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A review of the Southern Bluefin Tuna Commission's Scientific Research Program and considerations of current priorities and way forward

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Abstract

The Scientific Research Program (SRP) of the CCSBT was established in 2001 with the primary objective of improving the quality of the data available for input into stock assessments and to contribute to the development of reliable indices to monitor future trends in stock size. There were four main components to the SRP: 1. Characterisation of the catch; 2. CPUE interpretation and analyses; 3. The CCSBT conventional tagging program, and 4. Observers. This paper reviews the success of these main components in meeting the objectives of the SRP. No substantive progress has been made with respect to the first two components during the 6 years of the SRP. The revelations in 2006 of substantial and continuous overcatch of SBT since the at least the early 1990's has significantly compromised the ability to make any progress on these components without additional data on the nature of the overcatch and independent monitoring of future catch and effort. The conventional tagging program has been partially successful. The program has been successful in releasing tags in waters around southern Australia. However, the ability to make inferences about the wider stock has been compromised by lack of tagging in all areas, low reporting rates and lack of any information to estimate reporting rates from longline fishery. For the surface fishery, tag seeding experiments have provided estimates of reporting rates, but recent results suggest that the estimates may not be completely reliable. For the longline fleets, it was envisaged that reporting rates would be estimated by having sufficient observer coverage to independently record tag recaptures, but this coverage has not been realised across the majority of fleets and areas. While some progress has been made in the observer program, the average overall coverage is considerably less than the 10% target of the SRP and below the levels identified as required to provide meaningful estimates of reporting rates for the conventional tagging program. Moreover, there has been a lack of transparency in the national observer programs in that those data that have been collected are not available to the SC in their raw form for analyses. As a result of these factors, the outputs from the observer programs have had almost no impact on the analyses and assessments undertaken by the SC. The lack of observer coverage continues to compromise the ability of the SC to realise the full potential of the conventional tagging program, particularly for the adult component of the stock. Furthermore, the high uncertainty in the catch and effort data is likely to seriously limit confidence in future catch and effort data unless this can be addressed effectively in the short term. A number of issues are raised for consideration in developing a new work program for the SRP. Priority is given to independent catch and effort verification and improved observer coverage of the high seas longline fleets and development of fisheries independent indices of abundance that do not rely on CPUE.

1. Introduction

The Scientific Research Program (SRP) of the CCSBT was established in 2001 with the primary objective of improving the quality of the data available for input into stock assessments and to contribute to the development of reliable indices to monitor future trends in stock size. There were four main components to the SRP: 1. Characterisation of the catch; 2. CPUE interpretation and analyses; 3. Scientific Observer program; and 4. the CCSBT conventional tagging program. In addition to these main components there were five additional components that were recognised as ancillary research activities under the SRP. These research activities were already planned or being undertaken by members, and include: (5) Direct ageing, (6) Archival and Pop-up tagging, (7) Recruitment monitoring program, (8) Development of a Spawning biomass index and (9) Fisheries Oceanography for improved habitat definition.

The terms of reference for the Review of the SRP agreed at the 10th Meeting of the Scientific Committee (SC) are provided in attachment 11 of SC 10 (Anon 2005a). This paper reviews the success of the SRP in meeting the original objectives. In particular, it focuses on the effectiveness of the four main components of the program in providing statistically robust data and/or parameter estimates that improve the quality of the stock assessment and the provision of management advice.

Many of the components of the SRP have been the subject of reviews (e.g. Anon. 2001a (tagging), Anon. 2003a (Indonesian catch monitoring), Anon. 2006a (Commission meeting re overcatch), and Anon. 2005b (Recruitment monitoring)), and of discussions and evaluations in the proceedings of the SAG/SC. This document does not attempt to be a full technical review of all components, but we do attempt to evaluate whether the original objectives have been, or are likely to be, met.

The paper is structured around each of the four core components of the SRP program, followed by the ancillary components on the additional components, and concludes with considerations of priorities for the future SRP work program for CCSBT.

2. Review of the four key components of the CCSBT Scientific Research Program

2.1 Characterisation of SBT catches

The CCSBT SRP described characterisation of the SBT catch as fundamental to the stock assessment process (Anon. 2001b (SC report, Att D)). The program identified the fishery specific data that should be collected, and specified how it should be collected, who should collect the data and how collected data should be managed. Members are responsible for collecting data for their own flagged vessels. The CCSBT has been responsible for preparing quality standards, integrating the data into the CCSBT database, determining catch from non-members, and managing confidentiality of the data.

The CCSBT has developed a centralised database to store and manage catch, effort and size data reported to the CCSBT (CCSBT Sec., 2004a (CCSBT-ESC/0409/9)). The database design included data quality reporting standards for each data field, and agreements and protocols were determined for managing the confidentiality of data (CCSBT Sec., 2002a (CCSBT-ESC/0209/12)). The CCSBT also collates data on catches by non-members for addition to the CCSBT database. Required items that are not being collected by each member have been documented and discussed in previous meetings of the SC (CCSBT Sec, 2002b, 2003, 2004b, 2005 (CCSBT-ESC/0209/9, /0309/8, /0409/7, /0509/7); Anon., 2005a (SC report Att 8)).

There were 2 issues for data reporting standards that have not been agreed upon by members. These are: 1) reporting of data on "other species" and 2) the spatial resolution of the catch and effort data. Both of these data types are of particular relevance to CPUE interpretation and standardisation, and this is further discussed under that item (Section 2.2).

There were several important catch characterisation problems identified in the 5 years of the SRP program, including uncertainty about the magnitude of overall catches and the adequacy of size frequency sampling from catches.

In 2006, following a review[1] of the Japanese SBT market data, the CCSBT recognised substantial and continuous unreported catches of SBT over at least a 15 year period (Anon. 2006b). Since the reviews, no additional data on the over-catch have been provided to the SC, and it is unclear whether it would ever be possible to obtain information about the size frequency distributions of the associated unreported catches (but see CCSBT-ESC/0709/30).. The revelation of these unreported catches severely limits the Scientific Committee's ability to provide stock assessment advice on the likely current state of the stock or to evaluate management options using the historic data and current CCSBT Operating Model (Anon, 2006b). Several options for future verification of catch data were discussed at 2006 SC meeting (Davies et al, 2006), and this is issue is revisited under Section 4.

The review of the Australian farm operations concluded that there was little scope for over-catch via misreporting of tuna numbers in the surface fishery, but results suggested that the age frequency of the catch may have been biased (Anon. 2006c; para. 54). Australia has agreed to further investigate the feasibility of stereo video procedures to improve the monitoring of catch and particularly the estimation of the size structure of the catch (see Hender and Murphy, 2007). Size sampling in the Australian farms should improve with the implementation of stereo video equipment for measuring of fish when transferred from tow cages to the farms by substantially increasing the sample sizes and significantly reducing the potential for bias (Anon, 2006b). It should be noted that, for scientific stock assessment purposes, the relevant question is the number[2] of fish that are caught, and their size structure at time of capture. The weight of the fish at time of *harvest* is irrelevant for stock assessment purposes.

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[1] In 2005, Australia and Japan instigated "independent reviews of the Japanese SBT market data and of the Australian SBT farming operations to determine whether or not over-catching is occurring relative to the total allowable catch" (Agenda item 23, Report of the Twelfth Annual Meeting of the Commission). These reviews (The Japanese Market Review and the Australian Farm Review), were presented to the Commission in 2006 (both documents are currently confidential).

[2] The stock assessment model is formulated in terms of numbers of fish. Catches that are entered in terms of weight need to be turned into numbers via an associated size frequency distribution (in terms of weight).

In addition to catch characterisation of member catches, monitoring of catches by Indonesian vessels on the SBT spawning ground has been an ongoing collaborative project between CSIRO Division of Marine Research and the Research Institute of Marine Fisheries of Indonesia since 1993 (Proctor et al, 2007). More recently (2002), the Indian Ocean Tuna Commission (IOTC) and Overseas Fisheries Cooperation Foundation of Japan (OFCF) organisations have become collaborative partners in the project[3]. Data are collected each year on the longline catch of SBT and other tunas and billfish landed in the Port of Benoa, Bali, Muara Baru, and in the southern Java ports of Cilacap, Batere and Seleko. Data include catch in number, length, weight, and sex, as well as, otoliths for direct ageing and other biological samples.

The Indonesian catch monitoring has provided valuable information on the total catches of SBT on the spawning grounds (see e.g. Proctor et.al. 2007) and their associated size and age structure from direct ageing (see e.g. Farley and Proctor, 2007). In light of the implications of the unreported catches from the longline fleet, it now provides one of the few "unaffected" sources of information on the status of the SBT spawning stock. The Indonesian catch monitoring program has been recognized by the SC as a priority program to continue (Anon 2005a).

In addition to characterization of the catch, the Benoa monitoring program has provided the basis of a range of biological studies through the provision of biological samples (Proctor et al, 2006; Farley et al, 2006). A recent and important example of this is the provision of tissue samples and age information for independant estimation of spawning stock biomass using close-kin methods (Bravington and Grewe, 2007). Also see below under future directions.

With respect to sampling of the catch for size frequency distributions, the 2002 Scientific Committee noted that "...for size measurements, existing scientific observer coverage is unlikely to provide adequate coverage for many fisheries/areas." Some improvements in data collection have been made. For example, Taiwan subsequently reported significant progress in increasing sample sizes of length data (Anon, 2003b). However, as indicated above, the size distributions of the substantial historic unreported catches are currently unknown, and it is unclear whether it will ever be possible to obtain data or information to resolve this large uncertainty.

In summary, the catch characterisation component of the SRP has largely failed in meeting the objective of accurately characterising the catch of SBT. The 2006 scientific committee noted that "*Given the outcomes of the market and farm reviews it is clear that the catch characterisation component of the SRP has not been successful*" (Anon, 2006b). Useful progress has been made on the implementation of data storage and data management systems, the monitoring of Indonesian catches, the quantification of historic unreported catches, and further development of the monitoring systems for the purse-seine catches. However, the magnitude and duration of the unreported longline catches, and the outstanding questions about the potential bias in the estimates of the size structure of catches from the surface fishery, mean that the uncertainty in the recent historical catches is such that it is not possible

[3] The list of participating organisations currently include: Indonesia's Research Centre for Capture Fisheries/Research Institute for Marine Fisheries (RCCF/RIMF) and Directorate General for Capture Fisheries (DGCF), CSIRO Marine and Atmospheric Research, Australia's Department of Agriculture of Fisheries and Forestry (DAFF), Australian Centre for International Agricultural Research (ACIAR), the Indian Ocean Tuna Commission (IOTC) and the Overseas Fisheries Cooperation Foundation of Japan (OFCF) .

for the Scientific Committee to currently complete a stock assessment for SBT (Anon. 2006b). This is likely to remain the case in the short term, unless further detailed verifiable information is provided, particularly, on the amounts, size structure and time series of the unreported longline catches, that is sufficient to conduct a revised stock assessment. If fishery independent indices of abundance can be developed, particularly indices of absolute abundance, a stock assessment which does not rely heavily on an accurate historical catch series, may become feasible, but this can only be achieved in the medium to long term.

2.2 CPUE interpretation and analysis

The objective of the CPUE component of the SRP (Anon. 2001b) was i) to reduce the uncertainty in historical trend in stock size and thus uncertainty in the current assessments, and ii) to provide a reliable index to monitor future trends in stock size to be used as part of a decision rule to set TACs (i.e. as part of a Management Procedure). Guidelines for development of CPUE analysis methods in the future were agreed (Anon, 2001b (SC report Att D)).

In March 2002, a 1-day CPUE workshop was held, which discussed recent trends in CPUE, potential for bias and process errors, and use of existing CPUE series (Anon, 2002a). In most years, the CPUE working group met in the margins of SC meetings, and discussed new CPUE modelling methods (e.g. Anon. 2001c (SAG ATT7); Anon. 2003b (SC Att E); Anon 2004 (SC Att 9)), data required to improve CPUE analysis (e.g. Anon. 2001d (Att E); Anon. 2001e), and made a lists of future work tasks (e.g. Anon. 2003b (Att E); Anon 2005a (Att 9)). Despite this, little progress was made towards establishing and/or verifying a reliable CPUE index. Part of the problem with, and difficulty in standardising, the Japanese longline catch and effort data lies in the large changes in spatial coverage by the Japanese longline fleet over time. This issue, particularly the fact that many areas which were fished in the early years, were not fished in later years, has always been of concern with regard to interpreting Japanese longline CPUE as an index of overall SBT abundance.

In addition, as noted in Section 2.1, there were 2 issues for data reporting standards that have not been agreed upon by members. These are: 1) reporting of data on “other species” and 2) the spatial resolution of the catch and effort data. Both of these data types are of particular relevance to CPUE interpretation and standardisation. There was considerable discussion of the importance and utility of catch data on “other species” at the 2004 Scientific Committee, however collection and provision of these data has still not been resolved. Recommendations from the 2nd CPUE modelling workshop (Anon. 2007) included that “… bycatch data are clearly critical for the interpretation of CPUE and development of robust series.” Bycatch data should “… be analysed for any fleets for which CPUE should be considered …”. Regarding the spatial resolution of the data, the 2nd CPUE modelling workshop recommended that further work on comparisons between shot-by-shot data and aggregated data should be conducted. The Workshop considered that indices based on shot-by-shot data should be more robust (Anon, 2007). It was agreed that higher precision data would be provided if requested for specific analyses (Anon, 2004), however at the recent 2nd CPUE Modelling workshop (Anon, 2007) direct access to $1^{o}x1^{o}$ and shot by shot data was still restricted. Access to these data for detailed analysis is required to provide robust estimates of the variances associated with the CPUE. Importantly, it is also required to better understand the fine-scale operational patterns of fishing and associated catch rates.

The management procedures workshop (Anon, 2002b) requested that a single relative abundance index from Japanese longline CPUE series be developed and adopted for use in the management procedure. In the absence of an agreed series, a compromise solution which uses the median of 5 CPUE series was adopted as an interim measure for MP testing until 2009, when a single series would again be needed to implement the MP.

In 2006, the review of Japanese market statistics was tabled, and at the 2006 meeting of the SC, the issue of whether or not Japanese longline CPUE was likely to have been affected by the catch anomalies was reviewed. Analyses presented to the meeting suggested that it is possible that the CPUE series are not affected, i.e. that unreported catches occurred outside of the areas and times currently used in the CPUE analysis but it is also recognised that the indices could be affected (Polacheck et al, 2006a; Sakai and Itoh. 2006). In May 2007, a second CPUE modelling workshop was held to discuss the impact of the longline catch anomalies on existing CPUE series and to discuss future directions (Anon, 2007). On the basis of the analyses conducted at this meeting it could not be determined whether the Japanese longline CPUE series are affected by the catch anomalies described in the Japanese market review. From the data examined at the workshop there was no information on how to correct for the under reported catch in the CPUE series or whether or not this is possible.

In addition to the uncertainties about historic CPUE noted above, changes in the domestic management of the SBT quota in Japan in 2006 are also likely to have an impact (Itoh, 2006a). This may lead to a ‘discontinuity’ in the CPUE series, and it is unclear whether it would ever be possible to standardise the series for these changes.

2.3. Review of the Scientific Observer Program

The observer program was recognised in the design of the SRP to be “internationally accepted as an essential component of any fisheries management system”, and as a “key element” of the CCSBT SRP. The initial design specified the data to be collected and a 10% target level for observer coverage of catch and effort. However, it was recognised that, in the context of the CCSBT conventional tagging program, this level of observer coverage in the longline fleet may not be adequate., and that a higher level may be required to achieve appropriately precise estimates of F and M from the tagging program data. In particular, the aim was to estimate reporting rates in the longline fleets from observer-based tag return data. The nature of the surface fishery is such that observers do not play a role in tag recovery (because tags are recovered during harvesting and processing, not during capture; see section 2.4 below for further detail). The observer coverage required on longline fleets to provide appropriately precise estimates of F and M from the tagging program data was estimated to be 30% (Eveson et al, 2004).

Standards for the observer program for training of observers, data collection, reporting and deployment etc, were prepared and agreed at the 2003 SC (Anon, 2003b (Attachment F)). All members were expected to modify their observer programs to meet these standards. As noted above, the standards for observer coverage were to be updated when the coverage required by the tagging program had been determined, but this has not occurred.

Members were responsible for observer operations for their vessels, on the high seas and in their domestic EEZ. The program design stated that all fleets should be observed and target levels of observer coverage should be the same for all fleets, however most members have achieved the 10% target coverage of catch and effort in most years of the SRP and none, with the exception of NZ, have come close to the 30% objective for estimating tag reporting rates. There have been some modest improvements. In the case of fleets that previously did not have an observer program, observer training was initiated and observers deployed (e.g. Anon. 2006d (CCSBT-ESC/0609/SBT Fisheries –Taiwan); An et al 2006 (CCSBT-ESC/0609/SBT Fisheries –Korea)).

The program standards also required that observer coverage should be representative of different vessel types, areas and times, and recognise that to achieve this may require coverage greater than the target level. The spatial and temporal spread of observers has generally not been representative of the fleet composition (e.g. as noted in Harley and Kendrick, 2005, and Hobsbawn et al, 2006; also see other members' Fisheries and Observer reports), which limits the use of the data for providing estimates representative of the entire fleet.

The secretariat was tasked with ensuring that data collected by the observer program would become part of the CCSBT database. To date no members have provided the Secretariat with copies of their observer data (Anon, 2006b) nor has the observer data been included in the annual data exchange as originally intended.

Exchange of observers between countries and use of non-member observers was encouraged to maintain consistency. This has not occurred, as far as we are aware, except in the Australian Observer Program. Australia employed a South African Observer in 2006 and an American Observer in 2005.

In addition to the CCSBT SRP observer program, a trial observer program in Indonesia has been developed. This is a collaborative program between Indonesia and CSIRO, which commenced in mid-2005. The aim of the project is to address the lack of CPUE data available for this fishery, and to develop Indonesia's capacity to monitor, analyse and report on its tuna fisheries. The trial program will run until December 2008, focussing on vessels operating from the port of Benoa in Bali. Observers have been recruited and trained in species identification, safety, data management and report writing. Observer datasheets and a database have been developed. Development of a logbook/logsheet for the fishery is another key activity being run in parallel with the observer trials (Sadiyah et al, 2007)

In summary, observer coverage has generally not reached the 10% (of catch and effort), stated in the original SRP in most fleets. In the NZ Charter boat fishery it has been much higher, at nearly 100%. With respect to the additional coverage required in the longline fleets to meet the objectives of the CCSBT conventional tagging program, this has unfortunately not happened. Although summaries of observer activities have been reported annually to the SAG and SC, agreement about exchanging those data and submitting the data for inclusion in the CCSBT database has not yet occurred.

2.4. Review of the conventional tagging component of the SRP

The aim of the SRP conventional tagging program was to provide age-specific estimates of fishing mortality (F) and natural mortality (M) rates. The advantage of the tagging approach is that estimates are independent of other estimates of abundance (Anon. 2001a). The program aimed to tag fish over a broad geographic area to avoid problems with mixing, and to tag all components of the stock. The tagging program was explicitly linked to the observer program to provide estimates of recovery and reporting rates from the longline fishery. In the surface fishery, tags are retrieved during harvesting and processing rather than during the capture process, and observers on the purse seine vessels is therefore not useful for tag returns (tag seeding was used in the surface fishery to estimate reporting rates; see below). It should be noted that data on catch and catch at age are also required in some, but not all, types of tagging data analyses, and the program is therefore linked with the catch characterisation component.

Objectives for the tagging component were developed at a dedicated Tagging Workshop in Sep 2001 (Anon, 2001a):

- To provide age-specific estimates of the fishing mortality (F) and natural mortality (M) with associated estimates of uncertainty, for as many SBT cohorts as possible.
- To provide additional information on SBT migration and distribution patterns which may be useful in elucidating mixing rates of tagged fish.
- To provide direct estimates of growth rates of tagged and recaptured fish.

Tagging program design considerations were documented (Anon. 2001a), and were to be followed for all tagging projects undertaken. The design considerations aim to ensure the statistical validity of the information generated by the tagging projects. These include: multi-year, multi-cohort tagging; adequate numbers of fish tagged; stratification of tagging by area and school; collection of data and double tagging for tag shedding estimation; estimation of reporting rates; random tagging of fish sizes; and standardisation of tags. Standardised protocols for tagging and programs for training were also recognised as being required to ensure consistency across projects. Data from all programs was to be submitted to a dedicated database to be developed and maintained by the Secretariat. The database has subsequently been successfully developed and maintained by the Secretariat.

The importance to the tagging program of maximising the return of recaptured tags and quantifying non-reporting of recaptured tags was recognised as a central element of the program. Various mechanisms for maximising tag recoveries, i.e. through publicity materials, port liaison, incentives, and specific landing areas to be monitored, were specified, and the interdependency with the observer program emphasised. As noted above, tag seeding was identified as the mechanism to be used in the surface fishery where recaptures are only identified at the harvesting/processing stage. The collation and management of tag return data was primarily the responsibility of the Secretariat, while members were responsible for ensuring measures were in place for obtaining returns of tags caught by their respective fleets.

The tagging program has been implemented through several different projects conducted by members and also by the CCSBT. The CCSBT administered tagging project was designed to tag juveniles (ages 1-3) in the Australian surface fishery, using a dedicated pole and line vessel and releasing tags in waters off Western Australia (WA) and Southern Australia (SA). The design criteria for the project included tagging multiple cohorts over multiple years in large numbers, thereby directly addressing the design considerations detailed at the 2001 tagging workshop. The project commenced in 2001 and continued through to the 2006/07 season (CCSBT Secretariat, 2006 (CCSBT-ESC-0609/7)). The tagging has been implemented by the same project team over this period and the use of a set of taggers and double tagging has provided the basis for estimating both individual tagger effects and shedding rates.

In addition, conventional tagging from longline vessels has occurred in the south-eastern Indian Ocean region 2001-2003 (Itoh et al, 2006a), and opportunistically during other projects in other areas (e.g. Tasman Sea).

Progress against each of the objectives of the conventional tagging program is briefly reviewed below,

Objective 1: To provide age-specific estimates of the fishing mortality (F) and natural mortality (M) with associated estimates of uncertainty, for as many SBT cohorts as possible.

Age-specific fishing mortality rates have only been estimated for tagged juveniles in the Australian purse seine surface fishery (Polacheck and Eveson, 2006, 2005; Polacheck et al, 2004; Takahashi et al, 2004). These fishing mortality rates (Polacheck and Eveson, 2006, 2007) are estimated using a tag attrition model that is independent of catch and catch at age data. To minimise the effects of lack of, or low levels of mixing, only data from recaptures a year, or more, later than the year of release can be used. These harvest rates, however, only apply to the juveniles of each cohort that were in the Great Australian Bight (GAB) at the time of tagging. Assumptions about the representativeness of these fish in the wider population and assumptions about the proportion of juveniles present in the GAB each year would be required to extrapolate the F estimates to the full population of juveniles.

The estimates of fishing mortality provided from this project form an integral part of the Indicator Analysis conducted each year by providing the only independent source of fishing mortality rates for any component of the stock.

Tag recovery promotion efforts have been implemented to varying degrees and have met with varying levels of success. Estimates of reporting rates are available for the surface fishery, based on tag seeding experiments in farm cages. Initial tag seeding experiments were trialled in 2002 and then repeated in each subsequent fishing season. This work has demonstrated that reporting rates can and do vary among individual operators and among years and have a significant impact on the uncertainty of the estimated parameters (Polacheck et al, 2006b; Polacheck and Stanley, 2005; 2004) and, in extreme cases, the ability to estimate parameters reliably (Polacheck and Eveson, 2007).

To date there have not been sufficient returns or information on reporting rates from the high seas longline fleets to provide estimates of fishing mortality for this component of the stock. The 2003 SC concluded that "…the current levels of tagging, recovery rate and observer coverage are not high enough to provide useful estimates of fishing mortality rates from the longline fisheries." A technical review of the conventional tagging program was undertaken in 2004 (Anon, 2004 (Att 10 of the SC 2004 report)) and priorities for improving the tagging program were identified. The technical group agreed that observer coverage of at least 30% was required to provide estimates of fishing mortality with appropriate levels of precision (i.e. a co-efficient of variation (CV) of 0.20 (Anon, 2004). In this context, and as noted above, current observer coverage for the high seas longline fleets has not achieved this target (of 30%). The New Zealand Charter Fishery is the exception for the longline fleet. It has had nearly 100% observer coverage over recent years.

Estimates of natural mortality have not been calculated for juveniles using the current tagging program data, because fishing mortality rates for juveniles in the longline fisheries are required, and these can not be estimated in the absence of reliable estimates of reporting rates. For the same reason it is not possible to provide estimates of natural mortality for any of the age classes captured in the longline fisheries.

Objective 2: To provide additional information on SBT migration and distribution patterns which may be useful in elucidating mixing rates of tagged fish.

The design of the SRP conventional tagging program was for a broad distribution of tagging across the geographic range SBT, to provide information on mixing rates. With broad spatial coverage and estimates of reporting rates, it should be possible to quantify (i.e. estimate) mixing rates. The actual implementation of the tagging has not covered the full range of the stock, which combined with low tag returns and no information on reporting rates for the longline fisheries, means that mixing rates of tagged fish cannot be estimated. Even in the case of the surface fishery, the tagging has sometimes not been as well distributed as desired, usually due to the difficulty of locating fish and at sea conditions (CCSBT Secretariat, 2004c, 2006 (CCSBT-ESC/0409/8, CCSBT-ESC/0609/7)).

Notwithstanding this, the conventional tag data do provide qualitative information on mixing in the GAB and on large-scale direction of movement relative to patterns from earlier tagging programs (Polacheck and Eveson, 2006). Preliminary investigations of the returns of age 1 fish compared with age 2 fish in the GAB, indicate that there may not be complete mixing of the age 1 fish tagged in WA (Polacheck and Eveson, 2006; Takahashi et al, 2004).

Preliminary results from the Global Spatial dynamics Archival Tagging Project indicate that movement and migration patterns for 2-4 year olds may have changed from the 1990 archival tagging program results (Polacheck et al, 2006c). This project falls under item 6 of the SRP list and was endorsed by the SRP as one of those undertaken by member countries.

Qualitative analysis from tagging in the Off Cape South East Indian Ocean program by Japan, and Tagging in the Western Tasman Sea by Australia also provide some preliminary data on migration behaviour and mixing (Takahashi et al, 2004; Polacheck et al 2007; Evans and Patterson, 2007).

Objective3: To provide direct estimates of growth rates of tagged and recaptured fish.

The tagging program has provided information on growth rates for 1-5 year old fish tagged in the GAB and recaptured in the surface fishery (also in the GAB). Eveson et al. (2006; Eveson and Polacheck, 2005) have calculated juvenile growth rates from direct ageing and conventional tag recapture data and their results indicate that growth rates have continued to increase since the 1990's. This continues a trend of increasing growth rates for these year classes over four decades. While the mechanism underlying this increase in average size at age is not known, demonstrated changes such as these emphasise the need for ongoing monitoring of key population parameters. Comparative analyses of growth rates for other components of the fishery have not been undertaken to date and may not be possible given the paucity of available historical data. Given the changes in size at age demonstrated for the GAB component of the juvenile stock, a comparative analysis of juvenile size at age with other regions (e.g. New Zealand and South Africa) would be valuable to determine whether or not these changes are reflected in the broader population.

In summary, for the conventional tagging program:

1. Tags were successfully deployed on juveniles in the GAB, but not in sufficient numbers in other areas or for other ages/components of the stock.
2. Even for the deployments in the GAB (both WA and SA) there are concerns about the stratification of tagging effort by school, one of the design considerations of the program

3. Tag seeding in the surface fishery has provided estimates of tag reporting rates, which has enabled us to estimate fishing mortality rates, by age and cohort, for fish tagged in the GAB and recaptured in the surface fishery. There are, however, concerns that estimates of reporting rates from tag seeding may be biased (too low), leading to estimated harvest rates that are also biased (too high), particularly in the last couple of years (Polacheck and Eveson, 2007).
4. It has not been possible to estimate natural mortality for any age classes due to the lack of reporting rate information for the longline fleets.
5. Observer coverage for the longline fisheries has been too low for reporting rate calculations.
6. Tag returns rates have been low from the longline and, in some years, the surface fishery. On this basis, it is concluded that tag return promotional activities have not been successful, for the longline fleets in particular, and have compromised the quality of the results.
7. Mixing rates have generally only been qualitatively analysed because of the limited spatial coverage of tag releases, the paucity of returns, and lack of data to estimate reporting rates in the longline fisheries.
8. Growth rates have been estimated for juveniles in the GAB, captured in the surface fishery, but not for any other components of the stock.
9. A CCSBT tagging database has been successfully established.
10. Tagging from longliners has been demonstrated to be feasible, but to date the number of releases is low and the distribution uneven.

2.5 Summary of outcomes for the four key components of the SRP

The review of the four key components of the SRP, namely (1) catch characterisation, (2) CPUE standardisation and analysis, (3) scientific observer program and (4) conventional tagging program, does not paint an optimistic picture. In all cases there are some positive points where progress has been made, but on the whole, the objectives set out by the SC in 2001 have not been met.

Regarding catch characterisation, the authors agree with the statement by the SC that "*Given the outcomes of the market and farm reviews it is clear that the catch characterisation component of the SRP has not been successful*"(Anon, 2006b). There are now substantial uncertainties about the historic total catches and their associated size frequency distributions. This has serious implications for stock assessments, and for the development and evaluation of management procedures (MPs) (see e.g. Basson et al. 2007a). It is in fact, currently not possible to conduct a formal quantitative stock assessment (Anon. 2006b, 2006c)).

The issues with catch characterisation also potentially affect the Japanese longline CPUE series which has been relied on, in both stock assessments and the candidate MPs, as an indicator of abundance. The inherent limitations of CPUE as an indicator of abundance has long been recognised, but there are few alternative options, given the difficulties associated with obtaining fishery independent indices of abundance for such a broadly distributed pelagic species. It is now no longer clear how reliable these historic catch and effort data are, and the use of CPUE in assessments and MPs is, inevitably, being questioned. In addition, agreement has not yet been reached on the reporting of two major data components which have repeatedly been requested to assist in the standardisation and interpretation of CPUE.

The scientific observer program has generally not met the base-level coverage of 10%, though agreement has not yet been reached on the exchange of observer data, and entry of those data into the CCSBT database. A higher level of observer coverage (30%) in the longline fisheries was identified as being required to ensure acceptable levels of precision in the estimates of harvest rates from the CCSBT conventional tagging program. With one exception, the observer programs on the longline fleets have also not met the higher level of coverage, and reliable estimates of reporting rates cannot be obtained for the longline fisheries.

The CCSBT conventional tagging program has only been partly successful. Very large numbers of tags have successfully been deployed on juveniles off Western and Southern Australia. It is only possible to estimate harvest rates for juveniles recaptured in the surface fishery, and even here there are some concerns about the reliability of recent estimates of reporting rates based on tag seeding. It has not been possible to estimate harvest rates for the longline fleets, because it is not possible to estimate reporting rates, and because the number of tag returns are very low.

The broader spatial coverage of tag releases that had been envisaged has not really been achieved. Although good efforts have been made, and some tags have been deployed, this has not happened in sufficient numbers to be of great value. The lack of spatial coverage combined with the lack of reporting rates from the longline fleets means that our ability to obtain quantitative estimates of mixing rates is severely limited. Currently, only qualitative analyses of movement patterns and mixing are feasible.

The estimation of growth rates based on tag release and recapture information (as well as direct ageing) can also only be conducted for juveniles tagged off Australia, and recaptured in the surface fishery, because of the relatively low sample sizes for returns from elsewhere.

On a positive note, the CCSBT secretariat has constructed and maintained an extensive database to manage the data associated with these four core components of the SRP, to manage the confidentiality of those data, and to extract the necessary summaries or subsets required for stock assessment and for the operating model used to evaluate the performance of management procedures.

3. SRP components being undertaken as ongoing research by member countries

Items 5-9 of the SRP were considered important research activities that were already being undertaken or planned to be undertaken by member scientists. A brief review of progress under each of these five components is made below.

3.1 Direct Ageing (item 5)

The advantage of direct age information, over inferred age information from ‘cohort slicing’ of size frequency distributions, in an assessment is well known, particularly for long lived species such as SBT. The goal of direct ageing of SBT has therefore long been recognised. The CCSBT agreed to establish an otolith collection scheme in 1997, but there was no requirement to routinely read otoliths for age determination. Research into the reading of otoliths for age estimation, and the validation of age estimates derived from otolith readings culminated in a CCSBT Direct Age Estimation Workshop held in 2002. The Workshop developed standard methods for otolith collection, preparation and otolith reading methodologies. A manual for these procedures was produced, and a reference set of otoliths established (Anon. 2002c).

In 2003 (SC Report, paragraph 95), the SC agreed that otolith collections and age-determination (in all fisheries) should begin as soon as practical. Members now collect and routinely conduct age reading of otoliths (see member's Fishery reports; Farley, 2006; Itoh et al, 2006b). These data are submitted to the CCSBT, and entered into the database. These data have not yet been used in stock assessments or the operating model, but the time series of these data are now almost sufficient to warrant incorporating these data in to future analyses and assessments.

In addition, otoliths have been collected since the mid-1990's as part of the CSIRO/RIMF collaborative program in Indonesia (Farley et al, 2006). These data have been used in stock assessments and the operating model used for evaluating management procedures.

3.2 Archival and PAT Tagging (item 6)

Electronic tagging activities are summarised under three headings, essentially representing three programs. This is not necessarily a full list of all electronic activities on SBT, but as far as we are aware, these are the main programs or projects.

3.2.1 Archival and PAT tagging in the Indian Ocean

Japanese archival tagging activities were reported in Itoh et al. (2006a). Medium and large size southern bluefin tuna were tagged from a longline vessel in the south-eastern Indian Ocean during October to December 2005. Over a period of five years, 1159 SBT were released with conventional tags only, 283 with archival tags and 15 with PAT tags. Itoh et al. (2006a) note that 11 archival tags have been recovered.

3.2.2 **Global Spatial Dynamics juvenile archival tagging project**

As part of the CCSBT SRP, Australia initiated a Global Spatial Dynamics project involving the archival tagging of juvenile (2–4 year old) SBT throughout their range (i.e. from South Africa to New Zealand) with the objective of estimating movement and mixing rates, and periods of residency in different parts of this range. The project has been implemented as a collaborative project between New Zealand (NZ), Taiwan and Australia (Polacheck et al, 2003).

Archival tags have been released in NZ, Australian, central Indian Ocean and South African waters. Since 2004, 414 tags have been released. Out of the 88 released in 2004, 19 have been recaptured so far including the first recoveries ever from archival tags released in the central Indian Ocean and New Zealand. South Africa is the one targeted area where the project has not been very successful in achieving deployments so far. Plans for 2007 include having a trained Taiwanese observer release 25 archival tags off South Africa later in the year depending on fishing conditions for SBT (Polacheck et al, 2007).

The feasibility of conducting archival tagging from longline vessels and using trained observers to do the tagging has been demonstrated as part of this project. Ten recaptures have been made from the 85 fish tagged by Taiwanese observers in the central Indian Ocean in

July–August 2004 and 2005. Two of these recaptures were made by the Taiwanese fleet. Tags have also been released and recaptured by observers in New Zealand.

Reporting rates for archival tags appear to be declining. A total of 34 tags have been recaptured and returned to date (July 31, 2007). From the 88 releases in 2004, 19 or ~22% have been recovered to date. For the 2005 releases, 11% have been recovered to date. The recovery rate is approximately half of those for the 2004 releases at this time last year. This suggests that reporting rates have declined. In this regard we note that most of the recoveries to date have been from the Australian surface fishery and there has been a paucity of returns from the Japanese (0) and Korean longline fleets (0) (Polacheck et al, 2006c (CCSBT-ESC/0609/21)).

Preliminary analysis of the results indicate that the movement patterns of the archival tags returned to date from this project differs in the extent of their eastward movements from those seen from the archival tagged fish released during the 1990s. None of the recaptured fish from tags released in Western Australia or South Australia have moved into the Tasman Sea. Taiwan and Australia plan to continue to release the remaining archival tags under this project during the remainder of 2007 and early 2008. It is anticipated that this will result in a total of ~60 additional tags released in Western Australia and South Australia. Following the completion of the deployment phase of the project there is a further 3 years to allow time for further recaptures and completion of the full analyses. Further details of the initial results from this project are provided in Polacheck et al (2006d, 2007).

3.2.3 Pop-up tagging project in the Tasman Sea

In 2001 a pop-up satellite archival tagging program was initiated by Australia in the western Tasman Sea region (see Gunn et al. 2006 for further details). The aim of the project is to understand movement of adult sized SBT in the Tasman Sea, fidelity to the region and the frequency of return to the spawning grounds. Pop-up satellite archival tags provide a fishery independent method for estimating movement and habitat preferences in pelagic fish (Gunn & Block 2001). In 2006, this program was extended to include tag deployments in the Indian Ocean in an effort to (i) determine movement patterns of fish caught off the eastern South African coast (ii) their fidelity to this area and (iii) their connectivity with those fish moving from the Tasman Sea to the spawning grounds south of Indonesia.

The PSATs record ambient temperature, pressure (depth) and light level. Tags were programmed to release 364 days after deployment. A total of 24 PSATs were deployed in 2006 – data have been received from 20 of these. Combining all datasets from tags during the period 2001-2005, this program has now achieved records from 36 individuals of greater than 90 days duration post-deployment, 19 individuals of greater than 150 days post-deployment and 5 individuals greater than 200 days post-deployment. The 2006 deployments were generally of longer duration, which has provided an increased understanding of movements and degree of residency of SBT in the Tasman Sea region and new insights into the movements of SBT in the Indian Ocean (Evans and Patterson, 2007).

3.3 Recruitment monitoring program (item 7)

The Recruitment monitoring Program commenced in 1993 as a collaborative program between Japan and Australia aimed at developing methods to provide an index of recruitment. Since the commencement of the SRP in 2001, projects undertaken include: the scientific line transect aerial survey, the commercial spotter surface abundance per unit effort (SAPUE) index, the acoustic survey and the acoustic tagging of age 1+ fish in Western Australia. More recently a "piston line" troll survey has also been initiated in Western Australia.

Details of projects and results have been presented to the SAG and SC in the form of working documents and reports (e.g. Anon. 2002d). In 2005, a review of the RMP was conducted and outcomes of the review can be found in Anon. 2005b.

3.3.1 The RMP aerial survey

The index of juvenile abundance based on a scientific aerial survey in the Great Australian Bight (GAB) is one of the few fishery-independent indices available for assessment and management purposes (Anon, 2006b; Eveson et al., 2007). The aerial survey was conducted in the GAB between 1991 and 2000, but was suspended in 2000-01 due to logistic problems of finding trained, experienced spotters and spotter-pilots . A review of the data was conducted, which concluded that the scientific aerial survey does provide a suitable indicator of juvenile SBT abundance in the GAB (Bravington 2003).

In 2005, a full scientific line-transect aerial survey was re-established in the GAB. New analysis methods were developed, and all data were re-analysed. Based on these analyses, a revised index of abundance was constructed for the surveys in 1993-2000 and in 2005-2007 (Eveson et al 2007).

In addition, in 2007 a large-scale calibration experiment was conducted using a second plane containing a third observer (Eveson et al 2007). The calibration experiment was considered particularly important in the light of the over-catch issues, and the potential requirement to continue the survey into the future. The aims of the experiment were to:

(1) compare SBT sighting rates by one observer versus two observers in a plane - in light of the pending retirement of the only experienced spotter-pilot available for the survey (i.e., in case future surveys have only one observer in a plane), and

(2) provide additional data on observer variability to help reduce this source of uncertainty in the aerial survey indices.

Analyses of the calibration experiment data are still underway.

Results from the RMP review workshop and the re-instated aerial survey were considered in 2005 and the SC report (Anon.2005a SC10 Report, para.111) states that "*The ESC Chair noted that considerable work had been carried out recently to validate the aerial survey and that this had resulted in higher levels of confidence in the survey outcomes. The external panel suggested that the aerial survey outcomes may now be at the stage where they could be included in the tuning of the operating model*."

3.3.2 Commercial spotting in the Australian surface fishery

Since late 2001, data from sightings of SBT during commercial spotting operations in the Great Australian Bight have been collected using experienced industry-based tuna spotters. The systematic collection in a unified format, and subsequent computerisation of the data was started when the scientific line transect aerial survey was suspended. A large amount of information is collected by the spotters, as part of the commercial operations. The data have been used to estimate a fishery-dependent index of SBT surface abundance per unit effort (SAPUE index) for each of the seasons from 2002 to 2007 (Basson and Farley 2007). Interpretation of the results are difficult as the data suffers from many of the same problems that affect catch per unit effort data (e.g. lack of coverage in areas where commercial fishing is not taking place, changes in coverage over time, and changes in operations over time), as well as issues peculiar to aerial spotting (e.g. potential double counting, the definition of effort within a flight). These difficulties are likely to affect both the point-estimates of the index and, arguably more importantly, the estimates of variance. From a scientific point of view, the index derived from the scientific line transect survey is preferable as an index of abundance of juvenile SBT in the Great Australian Bight.

3.3.3 Acoustic survey for juveniles in Western Australia

As part of the joint RMP, an acoustic survey of juvenile fish (generally 1 year old) was initiated by Japan in south-west Western Australia. The aim of the survey was to develop an index of relative abundance of juvenile SBT before they entered the GAB (Itoh, 2006b). Associated with the acoustic survey were two other projects: the "piston line" troll survey which was initially designed to assist in locating the cross shelf position of the main "run" of juveniles for the acoustic survey (Itoh and Sakai, 2007); and the acoustic tagging project, which aimed to provide estimates of movement patterns and residency times of juvenile SBT in the area of the acoustic survey (Hobday and Kawabe, 2007). More recently, there have been initial attempts to explore the utility of the trolling method as a potential relative abundance index (Itoh, 2007).

The acoustic survey has been conducted from 1996-2003 and 2005– 2006 and indicates a rapid decline in the acoustic index for juvenile SBT from 1997 – 2001 to near zero values (Itoh 2006b, Hartog et al., 2007). While there is still considerable uncertainty about the relationship between the acoustic index and abundance of juvenile SBT, the near zero values of the index in the latter six years of the survey is of concern. At present it appears that the acoustic survey will not be continued.

3.4 Development of a spawning biomass index (item 8)

The development of a spawning biomass index includes a basic understanding of the reproductive biology and, ideally, estimates of quantities such as size/age at maturity, egg production, and the relationship between body size and egg production. Research on spawning adults was conducted in the late 1990s and early 2000s, and resulted in estimates of age at 50% maturity and of egg production as a function of body size (Davis et al, 2001, 2003).

Several spawning ground research cruises were conducted by Japan. Itoh et al. (2002) present results of two cruises aimed at analysing fish size and spawning activities at different depths, determined from hook depth monitors on longline branch lines. A total of 34 SBT were caught, and hooks set in shallower water caught both large and small fish. Hooks set in deeper water, only caught small fish. The surveys also analysed histological data, tracked two fish and attached pop-up archival tags to five fish, to obtain information on migration of SBT from spawning grounds to feeding grounds. Results of further investigation of the vertical distribution and spawning condition relative to fish size (of adult SBT) are given in Itoh et al. (2004). Small adults were again caught in a wide vertical range without any trend with depth and there appeared to be no relationship between maturity stage and depth.

With regard to the development of an index of abundance on the spawning grounds, the catch monitoring in Indonesia was considered a starting point, though catches are generally poor indicators of abundance because they are easily affected by external factors (e.g. fuel prices, changes in targeting practices). Another collaborative project with Indonesia was established to computerise and analyse catch and effort data collected by trainees from Indonesian

Fisheries High Schools (FHS). Trainees have accumulated a large amount of information on daily fishing operations of the Benoa-based longline fleet, including catch and effort data, as part of their seagoing training. It was known from that start that these data cannot be treated as robust observer data, though it is one of the very data sources of this kind for the fishery on the spawning grounds. Work on developing an index of abundance from these data is ongoing. In addition, improvements to the level of training provided to the FHS students before they depart have are being made in the hope that the FHS program can become a more reliable and valuable source of observer-generated data for the Indonesian longline fleet (also see Basson et al. 2007b).

Development of an index of spawning biomass has generally focussed on improving the quality and consistency of the catch and effort data available from the Indonesian spawning ground fishery and estimates from the stock assessment. More recently, investigations have been made into the potential utility of "close-kin" tagging methods as a means to estimating spawning stock biomass of SBT (see Bravington and Grewe, 2007). This approach uses DNA fingerprinting technology to identify parent-offspring pairs with the ratio of "matches" providing the basis for an estimate of spawning stock biomass. The proof of concept work for the genetic markers has been completed and samples of adults and juveniles have been collected for two spawning seasons (for adults) and two corresponding juvenile seasons, from the surface fishery in the GAB. Further details on the method and the approach being undertaken in the current study are provided in Bravington and Grewe (2007).

3.5. Fisheries Oceanography for improved habitat definition (item 9)

One of the aims of the electronic tagging work under the SRP was to develop a better understanding of the habitat preferences of SBT from analysis of movement patterns and oceanography.

Takahashi et. al. (2002) report results of preliminary analysis of potential habitat distribution for SBT and for fishing vessels, focusing on sea temperature as an oceanographic factor. They applied the concept of a Habitat Suitability Index (HSI) model to generate a map that represented habitat potential for SBT, and to generate a potential map of fishermen's "habitat". Results showed that high habitat potential regions are distributed along the longitudinal direction for both SBT and fishing vessels. These preliminary analyses were based mainly on archival tag data for juveniles. The study identified the need for archival tag data for adult SBT to resolve some of the differences between the SBT and fishing vessel habitat maps.

The ongoing projects investigating the spatial dynamics of SBT (discussed in Section 3.2.2 and 3.2.3) contain objectives focused on the integration of fisheries oceanography information with tag data to further improve our understanding of SBT spatial ecology, including preferred habitats (or conditions). This work is still underway and initial analyses can be found in Gunn et al. (2006).

One example of the use of data from pop-up archival tags for adult SBT in the Tasman Sea, is in the characterisation of preferred habitats. This characterisation is then used to predict the spatial distribution of preferred SBT habitat on the east coast of Australia, on a near "real-time" basis. This information, combined with other sources of operation information from the fishery and observers, is used to minimize the bycatch of SBT by non-quota holders in the Eastern Tuna and Billfish fishery.

3.6 Summary of outcomes for the additional five components of the SRP

Activities under items 5-9 of the SRP (direct ageing, electronic tagging, recruitment monitoring, spawning biomass index, and habitat definition) were primarily based on existing member activities and have therefore been progressed by members, rather than directly through the CCSBT. Progress and updates have been reported through the CCSBT, but many projects are still underway (e.g. analyses of electronic tag data), and it would therefore be premature to 'review' some of the aspects of these activities.

Good progress was made in terms of direct ageing which is now a routine activity, generating important information which can be incorporated into a stock assessment, or operating model, in the near future.

There have been many deployments of electronic tags by several members, under several projects. However, there have been difficulties in achieving the broad spatial coverage required to achieve some of the objectives of the programs. Better cooperation and a strong collective scientific effort are needed to achieve those deployments in future. Preliminary results have already provided new insights into SBT movement patterns and habitat preferences.

The recruitment monitoring program has generated the only fishery independent index of juvenile abundance. Although it only represents part of the total juvenile stock, this information is nonetheless considered an important indicator. The development of an index of recruitment (age 1 individuals) has been more difficult and alternative approaches are still being trialled.

In the context of the development of a spawning biomass index, the recently developed 'close-kin' approach is, in our view, very promising, particularly in the light of the difficulties associated with the analysis and interpretation of the Indonesian Fishery High School catch and effort data. Research under this item is therefore also still underway.

Some results on habitat characterisation based on fisheries oceanographic data and electronic tag data have been obtained, but much research is still underway under the electronic tagging programs.

4. Priorities and directions for Future SRP Work

Given the scale and period of the unreported longline overcatches and the outstanding questions about the potential bias in the size sampling procedures for the surface fishery, the highest priority for the future SRP must be the design and evaluation of programs for the collection and provision of accurate, independently verifiable catch and effort data. Furthermore, these data must be available for analysis by the SC in raw form at a spatial and temporal scale that allows for relevant statistics to be estimated from them and changes in fishing practices and sources of potential biases to be explored. We note that this is not the first call for the provision of data of this form for the assessment of the stock and the development and testing of Management Procedures for SBT (Anon, 2004, 2005, 2006). In the absence of data provided to the CCSBT in this form, the SC will be unable to provide the Commission with objective, transparent and robust advice on the current status of the stock or the risks associated with current and future levels of harvest.

It is also worth emphasising the relationship between the SRP and the development and implementation of a management procedure. In the past, the SRP had the primary aim of providing accurate data and information for improving the assessments of the status of the stock. The conditioning of the operating model relied on these same inputs. Also, in the case of the previous MPs, all relied on catch and effort information in the form of total catch, CPUE and/or size data. While the nature of future MPs may vary from this, they are all likely to be based on a formulation which determines the TAC in the next time step as an adjustment to the TAC in the previous time step. In this regard, the MPs are all likely to depend on, at least, accurate catch information[4], even if they do not use CPUE. If other indicators are to be used, either in a stock assessment, conditioned operating model, or in an MP, then they too should arguably form part of the SRP, under the original aim of the SRP. This aim of providing accurate data and information for improving the assessment of the status of the stock and hence, providing robust management advice, is by direct implication also relevant to the conditioning of an operating model, and the testing and implementation of an MP. Therefore, while the priorities for future work under the SRP should still focus on providing the data required to estimate the current state of the stock, the priorities required for development and implementation of a new MP should also be a focus. Accurate, verifiable catch and effort data are likely to be essential to both.

In addition to focusing on future data collection and research, there are now several outstanding issues regarding historic data, namely the large uncertainty about total historic catches, size frequencies of some of these catches and possible affects of unreported catches on the Japanese longline CPUE series. We also consider it an important part of the SRP to resolve as many of the historic data issues as possible, either by determining the appropriate ‘new’ historic series to use, or by quantifying and characterising the underlying uncertainties which need to be incorporated in future stock assessment and MP evaluation work.

At the SC in 2006, it was agreed that prioritization of activities would be required to ensure that resources are invested to achieve the greatest benefit in terms of the impact on the quality of management advice. The SC clearly identified its role as providing recommendations on the scientific data requirements for meeting the Commission objectives, and the risk of implications associated with failing to obtain the required data (Anon, 2006b) and recognized that non-scientific feasibility concerns (e.g. related to expense, commercial confidentiality) would require consideration by the Commission.

<u>The four core components of the original SRP</u>

1. Characterisation of catches

The characterisation of catches, both the magnitude and the associated size and age structure of the catch, is still a crucially important scientific data requirement (Anon 2006b). The SC recognized the great potential in adopting the measures such as fine scale catch and effort data reporting, provision of market and fleet statistics, independent at sea data verification, centralised VMS, international port monitoring and a catch documentation scheme to verify and improve the utility of future catch and effort data from the long line component of the fishery (Anon, 2006b). The meeting also noted that current uncertainty in catch composition in the farms could be reduced by the addition of stereo video cameras during tow cage transfers to holding pens and feeding during towing to reduce weight loss.

[4] In the previous set of MPs the catches taken were assumed to be identical to the TAC. If the actual catches are quite different from the TAC, the MPs performance would be jeopardised, so this at least needs to be monitored.

2. CPUE

Although there have always been concerns about the use of longline CPUE as an index of overall stock abundance (because of changes in the spatial distribution and extent of the fisheries and shifts in fishing practices), concerns about the reliability of those data means that the way in which the data are collected and used need to be reconsidered. Even if catch and effort data are not used to a construct a CPUE series for use in an assessment or an MP, there is still a need to obtain these (or similar) data from the fisheries to allow characterisation of the fleet dynamics and, at least, some indication of local densities of SBT where the fleets are operating.

We consider that work should continue to try to resolve the question of whether the historic CPUE series, based on Japanese longline catch-effort data, were affected by the unreported catches or not. As noted in section 2.2, the recent CPUE workshop (Anon, 2007) reported that they had been unable to determine whether or not the CPUE series have been affected by the unreported longline catches, and from the data examined at the workshop there was no information on how to correct for the unreported catch in the CPUE series and whether or not this is possible. Alternative analyses aimed at resolving these issues should be one of the highest priorities for the SAG and SC.

With regard to future catch-effort data, all attempts should be made to put in place processes that will allow for reliable, verifiable data to be collected. The notion of a 'sentinel' or 'survey' type CPUE series is promising. However, as noted in Basson et al. (2007a), there are still likely to be problems, such as limited spatial coverage, with regard to its use as a reliable index of overall population abundance. Notwithstanding this, given the significant changes occurring in the fishery there may be merit in the development of such a monitoring program as an indicator for particular areas of the high seas. This is discussed further below.

3. Scientific Observer program

The need for a scientific observer program has not changed and the statements made in this regard by the SC in 2001, when the original SRP was designed, still hold - the observer program was recognised in the design of the SRP to be "internationally accepted as an essential component of any fisheries management system", and as a "key element" of the CCSBT SRP. Two outstanding issues to resolve are achieving target levels of coverage, particularly in the context of non-random observer deployment, and agreeing on some form of data exchange within any constraints about confidentiality. In our view achieving both these objectives in a cost-effective manner is essential to providing the necessary data for future assessments and restoring confidence in the reliability of the fisheries catch and effort monitoring systems. The SAG and SC are well placed to provide advice on revised design criteria for such a program in light of the overcatch and the changes in the fishery.

There would be considerable short-term benefit if an expanded scientific observer program could be implemented in the immediate future. In particular, this would capitalise on the recently completed CCSBT conventional tagging program and cooperative archival tagging program, by providing the potential for high return rates from all sectors of the fishery and estimates of reporting rates for the longline fleets. This would help to address these deficiencies in the current SRP tagging program (see section 2.4 and below). It should be noted that target levels for observer coverage that will provide information relevant to the tagging program were estimated to be 3 times higher than the current target level of 10% (as discussed previously).

4. Conventional tagging

The two main problem areas for the most recent conventional tagging program were the lack of reporting rates for the high seas components of the fishery and the uneven spatial coverage of releases and returns. As noted above, if these issues can be overcome, then conventional tagging is still a promising approach to obtaining estimates of harvest rates and, possibly, even of natural mortality rates and mixing rates, which are all significant uncertainties in the assessment and operating model. Future directions for some form of 'conventional' tagging are further discussed under item 8 below.

Additional components of an SRP

In the remainder of this section we identify additional directions for future work under the SRP. However, as noted above, the utility of the majority of these components will be heavily dependent on the implementation of effective, independently verifiable catch and effort monitoring systems, for all fleets, to build the necessary confidence in the data and assumptions underlying the analysis and advice that would be based on them.

5. Fisheries Independent estimates of spawning biomass

We consider that the development and application of "Close-kin" tagging approach offers the most promising means of obtaining a truly fisheries independent estimate of absolute spawning stock biomass in the short, and potentially longer, term. Details of the approach and the progress to date in developing the necessary genetic markers and sampling programs are provided in Bravington and Grewe (2007). While this method has not been applied to teleosts before, the characteristics of the SBT stock means that it meets most of the criteria required for a successful application. Given this, the relatively low costs and the current absence of an alternative approach, we consider the close-kin approach to be worth pursuing. Furthermore, if successful, it would provide the basis for obtaining a fisheries independent estimate of SSB at regular intervals, which could be used in any future "conventional" assessment.

6. Fisheries independent estimates of relative (longline) fishable abundance

Longline CPUE (particularly for the Japanese fleet, given the long time-series and large spatial coverage in early years) has traditionally been used as an index of relative abundance, but this is obviously a fishery dependent index. It should be possible to construct a somewhat more fishery independent index of relative abundance by conducting so-called 'sentinel surveys. Sentinel surveys may be useful "indicators" of trend in relative abundance, free of shifts in fleet behaviour and changes in targeting, particularly if they were focussed in key areas of the stocks range. This would not replace or reduce the requirement for verified catch data from all the fisheries for assessment purposes, and verified effort data for the monitoring of total effort in the fisheries. (Also note the implications of how historic CPUE data issues are resolved and how future CPUE data are collected and used). Although there are still likely to be problems associated with the interpretation of such an index (primarily associated with sample size and spatial coverage), we consider that it (a sentinel survey) has the potential to serve as a useful indicator of trends in stock status, at least in some areas, if appropriately designed and implemented. We note the initial consideration given to this concept by the CPUE Working Group (Anon, 2007) and recommend that the SC give further consideration to the utility of a formal design and feasibility study as part of the future SRP.

7. Fisheries Independent Index of Recruitment

The scientific aerial survey provides the only current fisheries independent index of juvenile abundance (ages 2-4) of SBT in the GAB and, given the current state of the stock and recent low recruitments, should be considered a high priority for future monitoring under the SRP, in the absence of a viable alternative. At its 2006 meeting, the SC recognised the value of aerial survey (Anon. 2006 b).

Initial trials of the use of surface trolling, indicates that reasonable numbers of 1+ SBT can be caught in Western Australia as they migrate into the GAB. However, we consider that formal design studies and further development experiments are required before this approach could be considered by the SC as a reliable quantitative index for monitoring recruitment in the fishery.

8. Fisheries independent estimates of fishing mortality

Conventional tagging (although not entirely fishery independent in the case of the recent CCSBT tagging program) can provide estimates of harvest rates and, under some circumstances, also estimates of natural mortality and mixing rates[5]. We first discuss the issues associated with conventional tags and then consider other types of tags which could be used in a similar way, but which may reduce some of the problems encountered with the conventional tagging program.

While the overall objectives of the conventional tagging program have been compromised to varying degrees (see section 4), the program has provided valuable estimates of harvest rates for the surface fishery for most year classes and a number of cohorts. Note though, that there are concerns that recent estimates of reporting rates (from tag seeding in the surface fishery) may not be reliable (Polacheck and Eveson, 2007) Over the coming years additional returns will provide information on two or three additional cohorts, which may provide reasonable estimates of harvest rate if the number of returns and estimates of reporting rates improve. The value of the program would be substantially improved if the observer targets (in the longline fisheries) associated with the tagging program (i.e. 30%) were met to provide estimates of reporting rates. Attention to tag recovery and the estimation of reporting rates should be the highest priority for the future of the conventional tagging program, or any other tagging program.

Additional areas in which the program could be improved include:

- Improving the distribution of tag releases in the GAB, particularly offshore releases and further to the west in the WA grounds.
- Increasing considerably the number and distribution of releases from the longline component of the fishery to obtain much broader spatial coverage of releases.
- Substantially increasing the observer coverage on the longline component of the fleet to provide increased number of returns and estimates of reporting rates. In this regard we consider that any further investment in tag releases in the surface fishery will be of

[5] In theory tagging can be used to estimate abundance, but this was not the aim of the CCSBT conventional tagging program, and this use of tagging data is considered the least reliable.

limited value unless the observer systems and tag seeding projects are in place to ensure that the number of returns will be high enough and reporting rates can be reliably estimated

- Procedures for automatic tag detection/recovery. The further development and refinement of electronically readable PIT tags means that this technology may now be a viable alternative, or at least a complementary addition, to conventional tags to improve estimates of reporting rates or, potentially, provide for automatic tag recovery. This approach is currently being used successfully for Patagonian toothfish[6] and would be feasible to implement in both farm and longline operations.

An alternative to conventional tagging is the concept of using "genetic tags" in a conventional release-recapture design. In this case, tissue samples of individual fish are taken from live fish captured in the wild and the fish are released. The unique DNA fingerprint from the tissue sample of each fish forms the "tag" and recaptures are obtained from tissue samples as part of catch sampling programs. This technique has been used successfully in a pilot project for other pelagic species[7] where tissue samples from individual fish are obtained with specially designed hooks, which don't require the fish to be landed, and hence reduce the stress associated with "tagging". There is a significant cost associated with DNA fingerprinting of tissue samples. However, these costs are reducing rapidly and, as noted in the introduction to this section, the relative costs must be weighed against the relative value of the data and estimates obtained from alternative approaches. We also note that the genetic fingerprinting done on samples for the close-kin approach, could in addition be compared to the genetic tag sample for potential "recaptures", thereby providing two uses for one set of fingerprinting. In the case of the genetic tagging approach, there is another significant advantage in that it is not necessary to estimate "reporting rates" as the "recaptures" are obtained from subsequent tissue sampling, rather than relying on fishers or processes to recognise and return a conventional tag.

As noted above, there are also other options with novel (or existing) tags which can be detected in automated ways, and which may increase the potential for obtaining reliable 'reporting rates'. We do not discuss these alternatives in detail here, but note that any consideration of continued large scale tagging programs should first seriously reconsider the type of tag, its associated 'recapturing' process and implications of, or need for, estimates of reporting rates.

Comment on choice of Fisheries Independent approaches

Naturally, the trade-off between cost and the likely value of the information obtained from alternative approaches requires formal consideration. Notwithstanding this, we consider that novel approaches, such as the close-kin approach which provides an estimate of absolute spawning biomass, and alternatives to conventional tagging, such as "gene-tagging", are worthy of further consideration by the SC. In addition to the cost-value trade-off, the time required for completing the necessary design studies, implementing the preferred alternative and collecting sufficient data to provide robust and useful estimates of the relevant quantities for the different approaches, should be considered. With the exception of the close-kin approach and the aerial survey, the other alternatives for fishery independent approaches (sentinel survey, surface trolling) will require several years to trial and implement and then

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[6] CRD *pers. obs*

[7] Rick Buckworth pers.comm. Principal Investigator of the "FRDC Genetag" project, where this technique is being applied to Spanish Mackerel in the Gulf of Carpentaria, Australia.

several more years to collect sufficient data to provide useful estimates or trends. The time within which alternative types of tagging/tag-detection (e.g. genetic, PIT or other) programs can be functional will likely depend on the detail, but some could probably be implemented quite quickly. In this context we consider the former two approaches (i.e. close-kin and aerial survey) to be the highest priority, in the short term, for reducing the current uncertainty in the status of the spawning stock and to continue monitoring recruitment trends. If genetic tagging can be implemented soon, and make use of the genetic fingerprinting being done under the close-kin project, then this should also be seriously considered[8].

9. Development and Testing of MP

There are two aspects to future work on the development and testing of management procedures. As noted at the last SC meeting (Anon, 2006) consideration must be given to the development of an "interim MP" to provide a basis for setting catch levels while the uncertainties in the historic data are resolved (to the extent possible) and new monitoring programs are developed and implemented to provide reliable, verifiable catch and effort data. In the case that the current uncertainties in the historical data cannot be resolved sufficiently for the historic data to be "joined" with the future data, it will then take several more years before sufficient new data is available for a stock assessment and use in a "long-term" MP. So, realistically, it may be necessary for an "interim MP" to be in use for 5-10 years. If some of the historic data issues can be resolved, a central question for the SC to consider (particularly with respect to the historical catch and effort series) is what would be the criteria that would need to be met to provide sufficient confidence in the revised data series?

More detailed consideration of the way forward for MP development and testing is provided in Basson et al 2007, as a starting point for discussion in the SAG and SC. Suffice to say here, that there is a strong interaction between the nature of any future MP and the success of monitoring and assessment approaches developed and implemented under the SRP. That is, any future MP will be reliant on the successful implementation of future projects under the SRP and the quality and reliability of the data and information they provide. Given this, and in light of the recent overcatch revelations, independent, transparent measures to verify data collection and reporting must be an essential part of all future SRP activities.

10. Biology and Movement dynamics

Although the basic biology and movement dynamics of SBT may not be the top priority of an SRP in the immediate future, we note that there are still gaps in our knowledge of the reproductive biology and spawning behaviour of SBT, and their migration patterns as recruits, juveniles and adults. There are also existing and ongoing member programs of research on these topics which, in our view, remain important.

For example, the recent studies on the spawning migrations and Tasman Sea residency of adult SBT (section 3.2) indicate that at least some proportion of adults may not return to the spawning grounds each spawning season. As noted, this has implications for interpreting trends in the data from the Indonesian monitoring, assumptions about the selectivity/vulnerability of the spawning component of the stock and estimating annual spawning potential of the stock (though see Bravington and Grewe (2007), noting that the

[8] This is relevant in light of the results currently being obtained from the conventional tag returns in the surface fishery.

multi-year application of the close-kin approach is likely to be able to deal with spawning cycles). If the current positive trend in retention times of the pop-up archival tags can be maintained, it should be possible to obtain data on individual adult SBT for more than a single spawning season cycle. Information over this duration will be required to understand the significance of these initial results.

In addition, the changes in estimated growth rates of SBT over the past decades (Polacheck et al. 2002), support the ongoing need to monitor the basic underlying biological parameters of the SBT stock.

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