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Growth and Mortality of the Fantail Sole, *Xystreurys liolepis* (Jordan and Gilbert 1881) off the Western Coast of Baja California, Mexico

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Abstract.—Data on growth and mortality were obtained for fantail sole, *Xystreurys liolepis* collected with otter trawls during 11 cruises off the western coast of Baja California, Mexico, from April 1988 to December 1990. The Bottom temperature varied between 11 to 19°C. In all, 712 *X. liolepis* were caught and over the sampling period the sex ratio of males to females was 1:1.2. Males were smaller than females. The relationship between weight and length is described for males by, $W = 1.1013 \times 10^{-5} SL^{3.121544}$ and for females by, $W = 7.6274 \times 10^{-6} SL^{3.1932}$. Von Bertalanffy growth parameters were determined to be: $L_\infty = 443$ mm SL, $k = 0.16$, $t_0 = -0.098$ total sample, for males by, $L_\infty = 354.85$ mm SL, $k = 0.151$, $t_0 = -0.918$, and for females by, $L_\infty = 444.68$ mm SL, $k = 0.1636$, $t_0 = -0.423$. The total mortality (Z) rate was 0.62 and the estimated fishing mortality (F) was 0.46. Although fantail sole is not a target species of commercial fisheries, it suffers high mortality as part of the bycatch in the shrimp fishery.

Resumen.—Se obtuvieron datos de crecimiento y mortalidad del lenguado de dos manchas, *Xystreurys liolepis,* éstos fueron colectados con redes de arrastre de fondo durante 11 cruceros, que se llevaron a cabo en la costa occidental de Baja California, México, de abril de 1988 a diciembre de 1990. La temperatura de fondo varió de 11 a 19°C. Se capturaron 712 individuos de *X. liolepis,* y durante el período de muestreo, la proporción de hembras y machos fue de 1:1.2. Los machos presentaron tallas menores comparadas con las de las hembras. La relación peso-longitud esta descrita con la siguiente ecuación para los machos $W = 1.1013 \times 10^{-5} SL^{3.121544}$ y para las hembras fue de $W = 7.6274 \times 1.1013 \times 10^{-5} SL^{3.121544}$ $7.6274 \times 10^{-6} SL^{3.1932}$. Los parámetros de crecimiento de Von Bertalanffy fueron los siguientes $L_\infty = 443$ mm SL, $k = 0.16$, $t_0 = -0.098$ para la muestra total, para los machos fue de $L_\infty = 354.85$ mm SL, $k = 0.151$, $t_0 = -0.918$, y para las hembras por $L_\infty = 444.68$ mm SL, $k = 0.1636$, $t_0 = -0.423$. La tasa de mortalidad total (Z) estimada fue de 0.62 y la mortalidad por pesca fue de 0.46. Aunque al lenguado de dos manchas, no se le considera como una pesquería directa, éste pez sufre una alta mortalidad, debido a la captura incidental como fauna de acompañamiento, en la pesca del camarón.

The fantail sole ranges from Monterey Bay to the Gulf of California at depths from 4 to 79 m (Miller and Lea, 1972). A number of studies on the distribution and abundance of the fantail sole, *Xystreurys liolepis,* have been conducted. Love et al (1986) reported *X. liolepis* in soft sediments off southern California between

6 to 18 m depth. In this area it is most commonly found in shallow offshore waters and its biomass is relatively constant across all open coast depth strata, ranging from 14 to 16 kg (Kramer 1991). However Allen and Herbinson (1991) reported that its standing crop may vary inversely with temperature. Along the western coast of Baja California, Martínez-Muñoz and Ramírez-Cruz (1992) stated that fantail sole is an abundant species, reaching up to 50 cm in length between 24° to 28° north latitude at depths from 13 to 150 m. It was also observed that in summer these fish move into shallow waters to reproduce. Moser and Watson (1990) using CALCOFI samples between 1951 and 1981 mentioned that *X. liolepis* larvae were captured from Punta Concepción to Magdalena Bay, B.C.S and were relatively abundant between the coast of Sebastián Vizcaíno Bay to Magdalena Bay from July to October, reaching peak abundance in August (10 larvae/m^2).

Despite these frequent references to its occurrence, there have been very few studies on the biology of *X. liolepis.* Off California adults of fantail sole feed on polychaetes, shrimp, crabs, and euphasiids. They spawn at the end of winter and the beginning of spring (Frey, 1971).

Although it is not considered a commercially desirable fish, fantail sole has often been found as part of the bycatch in the trawl fishery for shrimp off Baja California and in the Gulf of California (Ramírez-Hernández and Arvizú Matínez 1965). Off the coast of Sinaloa and Baja California *X. liolepis* was caught with shrimp trawls Ramírez-Hernández et al (1965). Castro-Aguirre et al (1970) and van der Heiden (1985) found that fantail sole is frequently caught by shrimp trawlers in the Gulf of California. Pérez-Mellado and Findley (1985) reported 2% of shrimp catches along the Sonora and Sinaloa coasts consisted of *X. liolepis.* Many reach sizes > 30 cm long off the coast of Orange County, California (Mearns 1979).

In Mexico there are no regulations to monitor catching of flattish (Balart 1996), so the numbers reported are reliable. However it is known there is a great fishery for them associated with shrimp trawling with most of the catches sold to California markets.

As Martínez-Muñoz and Ramírez-Cruz (1992) consider this species a potential exploitable flatfish, the purpose of this paper is to provide information on the growth and mortality of *X. liolepis* populations in the Mexican Pacific Ocean, which is needed for the regulation of *X. liolepis* as a fishery resource.

Materials and Methods

Fish were collected from April 1988 to December 1990 from 160 otter trawls conducted during the course of eleven cruises aboard the B/O "EL PUMA" and B/I MARSEP XVI. The 34 sampling stations were located off the western coast of Baja California, from Boca del Carrizal (23°00′ N) to Sebastian Vizcaino Bay (28°51′ N) in depths of 10 and 250 m (Fig. 1). All fish were obtained by an otter trawl that measured 20 m wide and 9 m high at the mouth, 24 m in length, and has a stretched mesh size of 3 cm.

Trawling time and speed were recorded to estimate the area swept by net. The shrimp boat speed was standardized to 2.2 knots while for the "EL PUMA" this was 3 knots. Trawls were towed for 30 minutes along isobaths. Depth was recorded with the Simrad sounder aboard the "EL PUMA", and Furuno sounder

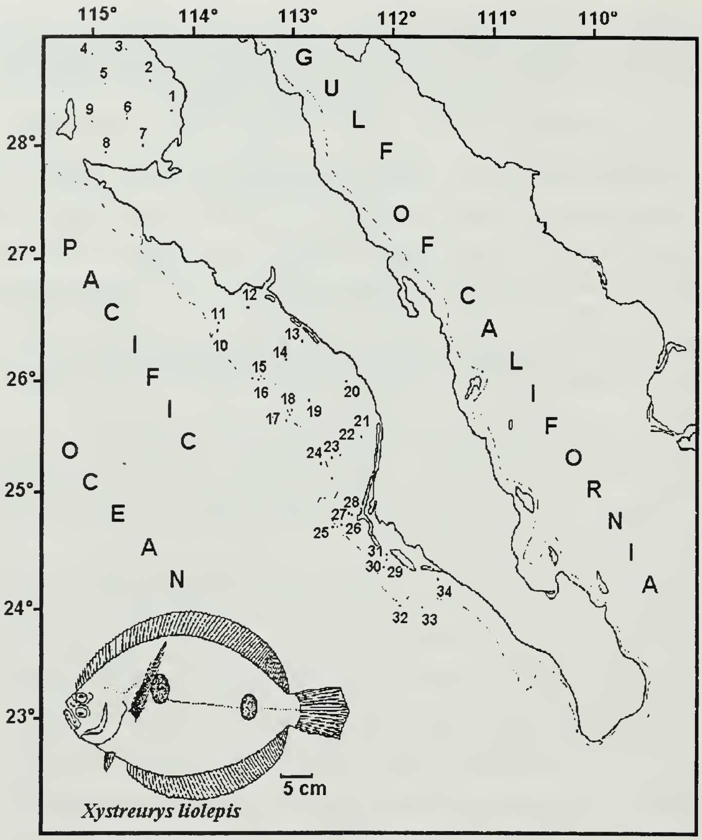

Fig. 1. Stations sampled off Baja California, México, 1988–1990.

on the "MARSEP". Temperature at bottom was recorded with Van Dorn bottles and substrate temperature was directly taken from grab samples.

Specimens of *X. liolepis* were measured (standard length, SL), to the nearest mm, weighed (g) and sexed by eye immediately on recovery. Gonads were examined macroscopically according Nikolskii (1963). These data were used to calculate length-weight relationships varying the logarithmic form of the equation $W = aL^b$ for each sex, where W is weight in grams, a, is the y-intercept, SL is standard length in mm, b: slope using FISAT software (The FAO-ICLARM Stock Assessment Tools; Gayanilo et al. 1994).

Age groups based in length frequency data of *X. liolepis* were estimated using the modal progression method of Petersen (1939). Mean lengths for age groups were fitted with the von Bertalanffy (1938) equation $L_t = L_\infty (1 - \exp^{-k(t-t_0)})$ using the Ford (1933) and Walford (1949) method by FISAT software to describe theoretical growth and growth parameters L_t = standard length of fish at t years, L_∞ = theoretical asymptotic length, k = growth coefficient rate of approach to L_∞, t_0 = theoretical age at which $L_t = 0$. LFDA (Length Frequency Distribution Analysis v. 3.1). Holden and Bravington (1992) and Ortega-Salas (1981, 1988a) basic programs were also used.

Estimation of the instantaneous total mortality rate (Z) was calculated by the

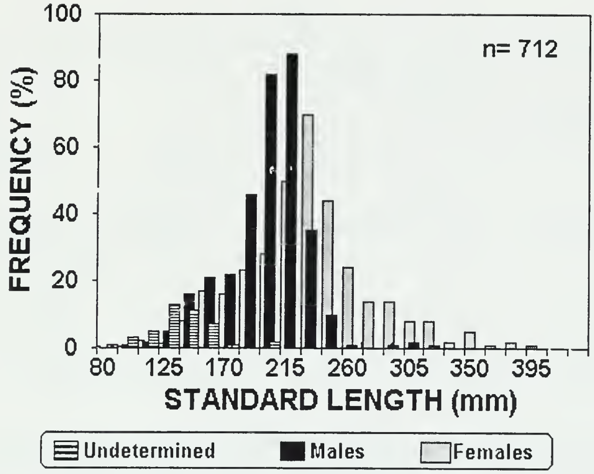

Fig. 2. Length frequency distributions showing population structure of *Xystreurys liolepis* during 1988–1990.

Beverton and Holt (1959) catch curve method described in Ricker (1975) which was based on all fish ≥ 3 years of age. The difference between the instantaneous total mortality coefficient (Z) which includes migration and the natural mortality coefficient (M) gave an estimate of fishing mortality (F): F = Z − M. Although *X. liolepis* is considered an exploited species, the natural mortality (M) was estimated as an index from the rate of growth (K) as described by Beverton and Holt (1959).

Results

Fish from all trawls were combined such that 712 fantail sole, ranging in size from 80 to 390 mm and weights from 1.45 to 9 kg were analysed. Of these 338 (47.5%) were females, 331 (46.5%) were males, and the sex of 43 (6.0%) were undetermined. As with most flatfish, females were considerably larger in length and weight relative to males (Fig. 2). The largest female measured 390 mm SL and 1,450 g weighed, compared with 320 mm and 500 g, respectively, for the largest male. The mean values for females were 222.4 mm SL ± 46.44 SD and 277.2 g ± 201.3 SD weight. For males values were 191.6 mm SL ± 30.26 SD and 158.6 g ± 67.74 SD respectively (Table 1).

The ratio of males to females throughout the year was generally 1:1.2 but it varied in winter when the ratio of females was slightly higher. A chi square test showed there was not a significant difference in numbers of females relative to males ($\chi^2 = 0.0732$; d.f. = 1; $P < 0.01$).

Length and weight were closely correlated with the regression coefficients ranging from 0.972 in females to 0.982 in males. The length-weight relationship was determined by non-linear least squares methods (Fig. 3).

Use of a t-test and mean differences showed there was not a significant difference between sexes according to the mean length with 31.19; confidence interval was 95%; d.f. = 669; t = 10.29; significance level = 3.30×10^{-9} at $P < 0.05$,

Table 1.

Sex	n	Minimum	Maximum	Mean	St. dev.
Males	331				
Standard length (mm)		93.0	320.0	191.64	30.26
Weight (g)		15.5	500.0	158.64	67.74
Females	338				
Standard length (mm)		100.0	390.0	222.38	46.44
Weight (g)		17.2	1450.0	277.21	201.3
Undetermined	43				
Standard length (mm)		80.0	197.0	127.26	24.59
Weight (g)		9.1	210.0	45.15	38.35

even with mean weight there was not significant differences between sexes with 115.87; 95%; d.f. = 669; t = 10.43; sig. level = 3.97×10^{-9}.

The von Bertalanffy equations describing theoretical growth of males and females of the fantail sole are shown in Fig. 4. After age 3 (210 mm), females were consistently longer and heavier than males due to differences in reproductive condition or general robustness of fish, although the rate of growth (K) for the two sexes was similar (Fig. 5). However females attained an older age and longer length than males.

For the estimation of mortality rates the best results were obtained by the Beverton and Holt (1959) method (Z = 0.62; M = 0.16; F = 0.46) (Fig. 6). Although these populations of *X. liolepis* are considered exploited, the natural mortality coefficient (M) was taken as the (K) value, as an index, obtained from the von Bertalanffy growth equation (Beverton and Holt 1959). These results suggest that even though fantail sole is not a target species in the commercial fishery, the rate of fishing mortality is higher than natural mortality, possibly due to the large bycatch of flatfish, including fantail sole, in the shrimp fishery. Chavez and Ramos-Padilla (1974) mentioned that along the western coast of Baja California between 25 and 100 m depth that of 75.5 tons caught 3.5 tons were brown

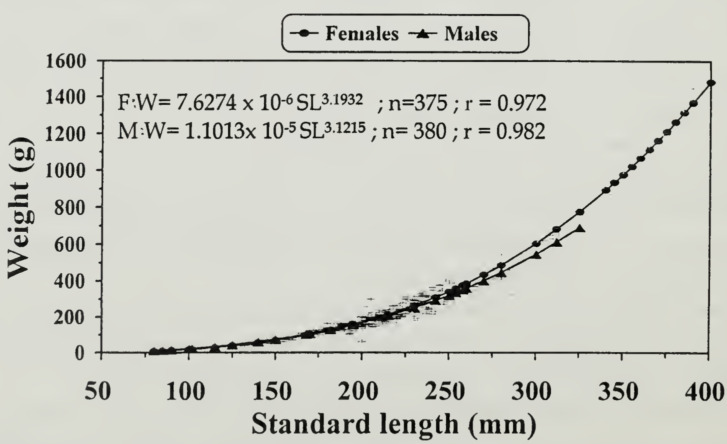

Fig. 3. Length-weight relationships of male and female *Xystreurys liolepis* from Baja California.

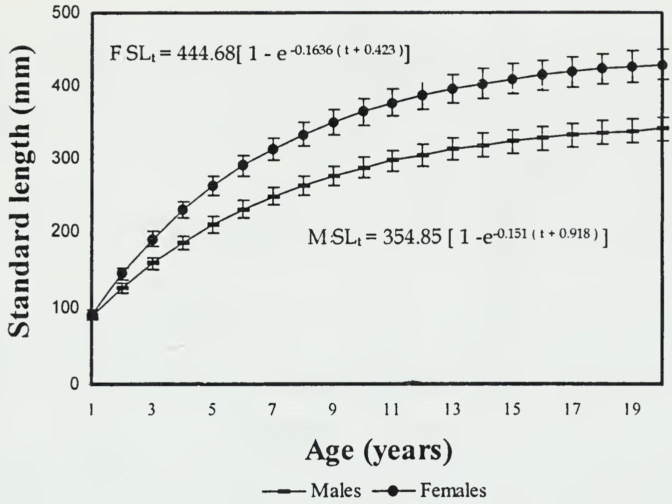

Fig. 4. Growth curve of female and male *Xystreurys liolepis* in standard length, showing standard dispersion error at 95% confidence.

shrimp, *Penaeus californiensis,* shark, flatfish, an other fish and 72 tons were considered rubbish such as red crab (*Pleuroncodes planipes*).

Discussion

There have been few previous studies concerned with the biology of *X. liolepis* so the growth and mortality parameters estimated here can only be compared with those obtained in studies of other species of flatfish (Table 2 and 3).

In comparison with many other flatfish species for which growth data are avail-

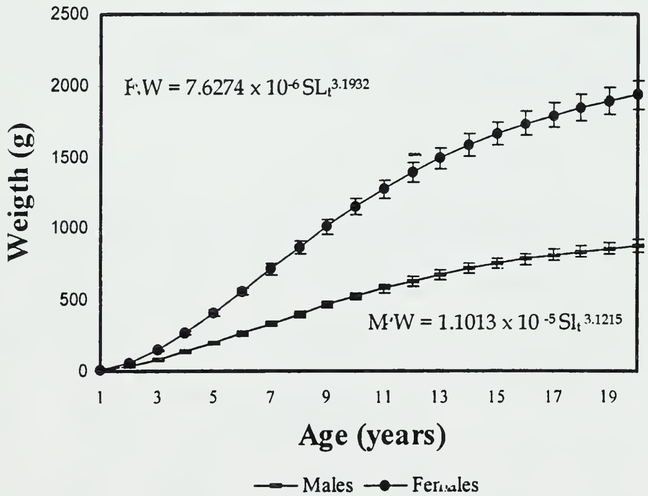

Fig. 5. Weight curve of female and male *Xystreurys liolepis* in weight, showing the standard dispersion error at 95% confidence.

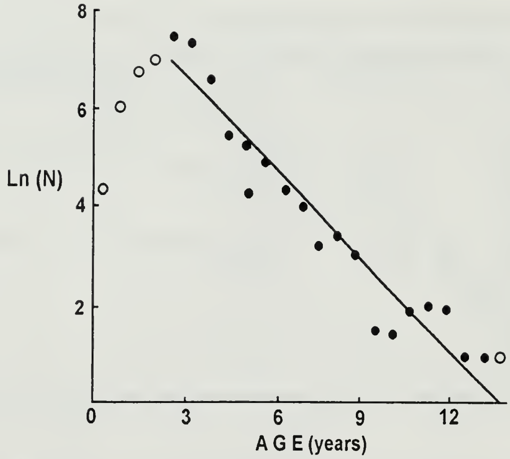

Fig. 6. Catch curve for fantail sole (*Xystreurys liolepis*) caught off Baja California, Mexico, (N = 712). The curve is slightly non-linear but regression analysis suggests a value of Z = 0.62. Open symbols indicate values not included in the regression.

able, the rate of growth of *X. liolepis* is comparatively high and the species attains a size large enough for commercial exploitation at 3 years age.

The ratio of the sexes in all species was generally 1:1. The females are also larger than males and have a higher rate of growth.

According to Dagang et al. (1992) as cited in Liu (1990), flatfish generally have a life span of up to 5–6 years, while the oldest fish are occasionally more than 10 years old. At most *X. liolepis* attains an age of 13 years. The age compositions for both sexes of the same stock are clearly different and males generally have a shorter life span than females. Thus, while males dominate the younger age-groups, females are more abundant in the older groups.

Off the western coast of Baja California, a high fishing mortality of flatfish, including *X. liolepis,* occurs resulting from intensive trawl fishing for shrimp according to Ramírez-Hernández and Arvizú Matínez (1965); Ramos-Padilla (1974); Ramírez-Hernández et al. (1965); Castro-Aguirre et al. (1970) and van der Heiden (1985).

Table 2.

Specie	Location	Sex	L_∞ (mm)	k	t_0	Source
Hippoglossina stomata	*Baja California México.*		*208.09 SL*	*0.1843*	*0.2096*	*Ramirez Murillo (1995)*
Xystreurys rasile	Mar del Plata, Argentina.		372.7	0.43	−0.169	Fabre and Cousseau (1988)
Eopsetta grigorijewi	Sea Yelow, China.	Male	342.47	0.23	−0.184	Dagang *et al.*, (1992) as cited by Liu (1990)
		Fem.	342.57	0.3	−1.02	
Limanda limanda	Isle of Man, UK.	Male	221.52	0.604	0.4254	Ortega-Salas (1981, 1988a, b)
		Fem.	329.73	0.3178	0.2394	
Xystreurys liolepis	Baja California, México.	Male	354.85 SL	0.918	−0.151	Present Paper
		Fem.	444.68 SL	0.163	−0.918	

Table 3.

Specie	Location	Z	Source
Hypsopsetta guttulata	*Anaheim Bay, USA*	*2.6*	*Lane (1975)*
Limanda limanda	*Isle of Man, UK*		*Ortega-Salas (1981, 1988 a and b)*
Female		*1.06*	
Male		*1.39*	
Xystreurys liolepis	Baja California, México	0.62	Present paper

This paper shows that females (L_∞ = 444.68 mm SL) grow bigger than males (L_∞ = 354.85 mm SL) and the total mortality rate was 0.62 of which fishing mortality was 0.46. Although *X. liolepis* is not a target species of commercial fisheries, the rate of fishing mortality is higher than natural mortality, possibly due to the large bycatch of flatfish, including fantail sole, in the shrimp fishery. It is considered a potential exploitable flatfish but needs to have regulations as a fishery resource.

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