第 22 回 ESC レポートの付属 7 を基にした、ミナミマグロ畜養のサイズと漁獲合計重量の不確実性についてのサマリーポイント

Summary points of farm uncertainty relevant to size and total catch estimation of southern bluefin tuna, based on Attachment 7 in Report of ESC22

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要旨

CCSBT においてミナミマグロの豪州畜養魚のサイズ、年齢、漁獲量に関わる不確実性については、長年に渡って議論されている。推定方法によって推定値が大きく異なっており、それに関連する様々なことで日豪間での見解が異なっている。2016 年及び 2017 年の ESC では議論すべき問題点が抽出された。本文書ではそれらの問題点に対応した議論の材料を提示する。推定に使用すべき体長体重関係、畜養魚の成長率を知るための方法論、など、小グループ及び ESC で合意を得るべきポイントを整理した。

Summary

The uncertainties related to the size, age, and total catch weight of Australian farming of southern bluefin tuna have been debated over the years in CCSBT. Estimated values are greatly different depending on estimation methods, and the viewpoints between Japan and Australia are different by various things related to it. In the ESC in 2016 and 2017, problems to be discussed were extracted. In this document we present materials for discussion corresponding to those points, including length-weight relationships to be used for estimation, and the methodology to know the growth rate of farmed fish. We also summarized the points to be agreed in the small group and ESC.

1. 緒言　　　Introduction

CCSBT においてミナミマグロの豪州畜養魚のサイズ、年齢、漁獲量に関わる不確実性については、2005 年に問題が指摘されて（Anon. 2005）から、長く議論されている。2006 年に行われた独立レビューにおいては、データ不足から結論が出なかった（Anon. 2006）。その後、より多くのデータや年の蓄積が増えていったが、解析結果はバイアスが依然として存在することを示していた（Itoh et al. 2009a, 2009b, 2010, 2011, 2012, 2014, Itoh and Takeda 2015, Itoh and Omori 2016, 2017a, Itoh and Ara 2018）。

問題が長引いている要因の一つは、議論がかみ合わず、一つの問題に対して、片方が意見を表明し、他方が科学的データに基づいて反論するというプロセスが形成されてこなかったことによる。近年、2016 年には日豪間で問題点に対する双方の意見を出す試みが行われた（Attachment 6, ESC21）。2017 年には再び、日豪の指摘する問題点が表にまとめられた（付属 7、ESC22）。このまとめられたポイントに従って小グループで議論し、合意した文書 ESC に提案することとなっている（Anon. 2017）。本文書では第 22 回 ESC の付属 7 でポイントに従いながら、Attachment 6, ESC21 での指摘も考慮し、議論の材料を提示する。

Uncertainty relevant to the size, age, catch of Australian farmed southern bluefin tuna (SBT), already had pointed out in 2005 (Anon. 2005), has been discussed long years in CCSBT. In the independent review conducted in 2006, there was no agreed conclusion in consensus mainly because of the scarcity of data (Anon. 2006). After that, the accumulation of more data and years increased, results from several analyses showed that bias still existed (Itoh et al. 2009a, 2009b, 2010, 2011, 2012, 2014, Itoh and Takeda 2015, Itoh and Omori 2016, 2017a, Itoh and Ara 2018).

One of the reasons the problem is prolonged is because the discussion has not formed a process of one opinion expressed on one issue and the other by counterpoint based on scientific data. In 2016, an attempt was made to exchange both sides' opinions on the problems between Japan and Australia (Attachment 6, ESC 21). In 2017 again, the problems pointed out by Japan and Australia were summarized in the table (Annex 7, ESC 22). Following the summarized points, discussions will be made in a small group and will be proposed an agreed document to the current ESC (Anon. 2017). In this document, we provide relevant scientific data and information to each point of Appendix 7 of the 22nd ESC Report, as well as Attachment 6 of ESC 21 Report, which would help the discussion.

2. 畜養漁業と測定、推定方法の概要　Outline of SBT farming, and measurement and estimation method

畜養のプロセスは、まき網による漁獲から開始される。ミナミマグロは GAB において、12 月から 2 月の間に漁獲される。この時点が漁獲であり、漁獲量の計算に用いられる。魚

をまいた網は曳航生簀としてポートリンカーンに約 2 週間を掛けて運搬される。曳航生簀からいくつかの畜養生簀に魚を移す。この時、網でできた水中トンネルを使って魚を移動させる。畜養生簀の魚の多くは 7 月か 8 月まで、約 6 ヶ月間飼育される。一部の魚は 6 ヶ月以前に収穫される。育った魚は取り上げられて殺され（収穫）、GG の形態に加工される。冷凍または鮮魚で、主に日本に出荷される。

いくつかの観察・測定が行われる。曳航生簀は乗船したオブザーバーが観察するが、魚のサイズ、尾数、総重量は計測されない。ポートリンカーンに到着してから、曳航生簀から 40 尾を手釣りで釣り上げて、船上で尾叉長と体重を測定する。曳航生簀から飼育生簀に移す際に、水中トンネルにビデオカメラを取り付けて映像を撮影し、後に映像から個体数を数える。収穫した後には加工場において、GG の体重が測定される。

現在までに、畜養魚のサイズや成長を調べるアプローチには 6 種類が存在する。40 尾サンプリング、体長モードからの年齢分解、スライシング方による年齢分解、SRP タグデータによる成長率を仮定した推定方法、ステレオビデオカメラシステム、餌料係数に基づく推定である。各方法の詳細を示した文書、推定した年を表 1 にまとめた。

これらの方法は特性がそれぞれ異なる。それらから推定されたサイズ、年齢、成長率、漁獲量の推定値の間には大きな食い違いが生じている。

The process of farming is initiated by catch of purse seine fishing. SBT are caught in the Great Australian Bight (GAB) between December and February. This time point is catch and used to calculate the catch amount. The SBT enclosed by net (towing cage) is transported to Port Lincoln in about two weeks. SBT in the towing cage are transferred into several farming cages through an underwater tunnel made of net. Most of SBT are farmed for about 6 months until July or August. Some fish are harvested before 6 months. The farmed SBT is picked up, killed (harvested), and processed into the form of gilled and gutted without tail (GG). Frozen or fresh fish, mainly shipped to Japan.

Several observations and measurements are made. An on board observer observes the towing cage, while fish size, number of SBT, and total weight are not measured by them. After arriving at Port Lincoln, they pick up 40 fish from the towing cage by hand-line fishing (called 40 fish sampling) and measure its fork length and body weight on the ship. When transferring from a towing cage to a farming cage, a video camera is attached to an underwater tunnel to capture footage, and then the number of individuals passed is counted from the footage. After harvesting, the body weight of GG is measured at the processing place.

To date, there are six approaches to investigate the size and growth of farmed SBT. The 40 fish sampling, age decomposition from fork length mode, age decomposition by slicing method, estimate assuming growth rate by SRP tagging data, stereo video camera system, and estimate based on food conversion rate (FCR). The documents showing the details of each method and years those estimate applied are summarized in Table 1.

These methods have different characteristics. A large discrepancy arises between estimates of size, age, growth rate and catch estimated from them.

3. 合意した小グループでの将来作業リストで示された問題点への判断材料 Materials for judging the issues indicated in the list of future work that agreed in the small group

3-1. ミナミマグロ個体数と収穫時の平均重量は正確か？ Are the number of fish and average weight out of farms are correct?

日本は、漁獲時の推定体重に最も大きなバイアスがあると考えている。それは、40 尾サンプリングには小型魚に偏るバイアスが存在することで引き起こしていると考えている。漁獲時の推定体重に比較すれば、漁獲尾数と収穫時の体重のバイアスは小さいと期待している。しかしそれを証明するデータは示されていない。現段階としては、漁獲尾数と収穫時の体重は正しいとの仮定の下で解析作業を進めながら、個体数や収穫時の平均体重の仮定も証明されるべきだろう。

Japan believes that there is the greatest bias on estimated weight at the point of catch. We believe that the 40 fish sampling is causing bias to smaller fish. Compared with the estimated weight at the time of catch, we expect that the bias in the number of fish and weight at harvest is small. But no data to prove it is given. At the present stage, we should treat the number of individuals and the average weight at harvest to be correct as assumptions, which should be validated, while proceeding with the analysis work.

3-2. 体長体重関係の非線形性 Length – weight relationship is non-linear

このポイントは 2016 年の ESC レポートの Attachment 6 で提起された。豪州は、「a 歳から a+1 歳への体長当たりの体重は、式 2 で仮定されているような直線とは明確に異なる」と主張した。我々は既に以前の文書（Itoh and Omori 2017b）で、i 歳から i+1 歳への成長で直線と仮定しているのは体重であり、体長ではないことを説明した。魚類サイズの非線形性は体長-体重関係で考慮されている。詳細は Appendix 1 を参照。

The point was raised in Attachment 6 of ESC21 Report in 2016. Australia claimed that “The change in weight-at-length as a fish ages from age a to a+1 will definitely not be linear (as implied in Eqn. 2)”. We have already explained in previous document (Itoh and Omori 2017b) that we assumed growth in body <u>weight</u> from age-i to age-i+1 to be linear in the equation, NOT growth in <u>length</u>. Non-linearity of fish size was taken account by length-weight relationship. See Appendix 1 for more detail.

3-3. 野生魚の体長体重関係　Length – weight relationship of wild fish

我々は Robins(1963)で示された体長-体重（LW）式が適切であることを、2015 年に示した（Itoh and Takeda 2015）。同文書の Attachment 1 を本文書の Appendix 2 として添付する。

We have shown in the document in 2015 that the length-weight (LW) equation given in Robins (1963) is appropriate for wild fish (Itoh and Takeda 2015). Attachment 1 of the document in 2015 is attached as Appendix 2 of this document.

3-4. 畜養魚の体長体重関係　Length – weight relationship of farm out fish

畜養魚の LW 関係は、2009 年の解析時に月及び製品（生鮮・冷凍）別に求められた（Itoh et al. 2012）。得られたアロメトリー係数を表 2 に示す。体長モード法やスライシング法においては、年、月、製品別の LW 関係式が使用されている。現在行われている成長率を仮定した方法では、収穫の最も多い 7 月の LW 関係式（2007 年 7 月の生鮮魚）を用いている。

我々は、2007 年 7 月の生鮮魚の LW 係数を使用することは適切と考える。しかし、別の具体的な LW データや関係式が存在するなら、それを検討することを歓迎する。

The LW relationship of farmed fish was made by each month and product (fresh / frozen) at the time of analysis in 2009 (Itoh et al. 2012). The obtained allometric coefficients are shown in Table 2. In the fork length mode method and slicing method, LW relationship by year, month, and product are used. In the method assuming the current growth rate, we use the July LW relationship (fresh fish in July 2007), which is the high season of harvest.

We think that it is appropriate to use LW coefficient of fresh fish in July 2007. However, if other concrete LW data or relationships are provided, we welcome consideration.

3-5. マグロ類の成長率　Growth rates of tunas

ミナミマグロ畜養魚の成長率について、Jeffriess(2014)は、大西洋クロマグロ及び太平洋クロマグロの畜養魚では野生魚よりも成長が速いことが多くの研究結果で示されている、と主張した。Itoh and Takeda (2015)は、以下のように反論した。同文書の Attachment 2 を本文書の Appendix 3 として添付する。

> 問題となっているのは、畜養魚の成長が野生魚よりも速いかではなく、どの程度速いかである。Jeffriess (2014)で具体的な成長率が示された事例で、豪州報告漁獲量に対応した成長率を支持するものはなかった（Attachment 2）。またその多くは、SRP タグからの成長率が妥当であることを支持した。

マグロ類の野生魚の成長として文献の報告としては、大西洋クロマグロでは Restrepo et al. (2010)、太平洋クロマグロでは Shimose et al. (2009)、メバチでは Hallier et al. (2005)、

キハダでは Wild (1986)がある。マグロ類畜養魚の成長について、Masuma et al.(2008)と Goto(2014)が太平洋クロマグロを日本の沿岸で飼育した結果を示している。Masuma (2008)において、太平洋クロマグロは、ミナミマグロの 3 歳魚に相当する 97.2cmFL から、6 ヶ月間で 124.5cm（八重山での飼育）及び 125.9cmFL（奄美での飼育）に成長した。Goto（2014)において太平洋クロマグロは、実験 1 では 2013 年 6 月 16 日に 89cmFL であった魚が 2013 年 12 月 16 日に 113cmFL に成長し、実験 2 では 2013 年 11 月 7 日に 77cmFL であった魚が 2014 年 5 月 26 日に 98.5cmFL に成長していた。

異なるマグロ類の間で、また畜養魚と野生魚との間で、成長率を比較することは単純ではない。種によって成長の能力は異なる。また、魚のサイズまたは年齢によってその後の一定期間に成長する量や割合も異なる。そこで Itoh and Takeda(2015)は、同種間で、ある年齢（ミナミマグロのある年齢当たりの体長と近い体長を与える年齢）から 6 ヶ月間（ミナミマグロの主要な畜養期間）の成長の割合を指数値で表現することを提案した。この RFW (Ratio of farmed fish growth over wild fish growth)は以下で定義される。

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

ミナミマグロ畜養魚の成長率については、これまで豪州側からは示されていない。畜養に関係する不確実性の中でも、情報が乏しく、不確実性の大きな点である。豪州の The Fisheries Research and Development Corporation (FRDC)のレポート（http://www.frdc.com.au/）に記述が存在する可能性がある。少なくとも以下のタイトルの FRDC レポートは有望である。このレポートの提供及び成長率に関するレビュー文書の提出を豪州に対して望む。

<1>

Aquafin CRC - SBT Aquaculture Subprogram: optimisation of farmed Southern Bluefin Tuna (Thunnus maccoyii) nutrition to improve feed conversion efficiency and reduce production costs

Project Number: 2001-249

Program(s): Industry

Organisation: South Australian Research and Development Institute

<2>

Aquafin CRC - SBT Aquaculture Subprogram: activity metabolism in live-held southern bluefin tuna (Thunnus maccoyii)

Project Number: 2003-228

Program(s): Industry

Organisation: University of Adelaide North Terrace Campus

<3>

Aquafin CRC - SBT Aquaculture Subprogram: activity metabolism in live-held southern bluefin tuna (Thunnus maccoyii), Phase 2

Project Number: 2005-200

Program(s): Industry

Organisation: University of Adelaide North Terrace Campus

<4>

Southern Bluefin Tuna Aquaculture Subprogram Project 2: development and optimisation of manufactured feeds for farmed southern bluefin tuna

Project Number: 1997-362

Program(s): Industry

Organisation: South Australian Research and Development Institute

<5>

ASBTIA: Optimising the use of praziquantel to manage blood fluke infections in commercially ranched SBT

Project Number: 2013-027

Program(s): Adoption, Environment, Industry

Organisation: South Australian Research and Development Institute

<6>

Southern Bluefin Tuna Aquaculture Subprogram Project 1: implementation and coordination of research experiments conducted with farmed southern bluefin tuna to assess manufactured diets, feeding regimes and harvesting techniques

Project Number: 1997-361

Program(s): Industry

Organisation: South Australian Research and Development Institute

既存の成長率の知見が不十分であれば、標識放流などで新たに、直接的に成長率を明らかにする必要がある。100 尾サンプリングで体長、体重を測定した魚について、曳航生簀に戻す際に通常標識を装着して畜養後の収穫時に回収する方法は直接的で、効果的であろう。

Regarding the growth rate of farmed SBT, Jeffriess (2014) argued that many research findings indicate that growth of fish from Atlantic bluefin and Pacific bluefin tuna is faster than that of wild fish. Itoh and Takeda (2015) argued as follows. Attachment 2 of the document in 2015 is attached as Appendix 3 of this document.

> The point is NOT farmed fish grow faster than wild fish. The point is HOW fast farmed fish grow than wild fish. We examined growth rate in Jeffriess (2014) which actual growth information was shown (Attachment 2). None of them support the high growth rates of SBT which relevant to 40/100 fish sampling and reported catch amount. Most of them support the growth rate for farmed SBT based on the SRP tagging data.

There are representative studies for growth of wild *Thunns* species, such as Reprepo et al. (2010) in Atlantic bluefin tuna, Shimose et al. (2009) in Pacific bluefin tuna, Hallier et al. (2005) in bigeye tuna, and Wild (1986) in yellowfin tuna. For growth of farming tunas, Musuma et al. (2008) and Goto (2014) show the results of breeding Pacific bluefin tuna on the coast of Japan. In Masuma (2008) for Pacific bluefin tuna in farming, fish in 97.2 cmFL, corresponding to age-3 SBT, grew in six months to 124.5 cmFL (captive in Yaeyama) and 125.9 cmFL (captive in Amami). In Goto (2014) in the experiment 1, Pacific bluefin tuna grew from 89 cmFL on 16 June 2013 to 113 cmFL on 16 December 2013. In the experiment 2, fish grew from 77 cmFL on 7 November 2013 to 98.5 cmFL on 26 May 2014.

It is not simple to compare growth rates among different tuna species and between farming and wild fish. Depending on the species, the ability to grow may be different. Also, it may be depending on the size or age of the fish, the increment and ratio growing in a certain period afterwards differs. Therefore, Itoh and Takeda (2015) proposed an index that showed the proportion of growth in the same species at a certain age (the age to give any fork length at age of SBT close to) for 6 months (major farming duration of SBT). This RFW (Ratio of farmed fish growth over wild fish growth) is defined as follows.

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

Australia has not provided growth rate of SBT farming. Among uncertainties related to farming, the growth rate is a large point of uncertainty. There may be a description in Australia's report on The Fisheries Research and Development Corporation (FRDC) (http://www.frdc.com.au/). The FRDC report of at least the following titles is promising. We would like to ask Australia to submit these report to CCSBT and also provide a review document on the growth rate of farmed SBT based on description in these reports.

<1>

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If the knowledge of the existing growth rate is insufficient, it is necessary to obtain the growth rate directly and newly, by means of conventional tagging. The tagging method will be direct and effective that implemented conventional tags when SBT are measured length and weight at the 40 fish sampling (100 fish at current), released the fish into the towing cage, farmed as in usual farmed condition, and retrieve tags when harvested with data of length and weight.

3-6. 標識装着の成長への影響　Effect of wearing tags on fish growth

Jeffriess（2014）は、標識を装着することは、ミナミマグロの成長に強い悪影響を与えることを主張した。その根拠は主に、Hampton (1986)、Hearn and Polacheck (2003)、Itoh et al. (2003)に依った。

Itoh and Takeda (2015)は、それらの文献は標識装着の影響が軽微であることを示していることを明らかにし、またはアーカイバルタグの腹腔内装着を混同したもので比較には不適切であることを指摘した。他の文献情報も示した上で、標識装着がマグロ類の成長に大きな影響を与えるとは思われない、と結論付けている。同文書の記述を本文書の Appendix 4 として添付する。

Jeffriess (2014) argued that wearing conventional tags had a strong negative impact on the growth of SBT. The grounds were primarily based on Hampton (1986), Hearn and Polacheck (2003), and Itoh et al. (2003).

Itoh and Takeda (2015) clarified that these documents indicate that the effect of tag attachment is minor. They also pointed out that Jeffriess (2014) inappropriately cited Itoh et al. (2003) which was for archival tag study implementing a large device in fish body cavity. Itoh and Takeda (2015) concluded that it was unlikely that wearing tags greatly affects the growth of tuna after showing other literature information. The description of Itoh and Takeda (2015) is attached as Appendix 4 of this document.

3-7. 年齢組成　Age composition from CDS data

CDS の個体別サイズデータは有益と考えられる。体長モードからの年齢分解及びスライシング法による年齢分解での解析結果を得ることができる。CDS の秘匿情報については、

蓄養会社の具体的な名称は不要である。ただし、蓄養場によって成長や魚のサイズが大きく異なるのであるならば、別途与えたコードによって区別する必要があろう。

Size data of individual fish included in Catch Documentation Scheme (CDS) are considered to be beneficial. It is possible to obtain analysis results by age decomposition from fork length mode and age decomposition by slicing method. Regarding confidential information of CDS, the specific name of farming company is unnecessary. However, if growth and fish size vary greatly depending on the farm, it will be necessary to distinguish them according to separately given codes.

3-8. 餌料交換係数　food conversion rate (FCR)

Jeffriess (2014, 2015)はミナミマグロ畜養魚の餌料交換係数（増肉係数; FCR）を提示した。しかしそこで示された数字には矛盾があり、見直しが必要である。例えば、2014 年の畜養では大きな赤字になっている（see Appendix 5)。これは、サイズや成長率の不確実性とは無関係である。また、マイワシの全ての量がミナミマグロのエサに使われたとは限らない。この点は、CCSBT-Itoh and Omori (2017b)で説明した（see Appendix 6)。
Jeffriess (2014, 2015) provided FCR values of farmed SBT. However, there are discrepancies in the numbers shown there, and a review of their calculation is necessary. For example, in the 2014 farming it is in a big deficit (see Appendix 5). This has nothing to do with uncertainty of size or growth rate. In addition, not all amounts of sardine may have been used for SBT. This point was explained in Itoh and Omori (2017b) (see Appendix 6).

3-9. 40/100 尾サンプリングのバイアス　Evaluation of bias in 40/100 fish sampling

2014 年の ESC21 のレポートでは、100 尾サンプリングした後にステレオビデオカメラシステムで撮影して、両者を比較すれば良いとしている（Anon. 2014c)。また、収穫時に 100 尾サンプリングするという方法も良いと、同レポートで記述されている。我々はそれらの提案を支持する。
It is described in the ESC 21 report of 2014 that an experimental trials comparing stereo video to the 100 fish sample could be used to investigate the accuracy of 100 fish sample (Anon. 2014c). Also, it suggested another approach that taking a 100 fish sample just prior to harvesting all the fish in pens. We support these suggestions.

3-10. 魚の肥満度　Fish condition index

豪州は、日本の使用した畜養魚の体長体重関係では、実際の畜養魚よりもひどく痩せていると主張した。Fulton の condition index（$K=10^5$xBody weight/(Fork length^3)）で表現すると、表 2 の通りである。これは、豪州の主張とは異なり、野生魚の K 値よりかなり大き

な値である。

ミナミマグロ畜養魚の妥当な K 値について、豪州側からは提示されていない。K 値は少なくとも尾叉長によって異なるが、豪州は季節、畜養場、その他によっても異なると説明してきたので、それらを明示した K 値の提出を望む。

Australia claimed that SBT calculated using LW relationship used in Japan is much thinner than actual farmed fish. Table 2 shows fish condition expressed in terms of Fulton's condition index (K = 10^5 x Body weight / (Fork length ^{3})) based on the LW relationship used by Japan. This value is considerably larger than the K value of wild SBT, contrary to Australian claim.

So far, Australian has not provided K values for farmed SBT which they think reasonable. It is desireble to be provided K value from Australia. K value varies depending on at least fish length, but if it also varies by other factors, such as by year, month, farming cage, as Australia has been explaining, each K values should be provided.

3-11. GAB での 4 歳魚の分布　Few age-4 fish distributed in GAB

豪州は、日本の解析結果では 4 歳魚が漁獲の主体である考えている。しかしこれは豪州の我々の主張に対する勘違いである。我々の解析では 2015 年畜養魚の場合、推定された年齢組成は 2 歳魚 31%、3 歳魚 45%、4 歳魚 21%であった。ミナミマグロの主要な要素は 3 歳魚であり、我々は GAB に多数の 4 歳魚が分布していることは仮定していない。この点は、Itoh and Omori (2017b)で説明した（see Appendix 7）。

Australia thinks that age-4 fish is the main component of farmed SBT in the results of Japanese analysis. But this is a misunderstanding of our claim in Australia. In our analysis, estimated age composition was 31% in age-2, 45% in age-3, and 21% in age-4 for the 2015 farmed fish. The main composition of SBT were still age 3, and we have not assumed plenty of age-4 SBT distributed in GAB. This point had been explained in Itoh and Omori (2017b) (see Appendix 7).

3-12. 畜養のための漁獲の仮定の理解　Understand logistics of catching for farming

我々は、豪州が提案している漁獲過程の説明を歓迎する。

We welcome Australian proposal that explain catching process.

4. 合意できるであろう事柄　Points can be agreed

我々は、以下の点は明らかであり、小グループ並びに ESC として合意に達することができると考える。

1. 40/100 尾サンプリングに基づく CDS サマリーからの成長率と、SRP 標識データに基

づく成長率との違いの原因は解明されるべきである。

2. 野生魚の体長・体重関係式は、Robins(1963)のものを使用するのが適切である。
3. 畜養魚の体長･体重関係式は､2007 年 7 月生鮮魚のものを使用することを基本とする。豪州から今後、LW 式が提供され、適切と判断された場合は感度分析をする。
4. 畜養期間中の成長率は、尾叉長で表現する。
5. 畜養期間中の成長率は､野生魚と比較する場合は Ratio of farmed fish growth over wild fish growth（RFW）で表現する。
6. 畜養期間中の成長率は、SRP タグデータに基づくものが、現在利用可能なものの中で最も信頼できる。
7. 畜養期間中の成長率について、FRDC レポートを含む既存文献に示されている値を収集し、2019 年 ESC までに検討する。
8. 畜養期間中の成長率は､2019 年 ESC までにより信頼できる値が得られない限り､SRP タグデータに基づくものを使用する。
9. 畜養期間中の成長率は、畜養魚の尾叉長成長が野生魚の尾叉長成長と同じであるとする仮定を、感度分析に使用する。
10. 畜養期間中の成長率について、2019 年 ESC で合意できない場合は、成長率を調べる新たな方法（e.g.100 尾サンプリング魚での標識放流）の計画を 2019 年 ESC で策定し、2019 年 CCSBT 年次会合に提案する。
11. 標識装着の成長への影響は、文献を調べた結果、深刻なものではない。
12. CDS の個体別サイズデータを解析（例えば、体長モード法）に使用することは、問題の解決に有益であろう。
13. ESC は、CDS の個体別サイズデータを畜養魚のデータ解析に使用させるよう、委員会に要請すべきである。
14. 肥満度について、豪州は豪州が妥当と信じる値を 2019 年 ESC で示す。
15. 畜養魚では、2017 年以前の魚の中で 4 歳魚が占める割合は 3 歳魚のものよりも低い。
16. 豪州は、Understand logistics of catching for farming の情報を提供する。
17. ステレオビデオカメラは不確実性の払拭に有効な方法と期待される。

We believe that the following points relevant to SBT farming are clear and we can reach an agreement as the small group and ESC.

1. The cause of the difference between the growth rate from the CDS summary based on the 40/100 fish sampling and the growth rate based on SRP tagging data should be elucidated.
2. It is appropriate to use the LW relationship in Robins (1963) for wild fish.
3. Any analysis that needs LW relationship of farmed fish, that derived from farmed

fish of fresh fish in July 2007 can be used. If other LW relationship is provided from Australia in the future, and if judged appropriate, sensitivity analysis will be done.

4. The growth rate during farming period is expressed in fork length.
5. The growth rate during farming period is expressed by the ratio of farmed fish growth over wild fish growth (RFW) when comparing to wild fish.
6. In the growth rates during farming, that based on SRP tagging data is the most reliable among currently available ones.
7. Regarding the growth rate during farming, collect the values shown in existing literature including FRDC reports and consider it by 2019 ESC.
8. Growth rate during farming will be uesed the one based on SRP tagging data unless a more reliable value is obtained by 2019 ESC.
9. An analysis that assume the growth rate in fork length are same in farming fish and wild fish is treat as a sensitivity test.
10. Regarding the growth rate during farming, if it is not possible to agree at the ESC in 2019, a plan of a new method to examine the growth rate (e.g. tagging in the 100 fish sampling) will be formulated in 2019 ESC, and it will be proposed to the annual meeting of CCSBT in 2019.
11. The influence of tag attachment on growth is not serious as a result of examining the literature.
12. Analysis of individual size data of CDS for analysis (e.g., body length mode method) would be useful for solving the problem.
13. ESC should ask Commission allow ESC to use CDS individual size data for data analysis of farmed fish.
14. Regarding the fish condition factor, Australia will provide the value that Australia believes to be appropriate by 2019 ESC.
15. In farmed fish, the proportion of age-4 fish among fish before 2017 is lower than that of age-3 fish.
16. Australia provides information on understand logistics of catching for farming.
17. Stereo video cameras are expected to be an effective way to dispel uncertainty.

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Table 1 Six methods of size and growth of farming SBT

Method	Years applied	Document	Remark
40 fish sampling	2001-2017	Anon. 2006	100 fish from 2013
Age decomposition from fork length mode	2007-2009	Itoh et al. 2009a, 2009b, 2010	
Age decomposition by slicing method	2007-2010	Itoh et al. 2011, 2012	
Assuming growth rate by SRP tagging data	2001-2017	Itoh et al. 2014, Itoh and Takeda 2015, Itoh and Omori 2016, 2017, Itoh and Ara 2018	
Stereo video camera system			There was an experiment in 2011
Food conversion rate (FCR)	2014, 2015	Jeffriess 2014, 2015	

Table 2 Length and weight relationship and Fulton's condition index (K) of SBT

Length-weight relationship parameters (*a, b*) and number of fish (*num*) are from the 2007 farming fish (Itoh et al. 2012) by month and by product (Fresh or frozen). Length-weight relationship of wild fish came from Robins (1963). Body weight and Fulton's condition index at fork length in 10 cm intervals are shown in the upper and lower tables, respectively.

Weight at length

Month	FresFroz	num	a	b	70cmFL	80cmFL	90cmFL	100cmFL	110cmFL	120cmFL	130cmFL	140cmFL
	Wild		3.131	2.906	7.2	10.6	14.9	20.3	26.8	34.5	43.5	53.9
4	Fresh	284	1.258	3.101	8.4	12.2	17.2	23.4	31.2	40.5	51.6	64.7
5	Fresh	1,479	0.395	3.356	7.9	11.7	17.0	23.7	32.3	42.9	55.8	71.3
6	Fresh	1,672	0.839	3.193	8.3	12.2	17.3	23.8	31.9	41.8	53.7	67.7
7	Fresh	4,267	1.392	3.090	8.8	12.8	18.0	24.6	32.7	42.5	54.1	67.8
8	Fresh	5,957	1.947	3.021	9.2	13.2	18.5	25.0	33.0	42.6	54.0	67.3
9	Fresh	5,089	2.388	2.971	9.1	13.1	18.1	24.4	32.1	41.3	52.1	64.6
10	Fresh	2,278	1.177	3.113	8.3	12.1	17.0	23.2	30.9	40.2	51.2	64.3
7	Frozen	8,040	1.253	3.110	8.7	12.7	17.8	24.3	32.4	42.1	53.8	67.5
8	Frozen	21,976	2.872	2.930	9.2	13.1	18.1	24.3	31.8	40.7	51.3	63.4
9	Frozen	25,038	2.093	2.989	8.7	12.4	17.3	23.3	30.6	39.5	49.8	62.0

Fulton's K

Month	FresFroz	num	a	b	70cmFL	80cmFL	90cmFL	100cmFL	110cmFL	120cmFL	130cmFL	140cmFL
	Wild				2.10	2.07	2.05	2.03	2.01	1.99	1.98	1.97
4	Fresh	284			2.46	2.39	2.36	2.34	2.34	2.34	2.35	2.36
5	Fresh	1,479			2.29	2.29	2.33	2.37	2.43	2.48	2.54	2.60
6	Fresh	1,672			2.42	2.38	2.37	2.38	2.40	2.42	2.44	2.47
7	Fresh	4,267			2.58	2.51	2.48	2.46	2.46	2.46	2.46	2.47
8	Fresh	5,957			2.67	2.58	2.53	2.50	2.48	2.47	2.46	2.45
9	Fresh	5,089			2.66	2.55	2.49	2.44	2.41	2.39	2.37	2.36
10	Fresh	2,278			2.42	2.36	2.33	2.32	2.32	2.32	2.33	2.34
7	Frozen	8,040			2.54	2.47	2.44	2.43	2.43	2.44	2.45	2.46
8	Frozen	21,976			2.68	2.56	2.48	2.43	2.39	2.36	2.33	2.31
9	Frozen	25,038			2.53	2.43	2.37	2.33	2.30	2.28	2.27	2.26

Appendix 1

(From CCSBT-ESC/1708/20 (Itoh and Omori 2017b); blue is Australian statement, while black is Japanese statement)

Australia [2016]: Your analysis of growth rates 'implied by Australian data' is based on the calculations in CCSBT-ESC/1609/24, with respect to this:

1. Australia [2016]: Bias in inferred weight-at-age (Eqn. 2). The change in weight-at-length as a fish ages from age a to a+1 will definitely not be linear (as implied in Eqn. 2) because of the effectively cubic relationship between length and weight. Using a simple linear approach like this one will always overestimate the weight-at-age at any point in the year as measured Jan 1st to Jan 1st. By over-estimating weight-at-age you will implicitly have to have a higher value for W.TIS.Catch.y to solve Eqn. 3. So, just from this issue alone, actual catch would HAVE to be higher than reported catch but driven only by a bias in the inferred weight-at-age.

Japan [2017]: Eqn.2 in CCSBT-ESC/1609/24 was the equation that estimate the date of wild capture. It is used to match the catch amount from fish with mean length-at-age on January 1st and grow in the period up to the date estimated, to the reported catch amount.

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

(Eq-2) in CCSBT-ESC/1609/24

where, $W_{JAN,i}$ = 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*.

We assumed growth in body weight from age-i to age-i+1 to be linier in this equation. It was NOT growth in length. Australian claim was not appropriate.

Furthermore, an attempt was made for non-linearity of growth in body weight. The von Bertalanffy growth curve was fitted between age-2 and age-5 of length-at-age used in CCSBT. (Although CCSBT's length-at-age was derived from more complex procedure using Richard's model and combined two stanza, any curve was enough for this examination.) Body length was converted to body weight by Robins (1963) and then compared with growth that assumed linearity (Fig. 1). As the result, the body weight increased linearly and little difference was observed between the two lines. Therefore, linear/non-linear issue on the equation cannot explain the large bias observed.

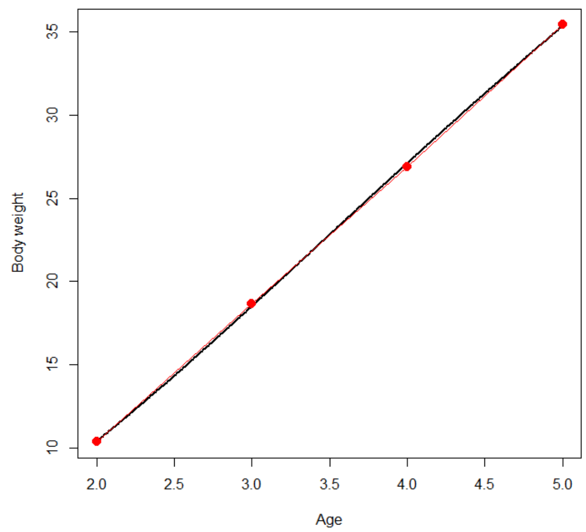

Fig. 1 Body weight at age in SBT from age-2 to 5. A non-linear curve (black line estimated from von Bertalanffy growth equation) and linear lines (red with dot) were compared.

2. Australia [2016]: The interaction of uncertainty in mean length-at-age, the nonlinear nature of in particular the length-weight relationship, and the various assumed and estimated parameters. If everything is linear, then using the expected values of all key parameters and relationships does not produce a bias. BUT because there are a number of nonlinearities and estimated quantities it is not at all clear what role these will have in biasing the estimates. The main point of the analysis is to try and estimate the potential bias in reported catch due to sampling issues. However, the main problem is that the sequential modelling approach is likely to have a number of unknown biases in it even if the data were correct, so how do we make any conclusions based upon it if the results cannot be demonstrated to be unbiased.

Japan [2017]: As mentioned above, our analysis did not approximate body length in linear. It took account of non-linearity in length-weight relationship. While there were several assumptions, the estimated biases in growth or catch amount were quite large, which is unlikely to be explained by uncertainties relevant to those assumptions.

Appendix 2

(From Attachment 1 of CCSBT-ESC/1509/32(Rev) (Itoh and Takeda 2015))

Attachment 1

Evaluation of length-weight relationship in Robins (1963)
Robins 1963 の体長体重関係式の適切さ

OMMP5（2014 年）で Robins (1963)の体長体重関係式の適切さが議論された。Robins (1963) では論文において体長体重関係式および曲線が示されているものの、測定個体数、具体的なプロットは示されておらず、信頼性が確保できない。また、50 年以上昔のデータであり、近年に当てはまるのかは定かではない。

そこで、利用可能な近年のデータを用いて体長体重関係式を求めた。データは 2011 年から 2014 年の曳縄調査によるミナミマグロの体長体重データ (N=529)、ならびに 2011 年から 2014 年の RTMP データにおける体長体重データを用いた。求めるべき体長体重関係はまき網が漁獲する 12 月から 2 月のものである。曳縄調査は 1 月から 2 月に行われるので、全てのデータを用いた。ボックスプロットでチェックしたところ、RTMP データでは肥満度が 11 月から翌年 5 月に同様であったことから、それ以外の月は除いた。RTMP は製品重量であることから、1.15 倍して原魚重量とした（Anon. 2014）。まき網では大型魚はほとんど漁獲されないので、>140cm のデータは除いた（N=73,125）。

体長体重関係式は以下のアロメトリー式で示される。

$W=aL^b$

Robins(1963)では $a=3.130859x10^{-5}$ （原記載は $10^{-4.161}$ でポンド単位）、b=2.9058 であった。我々のデータからは $a=2.274358x10^{-5}$, b=2.971 が得られた。両者にほとんど違いは見られなかった（Fig. A1）。よって、Robins(1963)の LW 関係式を解析に使用することは妥当と考えられた。

There was a discussion at OMMP5 (2014) whether the length-weight (LW) relationship of Robins (1963) is appropriate. In the paper of Robins (1963), there was a figure of LW curve and parameter values of equation, but lacked information of the number of individual measured or actual plots of each individuals, then we could not ensure its reliability. In addition, it should be confirmed that such a LW relationship obtained 50 years ago is applicable in recent years.

We calculated LW relationships by using available data in recent years. Data came from the trolling survey from 2011 to 2014 (N=529) and RTMP data in the same years. The LW relationship should be derived is for Australian purse seine catch in the period from December to February. All of data from the trolling survey were used because its periods were from January to February. In the RTMP data, monthly condition index (W/L^3) was similar between November and May in an observation by box plots, then the data in the period was used. Weights in RTMP were converted to round weight by a factor of 1.15 (Anon. 2014). Since large individuals are few in purse seine catch, data > 140 cmFL were excluded, resulted in records from 126,581 individuals in RTMP were used.

LW relationship was expressed as the following allometry equation.

$W=aL^b$

Parameters in Robins (1963) was $a=3.130859x10^{-5}$ (original description was $10^{-4.161}$ as the unit was pound) and b=2.9058. Our data provided $a=2.274358x10^{-5}$ and b=2.971. Two curves agreed well each other (Fig. A1). Therefore, it is considered to be appropriate to use the LW relationship in Robins (1963) for wild fish in the farming subject in recent years.

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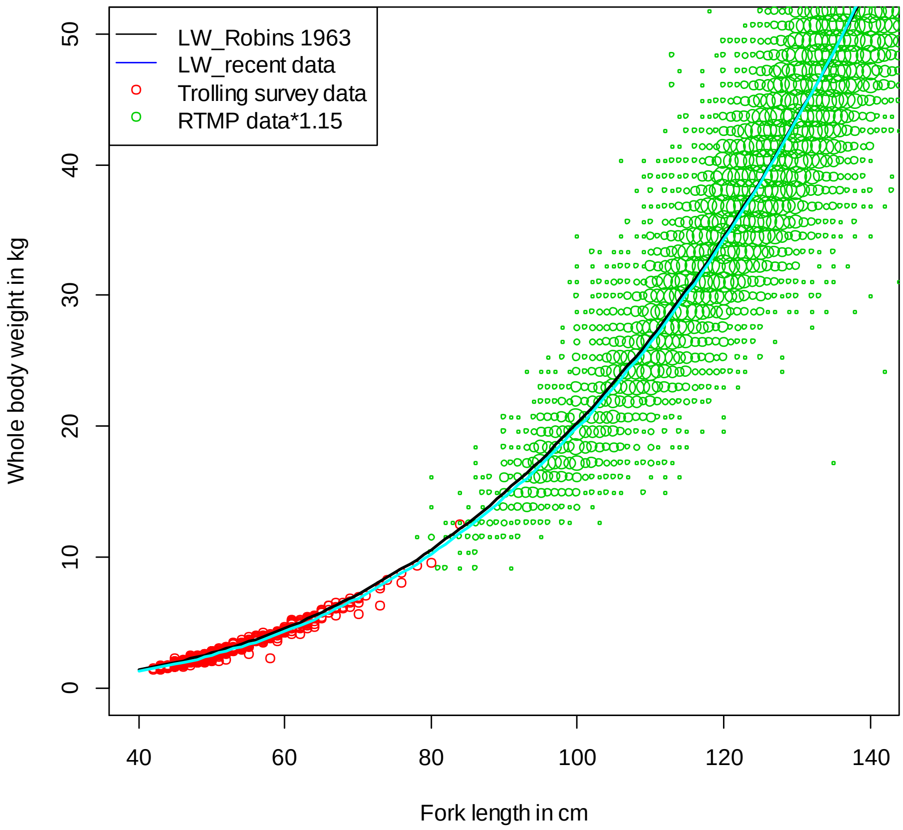

Fig. A1 Length-weight relationship of young SBT

Each plot in red is one individual measured in the trolling survey. The numbers of measured SBT in RTMP (green) are expressed as size of circles.

Appendix 3

(From Attachment 2 of CCSBT-ESC/1509/32(Rev) (Itoh and Takeda 2015))

Attachment 2

Evaluation of growth rate in farming of Atlantic, Pacific and southern bluefin tunas in literatures used in Jeffriess (2014)

Jeffriess(2014)で示された文献による大西洋クロマグロ、太平洋クロマグロ、ミナミマグロの畜養成長の検証

Jeffriess(2014 CCSBT-ESC/1409/11)において、ミナミマグロおよび近縁種である大西洋クロマグロおよび太平洋クロマグロについて、畜養魚の高い成長を示す証拠の情報としていくつかの文献情報が紹介された。その中で具体的な数字で示された事例について検討した。

【事例 1】Kataviæ et al. (2002) より。大西洋クロマグロ。"*In a trial conducted in the Adriatic Sea trial over 17 months (June 1999-December 2000) the results showed a much faster growth in length and weight in farms than in the wild. For example, in the 85-120cm category (10-25kg) the monthly growth was 2.16cm and 2.42kg. This was despite an initial tagging mortality of 50%, plus 5% during the trial, indicating stress on all tagged fish.*" (Table 1 in Jeffries 2014)
100cm の ABF が一ヶ月で畜養では 2.16cm 成長するとしている。Restrepo et al.(2009)では一ヶ月で野生魚は 1.59cm 成長する。よって、RFW=1.36。SBT3 歳魚の SRP タグから求めた RFW=1.49 を上回らない。

【事例 2】Deguara et al. (2010) より。大西洋クロマグロ。"*A 4 month trial in Malta (February to June 2009) on 5-6 year old Atlantic Bluefin Tuna achieved a 43.5% increase in weight and an increase in length from 142.5 cm to 157.9cm. In the wild, such ABT age groups take over one year to gain that length.*" (Table 1 in Jeffries 2014)
137 日間の実験で 142.5 cm から 157.9cm に成長したとしている。RFW=2.35 と計算された。SRP タグからの畜養 SBT の RFW を上回るが、豪州報告漁獲量に対応した RFW は下回る。また、ICCAT-SCRS での議論は明らかではないが、このレポートが出されてもなお、ICCAT-SCRS は畜養魚の体長成長は野生魚と同じと結論付けていることに留意すべきである。

【事例 3】Galaz (2012)より。大西洋クロマグロ。"*In cages with just young tunas, growth is more important as the direct competition for food has been removed. Data suggests juveniles under 20kg originating from the Balearic Islands show significant weight increase reaching a SGR of 88.8 % in November (121 days).*" (Table 1 in Jeffries 2014)

20kg の魚が 4 ヶ月で 1.888 倍になるとしている。

Table 5. Weight increase data for juveniles caught in the Balearic Islands.

Month	*Avg(Kg.)*	*Std Dev*	*n*	*Days*	*RGR%*
July	19.5	2.7	27	0	
August	22.1	3.9	11	31	13.5%
September	30.7	6.0	7	60	57.6%
October	--	--	--	91	--
November	36.8	4.7	52	121	88.8%
December	34.9	4.8	516	152	79.1%
January	34.4	4.4	108	167	76.5%

上記（Table 5 of Galaz 2012）が、Jeffriess(2014)が参照した表であろう。11 月で 1.888 倍になっているが、6 ヶ月経って 1 月になっても 1.765 倍でしかない。Galaz(2012)は、冬季には成長が停滞するとしている。よって、6 ヶ月後の平均体重は 11 月、12 月、1 月の平均体重=35.0kg とした。大西洋クロマグロで体重 19.5kg は 3.32 歳と推定され、6 ヵ月後の体長は 112.2cmFL となる。畜養 ABF35.0kg の体長は Galaz(2012)で示された WL 関係式から、121.0cmFL と計算された。よって RFW=(121.0-103.1)/(112.3-103.1)=1.95。SRP タグからの畜養 SBT の RFW を上回るが、豪州報告漁獲量に対応した RFW は下回る。
このレポートが出されてもなお、ICCAT-SCRS は畜養魚の体長成長は野生魚と同じと結論付けていることに留意すべきである。

【事例 4】Goto(2014)より。太平洋クロマグロ。実験 1 では 2013 年 6 月 16 日の 89cm が 2013 年 12 月 16 日に 113cm に成長した。実験 2 では 2013 年 11 月 7 日の 77cm が 2014 年 5 月 26 日に 98.5cm に成長した。
実験 1 では 89cmFL の魚で RFW=1.80、実験 2 では 77cmFL の魚で RFW=1.50 であった。SRP タグからの畜養 SBT の RFW を少し上回るが、豪州報告漁獲量に対応した RFW をはるかに下回る。

【事例 5】Gordon et al.(2006)より。これはミナミマグロ畜養魚の成長の具体的数字を示した Jeffriess (2014)の中で唯一のもの。

Days in culture	*Start*	*Finish*	RFW estimated	Source
173 days	*95 cmFL*	*108 cmFL*	1.476	Jeffriess(2014)
170 days	*97 cmFL*	*109 cmFL*	1.477	Jeffriess(2014)
174 days	*112 cmFL*	*120 cmFL*	1.144	Jeffriess(2014)
6 months	97.2 cmFL	110.1 cmFl	RFW=1.49	SRP tag estimation in the present study
6 months	110.2 cmFL	119.0 cmFL	RFW=1.21	SRP tag estimation in the present study

イタリックは Jeffeiess(2014)からの引用。SRP 標識データから求めた 6 ヶ月間の畜養魚の体長成長とよく一致した。RFW の分母は、CCSBT で用いている年齢別平均値について、月別成長を直線と仮定し、冬季 3 ヶ月間は成長が停滞すると仮定して求めた。推定した RFW は、SRP タグからの畜養 SBT の RFW と同じか少し下回り、豪州報告漁獲量に対応した RFW をはるかに下回る。
Jeffriess (2014)はこの実験での死亡率が高かったと記している。死亡率等の情報は示されていない。

Jeffriess (2014 CCSBT-ESC/1409/11) introduced several cases of results in growth of farmed tuna (southern bluefin tuna *Thunnus maccoyii* SBT and its closely related species, Atlantic bluefin tuna *T. thynnus* ABF and Pacific bluefin tuna *T. orientalis* PBF) by referring to literatures. Among them, we examined several cases that the actual data were available.

<Case 1> From Kataviæ et al. (2002) for ABF
"*In a trial conducted in the Adriatic Sea trial over 17 months (June 1999-December 2000) the results showed a much faster growth in length and weight in farms than in the wild. For example, in the 85-120cm category (10-25kg) the monthly growth was 2.16cm and 2.42kg. This was despite an initial tagging mortality of 50%, plus 5% during the trial, indicating stress on all tagged fish.*" (Table 1 in Jeffries 2014)
It states that 100 cmFL ABF grew 2.16 cm per month. Wild ABF at 100 cmFL grow 1.59 cm per month with growth equation in Restrepo et al. (2009). Then, RFW is 1.36. This does not exceed the RFW value (1.49) for age-3 SBT derived from the SRP tagging data.

<Case 2> From Deguara et al. (2010) for ABF.
"*A 4 month trial in Malta (February to June 2009) on 5-6 year old Atlantic Bluefin Tuna achieved a 43.5% increase in weight and an increase in length from 142.5 cm to 157.9cm. In the wild, such ABT age groups take over one year to gain that length.*" (Table 1 in Jeffries 2014)
It states fish grew from 142.5 to 157.9 cm in 137 days. RWF is calculated as 2.35. It exceed the RFW value (1.49) for SBT derived from the SRP tagging data, but below the RWF corresponds to the total catch that Australia reported.
Note that ICCAT-SCRS concluded that farm fish growth in length should be same as that of wild fish in their assessment calculation, even Deguara et al. (2010) and Galaz (2012) were available in the discussion.

<Case 3> From Galaz (2012) for ABF.

"*In cages with just young tunas, growth is more important as the direct competition for food has been removed. Data suggests juveniles under 20kg originating from the Balearic Islands show significant weight increase reaching a SGR of 88.8 % in November (121 days).*" (Table 1 in Jeffries 2014)

It states that body weight of 20 kg became 1.888 times in four months.

Following is the Table that Jeffriess (2014) would refer to (Table 5 of Galaz 2012).

Table 5. Weight increase data for juveniles caught in the Balearic Islands.

Month	*Avg(Kg.)*	*Std Dev*	*n*	*Days*	*RGR%*
July	19.5	2.7	27	0	
August	22.1	3.9	11	31	13.5%
September	30.7	6.0	7	60	57.6%
October	--	--	--	91	--
November	36.8	4.7	52	121	88.8%
December	34.9	4.8	516	152	79.1%
January	34.4	4.4	108	167	76.5%

While average growth in November was 1.888 times, the growth was 1.765 times in January after six months passed. Galaz (2012) stated that fish didn't grow in winter. Then, average growth in six months is expected to be 35.0 kg, by weighting average of November, December and January, which estimated to be 121.0 cmFL with LW equation in Galaz (2012). ABF of 19.5 kg is estimated to be age 3.32 with 103.1 cmFL and estimated to grow to 112.2 cmFL in six months. Then, RFW= (121.0-103.1)/(112.3-103.1)=1.95. It exceed the RFW value (1.49) for SBT derived from the SRP tagging data, but below the RWF corresponds to the total catch that Australia reported.

Note that ICCAT-SCRS concluded that farm fish growth in length should be same as that of wild fish in their assessment calculation, even Deguara et al. (2010) and Galaz (2012) were available in the discussion.

<Case 4> From Goto (2014) for PBF.

In experiment 1, fish grew from 89 cmFL on 16 June 2013 to 113 cmFL on 16 December 2013. In experiment 2, fish grew from 77 cmFL on 7 November 2013 to 98.5 cmFL on 26 May 2014. RFWs are calculated as 1.80 for the experiment 1 and 1.50 for the experiment 2. It slightly exceed the RFW value (1.49) for SBT derived from the SRP tagging data, but far below the RWF corresponds to the total catch that Australia reported.

<Case 5> From Gordon et al. (2006) for SBT

This is the only one information that actual SBT growth figures are present in Jeffriess (2014).

Days in culture	*Start*	*Finish*	RFW estimated	Source
173 days	*95 cmFL*	*108 cmFL*	1.476	Jeffriess(2014)
170 days	*97 cmFL*	*109 cmFL*	1.477	Jeffriess(2014)
174 days	*112 cmFL*	*120 cmFL*	1.144	Jeffriess(2014)
6 months	97.2 cmFL	110.1 cmFl	RFW=1.49	SRP tag estimation in the present study
6 months	110.2 cmFL	119.0 cmFL	RFW=1.21	SRP tag estimation in the present study

Italics are refer to Jeffriess (2014). Growth increment was agreed well to that from SRP tagging data. RFW was further calculated. For the denominator of RFW, monthly growth was assumed to be linier interpolation, with no growth in winter three months, between the mean length-at-age used in CCSBT. Estimated RFWs are similar or below the RFW value for SBT derived from the SRP tagging data, but far below the RWF corresponds to the total catch that Australia reported.

Jeffriess (2014) described mortality was high in this experiment. However, detail information about mortality and its influence on growth was not explained.

References

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Appendix 4

(From CCSBT-ESC/1509/32(Rev), page 22-23; Itoh and Takeda 2015)

1. Concern for impact of tag attachment on growth

Concern was made for conventional tags attachment on growth (Jeffriess 2014). It claimed tagging data were inappropriate for growth study because it give serious impact on SBT as shown in Hampton (1986).

Through examination in peer reviewed literatures including Hampton (1986), we conclude that tag attachment does not affect growth, especially in body length, of tunas seriously.

It is well known that conventional tagged tuna resume feeding immediately, and resulted in recaptured in pole-and-line in several times in successive days (Hallier and Fonteneau 2015). In SBT, the most frequent period in Hampton (1986) in which fish released with conventional tags recaptured, presumably by pole-and-line, was 6-10 days after release. Jeffriess (2014) referred Itoh et al. (2003) that observed less frequent feeding after release in PBF, but such a reference was inappropriate because it was "archival tagged" fish implemented in fish body cavity with surgery. The paper compared growth and fatness of recaptured fish against wild fish and did not report severe influence in short period at liberty.

Hampton (1986) compared the condition factor (W/L^3) of recaptured tagged fish to untagged fish. 94% of tagged fish were at liberty less than 20 days. He reported mean condition factor of tagged fish was 93.36% of that in wild fish. This method is indirect comparison between different individual and there is criticize. "*This method (deviations from the expected relationship) has recently been criticized as inaccurate and irrelevant to condition and likelihood of survival (Green, 2001).*" (Willis and Hobday 2015).

Hearn and Polacheck (2003) concluded, with referring Hampton (1986), that tagging had no substantial effect on the growth in body length even within the first 30 days. "*With respect to tagging effects, Hampton (1986) and Hearn (1986) have shown that there can be a significant weight loss of 7–12% for tagged fish in the first month after release. However, tagged fish recover this weight loss within a year at liberty, and there is no apparent difference between tagged and untagged fish after this time (Hearn, 1986). (There is little information available on weight loss of tagged fish at liberty between one month and one year.) In terms of length, Hearn and Hampton could not detect a reduction of growth from growth increment residuals in the tag-return data even within the first 30 days after release. Limited data from the effect of handling and tagging fish in commercial farm pens indicated no retardation in growth in length after 150 days. These farm fish did show a loss in weight when first caged, but the weight was regained over a period of a few months (Anonymous); therefore we do not think that tagging had any substantial effect on the growth rate of tagged* *fished in our study.*"

Appendix 5

Net income calculated from information provided in Jeffriess (2014 and 2015) for SBT farming in 2013 and 2014

		Item	Calculation	Farming in 2013 From Jeffriess(2014) Table 5 Australian report (40/100 fish sampl.)	Farming in 2014 From Jeffriess(2015) Table 5 Australian report (40/100 fish sampl.)
蓄養開始の体重	①	Mean body weithg at farming start	1	16.19	18.73
収穫時の体重	②	Mean body weithg at farming end	2	33.29	38.98
体重増加分	③=②-①	Growth increment	3=2-1	17.1	20.25
全畜養尾数	④	N farmed	4	255,486	255,486
畜養業全体の体重増加分(トン)	⑤=③*④/1000	Total growth weight of farmed fish (ton)	5=3*4/1000	4,369	5,174
エサ使用量(トン)	⑥	Weight bait used (ton)	6	51,550	57,373
餌料変換係数(FCR) 原魚重量用	⑦=⑥/⑤	FCR(Food conversion rate) for round weight	7=6/5	11.8	11.1
WW/GGの変換係数	⑧	Conversion round weight / gilled-gutted weight	8	1.1635	1.1635
餌料変換係数(FCR) 製品重量用	⑨=⑦/⑧	FCR(Food conversion rate) for GG weight	9=7/8	13.7	12.9
エサ価格 (kg当たりのドル単価)	⑩	Bait price (A$/kg)	10	$0.85	$0.88
マグロ1kg増重に要した費用	⑪=⑨*⑩	Bait cost for 1kg increase of SBT	11=9*10	$11.67	$11.35
エサはコストの40%なので1kg増重の費用全体は	⑫=⑪/40%	Total cost for 1kg increase of SBT	12=11/40%	$29.17	$28.39
バイヤーへの販売価格	⑬	Price sold for buyer	13	$15.23	$14.53
豪州はえ縄販売価格	⑭	Price of SBTof Australian longline catch	14	$18.06	$17.25
蓄養にかかるコスト	⑮=⑫*⑤*1000	Total cost for farming	15=12*5*1000	$127,454,153.13	$146,857,668.10
売り上げ総額	⑯=②*④*⑬	Total amount of sales	16=2*4*13	$129,533,113.76	$144,702,007.39
利益	⑰=⑮-⑭	Net income	17=15-14	$2,078,960.63	$ -2,155,660.71

Appendix 6

(From CCSBT-ESC/1708/20 (Itoh and Omori 2017b), page 7-8; blue, red, and blac is statement of Australia in 2016, Japan in 2016, and Japan in 2017, respectively)

2-4. Australia [2016]: Feed conversion ratio (FCR): Australia has provided the extensive literature showing that the benchmark for FCR in farming of Bluefins (including SBT) is ~10:1. Japan's hypothesis rests on Australia's FCR being up to 17:1. Does Japan have information which contradicts the literature on FCR?

Japan [2016]: We do not know what FCR value is appropriate for tuna. We welcome the information on actual observed FCR values for SBT from Australia, appreciating that this can vary with environmental conditions. The FCR values in Table 5 of CCSBT-ESC/1609/14 are based on the total amount of sardine used for food. These values may be larger than apply in reality to Bluefin alone because this food is also used to feed other species, or for other reasons.

Japan [2017]: We expect that Australia provide us the actual FRC values of SBT in this ESC.

Appendix 7

(From CCSBT-ESC/1708/20 (Itoh and Omori 2017b), page 6)

2-1. Australia [2016]: The average weight into farms: The implications of Japan's hypothesis is that – for example – the differences between the sampled weights and actual weights are:

	Sample			*Japan hypothesis*
	Sample size	*Av. Wt (kg)*		*Av. Wt (kg)*
2010/11	*2,471*	*16.7*		*27.2*
2012/13	*2,735*	*16.2*		*26.9*

Japan's hypothesis is that the SBT going into Australian farms are, on average, 4 year old SBT. Is Japan's hypothesis that there is so many 4-5 year olds on the Australian fishing grounds, and these could be targeted so well? Looking at 2013, the hypothesis is not supported by the SAPUE or the Transect Survey raw data. It is also not supported by the realities of tuna farming – that at-sea operations are relatively immobile because of the tow net, that fish of 15-16kg grow faster than SBT of 27kg, and that all SBT ≥21kg. (gg wt) bring a largely common price.

Japan [2016]: We need to check the average weights which have been associated here with the Japanese hypothesis, because the different growth rate by age should be considered. In the GAB, it is known where age 4 fish are distributed, as well as the age 5 fish. Purse seine fishermen can therefore select SBT size (age) that they want. Hence, the age distribution of the catch can be different from the age composition of the SBT distributed in GAB.

Japan [2017]: The age composition of purse seine catch reported by Australia was 49% in age 2, 43% in age 3 and 7% in age4 in 2015. From this information we can understand some amount of SBT age 4 is distributed in GAB and actually caught.

In our analysis for the 2015 farmed fish, estimated age composition was 31% in age 2, 45% in age 3 and 21% in age4. The main composition of SBT were still age 3 and we do not need to assume plenty of age-4 SBT distributed in GAB.