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Size Structure and Biomass of the Panama Grunt (*Pomadasys panamensis*) from Bycatch in the Southeastern Gulf of California

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ABSTRACT

A population analysis was made using data of the grunt *Pomadasys panamensis.* The information is from the catch from 260 hauls in estuarine waters, open-ocean waters, and off the coast of Sinaloa and northern Nayarit, Mexico, in the southeastern Gulf of California. The area of influence is about 120,000 km^2 and includes about a third of the drag area of the largest shrimp fleet of the American Pacific. The average length in the population was 210 mm. The maximum length was 430 mm and the minimum was 50 mm. The analysis for the frequency distributions of the lengths and the multinomial solution produced representative modal groups for 160 mm, 190 mm, and 230 mm. The simulation of the biomass density gave an estimate close to 90 t, with 650,000 organisms before starting the fishing season in the region. The density was 0.19 kg·ha^{-1}. The colonization was 0.42% or 42%. The model was validated using the Aikaikae criterion (AIC). The results provide an overview of the initial biomass densities and population structure of the species caught as bycatch, demonstrating the importance of this species abundance in the shrimp fishery, and generating a source of monetary income to the crew of the fishing fleet. The persistence of the species to fishing provides an example to study the mechanisms of survival.

Keywords: Colonization; Multinomial Solution; Model; *Pomadasys panamensis*; Aikaikae

1. Introduction

The species of the family Haemulidae are important as a part of the commercial catch from the fisheries of the Mexican Pacific and tropical and subtropical American Pacific. They are known as grunt [1-3]. In general, the evaluation of the catch contribution and their biomass has been studied. Using the magnitude the catch can reach as a relevant indicator makes it possible to estimate their abundance and population structure. These elements are resource management information. Moreover, it is fundamental knowledge of a species subject to high impact by trawling and discarding, but which still maintains high levels of abundance.

The bycatch under study is composed of about 300 species belonging to 10 major groups of organisms, such as annelids, sipunculids, porifera, crustaceans, mollusks, cnidarians, echinoderms, fish, algae, and reptiles. In the literature, the total number of species may amount to 1000 [4-9]. The magnitude of the catch in the region of the mouth of the Gulf of California reaches 100,000 t, with the discard of 70% and a ratio of the landed species of 1.4 kg per 1 kg of shrimp [10,11]. The magnitude of catch in the Gulf of California off the Pacific coast of Mexico, and particularly the coasts of Sinaloa and Nayarit, is becoming more economically important, reflected in the landings of the order of 10,000 t per season [11], where *P. panamensis* is up to 5%, and the Haemulidae family about 10%.

The shrimp fishery catches fish with commercial importance (with a higher monetary value), including rays, sting rays, sardine, anchovy, snapper, grouper, and flounder (Rajidae, Engraulidae, Clupeidae, Serranidae, Lutjanidae, and Pleuronectidae) and species of commercial grade (lesser value), like sunfish and grunts of the Scianidae and Haemulidae family. Some are discarded and others are kept. The species of this study belong to the second family, which is best represented in terms of abundance along the Mexican Pacific coast [9,12].

Pomadasys panamensis lives in the coastal zone, regularly associated with sandy-muddy and rocky bottoms. They live in the area of the continental shelf, in estuarine areas, at depths of up to 55 m but can reach 105 m [1,13]. The background characteristics of the environment that prevails in the study area are a favorable habitat for this species.

Pomadasys panamensis is an abundant species over the Pacific continental shelf of central Mexico, as shown in the work of Cruz-Romero [14] and Madrid-Vera [9]. This similar argument is explained by Van der Heiden and Findley [6] for the Gulf of California shrimp-trawl catch. Martinez-Tovar [15] mentioned again that *P. panamensis* is the most abundant in the Gulf of California bycatch. Rodriguez-Preciado [12] records an assessment of *P. panamensis* that recorded sizes over 30 cm.

The study area is characterized by an influence of the California Current, the Equatorial Countercurrent, and the north-streaming Costa Rica current [16-20]. The California current is a mass of cold water and its influence extends over the study region in winter [21,22]. The influence of the flow from Costa Rica extends to the tip of the Baja California peninsula and shows from August to December [17,19]. The Pacific is under the influence of the ENSO, which has a great influence on communities and populations [8,9,20,22,23].

Because of the importance of the species in the commercial catch and its role as part of the biological community, the objective was to generate indicators of abundance and size structure. These indicators are useful as part of fishery-biological studies to establish the condition of the population under study and the information about the population dynamics of the species.

2. Material and Methods

The study area includes several sampling stations set up by INAPESCA (Instituto Nacional de Pesca), which aims at the evaluation and management of the populations of shrimp of the different fisheries in the Mexican Pacific. We analyzed the bycatch in the states of Sinaloa and northern Nayarit in the southern Gulf of California. The study area extends from Punta Ahome, Sinaloa (25˚47'N and 109˚29'W) to the mouth of Custodio, Nayarit (21˚19'N, 105˚15'W). The area includes a zone of influence of some 120,000 km^2 and about half the drag area of the Gulf of California and a third of the Mexican Pacific region (**Figure 1**).

Sampling: In the estuarine estuarine system of Pabellon Altata, there were 38 sets, lasting between 10 min and 15 min, with the depth from 1 fathoms to 7 fathoms (1.8 m to 12.8 m) with a net type called suripera. The sampling was from July to November 2008. In the marine and estuarine system of Pabellon Altata there were 31 sets with a duration between 10 min and 15 min, at depths of 2 fathoms, 5 fathoms, 8 fathoms, and 12 fathoms (3.6 m, 9 m, 14.6 m, and 21.9 m), with the capture made using the trawl-net type "chango". The sampling was from April to November 2008. In the marine and estuarine system Caimanero Huizache there were 36 sets, lasting between 10 min and 15 min, at depths of 2 fathoms, 5 fathoms, 8 fathoms and 12 fathoms (3.6 m, 9 m, 14.6 m, and 21.9 m). The capture was made with a trawl net. The sampling for this area was from March to November 2008. For these three sampling areas we used pangas (boats) 5 m long and 2 m wide, with engines from 75 hp to 115 hp. In the open ocean from northern Nayarit to northern Sinaloa (areas 30, 40, and 60), 155 sets were made, 69 in July 2008 and 86 in August, with a duration about 60 min, in the isobaths of 5 fathoms to 35 fathoms, and a trawl rope 110 feet, using commercial shrimp boats with engines of at least 345 hp. For all sets in different areas of study, samples were collected of shrimp and bycatch with the minimum of 25 $kg \cdot haul^{-1}$. The samples were stored in plastic bags, which were processed in both the field and laboratory. The three different types of nets (suripera net, small trawl net "chango" and commercial trawl net) were standardized by the drag area method proposed by Sparre and Venema [24]. Logs were used to record the characteristics of the towing time, geographic position, depth, temperature, salinity, catch by species, total catch of shrimp and bycatch species. Data were entered and organized in a database by length and weight of organisms and as the composition and abundance of species.

We calculated the average drag area per set. For the suriperas net used for protected waters or estuarine systems, the area of drag and the average area was 0.9 ha (9000 m^2) for 10 min. For the small trawl net "chango", the drag area and the average area was 0.465 ha per 20 min. The trawl used in the open ocean was 13 ha for 60 min. Based on these data we calculated the densities of fauna caught by trawling.

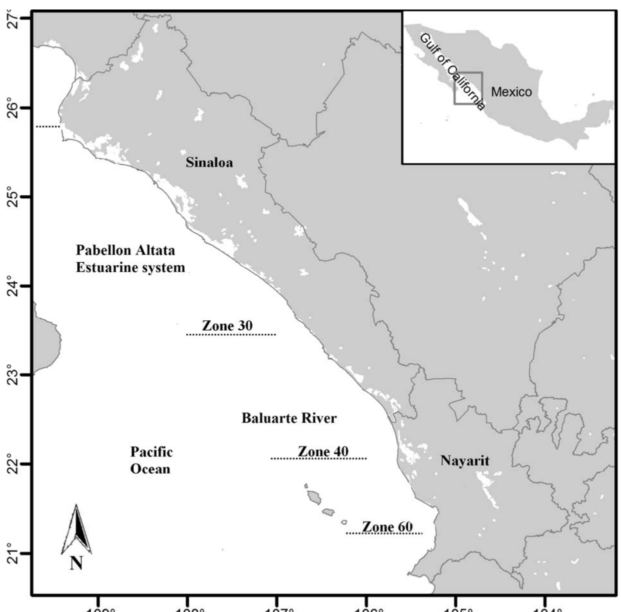

Figure 1. The study area extends from Punta Ahome, Sinaloa (25˚47'N and 109˚29'W) to the mouth of Custodio, Nayarit (21˚19'N, 105˚15'W).

The organism (*Pomadasys panamensis*) was classified in 10 mm increments calculating the frequency histograms by size. This information was used to identify the different age groups and sizes, and the modes observed in the distributions of a multinomial type [25,26] using

$$P\left\{x_i \middle| n, p_1, p_2, \cdots, p_k\right\} = n! \prod_{i=1}^{k} \frac{p_i^{x_i}}{x_i!},$$

where x_i is the number of times an *i* event happens in *n* samples, n is the size of the sample, and P_i is the probability of each possible *k* event. To estimate the model parameters, the previous equation is transformed into an expression of likelihood as

$$-\ln L\left\{x_i \middle| n, p_1, p_2, \cdots, p_k\right\} = \sum_{i=1}^{n} \left[x_i \ln\left(p_i\right)\right].$$

The assumption for the estimation of parameters is that the size distribution for each average or modal length can be estimated with a normal distribution, determining that each mode corresponds to a different population cohort [25]. Under this condition, estimates of the relative proportions of each category are expected to describe the density function as

$$p_{L_F} = \frac{1}{\sigma_n \sqrt{2\pi}} \times \mathrm{e}^{\frac{-\left(L_F - \mu_F\right)^2}{2\sigma_n}}$$

where μ_F and σ_F are the average length and standard deviation of each cohort. To estimate the expected frequencies and estimate the model parameters, the estimated values were tested and observed by the logarithmic function of multinomial distribution [25,26] as

$$-\ln L\left\{L \middle| \mu_F, \sigma_F\right\} = -\sum_{i=1}^{n} L_i \ln\left(\hat{p}_i\right) = -\sum_{i=1}^{k} L_i \ln\left(\frac{\hat{L}_i}{\sum \hat{L}_i}\right).$$

In this expression the parameters μ_F and σ_F are averages and standard deviations of the total length corresponding to *n* averages that are present in the distribution of lengths of each period. The model parameters were estimated by minimizing the likelihood function with the direct search algorithm of Newton.

The estimation of the biomass and the number of individuals in the population for each fishing area were made to estimate the densities of the multinomial distributions. We estimated the biomass per hectare and colonization. We assumed the total area and the average weight for each area using bootstrapping. Each was considered by the inverse of the normal distribution and the mean and standard error obtained previously. In cases not known, for example the area, we assumed a 10% error.

The model incorporates the indicators that can be described by

$$B_t = \left(na^{-1}\right)\left(ef\right)\left(w\right)\left(A_t\right)\left(exL^{-1}\right) + \varepsilon_i$$

when *B* is the capturable biomass, *n* is the number, *ef* is the efficiency of the trawl, *w* is the individual's weight, *A* is the area, *ex* is the positive capture of the species, all with respect to *t* is time, *a* is the drag area by the trawl, *L* is the total number of sets, ε_i is the random error. There are from B_1 to B_t sampling and resampling.

The result of these random fractions generated indicators of population size in numbers and biomass [24,25]. Each indicator is varied in each run as their average and standard error, in this case yielding 30 runs whose mean and standard error are simulated again a thousand times. Of these thousand runs there is formed a frequency distribution and histogram adjusted to normal and evaluated by the Aikaikae criterion (AIC) [25,27,28].

3. Results

The number of organisms analyzed was 622 from 260 sets in at least three environments of the study area. The average length of the population was 210 mm. The maximum was 430 mm and minimum was 50 mm. The monthly averages fluctuate around the average length of 210 mm (**Figure 2**).

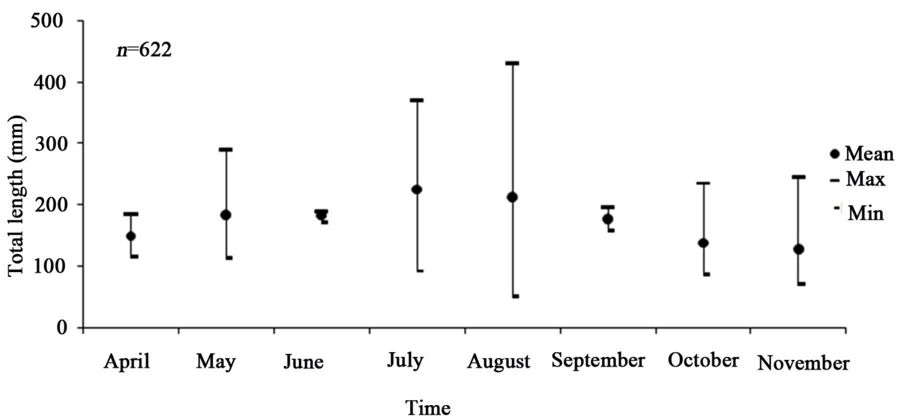

Figure 2. Monthly average, maximum, and minimum from length records of *Pomadasys panamensis* caught in lagoons, shallow marine waters, and the open sea from March to November 2008, in the southeastern Gulf of California.

The greatest difference in size was in August, from 50 mm to 430 mm total length. The next largest variance was in July with the range from 92 mm to 225 mm. The smaller intervals were recorded in June and September.

The size structure in July 2008 consists of five size-groups (**Figure 2**). Two of these, group 3 and 4, are the best represented and are in the mode of 150 mm and 240 mm. Organisms are seen of larger size and probably the oldest are in the mode of 310 mm and 340 mm. The best repre- sented group is the mode of 240 mm.

The size structure in August 2008 and the multinomial model in August 2008 consists of seven size groups, with the groups best represented are located in the 160 mm, 190 mm, and 230 mm modes (**Figure 3**). The modal group of smallest size is 60 mm and represents the juveniles caught with the adults and may represent the biological recruitment. The representation of multinomial distributions provides us with the idea that the density in $kg \cdot ha^{-1}$ was 0.19 ± 0.04 (**Figure 4**, **Table 1**), The area likely to be drawn was 1,000,000 ha ± 120,000 ha, the probability of success observed in the set was 0.42 ± 0.04 or 42% ± 4% (**Table 1**), and average body weight recorded was 137 g ± 14 g (**Figure 3**). The model outputs an initial biomass that can be captured in August 2008 for the grunt (*P. panamensis*) near 90 t, with a number of organisms of about 650,000. The evaluation by the Aikaikae criterion (AIC) was generally 44 and is considered adequate. The minimum value was 6, if there were no difference between the expected and observed (**Figure 4**, **Table 1**).

4. Discussion

The intensity and sampling area are important data about an influence area of 120,000 km^2, with the area of study is one of the largest for the shrimp fleet of the American Pacific.

The study includes 260 sets and is an effort of considerable laboratory and field work, considering the working hours of the network, the catch area covered, and the process in the laboratory to handle about 260 samples that on average were 25 kg.

The number of organisms could be considered low, but is representative of their presence in the sample and are spatially referenced data. Knowing the variance requires resampling or bootstrapping and is quite an adequate tool. This will generate a suitable estimator for the biomass variance that could be captured in August, before the start of the fishing season in this region.

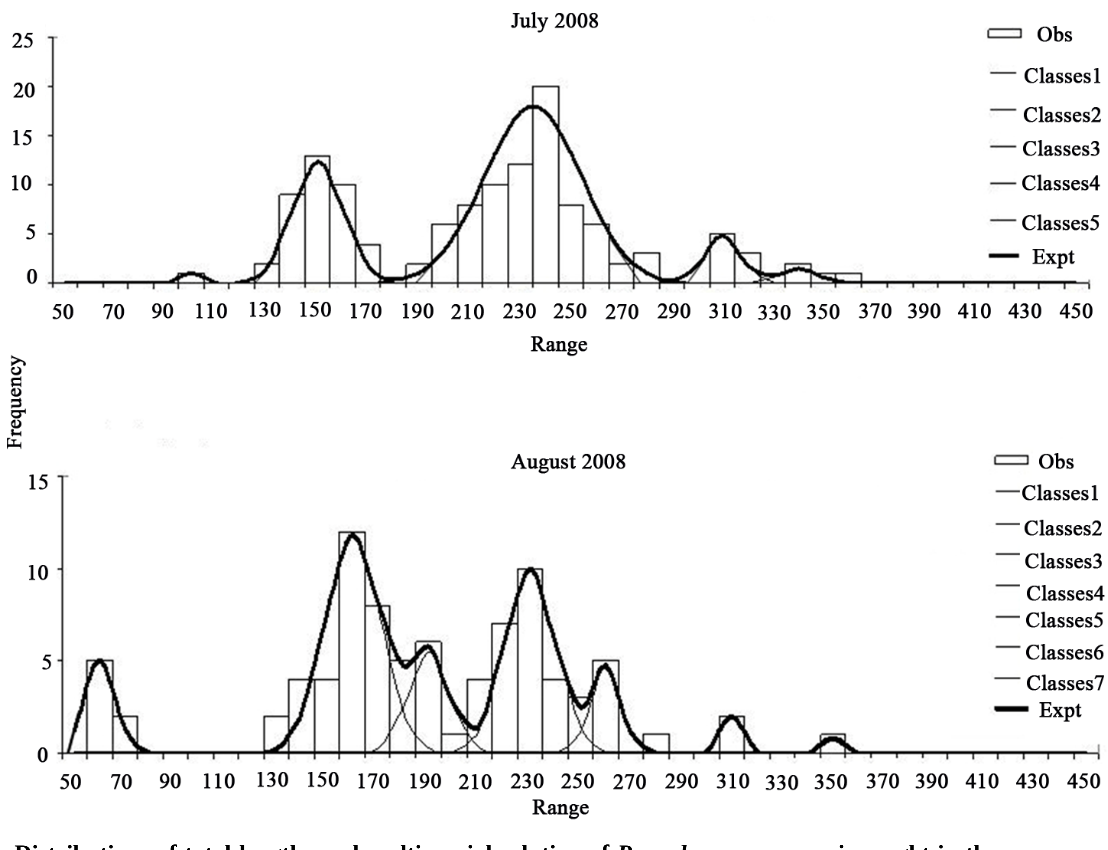

Figure 3. Distributions of total lengths and multinomial solution of *Pomadasys panamensis* caught in the open ocean during surveys in July and August 2008 in the Gulf of California. Bars: observed data. Lines show results of multinomial analysis-thin lines: cohorts; thick lines: total.

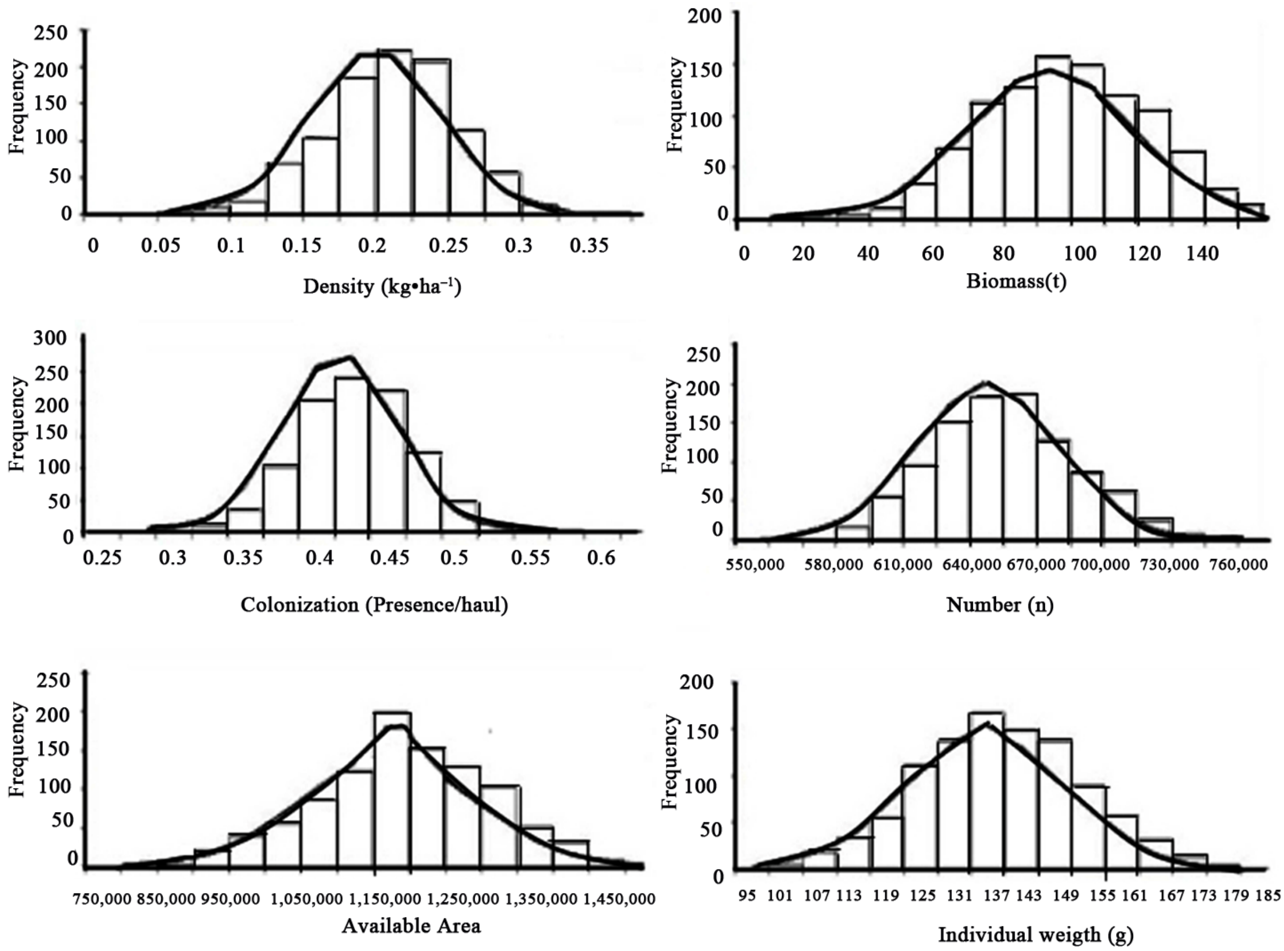

Figure 4. Parameter distributions for 1000 random runs of the biomass, colonization, the area, and the individual weights, and the indicators produced from biomass and number of *Pomadasys panamensis* in August 2008. The normal setting is scaled and evaluated by the Aikaikae criterion (AIC).

Table 1. Output values of the model, containing the distributions for 1000 random runs of the biomass, colonization, the area, and the individual weights and indicators produced from biomass and number of *Pomadasys panamensis* in August 2008. The normal setting is scaled and evaluated by the Aikaikae criterion (AIC), standard deviation (SD).

Parameter	Mean	SD (Standard Deviation)	AIC
Density ($kg \cdot ha^{-1}$)	0.19	0.04	34
Colonization	0.42	0.04	45
Area (ha)	1,140,200	121,100	32
Biomass (t)	90	25	30
Number	654,500	31,100	29
Weight (g)	137	14.7	29

The port cities, such as Mazatlan (in the center of the study area), had landing levels of fauna reaching 10,000 t. Much of the fauna captured is used by fishermen, constituting a significant fraction of the generated income of the region. A simple fraction of 150 kg per fisherman, per 500 boats with 6 crews produced nearly 500 t. This may seem a simple exercise, but it represents 500,000 servings of fish of various species. A fraction of 5% could be represented by the species studied. However, about 100,000 t are discarded and are not exploited. A simple example of businesses to process this additional fraction, two additional sailors per boat generated one thousand jobs in the port of Mazatlan and has increased their landings, quality, smell, and price. Among the species needed to be rescued are at least 51 fish including the grunt (includes *Pomadasys panamensis*), croaker, sea bass, yellowfin snook, jacks, rays, and 4 species of crustaceans such as crabs and crayfish. An example of the use of the bycatch is in the study by Castelo-Báez and Balsinde-Ruano [29] along the coast of Costa Rica. Of the sets made they collected 278 kg of bycatch, of which 80% was discarded. The most representative families in the catch were Carangidae, Scianidae, Ophicthidae, Paralichthyidae, Soleidae, Lutjanidae, Haemulidae, and Clupeidae. They had as a first step the classification of species according to the organoleptic attributes (physical, chemical, sensory) and, depending on the classification, was its use for human consumption (steak or pulp).

Moreover, Font-Chávez and García-Rodríguez [30] off Costa Rica processed the information from 64 sets made in the sampling cruises that were made by the Department of Research and Development INCOPESCA for 2001, in which close to 6400 kg of bycatch was caught, with about 4400 kg returned to the sea for a 32% use. They also noted the depths below 25 m were more productive. They estimated that process could take a level between 1250 t/year and 1880 t/year under the actual conditions of exploitation. They wrote that the most abundant species in the catch that are discarded are those belonging to the families Gerreidae, Haemulidae, Synodontidae, Scianidae, Bothidae, Serranidae, Muraenesocidae, Sphyraenidae, Lutjanidae, and Clupeidae.

Other authors [31-34] have reported results of using the flesh of fish from the material in the preparation of surimi-based products like shrimp, crab, shrimp meat, sausage, and other frozen products.

The prospect of a proper and sustainable management of fauna and fisheries needs the generation of indicators of biomass and size, as those generated in this work. This would allow a better understanding of the abundance and structure of the populations and would demonstrate the potential magnitude of landings to help make clear the current management of these resources.

5. Conclusions

Exploration, evaluation, and management of marine and estuarine species captured as bycatch in the shrimp fishery during 2008, such as *Pomadasys panamensis*, allowed an analysis of their size distribution and density of biomass in catch from March to November 2008 in the coastal waters of northern Sinaloa and Nayarit, Mexico, in the southeastern Gulf of California.

Pomadasys panamensis is likely to contribute significantly to the abundance of the bycatch. In the end of August there was an average 90 t of initial biomass, with an initial 650,000 organisms, and with an average weight of 137 g. The population continues to grow and recruit until the start of fishing season, and the survivors then continue to grow.

We have seen that *P. panamensis* resists the pressure of the shrimp fleet fishing off the Mexican Pacific coast, and of the local artisanal fishery. It is important to continue and deepen the studies of this species and those showing the same pattern of survival to try to understand the mechanism of success of this species.

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