2012年ミナミマグロ曳縄調査でのミナミマグロの亜年級構造

Sub-cohort structure of southern bluefin tuna in the recruitment monitoring trolling survey in 2012

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要約

ミナミマグロ加入量曳縄調査が実施された西オーストラリア州南岸におけるミナミマグロの年別体長を比較した。16年間の内で1996年から2010年までの14年間では尾叉長50 ㎝前後の魚が大きな割合を占めていた。しかし、2011年と2012年には、50 ㎝前後の魚も見られたものの60-70 ㎝の魚も多くみられ、過去の年と大きく異なっていた。ミナミマグロの発生時期には10月と2月の二つのピークがあると仮定した上で、既存の研究結果の成長率を用いると、多くの年で対象としてきた50 ㎝前後の魚は2月生まれ亜年級の1.0歳魚、2011年と2012年に見られた60 ㎝前後の魚は10月生まれ亜年級の1.3歳魚と考えられた。2011年のBremer Bay沖では2月生まれ1.0歳魚が97%を構成したのに対し、2012年のBremer Bay沖では2月生まれ1.0歳魚が33%、10月生まれ1.3歳魚が45%を構成したと推測された。亜年級を単位として考慮することがミナミマグロ加入量モニタリングの精度向上や資源動態の把握には重要である。

Summary

Annual SBT length frequencies were compared for fish in southern Western Australia where recruitment monitoring surveys conducted. It was observed that SBT around 50 cmFL had formed a large part in 14 years from 1996 to 2010 among 16 years. However, many SBT around 60-70 cmFL were also observed in 2011 and 2012, which was quite different with previous 14 years. Given two peaks of spawning in October and February and using daily growth rate in reported study, it was estimated that SBT around 50 cmFL was sub-cohort occurred in February and at age-1.0 and that SBT around 60 cmFL observed in 2011 and 2012 was sub-cohort occurred in October and at age-1.3. It was estimated that sub-cohort occurred in February in age-1.0 formed 33% and sub-cohort occurred in October in age-1.3 formed 45 % off Bremer Bay in 2012 while sub-cohort occurred in February in age-1.0 formed 97% for SBT off Bremer Bay in 2011. It is important to consider SBT recruitment stock based on sub-cohorts, not only on cohort, in

order to improve recruitment monitoring index and understanding of SBT stock dynamics.

1. Introduction

The recruitment monitoring of age-1 southern bluefin tuna (*Thunnus maccoyii* SBT) has been carried out since 1989 off Western Australia (Itoh et al. CCCSBT-ESC /1208/33). The SBT collected off southern WA had been mainly around 50 cm in fork length (FL) for many years. However, size distribution of SBT collected in the trolling monitoring survey conducted between January and February 2012 was quite different with those in previous years (Itoh et al. CCSBT-ESC/1208/33). It was reported that there are two peaks of longline catch rate for adult SBT in the spawning area in October and February within the spawning period which ranged from September to April (Mimura and Warashina 1962, Shingu 1970, Farley and Davis 1998). It suggests two sub-cohort for recruitment SBT stock. We examined SBT length distribution in the 2012 trolling survey in terms of sub-cohort.

2. Materials and methods

The SBT length data were collected from the acoustic monitoring surveys between 1996 and 2006 and trolling surveys between 2006 and 2012, those of which caught by trolling. Two areas concerned were defined as the whole area the surveys covered off the southern WA (117E-124E) and off Bremer Bay where the piston-line laid (119E-120E).

At first, because the survey periods extend in several months between December of the previous year and March, effect of difference in time of SBT catch on the SBT size was examined first. Growth during age-0 to age-2 was assumed as follows from the results based on otolith daily increment (Itoh and Tsuji 1996).

$$Y = 240.4 + 0.761X \quad (1),$$

where Y denotes fork length in millimeter and X denotes the number of otolith increment.

This growth rate (0.761mm/day) was applied, length at 1st February was estimated and length frequency distribution was made.

Then, compositions of cohorts/sub-cohorts were estimated by applying mixed normal distribution for length frequency distribution in 2011 and 2012. Firstly, expected length at 1st February for cohort/sub-cohort was calculated (Table 1). The growth rate mentioned above was applied to length at age used in CCSBT at 1st January after the 1980 cohort, 49.4 cmFL in age-1 and 79.4 cmFL in age-2. The length of age-0 occurred in October was calculated from the equation (1). Next, parameters of mixed normal distribution were estimated as to minimize the residuals by using the non-linear least square method (Itoh et al. CCSBT-ESC/1009/21). The initial values used were that mean lengths were which calculated above, standard deviations were 2.0 cm mainly and mixed rate were arbitrary. The estimated parameter values were compared with the expected lengths of sub-cohorts

3. Results

Fig. 1 shows annual length frequency of SBT off southern WA between 1996 and 2012. It was observed that SBT around 50 cmFL had formed a large part in 14 years from 1996 to 2010 among 16 years. However, many SBT around 60-70 cmFL SBT were also observed in 2011 and 2012, it is quite different with previous 14 years.

Fig. 2 shows annual length frequency off Bremer Bay where relates to the trolling index. It was observed that SBT around 50 cmFL had formed a large part up to 2011, however, many SBT around 60-70 cmFL were also observed in 2012.

The length frequencies that adjusted to at 1st February show little difference with those of original length frequencies. It was observed convergence on around 50 cmFL in some degree. The difference of survey period was not able to explain the difference of annual length frequencies. There were some years that length mode were close to the expected length of age-1.0 SBT occurred on February 49.4 cm FL at 1st February (e.g. 2005, 2006), though that were larger in several years (2001, 2007, 2008).

In the mixed normal distribution examination, the parameter values were estimated for two normal distributions in 2011 and four normal distributions in 2012 for both whole the southern WA and off Bremer Bay. The derived mixed normal distributions agreed well with the length frequencies (Fig. 5-8). In particular, the length which expected for sub-cohort occurred in February in age-1.0(49.4 cmFL) were agreed well with the length modes. To the length which expected for sub-cohort occurred in October in age-1.3 (58.8 cmFL), modal lengths of the length frequencies were larger in 3-5 cm and its standard deviations were larger than those of sub-cohort occurred in February (Fig. 5, Fig. 7, Fig. 8). To the length which expected for sub-cohort occurred in October in age-0.3 (33.4 cmFL), modal lengths of the length frequencies in 2012 were close though slightly smaller than that (Fig. 7, Fig. 8).

It was estimated that sub-cohort occurred in February in age-1.0 formed 58% and sub-cohort occurred in October in age-1.3 formed 42 % in the southern WA in 2011 (Table 2). For SBT off Bremer Bay in 2011, sub-cohort occurred in February in age-1.0 formed majority as 97%.

It was estimated that sub-cohort occurred in February in age-1.0 formed 40% and sub-cohort occurred in October in age-1.3 formed 50 % in the southern WA in 2012 (Table 3). For SBT off Bremer Bay in 2012, it was estimated that sub-cohort occurred in February in age-1.0 formed 33% and sub-cohort occurred in October in age-1.3 formed 45%.

As for previous years, it was estimated that sub-cohort occurred in February in age-1.0 formed its majority based on Fig. 3.

4. Discussion

It appears that the difference of length frequency related with abundance of sub-cohorts in the survey area of southern WA in austral summer season. Because length mode around 50 cmFL agreed well with the expected length of sub-cohort occurred in February, SBT collected in many years of the survey was considered to be sub-cohort occurred in February.

Larger SBT with length mode at 61-63 cmFL in 2011 and 2012 off southern WA was likely to belong to sub-cohort occurred in October. However there were 3-5 cm length difference between expected and observed. This could be attributed whether sub-cohort occurred in October attain faster growth (truly fast growth, or just resulted in slow grown fish did not distribute this area), the sub-cohort included not only fish occurred in October but also that in September, or the sub-cohort included slow grown age-2 fish. We did not reach conclusion at this stage.

Another question is that why sub-cohort occurred in October in age-1.3 appeared only in 2011 and 2012, or where were they distributed in previous years. It is also unknown at present.

Therefore, it is important to consider SBT recruitment stock based on sub-cohorts, not only on cohort, and to investigate season and area of each sub-cohort occurred, subsequent migration and distribution of them and environmental factors which affects on abundance of occurrence of them, in order to improve recruitment monitoring index and understanding of SBT stock dynamics.

References

Farley, J.H., and Davis, T.L.O. (1998) Reproductive dynamics of southern bluefin tuna, *Thunnus maccoyii*. Fish. Bull. 96: 223-236.

Itoh, T., Kawashima, T., and Yamamoto, T. (2010) Analysis of age composition of southern bluefin tuna used for farming in 2009. CCSBT/ESC/1009/21.

Itoh, T., Sakai, O., and Tokuda, D. (2011) Report of the piston-line trolling survey in 2011/2012. CCSBT-ESC/1208/33.

Itoh T., and Tsuji, S. (1996) Age and growth of juvenile southern bluefin tuna *Thunnus maccoyii* based on otolith microstructure. Fish. Sci. 62: 892-896.

Mimura and Warashina (1962) Studies on Indomaguro (*Thunnus maccoyii*?) – Description of the development of the fishery, geographical difference and seasonal change of distribution and relation which is seen among Indomaguro, Southern bluefin and Goshumaguro distributions. Rep. Nankai Reg. Fish. Res. Lab. 16:135-154. (in Japanese with English abstract)

Shingu, C. (1970) Studies relevant to distribution and migration of the southern bluefin tuna. Bull. Far Seas Fish. Res. Lab. 3: 57-113. (in Japanese with English abstract)

Table 1 Age and expected fork length at 1st February for four length modes

	1st mode	2nd mode	3rd mode	4th mode
Assumed season of occurrence	Oct. 2011	Feb. 2011	Oct 2010	Feb. 2010
Age corresponded	Age 0.3	Age 1.0	Age 1.3	Age 2.0
Expected length at 1st February	33.4 cmFL	49.4 cmFL	58.8 cmFL	79.4 cmFL

Table 2 Estimated parameter values of mixed normal distributions which applied for length frequency in 2011 in whole the survey area and off Bremer Bay

	1st mode	2nd mode	3rd mode	4th mode
SBT in whole the survey area in 2011				
Mean length		49.6 ± 0.21 cm	61.3 ± 0.57 cm	
Standard Deviation		1.4 ± 0.21 cm	0.5 ± 0.6 cm	
Proportion		58.0 ± 4.02 %*)	42.0 ± 4.02 %*)	
SBT off Bremer Bay in 2011				
Mean length		49.1 ± 0.06 cm	59.5 ± 0.52 cm	
Standard Deviation		2.2 ± 0.05 cm	4.4 ± 0.27 cm	
Proportion		96.5 ± 1.81 %*)	3.5 ± 1.81 %*)	

Value following ± is standard error of mean. *) denotes the standard error was calculated with delta method.

Table 3 Estimated parameter values of mixed normal distributions which applied for length frequency in 2012 in whole the survey area and off Bremer Bay

	1st mode	2nd mode	3rd mode	4th mode
SBT in whole the survey area in 2012				
Mean length	32.1 ± 0.34 cm	47.1 ± 0.21 cm	63.7 ± 0.68 cm	81.9 ± 5.73 cm
Standard Deviation	1.2 ± 0.35 cm	2.3 ± 0.21 cm	5.8 ± 0.7 cm	1.9 ± 5.63 cm
Proportion	9.2 ± 2.19 %	40.1 ± 3.13 %	49.6 ± 4.01 %	1.1 ± 5.53 %*)
SBT off Bremer Bay in 2012				
Mean length	32.0 ± 0.42 cm	47.6 ± 0.45 cm	63.6 ± 0.92 cm	80.5 ± 2.04 cm
Standard Deviation	1.4 ± 0.45 cm	2.2 ± 0.44 cm	4.4 ± 0.87 cm	1.4 ± 1.99 cm
Proportion	18.0 ± 4.6 %	33.0 ± 5.24 %	45.4 ± 6.26 %	3.7 ± 9.37 %*)

Values following ± is standard error of mean. *) denotes the standard error was calculated with delta method.

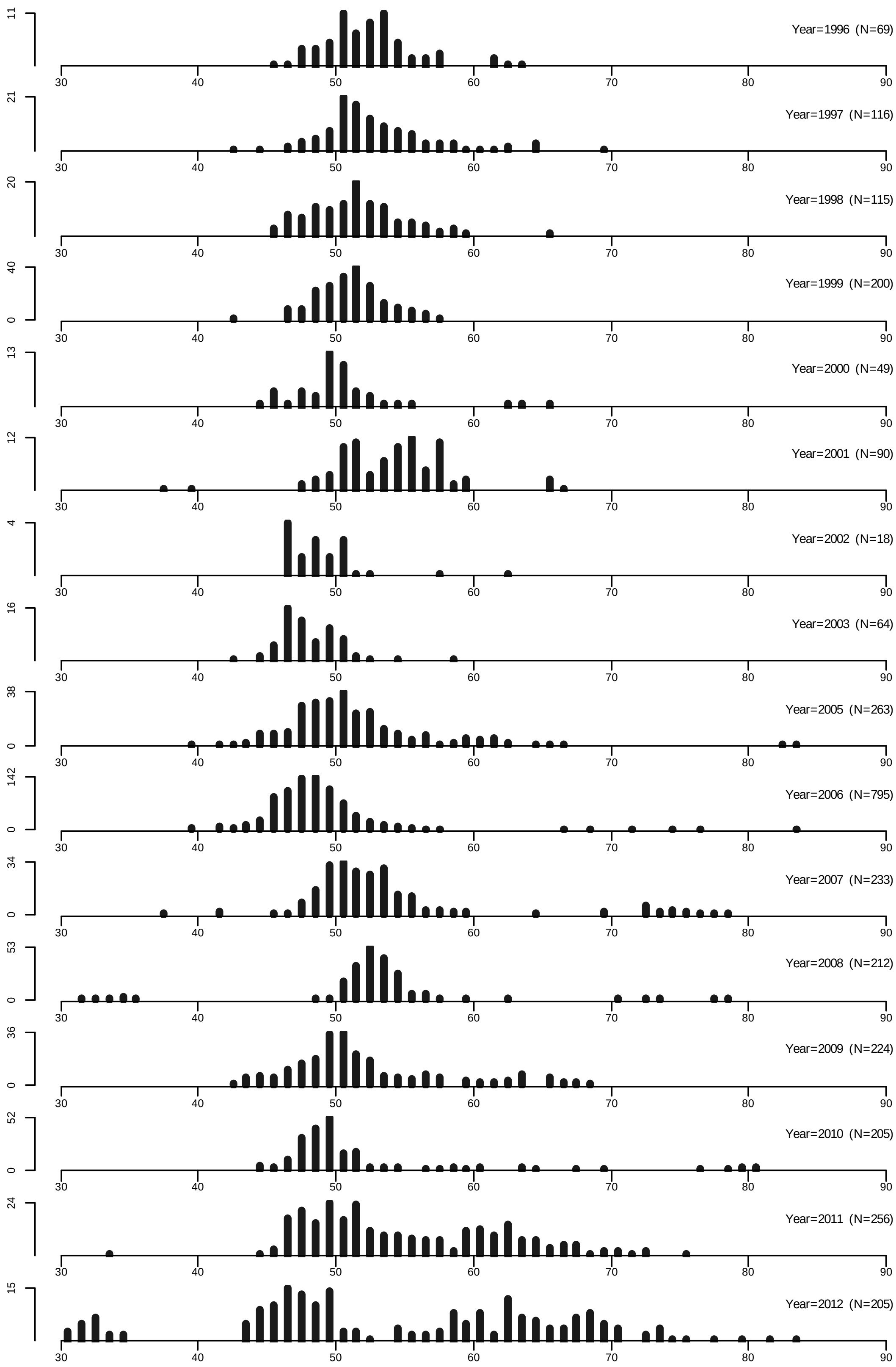

Fig. 1 SBT length frequency off southern Western Australia where recruitment surveys conducted.

X axis shows fork length in cm. Data came from the acoustic survey in 1996-2006 and the trolling survey in 2006-2012.

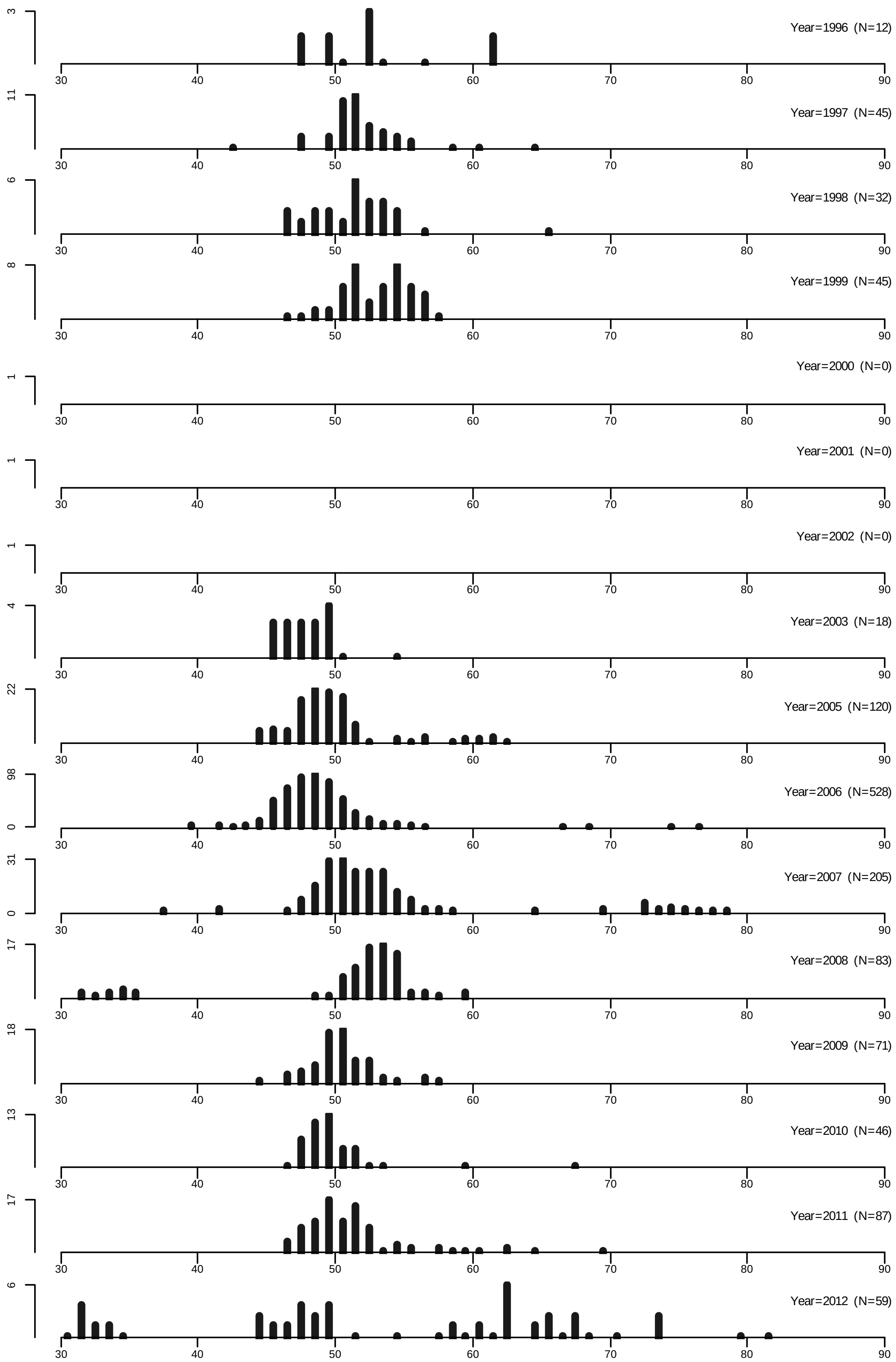

Fig. 2 SBT length frequency off Bremer Bay in southern Western Australia (119E-120E) in the recruitment surveys.

X axis shows fork length in cm. Data came from the acoustic survey in 1996-2006 and the trolling survey in 2006-2012.

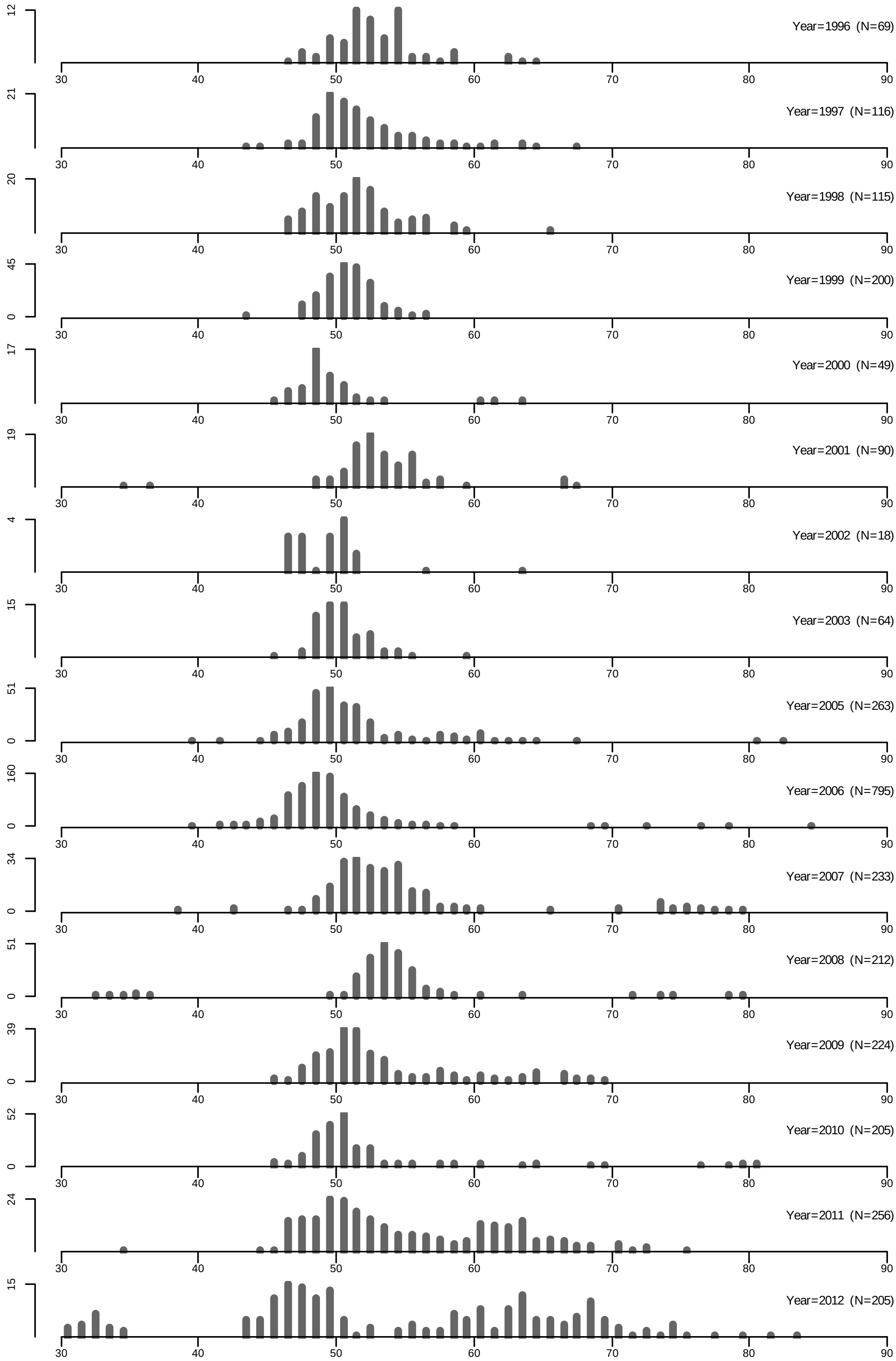

Fig. 3 SBT length frequency adjusted to be caught on 1st February off southern Western Australia where recruitment surveys conducted.

X axis shows fork length in cm. Data came from the acoustic survey in 1996-2006 and the trolling survey in 2006-2012.

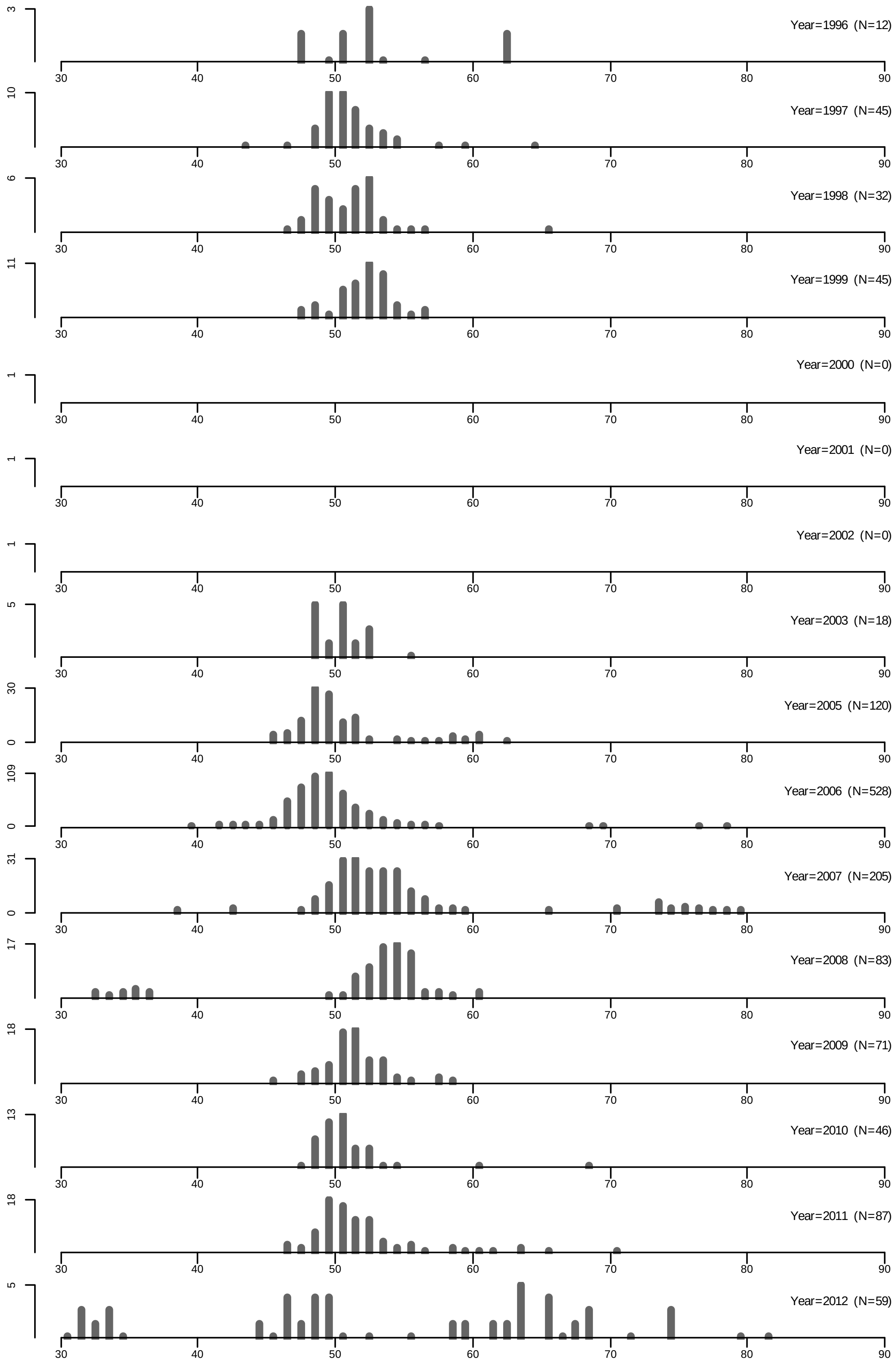

Fig. 4 SBT length frequency adjusted to be caught on 1st February off Bremer Bay in southern Western Australia (119E-120E) in the recruitment surveys.

X axis shows fork length in cm. Data came from the acoustic survey in 1996-2006 and the trolling survey in 2006-2012.

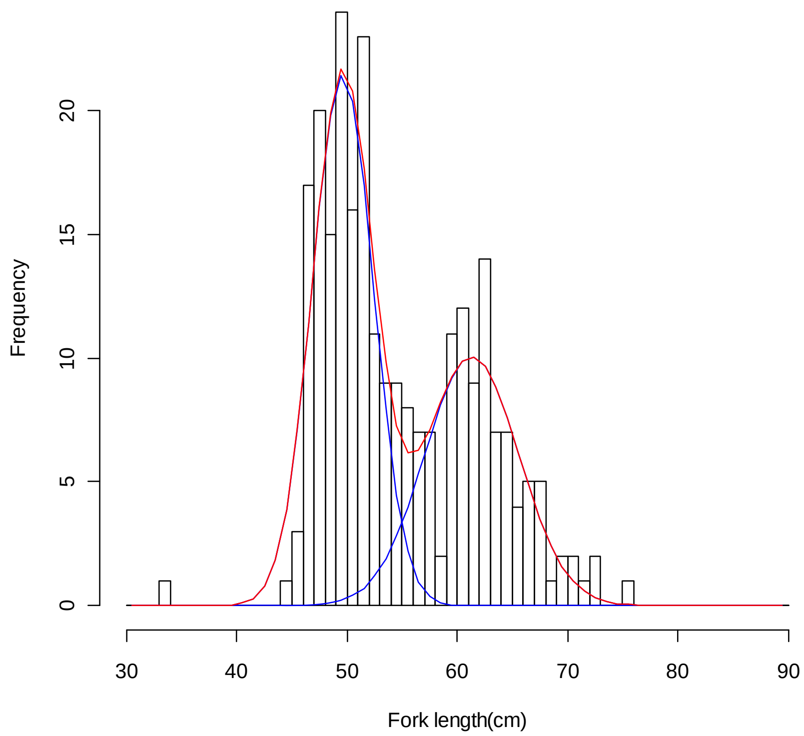

Fig. 5 SBT length frequency off whole the southern Western Australia in 2011 and applied mixed normal distribution with two normal distributions.

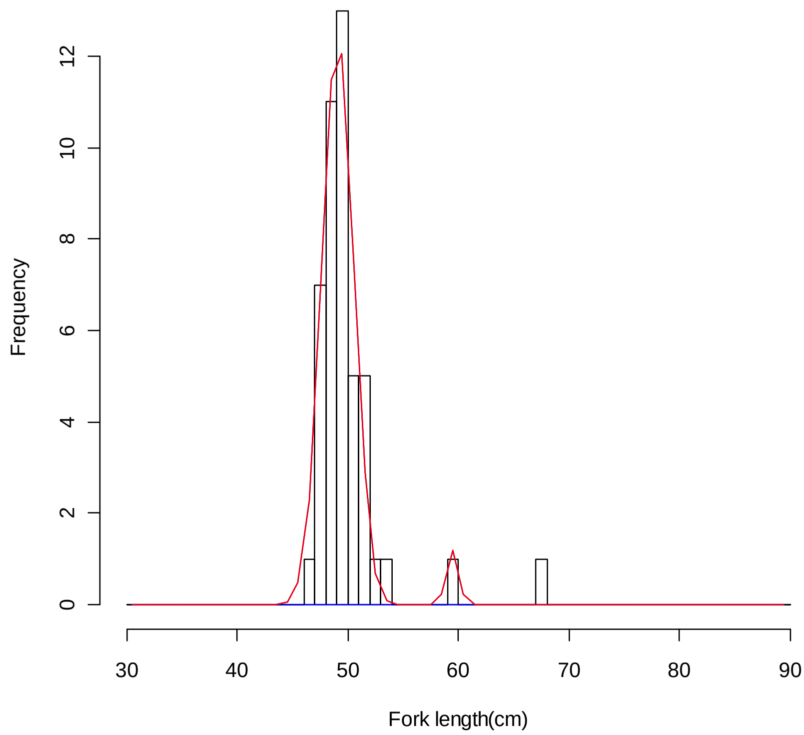

Fig. 6 SBT length frequency off Bremer Bay in 2011 and applied mixed normal distribution with two normal distributions.

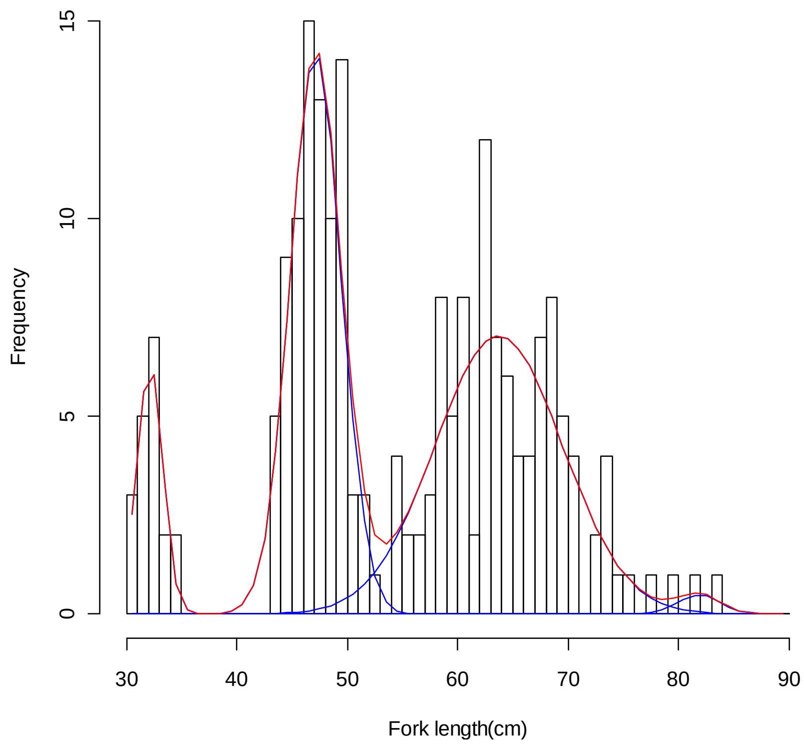

Fig. 7 SBT length frequency off whole the southern Western Australia in 2012 and applied mixed normal distribution with four normal distributions.

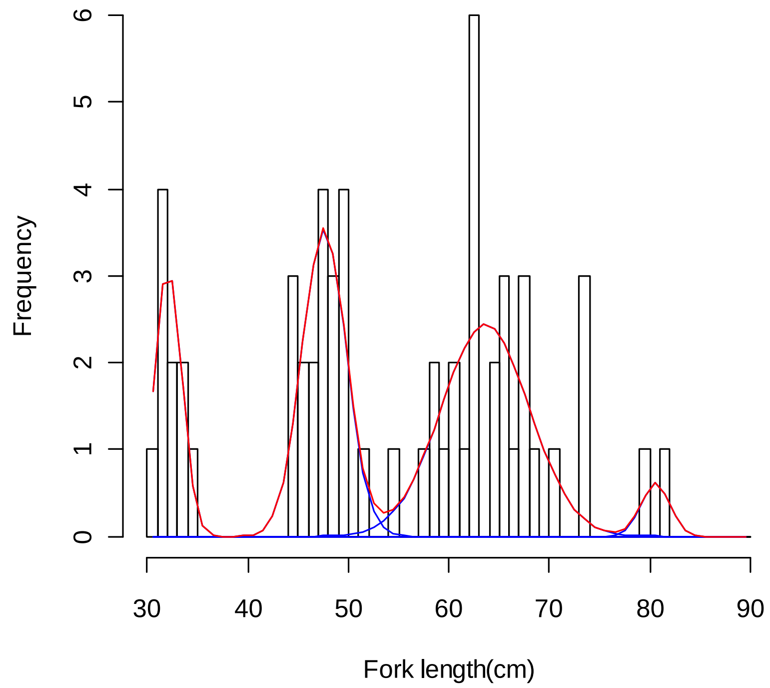

Fig. 8 SBT length frequency off Bremer Bay in 2012 and applied mixed normal distribution with four normal distributions.