Update of estimation for the unaccounted catch mortality in Australian SBT farming in the 2015 fishing season

2015 年漁期の豪州畜養ミナミマグロにおける未考慮漁獲量推定の更新

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要約

CCSBT 委員会は第 20 回年次会合において、全ての未考慮の漁獲死亡の影響評価を ESC に付託した。我々は、オーストラリア畜養に関係する表層漁業の漁獲について、未考慮の漁獲死亡量推定を継続して実施している。本文書では 2015 年漁期までの推定値を求めた。

SRP 標識データから推定した畜養魚の成長率は他のマグロ属野生魚の成長率と同程度にしかならなかった。豪州政府が報告する畜養終了後の収穫漁獲量を 40/100 尾サンプリングに基づく年齢組成から達成する成長率は、SRP 標識データから求めた成長率に比較して著しく高く、太平洋クロマグロ畜養魚の成長率よりも著しく高いことから、事実である可能性は低いと考えられた。

SRP 標識データから求めた成長率で推定した豪州まき網の漁獲量は、報告漁獲量よりも 724 トンから 2,546 トン、平均 1,650 トン多かった。推定超過漁獲量は報告量よりも 14% から 56%、平均 34.4%大きかった。推定超過漁獲量の割合は年々、増加する傾向にあった。

未考慮漁獲量および年齢組成の調節に際しては、本結果の年別の推定値（平均 34.4%）または 40%以上を用いた結果も考慮するべきである。本文書の解析の信頼性についてはオーストラリアが CCSBT 事務局に報告している CDS の個体別体長体重データを解析することで検証できる。ESC は、ステレビデオカメラシステムの導入によって信頼できる体長データを取得することでこの漁獲量に関わる不確実性に対する懸念を払拭することを、委員

会に勧告すべきである。

Abstract

The CCSBT Extended Commission (EC) requested the Extended Scientific Committee (ESC) to conduct sensitivity analyses around all sources of unaccounted catch mortality of southern bluefin tuna (SBT) at the 20th annual meeting. We have been continuing estimation of possible unaccounted catch mortality relevant to farming in the Australian surface fishery. We provide updated estimation up to the 2015 fishing season in this document.

Growth rates of farmed SBT estimated from the CCSBT-SRP tagging data were as low as those of other *Thunnus* species in wild. Assumed growth rates, which explain reported catch for Australian purse seine with 40/100 fish size sampling for the total of harvested farm fish, were extremely higher than growth rates inferred from the SRP tagging data and growth rate of farmed Pacific bluefin tuna, and then it was highly unlikely.

The Australian surface annual catches which estimated by using the SRP tagging growth rate were higher than reported catches. The excess weights ranged from 724 to 2,546 tons, with a mean of 1,650 tons. The proportions of this excess of the reported catch ranged from 14% to 56% with a mean of 34.4%.

When considering unaccounted catches and adjustment of age composition, the mean of 34.4%, and even the possibility of >40% should be considered. Reliability of our results can be further evaluated by analyzing CDS data which includes individual body weight information for all of the farmed individuals that Australia reported to the CCSBT Secretariat. Furthermore, the ESC should recommend the EC to dispel the concern of this uncertainty on catch by recommending immediate implementation of the stereo video camera system to provide reliable length data.

緒言

ミナミマグロ *Thunnus maccoyii* の資源管理は、2011 年に CCSBT において管理方式(MP)による TAC 決定システムが導入されたことで、新たな時代を迎えた。MP の導入はマグロ類の地域漁業管理機関においては初めての事例であり、CCSBT の取組みは世界的に注目を集めている(Hillary et al. 2015)。

一方、当然のことながら、適切な資源管理のためには、MP のように科学的な根拠に基づく漁獲枠の設定とともに、設定された漁獲枠に対する遵守を確保することが必要である。近年、CCSBT とその加盟国は遵守の強化に精力的に取り組んできた。しかしながら、漁獲枠の相当部分を占める畜養セクターに付随する表層漁業においては、漁獲量の過小報告のリスクが解決されないままとなっている。まき網で漁獲された種苗を畜養に利用する場合、ハンドリングによる種苗の死亡リスクを軽減する目的から、まき網から生け簀への移送量は推定値となる。このため畜養魚の漁獲量については高い不確実性が存在し、例えば大西洋クロマグロにおいては 1990 年代半ばからの畜養向けまき網漁獲の増加に伴って深刻な過小報告があり、資源の保全を損なうと考えられている（Anon. 2010）。このため ICCAT においては、2012 年にステレオビデオカメラ又は同等の正確性を持つ代替技術により 100% の活け込みをカバーすることが義務化され（Recommendation 12-03）、2013 年には活け込まれる魚の 20%以上を測定すること等が規定された（Recommendation 13-08）。

ミナミマグロについては、活け込み時に数千尾ほどの原魚の中から 40 尾を抽出サンプリングし、その平均体重で全漁獲量、活け込み量を推定する方法が唯一の畜養国である豪州によって用いられてきた。豪州は、2013 年からはサンプリング尾数を 100 尾に増加させているが、本質的な問題解決には結びついていない。抽出サンプリングによる漁獲量推定には根本的な問題があるものと考えられる。

豪州畜養魚の年齢組成に関わる不確実性については、2005 年に問題が指摘され（Anon. 2005）、独立レビューではデータ不足から結論が出なかった（Anon. 2006）が、その後の畜養後の体長体重測定データから大きなバイアスが存在することが強く示唆された（Itoh et al. 2009a, 2009b, 2010, 2011, 2012, 2014, Itoh and Takeda 2015）。その推定されたバイアス（過剰漁獲）は、毎年の報告量に対して 724 トン（14%）から 2546 トン（56%）、平均 1702 トン（35.5%）にも及んだ。

CCSBT 委員会は第 20 回年次会合において、全ての未考慮の漁獲死亡を含めた資源評価の感度分析を実施し、その影響を評価することを ESC に付託した（Anon. 2013）。1000 トンを超える未考慮漁獲死亡量は可能性のある未考慮漁獲死亡量の中でも最大規模のものであり、詳細な検討が必要である。

本文書はオーストラリア畜養に関係する表層漁業の漁獲について、未考慮漁獲死亡量の推定を 2015 年まで更新するものである。

Introduction

The management of southern bluefin tuna (*Thunnus maccoyii*; SBT) stock entered a new era with implementation of a management procedure (MP) in the CCSBT in 2011. The implementation of this MP was the first such instance amongst all the tuna-RFMOs, and has attracted attention worldwide (Hillary et al. 2015).

Without doubt, appropriate stock management requires not only setting catch limits on the basis of sound science, as reflected by the MP, but also securing compliance with such catch limits. In this regard, the CCSBT and its Members have rigorously reinforced compliance measures and efforts over recent years. However, a major uncertainty related to the catch taken has remained unresolved in purse seine fishery associated with the farming sector whose catch is a considerable portion of the global TAC for SBT. When accounting for the wild fish caught by purse seine in tuna farming operations, the catch weight is not measured directly but rather estimated in order to minimize the risk of death by handling. For this reason, it has been widely acknowledged that there can be a high level of uncertainty in estimation of the catch made for farming. For example, catches of Atlantic bluefin tuna (*Thunnus thynnus*) in the East Atlantic and Mediterranean were seriously underreported from the mid-1990s along with the development of farming in that region, and International Commission for the Conservation of Atlantic Tunas (ICCAT) considered that the underreporting of that catch had undermined conservation of the stock (Anon. 2010). To cope with this problem, ICCAT has introduced a regulation that a program using a stereo video system or an equivalently precise alternative technique must cover 100% of all caging operations (ICCAT Recommendation 12-03). In addition, at the ICCAT Commission meeting in 2013, it was agreed that the sampling intensity for stereo video systems may not be below 20% of fish being caged (ICCAT Recommendation 13-08).

For SBT, Australia, the only member nation with farming operating, has employed an estimation method which samples 40 individual fish from groups of several thousand fish just before transferring them to pens, measures them, and uses the average weight for estimation of their age composition and the total weight of the fish at the time of their capture. Although Australia has increased the number of sampled fish from 40 to 100 in 2013, the associated estimation accuracy does not appear to have been improved substantially. It seems that intrinsic problems remain with the current catch estimation method based upon sampling.

The uncertainty associated with age composition of farmed SBT was pointed out in 2005 (Anon. 2005). The issue was reviewed by the independent panel but they did not reach a final conclusion due to scarcity of data (Anon. 2006). However, the existence of a large bias became more evident following subsequent studies based on a large amount of data for length and weight measurements of fish after farming (Itoh et al. 2009a, 2009b, 2010, 2011, 2012, 2014, Itoh and Takeda 2015). The estimated excess of annual catches, relating this uncertainty, were large as ranged from 724 tons (14%) to 2,546 tons (56%) with mean of 1,702 tons (35.5%) in the previous analyses.

The EC requested at its 20th annual meeting to ESC to conduct sensitivity analysis around all sources of unaccounted catch mortality (Anon. 2013). Possible unaccounted mortality that may exceed 1000 tons is the largest one among several candidates of unaccounted catch mortality and detail evaluation is required on this uncertainty.

This paper provides SBT unaccounted catch mortality of surface fishery relating Australian farming up to the 2015 fishing season.

材料と方法

使用データ

推定には、豪州のまき網で漁獲し畜養に使用した魚について、漁期年別の統計値を用いた。オーストラリアの漁期は 12 月から 11 月までである。12 月から 3 月がまき網漁獲の主漁期であることから、本研究では前年 12 月からその年の 11 月までで漁期年を表記した。例えば、2015 年度は 2014 年 12 月から 2015 年 11 月までである。

統計値は漁獲、畜養開始時、畜養終了後の収穫時について必要となる（Fig.1)。オーストラリアのまき網による報告漁獲量、漁獲尾数および年齢別漁獲尾数は、CCSBT から 2015 年 1 月に各国に配布された CD に含まれたデータベースの値を用いた（Table 1, Table 2)。最近年については 2016 年データ交換で示された値を用いた。ただし 2001 年と 2002 年についてはまき網による統計値が独立していなかったので、漁獲重量については CCSBT-ESC/1309/SBT Fisheries-Australia (Hobsbawn et al. 2013)の Table1 の値を、漁獲尾数については延縄を除いた漁法の尾数を用いた。

野生魚（畜養原魚）の漁獲重量、生け込み尾数、畜養後の収穫時の尾数および重量について、2001 年から 2009 年までは TIS の Yearly Farm Data Summary の値を使用した。2010 年から 2015 年までは、半年ごとに各国に配布される CDS 情報サマリーの値を使用した。

野生魚の体長体重関係は、解析対象とする豪州沿岸の未成魚について求めた Robins (1963)のものを用いた。近年のデータと比較した結果、Robins (1963)の体長体重関係を使用することに問題はないと判断された（Itoh and Takeda 2015)。畜養魚の体長体重関係は、2007 年 7 月の生鮮魚 4267 個体の体長、製品重量 GG から求めたもの（Itoh et al. 2012）を用いた。畜養魚の製品重量から原魚重量への換算については、原魚重量は製品重量の 1.12 倍＋1kg の関係を用いた（Anon. 2014b)。

本文書で収穫とは、畜養が終了し、取り上げて殺した時点をいう。

SRP 標識データからの畜養魚の成長率の推定

畜養魚の成長率を、CCSBT-SRP 標識放流における再捕が畜養魚からであったデータから推定した。Sakai et al.(2009)で使用した 142 個体のデータのうち、外れ値および負の成長をしたデータを除いた 123 個体のデータを用いた（Itoh and Takeda 2015)。日成長率は体長の増加に伴って有意に低下したことから、体長を変数として含めた一次式で表した（Table 3)。

漁獲月の推定

野生魚の漁獲時と CCSBT の年齢区分である 1 月 1 日との漁獲時期の差、または CCSBT における年齢別平均体長値との差については、漁獲月にずれがあるものとみなして調整した（Table B)。年齢別漁獲尾数と年齢別平均体重との積が TIS（または CDS）に記載された漁獲総重量に合致するように、調整する漁獲月数 adj.mon$_y$を求めた。

$$W_{JAN,i} = Robins\ A \times (L_{JAN,i})^{Robins\ B} \quad (1)$$

$$W.catch_{y,i} = W_{JAN,i} \times adj.mon_y \times \frac{1}{12} \times (W_{JAN,i+1} - W_{JAN,i}) \quad (2)$$

$$\min\left(abs\left[W.TIS.catch_y - \sum_{i=0}\left(W.catch_{y,i} \times N_{y,i} \times \frac{N.Trans_y}{\sum_i N_{y,i}}\right)\right]\right) \quad (3)$$

ここで、

L$_{JAN,i}$：ミナミマグロ野生魚 i 歳における 1 月 1 日時点の平均尾叉長(cm)。CCSBT で使用している値を使用。

Age	Age1	Age2	Age3	Age4	Age5	Age6	Age7
Fork length	49.4	79.4	97.2	110.2	121.2	130.6	138.4

Robins A、Robins B：Robins(1963)における野生魚の体長体重関係式の係数。Robins A=3.13088x10^{-5}、Robins B=2.9058

W$_{JAN,i}$：ミナミマグロ野生魚 i 歳における 1 月 1 日時点の平均体重(kg)。原魚重量。

adj.mon$_y$：漁期年 y 年の 1 月 1 日からの月数。

W.catch$_{y,i}$：漁期年 y 年の豪州まき網によるミナミマグロ野生魚 i 歳におけるまき網漁獲時点の平均体重(kg)。原魚重量。

N$_{y,i}$：漁期年 y 年の豪州まき網によるミナミマグロ i 歳魚の漁獲尾数。

N.Trans$_y$：漁期年 y 年の豪州まき網による TIS（または CDS）に記載されたミナミマグ

ロ合計生け込み尾数。曳航中の死亡個体は含んでいない。

W.TIS.catch$_y$: 漁期年 y 年の豪州まき網による TIS（または CDS）に記載されたミナミマグロ合計漁獲重量。

報告漁獲量からの畜養魚の成長率の推定

“年齢別漁獲尾数”と “収穫時の推定体重”との積の合計が”TIS および CDS における収穫時の合計重量”に合致するように畜養期間中の日成長率を推定した。体長に対する一次式において、傾きは SRP 標識データで求めたのと同じものを使用し、切片を調整した。

漁期年 y 年、i 歳魚の畜養後（畜養期間 0.5 年間）の体長 L.Harv$_{y,i}$ および原魚重量 W.Harv$_{y,i}$ は以下で計算できる（Anon. 2014b）。

$$L.Harv_{y,i} = L_{JAN,i} + \left(I_y + L_{JAN,i} \times a\right) \times 365 \times (0.5 - \frac{adj.mon_y}{12}) \quad (5)$$

$$W.Harv_{y,i} = exp\left(\frac{1}{b.harv} \times \left(log\left(L.Harv_{y,i}\right) - log(a.harv)\right)\right) * 1.12 + 1 \quad (6)$$

ここで、I_y と a は日成長率一次式の切片と傾き、a.harv、b.harv は畜養魚の体長体重関係式のパラメータ値。

次式を最小とする I_y を求める。

$$\min\left(abs\left(W.TIS.Harv_y - \sum_{i=0}\left(W.Harv_{y,i} \times N_{y,i} \times \frac{N.TIS.Harv_y}{\sum_i N_{y,i}}\right)\right)\right) \quad (7)$$

ここで、

W.TIS.Harv$_y$: 漁期年 y 年の TIS における収穫合計重量 (kg)。原魚重量。

N.TIS.Harv$_y$: 漁期年 y 年の TIS における収穫合計尾数。

仮定した成長率による年齢組成と漁獲重量の推定

与えた成長率に合致するように畜養魚の年齢組成をシフトさせ、漁獲量を推定した（Table 4）。成長率は、CCSBT の SRP 標識データから推定した畜養魚の成長率を用いた（Case1）。また、畜養魚の成長が体長においては野生魚と同じとの仮定でも計算を行った（Case2）。この仮定は、ICCAT において大西洋クロマグロの資源評価モデルに使用するデータのベースケースとされている（Anon 2014a, Fonteneau 2013）。

これらの成長率に対応した漁期年 y 年、i 歳魚の畜養後の体長 L.Harv2$_{y,i}$、原魚重量 W.Harv2$_{y,i}$ は以下で計算できる。

$$L.Harv2_{y,i} = L_{JAN,i} + \left(I_y + L_{JAN,i} \times a\right) \times 365 \times (0.5 - \frac{adj.mon_y}{12}) \quad (8)$$

$$W.Harv2_{y,i} = exp\left(\frac{1}{b.harv} \times \left(log\left(L.Harv2_{y,i}\right) - log(a.harv)\right)\right) * 1.12 + 1 \quad (9)$$

次式を最小とするα_yを求める。

$$\min\left(abs\left(W.TIS.Harv_y - \sum_{i=1}\left(W.Harv2_{y,i} \times \left\{N_{y,i}\left(1-\alpha_y\right) + N_{y,i-1\times}\alpha_y\right\} \times \frac{N.TIS.Harv_y}{\sum_i N_{y,i}}\right)\right)\right) \quad (10)$$

ここで、

α_y: 漁期年 y 年にある年齢から 1 歳上の年齢へシフトさせる個体数の割合。ただしα_y>1 の場合は 2 歳上の年齢にシフトさせた。

豪州が漁期年 y 年にまき網で漁獲した重量は以下で計算される。

$$W.Est_y = \sum_{i=1}\left[\left(N_{y,i} \times \left(1-\alpha_y\right) + N_{y,i-1} \times \alpha_y\right) \times W.catch_{y,i}\right] \times \frac{TotalN_y}{\sum_i N_{y,i}} \quad (11)$$

ここで、

$TotalN_y$: 漁期年 y 年に豪州がまき網で漁獲した合計尾数。年齢別漁獲尾数の合計と異なる場合があるので補正する。

$W.Est_y$: 漁期年 y 年に豪州がまき網で漁獲した推定重量（kg）。

Materials and methods

Data used

Various statistics of the Australian purse seine catch for farming operations separated into “fishing years” were used for estimation. An Australian fishing year begins in December and finishes in November (the main season for purse seine fishing is usually from December to March). A fishing year therefore represents a period from December of the previous year to November of that year in the present study, e.g. the 2015 fishing year means the period from December 2014 to November 2015.

The statistics used are the times of the catches made, the start of farming (caging) and the end of farming (harvesting; grown out and killed) (Fig. 1). The data on the total catch reported by number and weight, and the catch in terms of numbers at age for the Australian purse seine fishery, were obtained from the database included in a CD which was distributed by the CCSBT Secretariat to each Member in January 2015 (Table 1, Table 2). The data for the most recent year were obtained from the 2016 data exchange process. However, for 2001 and 2002, as the total catch data were not separated by fishing gear, the catch weights in Table 1 of CCSBT-ESC/1309/SBT Fisheries-Australia (Hobsbawn et al. 2013) were used as the catch weight for farming, and the catch numbers from the CD database for all gears except longline were used as the catch numbers for farming.

For farming data, the total estimated weight of wild fish captured by purse seine for farming, the total number of fish transferred into farms, and the total whole weight and number of fish harvested from farms were obtained from Yearly Farm Data Summary of the Trade Information Scheme (TIS) between 2001 and 2009. Between 2010 and 2015, these numbers were obtained from the summary of Catch Documentation Scheme (CDS) statistics which were distributed to the CCSBT Members every six months.

The length-weight (LW) relationship in Robins (1963), which was based on young fish distributed in Australian coastal waters, was used for wild fish. Comparison to data in recent years shows that using the LW relationship in Robins (1963) is appropriate (Itoh and Takeda 2015). The LW relationship used for farmed fish was obtained from the measurement of 4267 harvested fresh individuals, for which both fork length and gilled and gutted weight were measured in July 2007 (Itoh et al. 2012). Gilled and gutted weight was converted to whole weight by multiplying by 1.12 and then adding 1kg, based on the method used by Australia (Anon. 2014b).

Estimation of growth rate of farming fish based on SRP tagging data

The CCSBT SRP tagging data that recaptured after farming were used for estimation of growth rate during farming. Among 142 individuals used in Sakai et al. (2009), subset of 123 individuals was selected after excluding anomalous or negative growth records (Itoh and Takeda 2015). Because daily growth rate decreased significantly as fork length increased, daily growth rate is expressed as linear equation including fork length as variable (Table 3).

Estimation of the month of capture

The difference between the actual date of wild capture and January 1st as the defined birth date for any age for SBT, or the difference of fork length between that at the actual wild capture and January 1st, was adjusted by using the mean difference between actual catch date and January 1st (Table 4). The adjustment for the number of months from January 1st $adj.mon_y$ was estimated so that the product of the catch-at-number multiplied by average body weight by age equaled the total catch weight reported in the TIS (or CDS).

$$W_{JAN,i} = Robins\ A \times \left(L_{JAN,i}\right)^{Robins\ B} \quad (1)$$

$$W.catch_{y,i} = W_{JAN,i} \times adj.mon_y \times \frac{1}{12} \times \left(W_{JAN,i+1} - W_{JAN,i}\right) \quad (2)$$

$$\min\left(abs\left[W.TIS.catch_y - \sum_{i=0}\left(W.catch_{y,i} \times N_{y,i} \times \frac{N.Trans_y}{\sum_i N_{y,i}}\right)\right]\right) \quad (3)$$

where $L_{JAN,i}$ = average fork length (cm) of wild SBT at January 1st for age *i*. The values used by the CCSBT were applied:

Age	Age1	Age2	Age3	Age4	Age5	Age6	Age7
Fork length	49.4	79.4	97.2	110.2	121.2	130.6	138.4

Robins A, Robins B = parameters of the length-weight relationship for wild SBT in Robins (1963). Robins A=3.13086x10^{-5}, Robins B=2.9058;

$W_{JAN,i}$ = average whole body weight (kg) of wild SBT at January 1st of age *i*;

$adj.mon_y$ = the number of months from January 1st to capture during fishing year *y*;

$W.catch_{y,i}$ = average whole body weight (kg) of wild SBT at wild capture by the purse seine fishery in the fishing year *y*;

$N_{y,i}$ = the number of SBT captured by the purse seine fishery of age *i* during fishing year *y*;

$N.Trans_y$ = the total number of SBT transferred into cages reported in the TIS (or CDS) during fishing year *y*; this does not include mortality during towing; and

$W.TIS.catch_y$ = the total weight of SBT reported in the TIS (or CDS) during fishing year *y*.

Estimation of growth rate during farming corresponds to reported catch

Daily growth rate during farming was estimated so that the product of the catch-by-number and the average body weight at harvest by age equaled to the total harvested weight reported in the TIS (or CDS). In linear equation of growth rate to fork length, the slope was assumed to be the same to the equation derived from the SRP tagging data, and intercept was estimated for each year.

$$L.Harv_{y,i} = L_{JAN,i} + \left(I_y + L_{JAN,i} \times a\right) \times 365 \times (0.5 - \frac{adj.mon_y}{12})$$

(5)

$$W.Harv_{y,i} = exp\left(\frac{1}{b.harv} \times \left(log\left(L.Harv_{y,i}\right) - log(a.harv)\right)\right) * 1.12 + 1 \qquad (6)$$

where I_y and a are intercept and slope of linear equation, respectively, and *a.harv* and *b.harv* are parameters of the length-weight relationship of farmed fish.

A value which minimize I_y in the following equation should be obtained.

$$\min\left(abs\left(W.TIS.Harv_y - \sum_{i=0}\left(W.Harv_{y,i} \times N_{y,i} \times \frac{N.TIS.Harv_y}{\sum_i N_{y,i}}\right)\right)\right) \qquad (7)$$

where W.TIS.Harv$_y$ = the total weight of the SBT harvested in whole weight reported in the TIS (or CDS) for the fishing year *y*;

N.TIS.Harv$_y$ = the total number of SBT harvested in the TIS (or CDS) for the fishing year *y*.

Estimation of total catch weight from growth rates assumed

The total catch weight was estimated by shifting the age composition of farmed fish according to the growth rate given (Table 4). Growth rates assumed for farming SBT were those derived from the SRP tagging data (case1). In addition, an alternative computation assumed that the growth in body length of farmed fish is the same as that of wild fish, although growth in body weight and also fatness are much larger in farmed fish (case 2). This is the assumption made for the base case for the stock assessment of Atlantic bluefin tuna in ICCAT (Anon. 2014, Fonteneau 2013).

The fork lengths (L.Harv2$_{y,i}$) and whole body weights (W.Harv2$_{y,i}$) of SBT after farming for age *i* during fishing year *y* were calculated using the following equations.

$$L.Harv2_{y,i} = L_{JAN,i} + \left(I_y + L_{JAN,i} \times a\right) \times 365 \times (0.5 - \frac{adj.mon_y}{12}) \qquad (8)$$

$$W.Harv2_{y,i} = exp\left(\frac{1}{b.harv} \times \left(log\left(L.Harv2_{y,i}\right) - log(a.harv)\right)\right) * 1.12 + 1 \qquad (9)$$

A value which minimize α_y in the following equation should be obtained.

$$\min\left(abs\left(W.TIS.Harv_y - \sum_{i=1}\left(W.Harv2_{y,i} \times \left\{N_{y,i}\left(1 - \alpha_y\right) + N_{y,i-1\times}\alpha_y\right\} \times\right.\right.\right.$$

$\left.\left.\left.\frac{N.TIS.Harv_y}{\sum_i N_{y,i}}\right)\right)\right)$

(10)

where α_y = the ratio of the number of fish shifted to one age older in the fishing year *y*. α_y >1 means shifted to two ages older.

The total catch weight by Australian purse seine fishery during fishing year *y* is calculated as follows.

$$W.Est_y = \sum_{i=1}\left[\left(N_{y,i} \times \left(1-\alpha_y\right) + N_{y,i-1} \times \alpha_y\right) \times W.catch_{y,i}\right] \times \frac{TotalN_y}{\sum_i N_{y,i}} \qquad (11)$$

where $TotalN_y$ = the total number caught by the Australian purse seine fishery during fishing year *y*. This adjustment was necessary because the sum of the catch-at-age was different to this value in some years;

$W.Est_y$ = the total weight of catch (kg) by the Australian purse seine fishery during fishing year *y*.

結果

報告漁獲量からの畜養魚の成長率の推定

豪州政府が報告する畜養終了後の収穫漁獲量を、40/100 尾サンプリングに基づく年齢組成から達成する成長率を求めた（Fig. 2、Table 5）ところ、SRP 標識データから求めた成長率に比較して著しく高かった。

マグロ属の他魚種と比較するため、その種の本来の成長率を考慮して RFW(Ratio of farmed fish growth to wild fish growth)で比較した。

$$\text{RFW} = \frac{Growth\ increment\ of\ farmed\ fish\ in\ 6\ months\ (cm)}{Growth\ increment\ of\ wild\ fish\ in\ 6\ months\ (cm)}$$

太平洋クロマグロの RFW はミナミマグロ 3 歳魚相当の 97.2cmFL からは RFW=1.47（八重山）および 1.55（奄美）であった。SRP 標識データから求めたミナミマグロ 3 歳の畜養魚では RFW=1.49 で、太平洋クロマグロとほぼ一致した。ミナミマグロ 2 歳魚と 4 歳魚では、3 歳魚よりも RFW が低かった。

仮定した成長率による年齢組成と漁獲重量の推定

ミナミマグロ畜養魚の成長率が SRP 標識データから求めたような値の場合（Case1；6

ヶ月で 2 歳魚は 20.0%、3 歳魚は 13.3%、4 歳魚は 8.0%の体長増加)、年齢組成は高齢にシフトし、推定漁獲量は報告漁獲量よりも 724 トンから 2,546 トン、平均 1,650 トン多かった（Table 4、Table 6、Fig. 3)。推定された超過漁獲量は報告量よりも 14%から 56%、平均 34.4%大きかった。

体長成長は畜養魚と野生魚で同じと仮定した場合（ケース 2）には、超過漁獲量は平均 2,225 トン、超過量の割合は平均 46.3%と推定された。

混合正規分布や年齢スライシング法を使用した従来の漁獲量推定値と比較する（Table 7, Fig. 3)。詳細は Itoh et al.(2012)を参照。今回の Case1 での漁獲量推定はほぼ一致した。ただし、わずかに過小推定であり、漁獲推定量はさらに大きかった可能性がある。

Results

Estimation of growth rate during farming corresponds to reported catch

Growth rates by year were estimated for farmed SBT which explain the reported harvest total weight from age compositions based on the 40/100 fish sampling (Fig. 2, Table 5). These were quite higher than growth rates estimated from the SRP tagging data.

Because intrinsic ability on growth differs in different species, comparisons were made using the following index, RFW (Ratio of farmed fish growth over wild fish growth).

$$\text{RFW} = \frac{Growth\ increment\ of\ farmed\ fish\ in\ 6\ months\ (cm)}{Growth\ increment\ of\ wild\ fish\ in\ 6\ months\ (cm)}$$

RFWs of Pacific Bluefin tuna *Thunnus orientalis* from 97.2 cmFL were 1.47 in Yaeyama and 1.55 in Amami, Japan. RFW of SBT in age-3 based on the SRP tagging data was 1.49, similar value to Pacific Bluefin tuna. RFWs were lower in age-2 and age-4 than age-3 of SBT farmed.

Estimation of total catch weight from growth rates assumed

In the case 1, where the mean growth rate derived from the SRP tagging data used (fork length increase was 20.0% in age2, 13.3% in age3 and 8.0% in age 4 in six months), age composition was shifted to higher age and then the estimated total catch weight during a fishing year was larger than the reported catch weight, ranging from 724 to 2,546 tons, with a mean of 1,650 tons (Table 4, Table 6, Fig. 3). These estimated weights were larger than reported ranging from 14% to 56 %, with a mean of 34.4%.

In the case 2, where assumed same growth in body length for wild and farmed fish, the mean estimated excess weight was 2,225 tons, with a mean excess ratio of 46.3% compared to the reported catch.

These estimated catch were compared to previous estimates, derived using the mixed-normal distributions or the cohort slicing method (Table 7, Fig. 3). Details were described in Itoh et al. (2012). The estimated catch in the present study (case 1) were similar to those in previous analysis, but were slightly underestimates which suggests larger catch

考察

ミナミマグロの2歳から4歳に相当する80cmFLから110cmFLのサイズ範囲において、ミナミマグロ野生魚の成長は他のマグロ属魚類よりも遅い。これはミナミマグロの、最大到達体長は小さくはないが、長寿命で、成熟が遅い生物学的特性から、この体長範囲では成長が遅いと考えられる。畜養された魚は豊富な餌が与えられることによって野生魚よりも成長が速いと期待される。

SRP標識データから求めた畜養魚の成長率からは、体重増加（Sakai et al. 2009）だけでなく、体長増加においても畜養魚の成長が野生魚の成長を上回ることが示唆された（Itoh and Takeda 2015）。ミナミマグロ3歳魚の畜養魚の成長率は、太平洋クロマグロの同体長の畜養魚の成長率と類似した（Itoh and Takeda 2015）。SRP標識データから求めた畜養ミナミマグロの成長率は、他のマグロ属魚類や畜養太平洋クロマグロの成長率と比較して妥当な値と考えられた。

一方、豪州政府が報告した漁獲量（まき網で巻いた時点）、40/100尾サンプリングによるサイズデータと収穫重量（蓄養後に殺した時点）とを説明する畜養SBTの成長率推定値は非常に高かった。年別推定値の中ではキハダの成長率さえ上回る値もあり、40/100尾サンプリングに関係した成長率は既存のマグロ属魚類の成長の知見では考えられない値であった。この高い成長率の真偽は、独立で客観的な科学データによって証明されるべきである。

これまで、体長組成を混合正規分布で分解するロバストな方法が2007年から2009年畜養魚に対して実施された（Itoh et al. 2012）。また、少し簡略な方法として年齢スライシング法で体長組成を分解する方法が2007年から2010年の畜養魚に対して実施された。さらに、成長率を仮定する方法によって対象年度を2001年から2015年までの15年間に拡大した（Itoh and Takeda 2015）。その結果、推定結果はこれまでの結果とほぼ一貫したものが得られた。本研究の方が過小推定である可能性も示唆された。

CCSBT委員会からは、全ての死亡要因を考慮した資源評価とともに、含まれていない死亡量の MP への影響を考慮するタスクが付託されている。本研究の推定によれば漁獲量の不確実性はグローバルTACの21%（2013年10,949トンに対するケース1の2,346トン）にも及び、これは看過できるものではない。

早急な不確実性の払拭が必要であるにもかかわらず、2013 年年次会合において、豪州政府はステレオビデオカメラシステムによる体長測定を2013年12月に開始するとのCCSBT年次会合における自国の表明（Anon. 2012）を反故にし、国内的な都合でステレビデオカメラシステムの導入を遅らせている（Anon. 2013）。

未報告漁獲量を考慮したMPへの評価を実施するには、少なくとも14%から56%、平均34.4%の過剰漁獲量を考慮する必要がある。しかし、本推定が過小推定である可能性を考慮すると、現実に起こり得る事態を確実に含めた試算をするためには、平均 40%またはそれ以上でも評価を実施する必要があるだろう。

これまでの解析結果について、ESC 等ではいくつかの問題点の指摘や提案があった。これらについてはItoh and Takeda(2015)で解決した。それらには、Robins(1963)の体長体重関係式を用いることの適切さ、2006年検討時のデータ不足、標識装着の成長への影響、経済的コストとの関係、畜養成長率の生簀ごとの変動の可能性などを含んでいた。

2014年ESC19レポートにおける別紙55における下記を想起すべきだろう(Anon. 2014c)。
“この推定手法（*混合正規モード解析による年齢組成の推定*）は、CCSBT が現在保有しているCDSデータ(収穫時の体長及び重量)を用いることにより向上させることができる”、ならびに”これらのモードをCDSデータから特定することができれば､モード解析により、漁獲量の推定及び40/100尾サンプリングによる報告漁獲量のバイアスを推定することができる可能性がある。”
“表層漁業の漁獲量にかかる不確実性は、表層漁業によるオーストラリアの漁獲量推定に対応したステレオビデオシステムの利用により低減することができる可能性がある。オーストラリアは、100尾サンプリングに替えてこの手法を用いることを企図して、その利用可能性について実証してきた。しかしながら、現在までのところ、この手法は実用化されていない。”
“100尾サンプリングの正確性を調査するため、ステレオビデオと100尾サンプリングの比較試験の実施が考えられる。”
“もう一つの手法として、生簀内の全ての魚を収穫する直前に100尾サンプリングを行う方法がある。100尾サンプリングによる推定重量を、体長組成及び重量・体長相関表を用いて算定した重量と、又は収穫魚の総重量と比較することができる。”
“ESCは、全ての国に対し、分析の促進及び改善を図るため、各国の CDS データデータを利用可能とするよう奨励する。”

また、2015 年の ESC20 における文章も想起すべきである(Anon. 2015a)。“議長は、本件は継続的な問題であり、事前に完全に独立したレビューが行われない限り、ESC でこれを解決することはできないとの見解を述べた。” (81 パラ)

さらに、2015年年次会合報告書の文章も想起すべきである(Anon. 2015b)。”複数のメン

バーは、オーストラリアに対し、手作業による手法の正確性を判断できるよう、2016 年初頭の表層漁業の漁期において、半自動的手法で得た推定値と 100 尾サンプリングによる手法の推定値とを比較するよう要請した。そこで正確性に関する何らかの問題があれば、そのことはメンバーに対して報告されるべきである。（パラ 33）”ならびに、”蓄養 SBT の成長率の推定に関するシンプルかつ実施可能な手法として、日本は、オーストラリアに対して、100 尾サンプリングの際に魚に標識付けし、その後の取り上げの際にこれらの魚を測定するよう要請した。（パラ 34）”

ESC が取るべき行動が、畜養ミナミマグロの CDS データを用いた独立レビューを実施すること、ならびに豪州によってステレビデオカメラシステムが導入されて現在の不確実性を解決する実験が行われることであることは明白である。

Discussion

Comparing to other *Thunnus* species, SBT grow slower than other species in the range of 80cmFL to 100 cmFL, in SBT age of 2 to 4. This is probably due to the aspect of SBT biological characteristics; while the maximum attainable body length is not so small (>180 cmFL), long life span (> 40 years) and late maturity (> age-8) may resulted in slower growth in this fork length range.

It is not surprising that farmed fish which fed a plenty of food grow faster than wild fish. The SRP tagging data suggested that SBT farmed fish grew faster than wild fish not only in body weight (Sakai et al. 2009) but also in fork length (Itoh and Takeda 2015). Growth rate of age-3 SBT in farming was similar to that of Pacific Bluefin tuna in farming in the same body length (Itoh and Takeda 2015). Estimated growth rate of farmed SBT derived from the SRP tagging data was considered to be appropriate from the comparison with growth rates of other *Thunnus* species and farmed Pacific Bluefin tuna.

On the other hand, growth rates of farmed SBT which can explain three sets of information (the estimated total catch weight in wild, size data from 40/100 fish sampling and total weight at harvest after farming) were estimated to be extremely high. There were several years that exceeding even the growth rate of yellowfin tuna *Thunnus albacares*. Growth rates relevant to the 40/100 fish sampling seems highly unlikely from the current knowledge on the growth rates of *Thunnus* species in both wild and farmed. This large uncertainty should be addressed by using independent and actual scientific data on growth.

So far, analysis of decomposition of length frequency into age with normal distributions, relatively robust method, was carried out for farmed SBT between 2007 and 2009 (Itoh et al. 2012). Another method using age-slicing for decomposition of length frequency into age, slightly simpler than the first method, was applied to farmed SBT between 2007 and 2010. Further method that assumed growth rates expanded the period subject for 15 years from 2001 to 2015 (Itoh and Takeda 2015). The present method provided consistent results with those from previous methods. It was also suggested slightly underestimate of catch in the present method.

The EC requested at its 20th annual meeting to ESC to conduct sensitivity analysis around all sources of unaccounted catch mortality (Anon. 2013). It is impossible to ignore the uncertainty in catch as large as 21% of the global TAC (2,346 tons in Case 1 compared to the 10,949 tons TAC in 2013). Urgent measures to clear out this uncertainly is necessary. The Australian government has postponed implementation of the stereo video camera system for domestic reasons (Anon. 2013), in spite of their own statement of intent in 2012 that fish length measurement using the stereo video camera system would be implemented by December 2013.

In the ESC, we have to evaluate the effects of unaccounted catch mortality on the stock assessment and management. Results of present study suggest that unaccounted catch mortality in the Australian purse seine catch for farming sector would be, at least, from 14% to 56%, with a mean of 34.4% of reported catch. However, taking into account the possibility that the present study provides underestimates, and in order to cover whole the range that may be plausible, examination using values with a mean of 40% or more may be necessary.

Several comments and concerns have been pointed out for our previous analyses in elsewhere including ESC and OMMP meetings. We have already addressed all of them in Itoh and Takeda (2015), including appropriateness of using the length-weight relationship in Robins (1963), scares of data in the independent review in 2006, influence of tagging on growth, economic cost, possible variability among fattening cages, etc.

It should be recall the attachment 5 of ESC 19 Report in 2014 for the following sentences (Anon. 2014c). "This approach (*mixed normal modal analysis to estimate the age composition of farmed fish*) could be improved by using CDS data (length and weight at time of harvest), which are held by CCSBT" and "If these modes (*modes in length representing ages*) are identified in the CDS data, modal analysis could be used to estimate catch and possible bias in catch reports resulting from the 40/100 fish samples."

"Uncertainty in the surface fishery catch may be reduced by the use of a stereo video system to address estimates of Australian catch by the surface fishery. Australia has demonstrated the potential utility of this method which it had planned to use to replace 100 fish samples. However, the method has not been made operational to date."

"Experimental trials comparing stereo video to the 100 fish sample could be used to investigate the accuracy of 100 fish sample."

"Another approach would be to take a 100 fish sample just prior to harvesting all the fish in pens. The estimated weight from the 100 sample could be compared to the calculated weight of harvested fish using their length frequency and a weight-length relationship or the sum of the weight of harvested fish."

"The ESC encourages all countries to make their CDS data available to facilitate and improve analyses."

In addition, it should be recall the ESC 20 Report in 2015 (Anon. 2015a) that "The chair commented that this issue was ongoing and expressed the view that it would not be resolved in the ESC without a prior full independent review." (paragraph 81)

Furthermore, it should be recall the EC22 Report in 2015 (Anon. 2015b) that "Some Members requested that Australia compare estimates obtained from the semi-automated method versus the manual 100-fish sampling method during its next surface fishery season in early 2016 in order to determine the accuracy of the manual method. If there are any accuracy issues, then these should be reported to Members." and "Japan requested Australia tag fish at the time of the 100 fish sampling and then measure them at the time of grow-out as a simple and feasible measure for estimation of growth rate of farmed SBT."

It is obvious for ESC that action should be taken are conducting a full independent review using CDS data of farmed SBT and implementation of the stereo video camera system by Australia with experiments for addressing the current uncertainty.

結論

我々は、以下を ESC に提案する。

- CCSBT は豪州畜養に関する潜在的で規模の大きな問題が存在することを認識すべきである。この問題は、CCSBT の対外的信頼性、ミナミマグロの資源管理、特に世界的に注目されている MP による資源管理を損なう恐れがある。科学データ面では、漁獲量、年齢組成に影響を及ぼし、頑健な資源評価を阻害する。
- ESC は、オーストラリアまき網の漁獲量および年齢組成の調節に際しては、本結果の年別の推定値（平均 34.4%）または 40%以上を用いた結果も考慮するべきである。
- 豪州は、この不確実性に関する懸念を早急に払拭するために必要な具体的な行動を実施すべきである。それには、ステレビデオカメラシステムによる半自動の体長測定値と 100 尾サンプリングによる体長組成の比較、100 尾サンプリング時の標識装着、取

り上げ時の 100 尾サンプリングといった具体的な実験を通じた、ステレオビデオカメラシステムの早急な導入による検証データの入手、畜養の成長率に関する情報の提供、及び我々の解析結果を検証するための CDS の畜養魚全個体の個体別データのメンバー科学者への提供を含む。

- ESC は、ステレビデオカメラシステムの導入によってこの不確実性の問題を早急に払拭すべきことを委員会に勧告すべきである。

Conclusion

We propose followings to the ESC.

- The CCSBT should recognize the presence of this potentially large-scale issue related to Australian SBT farming. This issue involves a high risk of damaging the credibility of the CCSBT, and the stock management of SBT by means of the MP which has attracted worldwide attention. In terms of the scientific data, it may seriously affect catch and age composition estimates and hinders accurate and robust stock assessment.
- When considering unaccounted catches and adjustment of age composition by year, the ratio estimated in the present study (a mean of 34.4%, which should perhaps be even higher than 40%) should be taken into account for Australian purse seine catch.
- Australia should resolve the issue by a full scale implementation of the stereo video camera system, including providing outputs of length measurements. In addition, they should provide information of the extent of farming growth estimated by using reliable scientific data. CDS data which including individual body weight for all the farmed individuals should be available for Member scientists in order to evaluate our results. Various experiments have been proposed to address the uncertainties, including comparing lengths from stereo video to those of the 100 fish sample, tagging for the 100 fish sampled which farmed after length measured, and take a 100 fish sample just prior to harvesting all the fish in pens.
- The ESC should recommend to the EC that the issue should be resolved immediately by full scale of implementation of the stereo video camera system.

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Table 1. Total weight of SBT caught for Australian farming by year

Fishing year	Period	Official weight	TIS	CDS	TIS or CDS/Official weight
2001	Dec 2000-Nov2001	5,162,000	5,141,446		99.6%
2002	Dec 2001-Nov2002	5,234,000	5,216,065		99.7%
2003	Dec 2002-Nov2003	5,374,626	5,354,939		99.6%
2004	Dec 2003-Nov2004	4,873,701	4,847,861		99.5%
2005	Dec 2004-Nov2005	5,213,693	5,198,504		99.7%
2006	Dec 2005-Nov2006	5,301,706	5,288,123		99.7%
2007	Dec 2006-Nov2007	5,229,957	5,220,813		99.8%
2008	Dec 2007-Nov2008	5,211,480	5,201,973		99.8%
2009	Dec 2008-Nov2009	5,026,407	5,005,419		99.6%
2010	Dec 2009-Nov2010	3,930,541		3,922,372	99.8%
2011	Dec 2010-Nov2011	3,871,605		3,863,160	99.8%
2012	Dec 2011-Nov2012	4,484,736	4,474,113	4,452,665	99.3%
2013	Dec 2012-Nov2013	4,198,281		4,194,783	99.9%
2014	Dec 2013-Nov2014	5,029,299		5,024,276	99.9%
2015	Dec 2014-Nov2015	4,946,940		4,941,938	99.9%

Unit is in kg. Value from the CDS was used in 2012.

Table 2. Total number of SBT caught for Australian farming by year

Fishing year	Period	N_Raised	Catch-At-Age	TIS	CDS	TIS or CDS/N_Raised
2001	Dec 2000-Nov2001	289,157	288,022	279,287		96.6%
2002	Dec 2001-Nov2002	281,143	281,143	279,456		99.4%
2003	Dec 2002-Nov2003	278,020	278,020	276,117		99.3%
2004	Dec 2003-Nov2004	298,703	298,703	297,748		99.7%
2005	Dec 2004-Nov2005	336,112	336,110	335,088		99.7%
2006	Dec 2005-Nov2006	332,958	324,088	332,104		99.7%
2007	Dec 2006-Nov2007	354,464	363,336	353,864		99.8%
2008	Dec 2007-Nov2008	324,754	324,754	324,160		99.8%
2009	Dec 2008-Nov2009	306,886	307,663	306,060		99.7%
2010	Dec 2009-Nov2010	212,204	212,204		211,749	99.8%
2011	Dec 2010-Nov2011	232,614	220,242		232,077	99.8%
2012	Dec 2011-Nov2012	307,896	320,268	307,139	305,727	99.3%
2013	Dec 2012-Nov2013	259,337	259,337		259,125	99.9%
2014	Dec 2013-Nov2014	268,518	268,518		254,214	94.7%
2015	Dec 2014-Nov2015	294,304	294,304		290,774	98.8%

The value from the CDS was used in 2012.

Table 3　Statistics of growth of farming SBT from the CCSBT SRP tagging data

Fish	Variable	Period	Age-2	Age-3	Age-4	説明
Wild	Fork length	0	79.4	97.2	110.2	野生魚の1月1日時点の体長
Wild	Fork length	1 year	97.2	110.2	121.2	野生魚の翌年の体長
Wild	Growth rate in length	1 year	0.224	0.134	0.100	野生魚の1年間の成長率
Wild	Growth rate in length	6 month	0.149	0.089	0.067	野生魚の6ヶ月の成長率。冬季3ヶ月はゼロ成長を仮定。
Farmed	N	variety	39	75	9	個体数
Farmed	Growth rate in length, mean	variety	0.181	0.124	0.092	標識魚の平均成長率
Farmed	Growth rate in length, SD	variety	0.093	0.071	0.050	標識魚の成長率のSD
Farmed	Growth rate in length, SE	variety	0.015	0.008	0.017	標識魚の成長率のSE
Farmed	Growth rate in length, mean	6 month	0.200	0.133	0.080	標識魚の6ヶ月の平均成長率
Farmed	Growth rate in length, SD	6 month	0.118	0.059	0.043	標識魚の6ヶ月を仮定した成長率のSD
Farmed	Growth rate in length, SE	6 month	0.019	0.007	0.014	標識魚の6ヶ月を仮定した成長率のSE
Wild	Fork length	6 month	91.3	105.9	117.5	野生魚の6ヶ月の到達体長。冬季3ヶ月はゼロ成長を仮定。
Wild	Whole body weight	0	10.4	18.7	26.9	野生魚の1月1日の体重。RobinsLW使用。
Wild	Whole body weight	6 month	15.6	23.9	32.4	野生魚の6ヶ月での到達体重。RobinsLW使用。
Farmed	Fork length	6 month	95.3	110.1	119.0	畜養魚の6ヶ月での到達体長
Farmed	Whole body weight	6 month	18.2	28.4	36.1	畜養魚の6ヶ月での到達体重。RobinsLW使用。
Farmed	Growth rate in weight	6 month	1.750	1.520	1.343	畜養魚の6ヶ月間の体重増加率

Growth rate in length in 6 months is (growth increment in 6 months)/(length at start).

Table 4. Track of estimation of catch-at-age and total catch at the time of wild capture of SBT for Australian farming

Year=2001

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	0	49.4	49.8	2.68	0	68.49	8.33	0	0	0	0	0	0	0
2	42,736	79.4	79.6	10.47	434	93.29	20.05	38983	781648	18,102	362,968	189,537	19,923	208,602
3	221,365	97.2	97.4	18.78	4,031	108.03	30.98	201927	6255427	114,648	3,551,650	2,153,075	126,180	2,369,645
4	18,807	110.2	110.3	27.01	493	118.82	41.23	17155	707236	116,126	4,787,319	3,136,586	127,806	3,452,083
5	4,225	121.2	121.3	35.58	146	127.94	51.56	3854	198710	10,979	566,061	390,637	12,083	429,930
6	889	130.6	130.7	44.18	38	135.74	61.70	811	50032	2,441	150,600	107,828	2,686	118,674
7	0	138.4	138.5	52.26	0	142.21	71.09	0	0	434	30,880	22,701	478	24,984
8	0	145.1	145.2	59.94	0	147.77	79.91	0	0	0	0	0	0	0
Total	288,022				5,141			262,730	7,993,054	262,730	9,449,478	6,000,364	289,157	6,603,918
														$W.Est_y$

0.1612	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9697	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.5356	p.shift	α_y	Proportion of age shift
1.1006	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2002

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	0	49.4	49.9	2.69	0	68.44	8.31	0	0	0	0	0	0	0
2	33,520	79.4	79.7	10.50	350	93.24	20.02	32335	647328	17,661	353,556	185,363	18,308	192,159
3	223,242	97.2	97.4	18.81	4,173	107.99	30.94	215346	6663467	132,292	4,093,499	2,488,043	137,142	2,579,262
4	20,825	110.2	110.4	27.04	560	118.79	41.19	20089	827508	108,701	4,477,714	2,939,245	112,686	3,047,006
5	2,837	121.2	121.4	35.61	100	127.92	51.53	2736	141015	10,611	546,833	377,882	11,000	391,736
6	564	130.6	130.7	44.20	25	135.73	61.68	544	33570	1,539	94,930	68,035	1,596	70,530
7	155	138.4	138.5	52.29	8	142.20	71.08	149	10620	329	23,358	17,183	341	17,813
8	0	145.1	145.2	59.96	0	147.77	79.90	0	0	68	5,418	4,066	70	4,215
Total	281,143				5,216			271,200	8,323,509	271,200	9,595,308	6,079,816	281,143	6,302,720
														$W.Est_y$

0.2063	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9940	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.4538	p.shift	α_y	Proportion of age shift
1.0367	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2003

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	138	49.4	55.2	3.61	0	66.41	7.66	130	995	16	120	56	17	60
2	61,166	79.4	82.8	11.74	713	91.11	18.71	57636	1078250	7,059	132,064	82,858	7,492	87,934
3	182,579	97.2	99.7	20.12	3,648	106.19	29.42	172040	5061981	71,421	2,101,446	1,436,788	75,796	1,524,803
4	31,709	110.2	112.3	28.44	896	117.46	39.82	29879	1189752	154,910	6,168,404	4,405,338	164,399	4,675,203
5	1,561	121.2	123.0	37.04	57	127.01	50.43	1471	74189	26,456	1,334,121	979,857	28,076	1,039,882
6	693	130.6	132.1	45.56	31	135.13	60.86	653	39726	1,373	83,540	62,539	1,457	66,370
7	174	138.4	139.7	53.59	9	141.91	70.64	164	11564	594	41,945	31,822	630	33,771
8	0	145.1	146.2	61.15	0	147.71	79.81	0	0	144	11,491	8,804	153	9,343
Total	278,020				5,355			261,972	7,456,457	261,972	9,873,131	7,008,063	278,020	7,437,366
														$W.Est_y$

2.3142	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9932	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.8795	p.shift	α_y	Proportion of age shift
1.0613	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2004

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	150	49.4	53.4	3.28	0	67.02	7.86	144	1130	59	466	195	62	203
2	124,070	79.4	81.8	11.31	1,399	91.78	19.12	118852	2271971	49,100	938,587	555,314	51,255	579,695
3	171,987	97.2	98.9	19.67	3,372	106.76	29.90	164754	4926504	137,782	4,119,990	2,710,206	143,831	2,829,198
4	2,253	110.2	111.7	27.96	63	117.88	40.25	2159	86889	97,699	3,932,424	2,731,930	101,988	2,851,876
5	0	121.2	122.5	36.55	0	127.30	50.77	0	0	1,268	64,401	46,367	1,324	48,403
6	0	130.6	131.6	45.10	0	135.31	61.11	0	0	0	0	0	0	0
7	139	138.4	139.3	53.15	7	142.00	70.77	133	9433	55	3,890	2,922	57	3,050
8	103	145.1	145.8	60.75	6	147.72	79.82	99	7864	177	14,116	10,743	185	11,215
Total	298,703				4,848			286,140	7,303,792	286,140	9,073,873	6,057,677	298,703	6,323,640
														$W.Est_y$

1.6056	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9968	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.5876	p.shift	α_y	Proportion of age shift
1.0439	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Table 4. (cont.)

Year=2005

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	353	49.4	54.4	3.45	1	66.68	7.75	335	2598	51	392	175	53	184
2	187,707	79.4	82.4	11.54	2,160	91.41	18.89	178192	3366114	27,148	512,845	313,319	28,598	330,053
3	138,514	97.2	99.4	19.91	2,750	106.45	29.64	131493	3897192	171,152	5,072,611	3,407,995	180,292	3,590,010
4	8,089	110.2	112.0	28.22	228	117.65	40.01	7679	307262	112,827	4,514,479	3,184,006	118,853	3,354,058
5	640	121.2	122.8	36.82	24	127.14	50.58	608	30754	6,613	334,501	243,471	6,966	256,474
6	765	130.6	131.9	45.35	35	135.21	60.97	726	44281	626	38,160	28,384	659	29,900
7	40	138.4	139.5	53.39	2	141.95	70.69	38	2682	622	44,005	33,234	656	35,009
8	0	145.1	146.0	60.97	0	147.71	79.81	0	0	32	2,572	1,964	34	2,069
Total	336,110				5,199			319,071	7,650,883	319,071	10,519,564	7,212,548	336,112	7,597,757
														$W.Est_y$

1.9905	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9970	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.8492	p.shift	α_y	Proportion of age shift
1.0534	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2006

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	4,447	49.4	53.3	3.25	15	67.08	7.87	4252	33477	1,387	10,919	4,510	1,490	4,846
2	138,097	79.4	81.7	11.27	1,595	91.85	19.15	132037	2529002	45,932	879,768	517,765	49,355	556,350
3	179,246	97.2	98.9	19.63	3,606	106.82	29.95	171380	5132202	144,870	4,338,306	2,843,916	155,666	3,055,852
4	1,553	110.2	111.6	27.92	44	117.92	40.29	1485	59840	115,965	4,672,250	3,237,832	124,607	3,479,123
5	745	121.2	122.4	36.51	28	127.32	50.80	712	36191	1,233	62,647	45,024	1,325	48,379
6	0	130.6	131.6	45.06	0	135.33	61.14	0	0	480	29,346	21,631	516	23,243
7	0	138.4	139.3	53.11	0	142.00	70.78	0	0	0	0	0	0	0
8	0	145.1	145.8	60.71	0	147.72	79.82	0	0	0	0	0	0	0
Total	324,088				5,288			309,866	7,790,713	309,866	9,993,236	6,670,678	332,958	7,167,793
														$W.Est_y$

1.5426	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
1.0247	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.6738	p.shift	α_y	Proportion of age shift
1.0745	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2007

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	1,257	49.4	53.7	3.33	4	66.91	7.82	1166	9118	162	1,267	540	170	568
2	223,673	79.4	82.0	11.38	2,479	91.67	19.05	207372	3949689	29,823	568,012	339,378	31,381	357,116
3	129,846	97.2	99.1	19.74	2,497	106.67	29.82	120383	3589938	195,283	5,823,528	3,855,602	205,490	4,057,116
4	7,706	110.2	111.8	28.04	210	117.81	40.18	7145	287054	104,646	4,204,388	2,934,381	110,116	3,087,747
5	854	121.2	122.5	36.63	30	127.25	50.71	792	40157	6,262	317,554	229,395	6,589	241,384
6	0	130.6	131.7	45.18	0	135.28	61.07	0	0	682	41,638	30,804	717	32,414
7	0	138.4	139.4	53.23	0	141.98	70.74	0	0	0	0	0	0	0
8	0	145.1	145.9	60.82	0	147.71	79.82	0	0	0	0	0	0	0
Total	363,336				5,221			336,858	7,875,956	336,858	10,956,386	7,390,100	354,464	7,776,346
														$W.Est_y$

1.7226	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9739	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.8610	p.shift	α_y	Proportion of age shift
1.0523	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2008

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	203	49.4	49.8	2.68	1	68.47	8.33	187	1557	137	1,137	366	148	398
2	118,697	79.4	79.7	10.48	1,241	93.28	20.04	109230	2189077	79,844	1,600,157	836,640	86,764	909,150
3	194,370	97.2	97.4	18.79	3,645	108.02	30.97	178868	5539078	160,101	4,957,925	3,008,070	173,977	3,268,773
4	11,060	110.2	110.4	27.02	298	118.81	41.22	10178	419487	55,638	2,293,120	1,503,313	60,460	1,633,602
5	266	121.2	121.3	35.59	9	127.94	51.55	245	12625	2,922	150,621	103,988	3,175	113,000
6	158	130.6	130.7	44.19	7	135.74	61.69	145	8953	172	10,612	7,600	187	8,259
7	0	138.4	138.5	52.27	0	142.21	71.09	0	0	39	2,780	2,044	42	2,221
8	0	145.1	145.2	59.94	0	147.77	79.91	0	0	0	0	0	0	0
Total	324,754				5,202			298,853	8,170,777	298,853	9,016,352	5,462,021	324,754	5,935,404
														$W.Est_y$

0.1755	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9982	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.2695	p.shift	α_y	Proportion of age shift
1.0867	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Table 4. (cont.)

Year=2009

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	145	49.4	52.0	3.03	0	67.56	8.03	127	1022	37	296	112	42	127
2	125,556	79.4	80.9	10.97	1,371	92.36	19.47	109900	2139487	31,952	622,035	350,640	36,412	399,581
3	165,762	97.2	98.3	19.32	3,185	107.25	30.31	145092	4397777	120,103	3,640,348	2,319,905	136,866	2,643,703
4	15,659	110.2	111.1	27.58	430	118.24	40.62	13706	556739	107,001	4,346,292	2,951,586	121,935	3,363,549
5	541	121.2	122.0	36.17	19	127.54	51.07	473	24177	9,870	504,028	356,979	11,247	406,803
6	0	130.6	131.3	44.74	0	135.47	61.33	0	0	336	20,618	15,039	383	17,138
7	0	138.4	139.0	52.80	0	142.07	70.88	0	0	0	0	0	0	0
8	0	145.1	145.6	60.43	0	147.73	79.84	0	0	0	0	0	0	0
Total	307,663				5,005			269,299	7,119,202	269,299	9,133,616	5,994,261	306,886	6,830,901
														$W.Est_y$

1.0361	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9948	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.7101	p.shift	α_y	Proportion of age shift
1.1396	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2010

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	262	49.4	51.9	3.01	1	67.61	8.04	205	1651	17	140	52	22	67
2	53,601	79.4	80.9	10.95	586	92.40	19.49	41914	817074	3,740	72,899	40,947	4,782	52,364
3	126,360	97.2	98.3	19.29	2,432	107.29	30.34	98808	2997920	46,735	1,417,982	901,537	59,767	1,152,920
4	29,152	110.2	111.1	27.56	802	118.26	40.65	22796	926588	92,367	3,754,431	2,545,384	118,123	3,255,134
5	2,828	121.2	122.0	36.14	102	127.56	51.09	2211	112982	21,052	1,075,529	760,824	26,922	972,970
6	0	130.6	131.2	44.71	0	135.49	61.35	0	0	2,024	124,170	90,496	2,588	115,730
7	0	138.4	139.0	52.78	0	142.08	70.89	0	0	0	0	0	0	0
8	0	145.1	145.6	60.40	0	147.73	79.85	0	0	0	0	0	0	0
Total	212,204				3,922			165,935	4,856,216	165,935	6,445,150	4,339,240	212,204	5,549,185
														$W.Est_y$

0.9947	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9979	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.9153	p.shift	α_y	Proportion of age shift
1.2788	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2011

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	0	49.4	45.3	2.03	0	70.74	9.10	0	0	0	0	0	0	0
2	79,888	79.4	77.0	9.48	798	95.42	21.42	75034	1607553	10,642	227,992	100,925	11,968	113,504
3	100,303	97.2	95.4	17.71	1,872	109.80	32.52	94209	3063446	77,754	2,528,360	1,376,958	87,445	1,548,576
4	30,915	110.2	108.7	25.85	842	120.14	42.63	29037	1237726	84,966	3,621,793	2,196,785	95,556	2,470,583
5	7,261	121.2	119.9	34.39	263	128.88	52.72	6820	359531	25,886	1,364,616	890,331	29,112	1,001,298
6	1,492	130.6	129.5	43.04	68	136.38	62.59	1401	87680	6,051	378,747	260,445	6,806	292,905
7	312	138.4	137.5	51.17	17	142.58	71.65	293	21014	1,244	89,120	63,647	1,399	71,580
8	43	145.1	144.3	58.94	3	147.91	80.15	41	3252	292	23,424	17,225	329	19,372
Total	220,215				3,863			206,835	6,380,202	206,835	8,234,054	4,906,316	232,614	5,517,817
														$W.Est_y$

-1.6364	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
1.0539	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.8582	p.shift	α_y	Proportion of age shift
1.1246	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2012

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	2,955	49.4	55.5	3.67	10	66.31	7.63	2683	20482	924	7,055	3,388	979	3,587
2	221,420	79.4	83.0	11.81	2,497	91.00	18.64	201052	3747518	71,012	1,323,636	838,939	75,185	888,235
3	84,400	97.2	99.8	20.20	1,627	106.09	29.34	76636	2248672	158,197	4,641,820	3,195,011	167,492	3,382,751
4	10,870	110.2	112.4	28.52	296	117.39	39.75	9870	392303	53,638	2,131,941	1,529,895	56,790	1,619,792
5	623	121.2	123.1	37.12	22	126.96	50.37	566	28515	6,665	335,740	247,439	7,057	261,978
6	0	130.6	132.2	45.65	0	135.10	60.82	0	0	371	22,572	16,939	393	17,935
7	0	138.4	139.8	53.67	0	141.90	70.62	0	0	0	0	0	0	0
8	0	145.1	146.2	61.22	0	147.71	79.81	0	0	0	0	0	0	0
Total	320,268				4,453			290,808	6,437,491	290,808	8,462,764	5,831,611	307,896	6,174,279
														$W.Est_y$

2.4391	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9546	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.6555	p.shift	α_y	Proportion of age shift
1.0588	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Table 4. (cont.)

Year=2013

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	0	49.4	53.7	3.33	0	66.92	7.83	0	0	0	0	0	0	0
2	117,218	79.4	81.9	11.37	1,332	91.68	19.05	11501	219134	5,306	101,086	60,342	54,073	614,984
3	135,534	97.2	99.1	19.74	2,673	106.68	29.83	13298	396674	6,135	182,986	121,077	62,522	1,233,971
4	5,950	110.2	111.8	28.03	167	117.81	40.18	584	23459	6,465	259,793	181,240	65,890	1,847,135
5	635	121.2	122.5	36.63	23	127.25	50.72	62	3162	7,193	364,798	263,441	73,305	2,684,897
6	0	130.6	131.7	45.17	0	135.29	61.07	0	0	314	19,207	14,206	3,205	144,785
7	0	138.4	139.4	53.22	0	141.98	70.75	0	0	34	2,376	1,788	342	18,218
8	0	145.1	145.9	60.81	0	147.71	79.82	0	0	0	0	0	0	0
Total	259,337				4,195			25,446	642,429	25,446	930,246	642,093	259,337	6,543,989
														$W.Est_y$

1.7116	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9992	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
1.5387	p.shift	α_y	Proportion of age shift
10.1917	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2014

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	345	49.4	53.8	3.35	1	66.87	7.81	327	2551	155	1,210	519	164	549
2	80,597	79.4	82.0	11.41	918	91.63	19.02	76303	1451275	36,349	691,361	414,632	38,395	437,962
3	142,503	97.2	99.1	19.77	2,815	106.63	29.79	134912	4019013	104,091	3,100,872	2,058,078	109,948	2,173,881
4	42,498	110.2	111.8	28.07	1,192	117.78	40.15	40234	1615380	90,022	3,614,328	2,527,020	95,088	2,669,209
5	2,340	121.2	122.6	36.66	86	127.23	50.69	2215	112290	22,208	1,125,746	814,255	23,458	860,071
6	31	130.6	131.7	45.21	1	135.27	61.05	29	1764	1,179	71,958	53,284	1,245	56,282
7	205	138.4	139.4	53.25	11	141.98	70.73	194	13697	107	7,569	5,698	113	6,019
8	0	145.1	145.9	60.84	0	147.71	79.82	0	0	102	8,127	6,195	108	6,544
Total	268,518				5,024			254,214	7,215,970	254,214	8,621,172	5,879,682	268,518	6,210,517
														$W.Est_y$

1.7676	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9990	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.5259	p.shift	α_y	Proportion of age shift
1.0563	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

Year=2015

Age	CAA	L.Jan	mean.L	mean.W	subSumWildW	harv.L	harv.W	caa.harv.rep	subSumHarvRepW	caa.harv.est	subSumHarvEstW	subSumWildEstW	caa.wild.est	subSumWildEstW2
i	$N_{y,i}$	$L_{JAN,i}$		$W.catch_{y,i}$		$L.Harv2_{y,i}$	$W.Harv2_{y,i}$							
0	112	0	0	0	0	0	1	111	111	69	69	0	70	0
1	0	49.4	55.6	3.68	0	66.28	7.63	0	0	42	317	153	42	155
2	144,501	79.4	83.1	11.83	1,708	90.97	18.62	142767	2658743	89,288	1,662,797	1,056,518	90,372	1,069,344
3	126,664	97.2	99.9	20.22	2,558	106.07	29.32	125145	3669542	131,746	3,863,108	2,663,366	133,345	2,695,699
4	21,000	110.2	112.5	28.54	599	117.37	39.73	20748	824306	59,854	2,377,947	1,708,425	60,581	1,729,165
5	1,823	121.2	123.1	37.14	68	126.95	50.36	1801	90716	8,899	448,120	330,540	9,007	334,552
6	204	130.6	132.2	45.67	9	135.10	60.81	201	12235	801	48,689	36,561	810	37,005
7	0	138.4	139.8	53.69	0	141.90	70.62	0	0	75	5,322	4,046	76	4,095
8	0	145.1	146.3	61.24	0	147.71	79.81	0	0	0	0	0	0	0
Total	294,304				4,942			290,774	7,255,652	290,774	8,406,370	5,799,609	294,304	5,870,017
														$W.Est_y$

2.4696	adj.mon	$adj.mon_y$	Adjustment of number of month to the time of catch
0.9990	p.N.trans		(Total numper of transported in TIS)/(Total number in Catch-at-age)
0.3746	p.shift	α_y	Proportion of age shift
1.0121	p.N.Rep		(Total number of SBT Australian reported)/(Total number of catch-at-age harvested)

When the value p.shift exceeded 1.0, in 2011, (proportion -1) in age_i was shifted to age_{i+2}.

Table 5 Estimated growth in fork length of farming SBT which explains the difference between estimated total weight at the onset of farming based on the 40/100 fish sampling and the total weight at harvest

Wild or farm	SBT Age-2				SBT Age-3				SBT Age-4			
	L_start	L_6 months later	Increment	RFW	L_start	L_6 months later	Increment	RFW	L_start	L_6 months later	Increment	RFW
wild	79.4	91.3	11.9		97.2	105.9	8.7		110.2	117.5	7.3	
Farm.Tag	79.4	95.3	15.9	1.34	97.2	110.1	12.9	1.49	110.2	119.0	8.8	1.21
Farm2001	79.4	111.7	32.3	2.72	97.2	123.2	26.0	3.00	110.2	132.6	22.4	3.06
Farm2002	79.4	110.8	31.4	2.64	97.2	122.3	25.1	2.89	110.2	131.7	21.5	2.93
Farm2003	79.4	122.2	42.8	3.61	97.2	133.7	36.5	4.22	110.2	143.2	33.0	4.49
Farm2004	79.4	115.8	36.4	3.07	97.2	127.3	30.1	3.48	110.2	136.8	26.6	3.62
Farm2005	79.4	122.2	42.8	3.60	97.2	133.7	36.5	4.21	110.2	143.1	32.9	4.49
Farm2006	79.4	117.2	37.8	3.19	97.2	128.7	31.5	3.64	110.2	138.1	27.9	3.81
Farm2007	79.4	121.6	42.2	3.56	97.2	133.1	35.9	4.14	110.2	142.5	32.3	4.41
Farm2008	79.4	108.9	29.5	2.49	97.2	120.5	23.3	2.68	110.2	129.9	19.7	2.68
Farm2009	79.4	116.2	36.8	3.10	97.2	127.7	30.5	3.52	110.2	137.1	26.9	3.67
Farm2010	79.4	118.0	38.6	3.25	97.2	129.5	32.3	3.73	110.2	138.9	28.7	3.92
Farm2011	79.4	112.9	33.5	2.82	97.2	124.4	27.2	3.14	110.2	133.8	23.6	3.22
Farm2012	79.4	121.1	41.7	3.52	97.2	132.7	35.5	4.09	110.2	142.1	31.9	4.35
Farm2013	79.4	124.1	44.7	3.76	97.2	135.6	38.4	4.43	110.2	145.0	34.8	4.74
Farm2014	79.4	114.5	35.1	2.96	97.2	126.0	28.8	3.33	110.2	135.5	25.3	3.44
Farm2015	79.4	114.1	34.7	2.92	97.2	125.6	28.4	3.28	110.2	135.0	24.8	3.38

RFW is the ratio Farm/Wild.
Unit is in centimeter, except RFW.

Table 6. Reported and estimated Australian purse seine catches by fishing year.

Fishing year is expressed as 2015 for the period between Dec. 2014 and Nov. 2015.
W.Reported: Catch weight reported in tons
W.Estimated: Estimated catch weight based on the farming growth rate given
W.Excess: Excess of catch weight of the estimated to reported
percent.excess: Proportion of excess of catch to the catch reported (%)

Case1
Growth rate of mean of SRP tagging data was used

Year	W.Reported	W.Estimated	W.Excess	percent.excess	percent.excess
2001	5,162	6,604	1,442	128%	28%
2002	5,234	6,303	1,069	120%	20%
2003	5,375	7,437	2,063	138%	38%
2004	4,874	6,324	1,450	130%	30%
2005	5,214	7,598	2,384	146%	46%
2006	5,302	7,168	1,866	135%	35%
2007	5,230	7,776	2,546	149%	49%
2008	5,211	5,935	724	114%	14%
2009	5,026	6,831	1,804	136%	36%
2010	3,931	5,549	1,619	141%	41%
2011	3,872	5,518	1,646	143%	43%
2012	4,485	6,174	1,690	138%	38%
2013	4,198	6,544	2,346	156%	56%
2014	5,029	6,211	1,181	123%	23%
2015	4,947	5,870	923	119%	19%
Average			1,650	134%	34.4%
Total			24,753		

Case2
Growth rate is assumed to be same as that of wild fish in body length

Year	W.Reported	W.Estimated	W.Excess	percent.excess	percent.excess
2001	5,162	7,324	2,162	142%	42%
2002	5,234	7,000	1,766	134%	34%
2003	5,375	7,845	2,470	146%	46%
2004	4,874	6,866	1,992	141%	41%
2005	5,214	8,155	2,942	156%	56%
2006	5,302	7,780	2,479	147%	47%
2007	5,230	8,413	3,183	161%	61%
2008	5,211	6,748	1,536	129%	29%
2009	5,026	7,466	2,439	149%	49%
2010	3,931	5,993	2,062	152%	52%
2011	3,872	6,323	2,451	163%	63%
2012	4,485	6,618	2,133	148%	48%
2013	4,198	6,980	2,782	166%	66%
2014	5,029	6,672	1,642	133%	33%
2015	4,947	6,288	1,341	127%	27%
Average			2,225	146%	46.3%
Total			33,380		

Table 7. Comparison of reported and estimated Australian purse seine catches by fishing year.

Year	Australia reported	Itoh et al. 2012 Mixed normal distribution	Itoh et al. 2012 Cohort slicing	Present study Case1	Present study Case2
2001	5,162			6,604	7,324
2002	5,234			6,303	7,000
2003	5,375			7,437	7,845
2004	4,874			6,324	6,866
2005	5,214			7,598	8,155
2006	5,302			7,168	7,780
2007	5,230	8,271 (8,264-8,277)	8,273	7,776	8,413
2008	5,211	6,159 (6,156-6,163)	6,659	5,935	6,748
2009	5,026	6,749 (6,773-6,754)	6,675	6,831	7,466
2010	3,931		5,689	5,549	5,993
2011	3,872			5,518	6,323
2012	4,485			6,174	6,618
2013	4,198			6,544	6,980
2014	5,029			6,211	6,672
2015	4,947			5,870	6,288

Median (5%-95%)

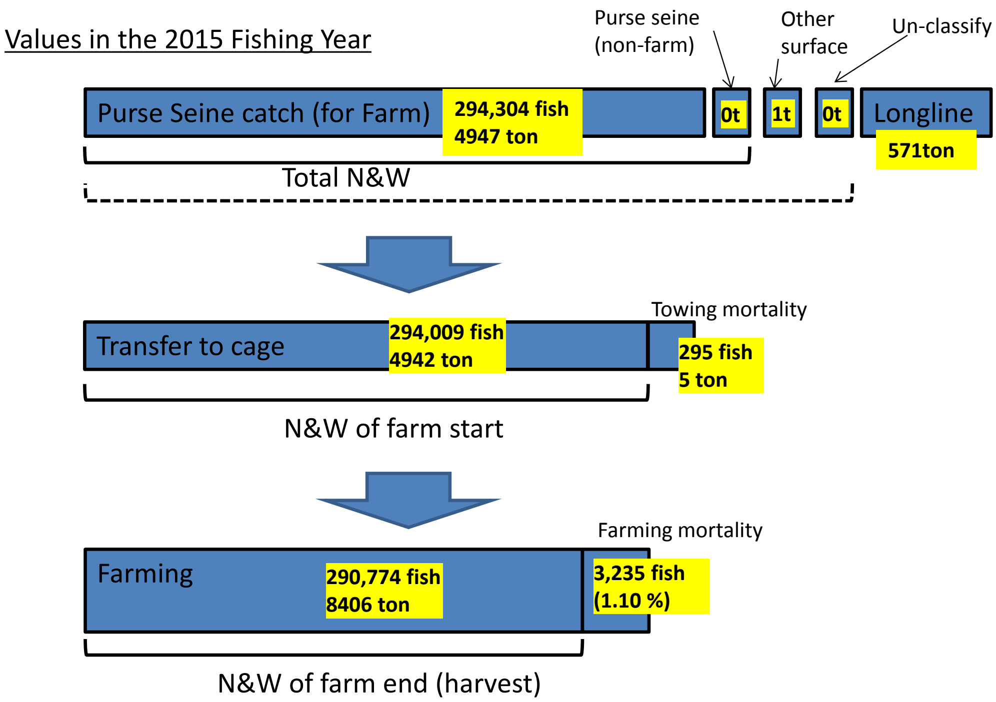

Fig. 1. Diagram of number and weight of southern Bluefin tuna from wild capture to harvest after farming in Australia.

The numbers are statistics in the 2015 fishing year (Dec 2014-Nov 2015) for reference.

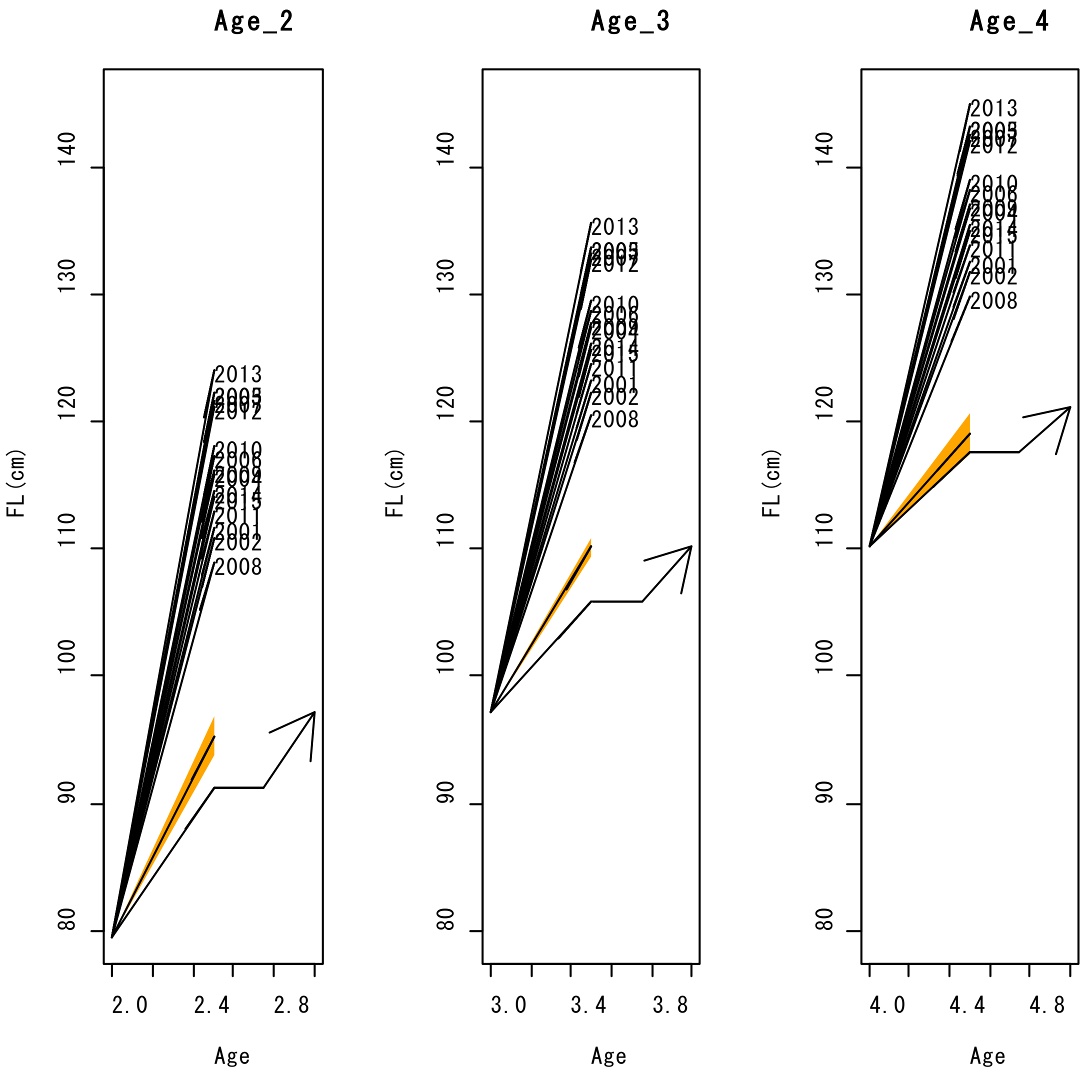

Fig. 2 Assumption of SBT growth in fork length by year for farmed fish

Black lines are assumptions of growth rate which explains the difference between estimated total weight at the onset of farming based on the 40/100 fish sampling and the total weight at harvest by fishing year. Black arrows denote growth of wild SBT used in CCSBT, assuming no growth in winter between July and September. Yellow polygons denote growth from the CCSBT SRP tagging data of mean with 1 standard error.

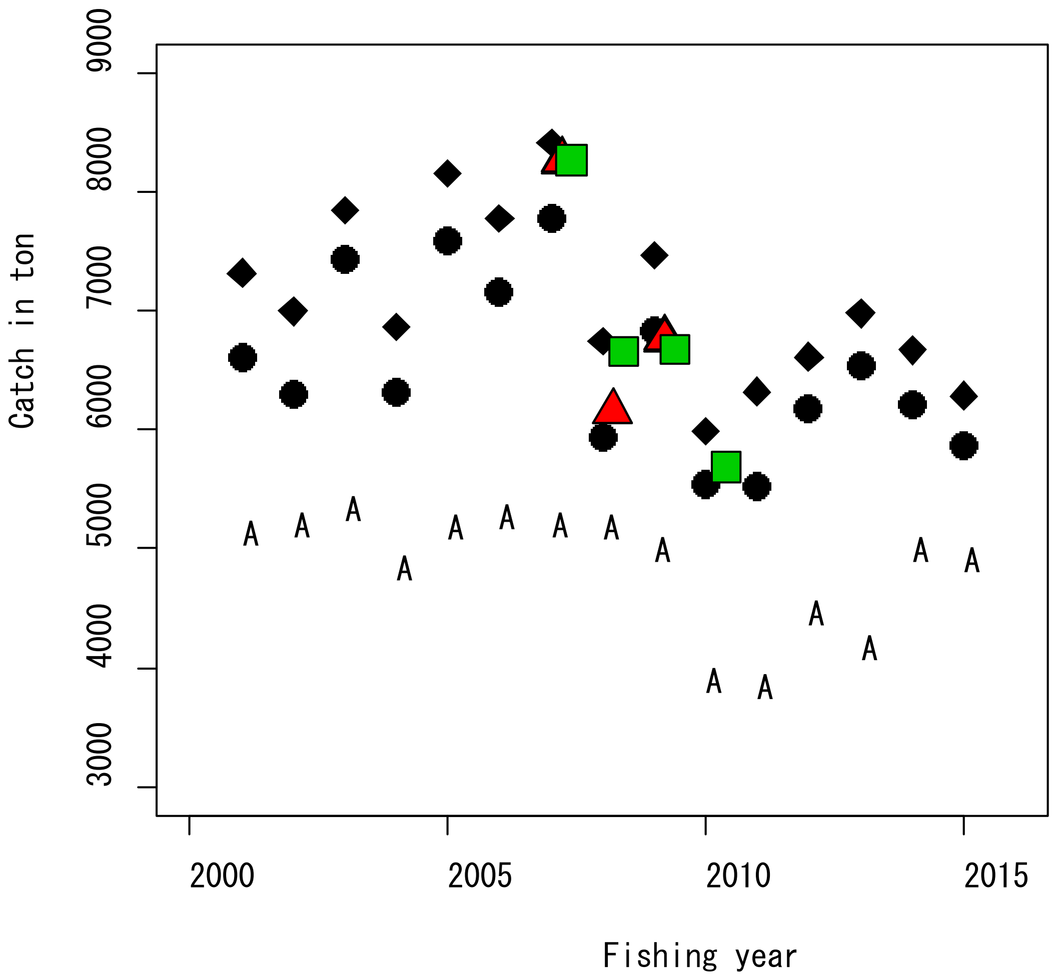

Fig. 3. SBT catch weight by the Australian purse seine fishery by fishing year

A denotes the catch that Australia reported. The black circle ● denotes the estimated catch based on the mean growth rate obtained from the CCSBT SRP conventional tagging data (Case 1). The black diamond ◆ denotes the estimated catch assuming the growth rate for body length in farmed fish is same as that in wild fish (Case 2). The red triangles ▲ are the estimated catch in the previous study that decomposed ages by applying mixed normal distributions to length frequency data (Itoh et al. 2012). The green squares ■ are the estimated catch in the previous study that decomposed ages by applying the cohort slicing method to length frequency data (Itoh et al. 2012).