POPULATION CHARACTERISTICS OF SPOTTED ROSE SNAPPER *Lutjanus guttatus* CAUGHT AS SHRIMP BYCATCH IN THE GULF OF CALIFORNIA

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SUMMARY

There are limited population biology studies of the spotted rose snapper Lutjanus guttatus. Adults of this highly valued commercial species are fished with gillnets and hook-and-line, while juveniles are caught as shrimp bycatch and usually discarded. The effects of this practice have not been studied. As a first step, this study assessed some population parameters of juvenile snapper caught by the Gulf of California shrimp fishery. We looked for early growth stages and determined by the least squares method the weight to standard length relationship as W= 0.000092, SL3.0509. Length frequency distributions were constructed; using the ELEFAN I method, von Bertalanffy growth parameters were found to be L∞= 515mm (standard length) and K= 0.13. Natural mortality (M= 0.35) was estimated from Pauly's empirical and Ralston equations; and total mortality was calculated by the catch curve equation. The recruitment pattern extended throughout the year, with spring and summer peaks. The sex ratio was 1:1 and the length at capture was 80mm (standard length). With an apparently high fishing mortality levels, it is recommended that abundance and distribution studies be performed to determine the impact of shrimp fishing on this population.

CARACTERÍSTICAS POBLACIONALES DEL PARGO LUNAREJO *Lutjanus guttatus* CAPTURADO CON LA FAUNA DE ACOMPAÑAMIENTO DEL CAMARÓN EN EL GOLFO DE CALIFORNIA

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RESUMEN

Son escasos los estudios sobre la biología poblacional del pargo lunarejo Lutjanus guttatus. Los adultos de esta especie, de alto valor comercial, son capturados con redes agalleras y anzuelos mientras que los juveniles son capturados como fauna de acompañamiento de la pesca de camarón y usualmente descartados. Los efectos de esta práctica no han sido evaluados. Como un primer paso, en este estudio se estiman algunos parámetros poblacionales de juveniles del pargo lunarejo capturados en la pesquería de camarón del Golfo de California. Se indagaron estadios de desarrollo y se determinó mediante mínimos cuadrados la relación longitud estándar-peso como W= 0,000092; SL3,0509. Se construyeron distribuciones de frecuencia de talla, y usando el método ELEFAN I se encontraron los parámetros de crecimiento de von Bertalanffy L∞= 515mm (longitud estándar) y K= 0,3. La mortalidad natural (M= 0,35) fue estimada por la ecuación empírica de Pauly y la ecuación de Ralston, y la mortalidad total se calculó mediante la ecuación de la curva de captura. El patrón de reclutamiento se extendió a lo largo del año, con máximos en primavera y verano. La proporción sexual fue 1:1 y la talla media de captura fue 80mm (longitud estándar). Con una tasa de mortalidad pesquera aparentemente alta, se recomienda evaluaciones de la abundancia y distribución de la especie para determinar el impacto de la pesquería del camarón sobre esta población.

Introduction

The spotted rose snapper *Lutjanus guttatus* (Steindachner 1869) is a highly valued species captured by hook and line and gillnets along the tropical eastern Pacific coast, from Mexico (SAGARPA, 2006) to Peru (Fischer *et al.*, 1995; Robertson and Allen, 2002). This species is part of a multi-species fishery. Under local common names (*huachinango*, *pargo*), various lutjanid species are landed without recording the catch of each species (CONAPESCA, 2002, 2003; SARGARPA, 2006). There is no minimum legal size or closed season (SARGARPA, 2006) and the species is considered overexploited (Andrade, 2003; Díaz *et al.*, 2004; Amezcua *et al.*, 2006) in recommendations for regulated conditions for the fishery. Juveniles are caught as shrimp bycatch and discarded or sold at lower prices than if they were obtained as a targeted fishing (Andrade *et al.*, 2003; Amezcua *et al.*, 2006). Claims of overfishing are countered by arguments that economic hardships make specialized fishing unattractive. This argument is not valid because snappers are captured in multi-species fisheries or as bycatch and not routinely evaluated, have a high market value that would increase as the species becomes scarcer

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CARACTERÍSTICAS POPULACIONAIS DO "PARGO LUNAREJO" *Lutjanus guttatus* CAPTURADO COM A FAUNA DE ACOMPANHAMENTO DO CAMARÃO NO GOLFO DE CALIFÔRNIA

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RESUMO

São escassos os estudos sobre a biologia populacional do "pargo lunarejo" Lutjanus guttatus. Os adultos desta espécie, de alto valor comercial, são capturados com redes de emalhar e anzóis enquanto que os juvenis são capturados como fauna de acompanhamento da pesca de camarão e usualmente descartados. Os efeitos desta prática não tem sido avaliados. Como um primeiro passo, neste estudo se estimam alguns parâmetros populacionais de juvenis do "pargo lunarejo" capturados na pescaria de camarão do Golfo da Califórnia. Indagaram-se estágios de desenvolvimento e se determinou mediante mínimos quadrados a relação longitude estandar-peso como W= 0,000092; SL3,0509. Construiram-se distribuições de frequência de tama-nho, e usando o método ELEFAN I se encontraram os parâmetros de crescimento de von Bertalanffy L∞= 515mm (longitude estandar) e K= 0,3. A mortalidade natural (M= 0,35) foi estimada pela equação empírica de Pauly e a equação de Ralston, e a mortalidade total se calculou mediante a equação da curva de captura. O padrão de recrutamento se extendeu ao longo do ano, com máximos em primavera e verão. A proporção sexual foi 1:1 e o tamanho médio de captura foi 80mm (longitude estandar). Com uma taxa de mortalidade pesqueira aparentemente alta, se recomenda avaliações da abundância e distribuição da espécie para determinar o impacto da pescaria do camarão sobre esta população.

(Dulvy *et al*., 2003); the apparent abundance of the genus may mask overfishing of one or several species in the complex (Marko *et al*., 2004). Exploitation thus affects species in a way that partly depends on intrinsic life history traits (Rochet *et al*., 2000). Excessive fishing pressure on immature individuals reduces potential yield by growth (Kristiansen *et al*., 2006). In addition to direct fishing, bycatch has detrimental effects on slow growing long-lived species under intense fishing pressure (Coggins *et al*., 2007). When trying to predict population size, population dynamics is controlled by recruitment and death from fishing (Caley *et al*., 1996). If there is rapid growth, this can be used as an indicator to predict species vulnerabil-ity or create a plan for better management (Jennings *et al*., 1998). Unfortunately, the relationship between size, age, and mortality is unknown for early stages of most marine fish species (Broadhurst *et al*., 2006). Given the lack of knowledge about the spotted rose snapper, specifically about the bycatch fraction, the goal of the present study was to use the bycatch of spotted rose snapper caught in shrimp trawling to estimate population parameters in the Gulf of California.

Materials and Methods

The study area encompasses the near-shore zone from San Blas, Nayarit (~23.5°N) to the Reserva de la Biosfera del Alto Golfo de California y Delta del Río Colorado (~31.5°N) on the eastern side of the Gulf of California, from the Colorado River Delta southward to Bahía San Luis Gonzága (~29.75°N) on the western side of the gulf, and north and south of Bahía Magdalena (~24° to ~26°N) on the Pacific Side (Figure 1). Information from sampling stations and samples was obtained from observers on commercial shrimp trawlers during the 2004-2005 season and research cruises by staff of the Instituto Nacional de la Pesca of Mexico the Gulf of California (2004-2005) during the closed shrimp season. Most trawling nets were ~21.5m wide with a 5.75cm mesh.

Each sample consisted of 20kg of bycatch. Spotted rose snappers were separated and keys were used to identify the species (Allen, 1995; Roberston and Allen, 2002). Measurements of total length (TL; ±1mm), standard length (SL; ±1mm), and total weight (W; ±0.1g) were taken. Sex and adult sexual maturity were determined using a six-stage morpho-chromatic scale: I (virgin), II (quiescent), III (ripening), IV (mature), V (reproducing), VI (spawned). Females in Stages III–VI were considered as mature (Nikolsky, 1963). The log weight-log standard length relationship was used to detect outli-ers and to look for growth phases in small fish (Froese, 2006). The standard length-total to length relationship (SL-TL) was determined using the least-squares method to fit the linear model TL= a + bSL. The weight-standard length relationship (SL-W) was determined by using a non-linear estimation to fit the potential model W= a + SL^b. We looked for a relationship between individual size and depth, estimated a condition factor: CF= 100W/SL^3 (Fulton, 1904), and looked for significant differences between months, using analysis of variance. Monthly length frequency (SL) distributions were constructed to estimate growth, using the von Bertalanffy equation $L_t = L_\infty 1-e^{-K(t-t_o)}$), where L_t: SL at age t, L_∞: asymptotic length, K: instantaneous growth rate, and t_o: theoretical age at zero length. A tentative initial L_∞ value was found by the Powell-Wetherall method (Powell, 1979; Wetherall, 1986). With this L_∞ value, the Shepherd method (Shepherd, 1987) was used to estimate K. The Powell-Wetherall method for the estimation of L_∞ gave unusual K values for lutjanids; therefore, an average from values reported by Rojas (2001) and Amezcua *et al*. (2006) was used as L_∞ value. A new estimate of K was made using the

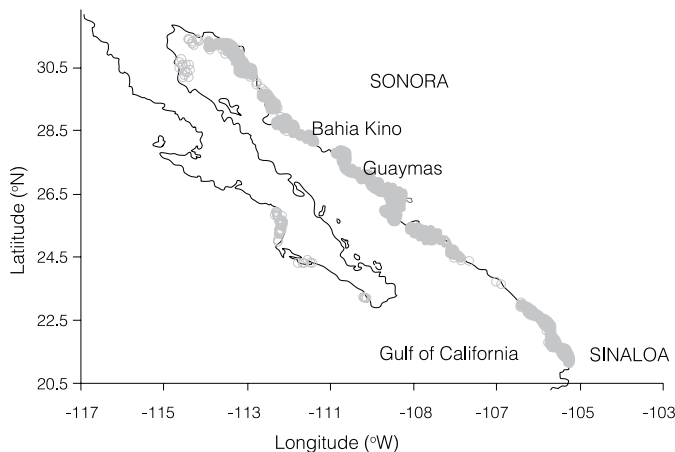

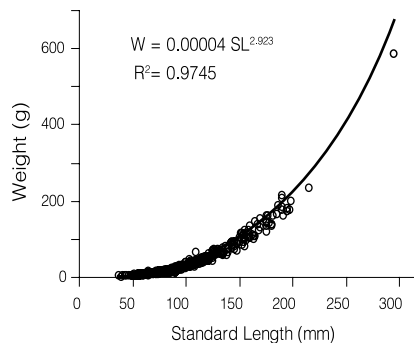Figure 1. Locations where commercial and research survey samples were obtained in 2004–2005.

Figure 2. Weight-standard length relationship of spotted rose snapper *Lutjanus guttatus* caught by shrimp trawling fleets in the Gulf of California.
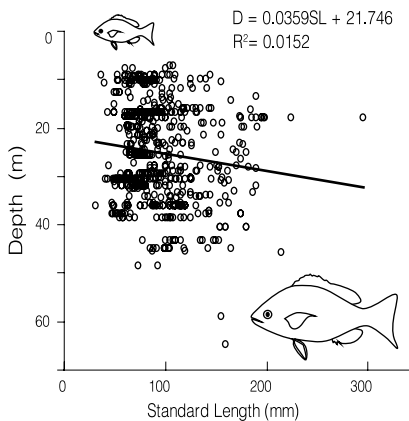

Figure 3. Size of spotted rose snapper *Lutjanus guttatus* in relation to depth where caught.
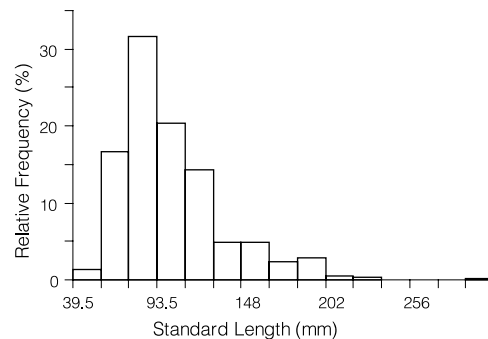

Figure 5. Total length frequency distribution of spotted rose snapper *Lutjanus guttatus* caught by shrimp trawling fleets in the Gulf of California.

ELEFAN I method, keeping L_∞ fixed (Pauly and David, 1981). The parameter t_0 was obtained by Pauly's empirical equation (Pauly, 1980)

$$t_0=1\times10^{[-0.3922-(0.2752LogTL\yen)-(1.038LogK)]}.$$

Longevity was estimated as $t_{max}= t_o+3/K$ (Taylor, 1958), where t_{max} is longevity (years) and other parameters are as described earlier. Total mortality rate (Z) was estimated by the linearized length-converted catch curve, $Ln(N_i/\Delta t_i)=a+bt_i$ (Pauly, 1984b), where N_i number of fish in length class i; Δt_i: time needed for the fish to grow through length class i; t: relative age where midlength is reached in class i; and b: an estimate of Z (sign changed). Natural mortality (M) was calculated using Pauly's empirical equation

$$LnM= -0.01521-0.279LnL_\infty +0.6543LnK+0.463LnT$$

(Pauly, 1980), where T is the mean annual sea surface temperature (°C) in the species' habitat. Fishing mortality (F) was calculated from $Z= N+F$ and the exploitation rate (E) was assumed to be $E= F/Z$ (Jones, 1984). Additionally, M was estimated according to the method of Ralston (1987) as $M= 0.0189+2.06K$. The recruitment pattern was estimated using the ELEFAN II method (Moreau and Cuende, 1991), providing an indirect idea of the reproductive season. From cumulated relative frequency, length at first capture was calculated by nonlinear least-squares fitting (Prager *et al.,* 1987) using the logistic function

$$P= \frac{1}{1+e^{-a(SL-SL_{50})}},$$

where P is the proportion of organisms caught and SL_{50} is the standard length at which 50% of the population is caught.

Results

Sampling stations ranged 10-70m deep. From commercial and research surveys, 693 *L. guttatus* specimens were obtained. Individual sizes ranged 31-295mm (SL) and 1.7-585.3g (W). Up to these sizes, small growth phases were not apparent using the log W-log SL plot. However, some outlying measurements were corrected using biometric relationships from 648 individuals and SL, TL, or W for some specimens that were previously excluded we re-estimated. The TL-SL relationship was described by $SL= 0.787TL-0.356(R^2= 0.985)$; W-SL by $W= 0.0004 SL^{2.928}(R^2= 0.9745$; Figure 2); and W-TL by $W= 0.0005 TL^{2.9408} (R^2= 0.9748)$. Given the close correlation between TL and SL, later analyses considered SL to be a measure of individual size.

Larger individual size was correlated with a deeper depth of capture ($D= -0.0359SL+21.74$, $R^2= 0.0152$, $P= 0.001$; Figure 3). The condition factor did not vary markedly ($F_{\alpha, 0.05, 9, 677}= 1.444$), showing only slight, non-significant ($P= 0.16$) higher values during autumn and lower values during summer. Length frequency distributions (Figures 4 and 5) reveal that the smallest individuals are better represented from Sep. through Dec. and larger sizes appeared from Aug. through Nov.

In the initial L_∞ estimate, unusual K values were obtained from what is commonly observed for lutjanids
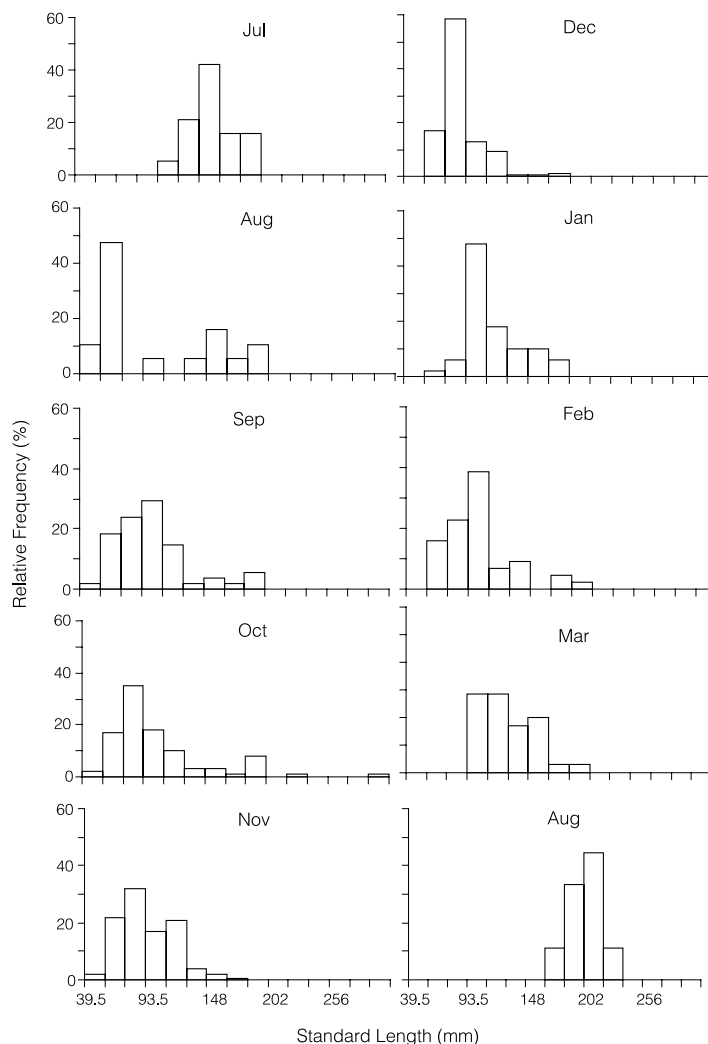

Figure 4. Monthly length frequency distribution of spotted rose snapper *Lutjanus guttatus* caught by shrimp trawling fleets in the Gulf of California.

(Martínez, 2003). The estimations from Amezcua *et al.* (2006) and Rojas (2001) were averaged for a new K estimate. The final K estimate was arrived at by the ELEFAN I method, with L_∞ fixed; the growth equation was determined as $SL= 515(1-e^{(-0.13(t-0.39))})$ and longevity (t_{max}) estimated as 23 years (Figure 6).

The pattern of recruitment extended throughout the year with higher values during spring and summer (Figure 7). We found 25 sexually mature males and 40 females (M:F= 1:1.63) with non-significant differences from a 1:1 ratio ($X^2_{\alpha, 0.05}$, = 3.46, P= 0.06). Total mortality (Z) was 1.00 ±0.56. Considering Pauly's equation at 23°C and the Ralston method, natural mortality (M) was 0.39 and fishing mortality (F) was 0.61; the exploitation rate was 0.61.

Data adjusted to the sigmoid function, considering cumulative frequency of all individuals, was

$$P= \frac{1}{1+e^{-0.0588(SL-80)}},$$

where length at first capture was 80mm SL (Figure 8).

Discussion

Snapper availability was limited to the shrimp fishing season and research survey. Most of the catch came from the most heavily fished areas offshore. Small snapper were most common in the shrimp bycatch (Andrade, 2003; Amezcua *et al.*, 2006). When large snapper appeared from Jul to Nov, they were present in small numbers. The trawl net, trawling velocity, bottom habitat conditions, and dietary preferences of juveniles may influence the findings. For example, when juvenile snapper are found over soft bottoms, they feed mainly on shrimp and, in smaller
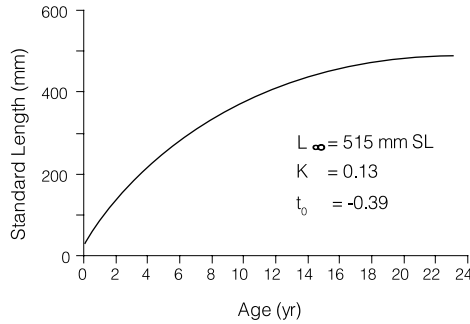

Figure 6. von Bertalanffy growth curve for spotted rose snapper *Lutjanus guttatus* caught by shrimp trawling fleets in the Gulf of California.
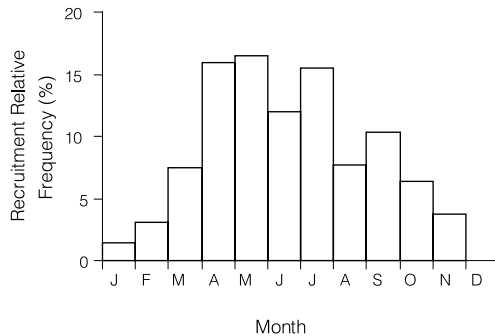

Figure 7. Pattern of recruitment for spotted rose snapper *Lutjanus guttatus* caught by shrimp trawling fleets in the Gulf of California.
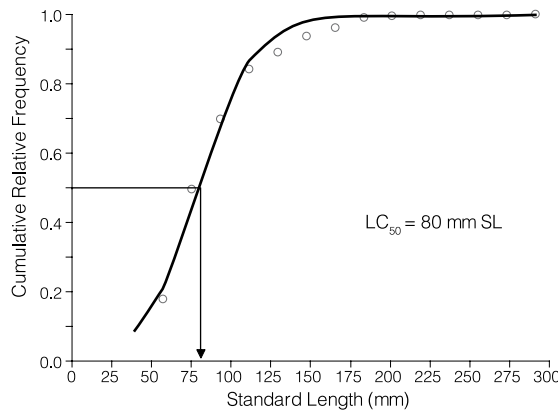

Figure 8. Cumulative length frequency plot and adjusted curve for length at capture estimation of spotted rose snapper *Lutjnaus guttatus* caught by shrimp trawling fleets in the Gulf of California.

proportions, on fish (Rojas, 1996; Saucedo and Chiapa, 2000).

In the W-SL relationship, the b value suggests negative allometric growth (Rojas, 2001; Andrade, 2003). The relationship depends on local and seasonal conditions such as food abundance and availability. Additionally, sampling in the gulf mainly yielded small juvenile snap-

per. Therefore, even when the allometric trend is clear, values of the relationship should not be considered because results were not the typical representation of the species, but part of the natural variation between certain limits (Froese, 2006). We used all pooled specimens and found that the condition factor varied only slightly. This result may be a consequence of the scarcity of mature snapper and that seasonal gonadic development strongly influences body proportions (Froese, 2006).

In the analysis of length frequency distribution, two cohorts were observed and yielded the L_∞= 51.5cm SL estimation, that is, L_∞= 65.3cm TL (from the TL-SL relationship). This is less than the 66.2cm TL obtained by Amezcua *et al.* (2006) using ring counting on vertebrae, and is also less than the 66.4cm TL obtained by Andrade (2003) using otoliths to establish age. However, the present results are much below the 70.6cm furcal length obtained by Rojas (2001) using vertebrae readings. The first two authors included small snapper from shrimp bycatch and medium to large snappers from artisanal fishery, while the third author sampled only the artisanal fishery. Aside from different age determination and adjustment methods, as a higher proportion of larger snapper are

included, higher L_∞ values are obtained for estimating growth. Methods of analysis of length frequency, such as ELEFAN, have been criticized for underestimating L_∞ (Martínez, 2003; Amezcua *et al.*, 2006); nevertheless, we suggest that the results are determined by the length frequency structure itself, as well as by the initial L_∞ value used in the estimation (García and Duarte, 2006). Even while direct age determination methods usually lead to higher and more accurate growth and longevity values, the present estimate of longevity (23 years) is similar to that in studies of lutjanids of medium to large size. This value is above the lower limit (<20 years) set by Martínez (2003).

The obtained estimate of Z (1.0) is between 0.33, the value obtained by Amezcua *et al.* (2006) and the estimated 1.24 by Rojas (1996), whereas the estimate of F (0.61) lies between the lower values (0.8-0.15) obtained by Amezcua *et al.* (2006) and the higher values (0.946-1.014) obtained by Rojas (1996). Estimates of F are partly dependent upon estimates of Z, which, at a given time, depend on the age or length frequency structure used in the converted catch curve method. Rojas (1996) included only large snappers caught by the local finfish fishery, whereas Amezcua *et al.* (2006) considered the mortality at the local fishery and fishing fleets. The present estimate, which appears high in comparison, would represent the additional mortality from juveniles caught by trawling. Ralston (1987) suggested that Pauly's empirical equation (Pauly, 1980) results in underestimated M of slow-growing fishes. However, direct and reliable estimates of M are difficult to obtain, and the equation was derived from data on 175 fish stocks composed of 84 species from freshwater and diverse marine environments. Therefore, we aver-

aged the results from both methods, would likely give a more accurate estimate of M. This value (0.39) is slightly higher than the value (0.20-0.29) reported by Amezcua *et al.* (2006) and that of 0.28 reported by Andrade (2003), being very similar to the mean of 0.38 reported for data of the Lutjaninae subfamily (Martínez, 2003). The exploitation rate is slightly higher than optimum (0.5) and may indicate overfishing (Gulland, 1983).

Shrimp-fishing gear and methods yielded only a few mature spotted rose snapper (Andrade, 2003). Samples showed a 1:1 sex ratio, which was similar to findings by Arellano *et al.* (1998). Analysis of length frequency distribution showed a recruitment pattern that extends throughout the year, with a peak during spring-summer. Along the central and southern Mexican Pacific coast, recruitment occurs over a broad time period, peaking in May and Nov-Jan (Chiapa *et al.*, 2004), while Rojas (2001) found recruitment from Dec through Aug, peaking in March, and Arellano *et al.* (2001) found peaks in Mar-Apr and Aug-Nov. Snapper of a size near sexual maturity, the largest in our samples, peaked in Aug-Nov. These findings reflect an extended spawning season (Rojas, 1997; Chiapa *et al.*, 2004). Additionally, the histological examination of gonads revealed asynchronic oocyte maturation in a partial spawning pattern (Arellano *et al.*, 2001). Under conditions of abundant food, reproduction may peak within a narrow range, while under conditions of resource scarcity, spawning is likely to be extended and occur at intervals (Grimes, 1987). Chiapa *et al.* (2004) suggested that this strategy is useful to diminish competitive interactions between different lutjanid fry.

In the present study mean size at capture was ~80mm SL, which appears very low compared to length at maturity (235mm FL) reported

by Rojas (2001). Even when age appears to be more critical than size in reaching sexual maturity (Martínez, 2003), the difference between the two lengths is considerable. Since the shrimp fleet captures young snapper before they reach reproductive age, there is a potential recruitment problem caused by overfishing (Díaz *et al.*, 2004). Andrade (2003) has suggested creating normative conditions to regulate direct and indirect fishing mortality of *L. peru* and *L. guttatus*. Notably, the shrimp bycatch contains many species (van der Heiden, 1985) and fishing effects are likely to be different for each species, depending on life history traits such as age at maturity, growth rate, and potential rate of population increase, which can influence abundances (Jennings *et al.*, 1998). In most of the limited reports on juvenile spotted rose snapper, they were caught by shrimp trawlers, and estimates may be biased by the localities where caught, including their preferred habitat. Even when juvenile spotted rose snapper are not dependent on estuarine coastal lagoons, they may inhabit these environments (Martínez, 2003) which are closed to industrial shrimp fishing fleets. A shrimp and fish diet (Rojas, 1996; Saucedo and Chiapa, 2000) could also extend their habitat over hard bottoms. The scarce landing records indicate that the snappers are fished mainly over large areas of the central and southern Mexican Pacific coast, where almost no shrimp fishing takes place (CONAPESCA, 2003). Therefore, it is important to determine the extent to which shrimp trawling affects populations of species subject to indirect fishing mortality.

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