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*Research Articles*

# Distribution and population dynamics of the rock shrimp *Sicyonia ingentis* and *Sicyonia penicillata* (Decapoda: Sicyoniidae) in the Gulf of California

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**ABSTRACT.** Aspects of distribution and population dynamics were assessed in two rock shrimp species of the genus *Sicyonia*. Samples were obtained by sea bottom trawling in depths from 50 to 460 m during two research cruises on board the B/I BIP XII in the Gulf of California, Mexico. Taxonomic identification of specimens was performed; measurements of individual length and weight data were taken to obtain biometric relationships and length frequencies. Growth parameter estimations were performed adjusting the von Bertalanffy growth model (VBGM), and the recruitment pattern was obtained by the ELEFAN II method. Longevity was estimated with the Taylor equation, natural mortality with six different models, and length at first maturity by the logistic model. A total of 67 fishing trawls were monitored, and 1,330 specimens were caught (65% *S. ingentis*; 35% *S. penicillata*) in the depth range from 124 to 338 m. Sex ratio (F:M) was 1.0:1.6 for both species; weight and length relationships (both sexes) showed an isometric growth for *S. ingentis* and positive allometric growth for *S. penicillata*. Growth parameters and longevity values were moderate (1.71 and 1.81 years) with age at first maturity around six months for both species. The recruitment pattern showed continuous periods all year long, with a notable peak from November to May. Average natural mortality was 2.47 for *S. ingentis* and 2.35 for *S. penicillata*. Distribution and population dynamics information reported in this study for these two shrimp species should be considered as base knowledge in subsequent studies on fisheries management in the Gulf of California.

**Keywords:** *Sicyonia*; recruitment; growth; natural mortality; population dynamics; Gulf of California

## INTRODUCTION

Shrimps of the family Sicyoniidae (Ortmann, 1898) are benthic penaeids comprising the monotypic genus *Sicyonia* (H. Milne-Edwards, 1830) with more than 52 species globally distributed (Pérez-Farfante & Kensley, 1997; Crosnier, 2003). This shrimp genus is distributing predominantly in tropical and subtropical waters in depths from few meters to nearly 1,000 m (Shanis *et al*., 2013; Patania & Mutlu, 2015). *Sicyonia* shrimps had been discarded from the large commercial catches of penaeid shrimps made in tropical and subtropical waters of the eastern Pacific and western Atlantic oceans because of their hard exoskeleton, commonly thought both consumers and processing industry would reject them. Nonetheless, increased demand for shrimp encouraged fisherman and dealers to bring the larger species to market (Kennedy *et al*., 1977; Pérez-Farfante, 1985; López-Martínez *et al*., 1999a, 2002a; Stiles *et al*., 2007).

*Sicyonia* spp. also primarily targeted in the south Atlantic (specifically Florida, USA), accounted for a smaller percentage of landings (1.8 million lb; 816,000 kg) valued at US$2.5 million (Kennedy *et al*., 1977; Bauer, 1992; Bauer & Rivera-Vega, 1992; NMFS, 2003). In the eastern Pacific, there was an intent to commercialize this shrimp (small scale) in the northern Pacific from Peru (Arana & Méndez, 1978), in the Gulf of California (Hendrickx, 1984, 1995; López-Martínez *et al*., 2002a,b) and in the eastern coast of Baja

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California, particularly Bahía Magdalena, Baja California Sur, Mexico (Mathews & González, 1975). However, exploration and location of new resources with fishery potential, as in the case of *Sicyonia* shrimps, required research on the biology, distribution, population structure and adequate catch technology to generate information to plan sustainable management (Quinn & Deriso, 1999). Population dynamics information has been poor for *Sicyonia* genus (López-Martínez *et al.*, 2002a,b; Nunes-Pralon, 2012; De Camargo-Silvestre, 2015).

In the American Pacific coasts, *Sicyonia* shrimps are widely distributed (Pérez-Farfante, 1985; Hendrickx, 1995). Twelve species of this genus have been reported for the eastern Pacific Ocean (Pérez-Farfante & Boothe, 1981; Hendrickx, 1995); the majority of which, similar to their conspecifics of the western Atlantic Ocean, are distributed from 40 to 630 m in depth, usually on coarse sand bottoms (Freitas, 1984; Sunada & Richards, 1992). In Mexico, particularly in the Gulf of California, nine species of the genus *Sicyonia* have been reported: *S. ingentis* (Burkenroad, 1938), *S. disparri* (Burkenroad, 1934), *S. disedwardsi* (Burkenroad, 1934), *S. penicillata* Lockington, 1879, *S. picta* Faxon, 1893, *S. aliaffinis* (Burkenroad, 1934), *S. disdorsalis* (Burkenroad, 1934), *S. martini* Pérez-Farfante & Boothe, 1981 and *S. laevigata* Stimpson, 1871, of which *S. disparri* is endemic to the region (Hendrickx, 1984).

In the Gulf of California region, several studies about genus *Sicyonia* have reported different aspects, such as: taxonomy (Hendrickx, 1984; Pérez-Farfante, 1985), geographic and bathymetric distribution (Freitas, 1984; Sunada & Richards 1992; Hendrickx, 1996, 2002; Estrada-Ramírez & Calderón-Aguilera, 2001), reproductive biochemical behavior (Anderson *et al.*, 1985; Bauer, 1992; López-Martínez *et al.*, 1999a), morphometric relationships (Hendrickx, 1984) and potential fishery analysis (Cobb *et al*., 1973; Arreguín-Sánchez, 1981; López-Martínez *et al*., 1999b, 2002a,b).

Despite the studies previously mentioned, little information is found related to the population dynamics of these species. Therefore, the objective of this study was to determine latitudinal and bathymetric distribution, sex ratio, weight and length relationship, growth, natural mortality and recruitment pattern of *S. ingentis* and *S. penicillata*, which are the most abundant rock shrimp species in the Gulf of California (Hendrickx, 1996; López-Martínez *et al.*, 1999b, 2002a,b).

## MATERIALS AND METHODS

### Study area and sampling

Samples were obtained in depths from 50 to 460 m during two prospective cruises in 2007 (June 3-20; October 16-20) on board B/I BIP XII in the Gulf of California, Mexico, between 30°59'N, 114°19'W, and 26°07'N, 109°55'W off Sonora and Sinaloa (Fig. 1).

For fishing operations, a polyethylene bottom-trawling net was used with 40 mm mesh opening, 38/34 m in length, mouth perimeter of 68 m and upper headline of 38 m. Following a systematic sampling (Thompson, 1991), fishing trawls were made in each sampling point with one hour of effective trawling at an average speed of 5 km $h^{-1}$.

In each trawl, a 20 kg sample was taken at random and preserved frozen until processing in the laboratory. Data related to each throw were recorded, such as depth and geographic coordinates with an echo sounder and a geographical position satellite (GPS). In the Fisheries Laboratory of Centro de Investigaciones Biológicas del Noroeste, the specimens of the family Sicyoniidae were identified to species following the dichotomous identification keys of Hendrickx (1984), Pérez-Farfante (1985) and Fischer *et al.* (1995). Reference samples were fixed with formaldehyde at 10% and later preserved in ethyl alcohol at 70%.

### Biometrics and sex ratio

For both species, each specimen was measured in total length (TL) and weight (TW) (TL 0.1 g precision and TW, 0.1 g precision, respectively). Sex ratio was determined (F: female, M: male), as well as the weight/length relationship (for both sexes) using the potential model: $W = a\ (TL)^{b}$; where $W$: individual weight in g, $TL$: total length in mm, $a$: regression constant, and $b$: regression coefficient (Ricker, 1975). This $b$ coefficient was statistically evaluated by the Student-*t* test (Zar, 1984) to determine growth type and confidence intervals (95%) for each species. A regression coefficient $b$ equal to 3 (statistically) indicates that the species present an isometric growth, that is, a proportional growth in length and weight of individuals. On the other hand, if $b \neq 3$ an allometric growth is presented by the species, suggesting a differential or disproportional growth of length and weight. When $b < 3$ the species shows a negative allometric growth (a preferential increase of length more than weight) and if $b > 3$, it indicates a positive allometric growth (a preferential increase of weight more than length) for the species (Gould, 1966; Gopalakrishnan *et al.*, 2014).

### Latitudinal and bathymetric distribution of the species

Geographic coordinates and sampling depth of each fishing trawl were used to map species distribution and establish bathymetric ranges.

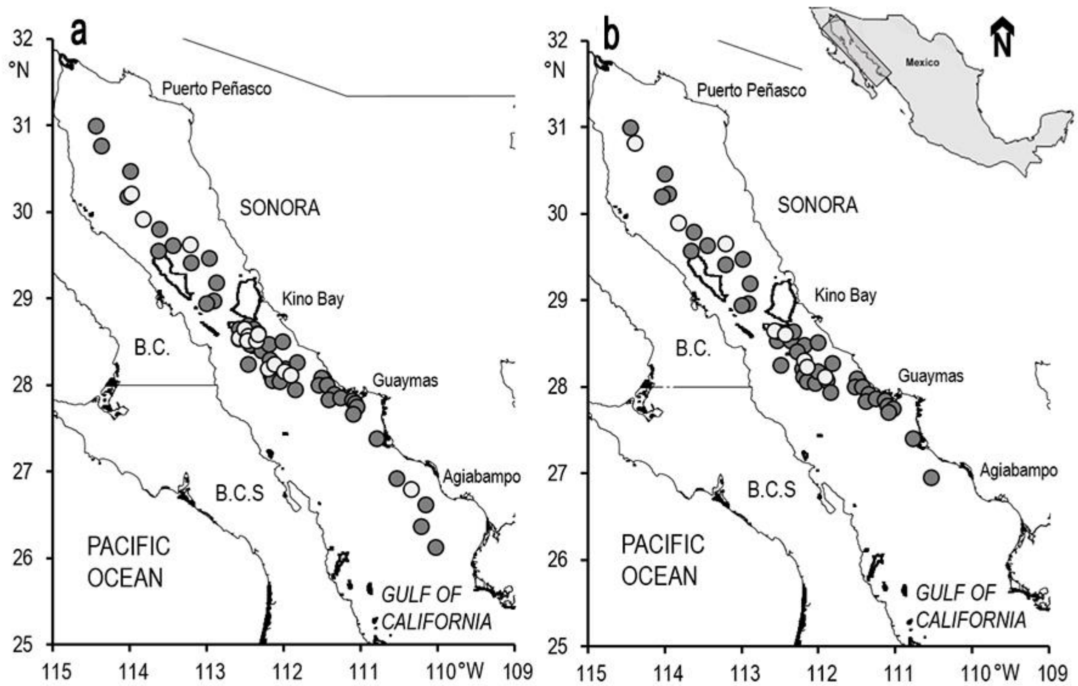


**Figure 1.** Distribution of: a) *Sicyonia ingentis*, and b) *Sicyonia penicillata* caught during the two 2007 cruises in the Gulf of California (white circles= positive captures and grey circles= negative captures).

**Individual growth and recruitment pattern**

Size frequency of each species was obtained in 5 mm intervals (males, females and both sexes), and due to the few specimens for each species in the samples, the combined sex size frequency was used to estimate growth through the von Bertalanffy growth model (VBGM) (Von Bertalanffy, 1938). The VBGM function is: $L_T = L_\infty$ (1- $e^{-K(t-t0)}$), where $L_T$: total length at time *t*; $L_\infty$: asymptotic total length; *K*: instantaneous growth coefficient; and $t_0$: hypothetical age when the specimens had an average length of zero (Hilborn & Walters, 1992).

Powell (1979) and Wetherall *et al.* (1987) methods were used for estimating input values for the $L_\infty$ parameters. In population dynamic's studies, it is common that when individual growth estimates are made with specimen's size data, a series of size frequencies is available over time. In case of only having samples from one or several surveys (as in this case), structure simulation is used; it is achieved by repeating the sample for an adequate time course, assuming that all cohorts follow the same growth curve, commonly known as a system of constant parameters (Sparre & Venema, 1995; Palomares & Pauly, 2008). A cohort is defined as a species group of specimens born at the same time and space. Once this simulation is performed, the Shepherd's Length Composition Analysis and NSLCA methods were used to estimate $L_\infty$ and *K*. The final estimates were obtained with electronic size frequency analysis (ELEFAN I).

The third growth parameter ($t_0$) was determined using the empirical equation proposed by Pauly (1980). The longevity for each species was estimated by Taylor's equation (1962): $T_{max} = 3/K + t_0$ where *K* is the growth coefficient (annual) and $t_0$ the hypothetical age at length zero.

The recruitment pattern was obtained with ELEFAN II method (using the combined sex size-frequency), which performs estimates with possible birthdates of individuals caught by retro calculus of the length frequencies, backward along the time axis. The recruitment patterns can be used to obtain objective information related to the length of the spawning season, as well as their relative magnitude (Pauly, 1987; Moreau & Cuende, 1991).

**Natural mortality**

Estimates of natural mortality rates (M) were obtained for each species (both sexes combined) through six different models: 1) Pauly's equation (1980), $\log M = -0.0152-0.279 \times \log L_\infty + 0.6543 \times \log K + 0.463 \times \log T$ where T is surface water temperature in °C; 2) Jensen's equation (1996), M = 1.5 (*K*) where *K* is instantaneous growth coefficient; 3) Rugolo *et al.* (1998), $M = 3/T_{max\,(years)}$ where $T_{max}$ is species longevity in years; 4) Hewitt & Hoenig (2004), $M = 4.22/T_{max}$

$_{(years)}$; Then *et al.* (2015) considering species longevity, 5) M = 4.899 $T_{max}^{-0.916}$ and taking into account growth parameter values 6) M = 4.118 $K^{0.73} L_{\infty}^{-0.33}$. Average values of M and standard deviation (SD) for each species were obtained. The M/*K* ratio was estimated, and according to Beverton & Holt (1956), the M/*K* ratio values should be from 1.5 to 2.5.

### Length at first maturity

Probability of mature females accumulated in each length interval was performed by calculating length at first maturity (FSM). Only were mature females in stages III, IV and V considered in the analysis, according to the maturation scale proposed by Barreiro (1986). The scale includes five steps, which agree to the macroscopic gonad aspect: I) immature, thin gonad confined to the abdomen, II) developing, thicker gonad, incipient cephalothoracic lobules, III) advanced maturity, very thick gonad, cephalothoracic lobules developed, IV) full maturity, gonad very thick and grainy, occupies all the cephalothorax, and V) spawned, gonad flaccid and thin.

The FSM was calculated using the logistic model: $P_i = 1 / (1 + e^{-r\,(TL-L50)})$ where $P_i$: mature female proportion; *r*: slope of the logistic curve; *TL*: observed total length interval; $L_{50}$: average total length at which the individuals were found sexually mature (King, 2007). Parameter values in the logistic model were fitted using Newton's method and as function objective the sum of squares criterion (Neter *et al.*, 1996).

## RESULTS

During the two cruises, 67 fishing throws were performed in depths from 50 to 460 m, and only in 21 of them, both rock shrimp species were caught. A total of 1,330 specimens were analyzed, of which 65% corresponded to *S. ingentis* and 35% to *S. penicillata*. The F:M ratio was 1.7:1 for *S. ingentis* and 1.5:1 for *S. penicillata*. The length/weight relationship (using both sexes), showed an isometric growth for *S. ingentis* with values of *a* = 0.000007, *b* = 3.049 (2.899-3.199, $P < 0.05$), and a positive allometric growth for *S. penicillata* with values of *a* = 0.000002, *b* = 3.341 (3.233-3.448, $P < 0.05$) according to the regression parameters.

### Latitudinal and bathymetric distributions

Both species were distributed in the central region (off Kino Bay) and north of the Gulf of California (Fig. 1). *Sicyonia ingentis* had a presence in the southern part of Sonora (off Laguna El Tobari) in only one fishing throw. Both species were caught in the range from 124 to 338 m in depth (Fig. 2). However, major abundance

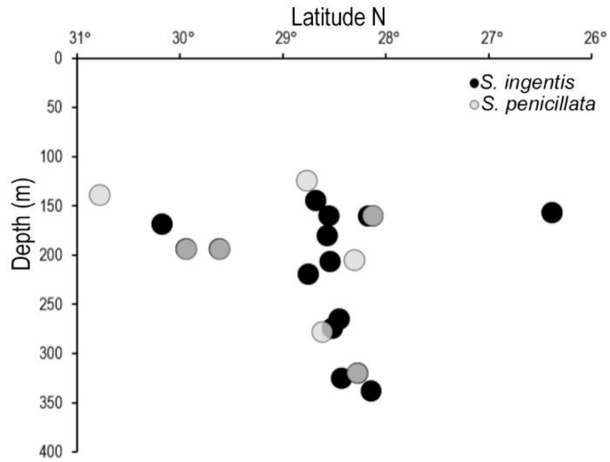


**Figure 2.** Bathymetric distribution of *Sicyonia* species (*S. ingentis* and *S. penicillata*) caught during two cruises in 2007 in the Gulf of California.

was obtained in depths from 195 to 325 m for *S. ingentis* and 205 to 320 m for *S. penicillata*.

TL of both species was in the range from 50 to 135 mm during the two cruises: *S. penicillata* was from 58 to 135 mm (mean 94.7 ± 11.5 mm), and *S. ingentis* from 58 to 130 mm (mean 93.5 ± 9.96 mm). The frequency distribution charts for both species show from one to three cohorts (age groups) on its size distribution (Figs. 3a-3b). *Sicyonia ingentis* did not show differences between sexes and sizes caught from 100 to 250 m and those from 251 to 350 m, whereas a difference was observed for *S. penicillata* between lengths caught from 100 to 250 m (58-191 mm TL, average 97 mm TL) and those from 251 to 350 m (66-116 mm TL, average 88 mm TL) (Figs. 3c-3d).

### Individual growth and recruitment pattern

The VBGM parameter values were $L_{\infty}$ = 150.0 mm TL, *K* = 1.64 annual and $t_0$ = -0.11 years$^{-1}$ for *S. ingentis* and $L_{\infty}$=150.0 mm TL, *K* = 1.55 annual and $t_0$ = -0.12 years$^{-1}$ for *S. penicillata*. The growth parameters obtained for these two species showed a moderate average growth, with theoretical longevity values of 1.71 years for *S. ingentis* and 1.81 years for *S. penicillata*. Estimated growth curves for both species in the Gulf of California are shown (Fig. 4).

The recruitment pattern showed a continuous period for both species with one recruitment peak of higher intensity from May to August for *S. ingentis*, with a major percentage value in June (12.0%). *S. penicillata* had a higher recruitment percentage from November to May, with a maximum value in May (13.8%) (Fig. 5).

### Natural mortality

The Then *et al.* (2015) model showed higher M values, and the Rugolo *et al.* (1998) model indicated the lower

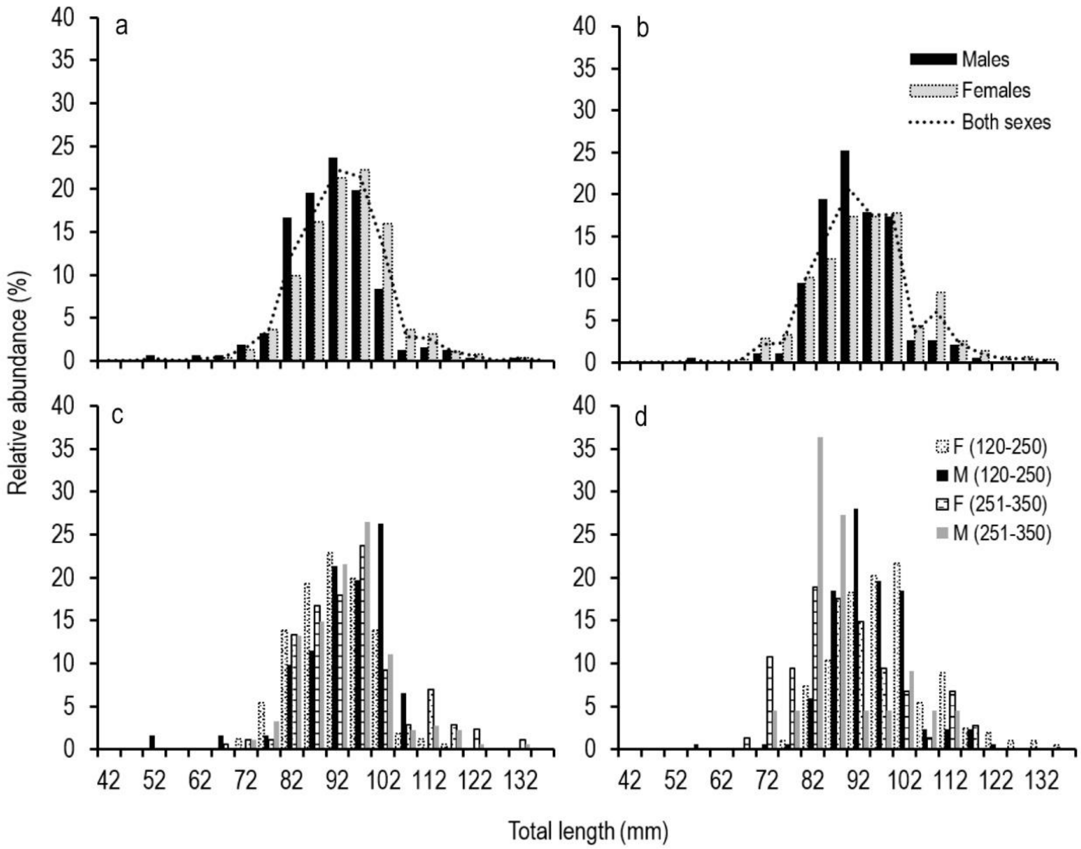


**Figure 3.** Length frequency distribution by sex of *Sicyonia ingentis* (a,c) and *S. penicillata* (b,d) by depth range during two cruises in 2007 in the Gulf of California.


**Figure 4.** Individual average growth curve of the two rock shrimp species (*Sicyonia ingentis* and *S. penicillata*; both sexes) in the Gulf of California, Mexico.

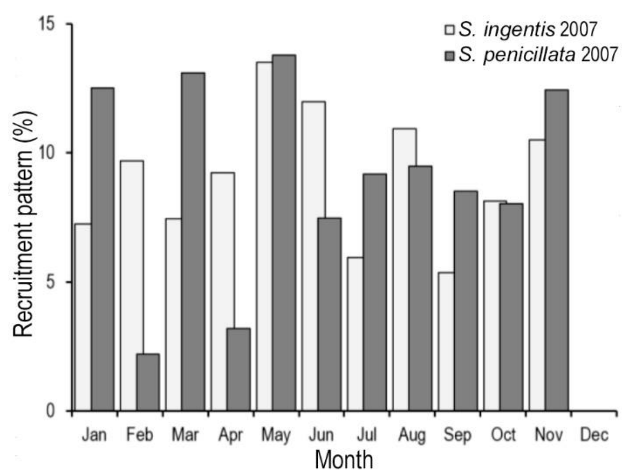


**Figure 5.** Retro-calculus of the perceptual recruitment pattern values for the two rock shrimp species (*Sicyonia ingentis* and *S. penicillata*; both sexes) in the Gulf of California, Mexico.

ones. The M average value was 2.47 ± 0.41 for *S. ingentis* and 2.35 ± 0.40 for *S. penicillata*, considering the six models (Table 1).

**Length at first maturity**

The $L_{50}$ value estimated for *S. ingentis* was 94.33 mm TL (a = 15.96; b = 0.169; $r$ = 0.169) with an adjusted value of $R^2$ = 0.984; while *S. penicillata* $L_{50}$ value was

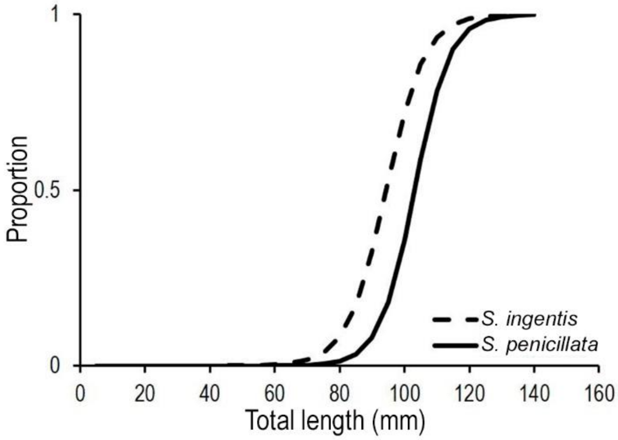


**Figure 6.** Length at first maturity sigmoidal curves shown, by the rock shrimp species (*Sicyonia ingentis* and *S. penicillata*; females), in the Gulf of California, Mexico.

103.11 mm TL (a = 19.19; b = 0.186; *r* = 0.186) and $R^2$ = 0.984. The projected sigmoidal curves obtained by means of the logistic model for the two species, where the 0.5 probability point of length at first maturity was shown for each species (Fig. 6).

## DISCUSSION

From the nine species of *Sicyonia* genus documented in the Gulf of California (Pérez-Farfante & Boothe, 1981; Hendrickx, 1984b), only two species (*S. ingentis* and *S. penicillata*) were found in our study, covering from the Upper Gulf of California (Puerto Peñasco, Sonora) southward to Sonora (GC central region). The major abundance of both species was concentrated in the central part of the Gulf (front of Bahía Kino) at depths from 195 to 325 m, on sandy and sandy mud substrates. López-Martínez *et al.* (2002b) mentioned that one of the principal fishing areas of *S. penicillata* in the GC was located off Bahía Kino, contributing with an average of 70% of the total catch of rock shrimp in the state of Sonora, with a greater exploitation pattern from February to April.

The depth records in our study agree with the catch records for *S. ingentis* reported by Hendrickx (1995) in the GC. However, it disagrees with those for *S. penicillata*, also reported by Hendrickx (1995), who mentioned this species was found in very shallow waters from 1 to 180 m in depth with major density from 30 to 80 m. Likewise, Hendrickx (1995) reported these species inhabited a great variety of substrates (several types of sand and green clayey mud), finding the higher densities on sandy bottoms.

Population parameters are important to understand sustainable management strategies of the resources. Despite the lack of documented information on population dynamics of both rock shrimp species, more published information was found for *S. penicillata*. For the GC, Hendrickx (1995) reported TL of 160 mm for males and 180 mm for females of *S. ingentis*, both values higher than those obtained in our study (*i.e.*, 130 mm TL for *S. ingentis* and 135 mm TL for *S. penicillata*).

For both rock shrimp species analyzed herein, females were more abundant than males, but the sex ratio of organisms smaller than 40 mm TL remains unknown because they could not be captured by trawls (mesh size of 40 mm). Therefore, future experimental samplings should use trawl nets with a smaller mesh size to obtain information about small-sized individuals.

López-Martínez *et al.* (2002b) reported an isometric growth for *S. penicillata* off Bahía de Kino, which disagrees with the results obtained in this study (positive allometric growth $b > 3$). This discrepancy could be due to sampling or measurement bias. Contrary to the results obtained for *S. penicillata*, *S. ingentis* had an isometric growth ($b = 3$), where a proportional increment was recorded between the total weight and total length. This finding agrees with those reported by Arreguín-Sánchez (1981) and López-Martínez *et al*. (2002b) for species of the same genus. The *b* values estimated for both species studied herein; however, were within the value interval reported for different penaeid shrimp species (Pauly *et al*., 1984).

Despite the few specimens used to estimate growth in this study, a wide size frequency of combined sexes was obtained for each species. Biases in growth parameter estimates, deriving from a narrow size frequency, can be generated. The results of the growth analyses of *S. ingentis* and *S. penicillata* indicated that both species had moderate individual growth ($K = 1.60$ average). These results were similar to other studies (Arreguín-Sánchez, 1981; López-Martínez *et al*., 1999a). The growth parameters $L_\infty = 150$ mm, $K = 1.64$ for *S. ingentis* and $L_\infty = 150$ mm, $K = 1.55$ for *S. penicillata* estimated in this study showed moderate growth. However, growth was faster during the first year of age where both species grew around 80% of its total length, but then the growth curve turned asymptote, and in the last year almost no growth was observed (Fig. 4).

It is important to note that when using electronic length analysis methods to estimate growth parameters when biological information is sparse, several species life history assumptions need to be made. For example, assuming a constant population parameter system (Hilborn & Walters, 1992; Jensen, 1996), especially in short life species such as rock shrimps, it could be hard to cover where the environment plays an important role

**Table 1.** Estimated M values for the rock shrimp species in the Gulf of California by six different equations, M/*K* relation values, M average values and standard deviations (SD). For Then *et al.* (2015) equations, $T_{max}$ based (a) and $L_\infty$ and *K* based (b) estimates are shown.

| Model | *Sicyonia ingentis* | | *Sicyonia penicillata* | |
|---|---|---|---|---|
| | M | M/*K* | M | M/*K* |
| Jensen (1996) | 2.46 | 1.5 | 2.33 | 1.5 |
| Pauly (1980) | 2.73 | 1.7 | 2.63 | 1.1 |
| Hewitt & Hoenig (2004) | 2.47 | 1.5 | 2.33 | 1.4 |
| Rugolo *et al.* (1998) | 1.75 | 1.1 | 1.65 | 1.0 |
| Then *et al.* (2015)[a] | 3.00 | 1.8 | 2.84 | 1.8 |
| Then *et al.* (2015)[b] | 2.42 | 1.5 | 2.32 | 1.8 |
| Mean ± SD | 2.47 ± 0.41 | 1.51 | 2.35 ± 0.40 | 1.52 |

in the stability of populations (Bauer & Rivera-Vega, 1992). However, when a long time series that allow making more robust population parameters estimates are not available, a representative length frequency data set of the species is required to make initial approximations (Palomares & Pauly, 2008). These first estimations should be done when there are populations that have an interest as a potential harvest resource (Quinn & Deriso, 1999). This fact emphasizes the importance of studies, which uncover missing information in understanding the underlying population biology and for formulating future management strategies.

The longevity values estimated in this study were below the range (3-3.7 years) from those reported by López-Martínez *et al.* (2002b) for *S. penicillata*. The longevity values ($T_{max}$) obtained by Taylor's equation in this estimate were very similar between both rock shrimp species, 1.71 years for *S. ingentis* and 1.81 years for *S. penicillata*.

Natural mortality is a key parameter on species biology knowledge, but in population dynamics assessment, it is difficult to obtain a reasonable estimate of this value (Pauly, 1980). This parameter is related to basic biological aspects, such as reproduction, growth and longevity (Hewitt & Hoenig, 2004; Then *et al.*, 2015). It is also the most influential parameter for stock assessing, and the magnitude of M is related directly with population productivity.

Given the importance of M value, it was necessary to determine the most suitable for the species. In this study, six models were selected to evaluate M; based on the results, the equation of Then *et al.* (2015) showed the highest M values in both cases when growth parameter values were considered and when taking into account longevity values for the two rock shrimp species. The equation of Rugolo *et al.* (1998) showed the lowest M values among all six candidates in natural mortality models. An average M value was calculated using mathematical and biological information from all models. The M average value was 2.47 for *S. ingentis* and 2.35 for *S. penicillata* with M/*K* relationship of 1.51 and 1.52 respectively. On the other hand, Beverton & Holt (1956) mentioned that species M/*K* relationship should be in the range values from 1.5 to 2.5. Therefore, the M values obtained by Then *et al.* (2015) (both solution cases) should be considered as appropriate since its relationship M/*K* was 1.8 for both species.

In the case of recruitment pattern (reproductive) of the two species, the indirect analysis performed can be used to obtain objective data related to the length of the spawning season, as well as its relative magnitude (Pauly, 1987). *Sicyonia penicillata* showed a continuous recruitment period (all year round) with a maximum from spring to summer. This behavior was similar to that found by López-Martínez *et al.* (2002b) for this same species. *S. brevirostris* has shown a massive spawning season from October to February, varying the starting and ending month, apparently in response to the length of the photoperiod (Cobb *et al.*, 1973; Kennedy *et al.*, 1977).

For this study, length at first maturity for females was 94.33 mm TL for *S. ingentis* and 103.11 mm TL for *S. penicillata*, which represented the first reproduction age at 29.2 and 38.6% of its theoretical longevity, respectively. It means that both species reached length at first maturity after 0.50 years of life (62.9% $L_\infty$) for *S. ingentis* and 0.66 years (68.7% $L_\infty$) for *S. penicillata*. With all this information, the two species could have a good capacity for redoubling their populations and reproducing more than once in their lives, which is important to consider in the near future in terms of fishery management of these two species.

As previously mentioned, until the last few years, individuals of the *Sicyonia* genus had been discarded from the great commercial penaeid shrimp catches in tropical and subtropical waters of the eastern Pacific and western Atlantic oceans due to their hard exoskele-

**Table 2.** Life-history values of rock shrimp *Sicyonia* spp. in several oceanic regions. Source length data converted to total length (TL, mm) when necessary. From northern to southern latitudes: SBC: Santa Barbara Channel, CW: California waters, GC: Gulf of California, WBCS: west Baja California Sur, WFS: west Florida shelf, EFS: east Florida shelf, STA: subtropical area, CTA: cool temperate area, QRGM: Quintana Roo, Gulf of Mexico, CGM: Campeche, Gulf of Mexico, PRW: Puerto Rico waters, SCP: southern coast of Brazil and SPB: São Paulo Brazil. Bolt numbers are calculated M (Jensen, 1996) and longevity (Taylor, 1962) values by using source growth parameter.

| Species | Oceanic region | Source | Sex | n | Length data | Min. Length (mm) | Max. Length (mm) | $TL_\infty$ (mm) | *K* (annual) | $t_0$ ($yr^{-1}$) | M | Z | F | Long. (years) | Sex ratio (F-M) | $L_{50}$ (mm) | Age at $L_{50}$ (years) | Recruit. period | Rep. period |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *S. ingentis* | SBC | Anderson *et al.* (1985) | F-M | - | CL | 6.00 | 45.00 | - | - | - | - | - | - | 8.00 | 1.0:1.0 | | - | Jun-Jul | Jul-Sep |
| *S. ingentis* | CW | Sunada & Richards (1992) | F-M | - | CL | - | 47.00 | - | - | - | - | - | - | 5.00 | - | 30.00 | - | - | Jul-Oct |
| *S. ingentis* | GC | Present study | F-M | 865 | TL | 58.00 | 130.00 | 150.00 | 1.64 | -0.12 | 2.47 | - | - | 1.71 | 1.7-1.0 | 94.33 | 0.50 | May-Jul | - |
| *S. penicillata* | GC | Present study | F-M | 466 | TL | 58.00 | 135.00 | 150.00 | 1.55 | -0.12 | 2.35 | - | - | 1.81 | 1.5-1.0 | 103.11 | 0.66 | Nov-May | - |
| *S. ingentis* | GC | Hendrickx (1995) | F | - | TL | - | 180.00 | - | - | - | - | - | - | - | - | - | - | - | - |
| *S. ingentis* | GC | Hendrickx (1995) | M | - | TL | - | 160.00 | - | - | - | - | - | - | - | - | - | - | - | - |
| *S. penicillata* | GC | López-Martínez *et al.* (2002a) | F-M | - | TL | 35.00 | 171.00 | 161.94 | 1.25 | - | 2.48 | 6.32 | 3.84 | 3-3.7 | - | - | - | Aug-Oct | - |
| *S. penicillata* | GC | López-Martínez *et al.* (1999b) | F-M | 1,783 | TL | 19.89 | 133.23 | 161.79 | 1.24 | -0.12 | 1.86 | | - | 2.40 | 1.0-0.97 | 88.00 | 1.50 | Aug-Dec | Oct-Apr |
| *S. penicillata* | GC | López-Martínez *et al.* (2002b) | F-M | 229,660 | TL | 42.56 | 148.34 | 161.79 | 1.25 | -0.12 | 2.40 | 4.05 | 1.57 | 5.00 | 1.0:1.0 | 88.00 | 0.50 | | Oct-Mar |
| *Sicyonia* sp. | WBCS | Mathews & González (1975) | F-M | - | TL | 16.00 | 130.00 | - | - | - | - | - | - | 2.50 | F>M | 50-60 | 1.00 | Feb, Aug | May-Jun |
| *S. brevirostris* | WFS | Cobb *et al.* (1973) | F-M | 973 | CL | 3.00 | 36.50 | - | - | - | - | - | - | - | 1.0-1.0 | 9.00 | - | Mar-Nov | Oct-Feb |
| *S. brevirostris* | EFS | Kennedy *et al.* (1977) | F-M | 33,270 | CL | 4.00 | 38.00 | - | - | - | - | - | - | 1.80 | 1.0-0.93 | 24.00 | - | Jun-Jul | Nov-Jan |
| *S. brevirostris* | STA | Bauer (1992) | F | - | CL | 17.00 | 35.00 | - | - | - | - | - | - | 1.66-1.83 | - | - | - | - | - |
| *S. ingentis* | CTA | Bauer (1992) | F | - | CL | 24.00 | 45.00 | - | - | - | - | - | - | >1.83 | - | - | - | - | - |
| *S. brevirostris* | QRGM | Arreguín-Sánchez (1981) | F-M | - | TL | - | - | 179.40 | 2.76 | 0.37 | 0.14 | 0.50 | 0.37 | - | - | - | - | Sep-Nov | - |
| *S. brevirostris* | CGM | Ruiz-Vázquez & Soto (2005) | F-M | 9,814 | TL | - | - | 178.93 | 0.80 | -0.23 | **1.20** | - | - | **3.52** | - | - | - | - | - |
| *S. brevirostris* | CGM | Ruiz-Vázquez & Soto (2005) | F | - | TL | - | - | 176.10 | 0.64 | -0.23 | **0.96** | - | - | **4.47** | - | - | - | - | - |
| *S. brevirostris* | CGM | Ruiz-Vázquez & Soto (2005) | M | - | TL | - | - | 168.50 | 1.83 | 0.00 | **2.74** | - | - | **1.64** | - | - | - | - | - |
| *S. brevirostris* | CGM | Ruiz-Vázquez (1993) | F-M | - | TL | - | - | 179.00 | 1.10 | 0.70 | **1.65** | - | - | **3.43** | - | - | - | - | - |
| *S. brevirostris* | CGM | Ruiz-Vázquez (1996) | F-M | - | TL | - | - | 179.00 | 1.20 | 0.70 | **1.80** | - | - | **3.20** | - | - | - | - | - |
| *S. brevirostris* | CGM | Ruiz-Vázquez (1996) | F | - | TL | - | - | 177.00 | 0.80 | 0.40 | **1.20** | - | - | **4.15** | - | - | - | - | - |
| *S. brevirostris* | CGM | Ruiz-Vázquez (1996) | M | - | TL | - | - | 168.00 | 1.60 | 0.50 | **2.40** | - | - | **2.38** | - | - | - | - | - |
| *S. parri* | PRW | Bauer & Rivera-Vega (1992) | F | 1,614 | CL | 3.00 | 9.00 | - | - | - | - | - | - | 0.5-0.66 | - | - | - | All year | - |
| *S. laevigata* | PRW | Bauer & Rivera-Vega (1992) | F | 711 | CL | 3.00 | 9.00 | - | - | - | - | - | - | 0.5-0.66 | - | - | - | All year | - |
| *S. dorsalis* | SCB | De Camargo-Silvestre (2015) | F-M | 1,154 | CL | 4.40 | 14.50 | 13.14 | 3.28 | 0.55 | **4.92** | - | - | 1.34 | 1.0-0.08 | 8.40 | - | Jul-Nov | - |
| *S. typica* | SPB | Nunes-Pralon (2012) | F-M | 942 | CL | 4.50 | 20.00 | 172.90 | 4.55 | - 0,16 | **6.83** | - | - | 1.01 | 2.0:1.0 | 122.00 | - | Jay-Jun, Oct | Oct-May |

ton, commonly thought consumers and the food processing industry would reject it. However, the increase in shrimp demand motivated fishermen and business people to bring the largest species into the market, and now the demand has rapidly grown since some customers prefer rock shrimp rather than the species with thinner exoskeletons (Arreguín-Sánchez, 1981).

This work concentrated all available information for life parameter values of the genus *Sicyonia* in different oceanic regions, which is a result of an extensive literature search. For comparative intentions, reported growth parameter values were standardized to total length (TL mm) and annual base (years$^{-1}$) output values when necessary and possible (some studies reported carapace and tail lengths and monthly based growth coefficients). This standardization was performed using length relationship equations reported for each correspondent species of rock shrimp (Table 2).

The lack of several population parameters estimates for the genus *Sicyonia* was notable since those values have been obtained only for *S. penicillata* (López-Martínez *et al*., 1999b, 2002b), *S. dorsalis* (see De Camargo-Silvestre, 2015), *S. typica* (Nunes-Pralon, 2012), and *S. brevirostris* (Arreguín-Sánchez, 1981; Ruíz-Vázquez, 1993, 1996; Ruíz-Vázquez & Soto, 2005). Some of those growth parameter values have been obtained repeatedly for a few rock shrimp species but in the same oceanic region as the Gulf of California, the Gulf of Mexico and the Caribbean Sea. The sparse or null growth values and other population dynamics parameters such as reproductive biology (first maturity length, reproductive period and sex ratio) for these species in other oceanic regions, where are also distributed, which did not allow making accurate geographic and demographic comparisons.

Bauer (1992) made a comparison of reproductive patterns among tropical, subtropical and cool temperate *Sicyonia* spp. reporting a continuous reproduction in the tropics with increased restriction of breeding season with an increase in latitude. Thus, a greater intensity of breeding effort appears to accompany the shorter breeding period associated with an increase in latitude at the tropical site, most females of all caridean species carried embryos during all months. With this respect, and due to the sparse life history information of the genus *Sicyonia*, robust inferences cannot be made; nevertheless, the empty values shown in Table 2 can be complemented in future studies.

Even though these species (*S. ingentis* and *S. penicillata*) have shown a high potential for fishery development in the Central Gulf of California, according to López-Martínez *et al.* (1999a, 2002a), it is worth performing further studies in more extended time periods and exploring on board research cruises to allow determining biomass and spatial and temporal distribution all year round. Likewise, an analysis of the possible migration pattern that these species perform is considered highly desirable since it is still unknown to date.

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