperature conditions in the nursery grounds play an important role in sardine/anchovy/mackerel cycles.

Discussion:

The question was asked on how those recruitment information were used in the stock management. There were two ways of using those pre-recruitment survey results; one was to tune VPA together with other recruitment indices available and the other was as a predicted recruitment of the current year when estimating the current stock abundance based on catch at age data up to the previous year.

Japan has a long history of experiences in catch forecast including recruitment forecast, which should be able to give a way to evaluate the reliability of those indices. It was explained that the egg census survey that had about 40 years' history did not give a good prediction of recruitment and was generally considered as an index of spawning biomass. However, the mid-water trawl survey was generally accepted to give reasonable estimates of the next recruitment, although the time series of this index limited only 7 to 8 years.

8. Wrap-up discussion

まとめ

Coordinator: John KALISH

This Session started off with the topic of impacts of oceanographic and biological environments on recruitments, fish behaviors and uncertainties of monitoring indices. This type of investigations would be extremely difficult particularly due to the highly migratory nature of southern bluefin tuna and the need for oceanographic and environmental data of the temporal and spatial scale reflecting the distribution and migration of the animal. Nevertheless, it was shown that there are relationships between oceanographic feathers and distribution of tuna that can be described using statistical models, and some of the variation of distribution of southern bluefin tuna seen in the Great Australian Bight described based on oceanographic data range of variables considered. Data of this type was less successful to describe acoustic survey information but nevertheless some variations were explained on the basis of oceanographic conditions. One of the things it clear is that we need to know more about details of movement of tuna, in addition to obtaining more detailed or more high resolution of spatial and temporal data in oceanography.

Certainly, the archival tagging data would help to improve our understandings of movement of tuna, across a day, week, month and even years. It was clear that the variation in fish behaviors had a large impact on what we are able to observe through the acoustic gears and aerial survey techniques. Acoustic techniques were proven to be valuable to look at migration of short-term

movement of schools and identify the directionality and speed of movement. Further work would be useful to combine some of acoustic techniques and archival tag works to investigate the behaviors of individuals and schools behaviors altogether.

A summary of some of the oceanographic indices commonly used to look at the large oceanographic changes of from years to decadal time scales were given. Although there were tremendous potential to investigate this area further, there were issues with spatial and temporal relationships of two data sources that distribution of tuna, the nature of data of oceanographic phenomenon. We were given examples for sardines, anchovy and mackerel with large fisheries with total catch in an excess of half million tons in some years, and has tremendous amounts of data collected. There are very good understanding relating between oceanography and recruitment. They demonstrate the power of combining oceanographic and fisheries researches in developing further understandings on SBT recruitments and distribution.

In summary, we had come a very long way and we were taking an advantage of some of latest technology available, technology development taking extremely important role to understand SBT and we need to continue to move forward in terms to technology to investigate behaviors of this animals but at the same time we had already collected very large amount of data and further analysis would be need.

SESSION 3 – Views from user side:

1. Evaluation of the current SBT recruitment monitoring survey and future effective investigation- Question and proposal from executive official

現行の SBT 加入量モニタリング調査の評価と今後の効果的な調査のあり方について－行政官からの質問・提言

Yasushi NAKAZATO (Fisheries Agency of Japan)
中里　靖 (水産庁漁場資源課)

Summary:

When evaluating Southern bluefin tuna (SBT) abundance, it is important to comprehend at as an early stage as possible the situation of the recruitment of juvenile SBT, as its necessity was confirmed in the previous CCSBT annual meeting. On the other hand, the result of the evaluating the abundance is reflected on the amount of fishing quotas, and it is also regulating the fishery operation currently performed as industrial activity. So it is necessary to evaluate the abundance based on scientific ground which makes the members concerned satisfied. However, comprehension of the situation of recruitment of SBT is not easy, as they are distributed and migrate throughout the Southern Hemisphere. The recruitment survey is conducted while examining technical points today. Moreover, as well as the SBT recruitment monitoring work which started in 1989 as the Japan and Australia collaborative research program has already been 15 years, the national budget will not satisfactorily allow the survey budget allotted to this survey. We need to establish an immediate survey method to conduct the survey to obtain data

which can be utilized for abundance evaluation from development of survey technology as well as the preparation of its efficient conductive system.

Please let us know of the view of this workshop about the following points considering above.

1. Evaluating the comprehension of recruitment at this time

   At present, while Japan and Australia conduct acoustic survey, sonic tag survey, and aerial surveys to develop survey technology, we perform the monitoring survey about juvenile fish recruitment. How much will be clarified by these surveys among the whole SBT recruitment abundance? How will it be utilized for evaluating abundance including presuming tendency by continuing these surveys?

2. Validity of survey, clarification of its limit

   How much do we comprehend the recruitment of SBT abundance by present acoustic survey? Also, how better will we come to comprehend with improvement in future technology? How about surveys other than the acoustic survey?

3. Rationalization of survey

   If we make the content of the comprehension about the acoustic survey or other surveys minimum in quality and in quantity, how could we rationalize the whole survey? If we cannot rationalize it at present, what should we do?

4. Knowledge required to comprehend the whole recruitment and the survey required to obtain the knowledge

   In order to comprehend the whole recruitment abundance, what knowledge is required in addition to the one acquired by the present survey? And what kind of survey can show the knowledge? Is there any possibility that we can conduct other efficient recruitment surveys including economical efficiency other than the monitoring survey conducted at present?

5. Ranking according to importance of each recruitment survey which include future surveys

   When comprehending the whole recruitment abundance, which survey is the most important? What about the priority?

6. Future practical system and expense charge

   Now the 3rd term RMP work is undertaken as the Japan and Australia collaborative research. Japan and Australia are investigating and analyzing by each about the acoustic survey and aerial survey which are the main subject of the investigation, wile the two countries together investigate and analyze the adjunctive acoustic tag survey. There seemed to be some trouble about data sharing in the past, and we consider that Australian government that manages her own fishery should charge the expense and conduct the surface abundance per unit effort (SAPUE) for which the current RMP budget is used. Also, as the knowledge acquired by recruitment monitoring survey leads to profits common with related countries, it

would be better to establish a proper survey method as soon as possible and shift to work of CCSBT direct control as well as to share the cooperation system and expense charge with each country.

7. Reason of recruitment reduction

Now it is suggested that the recruitment is decreasing, but what could this reason be?

Discussion:

No discussion was held.

2. Requirement from stock assessment points

資源評価の観点からの必要性

Tom POLACHECK (CSIRO Marine Laboratory)

Summary:

The recruitment monitoring is critically important for improving the assessments and reducing uncertainties (both in reducing variance and biases). In particular recruitment monitoring is important for providing fishery independent data and thus reduces the current reliance on CPUE, for which the danger of such reliance is well known, Recruitment is the most effective way of improving the most recent recruitment estimates, which are one of the most unreliable part of current SBT assessment. Recruitment monitoring also can reduce the current lag of at least four years in the recruitment estimates in current SBT assessment. Finally, recruitment monitoring can provide for testing underlying model assumptions and generate alternate hypotheses- improved robustness and quantification of uncertainty. The requirements that ideally a recruitment monitoring indices should satisfy for stock assessment purposes:

- Quantitative data collected from a properly designed sampling protocol
- Fully specified statistical model (e.g. likelihood function for the data; sufficient statistics – expected value, CV, co-variance matrix, biases)
- Statistical model needs to include relationship between index and abundance (not simply qualitative)
- Unbiased and reasonable levels of precision
- Representative sampling of entire population
- Consistent methodology

As a rule of thumb CV's in the order of 20-40% are required for an index to be informative within a stock assessment context. It was noted that CVs are frequently underestimated with harder components to estimates often being ignored - in particular process error. Process error results from factors that are not due to sampling/measurement error (e.g. annual variation in abundance in survey area, unaccounted factors in delectability). It is critical that process errors are independent of density (otherwise biases will be introduce) and it is important to minimize in design of recruitment monitoring index, Process error can be reduced or avoided by ensuring appropriate coverage (spatial

and temporal), representative sampling, consistent methodology and collection of appropriate ancillary data. The followings are the summary of the recruitment monitoring indices in terms of their current and near-future potential role in SBT stock assessment:

Tagging

- Absolute estimates and medium time series
- Well developed statistical models
- informs on natural mortality and growth
- large potential to improve both understanding of stock productivity and recent trends
- incorporated into current assessments

Aerial survey

- Medium time series of useable indices
- Consistent methodology
- Well developed statistical model
- Model for Abundance/index relationship
- Limited incorporation into recent assessments

Acoustic Survey

- Survey methodology/analyses still underdevelopment
- Relationship between abundance and index highly uncertain
- Incomplete statistical model –concerns about large process error
- Not used in any of the quantitative assessment

Discussion:

No discussion was held.

3. The role of recruitment indices in management decisions – with reference to Southern Bluefin Tuna

管理施策を決定する際の加入量指数の役割 – ミナミマグロを例に

Andy BODSWORTH (Australian Fisheries Management Authority)

Summary:

Southern Bluefin Tuna (*Thunnus maccoyii*) are the basis of valuable purse seine and longline fisheries throughout their distribution. The gross value of production of Australia's purse seine fishery for juvenile SBT varies between AUD 200-300 million per annum. Global SBT fisheries are culturally and economically significant and are threatened by the continued decline of the adult spawning biomass, and associated recruitment declines.

For Australia's juvenile surface fishery timely information on SBT recruitment trends is a critically important management objective. More broadly, members of the Commission for the

Conservation of Southern Bluefin Tuna (CCSBT) recognize the critical importance of accurate recruitment information to determine future stock management strategies.

CCSBT have recently agreed that reducing uncertainty in current stock assessment processes should precede any response to recent indications of further and possibly large recruitment declines. Analysis of recruitment indices will determine future management action by CCSBT members. If indicators of recruitment suggest no significant recruitment decline on an ongoing basis then the CCSBT management procedure process may be used to set Total Allowable Catch (TAC) levels. If recruitment indicators suggest ongoing and significant recruitment declines then CCSBT will consider significant TAC reductions as soon as possible. For 2005, recruitment indices will be a key part of the CCSBT indicator analysis that will determine if a full stock assessment is warranted.

Recruitment indices are fundamental to contemporary SBT management. Ideally they should be reliable and robust to uncertainty, cost effective, and credible to key fishery stakeholders. Like any fishery assessment process, the SBT indicator analysis is inherently uncertain. To facilitate effective management decisions in the face of scientific uncertainty, the precautionary principle suggests that an absence of scientific certainty should not be used as a reason to delay decision making. But in the presence of scientific uncertainty, and where the consequences of decisions are very significant, it is a difficult balance between precaution and production. For SBT fisheries, taking a precautionary approach may mean reduced catches with direct and adverse socio economic impacts in the short to medium term. On the other hand, delaying necessary management decisions because of scientific uncertainty may result in serious long term environmental, social, and economic consequences.

Discussion:

It was pointed that the reduction of catch, local economy and industries often tended to lead to a reduction of monitoring efforts and scientific researches, and subsequently a degrading of management quality. Although an inverse relationship between confidence in fisheries and stock management and knowledge on stock, it was cautioned that the science would not be able to resolve the uncertainty problems completely even putting a huge amount of efforts and resources into research.

4. Where do large-scale monitoring surveys go? - from a cost-performance view point

大規模モニタリング調査はどこへ行く？－コストパフォーマンスの視点から

Norio TAKAHASHI (NRI Far Seas Fishery, FRA)
高橋　紀夫 (水産総合研究センター　遠洋水産研究所)

Summary:

Strength of inference in ecological study generally decreases as spatial-temporal scale of study increases. From a budgetary point of view, cost for study increases as the spatial-temporal scale increases. Thus, cost-performance consideration is always a big issue in large-scale ecological

study to balance available budget and reliability expected from the study. In this presentation, cost-performance relationships of 4 surveys (troll, acoustic, aerial, and conventional tagging) in Recruitment Monitoring Program (RMP) of southern bluefin tuna are reviewed and some considerations on future surveys in RMP are briefly discussed, comparing to a case of large-scale surveys for Sika deer management in Hokkaido, Japan.

Facing increasing budget cut, Hokkaido decided to abandon helicopter census for monitoring deer population, which was the costliest among surveys and of which index had intermediate reliability. In RMP case, rough qualitative cost-performance evaluation showed: troll survey did not well in terms of cost-performance; acoustic, aerial, and tagging surveys performed moderately well; acoustic survey was costlier than other surveys. This result may be more variable counting the size of survey scale in RMP. Uncertainty in reliability of indices obtained from surveys is much greater in RMP case than in Hokkaido deer case due to large difference in survey scale. Therefore, cost-performance consideration in RMP case is not simple as in Hokkaido deer case. In making recommendations from the Review Workshop, uses of multiple long-term indices to monitor recruitment trend and balance between reliability of indices from surveys and available budget should be reconsidered with relation to needs for inputs to stock assessment and management procedure.

Discussion:

The relevance of the concept on the relationship between the scale of study and strength of inference presented in the first slide was questioned. Although it was noted that there might be some misunderstandings on what the concept actually tries to indicate, due to the constraint of time, further discussion was not held on this issue.

The Chair noted that the discussion on this presentation could be held as a part of the overall discussion in wrap up session.

5. Wrap-up discussion

まとめ

Coordinator: John KALISH

In this session, it was considered how recruitment indices can be used in stock assessment and management. It is clear about that we need to be confident about the nature of information that we are using, when cooperating them into assessment. It was pointed out that although considerable amount of information were collected on recruitment, much of this were not used in stock assessment. The goal is to ensure that the recruitment information we do collect is sufficient quality in terms of precision and accuracy to allow us to use it with confidence in a stock assessment.

Specific issues to be considered in relation to various recruitment investigation methods that has been used, and a range of conclusions were reached by different speakers. Ultimately though, we need to be able to inform managers and provide them with confidence the information of

recruitment and ultimately whether these fit in stock assessment, which may be going to help them decision, that decision in fact derived by many peoples. So, we need to look at what we are doing in the future very carefully in terms of how it impacts on stock assessment. At the same time, we need to be aware that we will have a limited budget to carry out our research of all aspects of SBT including recruitment. I don't know about the total level of expenditure of this area at this point of time, but there is a sense that it may require some reduction in future. Nevertheless, it is important to identify those methods that were proved to be most effective and informing stock assessment and ultimately to managers in terms of how to deal with SBT resources and its management. These are very difficult decisions that they need to make by both scientists and managers.

SESSION 4 – Overall conclusion:

Coordinators: John GUNN, Sachiko TSUJI

The discussion in this session concentrated on whether each of recruitment indices that we have now could be incorporated into the stock assessment and management at the CCSBT and how it could be used both in the short term and long term. It was noted that the original objective of the Recruitment Monitoring Program was to develop and establish one or more indices to monitor relative abundance change of cohorts.

Relative merit between having one index versus multiple indices would differ depending on reliability, potential biases, and required cost of available indices as well as the total resource available.

The meeting decided to review a set of currently available recruitment indices from the point how they could be used in the stock assessment and management. The following four categories were established for this purpose:

a) Do they inform 'significantly' on the current situation of recruitment?

b) How useful for embedding into future 'Decision Rule' within Management Procedure?

c) How useful for embedding into Meta Rule?

d) Can they be used/How useful in Stock Assessment Model?

The developed table and the summary table of characteristics and possible future improvements were as follows:

	Do they inform 'significantly' on current situation of recruitment? **Informative**	How useful for embedding into future 'Decision Rule' within MP? **Input to 'Decision Rule'**	How useful for embedding into Meta Rule? **Input for Meta-Rule**	Can they be used/How useful in Stock Assessment Model? **Input to Stock assessment**
Aerial indices (full-scale survey)	Yes (through a comparison with historical series even with suspended period); limitation by age aggregated nature	Yes	Yes	Possible and useful
SAPUE	Limited, or too short time-series to judge	No	When it become close to zero	No
Conventional tagging	Yes but limited	Yes	Yes	Should be yes
Acoustic indices	Yes but limited (caution on non-linearity to abundance, value in detecting signal at the earliest stage: age1)	Yes with further evaluation	Yes	Not in the current form
Troll	Unknown	No	No	No

	Summary of characteristics	Projected use in qualitative or quantitative	Current status and possible future development	Points for further improvement
Aerial indices (full-scale survey)	Informative for age 2-4, aggregated nature limit capability to detect change in recruitment by cohort level, subjectivities by relying on spotters' judgment	Quantitative, relative	Ready for moving to operational phase; not appropriate to reduce survey scale	Impacts of surfacing, school/individual behaviors within GAB, relative proportion available in GAB (esp. for bias); continuation of archival tag of age 1 and 2; automated procedure to estimate fish size in detected school?; impacts of FADs
SAPUE	Generally informative for age 2-4 but less reliable than aerial indices, subjectivities by relying on spotters' judgment	Qualitative, relative	Only available surface fishery related index, common problems in fishery-dependent indices	Inter-spotter calibration (low priority?)
Conventional tagging	Informative in age-specific way	Quantitative, absolute	Subject to the CCSBT discussion	
Acoustic indices	Qualitative indication of presence/absence of age 1 in survey area; subjectivities by relying on specialists' judgment	Qualitative (in the current form), relative, can be used in quantitative with further evaluation	Difficult to utilize as quantitative indices due to non-linearity to abundance and possible large impacts of process errors; only index available for age 1; potential benefits by altering survey design	Development of automated estimation procedure; behavior analyses, especially addressing process errors, alternative survey design
Troll	??? Not provide much information at all??	Qualitative, relative	Possibly useful as supplemental information especially when conducted in conjunction with other activities without additional cost	