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*Research Article*

# Catch composition of the spiny lobster *Panulirus gracilis* (Decapoda: Palinuridae) off the western coast of Mexico

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**ABSTRACT.** The lobster fishery in the Gulf of California and the south-central region of the western coast of Mexico consists of small-scale artisanal activity supported by *Panulirus gracilis* and *P. inflatus*, with an annual average catch of 132 ton. The present study analyzes the landing composition of this fishery and the population structure of *P. gracilis*. Carapace lengths (CL) for this species ranged from 35 to 125 mm, and the most frequent sizes were between 60 and 85 mm. The size distribution was approximately normal. This implies that the fishery is composed of several size classes, with annual recruitment to the fishing areas. For the 1989-1990 and 1990-1991 fishing seasons, the mean monthly sizes of males were between 70.18 ± 11.74 and 81.11 ± 6.76 mm CL, whereas females averaged from 73.60 ± 8.95 to 80.28 ± 7.53 mm CL. Power-law relationships between carapace length (CL in mm) and total weight (TW in g) were determined, resulting in the following equations: $PT = 0.0021\ CL^{2.7689}$ for males and $PT = 0.0009\ CL^{3.0038}$ for females. During certain periods of the year, males dominated the catch; however, the overall annual male:female ratio was near 1:1.

**Keywords:** population structure, spiny lobster, *Panulirus gracilis*, Gulf of California, Mexico.

# Composición de la captura de la langosta espinosa *Panulirus gracilis* (Decapoda: Palinuridae) en la costa oeste de México

**RESUMEN.** La pesquería de langosta en el golfo de California y en el centro-sur de la costa occidental de México es una actividad artesanal a pequeña escala y es sostenida por *Panulirus gracilis* y *P. inflatus*, con una captura promedio anual de 132 ton. En este estudio se analiza la composición de los desembarques de esta pesquería y la estructura de la población de *P. gracilis*. El intervalo de talla de esta especie fue de 35 a 125 mm de longitud del cefalotórax (LC) y el más frecuente se encontró entre 60 y 85 mm. La distribución de tallas fue aproximadamente normal. Esto implica que la pesquería está compuesta por varias clases de tallas, con un reclutamiento anual a las áreas de pesca. La talla media mensual de machos fue entre 70,18 ± 11,74 y 81,11 ± 6,76 mm LC y en hembras de 73,60 ± 8,95 a 80,28 ± 7,53 mm LC, durante las temporadas de pesca 1989-1990 y 1990-1991. Se determinó la relación entre la LC (en mm) y el peso total (PT, en g), obteniéndose las siguientes ecuaciones: $PT = 0.0021\ LC^{2.7689}$ en machos y $PT = 0.0009 LC^{3.0038}$ en hembras. Durante ciertos períodos del año los machos son dominantes en las capturas, pero la proporción machos:hembras durante todo el año es cercana a 1:1.

**Palabras clave:** estructura poblacional, langosta, *Panulirus gracilis*, golfo de California, México.

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## INTRODUCTION

On the Mexican coast of the Pacific Ocean and Gulf of California, *Panulirus gracilis* and *P. inflatus* are locally important fishery resources and their harvesting is exclusively a small-scale artisanal activity, developed mainly on the continental shelf. The annual landings of these species were estimated at approximately 500-650 t during the 15-year period from 1990-2005. This production includes the catches of these species obtained in Baja California (A. Vega-Velázquez, *pers. comm.*).

Traditionally, *P. gracilis* and *P. inflatus* were captured in traps and sometimes by divers (Pérez-

González *et al*., 2002a). A major change in the exploitation strategy of these species took place during the 1980s and early 1990s with the progressive introduction of tangle nets, which have almost totally replaced other fishing methods. These tangle nets (called "chinchorros langosteros" in the region) usually have stretched meshes of 101.6 and 114.3 mm, lengths between 75.0 and 200.0 m and a height between 0.9 and 1.8 m. In general, the nets are left in the water for 24 h (one fishing day). A longer set time leads to better catches of spiny lobster, as they are attracted by fishes, crustaceans, mollusks and other invertebrates caught in the nets (Olabarría, 1999; Plascencia-González & Van der Heiden, 2002; Pérez-González, 2006; Pérez-González *et al*., 2002b, 2006).

*Panulirus gracilis* (called güera, verde, arenera or playera spiny lobster) is distributed along the coastline of the eastern Pacific from Baja California, Mexico, to Paita, Peru and the Galapagos Islands (Holthuis, 1991; Hendrickx, 1995). *P. inflatus* is endemic to Mexico, but *P. gracilis* is also fished in Panama (Butler & Pease, 1965), on the continental coast of Ecuador (Loesch & López, 1966; Báez, 1983), and in the Galapagos Islands (Holthuis & Loesch, 1967). Most studies on the two spiny lobsters coexisting along the western coast of Mexico have considered them both; only a few have been performed on the latter species specifically.

The catch composition, population structure, sex ratio, and fishery characteristics of both species have been described on the Mexican Pacific (Weinborn, 1977; Briones *et al*., 1981; Juárez-Carrillo *et al*., 2006) and Gulf of California coasts (Pérez-González *et al*., 1992a, 1992b; Valadez-Manzano *et al*., 2003; Arzola-González *et al*., 2007). Here we report these characteristics for *P. gracilis* off the western coast of Mexico in the lower part of the Gulf of California.

## MATERIALS AND METHODS

Commercial lobster fishing on the western coast of the Gulf of California occurs in the south, primarily at the state of Sinaloa. Therefore, the study area in this region was located from the north of Punta Piaxtla to the south in Mazatlan Bay, between 23º10′-23º48′N and 106º24′-106º54′W (Fig. 1). The coast presents extensive sand beaches with some gravel-sand patches, while large areas offshore are rocky or covered with gravel-sand.

The target species was determined according to the catalogues of Holthuis (1991) and Hendrickx (1995) catches were weighed monthly. To determine the population structure of *P. gracilis*, catches were sampled by accompanying fishermen in the field. Lobsters caught with tangle nets from depths of approximately 0.5-35 m were sampled at random every month from September, 1989 to November, 1991.

To determine the relationships among total length (TL), carapace length (CL), total weight (TW) and carapace width (CW), regression equations for TL *vs* CL, TW *vs* CW and CW *vs* CL were calculated from sample of whole male and female *P. gracilis* caught in the same study area. The TL was measured from between the rostral horns to the posterior end of the telson with a modified ichthyometer (± 1 mm). CL and CW were measured with a vernier caliper (± 0.01 mm), with the former being measured along the mid-dorsal line, from the transverse ridge between the postorbital spines to the posterior edge of the carapace, and the latter at the greatest width of the carapace. TW was measured with a field balance (± 1 g).

Additionally, to obtain CL and TW to the nearest mm and g, respectively, selected individuals were transported to the laboratory each month to be measured with a digital caliper (± 0.1 mm) and weighed on an electronic balance (± 0.01 g). These data were used to estimate the parameters of the relationship between TW and CL by a linear regression analysis of the log-transformed data:

$$TW = aCL^{b} \rightarrow Ln\,(CL) + Ln(a)$$

where *a* and *b* are constants.

Data were grouped into 5-mm class intervals, weighed for each landing and compiled into annual distributions. The size distribution and sex ratio were obtained from the pooled sample (catch obtained by accompanying fishermen in the field plus commercial landings).

## RESULTS

From September, 1989 to November, 1991, a total of 13,834 spiny lobster were caught, of which 5,799 (41.92%) belonged to the species *P. gracilis* and 8,035 (58.08%) to *P. inflatus*. The observed relative proportions of these lobster species showed an inversion during the study period (Fig. 2). *P. inflatus* predominated from September 1989 to September 1990, whereas *P. gracilis* was more abundant from October 1990 to November 1991, except in February and October of 1991.

### Morphometric relationships

TL *vs* CL and CW *vs* CL exhibited linear relationships, while TW *vs* CW was potential, and their equations appear in Table 1. The determination coefficient ($R^2$) values were high.

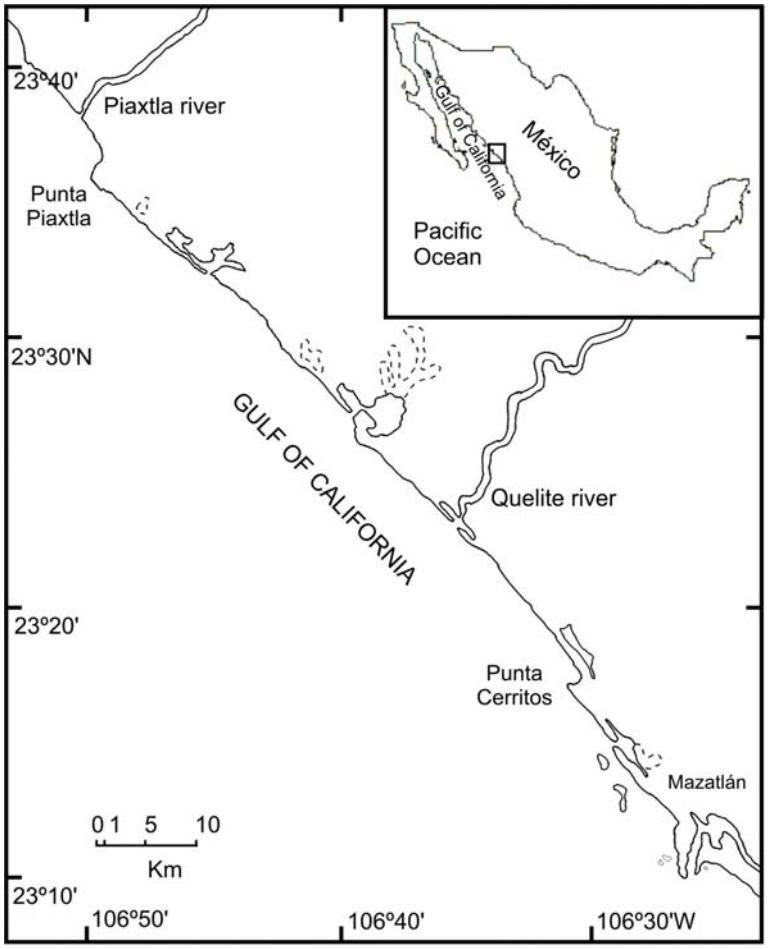


**Figure 1**. Map of the study area in the lower part of the Gulf of California, western coast of Mexico.

**Figura 1**. Mapa del área de estudio en la parte baja del golfo de California, costa occidental de México.

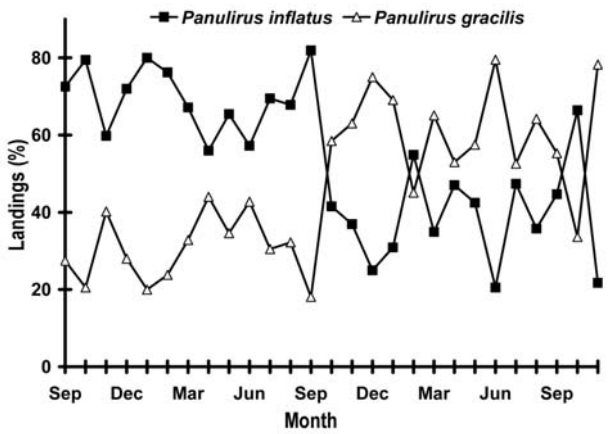


**Figure 2**. *Panulirus inflatus* and *P. gracilis* landings between September 1989 and November 1991 in the lower part of the Gulf of California, Mexico.

**Figura 2**. Capturas de *Panulirus inflatus* and *P. gracilis* desembarcadas entre septiembre de 1989 y noviembre de 1991 en la parte baja del golfo de California, México.

### TW-CL relationship

Data from 279 specimens (159 males; size range 42-92 mm CL, weight range 60-580 g, and 120 females; size range 48-86 mm CL, weight range 100-580 g), were used to determine the relationship between TW and CL (Fig. 3). The relationships between carapace length (CL in mm) and total weight (TW in g) were as follows: for males, $TW = 0.0021\ CL^{2.7689}$; for females, $TW = 0.0009\ CL^{3.0038}$. The male relationship was allometric ($b \neq 3$, $P < 0.05$), whereas for females it was isometric ($b = 3$, $P > 0.05$).

### Size distribution

The size of the landed *P. gracilis* individuals ranged from 40 to 120 mm CL in 1990, with most of the individuals sized from 65 to 90 mm CL; the mode was 75 mm CL (Fig. 4). In 1991, the specimens ranged from 35 to 125 mm CL, with most of the individuals sized from 60 to 85 mm CL; the mode was

**Table 1.** Regression equations for the relationships between total length (TL) and carapace length (CL), total weight (TW) and CL and carapace width (CW) and CL estimated for both sexes of *Panulirus gracilis* in the lower part of the Gulf of California, Mexico.

**Tabla 1.** Ecuaciones de las relaciones entre la longitud total (TL) y longitud del cefalotórax (CL), peso total (TW) y CL, y ancho del cefalotórax (CW) y CL estimadas tanto para ambos sexos como separados de *Panulirus gracilis* en la parte baja del golfo de California, México.

| Relationship | Equation | $R^2$ | n |
|---|---|---|---|
| | Males + females | | |
| TL *vs* CL | TL = 2.5027 CL + 16.036 | 0.898 | 271 |
| TW *vs* CW | $TW = 0.0017\ CW^{2.973}$ | 0.886 | 271 |
| CW *vs* CL | CW = 0.7458 CL + 4.271 | 0.930 | 271 |
| | Males | | |
| TL *vs* CL | TL = 2.3714 CL + 22.037 | 0.898 | 159 |
| TW *vs* CW | $TW = 0.002\ CW^{2.9241}$ | 0.890 | 159 |
| CW *vs* CL | CW = 0.7403 CL + 4.4196 | 0.930 | 159 |
| | Females | | |
| TL *vs* CL | TL = 2.8109 CL + 0.0933 | 0.949 | 112 |
| TW *vs* CW | $TW = 0.0012\ CW^{3.0784}$ | 0.896 | 112 |
| CW *vs* CL | CW = 0.7616 CL + 3.57 | 0.934 | 112 |

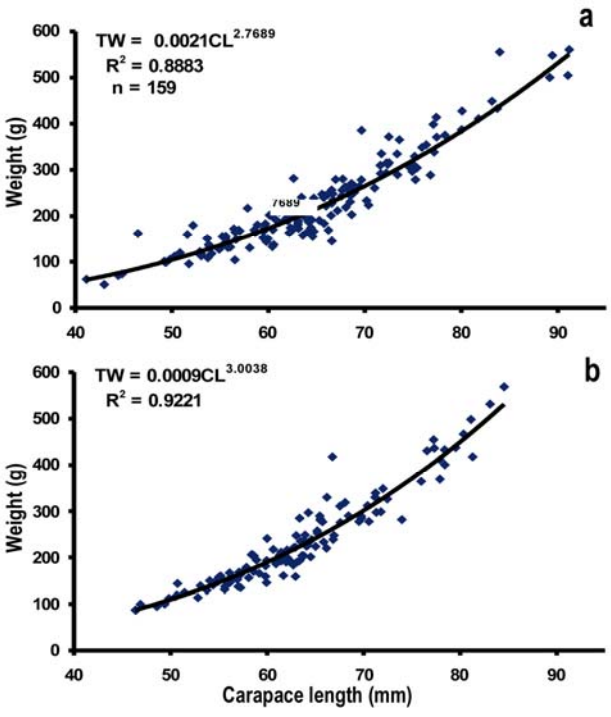


**Figure 3.** Relationship between carapace length and total weight in the spiny lobster *Panulirus gracilis* from the lower part of the Gulf of California, Mexico.

**Figura 3.** Relación entre la longitud del cefalotórax y el peso total en la langosta espinosa *Panulirus gracilis* en la parte baja del golfo de California, México.

75 mm CL (Fig. 5). No change in the modal size classes was found between the 1989-1990 and the 1990-1991 fishing seasons.

The sample mean and standard deviation were analyzed for the 1989-1990 and 1990-1991 fishing seasons. The monthly mean size, standard deviation and size range of the sample, as a whole and by sex, are presented in Table 2; the corresponding weight data are given in Table 3. In the 1989-1990 fishing season, the monthly mean sizes and weights of males were between 70.18 ± 11.74 and 81.11 ± 6.76 mm CL and 317.28 ± 142.59 and 427.73 ± 98.61 g TW, respectively, and for females they were between 75.06 ± 6.51 and 80.28 ± 7.53 mm CL and 371.86 ± 90.15 and 437.76 ± 109.91 g TW. For the 1990-1991 fishing season, the monthly mean sizes and weights of males were between 71.09 ± 11.31 and 79.30 ± 6.99 mm CL and 300.61 ± 150.38 and 417.33 ± 105.71 g TW, respectively, and for females, they were between 73.60 ± 8.95 and 77.23 ± 6.62 mm CL and 355.00 ± 124.12 and 431.67 ± 136.05 g TW.

### Sex ratio

A total of 5,799 *P. gracilis* lobsters were examined. Of these, 56.4% were males (3,272) and 43.6% were females (2,527). The overall sex ratio (M:F) was 1:1.3. However, the sex ratio varied monthly (Fig. 6). The catch rates of male lobsters were consistently higher in summer and autumn than those of females,

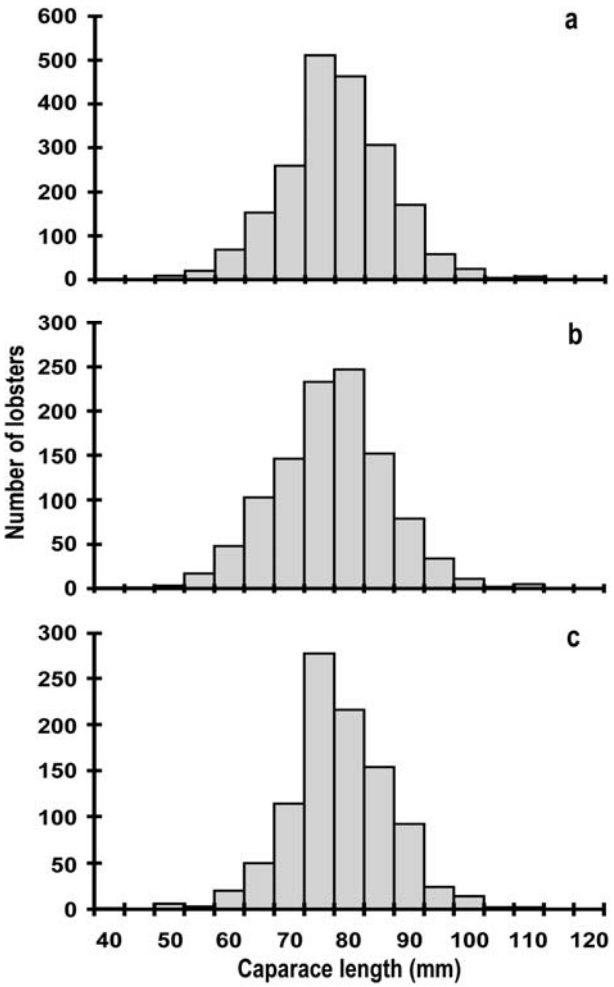


**Figure 4.** Size-frequency distributions of *Panulirus gracilis* for a) both sexes, b) males and c) females by 5-mm-CL size classes during 1990 in the lower part of the Gulf of California, Mexico.

**Figura 4.** Frecuencia de tallas (intervalo cada 5 mm de LC) de a) machos+hembras, b) machos y c) hembras de *Panulirus gracilis* durante 1990 en la parte baja del golfo de California, México.

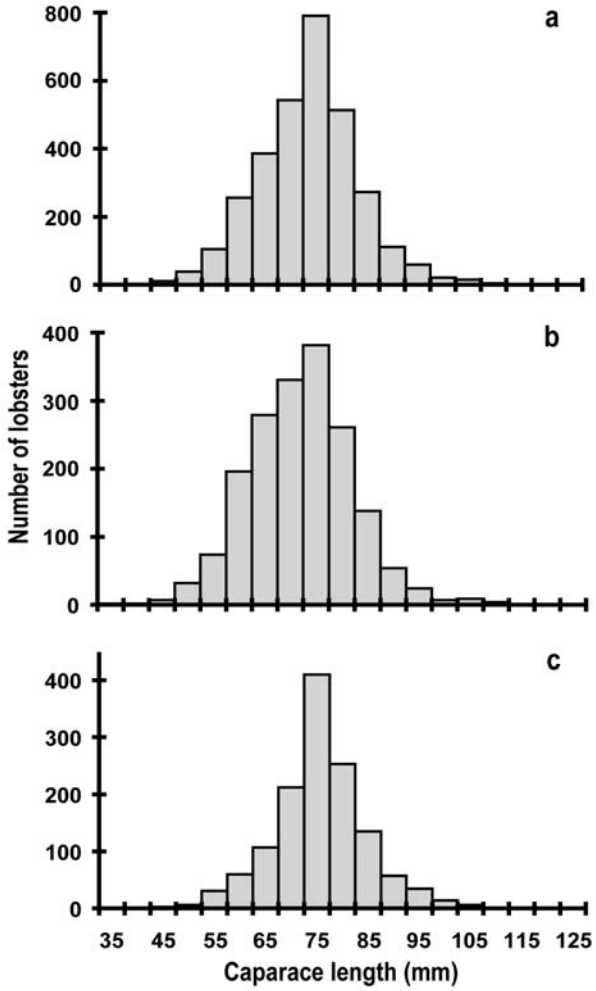


**Figure 5.** Size-frequency distributions of *Panulirus gracilis* for a) both sexes, b) males and c) females by 5-mm-CL size classes during 1991 in the lower part of the Gulf of California, Mexico.

**Figura 5.** Frecuencia de tallas (intervalo cada 5 mm de LC) de a) machos+hembras, b) machos y c) hembras de *Panulirus gracilis* durante 1991 en la parte baja del golfo de California, México.

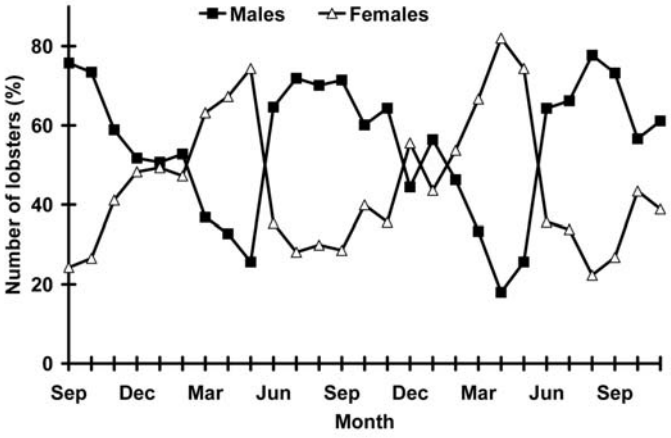


**Figure 6.** Percentage of males and females of *Panulirus gracilis* in monthly samples from September 1989 to November 1991 in the lower part of the Gulf of California, Mexico.

**Figura 6.** Porcentajes mensuales de machos y hembras de *Panulirus gracilis* entre septiembre de 1989 y noviembre de 1991 en la parte baja del golfo de California, México.

**Table 2.** Monthly mean size, standard deviation and size range whole and by sex of the carapace length (CL, in mm) of *Panulirus gracilis*, during 1989-1990 and 1990-1991 fishing seasons in the lower part of the Gulf of California, Mexico.

**Tabla 2.** Número de hembras y machos de *Panulirus gracilis* e intervalos de talla, medias y desviación estándar mensuales de la longitud del cefalotórax (CL, en mm), durante las temporadas de pesca 1989-1990 y 1990-1991 en la parte baja del golfo de California, México.

| Season 1989-1990 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | | Males | | | Females | | |
| Month | n | $\overline{X}$ CL ± SD | n | Range CL (mm) | $\overline{X}$ CL ± SD | n | Range CL (mm) | $\overline{X}$ CL ± SD |
| Sep | 132 | 76.38 ± 5.48 | 100 | 64.8-99.1 | 75.90 ± 4.88 | 32 | 64.1-93.8 | 77.86 ± 6.91 |
| Oct | 143 | 77.19 ± 5.96 | 105 | 65.8-87.1 | 76.06 ± 4.86 | 38 | 63.1-94.2 | 80.28 ± 7.53 |
| Nov | 158 | 76.96 ± 7.60 | 93 | 60.6-113.1 | 76.69 ± 6.71 | 65 | 61.2-98.6 | 77.35 ± 8.76 |
| Dec | 174 | 77.68 ± 7.76 | 90 | 53.1-101.8 | 79.06 ± 7.88 | 84 | 57.5-93.9 | 76.19 ± 7.38 |
| Jan | 142 | 79.39 ± 6.52 | 72 | 68.0-93.2 | 80.14 ± 6.21 | 70 | 63.5-96.0 | 78.62 ± 6.78 |
| Feb | 125 | 78.69 ± 7.56 | 66 | 62.7-98.2 | 81.11 ± 6.76 | 59 | 63.1-95.5 | 75.98 ± 7.54 |
| Mar | 178 | 76.03 ± 8.75 | 67 | 47.6-109.7 | 77.64 ± 11.44 | 111 | 56.0-95.0 | 75.06 ± 6.51 |
| Apr | 267 | 78.17 ± 7.53 | 87 | 55.8-109.3 | 80.31 ± 9.16 | 180 | 65.2-96.3 | 77.14 ± 6.37 |
| May | 272 | 75.17 ± 10.25 | 69 | 39.2-95.3 | 70.18 ± 11.74 | 203 | 47.0-100.0 | 76.87 ± 9.11 |
| Season 1990-1991 | | | | | | | | |
| | Total | | Males | | | Females | | |
| Month | n | $\overline{X}$ CL ± SD | n | Range CL (mm) | $\overline{X}$ CL ± SD | n | Range CL (mm) | $\overline{X}$ CL ± SD |
| Sep | 47 | 76.46 ± 7.94 | 34 | 61.3-96.9 | 76.73 ± 7.78 | 13 | 60.2-88.1 | 75.76 ± 8.63 |
| Oct | 168 | 78.22 ± 8.26 | 99 | 43.9-106.3 | 79.12 ± 7.75 | 69 | 56.9-102.6 | 76.93 ± 8.84 |
| Nov | 153 | 76.98 ± 5.17 | 98 | 68.9-90.1 | 77.43 ± 4.35 | 55 | 67.6-98.4 | 76.18 ± 6.35 |
| Jan | 261 | 75.70 ± 7.86 | 146 | 49.0-98.8 | 76.11 ± 8.70 | 115 | 60.5-101.4 | 75.19 ± 6.65 |
| Feb | 237 | 76.25 ± 7.87 | 108 | 52.6-107.4 | 75.95 ± 8.40 | 129 | 51.3-100.6 | 76.49 ± 7.43 |
| Mar | 278 | 77.93 ± 6.80 | 94 | 66.4-104.6 | 79.30 ± 6.99 | 184 | 67.1-96.1 | 77.23 ± 6.62 |
| Apr | 176 | 74.82 ± 8.43 | 32 | 46.8-107.0 | 71.38 ± 13.64 | 144 | 51.1-94.1 | 75.59 ± 6.59 |
| May | 190 | 72.96 ± 9.65 | 49 | 53.5-107.7 | 71.09 ± 11.31 | 141 | 53.4-100.3 | 73.60 ± 8.95 |

which were more abundant in spring; however, the overall sex ratio exhibited a significantly equal distribution (1:1, $P > 0.05$) during the winter months.

## DISCUSSION

### Catch composition

Nets are the main fishing method used in the study area and are deployed in rocky and gravel-sandy areas. Pérez-González *et al*. (2002a) indicated that the periodically inverse proportions of *P. gracilis* and *P. inflatus* observed in commercial catches during the fishing season or annually is due to their different behaviors and the meteorological conditions related to the habitat occupied by each species. In this study, we observed that the fishermen set their nets close to the coast over rocky bottoms, the preferred habitat of *P. inflatus* (0.5-8.0 m depth), during periods of calm water, whereas the nets were deployed offshore over gravel-sandy bottoms at depths between 8.0 and 25-35.0 m (the habitat of *P. gracilis*) in periods of strong ocean swells, coinciding with the observations recorded by Pérez-González *et al*. (1992a).

The periodic inversion in the proportions of *P. gracilis* and *P. inflatus* in commercial catches has previously been observed along the Mexican Pacific coast (Briones-Fourzán & Lozano-Álvarez, 1992; Valadez-Manzano *et al*., 2003; Arzola-González *et al*., 2007). Tangle nets and SCUBA diving are the fishing methods utilized in the south of this region of the Pacific Ocean and are associated with the different proportions of these species obtained in the commercial catches. Briones-Fourzán & Lozano-Álvarez (1992) and Valadez-Manzano *et al*. (2003) suggested that this pattern is related to the habitats of

**Table 3.** Monthly mean size, standard deviation and size range whole and by sex of the total weight (W, in g), *Panulirus gracilis*, during 1989-1990 and 1990-1991 fishing seasons in the lower part of the Gulf of California, Mexico.

**Tabla 3.** Número de hembras y machos de *Panulirus gracilis* e intervalos de talla, medias y desviaciones estándar mensuales del peso total (W, en g), durante las temporadas de pesca 1989-1990 y 1990-1991 en la parte baja del golfo de California, México.

| Fishing season 1989-1990 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | | Males | | | Females | | |
| Month | n | W $\overline{X} \pm SD$ | n | Range W (g) | W $\overline{X} \pm SD$ | n | Range W (g) | W $\overline{X} \pm SD$ |
| Sep | 132 | 355.0 ± 85.1 | 100 | 205-780 | 338.2 ± 73.8 | 32 | 220-630 | 407.4 ± 97.3 |
| Oct | 143 | 369.7 ± 87.3 | 105 | 230-590 | 345.1 ± 61.8 | 38 | 230-695 | 437.8 ± 109.9 |
| Nov | 158 | 377.4 ± 115.1 | 93 | 175-1075 | 361.7 ± 102.5 | 65 | 230-795 | 399.9 ± 128.6 |
| Dec | 168 | 395.3 ± 114.3 | 90 | 195-755 | 394.2 ± 104.5 | 78 | 165-700 | 396.6 ± 125.3 |
| Jan | 142 | 405.5 ± 102.7 | 72 | 220-630 | 402.4 ± 94.3 | 70 | 200-790 | 408.6 ± 111.4 |
| Feb | 125 | 410.4 ± 106.0 | 66 | 205-655 | 427.7 ± 98.6 | 59 | 220-695 | 391.0 ± 111.4 |
| Mar | 178 | 378.2 ± 116.5 | 67 | 84-960 | 388.7 ± 150.7 | 111 | 135-720 | 371.9 ± 90.2 |
| Apr | 267 | 414.3 ± 113.4 | 87 | 150-960 | 426.4 ± 139.2 | 180 | 230-735 | 408.4 ± 98.5 |
| May | 272 | 396.6 ± 139.8 | 69 | 47-730 | 317.3 ± 142.6 | 203 | 105-840 | 423.6 ± 128.5 |
| Fishing season 1990-1991 | | | | | | | | |
| | Total | | Males | | | Females | | |
| Month | n | W $\overline{X} \pm SD$ | n | Range W (g) | W $\overline{X} \pm SD$ | n | Range W (g) | W $\overline{X} \pm SD$ |
| Sep | 46 | 413.5 ± 119.5 | 34 | 200-780 | 407.1 ± 114.6 | 12 | 205-650 | 431.7 ± 136.1 |
| Oct | 168 | 421.4 ± 123.2 | 99 | 75-850 | 417.3 ± 105.7 | 69 | 175-975 | 427.1 ± 145.3 |
| Nov | 153 | 390.9 ± 75.1 | 98 | 280-550 | 388.1 ± 62.6 | 55 | 270-725 | 396.0 ± 93.7 |
| Jan | 261 | 365.1 ± 106.2 | 146 | 105-730 | 360.3 ± 111.6 | 115 | 195-860 | 371.1 ± 99.0 |
| Feb | 237 | 377.8 ± 112.4 | 108 | 110-850 | 360.9 ± 110.5 | 129 | 120-770 | 391.9 ± 112.5 |
| Mar | 278 | 400.7 ± 104.6 | 94 | 240-870 | 401.9 ± 110.9 | 184 | 270-725 | 400.2 ± 101.5 |
| Apr | 176 | 364.5 ± 110.7 | 32 | 90-870 | 318.1 ± 171.3 | 144 | 100-640 | 374.8 ± 89.7 |
| May | 190 | 341.0 ± 133.1 | 49 | 130-860 | 300.6 ± 150.4 | 141 | 140-790 | 355.0 ± 124.1 |

each species. These authors indicated that fishermen deployed their nets on the type of bottom where *P. gracilis* is more abundant to select for this species, whereas divers prefer rocky bottoms, where visibility is better, thus obtaining larger proportions of *P. inflatus*.

Additionally, Pérez-González *et al*. (2002b) reported that the abundance of *P. gracilis* and *P. inflatus* varies as a function of depth. In the study area (see Fig. 1), the bottoms are rocky between 0.5 and 10-15 m and gravel-sandy from 12-15 to 35-40 m. Therefore, *P. inflatus* is found inshore (0.5-15 m depth), whereas the abundance of the *P. gracilis* increases with depth. The two species coexist in a similar proportion at depths between eight to approximately 18 m.

**Size distribution**

The modal size of *P. gracilis* landed in this study (75 mm CL) during the 1989-1990 and 1990-1991 fishing seasons was smaller than that reported by Salazar-Navarro (2000) (85 mm CL) but similar to that recorded by Pérez-González *et al*. (1992a) and Flores-Campaña *et al*. (1993). However, the mean size found contrasts with other studies performed in study area or in adjacent zones. For example, during the 1977 fishing season, the mean sizes were higher than the minimum legal size (MLS) of 82.0 mm CL, with the catchable stock in the range of 75.0-110 mm CL (Wiedfeldt, 1997), whereas, beginning in the early 1980s, the mean sizes have been lower that the MLS. Pérez-González (1986), Quintero-Montoya (1999) and Valadez-Manzano *et al*. (2003) recorded mean sizes of

72.0 < 70 and 70 mm CL during the 1983-1984, 1996-1997/1997-1998 and 2001-2002 fishing seasons, respectively.

Pérez-González *et al*. (2002a) reported that, as a consequence of the high fishing mortality in sublegal sizes, the stock-turnover rate has increased, with an equivalent decrease in the age at first maturity and an increase in mean fecundity, suggesting a low rate of compliance with fishery regulations due to a lack of strict enforcement. Fishing pressure on sublegal sizes of the spiny lobsters *P. gracilis* and *P. inflatus*, including a high proportion of immature individuals, has increased since the early 1990s. Similarly, in the present study, we observed that ovigerous females were also being captured.

Yallonardo *et al*. (2002) did not find changes in the size frequency in the spiny lobster *P. guttatus* between 1986-1988 and 1998-99, suggesting that fishing pressure on this resource had not yet been increased to the point that it negatively affected the size structure of the population. Montgomery (1995) and Padilla-Ramos & Briones-Fourzán (1997) indicated that the fishing locality and/or pattern of movement of lobsters along the shore could be additional factors influencing the size composition of the catch and should be taken into account when analyzing the mean monthly size of the catch.

**Sex ratio**

As found in the present study, a *P. gracilis* sex ratio close to unity has been reported by Weinborn (1977); Briones *et al*. (1981); Pérez-González *et al*. (1992b); Flores-Campaña *et al*. (1993) and Salazar-Navarro (2000). However, Arzola-González *et al*. (2007) found that the sex ratio favored males over females in the 1995 (2.6:1), 1996 (1.6:1) and 1997 (2.4:1) fishing seasons.

MacDiarmid & Sainte-Marie (2006) suggested that many fisheries appear to have the potential to alter population sex ratio and sexual size dimorphism, and they noted a number of factors that could result in sex-biased exploitation. For example, one sex may be more vulnerable to capture due to its greater spatial and/or temporal exposure to fishing gear. Goñi *et al*. (2001) reported that the scarcity of males in February may indicate a substantial sex segregation of the *Palinurus elephas* population at this time, but the presence of recent postmolt males in the samples also suggested reduced activity and, thus, catchability, related to ecdysis. A decrease of approximately 70% in catchability has been estimated for late-postmolt *Panulirus argus* (Lipcius & Herrnkind, 1982) and *P. cygnus* (Morgan, 1974). In several species, males are more catchable than females, and larger males are more catchable than smaller males (e.g., Tremblay & Smith, 2001; Ziegler *et al*., 2002).

The seasonal disparity in the sex ratio of *P. gracilis* has been associated with the differential male and female movements associated with their reproductive activity, which occurs in summer and autumn (Pérez-González *et al*., 1992b; Briones-Fourzán & Lozano-Álvarez, 1992; Arzola-González *et al*., 2007). This timing of the main reproductive period in *P. gracilis* is evidenced by the higher abundance of larvae phyllosoma found in the study area from June to October (Muñoz-García *et al*., 2000, 2004), as well as by the observations of a higher value of the gonadosomatic index and the most females with mature gonads during these months (Puga-López, 2004).

The catch rates of male lobsters were higher during the reproductive period (summer and autumn) than those of females, which were more abundant during spring (the nonreproductive period). After mating and oviposition, the bulk of the female population is expected to migrate to deeper waters during egg development and to return to inshore areas prior to egg hatching. This suggests that *P. gracilis* females are less catchable than males during their reproductive period because the bulk of the female population probably migrates to deeper waters and/or presents decreased activity. This pattern of movement of the females toward deeper waters has been observed in *P. argus* in the northern Caribbean and Bahamas (Herrnkind, 1980, 1985; Kanciruk, 1980), south of Florida (Gregory & Labisky, 1986), on the continental shelf of the Quintana Roo, Mexico (Lozano-Álvarez *et al*., 1991), and in the northwest islands of the Cape Verde Archipelago (east-central Atlantic) (Freitas & Castro, 2005); it has also been observed in *P. ornatus* in the Gulf of Papua (Bell *et al*., 1987, Pitcher *et al*., 1992), in *P. guttatus* on the Caribbean coast of Mexico (Padilla-Ramos & Briones-Fourzán, 1997), and in *Palinurus elephas* in the western region of the Mediterranean Sea (Goñi *et al*., 2001).

*Panulirus inflatus* presents similar patterns of reproductive activity and male and female movements related to mating, oviposition, egg development and egg hatching (Pérez-González *et al*., 1992b, Briones-Fourzán & Lozano-Álvarez, 1992; Arzola-González *et al*., 2007). This species coexists with *P. gracilis* along the Mexican Pacific coast and in the lower part of the Gulf of California.

Kanciruk (1980) indicated that differences between male and female movements appear to cause these unbalanced sex ratios in a number of other spiny lobster species. Maturing adults of most well-studied palinurid species exhibit either an incremental

ontogenetic migration that culminates in mating and spawning in distinct adult habitats or seasonal inshore-offshore movements for mating or foraging (Butler *et al*., 2006).

There are other factors that could result in sex-biased exploitation. For example, the male-skewed sex ratio observed for *P. guttatus* (Losada-Tosteson *et al*., 2001) has been associated with the method of capture (traps *vs* handpicking, Briones-Fourzán, 1991), lower catchability (Evans & Lockwood, 1994), differential male and female movements associated with their reproductive activity (Briones-Fourzán & Contreras-Ortiz, 1999), and lower abundance due to differential mortality (Evans *et al*., 1995; Sharp *et al*., 1997). Furthermore, Losada-Tosteson *et al*. (2001) indicated that the evolutionary mechanics of skewed sex ratios in *P. guttatus*, if they exist, require further study.

Thus, obtaining information on the quantity and size composition of individuals harvested and changes in the abundance of species is fundamental for the effective management of fishery resources. Such data provide knowledge about the impact of harvesting on the population and on the temporal and spatial distributions of individuals of different sizes (Montgomery, 1995). For this reason, periodic evaluations of the lobster fishery should be conducted to improve monitoring of the status of this fishery on the Mexican Pacific and Gulf of California coasts.

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