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Composition of trawl catch fauna off the mouth of the Rio Baluarte, southeastern Gulf of California

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ABSTRACT: From April to December 2007, experimental trawls (n = 44, 4 to 22 m depth) were made off the mouth of the Rio Baluarte ecosystem (MRB) and compared to experimental trawls (n = 54, 7 to 40 m) in the adjacent offshore region (AOR) from 2002 to 2007. For both ecosystems, a total of 143 species belonging to 5 phyla were collected. Fishes comprised ca. 80% of the bycatch biomass, while molluscs and echinoderms contributed <20% bycatch. Eight species accounted for 50% of the numerical abundance: the crab *Portunus asper* (11%), the Panama grunt *Pomadasys panamensis* (8%), the curvina *Stellifer ericymba* (7%), the comb sand star *Astropecten armatus* (6%), the fishes *Orthopristis chalceus* (6%) and *Larimus effulgens* (4%), and the crabs *Callinectes arcuatus* (4%) and *Hepatus kossmani* (3%). Species with a high or medium survival rate with respect to trawling activity were well represented in the samples, e.g. the crabs *C. arcuatus*, *H. kossmani*, and *Euphilax robustus*, the hermit crab *Petrochirus californiensis*, and the sea star *Luidia brevispina*. For the MRB and AOR, the estimated mean biomass was 2.08 and 0.72 t km^{-2}, respectively. The population of the blue shrimp *Litopenaeus stylirostris* and white shrimp *L. vannamei* was composed of recruits, juveniles, spawners, and old individuals, whereas for grunts it was composed of recruits and juveniles, but rarely old individuals. The high diversity, population structure, and productivity of the studied fauna has positive effects, such as enabling the recruitment for coastal marine fisheries. This is an important reason to protect the river mouth and the adjacent shallow waters.

KEY WORDS: Gulf of California · Trawling · Bycatch · Closed season · Population structure

INTRODUCTION

The analysis of the structure and dynamics of the community and its populations is a key for fisheries management in subtropical and tropical fisheries that take place in multispecies grounds. Trawl fishing may cause the capture of non-target species, the extraction of some species, habitat modification, changes in size and age composition, changes in diversity and dominance, and also may produce artificial selection caused by gear selectivity, higher biomass extraction, and possible food-web modifications (Casey & Myers 1998, Gislason et al. 2000, Pope et al. 2000, Ye et al. 2000, Badalamenti et al. 2002, Nicholson & Jennings 2004, Shin et al. 2005). The bycatch of shrimp trawling is estimated to produce one-third of the total fishery discards in the world (Alverson et al. 1994). Fish, which are well represented in the bycatch of the tropical shrimp trawl fisheries (Pérez-Mellado & Findley 1985, Hall 1999), have a low survival rate in contrast to crustaceans and echinoderms (Wassenberg & Hill 1989, Hill & Wassenberg 1990, Kaiser & Spencer 1995).

An important approach in recent fisheries management is the change from single stock management towards ecosystem-based management. This recognizes that the exploitation of a target species may modify both its population and the inhabited community, considering that the target species interacts through competition, predation, and other biological processes.

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The interest in multispecies fisheries has been widely recognized, and some authors have suggested indicators of such good practices and solutions conducive to sustainable development of marine fisheries (Hall 1999, FAO 2003, Hall & Mainprize 2004) which allow to perform sensitivity analyses for fishing and environmental factors (Jennings & Kaiser 1998, Rochet & Trenkel 2003, Shin et al. 2005). In other studies, indicators based on assessment are contrasted with periods of fishing activity, regions, or previous models (Charvet et al. 2000, Pitcher & Preikhost 2001, Link et al. 2002, Gribble 2003, Link 2005). Jennings & Dulvy (2005) and Rochet et al. (2005) suggested that time trends could be compared by evaluating whether the status of an ecosystem is improving or deteriorating. The results are combined within the predefined framework to provide a diagnosis. The purpose of this method is not to provide a good fit, but to decide if the ecosystem is being affected. It is suggested that the integrative community indicators have not yet been well developed and tested, so it seems reasonable to complement them by monitoring a wide selection of populations, including target and non-target species, to achieve the best possible assessment.

To indicate the influence of any trawling on a community, it is necessary to assess the richness and contribution of the taxonomic groups of the bycatch (Alverson et al. 1994, Madrid-Vera et al. 1998, Hall 1999, Beddington et al. 2007). Several studies in the Gulf of California have included the systematic description of trawl catches. The results obtained may include a thousand species of at least 5 phyla (Hendrickx et al. 1984, Amezcua-Linares 1985, Hendrickx 1985, Pérez-Mellado & Findley 1985, Van der Heiden 1985, Van der Heiden & Findley 1988, Broadhurst & Kennelly 1994). The shrimp:bycatch ratio for shrimp trawl fishery in the Gulf of California was estimated between 10:1 and 10:3 on a weight basis (Hendrickx et al. 1984, Amezcua-Linares 1985, Pérez-Mellado & Findley 1985, Arvizu-Martinez 1987, Magallón-Barajas 1987, Alverson et al. 1994, Nance & Scott-Denton 1996). From these ratios, the annual bycatch can be assumed to be around 250 to 500×10^3 t for the Gulf of California. For the southern Gulf of California, for 1993 to 2004, Madrid-Vera et al. (2007) reported a bycatch: shrimp ratio of 6:1 to 31:1, a fish-landed:shrimp ratio of 1:1.44 ± 0.54, and an annual biomass bycatch of $90 \pm 45 \times 10^3$ t.

In the present study we analyze data on species composition and biomass of bycatch of species from the shrimp trawl fishery in the mouth of the Rio Baluarte in the southern Gulf of California. We assumed that the trawl catch would produce indicators of composition and abundance of the communities and would allow us to evaluate the effects of climate and trawl fishing. Our main objectives were to develop descriptive models of species richness and describe the community composition, group associations, and the population structure of 3 commercially important species, the white shrimp *Litopenaeus vannamei*, the blue shrimp *L. stylirostris*, and the Panama grunt *Pomadasys panamensis*. In this way we intend to support the management of the river mouth, which is of ecological and economic importance.

MATERIALS AND METHODS

The study was conducted in nearshore waters of the southeastern Gulf of California as part of the yearly assessment of the shrimp population made by the National Fisheries Institute of Mexico (INAPESCA). Two sets of data were used: (1) off the mouth of the Rio Baluarte (MRB; 22° 48′ 05′ N, 106° 04′ 06′ W to 22° 49′ 11′ N, 106° 02′ 50′ W), (2) from the adjacent offshore region (AOR) corresponding to INAPESCA fishing zone 40, that comprises the coastal waters off Mazatlán, Sinaloa (23° 18′ N, 106° 29′ W) to Cuautla, Nayarit (22° 11′ N, 105° 45′ W).

In the MRB, 44 demersal trawl hauls were made onboard artisanal boats 7.5 m long fitted with outboard engines of 75 to 115 hp and a small shrimp trawl net (average door spread 6.9 m), which was towed at 2 knots for 0.5 h trawling an area of about 1.2 ± 0.4 ha. Sampling was performed monthly from April to December 2007 at 4 different depths (4, 9, 15, and 22 m). During May, June, July and August there were 2 samplings per month that were averaged.

In the AOR, 54 demersal trawl hauls were made using boats with an inboard engine (345 to 520 hp) and a shrimp trawl net (average door spread 34.9 m), which was towed at 2.3 knots for 1 h trawling an area of about 14 ± 1.4 ha. During the closed season (April to September) of 2002 to 2007, sampling was performed every August at 7 different depths (from 7 to 40 m). The total area in the AOR, from the coastline to 83 m depth, is nearly 2800 km^2 (Fig. 1).

For both data sets, the catch per unit effort (CPUE) of all the gear was standardized to make the tows comparable. After each tow, the biomasses of shrimp and bycatch were estimated. Bycatch and shrimp were stored separately in plastic bags labeled with the date, station number, and fishing gear used, and frozen. Bycatch fauna was identified in the laboratory.

Community species richness was analysed using the exponential model $S_t = A(1 - e^{-bt})$ and the Michaelis-Menten model $S_t = at/(1 + bt)$. In both equations S_t represents the number of species in the sample t (for the trawled area), b is the instantaneous addition rate of newly identified species to the checklist over the effort in the trawled area, and the asymptote A is given by

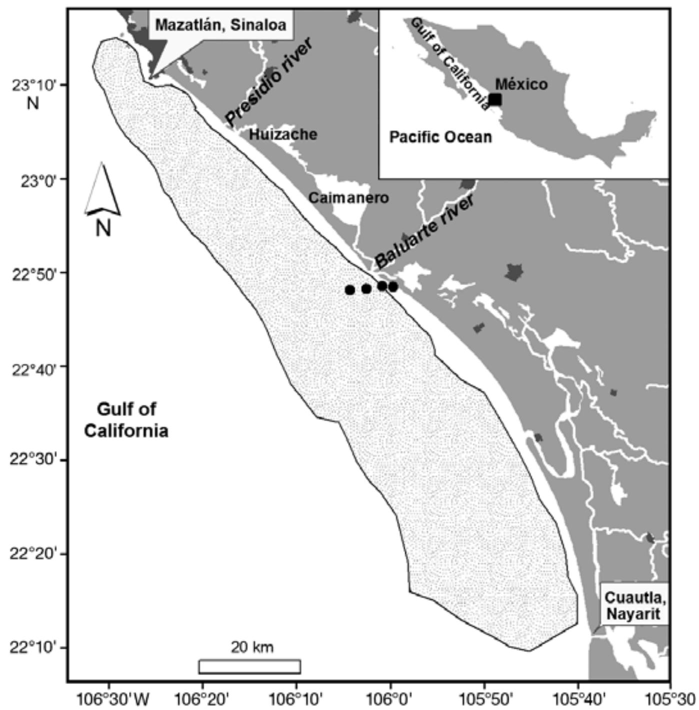

Fig. 1. Sampling stations at 4 different depths (•) off the mouth of the Rio Baluarte (MRB). The adjacent offshore region (AOR) where the hauls took place is stippled

a/*b*. The model parameters were estimated by minimizing the negative for log-likelihood function using Newton's direct search algorithm (Neter et al. 1996).

To estimate the confidence intervals for the parameters in the previous models, we used the likelihood profile (Venzon & Moolgavkor 1988, Hilborn & Mangel 1997) to determine confidence intervals for the parameters either together or individually. The confidence intervals for *n* parameters were estimated based on the chi-square distribution with *m* degrees of freedom (Zar 1974). For a single parameter *p*, the confidence interval is defined as all values of *p* that satisfy the inequality:

$$2[L(Y\,P_{est}) - L(Y\,P)] < \chi^2_{1,1-\alpha}$$

where $2[L(YP_{est})]$ represents the negative loglikelihood of the most likely value of *p* and $\chi^2_{1,1-\alpha}$ are the values of the distribution with 1 degree of freedom at a confidence level of $1 - \alpha$. Hence the CI for the estimator accepts all values ≤3.84 (Hilborn & Mangel 1997).

The total bycatch for the AOR, from the coastline to 22 m depth, was analyzed using Monte Carlo routines (Haddon 2001). The random numbers were simulated using the inverse normal distribution $n(\mu, \sigma^2, \alpha)$, where α is a random number from 0 to 1, and μ and σ^2 were estimated by generating $n = 100\,000$ random samples.

To test differences in bycatch in the MRB, a stratified survey design was used, with depth and month as factors and biomass as the independent variable. A stratified survey design was also used to test differences in bycatch in the AOR, with depth and latitude as factors and biomass as the independent variable.

For the MRB, a matrix of species abundance in number and weight was produced, standardized to density for the trawled area (Folmer & Pennington 2000), and scaled to total catch. For searching a gradient over time, the numerical abundance of the species was analyzed using multidimensional scaling analysis (MDS) of the Euclidian distance and the unweighted pair-group average. Only species that were present in at least 4 mo or samples were considered.

The length-frequency distribution was analysed using multinomial analysis (Haddon 2001) for the 3 most abundant commercial species: *Pomadasys panamensis*, *Litopenaeus vannamei*, and *L. stylirostris*.

RESULTS

A total of 44 samples from the MRB were analyzed. The trawling area covered 39.4 ha and the total catch was 1310 kg. For the AOR, 54 samples were analyzed from a trawling area of 756 ha and a total catch of 7700 kg (Table 1).

For the MRB, 37 species contributed nearly 75% to the total numerical abundance, which includes bycatch and the 2 shrimp species *Litopenaeus vannamei* and *L. stylirostris*. The most abundant species were the crab *Portunus asper*, the Panama grunt *Pomadasys panamensis*, the hollow stardrum *Stellifer ericymba*, and the sea star *Astropecten armatus*. Remarkable is the great number of species with a relatively high survival rate to trawling, such as the sea star *Luidia bre-*

Table 1. Basic sampling data from the mouth of the Rio Baluarte (MRB) and adjacent offshore region (AOR) in the southeastern Gulf of California. For AOR, only samples taken in August at ≤22 m were used. AT: area trawled, BB: bycatch biomass, Mo: month, Yr: year, Trawls: number of trawls

Mo	MRB Trawls	MRB AT (ha)	MRB BB (kg)	AOR Yr	AOR Trawls	AOR AT (ha)	AOR BB (kg)
Apr	4	3.2	60				
May	8	7.6	188	2002	9	126	715
Jun	8	4.2	175	2003	9	126	1330
Jul	8	8	74	2004	9	126	1582
Aug	8	9.2	254	2005	9	126	480
Sep	4	3.6	545	2006	9	126	2500
Dec	4	3.2	28	2007	9	126	1100
Total	44	39.4	1310	Total	54	756	7707

vispina, the crustaceans *Callinectes arcuatus*, *Hepatus kossmani*, and *Euphilax robustus*, and the hermit crab *Petrochirus californiensis*. The flatfishes *Cyclopsetta querna*, *Citharichthys gilberti*, *Syacium ovale*, *Symphurus elongates*, and *Etropus crossotus* have a lower survival rate (Table 2).

For the AOR, fishes (Chondrichtyes and Osteichtyes) are highly important: 509 individuals ha^{-1} (Fig. 2a), corresponding to a biomass of ~25 Kg ha^{-1} (Fig. 2b), and a presence of 97 species (Fig. 2c). The total weight-percentage contribution of fish is almost 79%, followed by crustaceans (15%), cnidarians (3%), echinoderms (2%), and molluscs (1%). Fishes are highly vulnerable to fishing activity and our results show that they represent the most catchable group.

Table 2. Species that contribute to 75% of the numerical abundance in the area off the mouth of the Rio Baluarte (MRB), southeastern Gulf of California, from May to December. Also given: taxonomic group of species, individuals per hectare, presence in number of samples

Species	Group	Ind. ha^{-1}	Presence	%
Portunus asper	Crustacea	80	6	11.29
Pomadasys panamensis	Pisces	44	6	8.47
Stellifer ericymba	Pisces	77	4	6.81
Astropecten armatus	Echinodermata	49	6	6.37
Orthopristis chalceus	Pisces	36	4	5.73
Larimus effulgens	Pisces	21	4	3.86
Callinectes arcuatus	Crustacea	25	4	3.65
Hepatus kossmani	Crustacea	21	6	3.40
Selene peruviana	Pisces	35	6	2.90
Achirus mazatlanus	Pisces	17	6	2.77
Arius furthi	Pisces	19	3	2.44
Luidia brevispina	Echinodermata	38	4	2.09
Cyclopsetta querna	Pisces	13	4	1.45
Citharichthys gilberti	Pisces	14	5	1.25
Sicyonia disdorsalis	Crustacea	6	4	1.18
Isopisthus remifer	Pisces	7	4	0.99
Diapterus peruvianus	Pisces	7	4	0.99
Synodus evermanni	Pisces	14	4	0.98
Centropomus robalito	Pisces	7	4	0.79
Syacium ovale	Pisces	13	4	0.78
Symphurus elongatus	Pisces	12	5	0.70
Litopenaeus vannamei	Crustacea	6	6	0.67
Ophioscion strabo	Pisces	6	5	0.64
Prionotus ruscarius	Pisces	7	5	0.63
Neverita reclusiana	Mollusca	3	4	0.55
Peprilus medius	Pisces	3	5	0.46
Litopenaeus stylirostris	Crustacea	4	6	0.46
Stellifer illecebrosus	Pisces	8	5	0.44
Opisthopterus dovi	Pisces	5	4	0.40
Euphilax robustus	Crustacea	4	6	0.40
Micropogonias ectenes	Pisces	4	4	0.39
Etropus crossotus	Pisces	3	5	0.29
Lolliguncula panamensis	Mollusca	3	5	0.26
Pseudupeneus grandisquamis	Pisces	2	5	0.23
Larimus argenteus	Pisces	1	4	0.23
Eucinostomus gracilis	Pisces	3	5	0.18
Petrochirus californiensis	Crustacea	2	5	0.14
Total				75.25

For both areas, 143 species from 5 taxonomic groups were identified: 3 Cnidaria, 20 Mollusca, 19 Crustacea, 4 Echinodermata, and 103 fish species, including 8 species of elasmobranches.

The estimated maximum richness was 216 species for the exponential model and 311 for the Michaelis-Menten model (Fig. 3a). For both models, the best fit for the parameter precision is shown in Fig. 3b,c and Fig. 3d,e, respectively.

For the MRB, the total mean biomass was 2.08 t km^{-2} and, with the exception of September, the total mean biomass was <4 t km^{-2}. In September 2007 there was an increase to 10.3 t km^{-2}. This maximum is evident when comparing September (end of closed season) with December (3 mo after the start of the fishing season). In total, the cumulative function indicates a surplus biomass that increased to 17.7 t km^{-2} (Fig. 4b). The random model fluctuation is shown for each month, without remarkable outliers (Fig. 4c). The data with values below the mean and the 0.68 standard deviation were 0.61 for May, 0.61 for June, 0.6 for July, 0.62 for August, 0.66 for September, and 0.62 for December, when the maximum fitted criteria is ≥0.68.

For the AOR, the bycatch biomass ranged from 0.35 to 1.49 t km^{-2} and the total mean was 0.72 t km^{-2}, with the values recorded in 2002, 2005, and 2007 ≤0.72 t km^{-2}, whereas those in 2003, 2004, and 2006 were ≥0.72 t km^{-2}. The model produced a maximum of 1.49 t km^{-2} in August 2006, double the total mean (Fig. 5). In the cumulative function, the value obtained was 4.3 t km^{-2} for 2002 to 2007 (Fig. 5b), which is an indicator of the important biomass surplus for the regional fisheries. The random fluctuation model showed no remarkable outliers in any year. The quantity of data under the mean and a 1.96 standard deviation was 0.60 for 2002, 0.56 for 2003, 0.59 for 2004, 0.66 for 2005, 0.61 for 2006, and 0.64 for 2007 (Fig. 5c).

Other results for the MRB data set were obtained from multivariate analysis of the community using only the species that were present in at least 4 mo. In Fig. 6, we can see a well-developed group from June to September and 2 isolated months December and May. The value for the stress < 0.05 is associated with a good representation of association of either sample.

The total length (TL) values for 340 grunts *Pomadasys panamensis* were 5 to 335 mm. From the graphical analysis of 15 cohorts (Fig. 7a) only 7 (85, 110, 125, 250, 280, 300, 295 mm) were well represented, whereas the other 9 were inconspicuous.

The TL values for 218 white shrimp *Litopenaeus vannamei* were 80 to 270 mm. From the graphical analysis of 11 cohorts (Fig. 7b) only 8 (110, 125, 135,

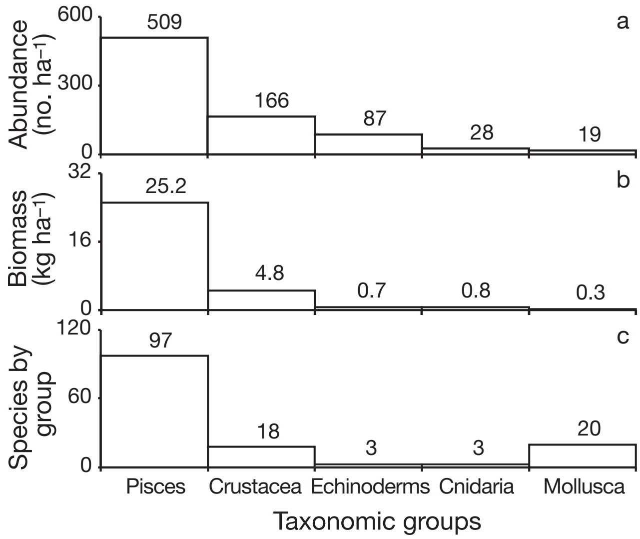

Fig. 2. (a) Abundance, (b) biomass per hectar, and (c) species by taxonomic group for the fauna off the mouth of the Rio Baluarte from May to December 2007

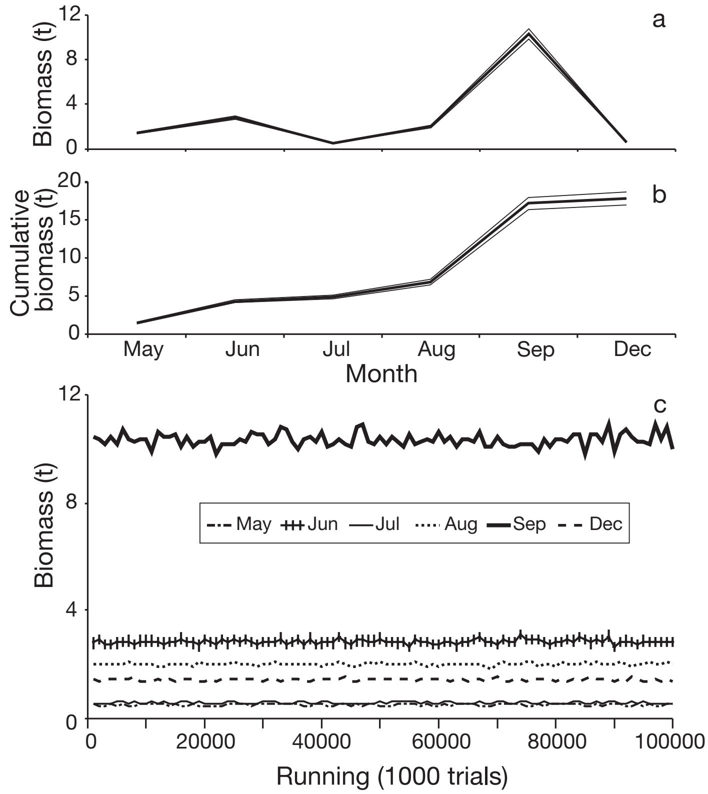

Fig. 4. (a) Generated biomass (catch in t per km^2) and (b) cumulative biomass from the central tendencies (bold line) and ±1.96 SD of dispersion (thin line) for the area off the mouth of the Rio Baluarte. (c) A simulated random sample from the population in 100 000 trials for each month from May to December 2007. The x-axis shows the number of trials (e.g. 20 000 represents 20 runnings of 1000 trials)

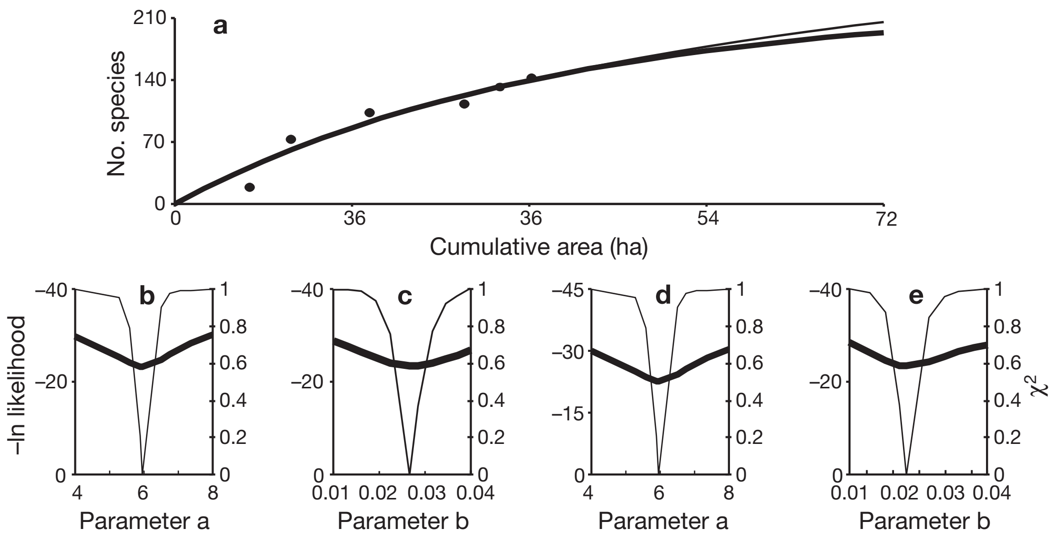

Fig. 3. (a) Species richness curves of the community off the mouth of the Rio Baluarte, according to trawling data. Both exponential (thin line) and Michaelis-Menten models (bold line) were used. The addition rate of newly identified species of the checklist over effort in the trawled area was used. In both cases the parameter precision is shown for the (b, c) exponential model and (d, e) the Michaelis-Menten model. The thin line is the negative log-likelihood profile (–ln L) and the bold line is the χ^2 probability profile

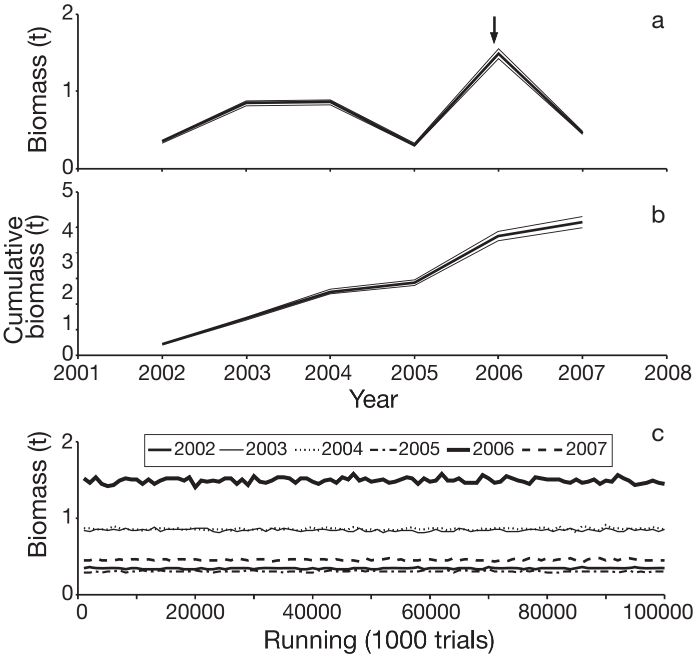

Fig. 5. (a) Generated biomass (catch in t per km^2) and (b) cumulative biomass from the central tendencies (bold line) and ±1.96 SD of dispersion (thin line) from the adjacent offshore region. (c) A simulated random sample from the population in 100 000 trials for each year in the period 2002 to 2007. The arrow indicates the El Niño Southern Oscillation

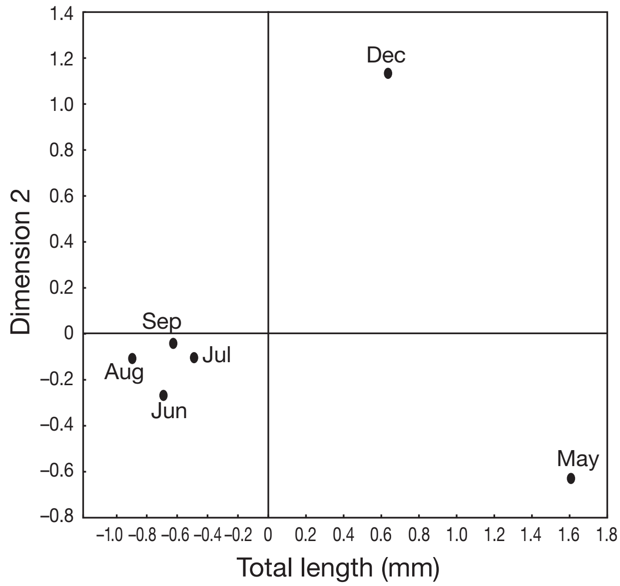

Fig. 6. Multidimensional scaling plot for the community using the species recorded in at least 4 mo. The matrix was produced from the Euclidian distance and the grouping was the unweighted pair-group average. The plot shows 2 single months and a cluster of 4 months clearly associated with a climate gradient. A stress value <0.05 is associated with a good representation of the samples association. Stress = 0.0000027

160, 175, 195, 215, 225 mm) were well represented, whereas the other 3 were inconspicuous. The first 3 groups were recruits, groups 4 to 6 were mature, and groups 7 and 8 were spawners.

The TL values for 148 blue shrimp *Litopenaeus stylirostris* were 115 to 275 mm. From the graphical analysis of 11 cohorts (Fig. 7c) only 9 (140, 155, 165, 175, 185, 200, 225, 240, 250 mm) were well represented, whereas the other 2 were inconspicuous. The first 2 groups were recruits, groups 3 to 5 were mature, and groups 6 to 9 were spawners.

DISCUSSION

The sampling power of the trawling gear was analyzed by using the richness curves. Sampling totaled to a richness of 143 species, which was 89% of the maximum predicted by the exponential model and 62% of the maximum predicted by the Michaelis-Menten model. Owing to the percentage obtained, we can conclude that this study has generated plausible information about the fauna off the river mouth of the Rio Baluarte.

For the MRB, the analysis of the taxonomic groups shows the importance of fishes (79% of total bycatch biomass), whereas molluscs and echinoderms contributed < 20%. Similar results were found by Madrid-Vera et al. (2007) in 2 nearby areas, the inshore area of Mazatlán and Teacapán.

For the AOR, the analysis of the taxonomic groups also shows the importance of fishes, with 509 individuals ha^{-1}, a biomass of ~25 kg, and a total of 97 species. Fishes are a vulnerable group with a high catch rate to trawling (Hendrickx et al. 1984, Pérez-Mellado & Findley 1985, Wassenberg & Hill 1989, Hill & Wassenberg 1990, Alverson et al. 1994, Stobutzki et al. 2001). In a regional trawling catch survey between 22 and 26° N, Madrid-Vera et al. (2007) reported 250 species of fish; some of the abundant species were similar to those found in the present study, such as the grunt *Orthopristis chalceus*, the pacific moon fish *Selene peruviana*, the Panama grunt *Pomadasys panamensis*, and *Synodus* spp. Using information from a variety of literature sources (de Groot 1984, Kaiser & Spencer 1994, Kaiser & Spencer 1995, Hill et al. 1999, de Juan et al. 2007), we considered 4 levels of survival to capture: high, mean, low, and none. There is a remarkable presence of species with a low survival rate, such as the flatfishes *Cyclopsetta querna*, *Citharichthys gilberti*, *Syacium ovale*, *Symphurus elongatus*, and *Etropus crossotus*. Other studies in the same area showed similar faunal groups that were obtained with similar fishing gear (Hendrickx et al. 1984, Hendrickx 1985).

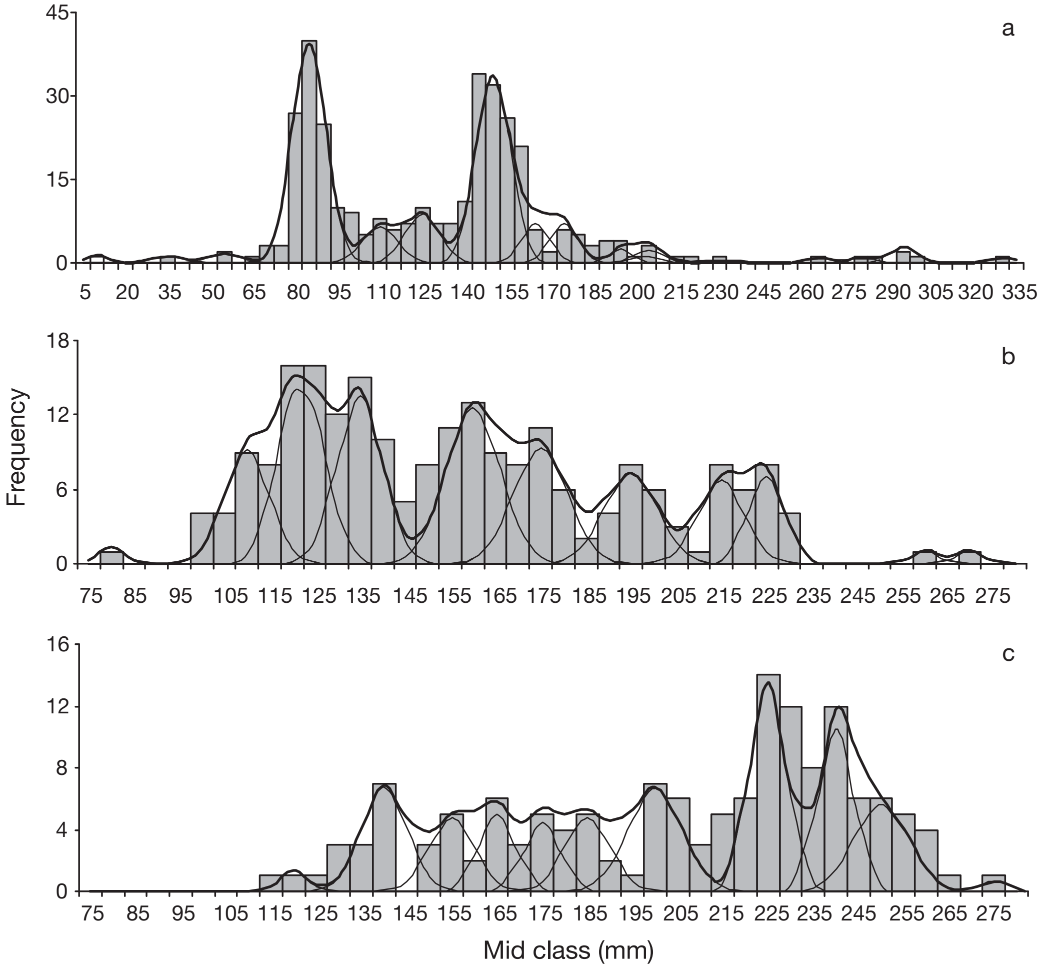

Fig. 7. Total length distribution and multinomial analysis for (a) the Panama grunt *Pomadasys panamensis*, (b) the white shrimp *Litopenaeus vannamei*, and (c) the blue shrimp *L. stylirostris*, sampled in the area off the mouth of the Rio Baluarte. Bars: observed data. Lines show results of multinomial analysis — thin lines: cohorts; thick lines: total

For the AOR, crustaceans were the second most important group in individual number and total weight per area, even though the species number can be higher, as shown in other studies (Hendrickx et al. 1984, Hendrickx 1985). The crustaceans with high and medium survival rates, including the crabs *Portunus asper*, *Callinectes arcuatus*, *Hepatus kossmani*, *Petrochirus californiensis*, and *Euphilax robustus* appear as an important group in our data. They contribute 75 % to the abundance of the crustacean group. By individual number per area, echinoderms are the third most important group. In the present study we found only 3 species, but the number of species caught by trawling can reach 13, as has been reported from a previous study in the region (Caso 1976) The echinoderm species caught in the present study have a high survival rate to trawling. By both individual number and total weight in relation to species, the mollusc contribution is small and may be related to the selectivity of the fishing gear.

The bycatch biomass for August 2007 was 0.46 t km^{-2} yr^{-1} for the experimental trawl in the MRB and 2 t km^{-2} yr^{-1} for the trawl in the AOR. The generated bycatch biomass for the MRB in September 2007 was 10 t km^{-2} yr^{-1}. For the Laguna Huizache-Caimanero, the input data for an Ecopath model (Zetina-Rejón et al. 2003, Pinnegar & Polunin 2004), which includes organisms potentially accessible to trawl fishing but does not consider zooplankton, phytoplankton, macrophytes, or detritus, resulted in a general biomass of 59.3 t km^{-2} yr^{-1}. The sum of exports (fishery catch), referent to the Ecopath model, was 7.4 t km^{-2} yr^{-1}. The input data used in the Ecopath model were taken from studies made in the coastal lagoon during the 1970s and the fishery catch was given for 1984 to 1986. In general, results from the present study were congruent with those from other models, even though the previous models used for the lagoons are not calibrated and do not have a robust reference framework.

Analysis of the population structure of grunts allowed us to deduce numerous cohorts. Recruits and juveniles were well represented, and there was a large presence of old individuals. For white shrimp there were also numerous cohorts, with good representation of recruits, mature individuals, and spawners, and the biggest individual recorded was 265 mm, which is big according to the literature references on longevity and size. For blue shrimp, it was also possible to deduce numerous cohorts, including large recruits (≥140 mm), which may be because recruitment occurred before the present study (INP 2007). The other cohorts were mature individuals, spawners, and old individuals >265 mm. The length-frequency distributions of these 3 species indicate the presence of a greater number of juveniles in shallow waters (MRB), with a larger number of shrimp spawners during the closed season.

The high diversity, population structure, and productivity that cause positive effects on recruitment for marine and lagoon fisheries are important for the protection of the mouth of and the shallow waters off the Rio Baluarte. The closure of fishing in the river mouth is already included in the shrimp management plan, with rules to protect the shrimp species mentioned in this study. However, a revision of these management tools is necessary for the ecosystem and its fisheries to be functional and sustainable.

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