Acta Oceanol. Sin., 2011, Vol. 30, No. 6, P. 72-81
DOI: 10.1007/s13131-011-0163-y
http://www.hyxb.org.cn
E-mail: hyxbe@263.net

Studies on ecological characteristics variation and population dynamics of four lizardfishes in the southern Taiwan Straits

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Received 30 October 2010; accepted 1 December 2010

Abstract

The ecological characteristics of four lizardfishes, *Trachinocephalus myops, Saurida undosquamis, Saurida tumbil* and *Saurida elongata*, were studied from specimens (910 *T. myops*, 454 *S. undosquamis*, 686 *S. tumbil* and 744 *S. elongata*) collected monthly in the southern Taiwan Straits from April 2005 to March 2006. The population dynamics of the four lizardfishes was also discussed by the comparison with the previous studies. All being composed of 7 a classes; the dominant group of *T. myops* and *S. tumbil* was 1–2 a, while *S. undosquamis* and *S. elongate* were 2–3 a. The total mortality coefficient Z and the fishing mortality F were at high as indicated by the exploitation ratio $E(>0.5)$, and a large number of by-caught juvenile and young fishes showing that the stock of lizardfishes in this area was overexploited and the fishing gear was irrational. Compared with the previous studies, the maximum and mean fork length, body mass and age of the four lizardfishes declined gradually, the lizardfishes populations were younger in age and smaller in size. The asymptotic fork length L_∞ decreased while increasing growth coefficient k, and age at the inflexion point of mass $t_{\rm r}$ was younger compared with the previous studies. The declining of older ones has moderated the feeding competition and the younger ones grew faster. The larger mortality parameters Z, M and F have revealed higher fishing pressure. The smaller change of the first mature fork length of female *T. myops* and the change from K selection pattern to r selection pattern of *S. tumbil* have indicated a more vulnerable fishery ecosystem in this area. The changes of ecological characteristics and population dynamics may be caused by over-exploitation of demersal fishes such as the lizardfishes, especially a large number of juvenile and young fishes by-catch by the current fishing gears and methods. Therefore, in addition to the traditional fishery management approach such as the minimum length-limit, ecosystem approach to fisheries management (EAF) should be taken to improve the practical marine ecosystem management, including increased fishing intensity of the non-economic species especially the feeding competitors of the lizardfishes and the conservation of the pelagic fishery population in the fisheries ecosystem, in order to restore the fishery population and achieve the sustainable use of the fishery stocks.

Key words: lizardfish, ecological parameters, population dynamics, ecosystem approach to fisheries management, southern Taiwan Straits

1 Introduction

The lizardfishes *Trachinocephalus myops, Saurida undosquamis, Saurida tumbil* and *Saurida elongata* are warm-water fishes distributed in the East China Sea, the South China Sea and the southern Yellow Sea in China (Liu, 2008). They are commercially important not only to the Chinese, but also to the Japanese and Korean trawl fisheries (Jiao et al., 1999). As one of the most important demersal fish, the stocks of lizardfishes in the East China Sea, the northern South China Sea and the southwestern continental of the Nansha Islands have experienced heavy exploitation (Huang and Chen, 2005; Shu and Qiu, 2004a; Yoneda et al., 2002).

Foundation item: Marine Public Welfare Project of China under contract Nos 200805065, 200905019-6, 200705029 and 200805064; Chinese Offshore Investigation and Assessment under contract No. 908-02-04008; the Scientific Research Foundation of the Third Institute of Oceanography, SOA under contract No. 2011006; Marine Science Foundation for Young Scientist under contract No.2011143.

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They are abundant in the southern Taiwan Straits (in the southern part of the East China Sea), and are usually fished at the depths between 20–120 m (Huang, 2008). Owing to intense fishing pressure in the southern Taiwan Straits, the population of demersal fish such as the lizardfishes also has been low in recent years (Lu, Dai and Yan, 1999; Lu, Dai, Zhu et al., 1999). The assessment of demersal fish like lizardfishes stocks and the establishment of fishery management guidelines are urgently needed in this area.

A number of studies about the age and growth (e.g., Liu et al., 2009; Shu and Qiu, 2004b; Yoneda et al., 2002; Zhang, 1997; Xu and Zhang, 1988; Lee et al., 1986; Xu and Zhang, 1986), feeding habits (Yan et al., 2010; Huang et al., 2008; Zhang and Yang, 1986; Zhang et al., 1981), biology (Shu and Qiu, 2004a), scale structure (Zhang and Xu, 1987) and stock variation (Huang and Chen, 2005) of these lizardfishes species in the East China Sea and the South China Sea are available. However, as most of these studies focused on single fish species and only little information on the ecological characteristics and population dynamics of these species is available, an adequate fishery assessment and management of lizardfishes in the southern Taiwan Straits has been impossible. This paper studies the ecological characteristics of lizardfishes in the southern Taiwan Straits, and discusses the changes of population dynamics by the comparison with the previous studies.

2 Materials and methods

2.1 *Sampling information*

The lizardfishes were sampled randomly by commercial trawlers monthly in the Minnan-Taiwan Bank Fishing Ground (22°00′–24°30′N, 117°30′–120°45′E) during the period from April 2005 to March 2006 (Fig.1). The fishing net circumference is 70.8 m, the net full length is 42.5 m, the mesh size at net mouth is 16 mm, and mesh size at bag is 30 mm. The fishing ground is located in the south of the Taiwan Straits, and it is an important interface between the East China Sea and the South China Sea. The subtropical monsoon climate, complex topography and water mass converge have made the marine environment of this area unique and complicated. Most specimens were landed from the waters between 20 and 60 m in depth.

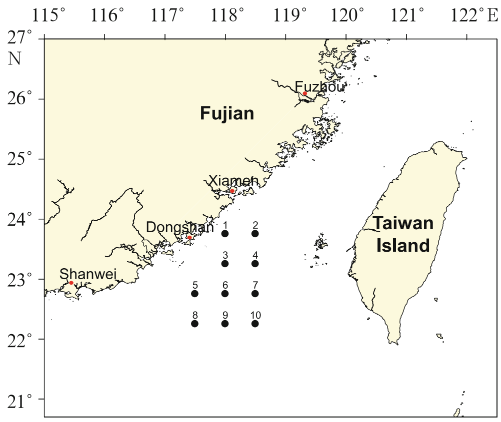

Fig.1. Sampling area and survey stations of four lizardfishes in the southern Taiwan Straits.

2.2 *Age determination*

The age of fish is determined by scales, as each scale contains concentric growth band pairs, including translucent and opaque bands. The growth band pairs on the scales were examined under a microscope (6×10) (Zeiss Stemi SV6). The distance from the focus to the outer margin of the translucent band of growth band pairs and the scale radius were measured as a straightline from the focus to the edge of the scale. All specimens were determined for their ages.

2.3 *Ecological parameters*

The fork length (l_{f}, in mm) and body mass (m, in g) of all the specimens were measured by following the Specifications for Oceanographic Survey: Part 6. Marine Biological Survey (GB/T 12763.6–1991). The gonadial maturity analysis and first mature fork length determination of female *T. myops* also followed the Specifications.

The relationship between fork length (l_{f}) and the scale radius (R) was estimated by the linear regression analysis.

The length-mass relationship was determined by following the allometric equation (Sparre and Venema, 1992):

$$m = a l_{\mathrm{f}}^{b}, \tag{1}$$

where m is the total body mass (g); l_{f} is the fork length (mm); a and b are the constants.

Growth was expressed in terms of the following equation of (von Bertalanffy, 1938):

$$l_t = l_\infty (1 - \mathrm{e}^{-k(t-t_0)}), \tag{2}$$

$$m_t = m_\infty (1 - \mathrm{e}^{-k(t-t_0)})^b, \tag{3}$$

where l_t and m_t are the fork length and body mass at age t, l_∞ and m_∞ are the asymptotic fork length and body mass; k is the growth coefficient; t is the age (year from birth); and t_0 is the theoretical age when the specimen is at zero fork length.

The surviving ratio S was estimated using the equation relating to age distribution data for species (Robson and Chapman, 1961), then the total mortality coefficient Z was calculated through the following equation (Richer, 1975):

$$S = \mathrm{e}^{-Z}. \tag{4}$$

The natural mortality M for each species was estimated using empirical equation relating M to l_∞, k and the mean water temperature (Pauly, 1980):

$$\ln M = -0.006\ 6 - 0.279\ln l_\infty + 0.654\ln k + 0.463\ln T, \tag{5}$$

where the mean temperature of demersal water in the southern Taiwan Straits is 23.47°C.

The fishing mortality, F, was obtained by subtracting M from Z.

The exploitation ratio, $E = Z/F$. The parameter E expressed the proportion of a given cohort/population that ultimately dies due to fishing under an existing exploitation pressure (Beverton and Holt, 1966).

The minimum mass-limit was estimated using equation relating m_r to E and mean fishery landing mass ($\overline{m}$) (Allen, 1953):

$$m_\mathrm{r} = E\overline{m}. \tag{6}$$

Then, the minimum length-limit (l_r) can be calculated through the allometric equation stated above (Sparre and Venema, 1992).

3 Results

3.1 *Population structure*

Totally 910, 454, 686 and 744 individuals were collected for *T. myops, S. undosquamis, S. tumbil* and *S. elongate* from the catch, respectively. The population structure analysis shows clear differences in the range of fork length, body mass and age distributions among the four lizardfishes, and the mean fork length (from 187 to 316 mm) were different obviously. The mean fork length of *S. undosquamis* was much greater than the other three species, although the maximum fork length of *S. elongata* was the greatest. The trend of body mass was similar to the fork length. The four species consisted of 7 a classes respectively in the age composition, of them, *T. myops* and *S. tumbil* were from Age 0 to Age 6, with a dominant group of 1–2 a, while *S. undosquamis* and *S. elongate* were from Age 1 to Age 7 with a dominant group of 2–3 a. The mean age of *S. undosquamis* and *S. elongate* was older than that of *T. myops* and *S. tumbil*, although the mean age of the four lizardfishes was all very small, not more than 3 a. One point should be noted is that the mean fork length, body mass and age of *S. undosquamis* were all much greater than those of the other three species (Tables 1 and 2). The gonadial maturity of female *T. myops* was analyzed and the first mature fork length was determined to 165 mm.

3.2 *FL-R relationships and back-calculated FL*

The regression analysis shows a linear relationship between the fork length and the scale radius:
for *T. myops*,

$$l_f = 18.13 + 3.511R$$
$$(n = 910, r = 0.962\ 1, F = 5\ 639 > F_{300,0.01} = 6.72);$$

for *S. undosquamis*,

$$l_f = 13.445 + 6.547R$$
$$(n = 454, r = 0.944\ 7, F = 3\ 477 > F_{300,0.01} = 6.72);$$

for *S. tumbil*,

$$l_f = 27.24 + 3.272R$$
$$(n = 686, r = 0.962\ 3, F = 5\ 507.7 > F_{300,0.01} = 6.72);$$

for *S. elongata*,

$$l_f = 20.321 + 4.214R$$
$$(n = 744, r = 0.934\ 2, F = 2\ 640.1 > F_{300,0.01} = 6.72).$$

The FLs of each fish were back-calculated to the time of formation of the nth annulus from each radius. The mean back-calculated FLs of each successive scale annulus in the time of annulus formation are shown in Table 2. The result shows that the back-calculated fork length was the same as the observed fork length, which indicated that the fl-R relationships of the four lizardfishes were reasonable and credible.

3.3 *m-FL relationships*

The relationship between the total mass and the fork length is described as follows:
for *T. myops*,

$$m = 2.213\ 5 \times 10^{-5} l_f^{2.893\ 2}$$
$$(n = 910, r = 0.948\ 8, F = 8\ 192.2 > F_{1\ 000,0.01} = 6.66);$$

Table 1. Changes of the fork length composition, body mass composition and age composition of four lizardfishes in the southern Taiwan Straits

Species	Year	Fork length composition/mm			Body mass composition/g			Age composition/a			Reference
		range	mean	dominant group	range	mean	dominant group	range	mean	dominant group	
T. myops	1976–1977	96–295	207	191–240	10–375	142	101–170	0–6	2.8	3–4	report*
	1983–1984	109–325	201	211–260	11–422	102	101–120	0–6	2.0	1–2	Lu, Dai, Zhu et al. (1999)
	1992–1993	80–324	189	160–200	8–415	92	91–110	0–6	1.6	1–2	Zhang (1997)
	1997–1998	80–320	188	141–220	8–396	90	91–110	0–6	1.5	1–2	Lu, Dai, Zhu et al. (1999)
	2005–2006	84–318	187	141–220	8–385	90	81–100	0–6	1.5	1–2	current study
S. undosquamis	1987	169–488	322	291–330	62–1 190	329	280–450	1–9	4.6	3–4	Lu, Dai and Yan (1999)
	2005–2006	153–465	316	281–330	46–1 053	283	251–400	1–7	3.1	2–3	current study
S. tumbil	1983–1984	195–537	238	191–210	65–1 714	128	91–120	0–8	1.5	1	Xu and Zhang (1988)
	1997–1998	111–458	217	191–200	15–1 205	115	81–110	0–6	1.4	1	Lu, Dai, Zhu et al. (1999)
	2005–2006	101–450	201	181–200	13–1 127	101	71–100	0–6	1.2	0–1	current study
S. elongata	1993–1994	110–507	249	231–270	14–1 520	199	141–210	1–7	3.4	3–4	Lu, Dai and Yan (1999)
	2005–2006	107–485	241	221–260	13–1 345	153	131–170	1–7	3.0	3	current study

Notes: *Fishery Investigation Team. 1980. Fishery investigation report of Minnan Taiwan Bank Fishing Ground.

Table 2. Mean observed fork length and back-calculated fork length at each age for four lizardfishes in the southern Taiwan Straits

Species		Age/a						
		1	2	3	4	5	6	7
T. myops	numbers/n	456	370	48	30	4	2	0
	observed length/mm	161	207	242	270	292	314	–
	back-calculated length/mm	166	209	240	268	302	318	–
S. undosquamis	numbers/n	2	287	89	56	12	5	3
	observed length/mm	171	248	317	375	416	443	467
	back-calculated length/mm	172	249	316	373	415	443	465
S. tumbil	numbers/n	521	109	38	14	3	1	0
	observed length/mm	182	261	316	352	400	450	–
	back-calculated length/mm	187	258	313	362	400	441	–
S. elongata	numbers/n	44	98	442	112	42	4	2
	observed length/mm	155	226	297	331	373	416	440
	back-calculated length/mm	158	225	283	330	369	419	431

Notes: –indicates that the data is not available. n indicates numbers of fish examined.

for *S. undosquamis*,

$$m = 3.292\ 4 \times 10^{-5} l_f^{2.813\ 6}$$

$(n = 454, r = 0.952\ 7, F = 7\ 723.9 > F_{1\ 000,0.01} = 6.66)$;

for *S. tumbil*,

$$m = 1.531\ 3 \times 10^{-5} l_f^{2.963\ 1}$$

$(n = 686, r = 0.963\ 1, F = 8\ 758.5 > F_{500,0.01} = 6.69)$;

for *S. elongata*,

$$m = 0.628\ 7 \times 10^{-5} l_f^{3.101\ 2}$$

$(n = 744, r = 0.943\ 7, F = 6\ 038.6 > F_{500,0.01} = 6.69)$.

The analysis shows that the exponent b of the four fishes is all close to 3.0, which indicates that the growth of the four lizardfishes is isometric, or their body shapes and specific gravities do not change with growth.

3.4 *von Bertalanffy equations*

The von Bertalanffy growth equation was fitted to all back-calculated FLs:

for *T. myops*,

$$l_t = 431.69(1 - \mathrm{e}^{-0.169\ 9(t+1.681\ 7)}),$$
$$m_t = 931.45(1 - \mathrm{e}^{-0.169\ 9(t+1.681\ 7)})^{2.893\ 2};$$

for *S. undosquamis*,

$$l_t = 563.06(1 - \mathrm{e}^{-0.232\ 8(t+0.558\ 8)}),$$
$$m_t = 1\ 804.98(1 - \mathrm{e}^{-0.232\ 8(t+0.558\ 8)})^{2.813\ 6};$$

for *S. tumbil*,

$$l_t = 647.57(1 - \mathrm{e}^{-0.160\ 2(t+1.157\ 8)}),$$
$$m_t = 3\ 274.74(1 - \mathrm{e}^{-0.160\ 2(t+1.157\ 8)})^{2.963\ 1};$$

for *S. elongata*,

$$l_t = 566.62(1 - \mathrm{e}^{-0.185\ 1(t+0.670\ 3)}),$$
$$m_t = 2\ 172.46(1 - \mathrm{e}^{-0.185\ 1(t+0.670\ 3)})^{3.101\ 2};$$

The growth rate curves of fork length and body mass of the four lizardfishes could be analyzed by calculating the first derivative. The growth rate of fork length is a curve which decrease with age until the curve approaches zero (Fig.2a), while the growth rate of body mass is a parabola increasing with age first until the age reaches to t_r (the age at the inflexion point of body mass), then decreasing with age (Fig.2b). The t_r of *T. myops*, *S. undosquamis*, *S. tumbil* and *S. elongata* is 4.57, 3.89, 5.62 and 5.44 a respectively (Fig.3b).

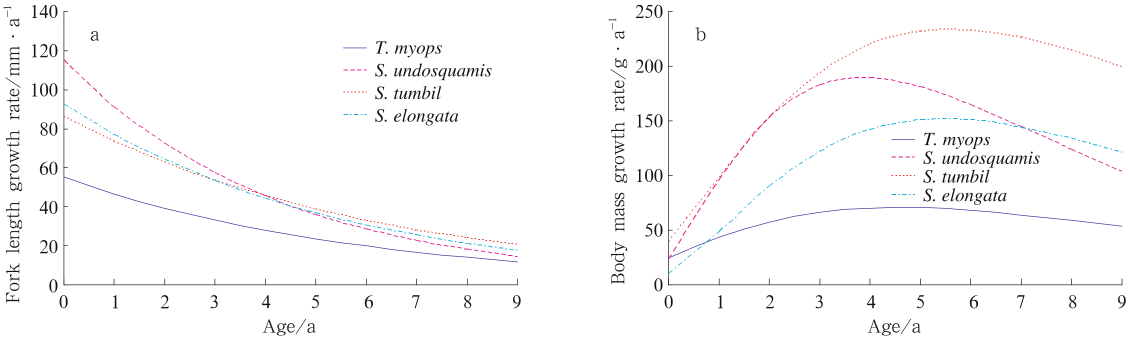

Fig.2. Growth rate curve of fork length and body mass of four lizardfishes in the southern Taiwan Straits.

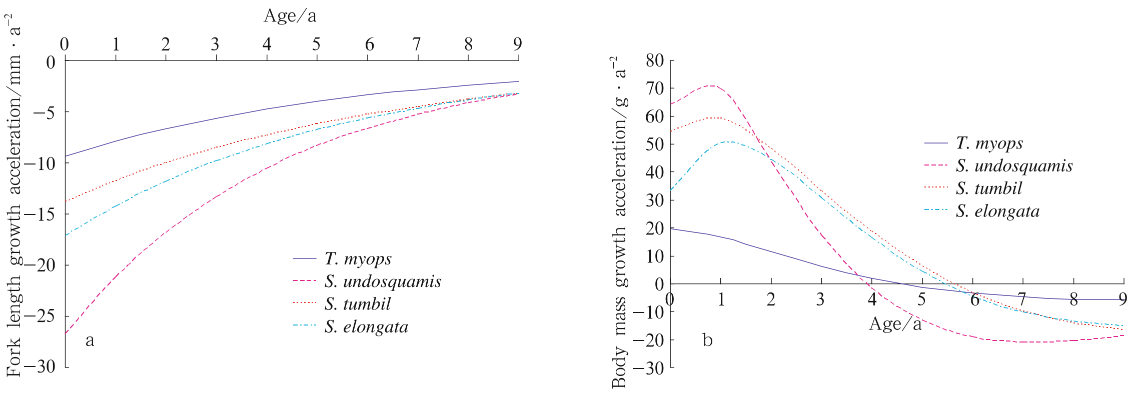

Fig.3. Acceleration curve of fork length and body mass of four lizardfishes in the southern Taiwan Straits.

The acceleration curves of fork length and body mass of the four lizardfishes could be analyzed by calculating the second derivative. The acceleration of body mass is positive before the age reaches the t_r when the growth rate of body mass increases. The growth rate of body mass reaches the biggest when the age reaches t_r when the acceleration of the body mass is 0. The acceleration of body mass is negative after the age has reached the t_r when the growth rate of body mass decreases (Fig.3).

3.5 *Mortality characteristics*

The natural mortality M of the four lizardfishes was of little difference (0.404 1–0.536 5), while the fishing mortality F was different obviously, ranging from 0.564 9 to 1.127 8, and F of *T. myops* was much higher than other species. The total mortality coefficient Z always changed with F, the Z of the four lizardfishes was all over 1.101 4 although the value for *T. myops* was the biggest, up to 1.598 0 (Table 3). As F of all the four lizardfishes was high, the exploitation ratio E was more than 0.5, and for *T. myops* the value was even as high as 0.705 8, indicating that the four lizardfishes were all exploited in the southern Taiwan Straits.

Based on E of the four lizardfishes, the minimum

Table 3. Changes of the ecological parameters of four lizardfishes in the southern Taiwan Straits

Species	Year	l_∞/mm	K/a^{-1}	t_0/a	t_r/a	Z	M	F	E	l_r/mm	Reference
T. myops	1983–1984	567.72	0.100 9	–1.420 0	10.51	1.526	0 0.307 0	1.218 9	0.798 8	187.91	Xu and Zhang (1986)
	1992–1993	609.26	0.085 0	–2.876 7	10.32	1.408 7	0.344 3	1.064 5	0.755 7	171.30	Zhang (1997)
	1997–1998	541.44	0.102 9	–2.523 6	8.34	1.583 3	0.318 0	1.265 4	0.799 2	–	Lu, Dai, Zhu et al. (1999)
	2005–2006	431.69	0.169 9	–1.681 7	4.57	1.598 0	0.470 2	1.127 8	0.705 8	166.08	current study
S. undosquamis	1987	599.90	0.169 0	–0.058 8	6.12	0.867 5	0.422 2	0.445 3	0.513 3	253.40	Lu, Dai and Yan (1999)
	2005–2006	563.06	0.232 8	–0.558 8	3.89	1.101 4	0.536 5	0.564 9	0.512 9	249.09	current study
S. tumbil	1983–1984	830.21	0.111 0	–0.427 1	6.79	1.061 6	0.294 0	0.767 6	0.723 1	215.20	Xu and Zhang (1988)
	1997–1998	784.01	0.114 1	–1.420 5	8.08	1.455 8	0.306 8	1.149 0	0.789 3	–	Lu, Dai, Zhu et al. (1999)
	2005–2006	647.57	0.160 2	–1.157 8	5.62	1.191 1	0.404 1	0.787 0	0.660 7	175.04	current study
S. elongata	1993–1994	576.80	0.171 3	–0.952 8	5.61	1.252 8	0.430 6	0.816 8	0.652 0	214.4	Lu, Dai and Yan (1999)
	2005–2006	566.62	0.185 1	–0.670 3	5.44	1.326 0	0.461 0	0.865 0	0.652 3	210.07	current study

Notes: –indicates that the data were not available.

length-limit of *T. myops, S. undosquamis, S. tumbil* and *S. elongata* was calculated as 166.08 mm, 249.09 mm, 175.04 mm and 210.07 mm respectively (Table 3). About 50.11% (*T. myops*), 63.83% (*S. undosquamis*), 59.33% (*S. tumbil*) and 17.77% (*S. elongata*) of the four lizardfishes landing from trawl fisheries were lower than the minimum length-limit, which indicated that a large number of juvenile and young fishes died due to bycatch, and the fishing gear was irrational.

4 Discussion

The fishes of *T. myops, S. undosquamis, S. tumbil* and *S. elongata* are all in the family of Synodidae. They were mix-distributed but had different living strategies (Xu and Zhang, 1986). Although the fork length growth rate of *S. tumbil* is lower than *S. undosquamis* and *S. elongate* before about 4 a, the body mass growth rate of *S. tumbil* is the highest in the four lizardfishes in the southern Taiwan Straits (Fig.2), and t_r of *S. tumbil* is the biggest (Fig.3), which may make the asymptotic fork length l_∞ and the asymptotic body mass m_∞ of *S. tumbil* the largest. However, the mean fork length, body mass and age of *S. tumbil* are almost the smallest in the four lizardfishes in 2005–2006 (Table 1), which indicates that the population of *S. tumbil* is more vulnerable than other species under fishing, agrees with the opinion of Xu and Zhang (1988).

Compared with the population structure of lizardfishes studied in the southern Taiwan Straits in the past years (Lu, Dai and Yan, 1999; Lu, Dai, Zhu et al., 1999; Zhang, 1997; Xu and Zhang, 1988; Xu and Zhang, 1986), the maximum and mean fork length, body mass and age of the four lizardfishes decreased gradually, the populations were younger in age and smaller in size (Table 1). For example, in the 1990s, the longevity of *T. myops* reached 6 a in South Fujian and the Taiwan Bank Fishing Ground, and the dominant group was composed of 1 and 2 a classes (Zhang, 1997; Xu and Zhang, 1986), to which our findings agreed well. The percentage of 3 a decreased from 13.4% in 1983–1984 to 5.27% in 2005–2006, and the percentage of 4 a decreased from 9.8% in 1983–1984 to 3.29% in 2005–2006. Compared with that of 1976–1977, the mean fork length, body mass and age of *T. myops* have decreased from 207 mm, 142 g and 2. 8 a to 187 mm, 90 g and 1.5 a respectively (Table 1), which indicates that the fisheries ecosystem has turned to be vulnerable gradually. It should be noted that, though the fishing pressure was kept at a high level during 1992–2006 (Du et al., 2008), the biological characteristics like average fork length, body mass and age of *T. myops* were relatively stable (Table 1), while the ecological parameters changed greatly (Table 3). Meanwhile, the first mature fork length of *T. myops* (females) became smaller and smaller, decreasing from 202 mm in 1983 to 180 mm in 1997 (Lu, Dai, Zhu et al., 1999), and then decreasing to 165 mm in 2005–2006, indicates that the energy transformation way of *T. myops* has changed, part of the energy was used to early maturation rather than individual growth, in order to adapt to overfishing and other environmental changes. There may be a threshold on the fish miniaturization and younger, the average fork length, body mass, age and other biological characteristics will keep stable when reaching this threshold, then the survival strategies will steer to maturation for reproduction as early as possible from individual growth.

The exploitation ratio E expressed the proportion of a given cohort/population that ultimately dies due to fishing under an existing exploitation pressure. Suitable exploitation ratio E was related to natural mortality, fecundity and other factors, and different species have different suitable exploitation ratio. The suitable E was suggested to be between 0.308 and 0.500 or no more than 0.500, the balance of recruitment and catch would be disturbed if E was over 0.500 (Zhan, 2000; Gulland, 1971; Cushing, 1968). For the four lizardfishes in the southern Taiwan Straits, The fishing mortality F was at a high level for a long time and became large year by year, which made the exploitation ratio E to be over 0.500 (Table 3). Among the four lizardfishes species, the stock of *T. myops* was the lowest, whose exploitation ratio reached 0.705 8, and over half of the catches (50.11%) were smaller than the minimum capture limit, which indicates that the stock of lizardfishes in this area was overexploited and the fishing gear was irrational.

The growth characteristics of the four lizardfishes in the southern Taiwan Straits also changed greatly by the comparison with the previous study (Lu, Dai and Yan, 1999; Lu, Dai, Zhu et al., 1999; Zhang, 1997; Xu and Zhang, 1988; Xu and Zhang, 1986). The growth coefficient k increased year by year, and the age at the inflexion point t_r of mass was younger than before (Table 3). The age composition of the four lizardfishes was a bit complex, the changes of the ecological characteristics were influenced by human disturbance, environmental changes and their biological characteristics, but the main factor was the overfishing (Huang and Chen, 2005; Lu et al., 1995; Luo et al., 1993; Zhang and Yang, 1986). The maximum sustainable yield (MYS) of the benthic and epibenthic fishes totals up to 269.4 kt in the Minnan-Taiwan Bank Fishing Ground, and can be calculated to 2 180 standard trawl boats in 2008. While from 1994 to 2007, the actual yearly catches were about 271.9–349.9 kt, and 2 249–3 500 standard trawl boats fished in this area, which have been over the MSY of the benthic and epibenthic fishes for 14 a (Du et al., 2008). The overfishing of benthic and epibenthic fish like lizardfishes has overtaken much more of the recruitment, resulting in significant declines of the population especially the older members. This has moderated the feeding competition and made the younger ones grow faster.

There were two groups of *S. undosquamis* in the East China Sea, the southern group and the northern group, their size being different. The specimens from the southern group reach greater than 400 mm in the total length, whereas the specimens from the northern group are rarely greater than 300 mm (Yamada and Ikemoto, 1979). This information about the northern group was in agreement with *S. undosquamis* in the Inland Sea of Japan (Tatara, 1965). Our results clearly indicate that *S. undosquamis* in the southern Taiwan Straits do exceed 400 mm in the FL, but it is a little shorter compared with the results from the studies in 1987. *S. undosquamis* in the northern South China Sea could be divided into the colony on continental shelf of the northern South China Sea and the colony in the Beibu Gulf, l_∞ of the two colonies being 455 and 400 mm, and their F being 0.79 and 1.11 (Shu and Qiu, 2004b). It is clearly shown that the fishing pressure is heavier than that in the southern Taiwan Straits.

In 1983–1984, *S. tumbil* from South Fujian and the Taiwan Bank Fishing Ground consisted of 9 a classes, from Age 0 to Age 8, and the maximum fork length was 537 mm (Xu and Zhang, 1988). There were no specimens with a seventh annual ring mark on their scales in our study (2005–2006), and the maximum fork length was only 450 mm, which indicates that lizardfishes were of younger ages and smaller sizes compared with the previous studies. One point should be noted is that, *S. tumbil* inclined to the K selection pattern species in 1983–1984, with bigger size (l_∞=830.21 mm), longer longevity (8 a) and lower natural mortality (0.294 0) (Xu and Zhang, 1988), but the ecological characteristics of *S. tumbil* with smaller size (l_∞=647.57 mm), shorter longevity (6 a) and higher natural morality (0.404 1) in 2005–2006. It suggests that this species has changed from K selection pattern to r selection pattern gradually.

l_∞ of *S. tumbil* in the Northern South China Sea was 585 mm (Shu and Qiu, 2004a), smaller than that in the southern Taiwan Straits. F was 1.55 in the Northern South China Sea in the 1980s, which increased two times compared with that in the 1960s, and F in the 1990s increased two times compared with that in the 1980s (Shu and Qiu, 2004a), much higher than that in the southern Taiwan Straits. F of male and female of *S. tumbil* in the Beibu Gulf was 1.97 and 1.83 in 2009 (Liu et al., 2009), also higher than that in the southern Taiwan Straits. It indicates that the miniaturization of *S. tumbil* population in the Northern South China Sea and the Beibu Gulf was much heavier than that in the southern Taiwan Straits.

Lizardfishes in the southern Taiwan Straits are commercially important, and they are in the middle layer of the food web as the middle carnivores playing an important role in the food web of fishes in the southern Taiwan Straits (Zhang et al., 1981). The whole marine ecosystem structure may be subject to impacts if the ecological characteristics and population dynamics of the lizardfishes continue to deteriorate. So the protection and management of the lizardfishes resources should be intensified. As a large number of juvenile and young fishes were captured in this area, the first capture length should be implemented in order to protect the juvenile. The minimum length-limit of *T. myops, S. undosquamis, S. tumbil* and *S. elongata* is 166.08, 249.09, 175.04 and 210.07 mm respectively based on our study, and a stricter management approach is than before (Table 3). The fishing gears and methods should be improved in order to reduce the juvenile and young by-catch, and the fish habitat especially the spawning ground should be protected. The management approach is very important too, awareness of the limitation of a single-species approach to management has led to global acceptance of the need to adopt a wider ecosystem approach to fisheries (EAF) assessment and management (FAO, 2003; FAO, 2008). EAF is a new concept which emphasizes integrated management from the perspective of the whole marine ecosystem and the implementing of EAF may improve the marine management in China (Chu, 2010; Tang and Zou, 2009; Zhang and Mu, 2006).

The four lizardfishes in the southern Taiwan Straits are carnivorous with cannibalism, the structure of digestive organs is adapted to their carnivorous habits in which *S. undosquamis* and *S. tumbil* are similar to each other, and their feeding habits are more ferocious than those of *T. myops* (Zhang and Yang, 1986). The trophic levels of *T. myops, S. undosquamis, S. tumbil* and *S. elongata* are 3.2, 3.4, 3.4 and 3.2 as they feed mainly on fishes and Cephalopods, and minorly on Macrura, Brachyura and Stomatopoda, whose trophic level is about 2.0–3.0, 2.5, 1.8, 1.6 and 1.6, respectively (Huang et al., 2008; Zhang et al., 1981). The pelagic fishes occupy a large proportion in the foodstuffs. So, based on EAF, the whole fishery ecosystem especially the pelagic fishes should be protected first if we want to protect the lizardfishes. Meanwhile, there are many demersal fish species competing in feeding with the lizardfishes, and many of them are non-economic species like *Uranoscopus japonicus*. So it is necessary to increase the fishing intensity on the non-economic species and to reduce the feeding competitors of the lizardfishes. At the same time, some predators of lizardfishes are non-economic species, like *Lophiomus setigerus*, the catch of them should be strengthened, a potential benefits for the conservation and sustainable use of the lizardfishes stock.

5 Conclusions

The ecological characteristics and population dynamics of fishes have an important role in the marine fisheries ecosystem study. The results of this study reveal that the lizardfishes *T. myops, S. undosquamis, S. tumbil* and *S. elongata* populations in the southern Taiwan Straits are younger in age and smaller in size, the younger fish grows faster, the fishing pressure heavier. The first mature fork length of *T. myops* (females) changed smaller and the *S. tumbil* changed from K selection pattern to r selection pattern, the fisheries ecosystem was vulnerably in this area. The above changes may be caused by the fact that the stock of demersal fish has experienced heavy overfishing, especially a large number of juvenile and young fishes die due to by-catch. Therefore, we suggest that the fishery management should be combined with the traditional fishery management and EAF in addition to increasing fishing intensity of feeding competitors of the lizardfishes and enhancing the conservation of pelagic fishes in the fisheries ecosystem.

Acknowledgements

The authors are grateful to Professor Zhou Qiulin in the Third Institute of Oceanography, State Oceanic Administration for his valuable suggestions. And we thank all anonymous reviewers for their constructive comments which greatly improve this paper.

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