J. Fish. Soc. Taiwan, **21**(2): 121-137 (1994)

Age Structure of Spotted Mackerel, *Scomber australasicus*, in the Coastal Waters of Taiwan as Estimated from Polymodal Length-Frequency Analysis

Jui-Feng Ku[1,2] and Wann-Nian Tzeng[1]

(Received April 1, 1994; Accepted June 10, 1994)

ABSTRACT

The age structure of spotted mackerel, *Scomber australasicus* Cuvier & Valenciennes, in the coastal waters of Taiwan in 1981 ~ 1983 was estimated from length frequency distribution using Bhattacharya's polymodal analysis. The age composition of spotted mackerel varied with area and season. In the waters off Pengchiahsu and Fishing Islands northeastern Taiwan, the mackerels were consisted of 1^+ to 3^+ year old fish during the good fishing seasons (autumn and winter), and 2^+ and 4^+ year old fish during the poor fishing seasons (spring and summer). In the waters off northern Pratas Islands southwestern Taiwan, the mackerels consisted of 2^+ to 5^+ year old fish in spring, but dominant with 3^+ and 4^+ year old fish. Except for the old fish, the mean length and proportion of mixture of age groups estimated both from polymodal length-frequency analysis as well as from scale reading was corresponding each other. Therefore, Bhattacharya's polymodal analysis was considered to be a reliable method for estimating age composition of the spotted mackerel.

Key words: Scomber australasicus, *Length composition, Bhattacharya's polymodal frequency analysis, Age structure, Taiwan.*

INTRODUCTION

Most analytical models of fish population dynamics depend largely on a knowledge of growth and mortality rates. For estimating the rates of growth, survival, fishing of a recruited population, it is desirable to determine the age of individual fish and the age composition of the catch (Ricker, 1975). The age and growth of spotted mackerel in the coastal waters of Taiwan have been studied previously (Ku and Tzeng, 1985). However, the age composition of the fish was not still understood yet.

In the recent years, many authors considered that age determination by reading age marks on the scales and other skeletal structures of the fish is time consuming, and sometimes almost impossible as in the case of many tropical fishes. Even though, approximately 80% of the rings on the scale of spotted mackerel were clearly observed (Ku and Tzeng, 1985). It is tedious and time consuming works in data acquisition of

[1] Department of Zoology, College of Science, National Taiwan University, Taipei, Taiwan 107.
[2] Present address: National Science Council, Executive Yuan, Taipei, Taiwan, 107.

large sample size by scale reading method.

Estimation of age composition is possible from length-frequency distribution data by separating the components of a polymodal length-frequency curve (Harding, 1949; Cassie, 1954; Tanaka, 1962; Bhattacharya, 1967; Schnute and Fournier, 1980; Foucher and Fournier, 1982; Pauly, 1983). Bhattacharya method is considered to be the most simple one (FAO, 1981). In this paper, we use this method to examine the age composition of spotted mackerel in the coastal waters of Taiwan.

MATERIALS AND METHODS

I. Estimation of length frequency distribution of the catch

The experimental fish was caught by the Taiwanese large-type purse seiner in the waters off Pengchiahsu-Fishing Island and northern Pratas Islands during November 1981 through October 1983 (Fig. 1). Fork length of the fish was measured in the Nan-fanao fish market with a needle by punching hole on a 0.5 cm interval marked water proof paper fixed on a wooden measuring board. The length composition of the catch was estimated monthly from the length composition of the sample and the total catches of the four large-type purse seiners (Table 1) as follows:

$$N_i = N * P_i \quad \text{.................... (1)}$$

$$N = Wt / \overline{Wt} \quad \text{.................... (2)}$$

where N_i: The number of the fish in the ith length stratum,

P_i: Frequency of the fish in the ith length stratum of the sample,

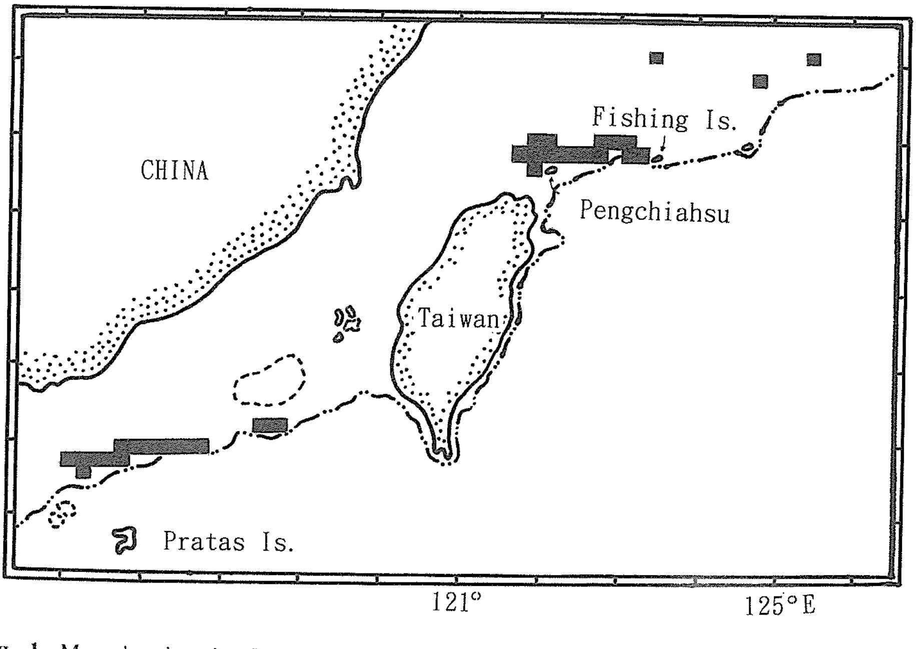

Fig. 1. Map showing the fishing grounds of large type purse seiner for spotted mackerel fishery in the continental shelf off northeastern and southwestern Taiwan. The black blocks indicate the sampling areas of the fish.

Table 1. Monthly catches of spotted mackerel (*Scomber australasicus*) from Taiwanese large type purse seiner operated in the waters off Pengchiahsu-Fishing Island and off northern Pratas Islands, Nov 1981 — Oct 1983.

		Catch (Tons)	
		Pengchiahsu and Fishing Islands	Northern Pratas Islands
Nov	1981	574	
Dec		75	
Jan	1982	419	
Feb			
Mar		85	745
Apr			519
May			120
June		130	294
July		315	
Aug		1025	
Sep		1390	
Oct		965	
Nov		730	
Dec		440	
Jan	1983	190	
Feb		1225	
Mar		438	
Apr		5	748
May			780
June		643	
July		75	
Aug		180	
Sep		405	
Oct		334	

N: The total number of fish in the catch,
Wt: Total weight of the catch, and
$\overline{Wt}$: Mean weight of one fish in the sample.

II. Estimation of age composition by age-length key

Based on the length composition of the catch and the age-length key established by age and growth studies (Ku and Tzeng, 1985), the age composition of the catch was estimated as follows:

$$aj = \sum_{i}^{n} Ni * Aij \quad \ldots\ldots\ldots\ldots\ldots\ (3)$$

where aj: The number of j aged fish in the catch,
Ni: The number of fish in ith length stratum, and
Aij: The probability of j aged fish appeared in the ith length stratum (age-length key).

III. Analysis of polymodal length-frequency distributions

The component of the length frequency distribution of the catch were analyzed by Bhattacharya method and compared with the age composition obtained from age-langth key. The Bhattacharya methed consists basically of separating normal distribution, each representing a cohort of fish, from the overall distribution, starting on the left-hand side of the total distribution. Once the first normal distribution has been determined it is removed from the total distribution and the same procedure is repeated as long as it is possible to separate normal distribution from the total distribution (Sparre, et al., 1989). The length frequency distributions obtained from the sample are usually skew and polymodal. In many cases, the modes correspond to individual age group and are very helpful for separating them. The computation procedure of the Bhattacharya polymodal length-frequency analysis was summarized as follows:

(I) Let y(x) be the observed frequency in the class with x as the mid-point and the class interval, then plot D log y against x on ordinary graph paper and look for regions where graph look like straight line with negative slope. Each line represents each one of age components. D log y = log y (x+h) − log y (x).

(II) To find out the mean (m_r) and standard deviation (Sr^2) of each r component.

$$m_r = Ir + h/2 \quad \dots\dots\dots\dots\dots\dots (4)$$

where m_r: The mean of the rth component, and
I_r: The intercept of the rth line.

$$Sr^2 = (dhcotAr/b) - h^2/12 \quad \dots (5)$$

where S_r: The standard deviation of the rth component,
A_r: The angle the rth line makes in the negative direction with the X-axis,
b: The relative scales of x, and
d: The relative scales of D log y.

(III) To calculate an estimate of the total frequency of the rth component (Nr). Nr is given by:

$$Nr = \Sigma y/\Sigma Pr \quad \dots\dots\dots\dots\dots\dots\dots (6)$$

$$Pr(x) = P\{(x+h/2-m_r) / S_r\} - P\{(x-h/2-m_r)/S_r\} \quad \dots\dots (7)$$

where y: Summation of the observed frequency of the concerned class, and
Pr: The distribution function of a standard normal deviate.

RESULTS

I. Monthly change of length frequency distribution

The length frequency distribution of the spotted mackerels in the waters off Pengchiahsu and Fishing Islands during the period from November 1981 to Octobor 1983 was shown in Fig. 2. It ranged from 20 cm to 40 cm in fork length. The main mode apparently shifted with seasons because of growth and recruitment of diffrent age groups. There is one 25~27 cm fish group appeared in November and December 1981, it grew to 30-35 cm in summer of the following year and became over 35 cm in the third year. The newly recruited fish, about 25 cm, always appeared from late summer to early winter.

In the waters off northern Pratas Islands, the spotted mackerels were relatively larger, ranged from 27 cm to 40 cm during the period from February to May (Fig.3). The mode length is 33-34 cm in February 1982, 34-35 cm in March, 36-37 cm in April and mixed with a small sized fish group in May. It also showed that modal length obviously shifted with season because of growth.

Polymodal analysis of the length-frequency distribution of the fish was conducted by season. Four seasons are defined as spring (March~May), summer (June~August), autumn (September~November) and winter (December~February). The monthly percentage length-frequency distribution of the sample (Figs. 2&3) was magnified by catch and combined by seasons to represent the length frequency distribution of the catch in number of the fish (Fig. 4). There are two peaks in the catch for the length frequency distribution of the spotted mackerels in the waters off Pengchiahsu and Fishing Islands during autumn season, one located at 26-28 cm; the other at 33-34 cm. But these two peaks seem to shift to large length class in winter. The former one became 28-29 cm, the latter one 34-35 cm. In the following spring,

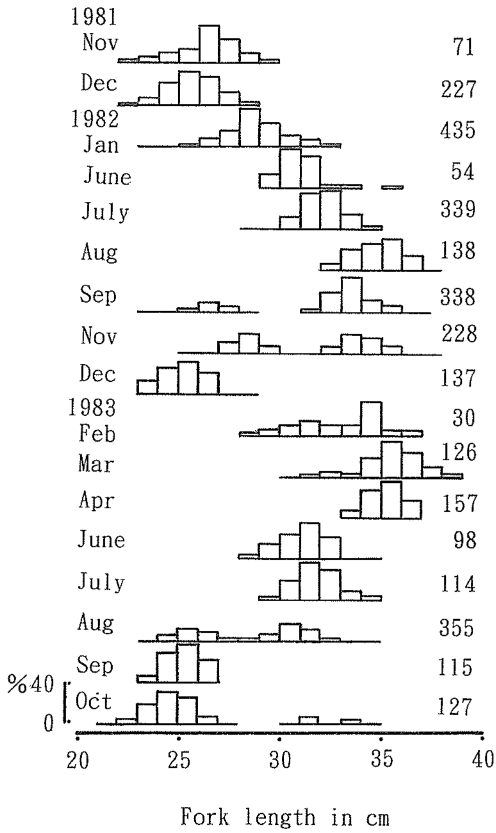

Fig. 2. Monthly length frequency distribution for the sample of spotted mackerels collected from the waters off Pengchiahsu and Fishing Islands, November 1981 — October 1983. Figures in the diagram indicate the sample size.

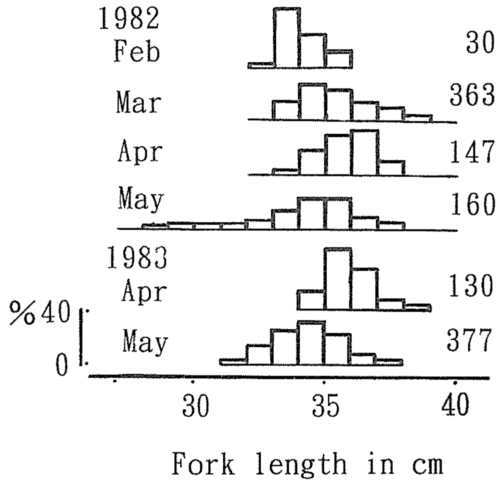

Fig. 3. Monthly length frequency distribution for the sample of spotted mackerels collected from the waters off northern Pratas Islands. Figures in the diagram indicate the sample size.

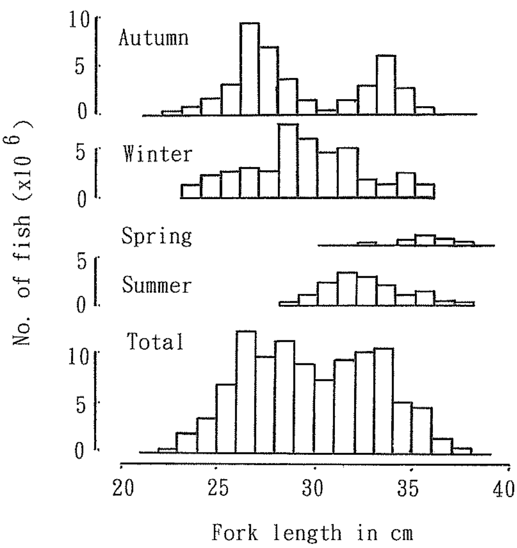

Fig. 4. Seasonal length frequency distribution for the catch of spotted mackerels collected from the waters off pengchiahsu and Fishing Islands during November 1981 to October 1983.

length frequency distribution seems to become mono-peak, appearing at 35-36 cm which may be originated from the latter peak in the previous two seasons. During summer, only one peak appeared, located at 31-32 cm. The length frequency distribution of the catch for the spotted mackerel in the waters off northern Pratas Islands were similar to that in the Pengchiahsu and Fishing Islands in spring (Fig. 5).

II. Age composition estimated from age-length key

The length compositions of the catch of the spotted mackerel (Figs. 4&5) were converted into age composition by age-length key (Tables 2&3). The age composition of the fish in the

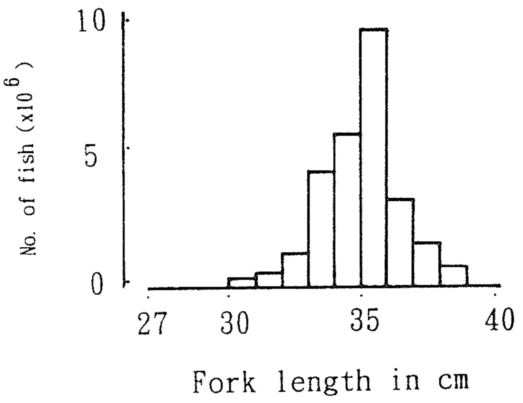

Fig. 5. Length frequency distribution for the catch of spotted mackerel collected from the waters off northern Pratas Islands during spring of 1982 and 1983.

Pengchiahsu and Fishing Islands varied with season (Fig. 6). In autumn, age classes were dominant with 1^+ and 3^+ year old fish, in winter 1^+ to 3^+. In spring, the catch became relatively small; it consisted of 3^+ to 5^+ year old fish. During summer, dominant age class become 2^+ year old fish. Overall, 1^+ to 3^+ year old fish were dominant in this area.

The age composition of the mackerel in the waters off Pengchiahsu and Fishing Islands was also estimated by year (Table 4). In 1981, only the data of November were available, dominant age class was age 1^+, making up 97.9% of the total catch. In 1982, almost four season data

Table 2. Age-length key for spotted mackerel collected from the waters off Pengchiahsu and Fishing Islands, during the autumn-winter (Sep-Feb) and spring-summer (Mar-Aug), Nov 1981 — Oct 1983.

Fork length (cm)	Spring — Summer					Autumn — Winter					
	Sample size	Age composition (%)				Sample size	Age composition (%)				
		2^+	3^+	4^+	5^+		0^+	1^+	2^+	3^+	4^+
21-22						1	100.00				
22-23						4	100.00				
23-24						9	77.78	22.22			
24-25						17	17.65	82.35			
25-26						27		100.00			
26-27						35		100.00			
27-28						47		100.00			
28-29	1	100.00				43		97.67	2.33		
29-30	16	100.00				15		86.67	13.33		
30-31	37	82.78	17.22			8		50.00	37.50	12.50	
31-32	44	68.18	31.82			14		14.29	64.29	21.42	
32-33	51	58.82	41.18			22			36.36	63.64	
33-34	30	36.67	56.67	6.66		23				100.00	
34-35	20		50.00	50.00		23				65.22	34.78
35-36	9		33.33	66.67		8				12.50	87.50
36-37	6		16.67	66.65	16.67	4					100.00
37-38	4				100.00						
38-39											
39-40	1				100.00						

Table 3. Age-length key for spotted mackerel collected from the waters off northern Pratas Islands, during the spring of 1982 and 1983.

Fork length (cm)	Sample size	Age composition (%)			
		2^+	3^+	4^+	5^+
28-29	1	100.00			
29-30	2	100.00			
30-31	9	77.78	22.22		
31-32	16	37.50	62.50		
32-33	26	23.08	57.69	19.23	
33-34	44		18.18	81.82	
34-35	53		15.09	84.91	
35-36	40			92.50	8.50
36-37	15		6.67	66.67	26.67
37-38	9			11.11	88.89
38-39	2				100.00
39-40	1				100.00

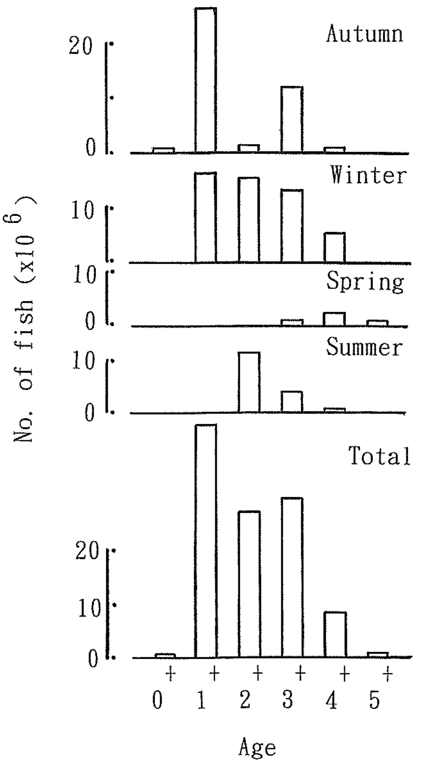

Fig. 6. Seasonal changes of age composition of spotted mackerel collected from the waters off Pengchiahsu and Fishing Islands during November 1981 — October 1983.

were available, dominant age class was age 1^+ (55.3%), the following is age 3^+ (30.5%) and then age 2^+ (11.1%). In 1983, dominant age class changed to 2^+ old fish (33.8%) that was significantly different from that in 1982. The disappearance of 1^+ year old fish in 1983, may be due to the data in November-December 1983 was lacking, which was believed to be the period of recruitment for age 1^+ fish.

Similarly, the age composition of the spotted mackerel in the water off northern Pratas Islands was shown in Fig. 7. The fishing seasons in this area was confined in spring. The old fish was predominant, especially 4^+ years old fish. The age composition of the mackerel in the Pratas Islands was similar to that in Pengchiahsu and Fishing Islands during spring (Fig. 6), although they are different in abundance. The age composition of the mackerel in the Pratas Islands was also estimated by year (Table 4). In 1982, dominant age class was 4^+ year old fish, making up 71.3% of the catch. In 1983, dominant age classes shared by 3^+ and

Table 4. Age composition of the yearly catch of spotted mackerel in the waters off Pengchiahsu and Fishing Islands, and off northern Pratas Islands, 1981-1983.

Fishing ground	Age	Age composition (%)		
		1981	1982	1983
		(Nov)	(Jan-Dec)	(Jan-Oct)
Pengchiahsu and Fishing Islands	0^+	2.1	0.7	0
	1^+	97.7	55.3	18.5
	2^+		11.1	33.8
	3^+		30.5	29.4
	4^+		2.4	17.1
	5^+		0	1.2
	Number of individuals (10^6)	13	60	52
			(Feb-May)	(Apr-May)
Northern Pratas Islands	2^+		0.6	2.1
	3^+		13.7	42.7
	4^+		71.3	55.2
	5^+		14.4	0
	Number of individuals (10^6)		18	7

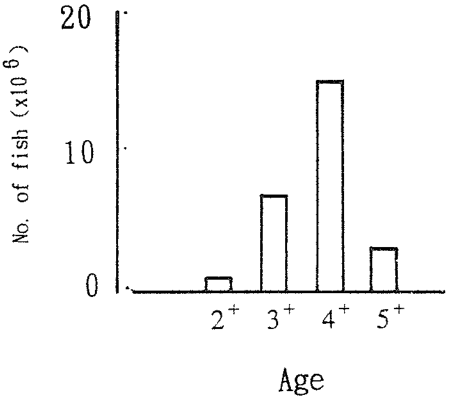

Fig. 7. Age composition of spotted mackerel collected from the waters off northern Pratas Islands during the spring of 1982 and 1983.

4^+ year old fish, making up 42.7% and 58.2% of the catch, respectively.

III. Components of length frequency distribution by polymodal analysis

The components of length frequency distribution of the spotted mackerel in the waters off Pengchiahsu and Fishing Islands, as shown in Figs. 4&5, were analyzed by Bhattacharya polymodal analysis method. The logarithmic differences of the adjacent class-frequencies, D log y , were calculated (Table 5) and plotted against the mid-point of the classes (Fig. 8).

There are four regression lines which denote four distinct components exist for the mackerel in autumn season (Fig. 8-A). The parameters used for estimating the mean (m_r) and standard deviation (S_r^2) of each lines were calculated as

Table 5. Frequency distribution of fork length of spotted mackerel in the waters off Pengchiahsu and Fishing Islands, and off northern Pratas Islands, Nov 1981 — Oct 1983.

(A) Pengchiahsu and Fishing Islands (autumn):

Class range (cm)	Middle point (X)	Observed frequency (Y)	$Log_{10}Y$	$Dlog_{10}Y$
21-22	21.5	1 ($\times 10^4$)	0.146	0.930
22-23	22.5	12	1.076	0.813
23-24	23.5	78	1.889	0.335
24-25	24.5	167	2.224	0.283
25-26	25.5	322	2.507	0.482
26-27	26.5	976	2.989	−0.129
27-28	27.5	724	2.860	−0.298
28-29	28.5	365	2.562	−0.373
29-30	29.5	155	2.189	−0.793
30-31	30.5	25	1.396	0.786
31-32	31.5	152	2.182	0.286
32-33	32.5	294	2.468	0.333
33-34	33.5	633	2.801	−0.367
34-35	34.5	271	2.434	−0.670
35-36	35.5	58	1.764	−0.615
36-37	36.5	14	1.149	−0.702
37-38	37.5	3	0.447	

(B) Pengchiahsu and Fishing Islands (winter):

Class range (cm)	Middle point (X)	Observed frequency (Y)	$Log_{10}Y$	$Dlog_{10}Y$
23-24	23.5	12 ($\times 10^5$)	1.072	0.310
24-25	24.5	24	1.382	0.083
25-26	25.5	29	1.465	−0.004
26-27	26.5	29	1.461	−0.003
27-28	27.5	29	1.458	0.463
28-29	28.5	83	1.921	−0.098
29-30	29.5	67	1.823	−0.128
30-31	30.5	25	1.695	0.032
31-32	31.5	53	1.727	−0.137
32-33	32.5	39	1.590	−0.356
33-34	33.5	17	1.234	−0.121
34-35	34.5	13	1.113	0.299
35-36	35.5	26	1.413	−0.300
36-37	36.5	13	1.113	

(C) Pengchiahsu and Fishing Islands (spring):

Class range (cm)	Middle point (X)	Observed frequency (Y)	$Log_{10}Y$	$Dlog_{10}Y$
30-31	30.5	2 ($\times 10^4$)	0.312	0.477
31-32	31.5	6	0.789	0.301
32-33	32.5	12	1.090	−0.073
33-34	33.5	10	1.017	0.666
34-35	34.5	48	1.683	0.280
35-36	35.5	92	1.963	−0.174
36-37	36.5	62	1.799	−0.398
37-38	37.5	25	1.391	−0.382
38-39	38.5	10	1.009	

Table 5. Frequency distribution of fork length of spotted mackerel in the waters off Pengchiahsu and Fishing Islands, and off northern Pratas Islands, Nov 1981 — Oct 1983 (Continued).

(D) Pengchiahsu and Fishing Islands (summer):

Class range (cm)	Middle point (X)	Observed frequency (Y)	$Log_{10}Y$	$Dlog_{10}Y$
28-29	28.5	20 ($\times 10^4$)	1.278	0.736
29-30	29.5	103	2.014	0.327
30-31	30.5	219	2.341	0.178
31-32	31.5	331	2.519	−0.070
32-33	32.5	281	2.449	−0.164
33-34	33.5	193	2.285	−0.260
34-35	34.5	106	2.025	0.002
35-36	35.5	107	2.027	−0.707
36-37	36.5	21	1.320	−0.924
37-38	37.5	3	0.396	

(E) Pengchiahsu and Fishing Islands (total):

Class range (cm)	Middle point (X)	Observed frequency (Y)	$Log_{10}Y$	$Dlog_{10}Y$
21-22	21.5	1 ($\times 10^4$)	0.146	0.933
22-23	22.5	12	1.079	0.544
23-24	23.5	42	1.623	0.988
24.25	24.5	408	2.611	0.233
25-26	25.5	698	2.844	0.222
26-27	26.5	1165	3.066	−0.131
27-28	27.5	862	2.936	0.124
28-29	28.5	1149	3.060	−0.121
29-30	29.5	869	2.939	−0.075
30-31	30.5	731	2.864	0.105
31-32	31.5	929	2.968	0.030
32-33	32.5	996	2.998	0.012
33-34	33.5	1026	3.012	−0.271
34-35	34.5	549	2.740	−0.021
35-36	35.5	523	2.719	−0.131
36-37	36.5	387	2.588	−1.157
37-38	37.5	27	1.431	−0.528
38-39	38.5	8	0.903	

(F) Northern Pratas Islands (spring):

Class range (cm)	Middle point (X)	Observed frequency (Y)	$Log_{10}Y$	$Dlog_{10}Y$
27-28	27.5	3 ($\times 10^4$)	0.477	0.222
28-29	28.5	5	0.699	0.079
29-30	29.5	6	0.778	0.426
30-31	30.5	16	1.204	0.075
31-32	31.5	19	1.279	0.734
32-33	32.5	103	2.013	0.597
33-34	33.5	407	2.610	0.127
34-35	34.5	545	2.736	0.246
35-36	35.5	961	2.983	−0.498
36-37	36.5	305	2.484	−0.391
37-38	37.5	124	2.093	−0.562
38-39	38.5	34	1.531	−0.929
39-40	39.5	4	0.602	

Table 6. Comparison of the mean length, standard deviation (S.D.) and proportion of mixture which estimated from age determination and polymodal analysis of frequency distribution for the spotted mackerel in the waters off Pengchiahsu-Fishing Island and northern Pratas Islands.

Area	Seasons	Age determination				Bhattacharya's polymodal analysis		
		Age	No. fish	Length Mean±S.D. (cm)	Age composition (%)	Component	Length Mean±S.D. (cm)	Proportion of mixture (%)
Pengchiahsu and Fishing Islands	autumn	0^+	15	22.73±0.89	0.4	1	25.94±1.31	29.5
		1^+	125	26.12±1.34	66.2	2	27.21±1.21	36.7
		2^+	19	31.90±0.47	2.7	3	32.57±0.89	17.0
		3^+	66	33.61±0.89	28.6	4	33.53±0.89	16.8
		4^+	6	35.69±0.58	2.1	5		
	winter	1^+	82	26.61±1.18	32.6	1	25.83±1.64	19.8
		2^+	5	30.06±0.62	31.4	2	29.27±1.18	39.7
		3^+	22	32.32±1.34	26.0	3	31.21±1.47	32.4
		4^+	13	34.86±0.70	10.0	4	35.50±0.80	8.1
	spring	3^+	20	32.62±1.24	12.4	1	3285±1.22	14.1
		4^+	24	34.85±0.94	66.9	2	35.76±1.05	85.9
		5^+	6	37.50±0.88	20.7	3		
	summer	2^+	130	31.36±1.15	76.2	1	32.15±1.57	80.5
		3^+	37	33.83±1.06	23.4	2	34.83±0.99	19.5
		4^+	2	36.25	0.4	3		
	total	0^+	15	22.53±0.95	0.1	1		
		1^+	207	26.62±1.33	40.3	2	26.47±1.13	33.1
		2^+	154	30.37±1.53	25.6	3	28.51±1.34	25.6
		3^+	145	32.56±1.36	26.3	4	32.23±1.58	32.3
		4^+	45	34.77±0.88	7.2	5	35.23±0.85	9.0
		5^+	6	37.45±1.11	0.5	6		
Northern Pratas Islands	spring	2^+	22	30.74±1.02	3.4	1	29.05±1.25	0.2
		3^+	42	32.90±1.15	29.9	2	31.21±1.27	0.9
		4^+	132	34.52±1.05	56.4	3	34.60±1.22	33.9
		5^+	18	36.89±1.08	10.3	5	35.67±1.30	29.4

follow:

$h=1$, $b=8$, $d=160\log e=69.4864$

1st line: $D \log y = 6.154 - 0.242\ x$

2nd line: $D \log y = 7.461 - 0.279\ x$

3rd line: $D \log y = 16.036 - 0.5\ x$

4th line: $D \log y = 16.566 - 0.502\ x$

$I1=25.44$, $I2=26.71$,

$I3=32.07$, $I4=33.03$

$A1=78.32$, $A2=79.85$,

$A3=84.29$, $A4=84.32$

Hence, from equations (4) and (5), the mean length and standard deviation of each component was estimated as follow:

$m1=25.94$, $m2=27.21$,

$m3=32.57$, $m4=33.53$

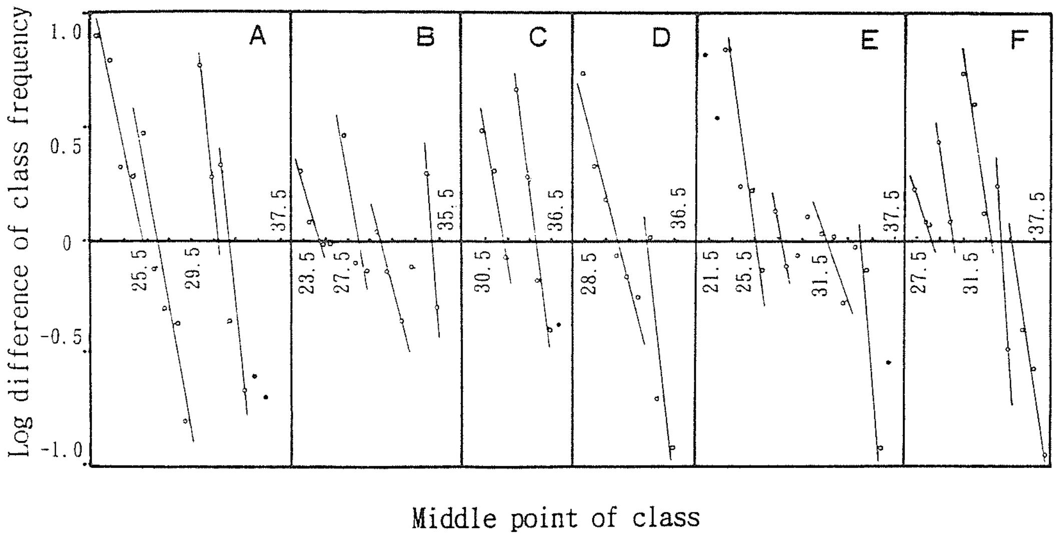

Fig. 8. Graphs of logarithmic difference of the adjacent class frequency against the mid-points of the class for separating the components of the length frequency distribution of spotted mackerel based on the data of Table 5 and Figs. 4&5. A-E indicate data of autumn, winter, spring, summer and overall seasons in Pengchiahsu-Fishing Is. respectively and F, Pratas Islands. Solid circles were not used in estimating the component.

$S1=1.31, \quad S2=1.21,$
$S3=0.89, \quad S4=0.89$

Then, the total frequency in the number of fish of each component was estimated by equation (6):

$$N1 = \{y(25.5)+y(26.5)\} \,/\, \{P1(25.5)+P1(26.5)\} = 2{,}341 \times 10^4$$
$$N2 = \{y(26.5)+y(27.5)\} \,/\, \{P2(26.5)+P2(27.5)\} = 2{,}909 \times 10^4$$
$$N3 = \{y(32.5)+y(33.5)\} \,/\, \{P3(32.5)+P3(33.5)\} = 1{,}345 \times 10^4$$
$$N4 = \{y(33.5)+y(34.5)\} \,/\, \{P4(33.5)+P4(34.5)\} = 1{,}339 \times 10^4$$

$N1 : N2 : N3 : N4 =$
$29.5 : 36.7 : 17.0 : 16.8$

Similarly, there are also four components to be found for the fish in the winter (Fig. 8-B). The mean length, standard deviation and total frequency of each component were also calculated respectively as follows:

$h=1, \quad b=6.5, \quad d=56.4577$

1st line: $D \log y = 3.976 - 0.157\, x$
$l1=25.33, \quad A1=72.33, \quad m1=25.83,$
$S1=1.64, \quad N1=1{,}274\times 10^4$

2nd line: $D \log y = 8.501 - 0.296\, x$
$l2=28.77, \quad A2=80.40, \quad m2=29.27,$
$S2=1.18, \quad N2=2{,}536\times 10^4$

3rd line: $D \log y = 5.957 - 0.194\, x$
$l3=30.71, \quad A3=75.55, \quad m3=31.21,$
$S3=1.47, \quad N3=2{,}060\times 10^4$

4th line: $D \log y = 20.965 - 0.599\, x$
$l4=35.00, \quad A4=85.23, \quad m4=35.50,$
$S4=0.80, \quad N4=519\times 10^4$

$N1 : N2 : N3 : N4 =$
$19.8 : 39.7 : 32.4 : 8.1$

In spring (Fig. 8-C):

$h=1$, $b=4$, $d=34.7432$

1st line: D log y = 8.898 − 0.275 x
$l1=32.35$, $A1=79.70$, $m1=32.85$,
$S1=1.22$, $N1=39\times10^4$

2nd line: D log y = 12.855 − 0.365 x
$l2=35.26$, $A2=82.19$, $m2=35.76$,
$S2=1.05$, $N2=237\times10^4$

N1 : N2 = 14.1 : 85.9

In summer (Fig. 8-D):

$h=1$, $b=4.5$, $d=39.0861$

1st line: D log y = 6.059 − 0.192 x
$l1=31.65$, $A1=75.36$, $m1=32.15$,
$S1=1.57$, $N1=1{,}292\times10^4$

2nd line: D log y = 15.894 − 0.463 x
$l2=34.33$, $A2=83.84$, $m2=34.83$,
$S2=0.99$, $N2=312\times10^4$

N1 : N2 = 80.5 : 19.5

For overall data (Fig. 8-E):

$h=1$, $h=8.5$, $d=73.8293$

1st line: D log y = 8.748 − 0.337 x
$l1=25.97$, $A1=81.56$, $m1=26.47$,
$S1=1.13$, $N1=4{,}187\times10^4$

2nd line: D log y = 6.862 − 0.245 x
$l2=28.01$, $A2=78.46$, $m2=28.51$,
$S2=1.34$, $N1=3{,}240\times10^4$

3rd line: D log y = 3.636 − 0.114 x
$l3=31.73$, $A3=66.43$, $m3=32.23$,
$S3=1.58$, $N3=4{,}094\times10^4$

4th line: D log y = 19.728 − 0.568 x
$l4=34.73$, $A4=84.97$, $m4=35.23$,
$S4=0.85$, $N4=1{,}443\times10^4$

N1 : N2 : N3 : N4 =
33.1 : 25.6 : 32.3 : 9.0

For those collected from the waters off northern Pratas Islands were also estimated (Fig. 8-F):

$h=1$, $h=6$, $d=52.1148$

1st line: D log y = 4.083 − 0.243 x
$l1=28.55$, $A1=70.73$, $m1=29.05$,
$S1=1.25$, $N1=19\times10^4$

2nd line: D log y = 10.781 − 0.351 x
$l2=30.71$, $A2=74.10$, $m2=31.21$,
$S2=1.27$, $N1=67\times10^4$

3rd line: D log y = 10.350 − 0.303 x
$l3=34.10$, $A3=71.76$, $m3=34.60$,
$S3=1.22$, $N3=2{,}678\times10^4$

4th line: D log y = 25.914 − 0.744 x
$l4=34.83$, $A4=82.34$, $m4=35.33$,
$S4=0.25$, $N4=2{,}820\times10^4$

5th line: D log y = 9.460 − 0.269 x
$l5=35.17$, $A5=69.61$, $m5=35.67$,
$S5=1.30$, $N5=2{,}328\times10^4$

N1 : N2 : N3 : N4 : N5 =
0.2 : 0.9 : 33.9 : 35.6 : 29.4

IV. Comparison of age composition between polymodal length-frequency analysis and age length key

The mean length, standard deviation and mixture ratio of each components estimated from the polymodal analysis of length frequency distribution of the fish (Fig. 8) were compared with the results obtained from age determination (Table 6).

In autumn, there are four components separated from the length frequency distribution of the catch of the spotted mackerel in the Pengchiahsu and Fishing Islands (Fig. 8A). The mean lengths of the first and second components were estimated to be 25.94 cm and 27.21 cm, respectively, which was considered to be the same age group because their mean was close to the mean length of 1^+ year old fish, 26.12 cm. Meanwhile, the summation of proportion of mixture of the first and second components, 66.2% (29.5% + 36.7%) completely equal to the ratio of composition of 1^+ year old fish. Mean lengths of the third and fourth components were estimated to be 32.57 cm and 33.53 cm which was considered to correspond to 2^+ and 3^+ year old fish, respectively. The fifth component which may correspond to the 4^+ year old fish was not estimated because D log y against x was only two points and irregular in distribution (Fig.8A). The 0^+ year old fish was not found in the polymodal analysis of length frequency distribution, may be due to its low ratio (0.4%) in age composition.

In winter, there are also four components were separated from the length frequency distribution of the mackerel in the same area (Fig. 8B). These four components corresponded to 1^+ to 4^+ year old fish. Their mean length and mixed percentage corresponded very well each other.

In spring, two components were separated from the length frequency distribution (Fig. 8C). These two components were considered to correspond to 3^+ and 4^+ year old fish groups, respectively, because the values of mean length and standard deviation were similar between them. The third component which may correspond to 5^+ year old fish group could not be estimated because only one point to be found for the regression of D log y on x (Fig. 8C). Accordingly, this may cause the mixed percentage of the first and second components to be higher than those of the corresponding age groups, 3^+ and 4^+ year old fish.

In summer, two components were separated from the length frequency distribution (Fig. 8D). These two components corresponded to 2^+ and 3^+ year old fish as viewed from their similarity in mean length, standard deviation and mixed percentage. The third component may be existed but not be found, it may be due to low percentage in mixed proportion.

Overall season, it seems that there are six components existed in the length frequency distribution of the catch of the spotted mackerel in the Penchiahsu and Fishing Islands (Fig. 8E). However, the first and sixth components have not been estimated because of lower percentage of mixed proportion and few points of D log y against x. The remainder second to fifth components were considered to be well corresponded to 1^+ to 4^+ year old fish as viewed from their similarity in mean length, standard deviation and proportion of mixture.

Similarly, there are five components were found in the catch of northern Pratas Islands (Fig. 8F). The mean length from polymodal analysis was similar to that from age-length key. However, the proportion of mixture of the components from polymodal analysis was not coincident with the percentage age composition from age-length key (Table 6). It seems that polymodal analysis of length frequency distribution is diffcult in older fish.

DISCUSSION AND CONCLUSION

Comparing the results estimated from the polymodal analysis of length frequency data with those from ageing data of scale reading, it was found that three aspects were not corresponding each other.

Firstly, single age group may be resolved into two components in the length frequency distribution (e.g. Table 6 in autumn). This phenomenon may be due to different cohorts existed in the same year class, which was especially significant in the young fish (Iizuka, 1971), or due to the combination of the same cohort measured in the different period, as shown in Fig. 2.

Secondly, the numbers of components from analysis of length frequencies were found fewer than that of age groups from scale reading (Table 6). The unestimated components were always existed in the two sides of length frequency distribution (Fig. 8, indicated by solid circles). The reason of underestimation was due to lower in proportion of mixture of the component as viewed from the percentage of age composition.

Thirdly, the mixed proportion of each components separated from the length frequency distribution of old fish did not quite match with that of the corresponding age groups, e.g. the data of the northern Pratas Islands (Table 6). The causes may be due to the growth rate became low during the fish get old, then modal length highly overlapped and not easily to be separated for each components. This phenomenon also appeared in the results of scale reading. The difficulty in resolution of the components of length frequency distribution of the old fish was also noted by other workers (Tanaka, 1962; Pauly, 1983; Peterson, 1892). Although, polymodal analysis of length frequency data have some problems as mentioned above, if a large samples were analyzed continuously in a enough and sampled randomly, the errors will be reduced to a minimum. Meanwhile, in order to understand that the mode (component) which calculated by the Bhattacharya method coincides with which one of the age group, the age determination and other biological information must be matched simultaneously.

Age composition of the spotted mackerel in the waters off Pengchiahsu and Fishing Islands in the northern Taiwan, varied with season. In autumn-winter, young fish was dominant in the age composition of the catch. In spring-summer, it seems that the proportion of old fish increased in the catch (Fig. 6). From the fluctuation of monthly catch, it indicated that the good fishing season of the spotted mackerel in the Pengchiahsu and Fishing Islands appeared in autumn-winter (Table 1). Therefore, for the overall catch, the age composition of the catch of the spotted mackerel in the Pengchiahsu and Fishing Islands was dominant by 1^+ to 3^+ year old fish. On the other hand, in spring-summer, the fishing grounds shifted to northern Pratas Islands in the southwestern Taiwan. In this period, the old fish was dominant in age composition of the catch, mainly 4^+ year old fish. This indicated that the age composition of the mackerel was extremely different between the Pengchiahsu--Fishing Islands and northern Paratas Islands.

ACKNOWLEDGEMENTS

This study was conduted under the financial support of Council of Agriculture, Executive Yuan (contract no. 71-4. 1-80 (3-3)). We wish to express our thanks to Mr. H. K. CHENG of Nanfanao Fishermen Association for collecting the specimens and catch data, to Mr. R. J. Shiao for typing and the colleagues of the laboratory of Fisheries Biology, Department of Zoology, National Taiwan University for their helps in data collection and laboratory works

REFERENCES

Bhattacharya, C. G. (1967). A simple method of resolution of a distribution into Gaussian components. *Biometrics*, 115-135.

Cassie, R. M. (1954). Some uses of probability paper for the graphical analysis of polymodal frequency distributions. *Aust. J. Mar. Freshw. Res.*, **5:** 513-522.

FAO (1981). Methods of collecting and analysing size and age data for fish stock assessment. *FAO Fish. Circ.*, **736:** 32-100.

Foucher, R. P. and D. Fournier (1982). Derivation of Pacific cod age composition using length-frequency analysis. *North Amer. J. Fish. Manag.*, **2:** 276-284.

Harding, J. F. (1949). The use of probability paper for the graphical analysis of polymodal frequency distributions. *J. Mar. Biol. Ass. U. K.*, **28:** 141-153.

Iizuka, K. (1971). On the ecology of young mackerel in the northeastern sea of Japan. I - Studies of the different broods in same year - class. *Bull. Tohoku Reg. Fish. Res. Lab.*, **31:** 97-108.

Ku, J. F. and W. N. Tzeng (1985). Age and growth of spotted mackerel, *Scomber australasicus* (CUVIER), in the shelf waters of northeast and southwestern Taiwan, *J. Fish. Soc. Taiwan,* **12**(2): 12-26.

Pauly, D. (1983). Some simple methods for the assessment of tropical fish stocks. *FAO Fish Tech. Paper,* **234:** 8-15.

Petersen, C. G. J. (1892). Fiskensbiologiske forhold i Holboek Fjord, 1890-91. *Beret. Dan. Biol. St.* 1890(91), **1:** 121-183.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd. Can.*, **191:** 382 pp.

Schnute, J. and D. Fournier (1980). A new approach to length frequency analysis: growth structure. *Bull. Fish. Res. Bd. Can.*, **37:** 1337-1351.

Sparre, P., Ursin, E. and Venema, S. C. (1989). Introduction to tropical fish stock assessment Part 1 - Manual. FAO Fish. Tec. Paper 306/1, Rome, 337 pp.

Tanaka, S. (1962). A method of analysing a polymodal frequency distribution and its application to the length distribution of the porgy, *Taius turmifrons* (T. and S.) *J. Fish. Res. Bd. Can.*, **19**(6): 1143-1159.

以多型量體長頻度解析法分析台灣近海花腹鯖族群的年齡結構

谷瑞峰[1,2] 曾萬年[1]

（1994年4月1日收件；1994年6月10日接受）

本文以Bhattacharya多型量解析法，配合年齡判讀結果所建立的Age-length key，分析漁獲物的體長組成，來推算1981～1983年臺灣近海產花腹鯖的年齡結構。台灣近海花腹鯖的年齡組成隨季節及漁場而改變。臺灣東北部澎佳嶼～釣魚台海域的花腹鯖，在漁獲盛期的秋冬季，以1^+至3^+歲魚爲主，漁獲淡季的春夏期間，2^+至4^+歲魚較多。臺灣西南部東沙群島附近海域產者，則以3^+及4^+歲魚爲主（漁期僅於春季）。除高齡魚外，Bhattacharya多型量頻度解析法在年齡組成解析的應用上，具有相當的可靠性。

關鍵詞：花腹鯖，體長組成，Bhattacharya多型量頻度解析法，年齡結構，台灣。

1. 國立臺灣大學動物學系，臺北，臺灣 107。
2. 行政院國家科學委員會，臺北，臺灣 107。