

ミナミマグロ蓄養原魚の年齢組成解析

Analysis on age composition of southern bluefin tuna used for farming

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。月別体長組成に正規分布を当てはめて、2歳魚6%、3歳魚54%、4歳魚36%と推定された。2007年漁期のまき網による総漁獲重量は7,934トンと推定された。これらは豪州政府からの報告値(5342トン)より2592トン(48%)大きい。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。また、この情報は、CCSBTが来る年次会合で効果的な漁獲証明制度(CDS)を作成する際に重要である。

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. We carried out the age decomposition based on the length frequencies using the framework of the mixture of normal distributions in each month independently. Age compositions were estimated as 6% for age 2, 54% for age 3 and 36% for age 4. The total catch of the Australian purse seine (PS) fisheries in the 2007 fishing season was estimated as 7,934 tons. This figure (7934 ton) is 2592 ton (48%) larger than Australian reported PS catch (5342 ton). Urgent examination of the bias in the 40 fish sampling, which is used by Australia to prepare its reported PS catch, and improvement of method to know age composition and catch amount by Australian surface fishery are required. Also, this information is important for the CCSBT when developing an effective CDS (Catch Documentation Scheme) at the coming annual meeting.

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。

Accurate data on catch-at-age in number as well as the total catch in weight are essential for stock assessment and management of southern bluefin tuna (SBT) in the CCSBT. We present, in this document, estimations of the catch-at-age and the total catch of Australian surface fishery for SBT farming based on size data at harvest. We also compare these estimations with catch and size information submitted by the Australia.

材料と方法 Materials and Methods

2007年5月以降に日本へ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。2008年3月までに収集、入力されたデータを用いた。表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168,556個体を解析対象とした。表2に生鮮と冷凍に区分したデータ数を示す。

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 52,795 個体について、体重量体長換算式のパラメータを計算した。肥満度（体重/体長³）が月別に有意に異なった（ $F = 751.0, p < 0.01$ ）ことから、体長体重関係式は月別に求めた（Fig.1）。

求めた体重量体長換算式を用いて体重データを体長に変換し、月別に 1cm 階級ごとにまとめた。月別体長組成を 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解を求めた。分析には R（Version 2.7.1 for Windows）を用いた。正規分布の数は、解が得られ、得られた平均値が妥当である最大のものを選択した。

得られた正規分布は野生魚の体長-年齢関係と比較し、年齢を推定した。年齢別体長値は CCSBT で使用されているものを用い、年齢・月別体長は直線内挿した。オーストラリアのまき網による漁獲は 11 月から翌年 4 月に及び、CCSBT でのミナミマグロの年齢区分は 1 月 1 日で変わることとしているが、12 月の n-1 歳魚は n 歳魚とし、1 月以降の n 歳魚と同一年級となるように扱った。

まき網で漁獲した時点の漁獲量を推定した。年齢別体重は、漁期中央の 2 月 1 日時点の年齢別平均体長に Robins(1963)の体長体重関係式を当てはめ、2 歳魚は 10.2kg、3 歳魚は 18.5kg、4 歳魚は 27.1kg、5 歳魚は 36.0kg とした。

豪州政府による漁獲量、年齢組成は、2008 年データ交換で提供された値を用いた。

Ministry of Agriculture, Forestry and Fisheries of Japan requested importers to submit size data on length and weight at harvest for farmed southern bluefin tuna which is imported to Japan after May 2007. The data collected from May 2007 to March 2008 were used for the analysis. A total of 168,556 individual records were analyzed after removing several anomalous records among the collected data (Table 1). Table 2 shows the number of data by product type (fresh SBT and frozen SBT).

Using data of 52,795 individuals which have both length data and weight data, parameters for weight-length relationship were estimated by applying the least square method for logarithmic scaled length (fork length in cm) and weight (gilled and gutted in kg) as follows.

$$FL = a \times PW^b,$$

where FL is fork length in cm, PW is processed weight (gilled and gutted with tail) in kg, and a and b are parameters to be estimated. Because the fatness (PW/FL^3) were significantly different by month ($F = 751.0, p < 0.01$), the weight-length relationships were estimated by month (Fig. 1).

Weight values were converted to length by using the monthly weight-length relationship, and monthly length frequencies with 1 cm bin from April to October 2007 were produced (Fig 2). From two to four normal distributions were applied to decompose the length frequency. The mean, standard deviation and relative strength of each normal distribution were obtained by the non-linear least square method with Gauss-Newton algorithm to minimize the sum of square. The R, version 2.7.1 for windows, was used for calculation. Among the cases with two to four normal distributions, the case with the maximum number which gave appropriate means and standard deviation were chosen.

Age of SBT in the normal distribution was estimated by comparing the length-at-age of wild fish. The length-at-age relationship used in the CCSBT was interpolated lineally by month, and then the length-at-month by age was obtained. The catch of SBT in Australian purse seine fisheries started from November 2006 and ended in April 2007. While the age changes at January 1st in the CCSBT definition, in this document, SBT of age $n-1$ in December was treated as SBT of age n so that treated as the same cohort.

The total catch amount of SBT caught by Australian purse seine fisheries was estimated. Body weights at age, which was used in this estimation, were 10.2 kg for age 2, 18.5 kg for age3, 27.1 kg for age 4 and 36.0 kg for age 5. These were derived by the length at February 1st, which is the middle of the fishing season ranged from November to April and length-weight (whole weight) relationship of young wild fish in Robins (1963).

Total catch amount and age composition submitted by Australia in the 2008 data exchange for SAG/SC were used to compare with the estimated total catch and age compositions.

結果と考察 Results and Discussion

2007年4月から10月の全ての体長頻度は、2個から4個の正規分布に分解された (Fig.2, Table 2)。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。また、生鮮蓄養ミナマグロと冷凍蓄養ミナマグロを区分して分析を行ったところ、両者の結果はよく一致していた (Fig. 3)。

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歳高年齢の魚に含めた。本解析による年齢組成 (2歳魚6%、3歳魚54%、4歳魚36%) と豪州報告の年齢組成 (2歳魚41%、3歳魚55%、4歳魚4%) とは大きな食い違いがある (Fig. 4)。

豪州は、2007年漁期のまき網の漁獲量を5,342トンと報告している。本推定で、まき網による漁獲時の平均体重は21.8kg (原魚重量) であった。これを豪州が報告した363,336尾に掛けると7,934トンとなる。

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。

All of the monthly length frequencies from April and October 2007 were decomposed into two to four normal distributions (Table 2 and Fig. 2). The normal mixed distributions were well fitted to the length frequency distributions on the graph. The correspondences were not met in some months for the large fish more than 130 cm FL. These lead to slightly underestimation of the size and age estimated.

The mean values of the normal distributions were around 92 cm, 106 cm, 120 cm and 130 cm. By comparing to the length-at-age of wild fish, these were corresponded with age 2, age 3 age 4 and age 5, respectively. However, the means between April and August were larger than the length-at-age of wild fish. One of the reasons is rapid growth of farmed fish with sufficient foods in 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 at October would have been reached around May or June by the age of SBT. If this is the case, the mean values of the normal distributions correspond to the

length-at-age of wild fish. The same analysis was also carried out for imported fresh farmed SBT and imported frozen farmed SBT respectively, and the age compositions were quite similar between them (Fig. 3).

Catch by age and total amount of catch by purse seine were reported by Australia. Note that fish caught in November and December 2006 was included in one year older fish in 2007 so that treated as the same cohort. There is quite a large difference between present study (6 % in age2, 54 % in age 3 and 36 % in age 4) and the reported age compositions (36 % in age2, 44 % in age 3 and 12 % in age 4) by Australia (Table 4, Fig. 4).

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 was 7,934 tons, as 1.5 times as reported (Table 4).

Uncertainties of age compositions and total amount of catch put 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 know age compositions and catch amount by Australian surface fishery are required.

References

- 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 data by month for 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データ数

Month of harvest	N_collected	N_collected and anomalous data removed	N_Length & Weight obtained
Feb	56	56	
Apr	368	368	123
May	1,864	1,864	1,441
Jun	2,415	2,415	1,633
Jul	34,872	34,863	4,083
Aug	71,769	71,751	21,346
Sep	41,174	41,168	21,865
Oct	16,071	16,071	2,304
Total	168,589	168,556	52,795

Table 2. Number of collected data by month and by product type (fresh SBT and frozen SBT) for Australian farmed SBT harvested in 2007
 収集したデータの生鮮と冷凍の内訳

Month of harvest	N_weight data		N_both weight and Length measured	
	生鮮 Fresh	冷凍 Frozen	生鮮 Fresh	冷凍 Frozen
Feb	56			
Apr	368		123	
May	1,864		1,441	
Jun	2,415		1,633	
Jul	5,696	29,167	4,083	
Aug	8,126	63,625	5,996	15,350
Sep	6,879	34,289	5,089	16,776
Oct	3,630	12,441	2,304	
Total	29,034	139,522	20,669	32,126

Table 3. Estimated mean length, standard deviation and mixing rate with standard error 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マガ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(±SE)

Month harvested	Apr	May	Jun	Jul	Aug	Sep	Oct
N_normal distribution	2	4	3	4	4	3	4
L_Mean_Age2		93.7 ±0.71	98.1 ±3.63	91.4 ±0.26	91.2 ±0.28	91.8 ±0.29	92.9 ±0.45
L_Mean_Age3	106.0 ±0.19	106.0 ±0.05	106.8 ±0.05	106.4 ±0.05	105.3 ±0.06	105.9 ±0.08	106.5 ±0.07
L_Mean_Age4	117.7 ±0.57	118.2 ±0.21	119.1 ±0.29	119.2 ±0.10	119.6 ±0.13	119.6 ±0.12	120.1 ±0.15
L_Mean_Age5		130.8 ±1.13		130.4 ±1.16	131.1 ±1.66		131.4 ±1.33
L_SD_Age2		3.91 ±0.75	7.57 ±2.36	2.88 ±0.26	3.01 ±0.29	3.73 ±0.30	3.00 ±0.46
L_SD_Age3	3.43 ±0.19	3.32 ±0.06	2.95 ±0.08	4.27 ±0.05	4.48 ±0.07	4.11 ±0.10	4.24 ±0.09
L_SD_Age4	4.02 ±0.58	4.01 ±0.26	4.77 ±0.26	3.74 ±0.12	3.88 ±0.14	4.86 ±0.12	4.03 ±0.16
L_SD_Age5		2.45 ±1.14		4.83 ±0.92	5.35 ±1.29		4.89 ±0.97
%Age2		6.0% ±0.89%	12.7% ±5.04%	4.1% ±0.29%	5.2% ±0.42%	8.8% ±0.55%	3.5% ±0.45%
%Age3	69.9% ±3.46%	70.9% ±1.25%	61.9% ±3.96%	56.8% ±0.60%	55.0% ±0.69%	49.0% ±1.06%	50.5% ±0.84%
%Age4	30.1%	21.5% ±1.08%	25.4%	33.9% ±1.32%	34.1% ±1.68%	42.3%	38.6% ±2.06%
%Age5		1.6%		5.2%	5.7%		7.4%

Table 4. 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

Month harvest	Age1	Age2	Age3	Age4	Age5	Total
Apr			257	111		368
May		112	1,322	400	30	1,864
Jun		306	1,495	614		2,415
Jul		1,425	19,788	11,834	1,817	34,863
Aug		3,737	39,492	24,464	4,057	71,751
Sep		3,612	20,159	17,397		41,168
Oct		568	8,113	6,204	1,185	16,071
Total		9,760	90,627	61,024	7,088	168,500
%		5.8%	53.8%	36.2%	4.2%	100%
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Estimated No. of PS catch		21,045	195,419	131,587	15,285	363,336 ¹⁾
Weight at Feb 1 (kg)		10.2	18.5	27.1	36.0	
Weight at age (ton)		215	3,608	3,561	550	7,934
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Australian reported catch for purse seine ²⁾						
Number	144	150,719	198,101	12,994	1,379	363,336
%	0%	41%	55%	4%	0%	100%
Weight (ton)						5,342

1) Total number of purse seine catch reported from Australia.

2) Fish caught in November and December 2006 was included in one year older fish in 2007.

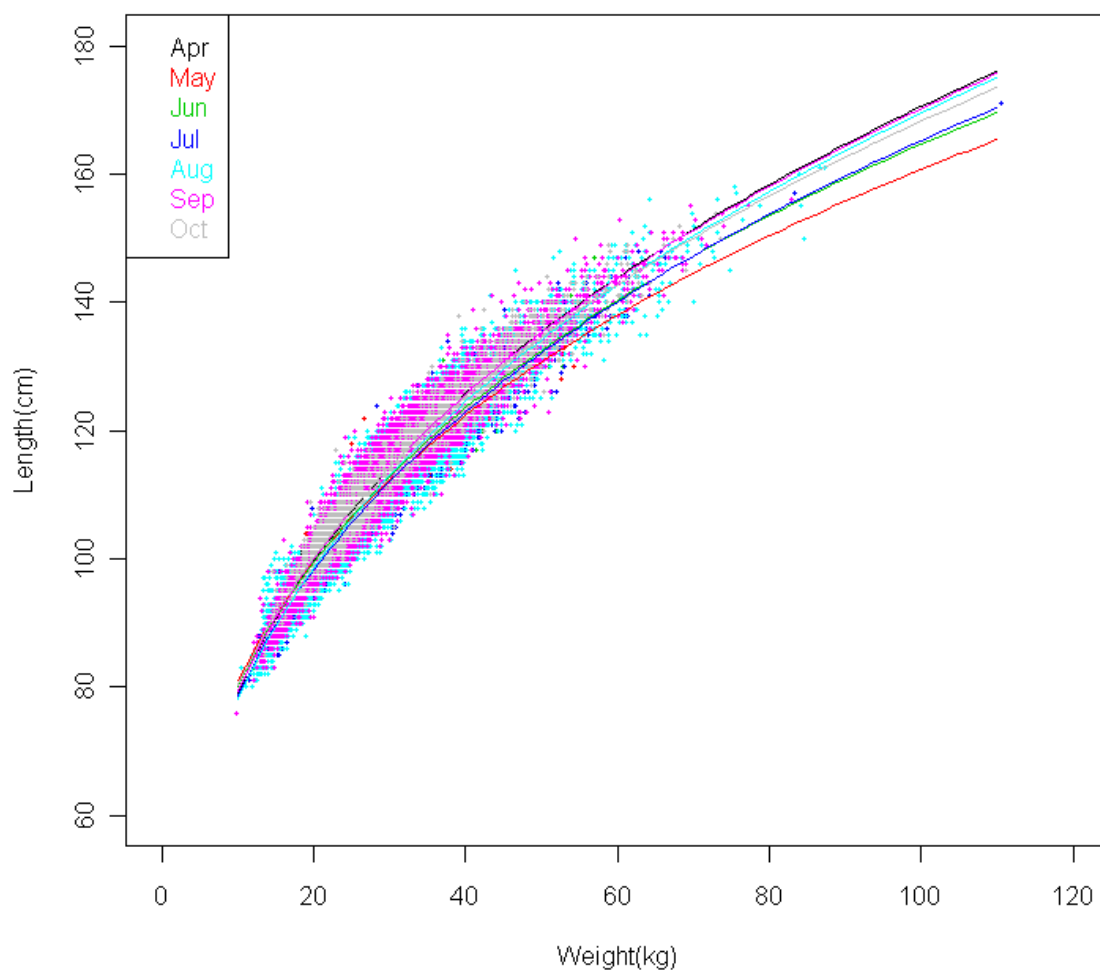


Fig. 1. Monthly weight (gilled and gutted in kg) – length (fork length in cm) relationship of Australian farmed SBT harvested in 2007

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=52,795.

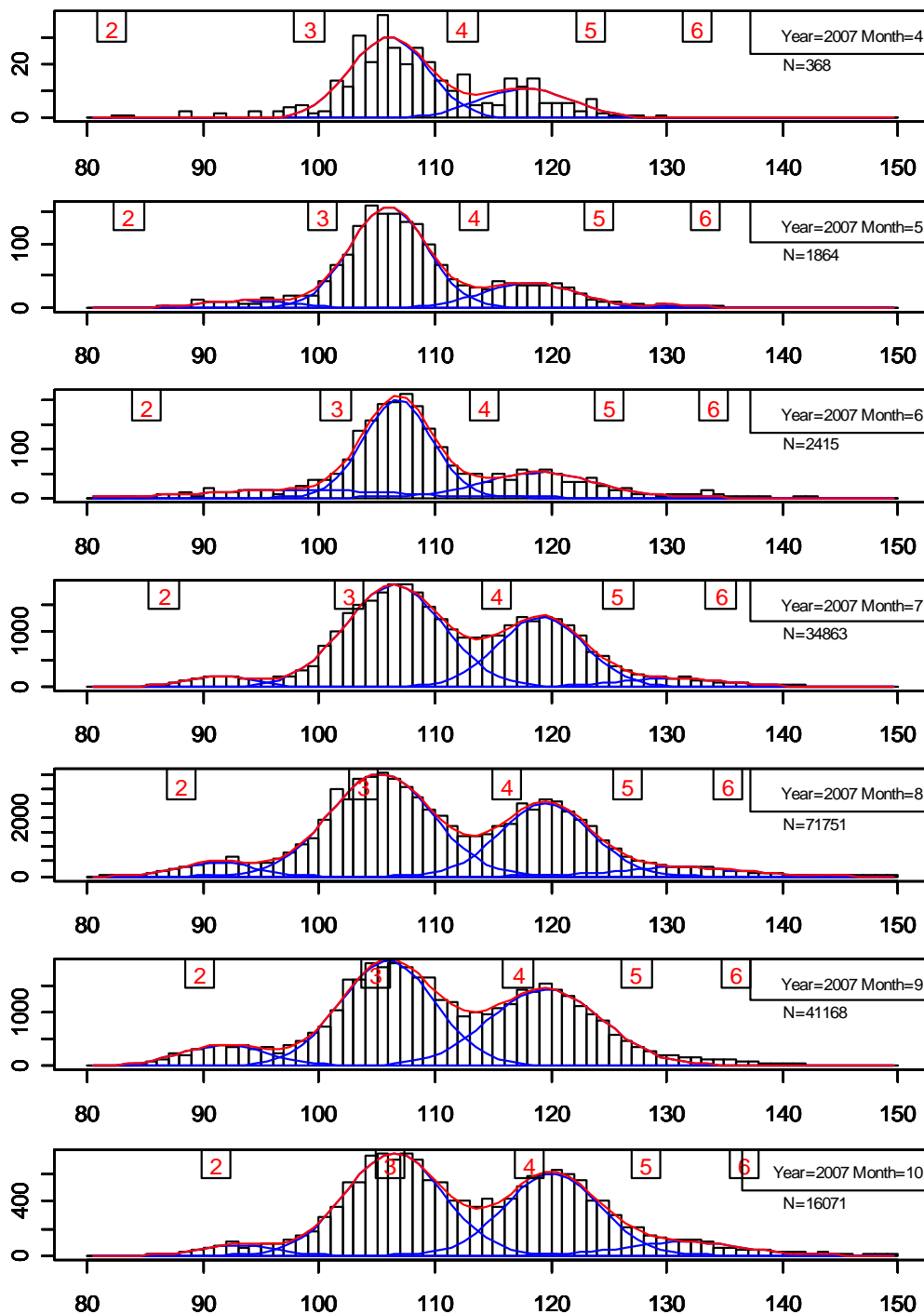


Fig. 2. Monthly length frequency and estimated probability density function of the normal mixture distribution of farmed SBT at harvest. Mean monthly length at age of wild fish is shown in square.

畜養ミナマガロ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。

Fresh

Frozen

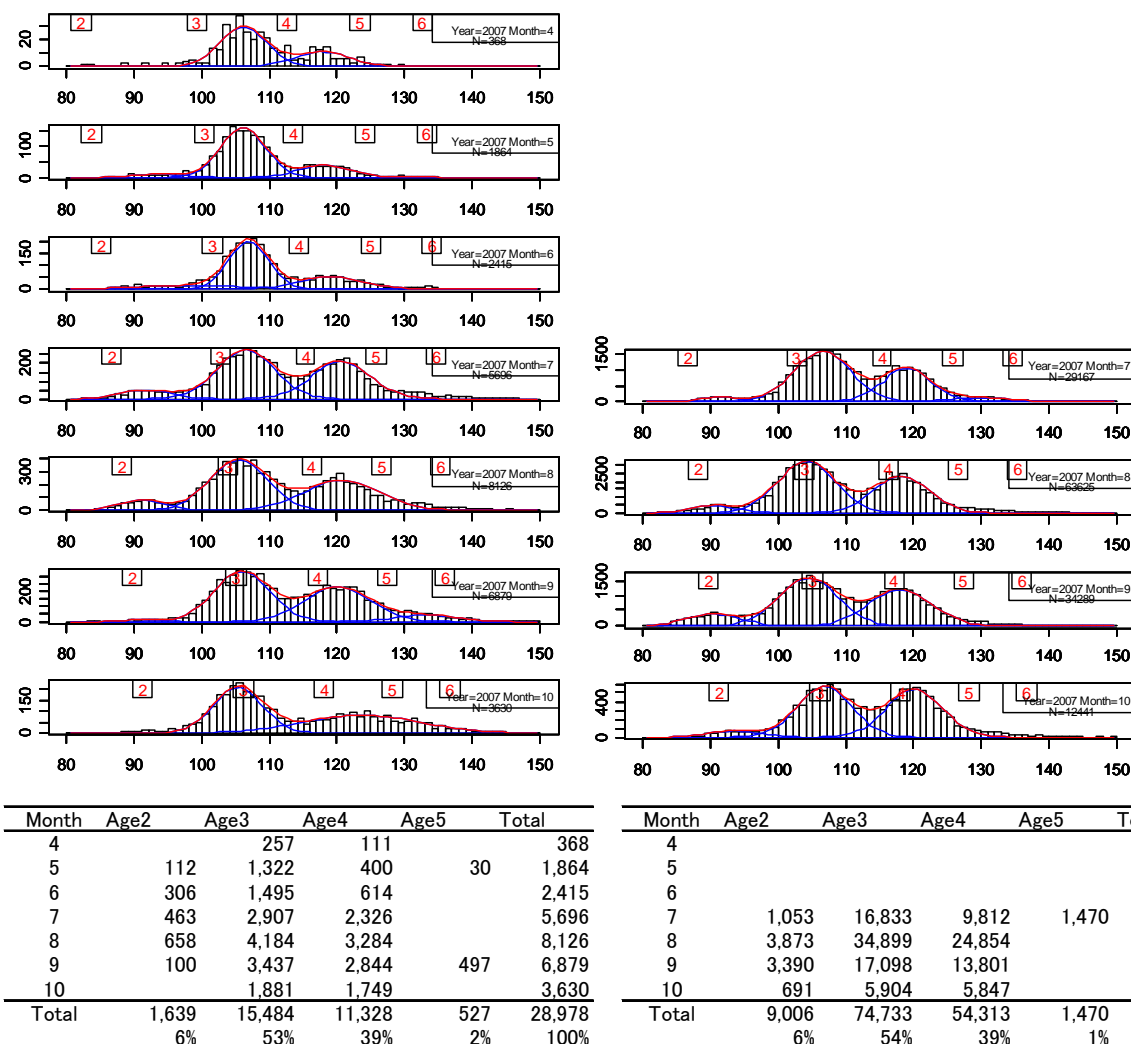


Fig. 3. Monthly length frequency and estimated probability density function of the normal mixture distribution of farmed SBT at harvest by product type (fresh farmed SBT and frozen farmed SBT). Mean monthly length at age of wild fish is shown in square.

生鮮と冷凍を分けた畜養ミナミマグロ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。

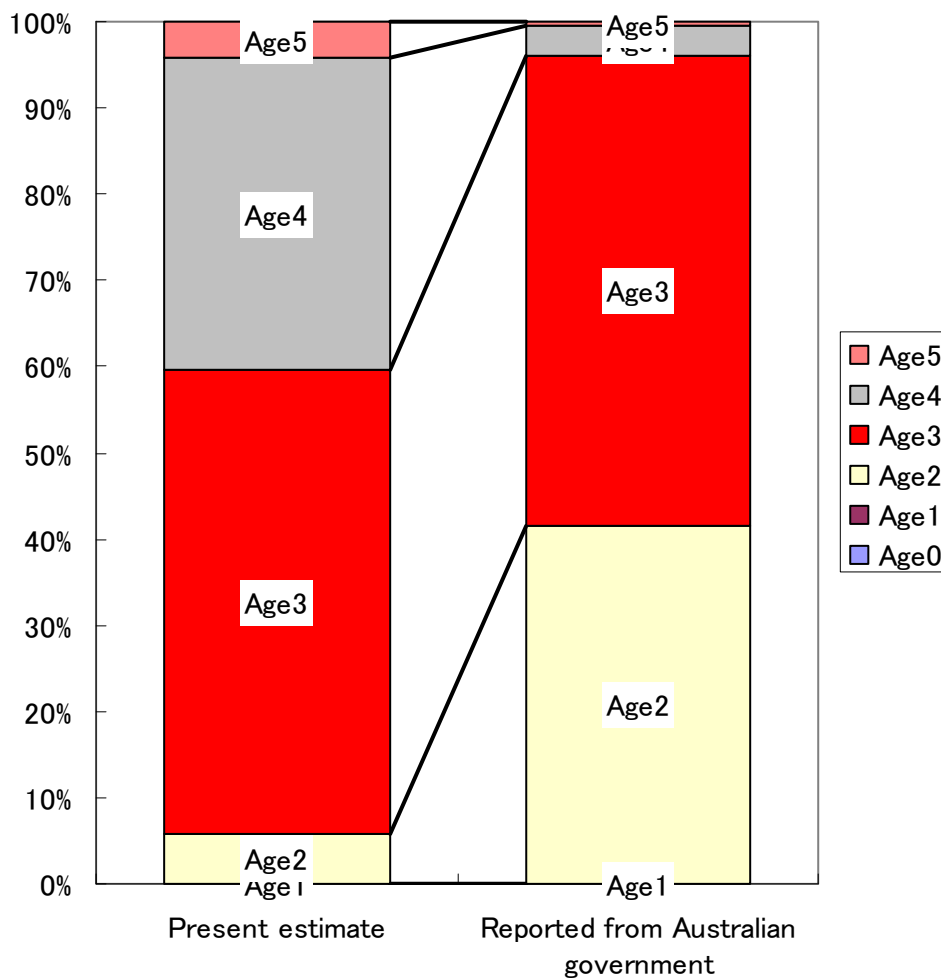


Fig. 4. Comparison of age compositions (in number) estimated in the present study with those reported by Australia to the CCSBT

Fish caught in November and December 2006 was included in one year older fish 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歳高年齢の魚に含めた。