2009 年畜養原魚の年齢組成の解析

Analysis of age composition of southern bluefin tuna used for farming in 2009

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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、2009 年の出荷時のサイズデータから年齢組成を推定した。月別体長組成に正規分布を当てはめた結果、2 歳魚 18%、3 歳魚 33%、4 歳魚 48%、5 歳魚 1%と推定された。2009 年漁期のまき網による総漁獲重量は 6529 トンと推定された。これは豪州政府からの報告値 5005 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 2009.　We carried out the age decomposition based on the length frequencies using the framework of a mixture of normal distributions, estimated independently for each month.　The age compositions was estimated as 18% for age 2, 33% for age 3, 48% for age 4 and 1% for age 5.　The total catch of the Australian purse seine fisheries in the 2009 fishing season was estimated to be 6529 tons.　This figure is 30% larger than the reported Australian purse seine catch (5005 tons).　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 年畜養魚ならびに 2008 年畜養魚について解析し、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）。本研究では豪州養殖魚の 2009 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 and 2008 and suggested existence substantial bias in size measurement (CCSBT/ESC/0909/29, CCSBT/ESC/0909/30). In this document we present estimates of the catch-at-age and the total catch in 2009 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。2010 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 61,843 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=58,964)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=1291、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 1-4 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（$\mu_2, \mu_3, \mu_4, \mu_5, \sigma_2, \sigma_3, \sigma_4, \sigma_5, k_2, k_3, k_4$）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：正規分布区分数（1,2,3,4 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。生鮮魚は収穫月に輸入されるとした。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、6 月以前の輸入物（376,929 kg）は前年の収穫として除外した。8 月と 9 月の輸入は 7 月の収穫物、9 月以降の輸入は 8 月の収穫物とみなした。次式(3)で尾数を求めた。

$$n_{i,k} = W_{i,k} \times \frac{1}{A_{i,k}} \qquad （３）$$

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。

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

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

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。

$FL_{\alpha,i}$：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＝$A\times$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 TIS 年間報告を基に豪州まき網による総漁獲尾数に引き伸ばした(式 6、式 7)。

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

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

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}: 2008 年 12 月から 2009 年 3 月までに豪州がまき網で漁獲した合計尾数。306,640 尾。日本輸入物には含まれない曳航中の死亡魚、畜養中の死亡魚、収穫されていない尾数、米国、EC への輸出を考慮。

比較対照とすべき豪州まき網の月別年齢別漁獲尾数は、豪州が報告した月別体長別漁獲尾数データ（AUS 2008 CatchAtSize data.xls, AU 2009 Catch at Size revised.xls）に対して日本が通常用いている体長から年齢への変換プログラムを用いて、2008 年 12 月から 2009 年 3 月の月別年齢別漁獲尾数を求めた。

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 2009, which were collected from May 2009 to March 2010 were used for the analysis. A total of 61,843 individual records were analyzed after removing several anomalous records among the data collected data (Table 1).

Using data for 58,964 individuals for which both length and weight information is 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 = 1291, $p < 0.01$), 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, frozen fish from freezer vessels and frozen fish from freezer containers) were produced (Fig 2). From one to four normal distributions were fitted to decompose the length frequency by minimizing 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, and these were estimated by the non-linear least squares method with the Gauss-Newton algorithm to minimize the sum of squares. Because k_i of the maximum age can be calculated from $\sum_{i=2}^{n} k_i = 1$ (e.g. $k_4=1-k_2-k_3$), the number of parameters to be estimated can 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 1, 2, 3, and 4.

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-3). 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 August and September were harvested in July, and SBT imported after October were harvested in August. There were some amount of SBT imported before June (376,929 kg), however, these were assumed to be harvested in previous year and not included in the analysis.

$$n_{i,k} = W_{i,k} \times \frac{1}{A_{i,k}} \qquad \text{(Eq-3)}$$

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 the estimated age composition (in number) of SBT imported to Japan were calculated using bootstrapping (1000 resamples) (Eq 4). Age compositions for frozen SBT were weighted by the number of fish measured from freezer vessels and from freezer containers. The weight of imported SBT at the time of the purse seine catch was calculated (Eq 5). As transfer from towing pens to farming cages was most frequent in February for the individual size data used in this analysis, length as at 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 on 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* as estimated by minimizing Eq-2,

n_{all}: Total number of SBT imported to Japan from Australia,

$FL_{\alpha,i}$: 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, the catch-at-age and catch weight were scaled upwards to the total number of SBT caught by Australian purse seiners based on the trade information scheme yearly farm data summary for 2009 fishing season of Australia (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 December 2008 and March 2009 (306,640 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 by month of Australian purse seine in 2009 were estimated using catch-at-size data (AUS 2008 CatchAtSize data.xls, AU 2009 Catch at Size revised.xls) in the data exchange and our program that converts length to age.

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 3 月から 10 月まで収集され、多くの月で 5000 個体以上であった。日本の輸入個体数に対し、生鮮魚の 52%、冷凍魚の 8%、全体の 26%をカバーした（Table 3）。

生鮮用、冷凍運搬船用、冷凍コンテナ用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 95cm、約 106cm、約 115cm、約 126cm に見られた。野生魚の年齢別体長と比較すると、それぞれ 2 歳から 5 歳に相当すると判断された。

サイズデータのカバー率が高かったことならびに 3 歳魚と 4 歳魚が多くを占めるという割合が生鮮／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(Table 5)。

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。2008 年 12 月に漁獲された魚は 2009 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 18%、3 歳魚 33%、4 歳魚 48%、5 歳魚 1%）と豪州報告の年齢組成（2 歳魚 31%、3 歳魚 62%、4 歳魚 7%）とは、大き

な食い違いがある（Table 5、Fig. 3)。

また 2009 年漁期のまき網の漁獲量も豪州が報告する 5,005 トンに対して、本推定では 6,526 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 between March and October and covered 26% (52% of fresh, 8% of frozen) of SBT imported to Japan from Australia (Table 3). The numbers of size records exceeded 5000 individuals in many months.

All of the monthly length frequencies were decomposed into between two and 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 mixture of normal distributions fitted the length frequency distributions well. 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. This leads to a slight underestimation of the age composition for higher ages.

The mean values of the normal distributions were around 95 cm FL, 106 cm FL, 115 cm FL and 126 cm FL. Comparison to the length-at-age of wild fish suggests that these normal distributions corresponded with age 2, age3, age4 and age5, respectively (Table 4).

Variances of estimated number of fish by age and estimated total weight of the all SBT imported to Japan obtained from bootstrapping were small (Table 5). This is due to the facts that coverage of the size data was high and that age compositions (for which age 3 and age4 were dominant) were similar in all months for both fresh and frozen SBT.

Catch by age and the total amount of catch by purse seiners have been reported by Australia. SBT caught in December 2008 were included as fish one year older in 2009 so that they were treated as the same cohort. There is a substantial difference between estimates from the present study (18 % for age2, 33 % for age 3, 48 % for age 4 and 1% for age 5) and the reported age compositions (31 % in age2, 62 % in age 3 and 7 % in age 4) by Australia (Table 5, Fig. 3). The estimated age-composition should replace the adjustments made in age composition for historical data to be used for the stock assessment by the Extended Scientific Committee.

Australia reported that the total amount of Australian purse seine catch in the 2009 fishing season was 5,005 tons. However, the total amount estimated in the present study is 6,529 tons (Table 5).

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.

References

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Table 1. Number of size data collected by month for Australian farmed SBT harvested and imported to Japan in 2009

2009 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
Mar	1,179	1,018
Apr	5,127	4,478
May	6,652	6,037
Jun	8,025	7,151
Jul	13,536	13,026
Aug	17,476	17,427
Sep	8,453	8,435
Oct	1,395	1,392
Total	61,843	58,964

Table 2. Parameters for conversion from processed weight to fork length by month for Australian farmed SBT harvested in 2009

2009 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
3	1,018	43.1337	0.283
4	4,478	40.9489	0.298
5	6,037	40.2266	0.301
6	7,151	39.1057	0.310
7	13,026	38.1202	0.318
8	17,427	38.0152	0.320
9	8,435	38.5308	0.320
10	1,392	38.7708	0.322

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 2009

2009 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
3	1,179			1,179	1,316		1,316	90%		90%
4	5,127			5,127	8,180		8,180	63%		63%
5	6,652			6,652	13,688		13,688	49%		49%
6	8,025			8,025	14,256		14,256	56%		56%
7	8,402	5,134	(2903 / 2231)	13,536	22,070	84,905	106,976	38%	6%	13%
8	10,125	7,351	(7351 / 0)	17,476	21,111	62,677	83,788	48%	12%	21%
9	8,453			8,453	12,589		12,589	67%		67%
10	1,395			1,395	1,641		1,641	85%		85%
Total	49,358	12,485		61,843	94,851	147,582	242,433	52%	8%	26%

Table 4. Estimated mean length, standard deviation and mixing rate (with S.E.) in each of normal distribution by month for Australian farmed SBT harvested in 2009

2009 年に収穫された豪州畜養ミナミマグロの月別の各正規分布の平均尾叉長、標準偏差、混合率の推定値（±標準誤差）

FleshFrozen	Month	N_norm_dist	Length_Mean				Length_standard deviation			
			Mode1	Mode2	Mode3	Mode4	Mode1	Mode2	Mode3	Mode4
Fresh	3	2		105.1 ±1.02cm	112.8 ±0.27cm			4.48 ±0.56cm	3.38 ±0.14cm	
Fresh	4	2		104.2 ±0.17cm	113.6 ±0.00cm			3.00 ±0.13cm	3.92 ±0.08cm	
Fresh	5	2		106.8 ±0.39cm	115.9 ±0.16cm			4.41 ±0.25cm	3.65 ±0.00cm	
Fresh	6	3	96.1 ±0.93cm	107.6 ±0.19cm	116.6 ±0.15cm		4.41 ±0.91cm	3.12 ±0.19cm	4.11 ±0.11cm	
Fresh	7	3	94.8 ±0.76cm	106.0 ±0.27cm	116.8 ±0.12cm		5.61 ±0.67cm	3.11 ±0.00cm	5.02 ±0.11cm	
Fresh	8	3	94.4 ±0.51cm	105.0 ±0.31cm	116.2 ±0.49cm		4.13 ±0.31cm	4.34 ±0.45cm	5.41 ±0.29cm	
Fresh	9	4	94.2 ±0.19cm	104.0 ±0.16cm	114.1 ±0.73cm	125.5 ±9.47cm	3.00 ±0.18cm	3.00 ±0.19cm	5.33 ±1.00cm	5.41 ±4.06cm
Fresh	10	3	95.6 ±0.13cm	105.6 ±0.05cm	116.2 ±0.32cm		3.59 ±0.13cm	2.87 ±0.06cm	3.62 ±0.32cm	
Freezer vessel	7	3	97.9 ±1.07cm	105.4 ±1.32cm	116.0 ±0.98cm		2.93 ±0.83cm	2.71 ±1.46cm	5.27 ±0.00cm	
Freezer vessel	8	4	94.6 ±0.47cm	105.7 ±0.00cm	117.0 ±0.69cm	126.6 ±7.99cm	1.97 ±0.47cm	4.58 ±0.75cm	3.42 ±0.93cm	3.69 ±6.15cm
Freezer container	7	3	93.3 ±0.08cm	104.5 ±0.22cm	116.1 ±0.29cm		2.76 ±0.08cm	3.36 ±0.25cm	4.67 ±0.27cm	
Age assigined			Age 2	Age 3	Age 4	Age 5				

FleshFrozen	Month	N_norm_dist	Mixing rate			
			Mode1	Mode2	Mode3	Mode4
Fresh	3	2		37.3 ±7.77%	62.7 ±7.77%	
Fresh	4	2		29.5 ±1.58%	70.5 ±1.58%	
Fresh	5	2		39.2 ±3.11%	60.8 ±3.11%	
Fresh	6	3	6.1 ±1.02%	28.2 ±2.51%	65.7 ±2.71%	
Fresh	7	3	13.6 ±1.46%	14.2 ±2.16%	72.2 ±2.61%	
Fresh	8	3	20.9 ±2.49%	34.3 ±5.55%	44.8 ±6.08%	
Fresh	9	4	18.7 ±0.00%	29.5 ±3.98%	46.7 ±12.73%	5.1 ±13.37%
Fresh	10	3	31.8 ±0.00%	56.5 ±1.25%	11.7 ±1.54%	
Freezer vessel	7	3	27.6 ±8.85%	18.0 ±13.27%	54.4 ±15.95%	
Freezer vessel	8	4	10.3 ±2.65%	53.5 ±7.00%	32.6 ±11.27%	3.6 ±14.01%
Freezer container	7	3	36.9 ±0.89%	26.3 ±2.06%	36.8 ±2.24%	
Age assigined			Age 2	Age 3	Age 4	Age 5

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

Table 5. Age compositions and amount caught by Australian surface fisheries for SBT farming estimated from the size data at harvest in 2009

2009 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 for fish imported to Japan

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	N_total	Estimate total weight at catch in ton
Median		44,548	79,086	115,900	2,894	242,428	5,162
%		18%	33%	48%	1%		
5 %ile		44,857	79,057	115,638	2,876	242,428	5,157
95% ile		44,123	79,232	116,263	2,810	242,428	5,167

Present estimate raised to all Australian purse seine catch

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	N_total	Estimate total weight at catch in ton
Median		56,347	100,034	146,598	3,661	306,640	6,529
%		18%	33%	48%	1%		
5 %ile		56,738	99,997	146,267	3,638	306,640	6,522
95% ile		55,810	100,218	147,058	3,554	306,640	6,535

Australian reported catch for purse seine[1)]

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	N_total	Total weight at catch in ton
Number	0	94,117	188,821	22,992	710	306,640	5,005
%	0%	31%	62%	7%	0%		

1) Total number of purse seine catch reported from Australia.　Fish caught in December 2008 were included as fish one year older in 2009.　Catches at age by month were estimated in the present study.

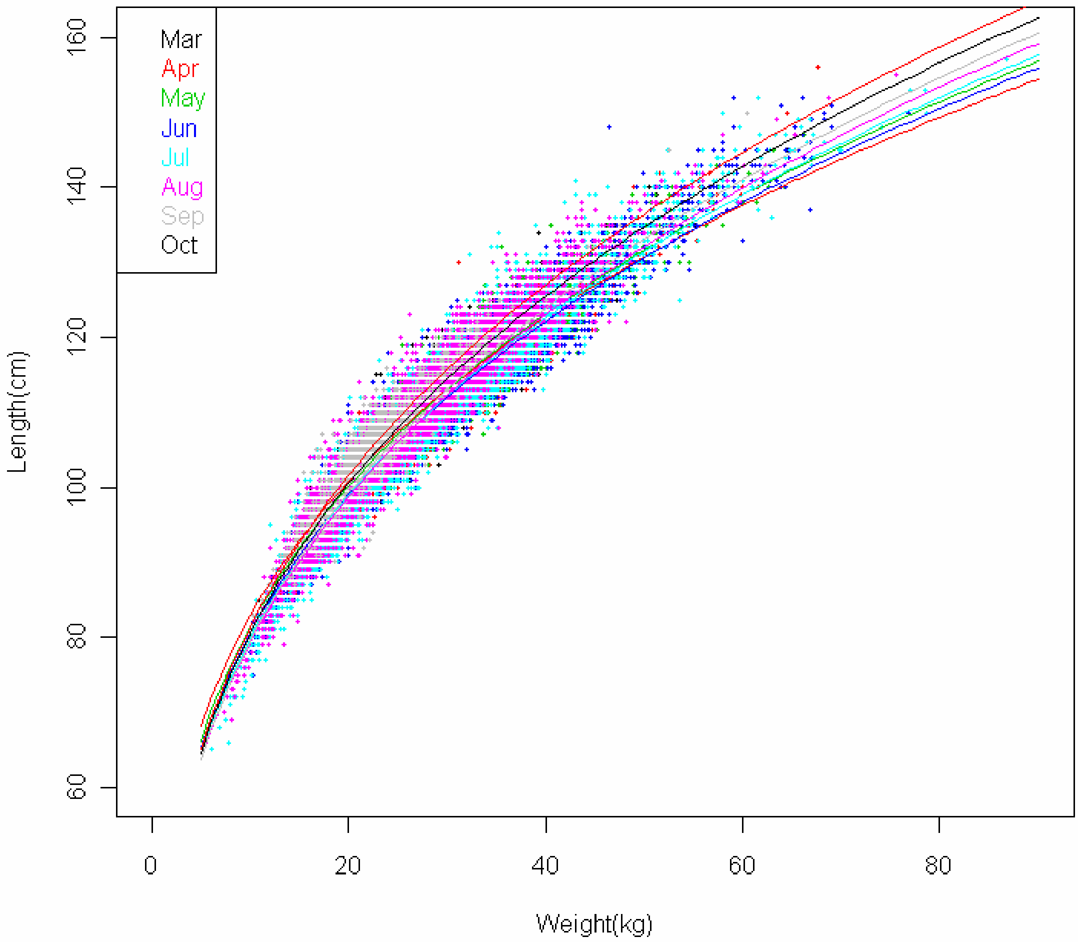

Fig. 1. Monthly weight (gilled and gutted in kg) – length (fork length in cm) relationship for Australian farmed SBT harvested in 2009

2009 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=58,964.

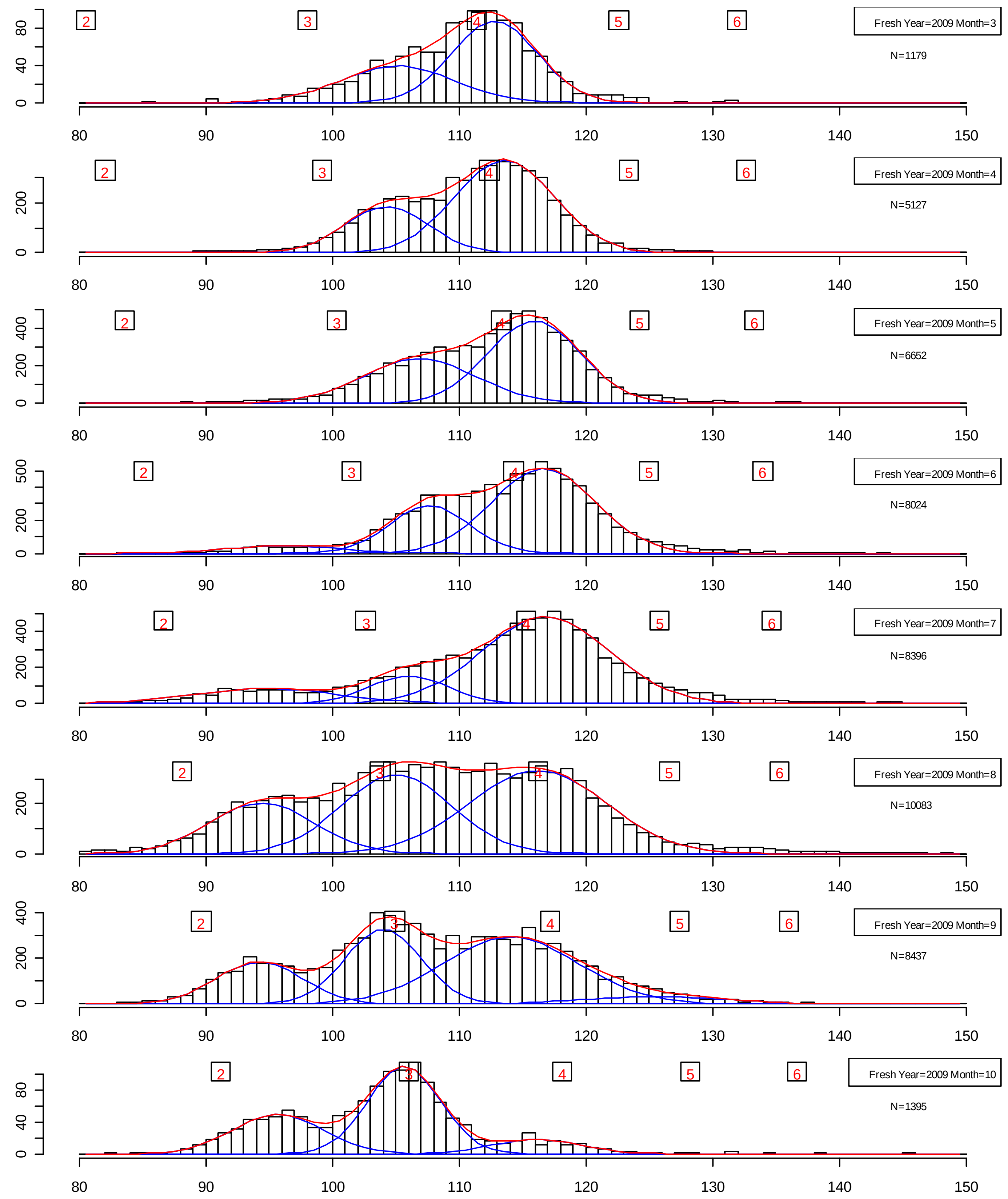

Fig. 2a. Monthly length frequency and estimated probability density functions of the normal mixture distribution of farmed SBT at harvest (for Fresh SBT). Mean monthly length at age of wild fish is shown in the squares.

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。

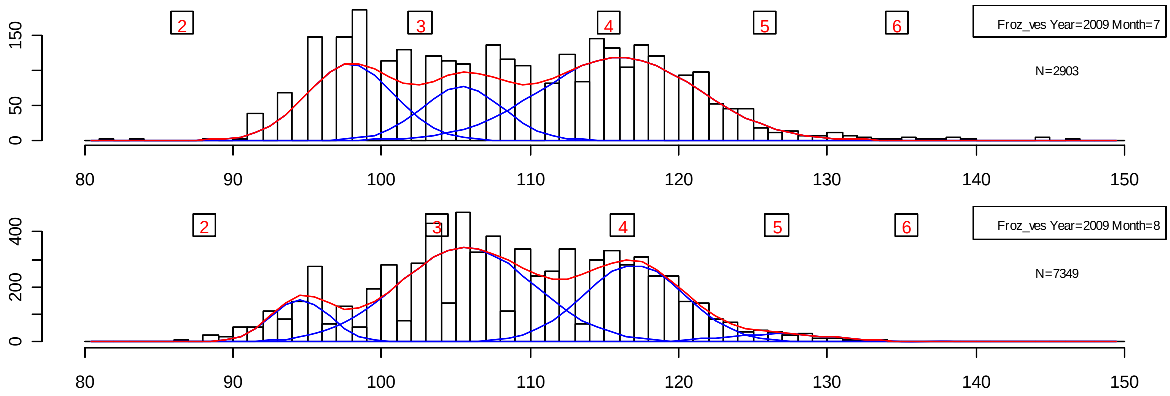

Fig. 2b. (Contd.) (For frozen SBT from freezer vessels)

（つづき）（冷凍運搬船）

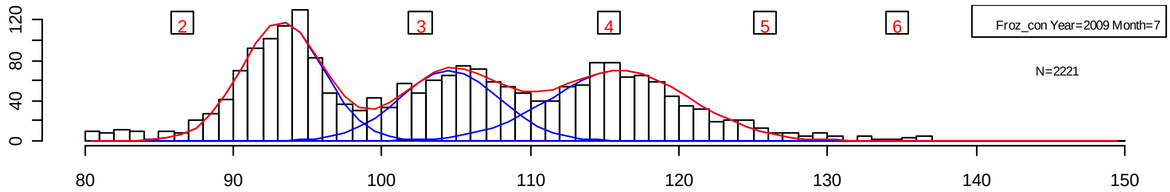

Fig. 2c. (Contd.) (For frozen SBT from freezer containers)

（つづき）（冷凍コンテナ）

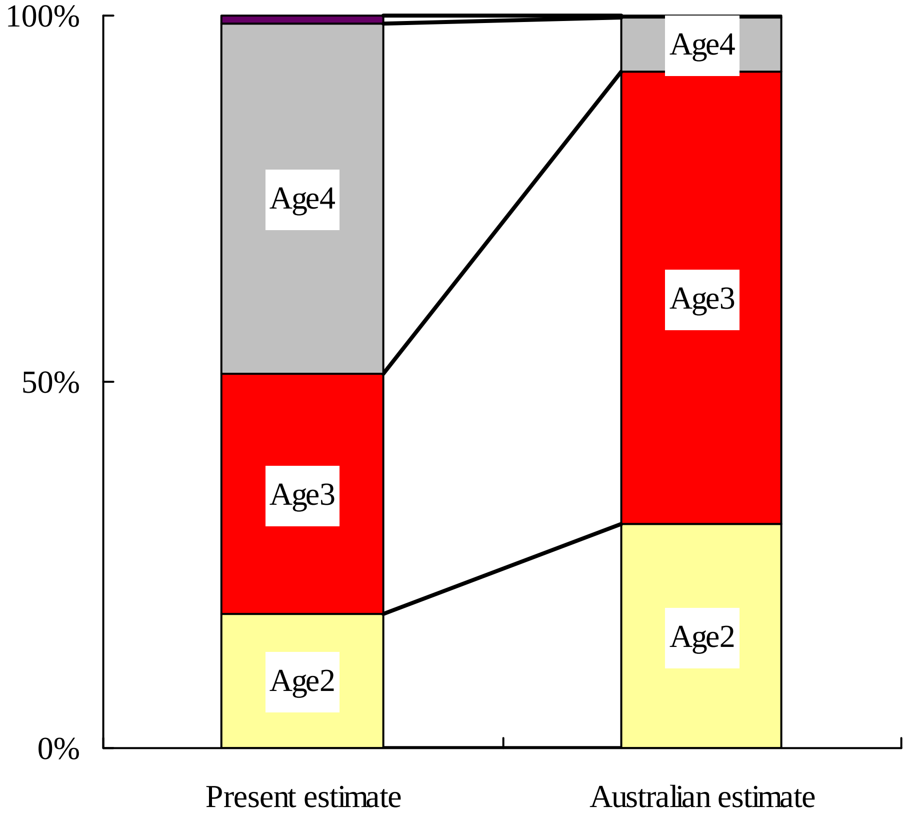

Fig. 3. Comparison of age compositions (by number) estimated in the present study with those reported by Australia to the CCSBT. Fish caught in December 2008 were included as fish one year older in 2009.

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. 2008 年 12 月に漁獲された魚は 2009 年の 1 歳高齢の魚に含めた。