2010 年畜養原魚の年齢組成及び漁獲重量の解析

Analysis of age composition and catch amount of southern bluefin tuna used for farming in 2010

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要約

オーストラリアのミナミマグロ養殖魚について、2010 年の出荷時のサイズデータから年齢組成を推定した。月別体長組成を体長カットポイントを変えた 5 つの仮定でスライシング方により年齢分解した。実際のタグ再捕データから求められた畜養期間中の成長率を用いた仮定では 2 歳魚 3%、3 歳魚 28%、4 歳魚 48%、5 歳魚 18%、まき網による総漁獲重量は 5663 トンと推定された。これは豪州政府からの報告値における年齢組成（2 歳魚 25%、3 歳魚 60%、4 歳魚 14%、5 歳魚 1%）や総漁獲重量 3931 トンと大きく異なっている。40 尾サンプリングのバイアスに関する早急な検証と、豪州巻き網漁業による漁獲量及びサイズ組成を把握する方法の改善が必要である。

Summary

The age composition of southern bluefin tuna (SBT) caught by Australian purse seine fisheries and used for farming was estimated based on size data from the harvest in 2010.　We carried out the age decomposition for monthly length frequency based on age slicing method with five assumption cases in different length cut points.　In the case of which assumed growth rate during farmed period using estimated values from actual tagging data, age compositions were 3% for age 2, 28% for age 3, 48% for age 4 and 18% for age5, with a total amount of purse seine catch of 5663 tons.　These figures are quite different with those reported (age composition of 25% for age 2, 60% for age 3, 14% for age 4 and 1% for age5) and as 1.44 times high as total catch (3931 ton).　The age composition estimated in this analysis should replace the current adjustments made in age composition for historical data and be used for stock assessment by the Extended Scientific Committee.　Urgent examination of the bias in the 40 fish sampling, which is used by Australia to calculate its reported purse seine catch, and improvement of method to obtain the age composition and amount caught by the Australian surface fishery is required.

緒言　Introduction

年齢別漁獲尾数、漁獲重量は CCSBT における資源評価において重要な情報である。これまで、2007 年、2008 年、2009 年畜養魚について解析し、全ての年でサイズ測定に大きなバイアスがあることが示唆されてきた（CCSBT-ESC/0909/29、CCSBT-ESC/0909/30、CCSBT-ESC/1009/21）。本研究では豪州養殖魚の 2010 年の年齢別漁獲尾数や重量を、収穫時のサイズ測定データに基づいて推定する。

Accurate data on catch-at-age by number as well as the total catch in weight are essential for stock assessment and management of southern bluefin tuna (SBT) in the CCSBT. Age compositions have been estimated for Australian farmed fish harvested in 2007, 2008 and 2009 and suggested existence substantial bias in size measurement (CCSBT/ESC/0909/29, CCSBT/ESC/0909/30, CCSBT-ESC/1009/21). In this document we present estimates of the catch-at-age and the total catch in 2010 of the Australian surface fishery for SBT farming based on size data at harvest.

材料と方法　Materials and Methods

2007 年 5 月以降に日本に輸入する畜養ミナミマグロについては、個体ごとの体長及び体重を報告するよう、農林水産省が輸入業者に対して指示をした。2011 年 5 月までに収集、入力されたデータを解析に用いた。Table 1 に月別収集個体数を示す。若干の体長、体重値のエラーレコードを除いた 90,539 個体を解析対象とした。

体長（尾叉長 cm）と体重（鰓と内臓を除いた製品重量 kg）の両方が得られたデータ(N=72,953)を用いて、体重体長換算式のパラメータ値を計算した。収穫月別に有意に異なった（F=2031、p<0.01）ことから、式(1)の換算のパラメータ値は月別に求めた（Table 2、Fig.1）。

$$FL = a_i \times PW^{b_i}, \qquad (1)$$

ここで、FL は尾叉長(cm)、PW は体重(kg)、i は収穫月、a_i、b_i は月別の定数。

求めた体重体長換算式を用いて、収穫時サイズデータの体重データを体長に変換し、出荷状態（生鮮、冷凍）別、月別に 1cm 階級ごとの個体数を集計した。

この体長組成に対して、以前の年の解析と同様に 1-4 個の正規分布を当てはめて年齢組成を推定した（CCSBT-ESC/1009/21）。また、スライシング法による年齢分解も年齢・月別体長カットポイントを変えた以下の 5 つのケースで行った（Table 3）。

ケース 1：野生魚と同じ成長で、各月の成長は一定を仮定。野生魚の年齢別体長は、CCSBT で使用しているものを使用。(Fig.2a)

ケース 2：野生魚と同じ成長で、1 年間の成長には季節変化を仮定。6 月中旬から 9 月中旬までは

成長停止。(Fig.2b)

ケース 3 : CCSBT-ESC/0909/31 で CCSBT 通常標識再捕データから求めた、畜養ミナミマグロの体重増加率を使用。2 歳、3 歳、4 歳の各年齢の平均推定値を 6 ヶ月間のものとして使用。1 歳の増加率は 2 歳、3 歳、4 歳の値から式(2)で求めた。5 歳以上は 4 歳の増加率と同じと仮定した。(Fig.2c)

$$
\begin{aligned}
R_1 &= R_2 \times (R_2 - R_3)/(R_3 - R_4) \\
R_2 &= 1.818 \\
R_3 &= 1.544 \\
R_4 &= 1.448 \\
R_{>4} &= R_4
\end{aligned}
\qquad (2)
$$

ここで、R_j : j 歳魚の六ヶ月間の体重増加率。6 歳以上は 6 歳に含む。

収穫時サイズデータにおいて最も生け込み時期頻度が高かったのが 2 月であったことから、2 月 1 日を野生魚の漁獲日とした。2 月 1 日の各年齢の下限体長はケース 1 に従って直線補完で求めた（式 3）。各年齢の下限体長は、野生魚の体長体重関係式で 2 月 1 日時点の体重に変換した（式 4）。体重増加率を掛けて 8 月 1 日時点の体重を求めた（式 5）。製品重量に変換した後、畜養魚について求めた 8 月の体重体長関係式（Table 2）で体長に変換した（式 6）。野生魚の体長体重関係は Robins(1963)の関係式を用いた。原魚重量・製品重量の換算係数は、1.21 を用いた。

$$LL_{Feb,j} = LL_{Jan,j} + \left(LL_{Jan,j+1} - LL_{Jan,j}\right)/12, \qquad (3)$$

$$LW_{Feb,j} = a_{wild} \times \left(LL_{Feb,j}\right)^{b_{wild}}, \qquad (4)$$

$$LW_{Aug,j} = LW_{Feb,j} \times R_j \qquad (5)$$

$$LL_{Aug,j} = a_8 \times \left(LW_{Aug,j} / WP\right)^{b_8} \qquad (6)$$

ここで、$LL_{Jan,j}$ は CCSBT で使用される 1 月 1 日時点の j 歳の下限体長、$LL_{Feb,j}$ は 2 月 1 日時点の j 歳の下限体長、$LW_{Feb,j}$ は 2 月 1 日時点の j 歳の下限体重、$LW_{Aug,j}$ は 8 月 1 日時点の j 歳の下限体重、$LL_{Aug,j}$ は 8 月 1 日時点の j 歳の下限体長、a_{wild}、b_{wild} は野生魚の体長体重換算式の定数、a_8、b_8 は式(1)で求めた畜養魚の 8 月の体重体長換算式の定数、WP は原魚重量と製品重量の換算係数。

ケース 4: ケース 3 と同様だが、各年齢の体重増加率には推定値の平均値+1 標準偏差を用いた（Fig. 2d）。

ケース 5 : ケース 3 と同様だが、推定されたまき網漁獲時の重量が、豪州報告値と同じになるよ

うに、調整した。体重増加推定値の平均値+標準偏差×X の X を調整した(Fig. 2e)。

続いて、日本に輸入された魚全体に対する推定に拡張した。輸入統計（日本が CCSBT に提出）の月別製品重量から、日本に輸入された収穫月別尾数を計算した（式 7)。生鮮魚は収穫月に輸入されたとした。冷凍魚は、収穫時サイズデータにおける収穫月と報告月との関係を集計した結果から、7 月の輸入は 6 月の収穫物、8 月の全てと 9 月の半分の輸入は 7 月の収穫物、9 月の半分と 10 月の輸入は 8 月の収穫物とみなした。

$$n_{i,k} = W_{i,k} \times \frac{1}{A_{i,k}} \qquad (7)$$

ここで、

$n_{i,k}$：収穫 i 月、生鮮冷凍 k の輸入尾数、

$W_{i,k}$： i 月に収穫された生鮮冷凍 k の輸入重量(kg)、

$A_{i,k}$：ハーベストデータから求めた収穫 i 月、生鮮冷凍 k の平均体重 (kg)。

日本に輸入された魚全体の年齢別漁獲尾数に、まき網で漁獲した時点（2 月 1 日）の野生魚の平均体重を掛けて漁獲重量を求めた。

$$w_{import} = \sum_{j=2}^{6} n_j \times a_{wild} \times FL_{j,2}^{b_{wild}} \qquad (8)$$

ここで、

n_j：日本に輸入された j 歳魚の尾数、

w_{import}：日本に輸入された魚の原魚重量合計、

$FL_{j,i}$：野生魚の漁獲 i 月、j 歳の平均体長(cm)、

a_{wild}、b_{wild}：尾叉長－原魚重量の関係式　$原魚重量 = a_{\mathrm{wild}} \times 尾叉長^{b_{wild}}$　の係数。

次いで、年齢別漁獲尾数および漁獲重量を豪州まき網による総漁獲尾数に引き伸ばした(式 9、式 10)。

$$N_j = n_j \times \frac{N_{all}}{\sum_{j=2}^{6} n_j} \qquad (9)$$

$$PSW = W_{import} \times \frac{N_{all}}{\sum_{j=2}^{6} n_j} \div 1000 \qquad (10)$$

ここで、

N_j：豪州まき網が漁獲した j 歳魚の尾数、

PSW：豪州まき網が漁獲したミナミマグロの重量（トン）、

N_{all}： 2010 年漁期に豪州がまき網で漁獲した合計尾数。212,204 尾。

比較対照とすべき豪州まき網の年齢別漁獲尾数組成は、豪州が報告した 2010 年漁期（AU_SurfaceCatchAtAge_0910.xls）を用いた。

分析には R（Version 2.8.1 for Windows）を用いた。

The Ministry of Agriculture, Forestry and Fisheries of Japan requested importers to submit data on the length and weight at harvest of farmed SBT which is imported to Japan after May 2007. The data on farmed SBT imported to Japan in 2010, which were collected up to May 2011 were used for the analysis. A total of 90,539 individual records were analyzed after removing several anomalous records among the data collected (Table 1).

Using data of 72,53 individuals for which both length and weight information was available, parameters for the weight-length relationship were estimated by applying the least squares method for logarithmic scaled length (fork length in cm) and weight (gilled and gutted in kg) as follows:

$$FL = a_i \times PW^{b_i}, \qquad \text{(Eq-1)}$$

where *FL* is the fork length in cm, *PW* is the processed weight (gilled and gutted with tail) in kg, and a_i and b_i are month-specific parameters to be estimated. Because the fatness index (PW/FL^3) differed significantly by month ($F = 2031$, $p < 0.01$), the weight-length relationships were estimated by month (Table 2, Fig. 1).

Weight values were converted to length by using the derived monthly weight-length relationships. Next, length frequencies by one centimeter bin by month and by classes of markets/fates (fresh or frozen fish) were produced.

For the length frequency, from one to four normal distributions were fitted to decompose it as the same method used in previous year (CCSBT-ESC/1009/21). In addition, age decomposition by slicing method was carried out in five cases of different length-at-age cut points (Table 3).

Case 1: Growth in length is same as that of wild fish and assuming constant growth among months. Lower length cut points used were those used in CCSBT (Fig. 2a).

Case 2: Same as Case 1 but assuming variable growth among months. The growth stopped from mid-June to mid-September (Fig. 2b).

Case 3: Growth rates of farmed SBT in body weight by age was that estimated in CCSBT-ESC/0909/31 which analyzed CCSBT conventional tagging data. Mean estimated values for age2, age3 and age4 were used as growth rate in six months. Growth rate of age1 was calculated as Eq-2 as follows. Growth rates of age 5 and more were assumed to be same as that of age 4 (Fig. 2c).

$$R_1 = R_2 \times (R_2 - R_3)/(R_3 - R_4)$$
$$R_2 = 1.818$$
$$R_3 = 1.544 \qquad \text{(Eq-3)}$$
$$R_4 = 1.448$$
$$R_{>4} = R_4$$

where, R_j: Growth rate of weight in six months for fish age j. Age six include six and more.

As transfer from towing pens to farming cages was most frequent in February for the individual size data used in this analysis, 1st February was used as the time of fish caught. Lower cut point length by age on 1st February was calculated as in Case 1 (Eq-3). It was converted to weight on 1st February by using length-weight relationship for wild fish (Eq-4). It was converted to weight on 1st August by multiply with growth rate by age (Eq-5). After convert to processed weight, it was converted to lower cut point length on 1st August by using the weight-length relationship derived from farmed fish harvested in August (Table 2) (Eq-6). The length-weight relationship for wild fish used was Robins (1963). The conversion factor between processed weight and whole weight used was 1.21.

$$LL_{Feb,j} = LL_{Jan,j} + (LL_{Jan,j+1} - LL_{Jan,j})/12 , \qquad \text{(Eq-3)}$$

$$LW_{Feb,j} = a_{wild} \times (LL_{Feb,j})^{b_{wild}} , \qquad \text{(Eq-4)}$$

$$LW_{Aug,j} = LW_{Feb,j} \times R_j \qquad \text{(Eq-5)}$$

$$LL_{Aug,j} = a_8 \times (LW_{Aug,j} / WP)^{b_8} \qquad \text{(Eq-6)}$$

where,

$LL_{Jan,j}$: lower cut point length of age j fish on 1st January used in CCSBT,

$LL_{Feb,j}$: lower cut point length of age j fish on 1st February,

$LW_{Feb,j}$: lower cut point weight of age j fish on 1st February,

$LW_{Aug,j}$: lower cut point weight of age j fish on 1st August,

$LL_{Aug,j}$: lower cut point length of age j fish on 1st August,

a_{wild}, b_{wild} : Parameters of length-weight relationship of wild fish *Whole weight*= a_{wild} x *Forlk length*^{bwild},

a_8 ,b_8 : Parameters of length-weight relationship of farmed fish in August *Whole weight*= a_8 x *Forlk* *length* ^{b8}, and

WP: Conversion factor between processed weight and whole weight.

Case 4: Same as Case 3 but using growth rate by age of mean + 1 standard deviation, instead of mean in Case 3 (Fig. 2d).

Case 5: Same as Case 3 but using growth rate by age of mean + *X* * standard deviation, instead of mean in Case 3. *X* was adjusted to resulted in the same total amount of catch in weight as reported from Australia (Fig. 2e).

The estimation was then expanded from samples for which the size was measured to all of the farmed SBT imported to Japan. The total number of SBT imported to Japan by month was calculated from the monthly total SBT product weight in the Japan Import Statistics which have been submitted to CCSBT (Eq-7). Fresh fish were assumed to be imported in the same month that they were harvested. For frozen fish, information of harvest month and imported month were analyzed using the size data at harvest, and it was inferred that SBT imported in July were harvested in June, SBT imported in August and half of September were harvested in July, and SBT imported half of September and in October were harvested in August.

$$n_{i,k} = W_{i,k} \times \frac{1}{A_{i,k}} \qquad \text{(Eq-7)}$$

where

$n_{i,k}$: Number of SBT imported in harvest month *i* of fresh/frozen state *k*,

$W_{j,k}$: Weight of SBT imported in month *j* of fresh/frozen state *k* (kg),

$A_{i,k}$: Average body processed weight of SBT in harvest month *i* of fresh/frozen state *k* based on harvest data (kg),

The calculated length on 1st February was converted to body weight using the length-weight relationship for wild fish in southern Australia (Robins 1963), then obtained total weight of SBT imported in Japan.

$$w_{import} = \sum_{j=2}^{6} n_j \times a_{wild} \times FL_{j,2}^{b_{wild}} \qquad \text{(Eq-8)}$$

where

n_j: Number of SBT in age *j* imported to Japan,

w_{import}: Total weight of whole SBT imported to Japan,

$FL_{j,i}$: Length at month of catch *i* of age *j* SBT (cm),

a_{wild}, b_{wild}: Parameters of length-weight relationship of *Whole weight*= a_{wild} *x Forlk length* ^{bwild}, In the next step, the catch-at-age and catch weight were scaled upwards to the total number of SBT caught by Australian purse seiners (Eq-9 and Eq-10).

$$N_j = n_j \times \frac{N_{all}}{\sum_{j=2}^{6} n_j} \qquad \text{(Eq-9)}$$

$$PSW = W_{import} \times \frac{N_{all}}{\sum_{j=2}^{6} n_j} \div 1000 \qquad \text{(Eq-10)}$$

where

N_j: Total number of age j SBT caught by Australian purse seine,

PSW: Weight of Australian purse seine catch (kg),

N_{all}: Total number of SBT caught by Australia in the 2010 fishing season, from December 2009 and November 2010 (212,204 individuals). This includes SBT not imported to Japan, i.e. died during transferred and farming, not yet harvested or exported to other countries, such as U.S.A and EU.

Catch-at-age of Australian purse seine in 2010 reported from Australia were derived from AU_SurfaceCatchAtAge_0910.xls.

The computer package R, version 2.8.1 for Windows, was used for the calculations conducted.

結果と考察　Results and Discussion

パッキングリストにおけるサイズデータは 2 月から 10 月まで収集された。日本の輸入個体数に対し、生鮮魚の 65%、冷凍魚の 45%、全体の 50%をカバーした。

生鮮用、冷凍用で区分した全ての体長頻度は、個体数の少なかった 2 月を除き、1 個から 3 個の正規分布に分解された（Fig.3）。しかし求めた混合正規分布は、体長頻度に良くフィットしているものの、各正規分布は年齢に対応しているとは思われなかった。特に、120cmFL 以上には 4 歳魚と 5 歳魚が含まれているようである。大型魚・高齢魚になると、個体間の成長のばらつきに対する年齢間の体長差が小さくなることから、年齢に対応した体長グループの分離が困難となる。このため 2009 年とは異なって 5 歳と思われる大型魚が含まれるようになった 2010 年では、混合正規分布による年齢組成解析は不適当であった。

スライシング法では、ケース 1、ケース 2、ケース 3 では、同様の年齢組成（Age2 約 3%、Age3 約 28%、Age4 約 46%、Age5 約 20%）が得られた（Table 4, Fig. 4）。これらは豪州が報告している年齢組成（Age2 25%、Age3 60%、Age4 14%、Age5 1%）と大きく異なっている。体重増加率の高いケース 4、ケース 5 では、低年齢化した。ケース 5 では、豪州が報告した年齢組成と近い年齢組成が得られた。

漁獲重量は、2010 年漁期の豪州が報告する 3,931 トンに対して、本推定のケース 1、ケース 2、ケース 3 では 5,663-5,834 トンと異なった（Table 5, Fig. 5）。

スライシング方で仮定した 5 つのケースのどれが正しいかは明らかでない。結果は体重増加率の仮定に強く依存する。現時点では、実際の標識再捕データから推定した畜養中の体重増加率（CCSBT-ESC/1009/21）を用いたケース 3 が最も妥当と考えられる。ケース 3 の成長の仮定は、野生魚の体長成長と類似していること（Fig.1c）から、ケース 1 、ケース 2 とも類似した結果を導いた。畜養魚の体長成長は野生魚と同様であることは、通常標識データからミナミマグロの成長を解析した論文（CCSBT-ESC/1107/09）でも仮定されており、その解析結果からも支持される。また 2007 年、2008 年、2009 年の蓄養魚の解析では体長モードが明瞭に認められ、それらは野生魚の成長の範囲内に収まっていた（CCSBT/ESC/0909/29, CCSBT/ESC/0909/30, CCSBT-ESC/1009/21）。

豪州が報告した年齢組成及び漁獲量に対応するのはケース 5 である。この仮定での成長は、体長が著しく増加し、3 歳魚では 1 年間で野生魚の 2 年分の増加を遂げ、4 歳時点で 5 歳の体長に到達する。このような著しい成長が起きるとは考え難いが、実際に起きているのであればタグシーディング等の既存のデータ（CCSBT-ESC/0909/18）を解析することで、この顕著な性質は容易に検出されるだろう。

これらの年齢組成、漁獲量の不確実性は資源推定に大きなバイアスをもたらすものである。漁獲量及びサイズ組成を報告するために豪州が用いている 40 尾サンプリングのバイアスに関する早急な検証と、豪州巻き網漁業による漁獲量及びサイズ組成を把握する方法の改善が必要である。有効な解決策として、ステレオビデオの導入促進、事務局が所有する CDS データ、特にタギングデータの解析などが挙げられる。

The size data were collected between February and October 2010 and covered 50% (65% of fresh, 45% of frozen) of SBT imported to Japan from Australia.

In the method of mixed normal distributions, length frequency distributions by month and fate (fresh / frozen) were decomposed from one to three normal distributions in all months but February which had small number of individuals (Fig. 3). Although the mixed normal distribution fitted well to the length frequency distribution, it was not appeared that each estimated normal distribution corresponded with age. Especially, fish > 120 cm were seemed to include both age4 and age5. Usually, age decomposition from size frequency become difficult for large and older fish because growth increment between successive age become smaller compare to variance of growth among individuals along with age increased. Therefore, this method was inappropriate for farmed fish in 2010 when large size SBT probably age 5 were included.

In the age slicing methods, similar results in terms of age composition were obtained for Case 1, Case 2 and Case 3 (Age2 ca. 3%, Age3 ca. 28%, Age4 ca. 46%, Age5 ca. 20%) (Table 4, Fig. 4).

There are quite different from that Australia reported (Age2 25%, Age3 60%, Age4 14% and Age5 1%). In Case 4 and Case 5 which assumed higher growth rates, younger age had larger proportion. In Case 5, it was obtained similar age composition reported from Australia.

Estimated total catch in weight of 2010 fishing season was different between that Australian reported as 3,931 tons and those estimated in Case 1, Case 2 and Case 3 as 5,663-5,834 tons (Table 5, Fig. 5).

It is not certain which of the five cases are most appropriate. The results heavily depend on growth rate in weight during farming. Based on the available information, Case 3 is considered to be most plausible. Because of that growth rate used in Case 3 was based on actual data from conventional tagging (CCSBT-ESC/1009/21). Growth rate in length of Case 3 was similar to that of wild fish (Fig 1c) so that its result was similar to Case 1 and Case 2 which used wild fish growth rate in length.

Similar growth rate in length for both wild and farmed fish was assumed in the analysis of growth of wild SBT stock based on the conventional tagging data and was supported in the result of the document (CCSBT-ESC/1107/09). In addition, distinctive modes which seemed to be corresponding to age were observed in the length frequency of farmed fish in previous years (2007, 2008 and 2009) and those modes were within the range of one year growth in length (CCSBT/ESC/0909/29, CCSBT/ESC/0909/30, CCSBT-ESC/1009/21).

Case 5 is corresponding to the total catch in weight which Australia reported. Its assumed growth rates were quite high. For example, age 3 fish reaches to the length of age 5 fish in wild after one year. It is not likely to occur. However, if it were true, such a remarkably high growth rate would be found distinctively in the existed information, such as tag seeding data (CCSBT-ESC/0909/18).

Uncertainties concerning age composition and the total amount of catch give rise to difficulties in the stock assessment of SBT within the CCSBT. Urgent examination of bias in the 40 fish sampling, which is used by Australia to prepare its reported catch and size compositions, and improvement of method to obtain age compositions and the amount caught by the Australian surface fishery are required. Possible improvement methods would include further introduction of stereo video, analysis of CDS data submitted to the CCSBT Secretariat, especially catch tagging data.

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Table 1. Number of size data collected by month for Australian farmed SBT harvested and imported to Japan in 2010
2010 年に収穫され日本に輸入された畜養ミナミマグロの月別サイズデータ数

Month of harvest	N_collected and anomalous data removed	N_Length & Weight obtained
Feb	85	85
Mar	659	361
Apr	2,807	2,495
May	4,315	4,270
Jun	4,495	4,486
Jul	46,084	33,778
Aug	25,605	20,992
Sep	5,039	5,037
Oct	1,450	1,449
Total	90,539	72,953

Table 2. Parameters for conversion from processed weight to fork length by month for Australian farmed SBT harvested in 2010
2010 年に収穫された畜養ミナミマグロの月別の体重体長関係パラメータ値

Month	N	a	b
2	85	44.0612	0.288
3	361	36.5048	0.339
4	2,495	39.0918	0.320
5	4,270	39.5786	0.315
6	4,486	37.4933	0.329
7	33,778	38.2494	0.318
8	20,992	38.4053	0.320
9	5,037	38.4223	0.327
10	1,449	37.3188	0.335

Table 3. Growth rate of weight for each age in six months by different cases
ケースごとに仮定した六ヶ月間の年齢別の体重増加率

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	N_Age6+	Explanation
Case3	2.725	1.818	1.544	1.448	1.448	1.448	Rate=mean
Case4	3.135	2.228	1.824	1.748	1.748	1.748	Rate=mean+1SD
Case5	3.636	2.729	2.166	2.115	2.115	2.115	Rate was adjusted to reported catch

Table 4. Estimated age composition for Australian farmed SBT harvested in 2010 in different cases assumed different length-at-age cut points.
2010 年に収穫された畜養ミナミマグロの推定年齢組成

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	N_Age6+	Explanation
Case1	0.0%	2.5%	26.4%	45.9%	21.0%	4.3%	Wild fish, linear
Case2	0.0%	2.6%	27.8%	45.8%	19.8%	3.9%	Wild fish, seasonal
Case3	0.0%	3.3%	28.2%	48.0%	17.7%	2.8%	Rate=mean
Case4	0.2%	10.3%	47.5%	36.2%	5.2%	0.6%	Rate=mean+1SD
Case5	0.9%	26.3%	55.8%	15.3%	1.6%	0.1%	Rate was adjusted to reported catch
Aust Rep	0.1%	24.8%	60.0%	13.8%	1.3%	0.0%	Australia reported for 2010 fishing seasc

Table 5. Estimated total weight of Australian purse seine catch used for farming in 2010
豪州まき網による 2010 年全漁獲量の推定値

	推定漁獲時重量（日本輸入魚）	尾数比（豪州報告／日本輸入魚）	推定漁獲時合計重量	豪州報告の漁獲時重量
	Estimated total catch (Imported in Japan)	Ratio of SBT number (Australia report / Imported in Japan)	Estimated total catch by purse seine in ton	Reported total catch by purse seine in ton
Case1	4,954	1.178	5,834	3,931
Case2	4,899		5,770	
Case3	4,809		5,663	
Case4	4,042		4,760	
Case5	3,338		3,931	

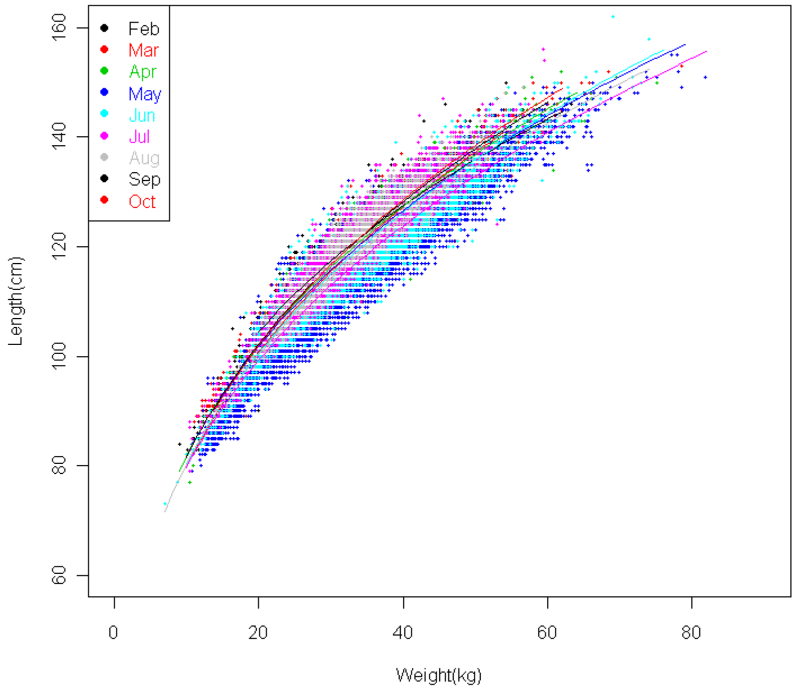

Fig. 1. Monthly weight (gilled and gutted in kg) – length (fork length in cm) relationship for Australian farmed SBT harvested in 2010

2010 年に収穫された豪州畜養ミナミマグロにおける月別の体重（鰓、内臓抜き kg）と体長（尾叉長 cm）の関係。N=72,953.

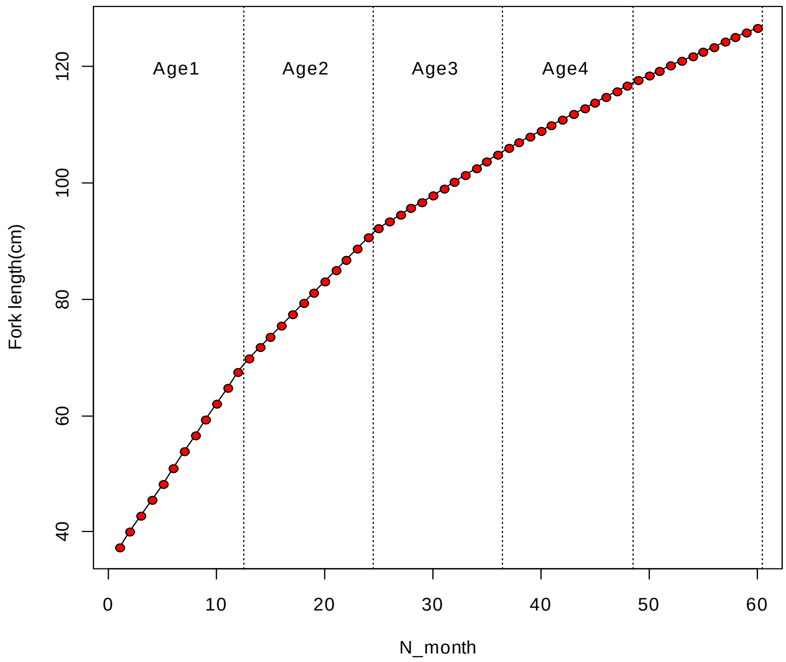

Fig. 2a. Lower cut point of fork length at age and month for Case 1.

仮定した成長による月別下限体長（ケース 1）。

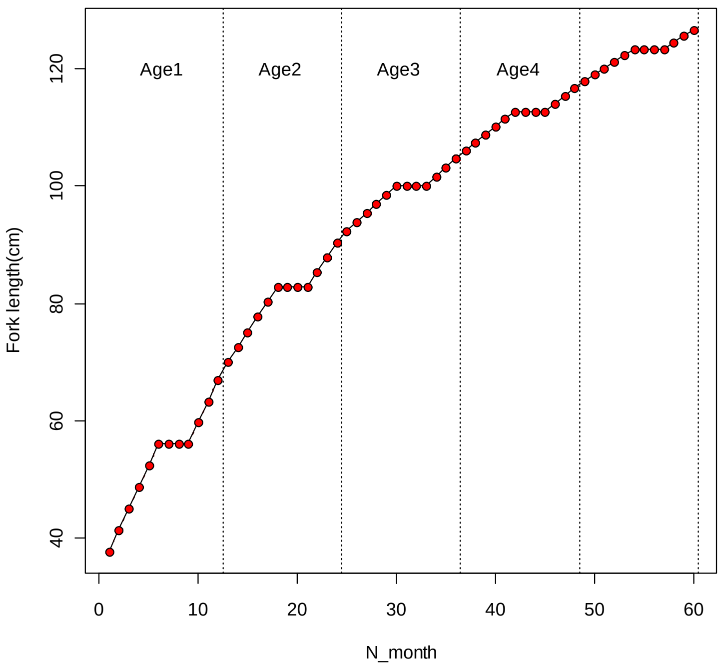

Fig. 2b. Lower cut point of fork length at age and month for Case 2.
仮定した成長による月別下限体長（ケース 2）。

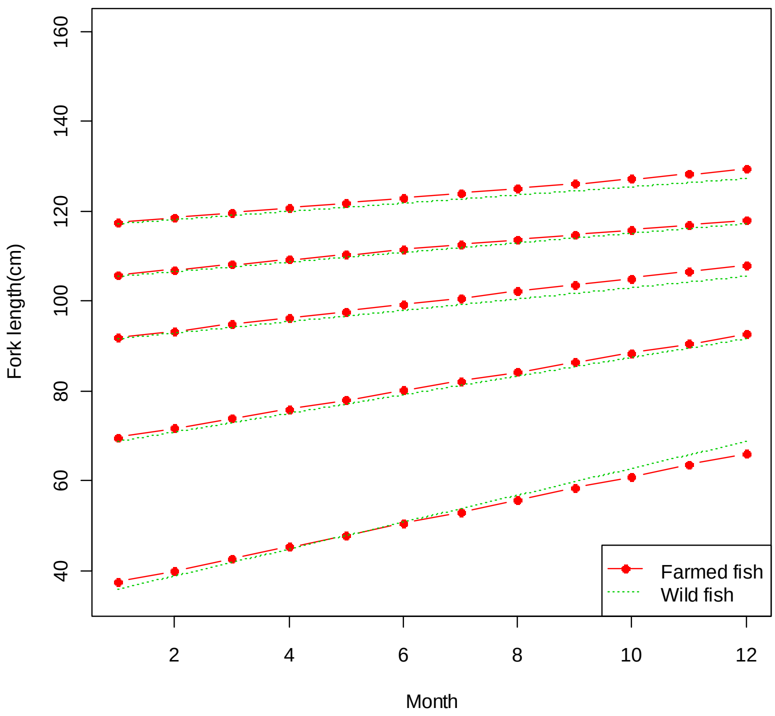

Fig. 2c. Lower cut point of fork length at age and month from age1 to age 5 for Case 3.
仮定した成長による 1-5 歳魚の月別下限体長（ケース 3）。

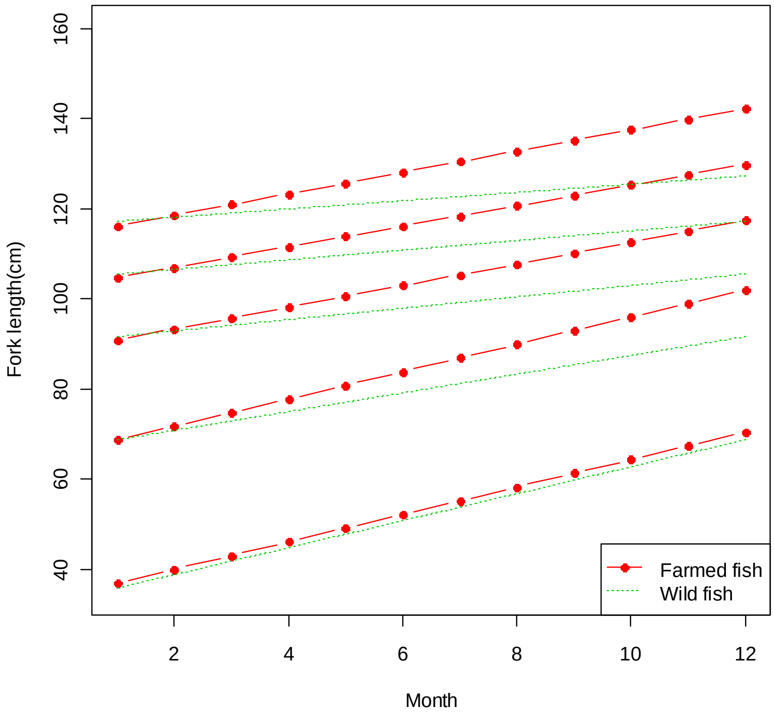

Fig. 2d. Lower cut point of fork length at age and month from age1 to age 5 for Case 4.
仮定した成長によるる 1-5 歳魚の月別下限体長（ケース 4）。

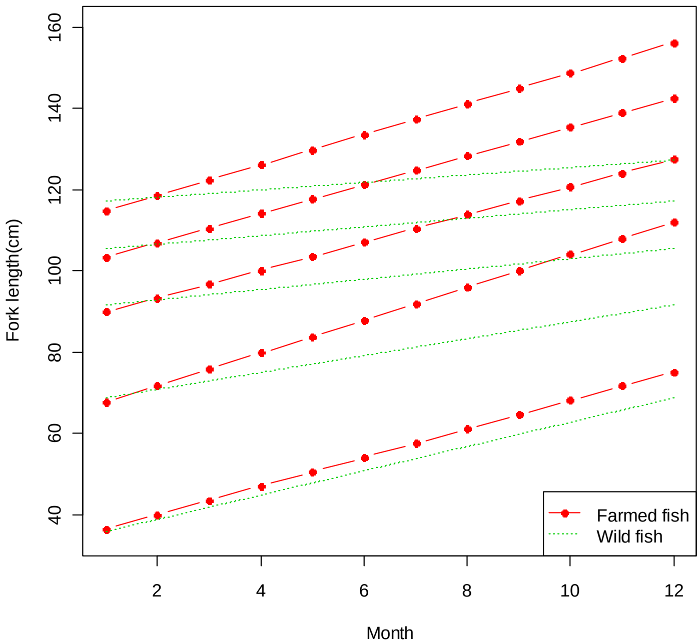

Fig. 2e. Lower cut point of fork length at age and month from age1 to age 5 for Case 5.
仮定した成長によるる 1-5 歳魚の月別下限体長（ケース 5）。

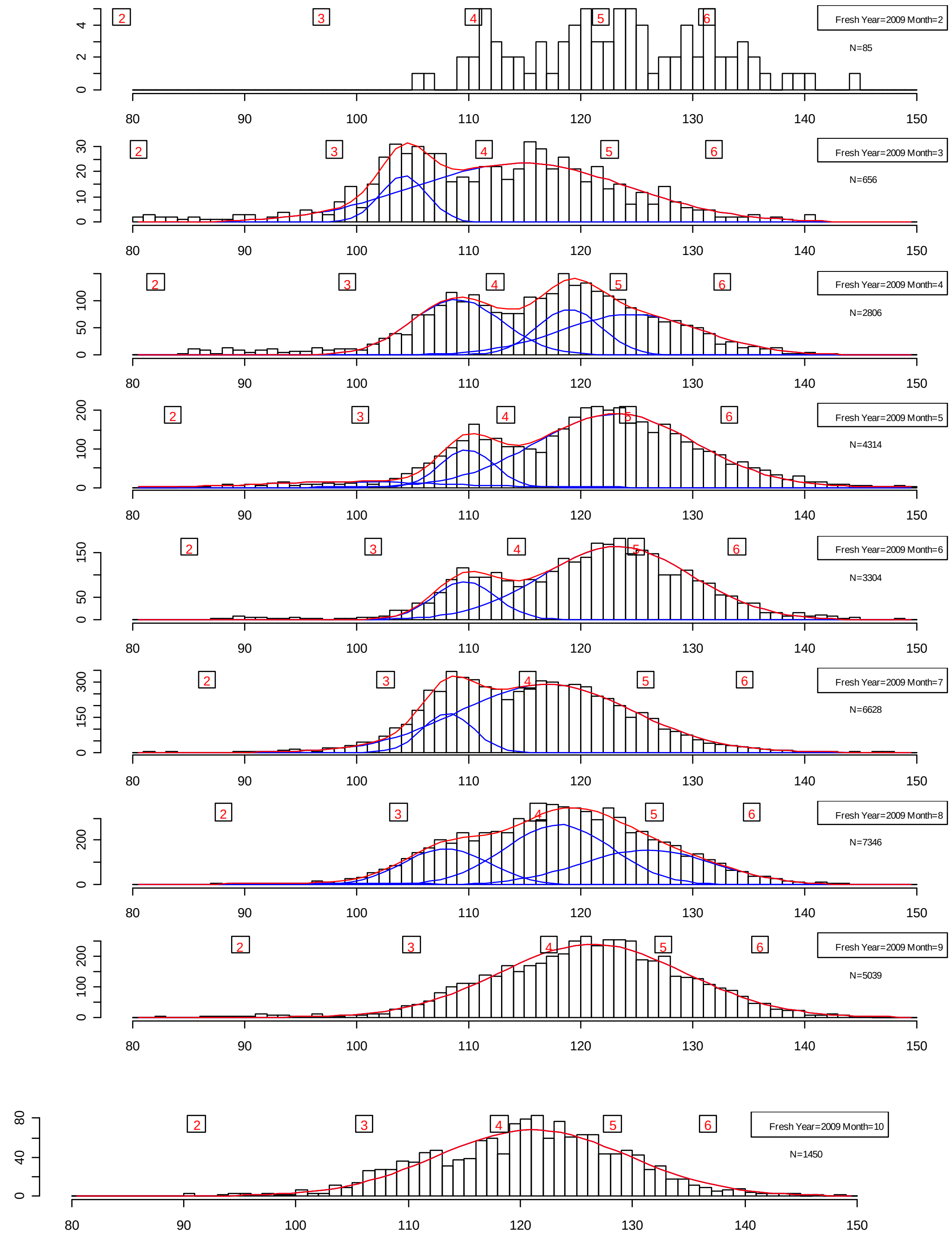

Fig. 3a. Monthly length frequency and estimated probability density functions of the normal mixture distribution of farmed SBT at harvest (for Fresh SBT). Mean monthly length at age of wild fish is shown in the squares.

畜養ミナミマグロ（生鮮出荷魚）の収穫時の体長頻度（棒）と推定した混合正規分布（線）。四角内は野生魚の年齢月別平均体長。

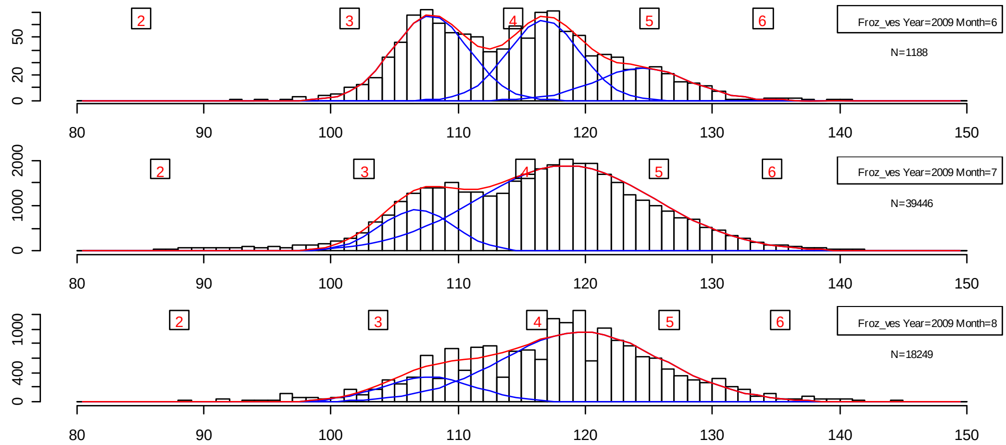

Fig. 3b. (Contd.) (For frozen SBT)
（つづき）（冷凍）

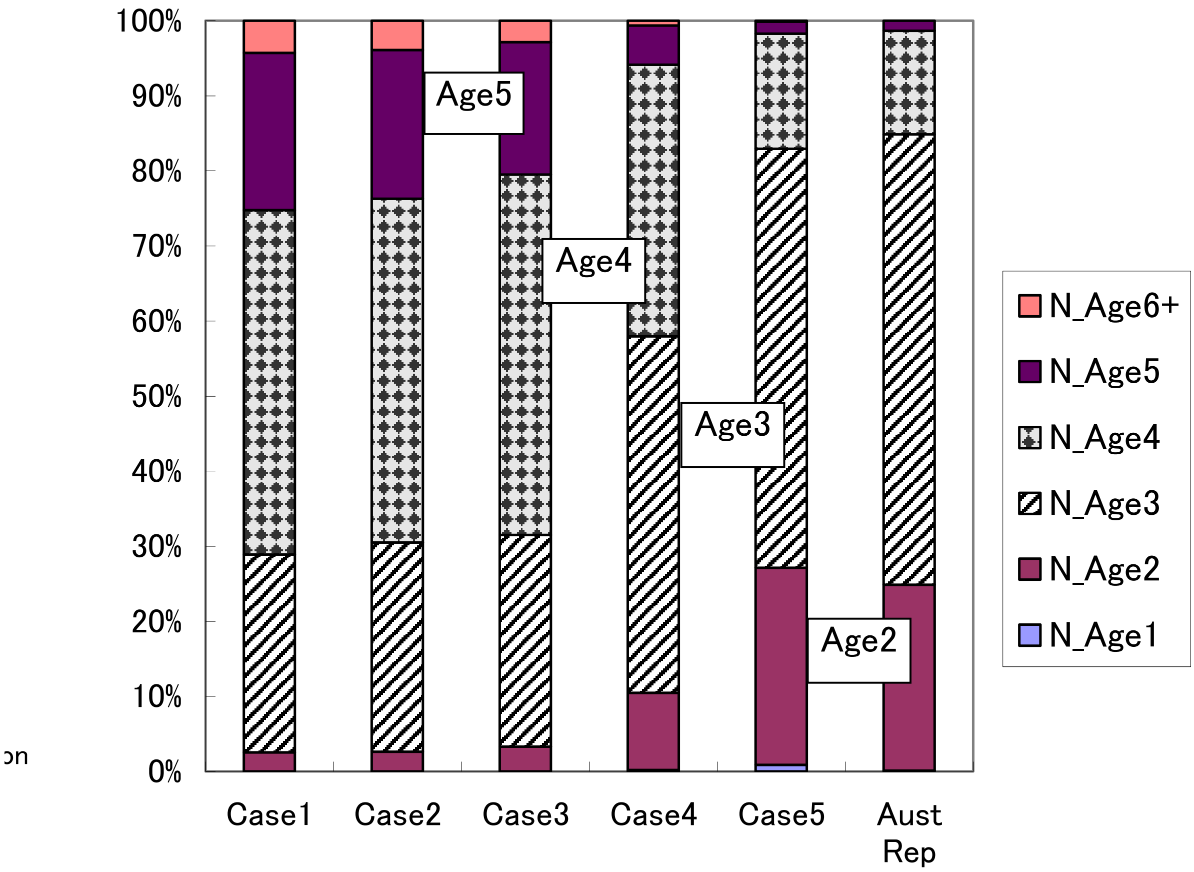

Fig. 4. Comparison of age compositions (by number) estimated in the present study with those reported by Australia to the CCSBT.
本研究の推定結果と豪州政府が報告した年齢組成の比較.

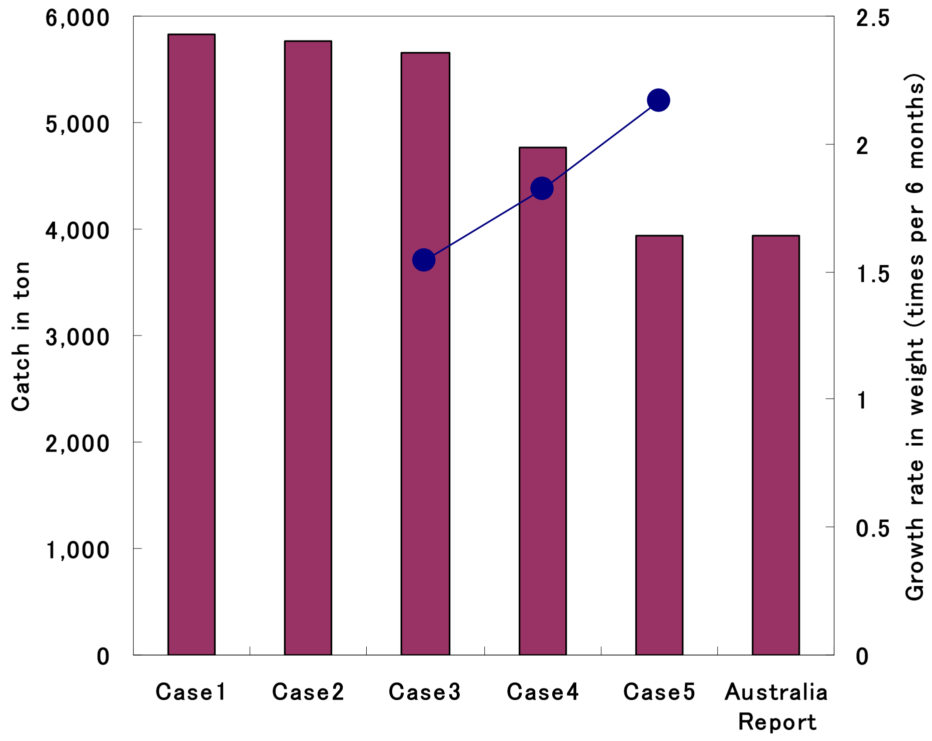

Fig. 5. Estimated Australian purse seine catch in 2010 (bar) and assumed growth rate (plot and line).

豪州まき網の 2010 年推定漁獲量（棒グラフ）及び仮定した成長率（プロット及びライン）。