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Research Article

Bycatch of the Isla del Rosario (Gulf of Salamanca, Colombian Caribbean) artisanal shrimp fishery in an approximation to the biodiversity impact

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ABSTRACT. In the period March 2009-February 2010 the fish bycatch of the artisanal shrimp fishery operating off the beach of Isla del Rosario (Gulf of Salamanca, Colombian Caribbean) was evaluated and length-frequency data analysis were done for five of the main ichthyic species. For this purpose, data registered in the project "Pesca artesanal del Magdalena", processed in the Fisheries Information System of Invemar (SIPEIN) to obtain fishery variables, on a monthly basis, was used. Between shrimp and fish fauna 38,265 kg were registered. The ichthyic bycatch fauna was composed of 59 fish species, distributed in 23 families, being Engraulidae, Sciaenidae, and Mugilidae the most representative. Regarding the engraulid *Cetengraulis edentulus* biomass, it was the most important species. Ichthyic bycatch to shrimp relationship was 1.2:1.0 with shrimp beach seine. During the assessed year, the highest mean Landing Per Unit Effort (LPUE) was present in the dry season, but November (rainy season) was the month with the highest shrimp LPUE. The indicators, Lc (mean length) and spawning/juvenile proportion, evidence growth overfishing for the species *Bairdiella ronchus*, *Cathorops mapale*, *Mugil incilis* and *Trichiurus lepturus*. The state of this fishery and the impact it generates on the ecosystem is discussed. Measures for its proper management are recommended.

Keywords: artisanal fishery, shrimp-to-bycatch ratio, Isla del Rosario, Colombian Caribbean.

INTRODUCTION

Bottom trawling is the most used method for artisanal fishing, but also the most harmful for the oceanic environment (Alverson *et al.*, 1994). This method consists of the use of large-scale fishing nets that drag along the seabed to catch various marine species, mainly demersal and benthic crustaceans (Kelleher, 2005). Estimates made by the FAO worldwide, indicate that the shrimp species were between 3 and 5 million ton that is between 200 and 500 million ton of protein (Rosa, 2005). The bycatch, considered of little economic value, is not marketed or processed since it is composed of a large number of species of different shapes or sizes with a predominance of small-sized specimens, which hinders its use by applying traditional methods (Cabello *et al.*, 2005).

In Colombia, shrimp fishing is practiced both at an industrial and artisanal level, constituting an important source of income and food. However, these fisheries are affecting marine ecosystems by capturing large volumes of accompanying fauna. In the case of artisanal fishing, this is done mainly in the coastal zone and, in some cases, in areas near essential habitats, such as swamps. This situation occurs in Isla del Rosario, in the Gulf of Salamanca (Magdalena), where artisanal shrimp fishing takes place in an area less than a kilometer close from the mouth of Ciénaga Grande de Santa Marta (CGSM). This largest estuary in the Colombian Caribbean becomes a nursery for many fish and invertebrates breeding in the high seas and then migrating to the swamp to pass their juvenile stage before returning to the ocean (Criales *et al.*, 2002).

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Due to the low selectivity of the shrimp beach seine trawl, locally called "chinchorro camaronero," high volumes of bycatch are collected, mainly bonefish and crustaceans, some commercially important and mostly juveniles (Blanco *et al.*, 2007; Bustos *et al.*, 2009).

However, despite the impact of this fishery, knowledge about the bycatch in terms of composition, volume, and proportion regarding shrimp catch is limited. Between November 2010 and April 2011, Duarte *et al.* (2013) evaluated the bycatch of the artisanal shrimp trawl fishery in the Gulf of Salamanca (GS), made up of boats propelled with an outboard motor that drag a net of 7.7 m long, with a mesh size between 1/2 and 7/8". They found that the proportion of bycatch/shrimp and discards/shrimp is higher during the wind season than in the dry season.

Currently, there are no measures to regulate fisheries in the area. Control and management actions that mitigate the impacts of this activity on the ecosystem without affecting life quality of fishermen population are needed.

The objective of this study is to characterize the fish fauna caught by beach seine in Isla del Rosario's artisanal fishery, to estimate the bycatch/shrimp ratio and to compare the juvenile- adult ratios of the main species of fish collected.

MATERIALS AND METHODS

Study area

The continental shelf of the Magdalena Department, in the central sector of the Colombian Caribbean coast, is located between 11°00'-11°15'N and 74°10'-75°30'W (Franco-Herrera, 2005), the main coastal geographical accident is the Gulf of Salamanca (GS), with an approximate extension of 400 km^2 comprised within an imaginary line that joins Bocas de Ceniza (Atlantic) and Cabo de la Aguja (Magdalena), limited by the continental littoral between these two points (Blanco *et al.*, 2007). Isla del Rosario is located less than 1 km from Boca de la Barra, the only natural communication with the sea of Ciénaga Grande de Santa Marta (CGSM), with an area of 450 km^2 (Franco-Herrera, 2005).

In the Gulf of Salamanca (GS) climatic periods are governed by the general patterns that influence the Colombian Caribbean Coast. The north-south displacement of the Intertropical Convergence Zone (ITCZ) defines the dry and rainy season; the former is from December to April influenced by the trade winds from the north and the last from May to November when the speed of these diminishes (Franco-Herrera, 2005). When the trade winds increase their intensity, Ekman transport gives place to an upwelling system in the Gulf of Salamanca, whereas in the periods of highest rainfall the area receives continental discharges from the CGSM (Criales *et al.*, 2002).

In the GS fishermen use different type of gears, among the most used, are gillnets, hand lines and beach seine nets, locally called "chinchorros". The Economic Fishing Units (EFU) are composed mainly of boats made of fiberglass or wood and propelled with a paddle or outboard motor (Páez, 2009). Fish is landed in several areas of the sector, such as Tasajera, Palmira, Isla del Rosario, Pueblo Viejo and Ciénaga, where the landing is commercialized as animal and human food (Páez, 2009). Isla del Rosario uses shrimp beach seines with a mesh size equivalent to 0.5 inches, with 26.4 to 52.8 m in length and 2.1 to 4.2 m in height, the number of fishermen varies between 7 and 9 per EFU. During the period between March 2009 and February 2010, landings were daily registered from a representative sample of the EFU in Isla del Rosario, taking into account date, name of the boat, site of fishing, type of fishing gear (beach seine), duration of the fishing trip and weight of shrimp and bycatch (kg). Then, the monthly estimate of the landing was calculated from the daily activity and effective fishing days, identifying the bycatch to the lowest possible taxonomic level following the identification guide of Atlantic fish (Carpenter, 2002). The fish size information of the species was taken fortnightly. It should be noted that although the term of bycatch includes all the animals that are not targeted and the inert material captured while fishing (Eayrs, 2007), in this work only the fish species registered in the landings were taken into account.

Data analysis

The data were processed in Invemar's Fisheries Information System (SIPEIN) (Narváez *et al.*, 2005), which extrapolates the sampling units, obtaining fishing variables on a monthly basis. These include the composition of the catches by species, the relative abundance of the fish resources regarding Landing per Unit of Effort (LPUE) and an approximation of the monthly disembarkation.

Temporal variation analysis

The climatic periods were defined according to the precipitation values registered in Santa Marta (Simón Bolívar airport station) by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM). It is important to mention that El Niño event was occurring during the period evaluated in this study (IDEAM, 2009-2010). In this context, the rainy period was defined during April to December 2009 and the dry season during March 2009 and January-February 2010.

Statistical analysis

The exploratory analysis of the data was carried out through descriptive statistics (maximum, minimum, average, standard deviation). The differences of shrimp to bycatch LPUE between climatic seasons were verified through the BIOENV statistical test using Primer 5® software.

Size frequency

Histograms of length frequencies were made for the five most representative species in the landing, organized in classes calculated by the Sturges method (Daniel, 2002), the mean length (Lc) and the spawning/ juvenile ratio were used (Rueda *et al.*, 2014) to evaluate the fisheries pressure on these resources.

RESULTS

During the evaluated period, 916 fishing trips were registered. The higher number of trips was made in April 2009 (117) and the lowest in February 2010 (12). It is important to note that in December 2009 and February 2010 the adverse oceanographic conditions prevented fishing activities, reducing the effort during those months.

Additionally, a total landing of 34,195 kg was registered, of which 15,394 kg correspond to shrimp and 18,802 kg to bycatch. The landing corresponding to shrimp was composed mainly of three species *Xiphopenaeus kroyeri* (Heller, 1862), *Farfantepenaeus subtilis* (Perez-Farfante, 1967) and *Litopenaeus schmitti* (Burkenroad, 1936), the former has the higher abundances registered in this area (Duarte *et al*., 2013). On the other hand, the bycatch consisted of 58 species, being the families Carangidae (9 species), Sciaenidae (8 species) and Engraulidae (8 species) the best represented in richness.

Concerning biomass, the highest proportion of bycatch corresponded to the families Engraulidae, Sciaenidae, and Mugilidae with values of 8,687.5; 2,873.6 and 1,624.1 kg respectively. *Cetengraulis edentulus* was the species with the highest relative abundance (18.47%), followed by *Anchoa spinifer* (4.55%) and *Ophioscion punctatissimus* (4.05%) (Table 1).

Furthermore, the landing per month of shrimp fluctuated between 2.0 and 2,832.0 kg, with an average of 1,282.8 ± 940.7 kg, whereas the bycatch presented values between 23.9 kg and 3,757.3 kg, with an average of 1,566.8 ± 1,167.6 kg. The highest shrimp landings were registered during April, May, June, and November, while the bycatch values where higher between March and June (Fig. 1). Furthermore, the period between March and June was characterized by high effort values matching high landings, however, during July to October landings were low with a relatively high effort, while in November a relatively low effort contrasted with high landing values, mainly from shrimp (Fig. 1).

Average per month of shrimp LPUE fluctuated between 0.2 and 36.0 kg trip^{-1} and showed a temporary behavior according to the landing. In case of bycatch, these values oscillated between 0.2 and 36.0 kg trip^{-1}, with highest values occurring between March and June (Fig. 1). During most of the sampled period shrimp landings per month were lower than bycatch, only in November and December, the opposite scenario occurred (Fig. 1).

Despite of the monthly variation of LPUE during the year, there were no significant differences in this variable between seasons (dry-rainy) when calculated with shrimp (BIOENV, R = 0.221, P = 0.164), bycatch (BIOENV, R = 0.366, P = 0.077) and total LPUE [shrimp + bycatch] (BIOENV, R = 0.136, P = 0.268).

The bycatch-shrimp ratio with beach seine in the sampled year was 1.2: 1, the highest monthly value was presented in February 2010 with a proportion of 12.0: 1 while the lowest was recorded in November, 0.4:1 (Table 2).

Length frequency data were analyzed from a sample of 1,485 individuals of the five most commercially important species (Table 3) among them *Bairdiella ronchus* (Sciaenidae), *Cathorops mapale* (Ariidae), *Mugil incilis*, (Mugilidae), *Trichiurus lepturus* (Lepturidae) and *Cetengraulis edentulus* (Engraulidae).

In all the species, except *C. edentulus*, the mean length (Lc) was lower than the length at first maturity (Lm) (Table 3), and the proportion of juvenile individuals ranged between 95 and 100% (Fig. 2).

DISCUSSION

Fishing in Isla del Rosario, due to its proximity to Boca de la Barra, is related to the dynamics and productivity of CGSM, a very productive ecosystem (Narváez *et al.*, 2008), favoring the presence of various species of fish with different needs for their growth and reproduction (CORPES, 1992, Criales *et al.*, 2002; Narváez *et al.*, 2008; Souza & Schwingel, 2011). As a consequence 59 fish species were recorded in Isla del Rosario during the period evaluated.

The fish fauna that has been caught by the artisanal shrimp fishery in Isla del Rosario is mainly composed of small pelagic fish of the families Engraulidae, Mugilidae and Clupeidae, and demersal fish of the Sciaenidae family, which inhabit in coastal waters and estuaries. In terms of composition, the Carangidae fami-

Table 1. Shrimp and bycatch landings in Isla del Rosario's artisanal fishery (March 2009-February, 2010).

Family	Species	Landing (kg)	Relative abundance (%)
Shrimp		15.393,50	45.02
Engraulidae	*Cetengraulis edentulus*	6,316.46	18.47
	Anchoa spinifer	1,554.48	4.55
	Anchoa trinitatis	572.63	1.67
	Lycengraulis grossidens	156.08	0.46
	Anchoa lyolepis	46.93	0.14
	Cetengraulis sp.	21.98	0.06
	Anchoa sp.	18.43	0.05
	Anchoa colonensis	0.50	<0.01
		8,687.48	**25.41**
Sciaenidae	*Ophioscion punctatissimus*	1,384.51	4.05
	Larimus breviceps	602.28	1.76
	Bairdiella ronchus	459.55	1.34
	Isopisthus parvipinnis	136.75	0.40
	Paralonchurus brasiliensis	136.52	0.40
	Ophioscion sp.	102.18	0.30
	Menticirrhus littoralis	51.63	0.15
	Menticirrhus americanus	0.20	<0.01
		2,873.62	**8.40**
Mugilidae	*Mugil incilis*	1.232,55	3.60
	Mugil curema	360,63	1.05
	Mugil sp.	30,88	0.09
		1.624,06	**4.75**
Clupeidae	*Odontognathus compressus*	435,54	1.27
	Harengula jaguana	388,53	1.14
	Opisthonema oglinum	343,45	1.00
	Alosa sp.	140,91	0.41
		1.308,42	**3.83**
Other families (20)		4.308,16	12.60
Total		**34,195.24**	**100.00**

ly was the best represented (9 species), which together with Mugilidae and Sciaenidae, are important for the fisheries in CGSM (Narváez *et al.*, 2008).

Cetengraulis edentulus (Engraulidae), the species with the greatest contribution to the landing (28.51%), is a pelagic fish inhabiting shallow coastal waters and entering lagoons and estuaries such as swamps (Carpenter, 2002; Osorio & Báez, 2002b), which makes it susceptible to be fished. The lengths of this species are greater during March to June compared to the other months of the year (Osorio & Báez, 2002b), a period where the effort was high, and the landing values increased.

On the other hand, Criales *et al*. (2002) report that 81% of the larvae that are born in the CGSM belong to the Engraulidae family, which explains the dominance of *C. edentulus* and the high catch rate of *Anchoa spinifer* and *A. trinitatis* in relation to other species. Similarly, *Mugil incilis* has a reproductive dynamic dependent on CGSM and the adjacent marine zone (Ramírez *et al*., 1998), it is one of the most important fishery resources in the area, with catches and lengths that have decreased over time due to excessive fishing exploitation (Mármol *et al.*, 2010). Rueda *et al.* (2014) concluded that in CGSM, *M. incilis* is highly exploited based on the mean lengths obtained between the years 2000 and 2013.

Besides, the catch of these resources could be modifying the trophic dynamics of the ecosystem and biodiversity, since some of these small pelagic fish are prey to medium pelagic species (*e.g.*, Carangidae and Scombridae) that approach the coasts of the Magdalena Department during specific periods of the year, taking advantage of the high productivity of the ecosystem (Márquez, 1982; Moreno, 1986; Pinilla, 1986; Blanco, 1988, 1992; García & Posada, 2013, 2014).

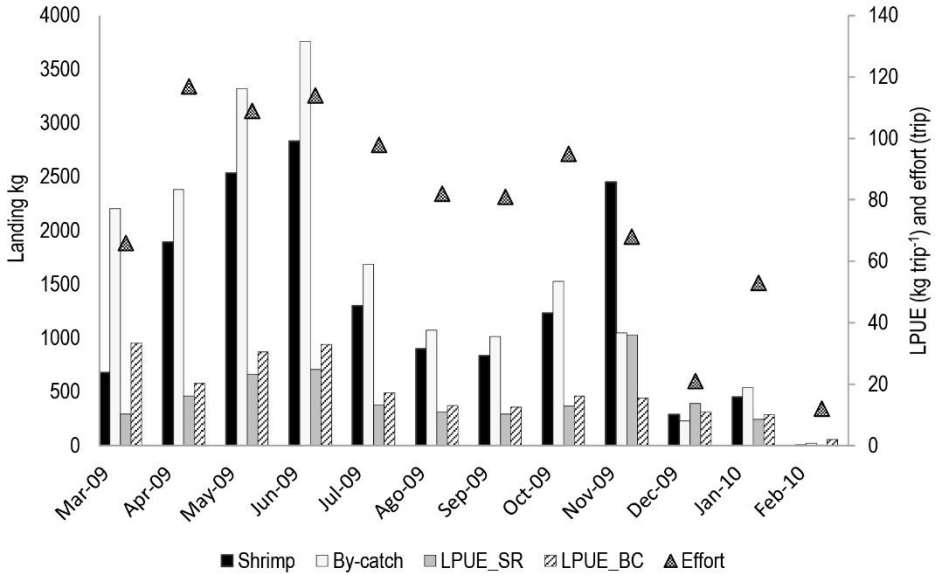

Figure 1. Landing (kg), effort (faenas) and LPUE (kg trip^{-1}) per month of the beach seine fishery in Isla del Rosario, Magdalena, between March 2009 and February 2010. LPUE_SR: LPUE shrimp; LPUE_BC: LPUE bycatch.

Table 2. Bycatch to shrimp ratio of the beach seine fishery in Isla del Rosario, Magdalena, between March 2009 and February 2010.

Date	Bycatch: shrimp ratio
Mar-09	3.2:1
Apr-09	1.3:1
May-09	1.3:1
Jun-09	1.3:1
Jul-09	1.3:1
Aug-09	1.2:1
Sep-09	1.2:1
Oct-09	1.2:1
Nov-09	0.4:1
Dec-09	0.8:1
Jan-10	1.2:1
Feb-10	12.0:1
Total	1.2:1

With respect to the shrimp LPUE, the highest values were presented during the first months of the year; however the month with the highest value was November, possibly due to the catches of *Farfantepenaeus* spp., and *Xiphopenaeus kroyeri*, species that are abundant in the area during the wet season (López & García, 2001). In contrast, bycatch obtained the highest catch values during the first half of the year. However, BIOENV analysis did not show significant differences between dry and wet seasons, differing from that reported by Duarte *et al.* (2013), who showed a seasonality of the bycatch where *Anchovia clupeoides* and *Trichiurus lepturus* catches were higher during the rainy season and *Cetengraulis edentulus* and *Conodon nobilis* during the dry season.

The above can be related to the period evaluated where the wet season was atypical, during April to July when the rains are not representative in the coastal margin of the Magdalena Department, high levels of precipitation were evidenced (IDEAM, 2009-2010). For the period June 2008-June 2010 the dynamics of the ITCZ presented anomalies regarding its historical behavior, a product of the El Niño-La Niña events recorded between 2008-2010, which caused a low rainfall system in 2009 and strong rains throughout 2010 (Grijalba-Bendeck *et al.*, 2011; Franco-Herrera, 2012). The latter affected the catch rate of shrimp and fish fauna, mainly due to the difficulty to execute fishing activities.

Also, it was identified that the bycatch temporal variability regarding composition is associated with the reproductive dynamics of the species that migrate from the CGSM to the sea and vice versa. Fish such as *M. incilis* migrate to the sea during the late October to the late December, returning to CGSM already spawned from January to March, where they stay until the cycle starts again (Ramírez *et al.*, 1998). Thus, the high LPUE were high in October, suggesting an impact from the fishery on the migratory behavior of these organisms, as proposed by Narváez *et al.* (2008) and Mármol *et al.* (2010).

On the other hand, spawning/juvenile ratio also represents how the fish population is being affected by the fishery. Four out of five species analyzed were caught with a higher proportion of fish in a juvenile stage.

Table 3. Length range and length at first maturity of the five most commercially important species of the beach seine fishery in Isla del Rosario, Magdalena, between March 2009 and February 2010.

Species	Total length range (cm)	Mean lenght (cm) (n)	Length at first maturity (cm)	References
Cetengraulis edentulus	4.5-17.5	15.4 (120)	15.0	Osorio & Báez (2002a)
Bairdiella ronchus	5.0-15.0	10.3 (49)	15.8	Castro *et al.* (1999)
Cathorops mapale	7.0-31.0	13.3 (86)	23.0	Narváez *et al.* (2008)
Mugil incilis	5.0-38.0	16.2 (85)	25.7	Mármol *et al.* (2010)
Trichiurus lepturus	13.0-56.5	39.1 (120)	77.9	Grijalba-Bendeck *et al.* (2011)

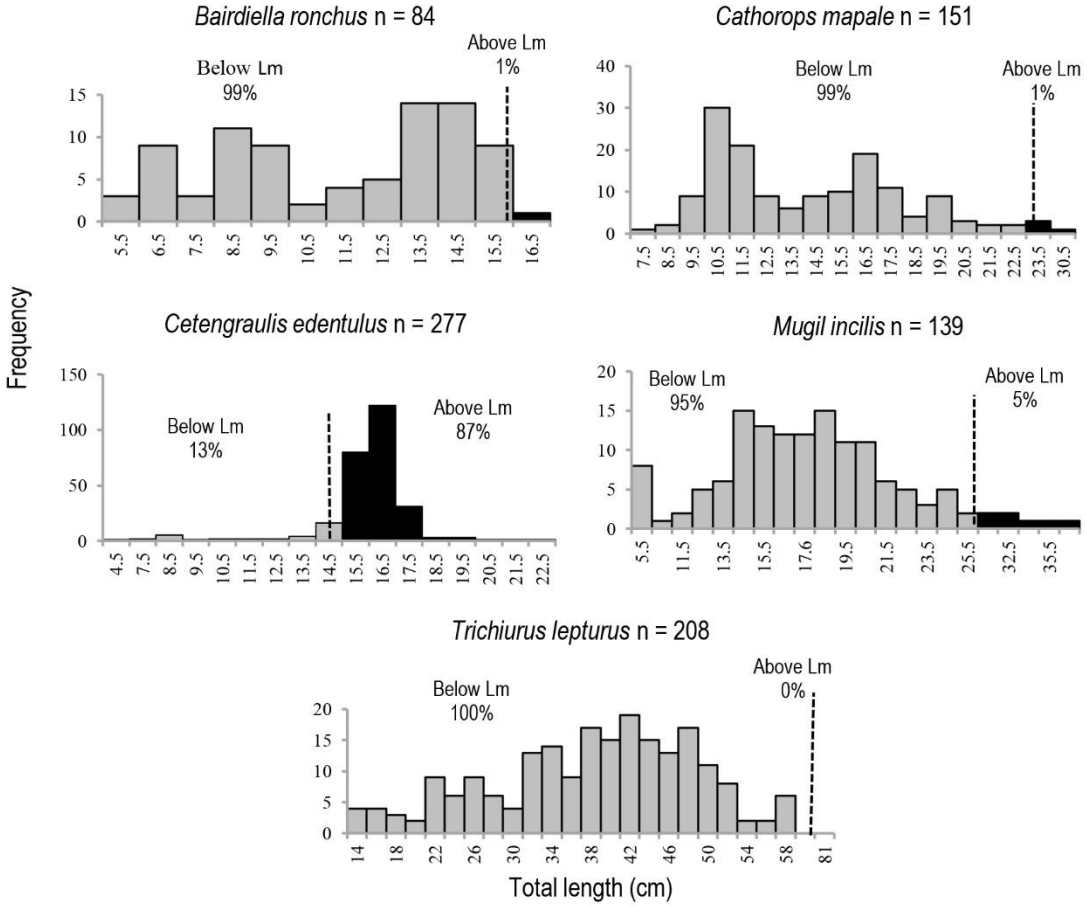

Figure 2. Length frequency histograms from the most commercially important fishes in Isla del Rosario between March 2009 and February 2010. The dotted line indicates the length at first maturity (Lm) for *B. ronchus* (Castro *et al*., 1999); *C. mapale* (Narváez *et al*., 2008); *C. edentulus* (Osorio & Báez, 2002); *M. incilis* (Mármol *et al*., 2010) and *T. lepturus* (Grijalba-Bendeck *et al*., 2011).

C. edentulus was the only species whose Lc was superior to the Lm, however, this does not mean that the species is not at risk of being overexploited since it is the most abundant regarding biomass and Lc is similar to Lm.

In a bycatch assessment of shrimp trawl fishing, carried out by Duarte *et al*. (2013) in the Gulf of Salamanca, several of the species that dominated the catches were caught as juveniles (*e.g.*, *Cathorops mapale*, *Trichiurus lepturus*, *Paralonchurus brasiliensis*, *Conodon nobilis*).

Another adverse effect that has been identified in the area, associated with the use of fishing gear of low selectivity, is the decrease in fish length. Narváez *et al*. (2008) reported a decrease in time of catch lengths for *C. mapale* with several gears like cast net, longline,

beach seine and gill nets, which oscillated between 9.5-31.0 cm in the period 1994-1996 and 7.0-29.5 cm in the period 2000-2004. Compared to the length range here obtained (7.0-31.0 cm), the lowest lengths are as critical as those of 2000-2004.

Bycatch landing proportion in some Caribbean countries like Suriname (83.9%), Guatemala (81.8%), Honduras (78%), Nicaragua (65.3%), El Salvador (28.6%) and Cuba (22.7%) (Davies *et al.*, 2009), exceeds 50% of the landing and only two countries had a higher proportion of target species. In the Colombian Caribbean, Viaña *et al*. (2004) reported for an industrial fishery that the bycatch-shrimp ratio was 5.7:1. In contrast, Duarte *et al.* (2010) found a much higher relationship with a mean of 16.6 (13.4-21.3 IC 95%) in the northern Colombian Caribbean and 10.8 (9.8-11.8 IC 95%) in the south.

Regarding the bycatch to shrimp ratios obtained (1.2: 1 or 55: 45%), they were not as high as those reported in the literature; still they are worrisome because the organisms caught in Isla del Rosario are very small in length and most of them have not reached their sexual maturity.

Shrimp fishery has a strong impact on ecosystems due to the amount of bycatch it involves. As a consequence, fisheries have tried to implement measures that reduce this problem (Alverson *et al.*, 1994; Eayrs, 2007). In Colombia, attempts have been made by the use of bycatch reduction devices, although these are designed for industrial and not artisanal fleets (Manjarrés *et al.*, 2008).

Moreover, bycatch represents very little economic value for local fishermen in Isla del Rosario. Per fishing trip, 40 kg are caught with a price of 200 Colombian pesos per kilo (around 0.07 USD), for a total of 8,000 Colombian pesos per fishing trip (2.8 USD). On the other hand, it is essential to consider that the high catches of juvenile fish may reduce the recruitment of different stocks in the area, hence affecting other fisheries.

CONCLUSIONS

The shrimp fishing that is carried out in Isla del Rosario with a beach seine generates a strong pressure on the ecosystem of the Gulf of Salamanca because the bycatch is composed mainly of juvenile individuals. In four out of five species analyzed, the proportion of juvenile individuals was over 95%, which shows the high impact on recruitment. On the other hand, some of the species caught are preys of higher trophic levels, such as medium and large pelagic fish, the removal of this biomass could be altering the availability of food and the dynamics of the trophic network. Besides altering the ecosystem, the latter could be causing negative impacts for other fisheries in the region, whose target is this kind of resources. Therefore, it is important to monitor this fishery, find and implement sustainable production alternatives in conjunction with the local community of fishermen and/or establish other types of co-management measures (*e.g.*, fishing restrictions or closures).

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