2007 年畜養原魚の年齢組成の再解析

Follow-up analysis on age composition of southern bluefin tuna used for farming in 2007

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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、2007 年の出荷時のサイズデータから年齢組成を推定した。生鮮魚、冷凍運搬船、冷凍コンテナに区分して解析し、それぞれでサイズが異なる可能性にも対応した。月別体長組成に正規分布を当てはめた結果、2 歳魚 6%、3 歳魚 54%、4 歳魚 38%、5 歳魚 3%と推定された。2007 年漁期のまき網による総漁獲重量は 7,891 トンと推定された。これらは豪州政府からの報告値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

Age composition of southern bluefin tuna (SBT) caught by used Australian purse seine fisheries for farming was estimated based on size data at harvest in 2007. Fresh and frozen SBT were analyzed separately because of the possibility of difference in size between them. The analysis of frozen SBT was disaggregated further by dividing into two classes of markets/fates: frozen fish from freezer vessels and frozen fish from freezer containers. We carried out the age decomposition based on the length frequencies using the framework of a mixture of normal distributions and analysing each month independently. Age compositions were estimated as 6% for age 2, 54% for age 3, 38% for age 4 and 3% for age 5. The total catch of the Australian purse seine fisheries in the 2007 fishing season was estimated as 7,891 tons. This figure (7891 ton) is 48% larger than Australian reported purse seine catch (5342 ton). The age-composition estimated in this analysis should replace the current adjustments made in age composition for historical data and be used in the stock assessment by the Extended Scientific Committee. Urgent examination of the bias in the 40 fish sampling, which is used by Australia to prepare its reported PS catch,

and improvement of the 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。本研究は豪州養殖魚における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。本解析結果は 2008 年 ESC でも提示した（CCSBT-ESC/0809/39）が、データがさらに追加されたこと、生鮮と冷凍運搬船、冷凍コンテナを区分する必要性が指摘されたことから、再度解析を実施した。

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. In this document, we present estimates of the catch-at-age and the total catch of Australian surface fishery for SBT farming based on size data at harvest. While we have previously presented results of analysis of this issue at the ESC 13th in 2008 (Itoh and Sakamoto, 2008: CCSBT-ESC/0809/39), we have carried out this follow-up analysis because additional individual size data on farmed SBT are now available, and also because concern was expressed at the ESC 13th meeting that reliable results might require separate analyses for different classes of markets/fates of SBT, namely fresh fish, frozen fish from freezer vessels and frozen fish from freezer containers.

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。2007 年に輸入された畜養ミナミマグロで、2009 年 3 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 187,632 個体を解析対象とした。昨年の解析時に比較して個体数が 11%増加した。

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=76,288)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=971、$p<0.01$）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、冷凍運搬船、冷凍コンテナ）別、月別に 1cm 階級ごとにまとめた。この体長組成を式(2)によって 2-4 個の正規分布に分解した。適当な初期値について残差平方和が最小となるよう Gauss-Newton algorithm による非線形最小二乗法でパラメータベクトル Θ（μ_2, μ_3, μ_4, μ_5, σ_2,

σ_3, σ_4, σ_5, k_2, k_3, k_4）の最大 11 パラメータの解を求めた。なお、$\sum_{i=2}^{n} k_i = 1$により、最高齢の k_i は計算できる（e.g. k_4=1-k_2 -k_3)ので、推定不要である。正規分布の数は、解が得られ、得られた平均値、標準偏差が妥当（e.g. $\mu_2<\mu_3<\mu_4$, $\sigma_4<6$）である最大のものを選択した。

$$SSQ = \sum_{x=\min L}^{\max L} \left(H_x - \sum_{\alpha=2}^{n} k_\alpha \frac{1}{\sqrt{2\pi\sigma_\alpha^2}} \exp\left(-\frac{(x-\mu_\alpha)^2}{2\sigma_\alpha^2} \right) \right)^2 \qquad (2)$$

ここで、

x：1cm ごとの体長階級

$minL$：最小体長階級

$maxL$：最大体長階級

H_x：x cm の体長頻度

n：年齢区分数（2,3,4 のいずれか）

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。日本に輸入された収穫月別尾数を、輸入統計（日本が CCSBT に提出）の月別製品重量から計算した。ただし、輸入統計における月は収穫月とは異なる可能性があるので、生鮮魚は収穫月に輸入されるとし、冷凍魚は収穫月から 1.5ヵ月後に輸入される（冷凍魚の収穫は 7 月からだったのに対し、輸入は 8 月からであったため）と仮定し（なお輸入 8 月分は全てを収穫 7 月に、輸入 12 月分は全てを 10 月に含めた）、次式(3)で求めた。

$$n_{i,1} = W_i \times \frac{1}{A_{i,1}} \qquad （３　生鮮魚）$$

$$n_{i,2} = (0.5 \times W_{i+1,2} + 0.5 \times W_{i+2,2}) \times \frac{1}{A_{i,2}} \qquad （３　冷凍魚）$$

ここで、

$n_{i,k}$：収穫 i 月、生鮮冷凍 k の輸入尾数

$W_{j,k}$： j 月に輸入された生鮮冷凍 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ついては、サイズ測定個体数が全体の一部であるので、ブートストラップ（1000 回のリサンプリング）で信頼範囲を求めた（式 4）。冷凍魚の年齢組成は、冷凍運搬船と冷凍コンテナ船それぞれの年齢組成に対して、それぞれの測定個体数で重み付けをした（式 5）。まき網で漁獲した時点の体重を掛けて漁獲重量を求めた。CCSBT で使用している 1 月 1 日時点の各年齢の体長間を直線補完して、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 日時点の体長に対応する体重を、Robins(1963)の関係式から推定した。

$$n_\alpha = \sum_{k=1}^{2}\sum_{i=4}^{10}\left(sample(m_{i,k} \times k_{\alpha,i,k}, n_{i,k}) \times \frac{n_{all}}{\sum_{i=4}^{10} n_{i,k}} \right) \quad (4)$$

$$w_{import} = \sum_{\alpha=2}^{5} n_\alpha \times A \times FL_{\alpha,2}^{B} \quad (5)$$

ここで、

n_α：日本に輸入された α 歳魚の尾数

w_{import}：日本に輸入された魚の原魚重量合計

$m_{i,k}$：ハーベストデータにおける収穫 i 月、生鮮冷凍 k の測定尾数。

$n_{i,k}$：収穫 i 月、生鮮冷凍 k の輸入尾数。(3)式で求めた。

$k_{\alpha,i,k}$：収穫 i 月、生鮮冷凍 k、 α 歳の個体数割合。(2)式で求めた。

n_{all}：日本に輸入された尾数の総数。2 月は年齢組成を推定していないため補正した。

$FL_{\alpha,i}$：野生魚の漁獲 i 月、 α 歳の体長(cm)。

A,B：尾叉長－原魚重量の関係式　原魚重量＝A×尾叉長^B　の係数。

$sample(x,y)$：サンプルデータ x から y 個をリサンプリングする。

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 6、式 7)。

$$N_\alpha = n_\alpha \times \frac{N_{all}}{\sum_{\alpha=2}^{5} n_\alpha} \quad (6)$$

$$PSW = W_{import} \times \frac{N_{all}}{\sum_{\alpha=2}^{5} n_\alpha} \quad (7)$$

ここで、

N_α：豪州まき網が漁獲した α 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（kg）

N_{all}: 2006 年 11 月から 2007 年 4 月までに豪州がまき網で漁獲した合計尾数。363,336 尾。日本輸入物には含まれない畜養中の死亡魚や米国、EC への輸出を考慮。

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 for farmed SBT which was imported to Japan after May 2007. The data on farmed SBT imported to Japan in 2007, which were collected from May 2007 to March 2009 were used for the analysis. A total of 187,632 individual records were analyzed after removing several anomalous records among the collected data (Table 1). The number of individual records was increased by 11% from the previous analysis (Itoh and Sakamoto, 2008).

Among the 187,632 records, 76,288 individual records which have both length and weight data. Based on these 76,288 records, parameters for a 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 fork length in cm, PW is processed weight (gilled and gutted with tail) in kg, and a_i and b_i are parameters by month to be estimated. Because the fatness index (PW/FL^3) differed significantly by month ($F = 971$, $p < 0.01$), the weight-length relationships were estimated by month (Table 2, Fig. 1).

Weight values were converted to length by using the monthly weight-length relationships. Next length frequencies by one centimeter bin by month and by classes of markets/fates (fresh fish, frozen fish for freezer vessels and frozen fish for freezer containers) were produced (Fig 2). From two to four normal distributions were used to decompose the length frequency by Eq-2. The largest dimension considered for the parameter vector Θ ($\mu_2, \mu_3, \mu_4, \mu_5, \sigma_2, \sigma_3, \sigma_4, \sigma_5, k_2, k_3, k_4$) was 11. This vector includes the mean, standard deviation and relative strength of each normal distribution; estimates of these values were obtained by the non-linear least squares method with the Gauss-Newton algorithm applied to minimize the sum of squares. Because k_i for the maximum age can be calculated from $\sum_{i=2}^{n} k_i = 1$ (e.g. $k_4=1-k_2-k_3$), this allows the number of parameters to be estimated to be reduced by one. Among the cases with two to four normal distributions, the case with the maximum number of distributions which nevertheless gave appropriate means and standard deviations (e.g. $\mu_2<\mu_3<\mu_4$, $\sigma_4<6$) was chosen.

$$SSQ = \sum_{x=\min L}^{\max L} \left(H_x - \sum_{\alpha=2}^{n} k_\alpha \frac{1}{\sqrt{2\pi\sigma_\alpha^2}} \exp\left(-\frac{(x-\mu_\alpha)^2}{2\sigma_\alpha^2} \right) \right)^2 \qquad \text{(Eq-2)}$$

where,

x: Length class of one centimeter bin,
$minL$: Class of the minimum length,
$maxL$: Class of the maximum length,
H_x: Frequency in length class of x cm,
n: Number of age classes among 2, 3, and 4.

The estimation was then expanded from samples for which 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-3). Because there may be some time difference between the month of harvest and the month of import for frozen fish, it was assumed that frozen fish were imported 1.5 months after harvest (note that frozen fish harvest began in July and frozen fish imports began in August 2007). All SBT imported in August were assumed to have been harvested in July, and all SBT imported in December were assumed to have been harvested in October); in contrast for fresh fish it was assumed that there was no difference between the month of harvest and that of importation.

$$n_{i,1} = W_i \times \frac{1}{A_{i,1}} \qquad \text{(Eq-3 for fresh SBT)}$$

$$n_{i,2} = (0.5 \times W_{i+1,2} + 0.5 \times W_{i+2,2}) \times \frac{1}{A_{i,2}} \qquad \text{(Eq-3 for frozen SBT)}$$

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).

Confidence intervals for estimates of age composition (by number) of SBT imported to Japan were calculated by applying a bootstrap approach (1000 resamples) (Eq 4). Age compositions of frozen SBT were weighted by number of fish measured for freezer vessels and for freezer containers. The weight of imported SBT at the time of purse seine catch was calculated (Eq 5). As transfer from towing pens to farming cages was most frequent in February in the individual size data used in this analysis, length as of 1st February was calculated based on information on the length at age on 1st January, which is as used in CCSBT, and on interpolation. Finally, the calculated length for 1st February was converted to body weight using the length-weight relationship for wild fish in southern Australia (Robins 1963).

$$n_\alpha = \sum_{k=1}^{2} \sum_{i=4}^{10} \left(sample(m_{i,k} \times k_{\alpha,i,k}, n_{i,k}) \times \frac{n_{all}}{\sum_{i=4}^{10} n_{i,k}} \right) \qquad \text{(Eq-4)}$$

$$w_{import} = \sum_{\alpha=2}^{5} n_\alpha \times A \times FL_{\alpha,2}^{B} \qquad \text{(Eq-5)}$$

where,

n_α: Number of SBT in age α imported to Japan,

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

$m_{i,k}$: Number of fish measured in harvest month i of fresh/frozen state k,

$n_{i,k}$: Number of SBT imported in harvest month *i* of fresh/frozen state *k*, as estimated using Eq-3,

$k_{\alpha,i,k}$: Proportion of number of age *a* SBT in harvest month *i* of fresh/frozen state *k*, estimated by minimising Eq-2,

n_{all}: Total number of SBT imported to Japan from Australia. This adjusts the total number of SBT harvested by including a correction for SBT harvested in February when the age composition was not estimated due to the small number of SBT harvested,

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

A,B: Parameters of length-weight relationship of *Whole weight=A x Forlk length*^{B},

sample(x,y): resample *y* individual data from sample size of *x*.

In the next step, catch-at-age and catch weight were scaled upwards to the total number of SBT caught by Australian purse seine (Eq-6 and Eq-7).

$$N_\alpha = n_\alpha \times \frac{N_{all}}{\sum_{\alpha=2}^{5} n_\alpha} \qquad \text{(Eq-6)}$$

$$PSW = W_{import} \times \frac{N_{all}}{\sum_{\alpha=2}^{5} n_\alpha} \qquad \text{(Eq-7)}$$

where

N_α: Total number of age *a* SBT caught by Australian purse seine,

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

N_{all}: Total number of SBT caught by Australia between November 2006 and April 2007 (363,336 individuals). This includes SBT not imported to Japan, i.e. died during farming or exported to other countries, such as U.S.A and EU.

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

結果と考察　**Results and Discussion**

畜養収穫時に収集されたサイズデータは 4 月から 10 月まで、生鮮と冷凍を区分しても 4 月以外は 1800 個体以上あり、日本への輸出個体数の 30%以上をカバーしていた（Table 3)。4 月から 10 月の合計に対しては生鮮魚の 73%、冷凍魚の 58%、全体の 60%をカバーした。

2007 年 4 月から 10 月の生鮮魚と、冷凍運搬船の冷凍魚、冷凍コンテナ船の冷凍魚で区分した全ての体長頻度は、2 個から 4 個の正規分布に分解された（Fig.2, Table 4)。グラフ上で、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ことが分かる。体長 130cm 以上については正規分布がカバーできていない部分もあり、これはわずかにサイズや年齢の過小推定につながる。

正規分布の平均値は、体長約 92cm、約 106cm、約 120cm、約 130cm に見られた。野生魚の年齢別体長と比較すると、それらが 2 歳、3 歳、4 歳、5 歳魚に相当することが分かる。4 月から 8 月では野生魚の年齢別体長よりも正規分布の平均値のほうが大きい。この理由の一つは豊富なエサを与えられる畜養魚では成長が早いためであろう。別の理由は月別体長を直線内挿したためであり、冬季に停滞する季節成長を考慮すれば 10 月の体長には 5-6 月には達していたであろう。そうであれば、正規分布の平均値は各年齢の体長と良く一致する。

サイズデータのカバー率が高かったことならびに 3 歳魚が最も多く 4 歳魚が次ぐという割合が生鮮／冷凍、月に関わらず同様であったことから、ブートストラップで推定した母集団（日本への輸出個体全体）の年齢別尾数範囲及び合計重量における分散は小さかった。冷凍運搬船と冷凍コンテナ船とで扱われた魚の年齢組成は 7 月、8 月はほとんど同じで、9 月に若干の違いが見られただけであった。このため、冷凍魚の扱いを冷凍運搬船と冷凍コンテナ船に区分しても結果にほとんど影響を及ぼさなかった。

豪州からは、まき網による年齢別漁獲尾数、漁獲重量が報告されている。2006 年 11-12 月に漁獲された魚は 2007 年の 1 歳高齢の魚に含めた。本解析による年齢組成（2 歳魚 6%、3 歳魚 54%、4 歳魚 38%、5 歳魚 3%）と豪州報告の年齢組成（2 歳魚 41%、3 歳魚 55%、4 歳魚 4%）とは、生鮮／冷凍によるサイズの違いを考慮したとしても大きな食い違いがある（Table 5、Fig. 3）。CCSBT 科学委員会は、現在使用している年齢組成の調整ではなく、本解析によるによる年齢組成を用いて資源評価を行うべきである。

また 2007 年漁期のまき網の漁獲量も豪州が報告する 5,342 トンに対して、本推定では 7,891 トンと異なった。

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。

The size data collected and used in this analysis covered 60% of farmed SBT imported to Japan from Australia in 2007 (Table 3). The number of size records exceeded 1800 individuals in all months between May and October for fresh SBT and frozen SBT. The proportions of fish which were individually measured for size amongst all imported fish were 73% for fresh fish and 58% for frozen fish.

All of the monthly length frequencies between April and October 2007 were decomposed into between two to four normal distributions for each of fresh SBT, frozen SBT from freezer vessels and frozen SBT from freezer containers (Table 4 and Fig. 2). The mixtures of normal distributions fitted the length frequency distributions well. (see Fig 2).. No normal distribution was estimated for large fish of more than 130 cm FL, whose length frequency distribution did not show a peak in some months (e.g. fresh SBT in July in Fig. 2a and frozen fish from freezer containers in October in Fig. 2c). This leads to a slight underestimation of the age composition for higher ages.

The mean values of the normal distributions fitted were around 92 cm FL, 106 cm FL, 120 cm FL and 130 cm FL. Comparison to the length-at-age of wild fish suggests that these groups corresponded to age 2, age 3 age 4 and age 5, respectively. However, the mean values between April and August were larger than the length-at-age of wild fish. One of the reasons of this is rapid growth of farmed fish with plentiful food provided in the farming. Another reason is that growth of SBT in temperate water changes by season, not linearly as assumed in the above. By taking account of slow growth in winter, the length of wild fish in October would have been reached by farmed fish around May or June. If this is the case, the mean values of the normal distributions correspond well to the length-at-age of wild fish.

Variances of estimated number of fish by age and estimated total weight of the all SBT imported to Japan obtained from bootstrapping were small. This is due to the facts that coverage of the size data was high and that age compositions (for which age 3 was most dominant, followed by age 4) were similar in all months for both fresh and frozen SBT. Age compositions of frozen SBT from freezer vessels and those from freezer containers were quite similar to each other in July and August though slightly different in September. In these two classes of markets/fates (frozen SBT for freezer vessels and freezer containers), age 3 fish and age 4 fish were dominant (Fig 2b and 2c). Furthermore, analysis of farmed SBT taking into account three classes of markets/fates (fresh fish, frozen fish for freezer vessels and frozen fish for freezer containers) and analysis of farmed SBT without taking into account the classification, as conducted in CCSBT-ESC/0809/39, reached the same broad result, which was that age 3 fish and age 4 fish were dominant amongst the farmed SBT (purse seine catch) in 2007.

Catch by age and the total amount of catch by purse seine have been reported by Australia. SBT caught in November and December 2006 are included as fish one year older in 2007 so that they were treated as the same cohort. There is quite a large difference between estimated age composition obtained in the present study (6 % in age2, 54 % in age 3, 38 % in age 4 and 3% in age 5) and the reported age compositions (41 % in age2, 55 % in age 3 and 4 % in age 4) by Australia (Table 5, Fig. 3), even after having considered the size difference between fresh SBT and frozen SBT. The estimated age-composition should replace the adjustments made in age composition for historical data and be used in the stock assessment by the Extended Scientific Committee.

Australia reported that the total amount of Australian purse seine catch in the 2007 fishing season was 5,342 tons. However, the total amount estimated in the present study is 7,891 tons, which is 1.5 times larger than the reported catch (Table 5).

Uncertainties of age compositions and 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 the age composition and amount caught by the Australian surface fishery is required.

References

Itoh, T., and T. Sakamoto, T. 2008. Analysis on age composition of southern bluefin tuna used for farming. CCSBT/ESC/0809/39.

Robins, J. P. 1963. Synopsis of biological data on bluefin tuna *Thunnus thynnus maccoyii* (Castelnau) 1982. Species synopsis No. 17. FAO Fisheries Biology Synopsis No. 60.

Table 1. Number of collected size data by month for Australian farmed SBT harvested and imported to Japan in 2007

2007 年に収穫され日本に輸入された豪州畜養ミナミマグロの月別サイズデータ数

Month of harvest	N_collected	N_collected and anomalous data removed	N_Length & Weight obtained
2	182	182	182
4	368	368	284
5	1,891	1,891	1,479
6	2,425	2,425	1,672
7	42,004	41,988	12,307
8	75,313	75,278	27,933
9	49,452	49,430	30,127
10	16,045	16,044	2,278
12	26	26	26
Total	187,706	187,632	76,288

Table 2. Parameters for conversion from processed weight to fork length by month of Australian farmed SBT harvested in 2007

2007 年に収穫された畜養ミナミマグロの月別の体長体重関係パラメータ値

Month	N	a	b
4	284	38.038	0.322
5	1,479	40.777	0.298
6	1,672	38.912	0.313
7	12,307	37.641	0.321
8	27,933	35.902	0.337
9	30,127	36.792	0.334
10	2,278	38.314	0.321

Table 3. Number of weight data collected, estimated number of farmed SBT imported to Japan and their proportion by month of harvest for Australian farmed SBT in 2007

2007 年の畜養ミナミマグロの収穫月別の体重測定尾数と日本への輸入尾数推定値、体重測定個体数割合

Harvest month	Number of weight data collected (A)				Estimated number of farmed SBT imported in Japan (B)			Proportion (=A/B)		
	Fresh	Frozen	Frozen(Freezer vessels/Container)	Total	Fresh	Frozen	Total	Fresh	Frozen	Total
4	368			368	1,932		1,932	19%		19%
5	1,891			1,891	2,437		2,437	78%		78%
6	2,425			2,425	2,901		2,901	84%		84%
7	5,715	36,273	(15451/20822)	41,988	6,505	78,236	84,741	88%	46%	50%
8	8,001	67,274	(35121/32153)	75,275	12,419	91,444	103,863	64%	74%	72%
9	6,878	42,552	(18890/23662)	49,430	8,755	61,775	70,530	79%	69%	70%
10	3,603	12,441	(/12441)	16,044	4,508	39,987	44,495	80%	31%	36%
Total	28,881	158,540	(69462/89078)	187,421	39,456	271,442	310,898	73%	58%	60%

Table 4. Estimated mean length, standard deviation and mixing rate (with S.E.) for age 2-5 in the normal mixture distribution in each month for Australian farmed SBT harvested in 2007

2007 年に収穫された豪州畜養ミナミマグロの月別の混合正規分布における 2-5 歳魚の平均尾叉長、標準偏差、混合率の推定値（±標準誤差）

Fresh/Frozen	Month	N_norm_dist	L_Mean_Age2	L_Mean_Age3	L_Mean_Age4	L_Mean_Age5	L_SD_Age2	L_SD_Age3	L_SD_Age4	L_SD_Age5
Fresh	4	2		105.8 ±0.13cm	117.4 ±0.39cm			3.31 ±0.13cm	3.98 ±0.0cm	
Fresh	5	3	91.9 ±0.58cm	105.8 ±0.06cm	119.3 ±0.26cm		4.54 ±0.0cm	3.64 ±0.07cm	4.99 ±0.26cm	
Fresh	6	4	96.7 ±2.72cm	106.7 ±0.05cm	119.6 ±0.22cm	134.6 ±0.62cm	7.41 ±1.93cm	3.16 ±0.07cm	4.88 ±0.25cm	1.86 ±0.62cm
Fresh	7	3	91.7 ±0.48cm	106.6 ±0.11cm	121.1 ±0.15cm		3.94 ±0.49cm	4.37 ±0.14cm	4.66 ±0.15cm	
Fresh	8	3	92.1 ±0.36cm	106.5 ±0.11cm	121.9 ±0.22cm		3.49 ±0.37cm	4.28 ±0.13cm	5.76 ±0.22cm	
Fresh	9	4	92.9 ±0.84cm	107.1 ±0.09cm	121.6 ±0.15cm	135.4 ±0.87cm	2.42 ±0.84cm	4.07 ±0.09cm	5.24 ±0.26cm	4.13 ±0.72cm
Fresh	10	4	92.4 ±1.25cm	105.1 ±0.00cm	122.4 ±1.02cm	134.4 ±1.93cm	2.93 ±1.28cm	3.83 ±0.11cm	6.52 ±1.07cm	4.32 ±1.23cm
Freezer vessel	7	4	92.5 ±0.35cm	105.9 ±0.07cm	119.9 ±0.13cm	133.2 ±1.07cm	3.53 ±0.36cm	3.99 ±0.00cm	4.24 ±0.17cm	3.21 ±1.09cm
Freezer vessel	8	3	92.5 ±0.45cm	106.1 ±0.00cm	119.4 ±0.12cm		2.84 ±0.45cm	4.35 ±0.12cm	3.97 ±0.12cm	
Freezer vessel	9	4	93.3 ±0.25cm	106.8 ±0.08cm	120.2 ±0.07cm	130.9 ±0.81cm	2.31 ±0.25cm	4.0 ±0.00cm	3.57 ±0.07cm	4.72 ±0.64cm
Freezer vessel	10									
Freezer containers	7	4	89.6 ±0.00cm	106.8 ±0.06cm	119.2 ±0.00cm	131.6 ±0.71cm	3.27 ±0.0cm	4.27 ±0.06cm	3.91 ±0.14cm	4.05 ±0.67cm
Freezer containers	8	4	90.3 ±0.27cm	104.5 ±0.05cm	119.3 ±0.00cm	131.7 ±0.68cm	3.05 ±0.28cm	4.0 ±0.06cm	4.01 ±0.14cm	3.0 ±0.67cm
Freezer containers	9	3	91.5 ±0.19cm	105.5 ±0.07cm	118.7 ±0.14cm		3.75 ±0.19cm	4.01 ±0.08cm	4.92 ±0.13cm	
Freezer containers	10	3	92.4 ±0.55cm	106.5 ±0.09cm	120.4 ±0.00cm		3.52 ±0.55cm	4.39 ±0.12cm	4.36 ±0.00cm	

Fresh/Frozen	Month	N_norm_dist	%Age2	%Age3	%Age4	%Age5
Fresh	4	2		69.0 ±2.00%	31.0 ±2.00%	
Fresh	5	3	7.9 ±0.79%	68.8 ±1.22%	23.2 ±1.45%	
Fresh	6	4	11.2 ±3.00%	62.7 ±3.06%	24.5 ±1.03%	1.6 ±4.41%
Fresh	7	3	8.2 ±0.00%	50.2 ±1.37%	41.6 ±1.37%	
Fresh	8	3	8.6 ±0.72%	50.3 ±1.42%	41.1 ±1.59%	
Fresh	9	4	1.5 ±0.41%	48.8 ±1.07%	43.8 ±1.88%	6.0 ±2.20%
Fresh	10	4	2.0 ±0.73%	54.4 ±1.00%	36.0 ±6.47%	7.5 ±6.59%
Freezer vessel	7	4	8.7 ±0.72%	55.3 ±1.09%	33.5 ±1.00%	2.4 ±1.65%
Freezer vessel	8	3	5.1 ±0.65%	54.6 ±1.25%	40.3 ±1.41%	
Freezer vessel	9	4	3.5 ±0.31%	38.4 ±0.62%	50.3 ±1.36%	7.9 ±1.53%
Freezer vessel	10					
Freezer containers	7	4	1.8 ±0.34%	61.8 ±0.78%	31.8 ±1.12%	4.6 ±1.41%
Freezer containers	8	4	5.9 ±0.44%	58.6 ±0.66%	30.9 ±0.92%	4.6 ±1.21%
Freezer containers	9	3	11.8 ±0.47%	52.0 ±0.98%	36.2 ±1.09%	
Freezer containers	10	3	5.1 ±0.64%	48.7 ±1.17%	46.2 ±1.33%	

Standard error of mixing rate of the maximum age was calculated using the delta method approximation, and likely too high as fails to allow for covariance.

Table 5. Age compositions and catch amount by Australian surface fisheries for SBT farming estimated from the size data at harvest in 2007

2007 年の収穫時のサイズデータから推定した豪州巻き網漁業（畜養用）のミナミマグロ漁獲量及び年齢組成

Present estimate of SBT imported to Japan

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	Weight in ton
Median[1)]		18,239	166,468	118,340	7,844	310,891	6,752
%		6%	54%	38%	3%	100%	

Present estimation raised to all Australian purse seine catch

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	Weight in ton
Number		21,316	194,550	138,303	9,167	363,336[1)]	7,891
%		6%	54%	38%	3%	100%	

Australian reported catch for purse seine[1)]

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	Weight in ton
Number	144	150,719	198,101	12,994	1,379	363,336	5,230
%	0%	41%	55%	4%	0%	100%	

1) Total numbers from purse seine catch reported from Australia. Fish caught in November and December 2006 were included as fish one year older in 2007.

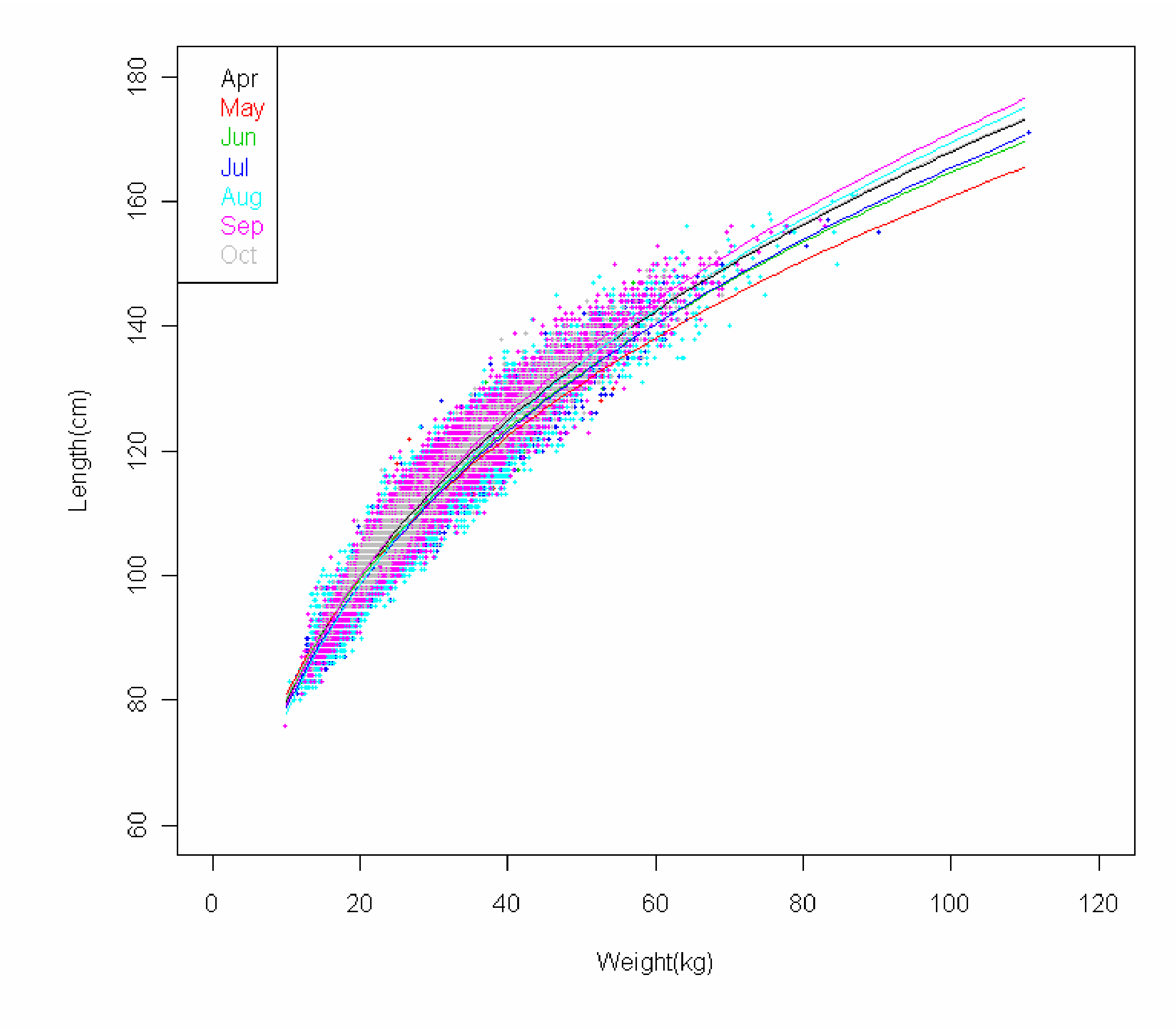

Fig. 1. Monthly weight (gilled and gutted in kg) – length (fork length in cm) relationship of Australian farmed SBT harvested in 2007

2007 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=76,288.

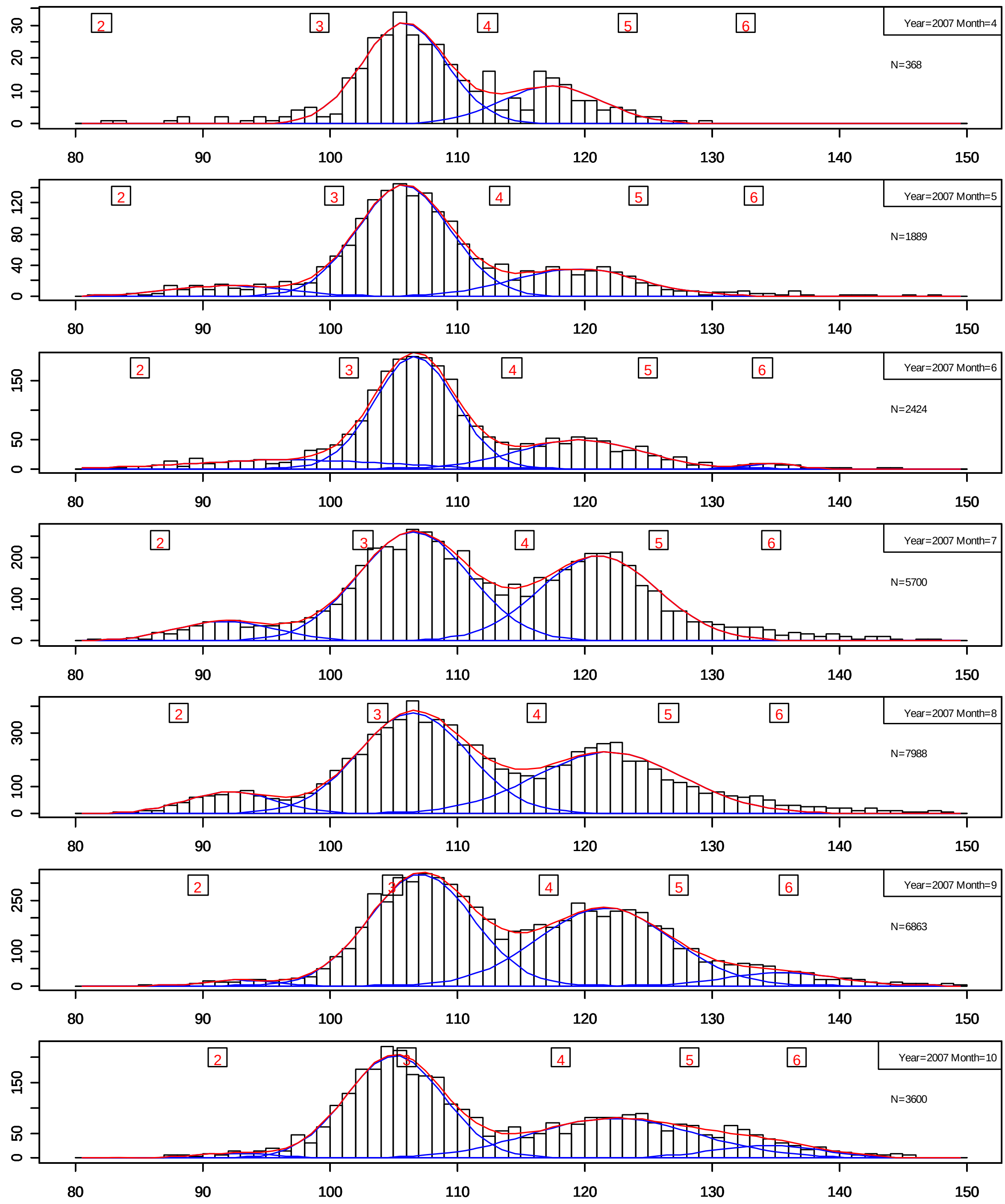

Fig. 2a. Monthly length frequency and estimated probability density function of the normal mixture distribution of farmed SBT at harvest (for Fresh SBT). Mean monthly length at age of wild fish is shown in the squares.

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。

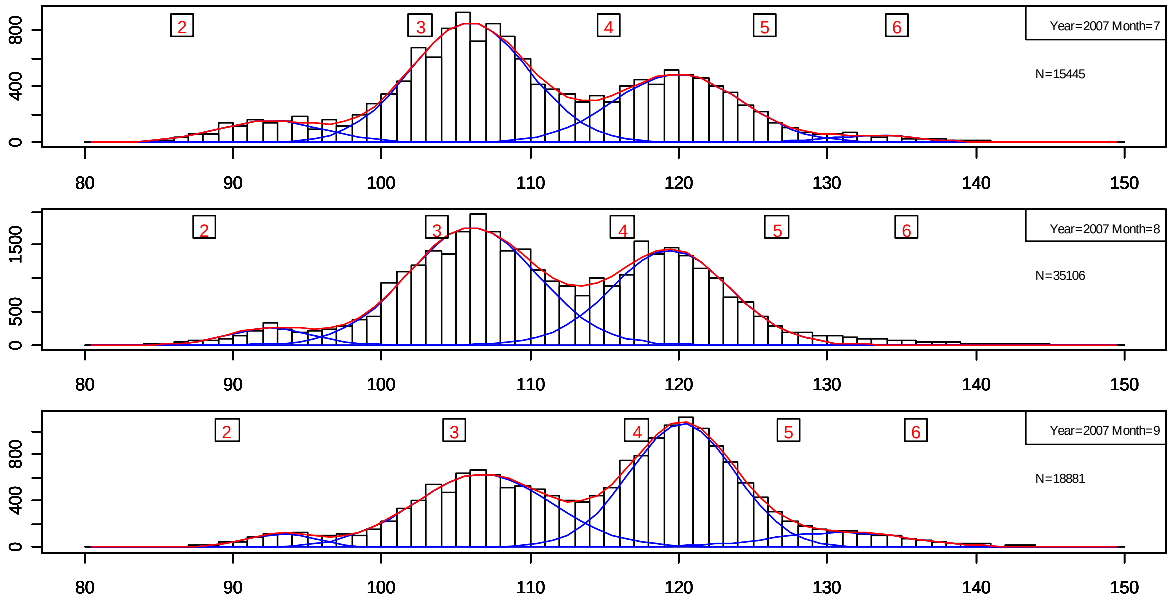

Fig. 2b. (Contd.) (For frozen SBT from freezer vessels)
（つづき）（冷凍運搬船）

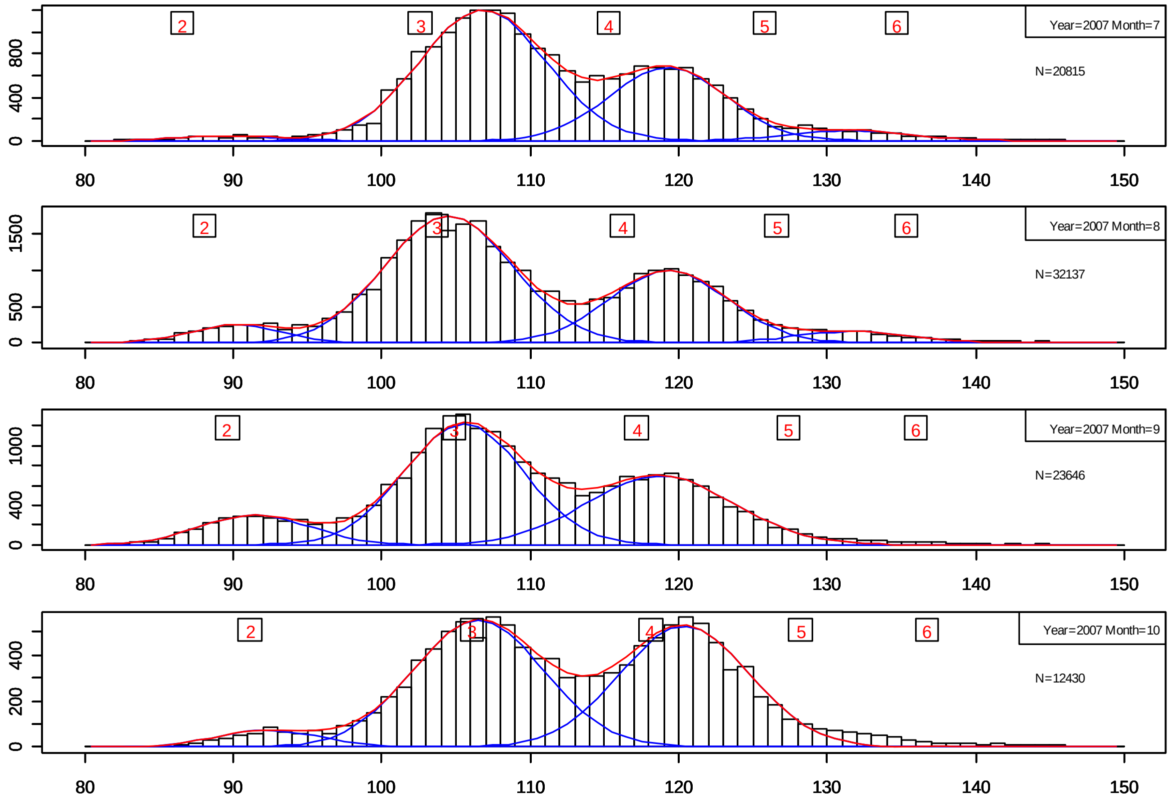

Fig. 2c. (Contd.) (For frozen SBT from freezer containers)
（つづき）（冷凍コンテナ）

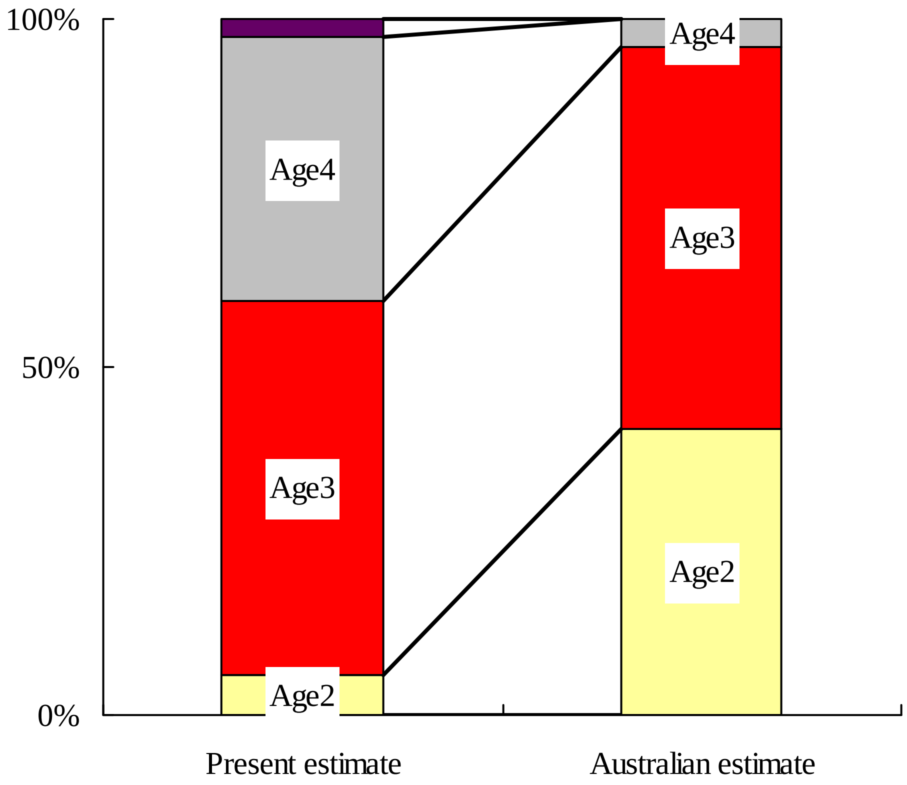

Fig. 3. Comparison of age compositions (in number) estimated in the present study with those reported by Australia to the CCSBT. Fish caught in November and December 2006 were included as fish one year older in 2007.

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. 2006 年 11-12 月に漁獲された魚は 2007 年の 1 歳高齢の魚に含めた。