Population parameters of the Pacific flagfin mojarra *Eucinostomus currani* (Perciformes: Gerreidae) captured by shrimp trawling fishery in the Gulf of California

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Abstract: Shrimp trawling fishery in the Gulf of California captures a wide variety of non-target species of fish, crustaceans, and mollusks that are relatively unknown. The Pacific flagfin mojarra *Eucinostomus currani* is a frequently found species in these catches, nevertheless, nothing is currently known about its population dynamics. To contribute to the knowledge on this fish species, we studied the size structure, growth, mortality, and the recruitment pattern during the 2004-2005 seasons. A total of 6 078 mojarra were captured from 350 samples, with minimum and maximum lengths of 4.5cm and a maximum of 21.0cm. The average total length of the four major cohorts was 11.4, 13.7, 15.6 and 18.0cm, corresponding to ages 0.9, 1.2, 1.6 and 2.2 years, respectively, being the most abundant the 1.2 year-old group. The instant growth coefficient indicated moderate growth rates (K_S=0.81/year, K_E=0.85/year), corresponding to individuals living between 3.5 to 3.7 years. The estimated asymptotic lengths was L_∞=21.8cm. In general, the population could be considered healthy: natural mortality (M=1.53/year); total mortality (Z=2.73 /year); condition factor (K=0.01072); fishery mortality (F=1.2/year) and exploitation rate (E=0.43/year). The maximum reproduction period almost coincided with the closed season for shrimp fishing (March to August), thus we concluded that survival of the species is ensured because reproduction is indirectly protected. Rev. Biol. Trop. 59 (2): 887-897. Epub 2011 June 01.

Key words: Pacific flagfin mojarra, *Eucinostomus currani,* Gulf of California, shrimp bycath.

The shrimp trawling is one of the most important economic activities in the Gulf of California. During trawling activities many fish, crustacean and mollusk species are caught as bycatch. Based on preliminary surveys, has been demonstrated that over 98% of fish and invertebrate by-catch are obtained during this region shrimp trawling (Rodríguez *et al*. 2009). Most of the bycatch is thrown back into the sea, because it has no commercial value or the organisms have too small sizes (Herrera 2004).

The Gerreidae family has a wide distribution in tropical and subtropical latitudes and constitutes an abundant resource of commercial importance in Mexico coastal lagoons (Grijalva-Chon *et al*. 1996).

Eucinostomus currani Zahuranec in Yáñez-Arancibia, 1980 is a coastal species found from California and the Gulf of California to Northern Peru, the Galapagos Islands and the Cocos Island. They congregate in small shoals. Larvae are pelagic and the juveniles are commonly found in protected environments, from as estuaries, mangroves, tidal channels, rivers deltas to 20km offshore, and hypersaline mangroves. Adults often occur in deeper waters

(0 to 30m). It is an omnivorous fish that feeds on plants, organic matter, micro-invertebrates, mollusks and detritus (Bussing 1998). A maximum size of 24cm has been observed (Franke & Acero 1996); this species has low commercial value and is commonly used as bait.

Although *E. currani* is one of the most frequent species in the shrimp bycatch, no study has addressed the effect of the incidental capture on its population dynamics, because there is very little knowledge about the species on wild or captivity conditions. Previously, it was reported that *E. currani* is a slow growing species, since in captivity the specimen reached 0.24g in one day, making it unattractive for commercial purposes (Rubio *et al*. 2004). The main objective of this study was to estimate the population parameters of the Pacific flagfin mojarra obtained from the shrimp trawl catches in the Gulf of California.

MATERIALS AND METHODS

Study area: In the Gulf of California, the trawling shrimp takes place on the continental shelf at depths between nine to 90m. During the shrimp season (August-March 2004-2005), 10 observers on board the Sonora shrimp fleet homeport, operating on the Sonora, Sinaloa and Nayarit platform (21°1'37''-31°24'35'' N-105°16'06''-114°22'51'' W) (Fig. 1). All tows were made at night. In each throw, the observers took randomly 20kg samples of the total capture. The samples were stored in plastic bags at -20°C and labeled with the data collection site. The samples were processed at the Fisheries and Ichthyology Laboratory CIBNOR.

Morphometric measurements: In the laboratory, samples were thawed and separated by taxonomic groups. Identification to species level was done using the taxonomic keys of Bussing (1995), Jordan & Everman (1896), Allen & Robertson (1994) and Nelson *et al*. (2004, 2006) taxonomic keys. The diacritical characteristics of *E. currani* used for identification were: tri-banded dorsal fin (grey at the base, silver-light in the midsection, and deep black at the tip), no color pattern on either side

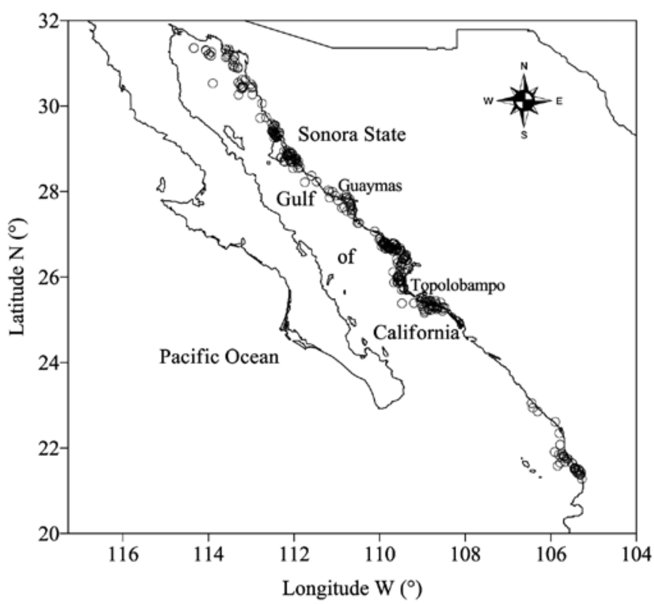

Fig. 1. Sampling areas along the coast of Sonora, Sinaloa and Nayarit, México.
Fig. 1. Áreas de muestreo a lo largo de la costa de Sonora, Sinaloa y Nayarit, México.

of the body. Some young specimens have dark spots (Yáñez-Arancibia 1980).

Morphometric measurements of each organism included total length (from the mouth to the end of the caudal fin), standard length (from the mouth to the end of the caudal peduncle), weight, sex and sexual maturity. To determine sexual maturity, the reference scale of Nikolsky (1963) was used (gonad morphochromatic characterization), which is based on color and gonad texture, as well as its space in the abdominal cavity.

The parameters a and b of the length-weight relationship ($W=aL^b$), where W is weight (g) and L is length (cm), were determined by means of a potential regression. The b value of the weight-length relationship was used for the condition factor calculation. Individual values of the condition factor were obtained through the formula $K=W/TL^b$, where W is weight and TL is total length. The monthly means were calculated from individual values.

In order to obtain size frequencies for each two-week period, data were grouped by intervals of five total length subgroups. To determine number of the cohorts in a capture, Bhattacharya proposed a method (Pauly & Caddy 1985), assuming a normal distribution around the average size of each cohort.

By using the mean and standard deviation of each cohort like the initial data, NORMSEP analysis (maximum verisimilitude) was performed (Sparre & Venema 1995). Growth was calculated from the size frequency distribution analysis assuming that *E. currani* follows a von Bertalanffy kinetics model (Pauly *et al*. 1984, Brey & Pauly 1986). Besides, ELEFAN I was used to estimate growth parameters (Pauly & David 1981, Pauly 1987). This method was selected because it incorporates seasonal growth, which is characteristic of the fauna in the transition from tropical to temperate areas, such as the one from the Gulf of California (Pauly *et al*. 1984, García 1988). The seasonal-growth model has the following form:

$$L_t = L_\infty \left(1 - e^{-[K(t-t_0)+C(K/2\pi)\sin 2\pi(t-t_s)]}\right)$$

where L_t is the length at time t, L_∞ is the asymptotic length, K is the instant growth coefficient (per year), t_0 is the hypothetical time at which the length of the organism is zero, t_s is the beginning of sinusoidal growth oscillation with respect to t=0, and C is the intensity of the oscillation of growth.

To start the estimations, seed values of L_∞ were calculated by the methods of Powell (1979) and Wetherall *et al*. (1987). The K value was calculated by the Shepherd's length composition analysis (NSLCA) (Shepherd 1987, Pauly & Arreguín 1995), while estimates of the third parameter (t0) were performed with the empirical equation proposed by Pauly *et al*. (1984).

Natural mortality (M) was determined by the empirical equation proposed by Pauly (1980),

$$\ln M_i = -0.0152 - 0.279 * \ln L_{\infty i} + 0.6543 * \ln K_i + 0.463 * \ln T_i$$

where T is the habitat's average annual sea surface temperature, and by the M=1.5×K equation (Jensen 1996), where K is the instant growth coefficient.

Total mortality and capture probability (selectivity) were estimated with the length-converted catch curve method (Pauly *et al*. 1984). Fishing mortality was estimated from the difference of Z=F+M, and the exploitation rate E=F/Z, where values over 0.5 reflect overexploited populations, and values under 0.5 denote a sub-exploited ones (Gulland & Rosemberg 1992).

Because the information on *E. currani* only includes the months of the fishing season (September to March), the pattern of reproductive recruitment was used as an alternative method to determine the probable birth date of the organisms caught, by the method ELEFAN II (Pauly 1980, 1987), that analyses the size structure of catches once the selection bias is corrected. The results generated by this model should be treated as approximations, since statements on the annual reproductive pulses number and on their relative strength, is based on the assumptions that fish in the sample grow as described by a single set of growth parameters, and that one month a year has zero recruitment (Moreau & Cuende 1991).

Size at first maturity was calculated from the number of mature females at stages III and IV in each size group. The relationship between size and maturity was fitted to a nonlinear estimate, using the least squares procedure. To test the appropriateness of the logistic model, we used the determination coefficient (R^2). The maturity-length relationship describes a logistic curve (Pauly 1984):

$$S_L = \left(\frac{1}{1 + \exp(-r * (X - X50))} \right)$$

where r and $X50$ are sigmoid parameters. The size at first maturity (L50%) is described as the point that intercepts 50% of the logistic model. In this case, L50%=X_{50} (Pauly 1984). As the same, the selectivity-length relationship describes a logistic curve and was fitted to a nonlinear estimate, using the least squares procedure.

RESULTS

In the samplings, Pacific flagfin mojarra was one of the most common by-catch species (9%). In this study were measured 6 078 mojarra from 350 samples collected from August 15th 2004 to March 15th 2005 (Fig. 2). Their lengths ranged from 4.6 to 21.0cm. Four cohorts, in terms of mean total length, were 11.4, 13.7, 15.6, and 18.0cm, corresponding to ages 0.9, 1.2, 1.6, and 2.2 years were found; the 1.2 year-old group was the most abundant.

Estimates for the weight-length relationship showed that coefficient b was 3.065 (Lo conf. limit=3.021817, Lu conf. limit=3.040513; p-level=0.00) and coefficient was 0.000011 (Lo conf. limit=0.000011, Lu conf. limit=0.000011; p-Level=0.00) and the correlation coefficient R was R=0.9750 (p-level=0.00). Was found a moderate growth (K_S=0.81/year, K_E=0.85/year) corresponds to specimens that were ~3.7 years old (longevity=3/K) as well as an asymptotic length of L_∞=21.8cm (W_∞=128.1g) by the Shepherd and ELEFAN I methods, when t_0=-0.216 (Table 1). The resulting curve is shown in Fig. 3.

TABLE 1
Eucinostomus currani growth parameters based on bycatch from commercial shrimp trawling in the Gulf of California

CUADRO 1
Parámetros de crecimiento de *Eucinostomus currani* basado en la fauna de acompañamiento del camarón obtenido por arrastres en el Golfo de California

Method	K/year	L_∞ (total, cm)	T_0
Powell-Wetherall		22.0	
Shepherd	0.81	21.81	–0.216
ELEFAN I	0.85	21.80	

K=instant growth coefficient, L_∞=asymptote length, T_0=time to length equal to zero.

The condition factor average was K=0.01072, and K index showed the lowest value in February and the highest value in March (this is, at the beginning of the reproductive period) (Fig. 4).

The estimated natural mortality was M=1.53/year; total mortality Z=2.73/year (CI 1.9-3.5); fishery mortality F=1.2/year, and exploitation rate is E=0.43/year. Mortality values for fishery and exploitation rates suggest a healthy population. Although samples were as small as 4.6cm, first-capture estimated size was 12.85cm, with a value of $L_{50\%}$=12.8cm ($t_{50\%}$=10 months) and $L_{75\%}$=14.3cm ($t_{75\%}$=13.2 months) and selection rank R=30mm (Fig. 5). The resultant adjusted equation to the logistic selectivity model is:

$$P = \frac{1}{1 + e^{-0.0731(X - 12.85)}} ,$$

where P is the probability of capture and X is the total length in cm.

Incorporation of new recruits was observed throughout the year, with two peaks: the first of 30.07% from March to April and the

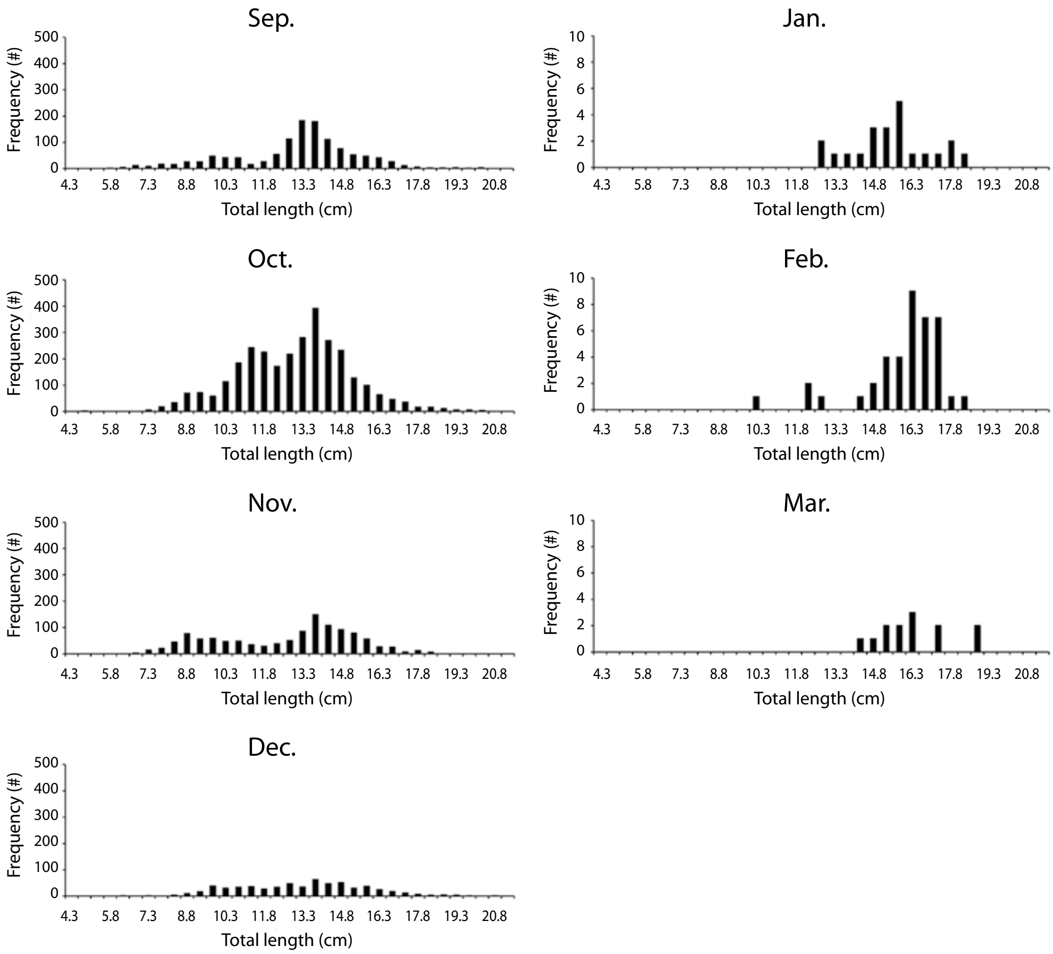

Fig. 2. Size structure of *Eucinostomus currani* based on by-catch from commercial shrimp trawling during the catch seasons of 2004 and 2005.

Fig. 2. Estructura de tallas de *Eucinostomus currani* badasa en muestreos de fauna de acompañamiento del camarón capturado con arrastre en las temporadas de pesca 2004 y 2005.

second of 29.19% from June through August (Fig. 4). The size at first maturity was estimated at 14.2cm of total length, corresponding to an approximate age of 15 months (Fig. 5). The adjusted equation to the logistic model was:

$$P = \frac{1}{1 + e^{-0.1076(X - 14.2)}}$$

DISCUSSION

The Pacific flagfin mojarra is the most abundant species in shrimp bycatch in the Gulf of California (López-Martínez *et al*. 2010). It occupies coastal zones from three to 77m. In the literature, the maximum depth is stated as 60m (Ayala & Tapia 1990), but our samples extend this range to 77m. This mojarra is a

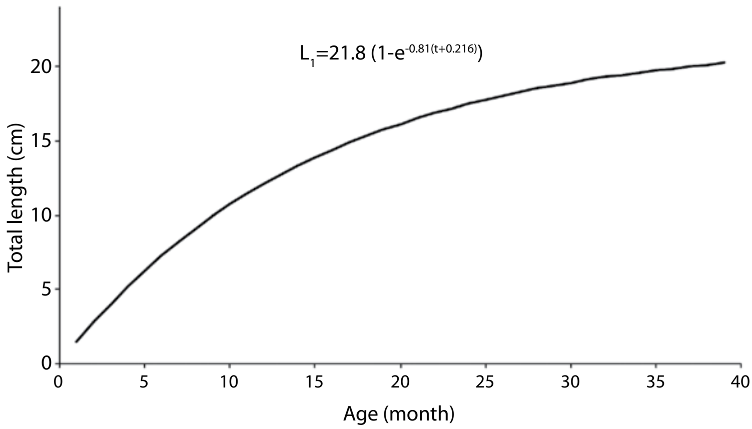

Fig. 3. Growth curve of *Eucinostomus currani* in the Gulf of California adjusted to the von Bertalanffy model.
Fig. 3. Curva de crecimiento de *Eucinostomus currani* ajustada al modelo de von Bertalanffy en el Golfo de California.

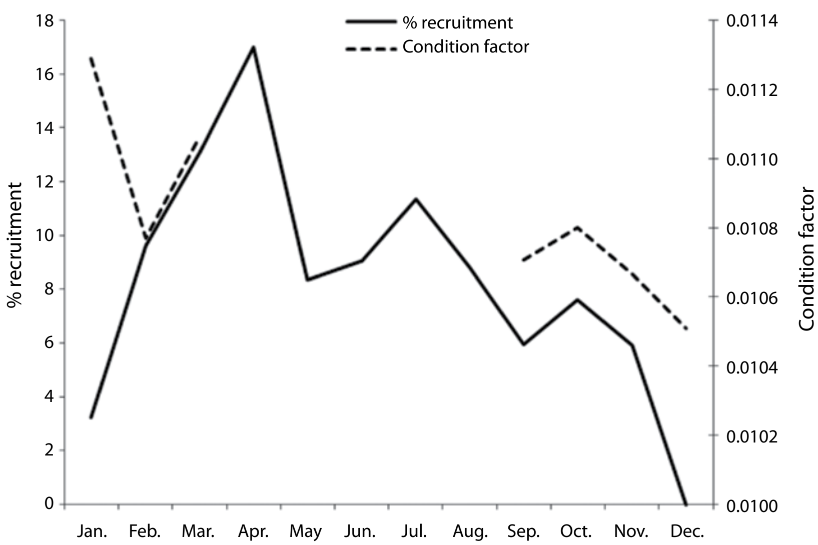

Fig. 4. Monthly recruitment and condition factor of *Eucinostomus currani* present as by-catch in commercial shrimp trawling in the Gulf of California.
Fig. 4. Reclutamiento y factor de condición mensual de *Eucinostomus currani* presente en la fauna de acompañamiento de camarón obtenido con redes de arrastre en el Golfo de California.

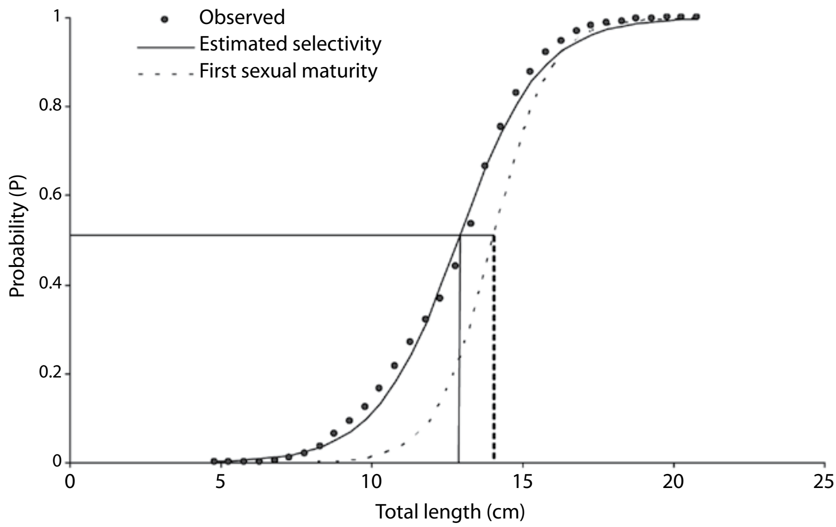

Fig. 5. Selectivity curve and first sexual maturity curve of *Eucinostomus currani* in the shrimp by-catch in the Gulf of California, adjusted to the logistic model.
Fig. 5. Curvas de selectividad y de primera madurez sexual ajustadas al modelo logístico de *Eucinostomus currani* en la fauna de acompañamiento del camarón en el Golfo de California.

demersal, freshwater and marine inhabitant in the Mexican Pacific coasts that uses lagoons for protection and feeding in their early developmental stages (Amezcua 1976, Grijalva-Chon *et al*. 1996). The wider distribution range to depth of the mojarra allow it to remain highly productive, in spite of the high bycatch, and remain competitive in the ecosystem where this species take advantage of habitat and food, as documented for other species from the Southern Baja California peninsula (Rodríguez-Romero *et al*. 2008). The same as the latitudinal distribution, the distribution in depth of the species, can be limited by thermal barriers and of pressure as well as of type topographical existent in the Gulf of California. The different depth distribution (5-77m) of this species, can be due to the existence of big sandy-muddy coastal extensions, that are very productive areas, in the Oriental side of the Gulf of California, and where they support a great diversity of species of fish and other organisms, including this species (Grijalva-Chon *et al*. 1996, López-Martínez *et al*. 2010).

The weight-length relationship is according to the value estimate from the same species by Ruíz-Ramirez *et al*. (1997), González-Acosta *et al*. (2004), Aguirre *et al*. (2008) and Velázquez-Velázquez *et al*. (2009) (Table 2) and show an isometric growth.

The Pacific flagfin mojarra has relatively slow growth and a lifespan close to four years. Our results on maximum sizes agree with previous reports (Franke & Acero 1996, Ruíz-Ramirez *et al*. 1997). The calculated K value was greater than previously reported values (K=0.58), corresponding to 4.9 year-old mojarra. This result can be attributed to larger sizes being sampled previously (Ruíz-Ramirez *et al*. 1997).

The recruitment pattern (the reproductive period) was from March to August and size at first sexual maturity being slightly smaller compared to a previous report on this species in the Gulf of Tehuantepec (14.5cm) (Ruíz-Ramirez *et al*. 1997). The condition factor is an index reflecting interactions between biotic and abiotic factors in the physiological

TABLE 2
Length-weight- relationship of *Eucinostomus currani* in the Gulf of California from different reports

CUADRO 2
Relación longitud-peso de *Eucinostomus currani* en el Golfo de California según varios reportes

Author	n	A	b	R	p-level	Country
Ruíz-Ramírez *et al*. (1997)	55	0.0268	2.7500			Mexico
De la Cruz Agüero *et al*. (2004)	2 709	0.0180	3.0300			Mexico
Aguirre *et al*. (2008)	174	0.000013	3.1900	0.970		Mexico
Velázquez-Velázquez *et al*. (2009)	312	0.019	3.1700	0.98		Mexico
This manuscript	6 078	0.000011	3.0218	0.975	0.00	Mexico

condition of fishes. It shows the population's welfare during various stages of the life cycle (Angelescu *et al*. 1958). In the case of *E. currani*, the condition factor decreases at the start of the spawning period due to very high metabolic rates. Unfortunately, we have data of *E. currani* only for the months of shrimp fishing (September to March), being impossible to follow the behavior of K during the period of maximum recruitment. Vazzoler & Vazzoler (1965), Martins-Juras (1980) and Lizama & Ambrosio (2002) state that the condition factor does not merely reflect the feeding condition of the adult stage, but includes the state of gonadal development, based on the consumption of fat reserves during the spawning period.

The size structure and the size at first sexual maturity indicated that 58% of the sample were juveniles (<13 months), this is, sexually immature. In some previous reports, juveniles are commonly found in estuarine regions, mangroves, tidal streams and rivers far from the coast, and the adults occur in deeper waters (De la Cruz-Agüero *et al.* 1997). This finding is very important, indicating the low selectivity of shrimp nets. *E. currani* represents an important component of the trophic chain for many marine species in areas of high biological productivity (Ramírez-Luna *et al*. 2008). By-catch arises because fishing gears have imperfect selection properties, but the problem is made worse by economic pressures resulting from overexploitation. This fact can lead to the decrease in the abundance of both target and non-target species and to inefficient use of resources (Cook 2001).

The consequences of trawling activities on ecosystems have been frequently studied during the past years. Common trends of community responses have been detected, for instance, areas with high disturbance may become more uniform and characterized by fewer and more dominant species (Escolar *et al*. 2009). In this context, we stress out the important ecological role of the species of bycatch herein analyzed. Reyes-Bonilla *et al*. (2009) have outlined that in the Gulf of California has diminished the trophic level of the captures, as consequence of the fishing pressure. Arreguín-Sánchez *et al*. (2002) suggests that fish mortality in the bycatch could have a positive impact on the shrimp stock, due to fact that some species has a diet based in shrimp, diminishing the pressure of the predators to the shrimp. This is the case of the Pacific flagfin mojarra, which bases 45% of their diet on shrimps (Ramírez-Luna *et al*. 2008).

The mortality indicators here obtained are relatively low, considering natural and catch conditions, as well as an exploitation rate close to maximum. *E. currani* is reported as highly "resilient" because its population doubling time is less than 15 months (Froese & Pauly 2000). Additionally, the recruitment pattern coincides with the peak reproduction period, which closely matches the end of the shrimp fishery season (March through August). We concluded that survival of this mojarra is ensured because the reproduction season is indirectly protected. A detailed analysis of the mojarra reproductive biology is recommended.

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RESUMEN

La pesquería de camarón del Golfo de California captura una amplia variedad de especies incidentales, relativamente no conocidas que incluye peces, crustáceos y moluscos. La mojarra bandera del Pacífico *Eucinostomus currani* es frecuentemente encontrada en las capturas del camarón y no hay información sobre su dinámica poblacional. La estructura de tallas, crecimiento, mortalidad y patrón de reclutamiento fueron determinados durante la temporada 2004-2005. De manera que se recolectaron 6 078 organismos de esta especie en 350 muestras, las tallas mínima y máxima fueron 4.5cm y 21.0cm. La talla media de las cuatro cohortes presentes fueron 11.4, 13.7, 15.6 y 18.0cm, correspondiendo a edades de 0.9, 1.2, 1.6 y 2.2 años. El coeficiente instantáneo de crecimiento indica un crecimiento moderado (K_S=0.81/año, K_E=0.85/año), con una longevidad de 3.5 años. La longitud asintótica estimada fue L_∞=21.8cm. En general, la población se mostró saludable, con una mortalidad natural (M=1.53/año); factor de condición (K=0.01072); mortalidad total (Z=2.73 /año); mortalidad por pesca (F=1.2/año) y tasa de explotación (E=0.43/año). El periodo de máxima reproducción coincide con la temporada de veda de la pesca de camarón (marzo a agosto). Concluimos que la sobrevivencia de la especie se encuentra indirectamente protegida.

Palabras clave: mojarra bandera del Pacífico, *Eucinostomus currani,* Golfo de California, fauna acompañante.

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