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A Study on Recent Variations in the Population Structure of European Anchovy *(Engraulis encrasicolus* L., 1758) in the Southern Black Sea

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Özet: ***Güney Karadeniz'deki hamsi (***Engraulis encrasicolus ***L., 1758) populasyon yapısındaki son değişiklikler üzerine bir çalışma.*** Bu araştırma Karadeniz'in Güneyindeki Türkiye Sinop sahilinde 2000-2003 yılları arasında hamsi balığının stok yapısındaki değişikliklerin belirlenmesi için yürütülmüştür. Tüm örneklerde dişilerin ve erkeklerin oranı %59 ve %41 olarak belirlenmiştir. Uzunluk-ağırlık ilişkisi katsayısı b, 2000-2001, 2001-2002, 2002-2003 ve 2000-2003 av sezonları için sırasıyla 2.7101, 3.0568, 2.8946, 2.8695 olarak bulunmuştur. Sonuçlar hamsinin 0-3 yaşında olduğunu gösterdi. Von Bertalanffy büyüme parametresi $L\infty$ (cm) av sezonları için sırasıyla 16.84 cm, 18.46 cm, 18.73 cm ve 18.91 cm olarak hesaplanmıştır. Tüm örneklerde (N=7487) toplam, doğal, avcılık ölüm oranları ve işletme oranı, $Z=2.07$ year^{-1}, $M=0.30$ year^{-1}, $F=1.77$ year^{-1} ve $E=0.86$ year^{-1}olarak hesaplanmıştır.

Anahtar Kelimeler: Hamsi; *Engraulis encrasicolus*; populasyon yapısı; Karadeniz; av çabası.

Abstract: This research was carried out to estimate variation of stock structure anchovy (*Engraulis encrasicolus*, L. 1758) (N=7487) of the in Sinop Turkish coast in the southern of the Black Sea between 2000 and 2003. The mean sex ratio was 59 % (female): 41 % (male). The b constant of weight-length relationships were 2.7101, 3.0568, 2.8946 and 2.8695 for 2000-2001, 2001-2002, 2002-2003, and 2000-2003 fishing seasons, respectively. The result showed that fish were 0-3 years old. The von Bertalanffy growth parameter value of L_∞ (cm) were 16.84 cm, 18.46 cm, 18.73 cm and 18.91 cm for fishing seasons, respectively. Total (Z), natural (M), fishing (F) mortality rates and exploitation rate (E) were $Z=2.07$ year^{-1}, $M=0.30$ year^{-1}, $F=1.77$ year^{-1}, $E=0.86$, respectively for overall samples.

Key Words: Anchovy; *Engraulis encrasicolus*; population structure; Black Sea; fishing effort.

Introduction

The European anchovy (*Engraulis encrasicolus* L.) is widely distributed along the East Atlantic from the Scandinavia to the Gulf of Guinea, Mediterranean and the Black Sea (Ivanov and Beverton, 1985). The European anchovy was caught 280.000 tons in 2000 in the Turkish coast of the Black Sea which consisted 72% anchovy catches of the FAO statistical sub area (27., 34. and 37. area) (FAO, 2002). Since 1981, the highest annual fish catches among all Mediterranean and Black Sea countries has been achieved by Turkey. In fact, the Black Sea fisheries have special importance of Turkish fisheries. In the 1990's, dramatic reductions have been reported not only for Turkish Black Sea fisheries, but also in the fisheries of other riparian countries (Kideys, 1994) (Fig. 1).

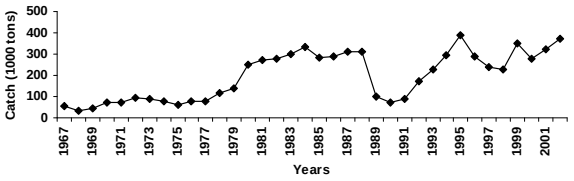

Fig. 1. *E. encrasicolus* catch from 1967 to 2002 in the Turkish Coast of the Black Sea (Anonymous, 1968-2004).

Because of the economic importance of the fishery, studies on the anchovy are increasing year by year in Turkey and other countries (Özdamar *et al*., 1991; Düzgüneş and Karaçam, 1989; Erkoyuncu and Özdamar, 1989; Ünsal, 1989; Karaçam and Düzgüneş, 1990; Özdamar *et al*., 1994; Özdamar *et al*., 1995; Cihangir and Uslu, 1992; Kayalı, 1998; Avşar *et al*., 1999; Lee and Lee, 1996; Gordina *et al*., 1997; Kideys *et al*., 1999; Bellido *et al*., 2000; Mullon *et al*., 2002; Gücü, 2002, Samsun *et al*., 2004).

Environmental fluctuations are believed to strongly influence the abundance of short-lived pelagic species and may also result in changes in life-cycle and growth patterns. Thus, it is important to have data from as long as period as possible, to determine average growth parameters (Bellido *et al*., 2000).

The monitoring of anchovy stocks by years is essential for Turkey as well as other countries around the Black Sea, as this species is being caught and consumed in large amounts in the Black Sea. For this reason, this study has been carried out to determine, growth, mortality and population structure of the anchovy along the Turkish coast of the Black Sea between 2000 and 2003.

Materials and Methods

This study was conducted in Sinop coasts that one of the most important fishing regions of the Black Sea between 2000 and

2003 fishing seasons. Monthly sampling was carried out during three anchovy fishing season. A total of 7487 specimens of anchovy were sampled by a random stratified method from purse-seine fishing boats. In the laboratory, total length (Tl) was measured to the nearest 0.1 cm while total weight was measured with 0.01 g sensitively. Comparision of length frequency distributions by different fishing seasons were carried out using the Kolmogorov-Smirnov test (Zar, 1999). Sagittal otoliths were used for age determination. Otoliths were removed in the laboratory and stored in labelled envelopes. Ages were determined by reading whole otoliths against a black background under reflected light in the stereoscopic microscope (Anonymous, 1981) and recorded as group of 0, 1, 2 and 3 years old. Sex was determined visual examination from gonad. Mean length at age data was used estimate the growth parameters of the von Bertalanffy growth equation (VBGF) by using the FISAT computer program (Gayalino *et al*., 1995). The length-weight relationship was determined by the equation $W= aL^b$, where, W is the weight, L is the length, a and b are the coefficients of the functional regression between W and L (Ricker, 1975).

The growth performance index (Ø') was calculated as Ø'= log k+2 log L_∞, where k and L_∞ are von Bertalanffy growth equation parameters. Comparison of the growth parameters between the presents and previous results was determined according to Munro's phi prime test (Pauly & Munro, 1984). The total instantaneous mortality (Z) was estimated from the length converted catch curve (Pauly, 1983) by using the FISAT computer program (Gayalino *et al*., 1995). The natural mortality rate (M) was estimated from empirical formula (Djabali *et al*. 1994). Fishing mortality rate (F) and exploitation ratio (E) were estimated from: F= Z – M and E = F/Z respectively (Ricker, 1975).

To test for possible significant differences between sexes (P<0.05) we used Student's t-test for comparison of two slopes. One-way analysis of variance (α=0.05) was used to compare mean size and weight among years. A chi-square (χ^2) test was used to for differences in sex ratios (Sümbülolu and Sümbüloğlu, 2000).

Results

The anchovy population consisted of 4 different age-groups (0, 1, 2 and 3). The age distribution of anchovy determined 26.62 %, 28.44 %, 38.49 % and 12.45 % as 0, 1, 2, 3 age, respectively for overall samples (Table 1 and Fig 2).

The female ratio were 57%, 59%, 60% and 59% for 2000-2001, 2001-2002, 2002-2003 and 2000-2003 fishing seasons respectively. There was a significant difference between sex ratio for 2002-2003 fishing season (χ^2 test, P<0.05) while there were not differences in other fishing seasons (Table 2).

The von Bertalanffy growth equations and growth performances are shown in Table 2 according to sex and fishing seasons. The growth equations for the total samples for each season were found to be: $Lt=16.84\ [1 - e^{-0\ 2.33\ (t+3.08)}]$ for 2000-2001, $Lt=18.46\ [1 - e^{-0.217\ (t+2.86)}]$ for 2001-2002, $Lt=18.73\ [1 - e^{-0.156\ (t+3.969)}]$ for 2002-2003, $Lt=18.91\ [1 - e^{-0.163\ (t+3.70)}]$ for total samples. The values $L\infty$ were found high females than males. The of growth performance index (Ø') was the highest 1.90 for females for 2001-2002 fishing season. There were not significant differences in the von Bertalanffy growth equation parameters between the presents and reported results (P>0.05).

Table 1. Age-length data for anchovy in the overall samples (2000-2003).

Length Groups (cm)	Age Groups (year)				Total
	0	1	2	3	
5.0	1				1
5.5	1				1
6.0	1				1
6.5	10				10
7.0	38				38
7.5	91				91
8.0	163				163
8.5	270	2			272
9.0	390	5			395
9.5	442	23			464
10.0	125	409	48		582
10.5	12	1054	87		1153
11.0		617	381	2	1000
11.5		19	1187	8	1214
12.0			891	33	924
12.5			200	365	565
13.0			84	342	426
13.5			4	134	138
14.0				41	41
14.5				4	4
15.0				3	3
Total	1544	2129	2882	932	7487
%	26.62	28.44	38.49	12.45	
Mean Lt (cm)±SE	8.54±0.019	10.22±0.007	11.34±0.007	12.61±0.056	
Mean W (g)±SE)	3.87±0.028	6.51±0.019	8.62±0.024	11.58±0.056	

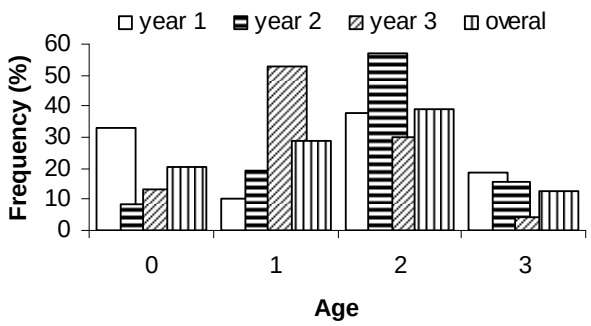

Fig. 2. Age-frequency distribution *E. encrasicolus* for years and overall catch.

The lengths and weights of 7487 specimens ranged from 5.3 to 14.9 cm and from 1.02 to 17.05 g, respectively. The length-frequency distributions of anchovy shown in Fig 3 according to years. There were significant differences mean length values between fishing seasons (P<0.05). Mean length, weight, min-max values of length and weight of anchovy are shown in Table 3. The Kolmogorov-Smirnov test indicated that the length frequencies of anchovy differed significantly between all pairs of years (P<0.001).

There are important differences between females and males individuals on their length and weight (P<0.05, Table 3). The length-weight relationships for the total samples for each season were as follows:

$W=0.0118\ L^{2.7101}$ for 2000-2001 r=0.96
$W=0.0051\ L^{3.0568}$ for 2001-2002 r=0.96
$W=0.0075\ L^{2.8946}$ for 2002-2003 r=0.92
$W=0.0080\ L^{2.8695}$ for 2000-2003 r=0.95

The slopes (b) of the length-weight relationship were significantly different between sexes for only 2002-2003 fishing season (P<0.05). In 2001-2002 season the growth of the female and male isometric. Whereas the growth of both sexes was negative allometric scale in other seasons (Table 4). There were significant differences among three fishing season for the slopes of b of males (P<0.05). The values of b for females were only significantly different between 2000-2001 and 2001-2002 seasons (Table 4).

Table 2. Von Bertalanffy growth parameters ($L\infty$, K, t_0) and growth performances (Ø') and sample size (N) for *E. encrasicolus* in the Turkish coast of the Black Sea.

Fishing Seasons		L∞±SE	K±SE	to±SE	Ø'±SE	N
2000 2001	♀	19.27±2.64	0.167±0.053	-3.557±0.484	1.79±0.182	1506
	♂	15.86±0.69	0.273±0.038	-2.846±0.224	1.84±0.072	1158
	♀+♂	16.84±2.437	0.233±0.096	-3.08±0.665	1.82±0.219	3059
2001 2002	♀	19.94±5.717	0.202±0.132	-2.65±0.791	1.90±0.378	847
	♂	17.37±8.868	0.237±0.113	-2.766±1.956	1.85±0.743	591
	♀+♂	18.46±5.777	0.217±0.166	-2.86±0.069	1.87±0.423	1519
2002 2003	♀	18.78±3.760	0.154±0.073	-4.086±0.819	1.74±0.286	1690*
	♂	18.40±3.398	0.177±0.077	-3.397±0.654	1.78±0.248	1116
	♀+♂	18.73±5.565	0.156±0.018	-3.969±1.168	1.74±0.396	2909
2000 2003	♀	18.97±5.890	0.162±0.018	-3.732±1.167	1.77±0.419	4095
	♂	17.16±3.270	0.204±0.104	-3.369±0.837	1.78±0.276	2886
	♀+♂	18.91±5.720	0.163±0.114	-3.700±1.114	1.77±0.402	7487

**There was a significant difference between sex ratio for 2002-2003 fishing season*

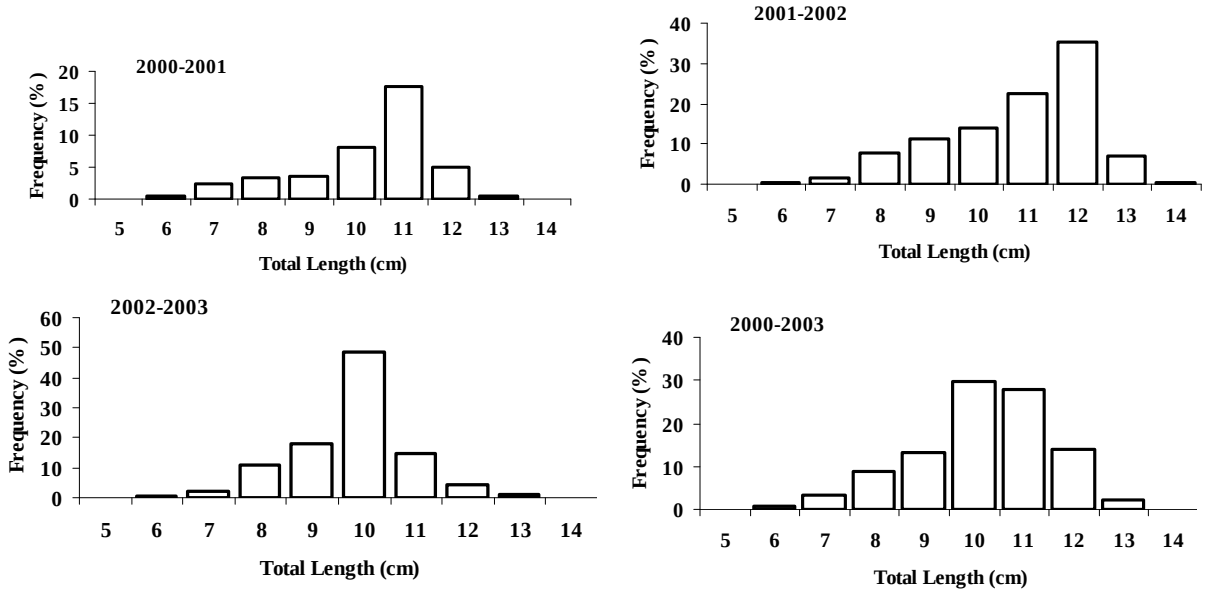

Fig. 3. Length-frequency distribution *E. encrasicolus* for years and overall catch.

Table 3. Mean length, weight, minimum-maximum values of length and weight for *E. encrasicolus* in the Turkish coast of the Black Sea (P<0.05 there were significant differences both lengths and weights between sexes in each season).

Fishing Seasons		Tl (cm)±SE min-max	Weight (g)±SE min-max
2000-2001	♀ P<0.05	11.21±0.023 6.6-14.1	8.37±0.046 2.19-17.05
	♂	10.87±0.030 6.5-13.8	7.81±0.059 2.2-16.55
	♀+♂	10.66±0.025	7.50±0.044
2001-2002	♀ P<0.05	11.67±0.043 7.6-14.6	9.95±0.10 2.18-18.12
	♂	10.91±0.058 6.7-13.6	8.28±0.13 2-16.2
	♀+♂	11.25±0.039	9.07±0.085
2002-2003	♀ P<0.05	10.55±0.022 7.3-14.9	7.05±0.04 2-16.48
	♂	9.97±0.03 6.8-13.3	5.99±0.05 2.09-15.23
	♀+♂	10.24±0.002	6.48±0.036
2000-2003	♀ P<0.05	11.04±0.017 6.6-14.9	8.17±0.04 2.01-18.12
	♂	10.52±0.022 6.5-13.8	7.18±0.04 2.05-18.00
	♀+♂	10.61±0.016	7.42±0.031

Table 4. Length-weight relationships for *E. encrasicolus* in the Turkish Coast of the Black Sea. Estimates were obtained for the parameters a and b of the relationship $W=aL^b$ confidence limits of b. growth shape and correlation coefficient.

Fishing Seasons		a	b	95% confidence limits for b	SE (b)	Growth character	r
2000 2001	♀	0.0174	2.5498a	2.4886-2.6109	0.03113	- allometric	0.90
	♂	0.0179	2.5368x	2.4726-2.6001	0.03266	- allometric	0.90
	♀♂	0.0118	2.7101	2.6828-2.7372	0.01386	- allometric	0.96
2001 2002	♀	0.0057	3.0228b	2.9553-3.0902	0.03435	isometric	0.95
	♂	0.0059	3.0089y	2.9309-3.0869	0.03970	isometric	0.96
	♀♂	0.0051	3.0568	3.0204-3.1112	0.02309	+ allometric	0.96
2002 2003	♀	0.017	2.5395ac	2.4722-2.6068	0.03424	- allometric	0.87
	♂	0.0086	2.8332z*	2.7521-2.9143	0.04129	- allometric	0.90
	♀♂	0.0075	2.8946	2.8485-2.9407	0.02346	- allometric	0.92
2000 2003	♀	0.0102	2.7704	2.7344-2.8064	0.01833	- allometric	0.92
	♂	0.0074	2.9067	2.8762-2.9372	0.01553	- allometric	0.95
	♀♂	0.0080	2.8695	2.8481-2.8909	0.01091	- allometric	0.95

**The values of b for females and males were significantly differences only 2002-2003 fishing season. a, b, c for female and x, y, x for males: values of b in column different letters are significantly different (P<0.05) among seasons.*

The values of total mortality (Z) estimated as 3.59 year $^{-1}$, 3.37 year $^{-1}$, and 1.90 year $^{-1}$ for 2000-2001, 2001-2002 and 2002-2003 fishing season, respectively.

The total, natural and fishing mortality rates and the exploitation ratio for three seasons are given in Table 5. The exploitation ratio was E=0.86 year $^{-1}$ for total samples, indicating that fishing pressure on anchovy in the Southern Black Sea is high.

Table 5. Mortality parameters of the *E. encrasicolus* in the Turkish Coast of the Black Sea in 2000-2003 fishing seasons.

Parameters	Fishing Seasons			
	2000-2001	2001-2002	2002-2003	2000-2003
M (Natural mortality)	0.36	0.35	0.29	0.30
Z (Total mortality)	3.59	3.37	1.90	2.07
F (Fishing mortality)	3.23	3.02	1.61	1.77
E (Exploitation ratio)	0.90	0.90	0.85	0.86

Discussion

Mean length and weight data were similar with reported by other authors (Table 6). It has been showed that the anchovy in the Black Sea have statistical differences both length and weight between female and male (P<0.05). The females are larger than males.

There have differences in anchovy populations parameters among fishing seasons (Table, 2, 3, 4). Thus, the result demonstrated that significant differences (P<0.001) were found in the length frequencies for anchovy caught by different years. That's why, anchovy stocks must be investigated for each fishing season.

The growth of the female and male were isometric in the 2001-2002 season whereas, other seasons were negative allometric. The mean values of b were 2.7101, 3.0568 and 2.8946, respectively for 200-2001, 2001-2002 and 2002-2003 seasons. The slopes (b values) of the length-weight

relationship were ranged from 2.7 to 3.59 from the Biscay Bay, Mediterranean Sea, Adriatic Sea and Black Sea (Anonymous, 2004). It is clear that there are some differences between the growth characteristics from year to year. The functional regression "b" value represents the body form, and it is directly related to weight affected by ecological factors such as temperature, food supply, spawning conditions and other factors, such as sex, age, fishing time and area and fishing vessels (Ricker, 1975). In 2001-2002 season the mean length and weight were high than other seasons (Fig 3 and table 3). And this may have been effected isometric growth of female and male in this season.

Table 6. Some study results of *E. encrasicolus* in the Turkish Coast of the Black Sea (mean length and weight, Length- weight relationship values of, Von Bertalanffy growth values of L∞ and growth performance (Ø'), natural mortality (M), exploitation ratio (E) and fishing mortality (F)

Studies	Fishing Seasons	Parameters							
		L (cm)	W (g)	b	L∞ cm)	Ø'	M year^{-1}	E	F year^{-1}
1	85-86	11.33	10.53	3.4128	16.77	1.96*			
2	86-87	10.83	8.65	3.3832	16.85	1.96*			
3	87-88	9.34	6.62	3.3868	14.14	2.26*			
4	88-89	-	-	2.9743	15.73	1.89*			
5	87-88	9.7	-	-	17.99	1.98			
5	88-89	10.6	-	-	15.65	1.84*			
6	88-92			3.1275	16.16	2.07	0.88	0.64	1.55
7	94-95	9.02	4.79	3.0975	16.83	1.94*	0.47	0.62	0.78
8	96-97	9.6	7.20	3.117	17.42	1.94*	0.68		
9	98-99	11.22	8.67	3.015	16.97	1.87*	0.49		0.88
10	98-99	10.82	8.02	2.872	15.66	4.41	0.49	0.66	0.95
10	99-00	10.53	7.69	2.919	17.07	4.41	0.46	0.71	1.14

*1. Özdamar et al., (1991); 2. Karaçam and Düzgüneş, (1990);3. Düzgüneş and Karaçam, (1989);4. Ünsal (1989); 5. Özdamar et al., (1994); 6. Bingel et al., (1996);7. Özdamar et al., (1995); 8. Kayalı (1998); 9. Gözler and Çiloğlu (1998);10. Samsun et al., (2004) * Estimated from our research team.*

M/k ratios of fish were 1.55, 1.61, 1.89 and 1.84 for years and total samples, respectively. The reliability of the estimated M was ascertained with M/k ratio, which has been reported to be within the range of 1.12-2.5 for most fishes (Beverton and Holt 1959). The M/k ratios of this study fall within the defined range. Mortality parameters of anchovy on the Turkish coast of the Black Sea are shown in Table 5 and 6. The natural mortality of anchovy in this study is M=0.30 year^{-1} , indicating that the species is characterized by very low natural mortality, which in turn provides high fishing rates F=2.07 year^{-1}. Bingel *et al*. 1996 reported that mean natural mortality (M) and exploitation rate (E) was determined as 0.88 year^{-1} and 0.64 year^{-1} respectively for 1986-1992 years of the Black Sea. The natural mortality (M) and exploitation rate (E) was found as 0.47 year^{-1} and 0.62 year^{-1} for 1994-1995 fishing season (Özdamar *et al*., 1995) and this values was reported as M= 0.49 year^{-1} and M=0.4 year^{-1} , E=0.65 year^{-1} and E=0.71 year^{-1} for 1998-1999 and 1999-2000 fishing seasons, respectively (Samsun *et al*., 2004). In the present study, natural mortality was (M) 0.29 year^{-1} and fishing mortality (E) was 0.85 year^{-1} for 2002-2003 fishing season. The main reason for getting higher exploitation rates (E) is mainly increasing of fishing pressure. Patterson (1992) reported that if exploited rate is about E=0.4, the stock is safe and may be used a guideline for the appropriate exploitation of small pelagic species. In general results show that the stock is being heavily exploited in the fishing seasons.

The numbers of the fishing vessels, fishing capacity and longer than length of 20 m have been remarkable increased by 100% especially from 1984 to 2002 in Turkey (Anonymous, 1985-2004). The increase of length and power of the fishing vessels have given to fisherman opportunity for fishing in the rough weather. Because of this the fishing effort has rather increased. The uncontrollable increase in the number of fishing boats has most remarkable effect on anchovy fishing. This impact over the anchovy stocks can be possibly observed of the exploitation ratio in the studies by the years.

The exploitation rate (E) is higher than optimum exploitation rate. Gonadal examinations have demonstrated that age group 0 was not reached sexual maturity. Age group 0 is consisted 26% of total samples. Because of this, an appropriate management system of fisheries including restriction of fishing effort by limiting entry to fishing ground that especially nursery grounds and fish size should be applied for anchovy fisheries. It has been point out that it is use to impose the restriction of the length in the catch of the fish with an extensive control for the fishing. In order to optimum management, anchovy stocks should be monitored by continuous investigations.

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