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Exploitation and reproduction of the bullnose ray (*Myliobatis freminvillei*) caught in an artisanal fishery in La Pared, Margarita Island, Venezuela

Alejandro Tagliafico (contact author)[1,2]
Nicolás Ehemann[1]
María Salomé Rangel[1,2]
Néstor Rago[3]

Email address for contact author: tagliaficoa@gmail.com

[1] Escuela de Ciencias Aplicadas del Mar
Núcleo de Nueva Esparta
Universidad de Oriente
Calle La Marina
Boca de Río, 6304 Isla de Margarita, Venezuela

[2] National Marine Science Centre
Southern Cross University
2 Bay Drive
Coffs Harbour, New South Wales 2450, Australia

[3] Universidad Nacional de Costa Rica
Escuela de Biología
Avenida 1, Calle 9
Heredia 86-3000, Costa Rica

Abstract—Species of the genus *Myliobatis* have been poorly assessed because of a lack of available information regarding their capture and life history. We provide valuable data based on the commercial landings of the bullnose ray (*Myliobatis freminvillei*), which we studied during 2 separate time periods (October 2005–December 2007 and January–December 2013). A total of 187 individuals were analyzed: 85 females (24.0–96.0 cm in disc width [DW]) and 102 males (22.8–118.0 cm DW). There was no difference in the overall sex ratio (females to males: 4:5); however, differences were found between the annual sex ratio in 2005, 2006, and 2013. Estimated capture per unit of effort for this species was 0.8 individuals/trip (standard deviation [SD] 1.3) or 2.9 kg/trip (SD 5.5), showing an increase in effort through time and significant differences between years. Approximately 25% of both sexes were shorter than the estimated median DW at maturity. No pattern in the reproductive cycle was identified because of the lack of landings during several months; however, mature individuals were observed frequently throughout the study period; gravid females were observed on only 2 occasions. This study provides baseline biological information on the life history of the bullnose ray for necessary fishery management.

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Elasmobranch overfishing has been documented since the late 1940s (Castro, 2013) and recent analyses have demonstrated that population diminution has occurred around the world, with at least one in 4 species being actually threatened with extinction (Dulvy et al., 2014). Nonetheless, numerous species of rays and skates have been poorly studied, preventing definition of their status and identification of threats (Molina and Lopez, 2015). Such is the case for the genus *Myliobatis*, which comprises 11 species (White, 2014). Of those species, 6 have been documented as data deficient by the International Union for Conservation of Nature (IUCN) in the IUCN Red List of Threatened Species, vers. 2015.4, available at website, accessed December 2015), 2 have been classified as species of least concern, and the remaining 3 species have been categorized as endangered, near threatened, or have not been assessed to date. The bullnose ray (*Myliobatis freminvillei*) is included within the data-deficient group, as a result of the lack of available information required to evaluate population trends; as a consequence, the need for further investigations of its biology and the fishery are required to re-assess the status of this species in the IUCN Red List (Stehmann, 2009).

The bullnose ray is a benthic–pelagic eagle ray widely distributed in the western Atlantic and captured mainly with artisanal long lines, gillnets, and industrial shrimp trawls (Cervigón et al., 1992; Stehmann, 2009; Froese and Pauly, 2015). In Brazil, a similar species, the southern eagle ray (*M. goodei*), is discarded as bycatch of beach seining (Velasco et al., 2011). However, in many Venezuelan coastal communities, the bullnose ray is commercially valuable and is consumed fresh or salted (Cervigón et al., 1992; Cervigón and Alcalá, 1999). Between 2006 and 2007, 13,000 kg of bullnose ray were landed in the state of Nueva Esparta in Venezuela, representing 0.03% of the total landings from 176 commercially fished species (Marval and Cervigón, 2009). Although no fishery specifically targets this species, it is often landed as bycatch.

The results of this study provide insight on the life history and landings data of the bullnose ray captured as part of a small-scale, artisanal fishery in Margarita Island—baseline information that would be useful for management and conservation of this little known and potentially vulnerable species.

Materials and methods

La Pared is a small and isolated fishing community located on the northern coast of Macanao Peninsula, Margarita Island, in the state of Nueva Esparta in northeastern Venezuela (11°03′32.53″N, 64°18′47.25″W). At this place, fishermen manage the resources, rotating target species and using different gears depending on the time and abundance of fish (Tagliafico et al., 2013a).

All bullnose ray used in analysis for this study were sampled from fish landed with bottom gillnets at a site in this community. Descriptions of the boats and fishing gear of this fishery can be found in Méndez-Arocha (1963), Ginés et al. (1972), Iriarte (1997), Suárez and Bethencourt (2002), and González et al. (2006).

Sampling was carried out weekly from October 2005 through December 2007 and, 5 years later, from January through December 2013. The number of fishing boats, number of individual bullnose ray landed, and the total weight landed (kilograms) were recorded during each visit. Catch per unit of effort (CPUE) was defined as the number of individuals caught per trip and the total kilograms caught per trip. To identify statistical differences in the CPUE between years and months (except for 2005, because sample data were collected over only 3 months during that year), homogeneity of variances were tested with Levene's test, followed by 2-way fixed-effects analyses of variance (ANOVA), based on permutations; all of these analyses were conducted with Primer 6[1] (PRIMER-E Ltd., Ivybridge, U.K.; Clarke and Warwick, 2006) and PERMANOVA+ add-on software for Primer (Anderson et al., 2008). When statistical differences were detected, a Tukey's honestly significant difference (HSD) test was performed.

To determine the size-frequency distribution of the bullnose ray that were captured and analyzed, the disc width (DW), of each individual was measured in centimeters; therefore, all subsequent references to size in this article refer to DW. Sexes were differentiated by the presence of claspers in males and their absence in females (Conrath, 2005). Differences in the proportions of sexes were tested with a chi-square test (χ^2) (Zar, 1996).

Maturity was determined by macroscopic observation of reproductive organs at the landing site. Females were considered mature or immature on the basis of the presence or absence of fully developed ova in the ovaries. Gravid females were recognized by the presence of embryos in the uterus, and post-gravid females were recognized by the presence of a well-developed, large, and highly vascularized uterus (Conrath, 2005). For males, maturity was determined by inspecting and manipulating claspers. Organisms were considered mature when claspers were strongly calcified and could be easily rotated around the base (Conrath, 2005). They also had to have an extensible distal portion (Conrath, 2005) and show the presence of seminal fluid (Bizarro et al., 2007). Male bullnose ray that lacked these characteristics were considered to be immature.

The proportion of males to females at different reproductive stages was examined monthly to identify the reproductive cycles of the species in the study area. Other measurements, such as follicle diameter, uterus width, clasper length, gonad weight, and liver weight could not be obtained consistently because of the speed at which animals were cut and sold on arrival at the landing site.

The median size at maturity was estimated for males and females through the use of the logistic function:

$$M_f = 1/1 + \exp^{-a(L_i - b)}, \qquad (1)$$

where M_f = the fraction of mature individuals;
a = the change in slope of M_f as a function of the size intervals (L_i); and
b = the DW at 50% maturity (DW_{50}).

Parameter estimates for a and b were obtained by using the least squares method with the statistical software R, vers 3.1.1 (R Core Team, 2014). A covariance analysis of these logistic regressions by sexes was performed.

Results

For this study, 187 bullnose rays were analyzed. General characteristics of these specimens are summarized in Table 1. The size ranges for all organisms analyzed were 22.8–118.0 cm DW and 0.2–19.0 kg. Both average DW and average weight increased slightly in recent years (Table 1). The size-frequency distribution shows that, although the fishery-captured specimens were of several size classes, the greatest number of individuals were between 55.0 and 60.0 cm DW (Fig. 1). The largest recorded individuals were males; however, only 4 males were larger than 75.0 cm DW, whereas 25 females were found above that size.

As summarized in Table 2, during the 39-month sampling period, 225 fishing trips were analyzed and

[1] Mention of trades names or commercial companies is for identification purposes only and does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1

Biological measurements of the bullnose ray (*Myliobatis freminvillei*) caught by the artisanal fishery of La Pared, Margarita Island, Venezuela, during 2 periods: 2005–2007 and 2013. Average disc widths (DWs) and average weights are given with standard deviations (SDs). An asterisk (*) indicates statistical differences at level of significance (α) of 0.05.

Year	2005	2006	2007	2013	All years
n	14	33	91	49	187
Number of females (F)	2	10	42	31	85
Number of males (M)	12	23	49	18	102
Sexual ratio (F:M)	1:5*	2:5*	9:10	17:10*	4:5
DW intervals (F) (cm)	40.8–50.5	24.0–82.4	26.4–96.0	54.4–93.5	24.0–96.0
Weight intervals (F) (kg)	1.0–1.8	0.2–7.4	0.3–12.0	2.2–10.6	0.2–12.0
DW intervals (M) (cm)	42.0–56.4	45.0–60.2	22.8–118.0	37.6–86.5	22.8–118.0
Weight intervals (M) (kg)	1.0–2.8	1.3–3.0	0.2–19.0	0.6–8.6	0.2–19.0
Average DW (cm)	51.9 (SD 4.4)	56.2 (SD 10.0)	58.5 (SD 16.0)	69.4 (SD 13.3)	60.0 (SD 15.0)
Average weight (kg)	2.0 (SD 0.5)	2.7 (SD 1.7)	3.4 (SD 3.1)	5.1 (SD 2.8)	3.4 (SD 2.8)
First gravid (cm)	–	–	75.8	84.6	75.8
Immature (%)	50	33	18	10	25
Gravid (%)	0	0	1	1	1
DW 100% maturity (cm)	>54.0	>54.0	>54.0	>55.0	>55.0
Maximum fecundity	–	–	1	6	6
Maximum DW embryo (cm)	–	–	9.0	20.6	20.6

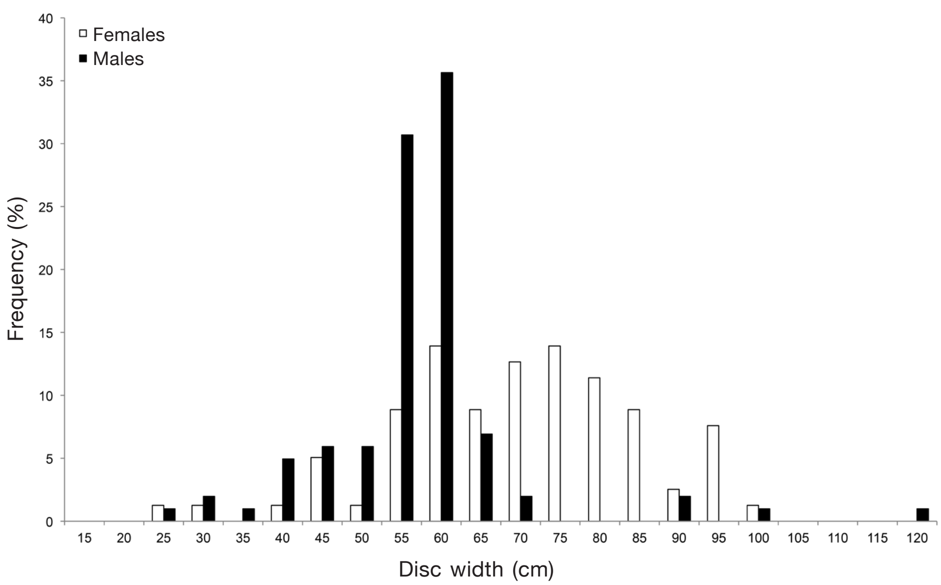

Figure 1

Frequency distribution of disc-widths of male and female bullnose ray (*Myliobatis freminvillei*) caught in the artisanal fishery of La Pared, Venezuela, during 2 periods: 2005–2007 and 2013.

provided a total yield of 648.1 kg of the bullnose ray. The estimated overall CPUE was 0.8 individuals/trip (standard deviation [SD] 1.3) or 2.9 kg/trip (SD 5.5). Differences in the number of trips, individuals, and kilograms of catch were observed over the years sampled. In 2013, the number of trips reached a maximum, but that peak occurred without a concomitant increase in the number of kilograms or animals captured. Monthly analysis showed a higher level of fishing effort during April–June 2013 in comparison with previous years, although there were high numbers of trips with no catches of the bullnose ray (Fig. 2A).

Table 2

Mean catch per unit of effort (CPUE), measured as individuals per trip and as kilograms per trip and given with standard deviations in parentheses, for bullnose ray (*Myliobatis freminvillei*) captured in La Pared, Venezuela, during 2 periods: 2005–2007 and 2013.

Year	Number of trips	Number of individuals	Catch (kg)	CPUE (individuals/trip)	CPUE (kg/trip)
2005	10	14	27.8	1.4 (1.8)	2.8 (3.7)
2006	48	33	87.3	0.7 (1.1)	1.8 (3.0)
2007	69	91	306.6	1.3 (1.4)	4.4 (5.5)
2013	98	49	226.4	0.5 (1.2)	2.3 (6.4)
All years	225	187	648.1	0.8 (1.3)	2.9 (5.5)

The highest monthly catch of 78.5 kg was registered in April 2013 (Fig. 2B).

A clear trend for estimated CPUE, expressed as both the number of individuals caught per trip and kilograms caught per trip, was not observed during the study period (Fig. 2, C and D). Variance between years was homogeneous (Levene's test: P>0.05). Statistical differences were observed in the number of individuals per trip and in the weight of the catches (kilograms per trip) between years but not between months (Tables 3 and 4). The posteriori Tukey's HSD test (P<0.05) revealed that both the average number of individuals per trip and kilograms per trip were significantly higher in 2007 than in 2006 or 2013 (Table 2). During the study period, 59% of trips resulted in no catch of bullnose ray.

Over the entire period of study, males occurred in slightly greater numbers than those of females, yet no significant difference was detected (χ^2 (1, n=187): 1.37, P=0.242). In contrast, when considering each year independently, differences were found in 2005 (χ^2 (1, n=14): 5.79, P=0.016), 2006 (χ^2 (1, n=33): 4.36, P=0.037), and 2013 (χ^2 (1, n=49): 4.00, P=0.046).

Results from covariance analysis of the logistic regressions indicated that sex had no significant effect (P=0.673), and, as a consequence, an average value of DW_{50} was estimated for both sexes at 53.3 cm DW, in which 95% confidence intervals ranged from 52.6 to 53.9 cm DW, whereas the slope of the regression was estimated at 0.42 with 95% confidence intervals from 0.35 to 0.51.

Immature females occurred less frequently (17%) than immature males (31%) in catches. Only 2 gravid specimens were reported during the entire study period: one in July 2007 (with 1 embryo of 9.0 cm DW) and the other in March 2013 (with 6 embryos: 2 females and 4 males between 19.7 and 20.6 cm DW). In addition, a postgravid female was captured in July 2007. Mature individuals were observed in almost all months for which landings were registered; however, a low number of gravid and postgravid females were recorded over the study period (Fig. 3).

Discussion

The maximum size of bullnose ray examined in this study (118.0 cm DW) exceeded the previous maximum size reported for this species in Venezuela (97.0 cm DW; Cervigón and Alcalá, 1999), in Brazil (100.0 cm DW; Bernardes et al., 2005), and in Argentina (106.0 cm DW; Refi, 1975). It is probable that the larger maximum size observed is due to the long duration of our study and the greater number of individuals analyzed, in comparison with other studies of the bullnose ray. Schwartz (2011), for example, reported the occurrence of a greater maximum DW (males: 165.0 cm, females: 147.0 cm) in Onslow Bay, North Carolina, over an extremely long time period (1972–2010) using 2 different capture methods (braided nylon long lines and otter trawls). On the other hand, Stehmann (2009) reported that 70.0 cm DW was the most common size for this species; in contrast, the most common size interval recorded in this study was between 55.0 and 60.0 cm DW. The average size of the bullnose ray observed (n=187) was 60.0 cm DW (SD 15.0 cm), similar to the mean size reported by Schmidt et al. (2012) for this species in Brazilian fisheries (63.8 cm DW [SD 7.0 cm], n=8); however, the average weight calculated in our study (3.4 kg [SD 2.8]) was slightly lower than that reported for bullnose ray in Brazil (3.6 kg [SD 1.3]).

Average DW of captured organisms increased from 51.9 cm (SD 4.4) in 2005 to 69.4 cm (SD 13.3) in 2013. In addition, the average recorded weight of captured organisms increased from 2.0 kg (SD 0.5) in 2005 to 5.1 (SD 2.8) in 2013 and weight increased steadily over the study period (average annual weights were 2.0, 2.7, and 3.4 kg per individual for 2005, 2006, and 2007, respectively). However, it is important to note that applied fishing effort was greater in 2013 than in previous years. Also, a total ban of the Venezuelan industrial trawling fishery occurred in 2008, a change that potentially may have increased food availability for bullnose ray, resulting in an increased size of bullnose ray and in a redirection of fishing effort. Both of these factors could explain the observed increase in

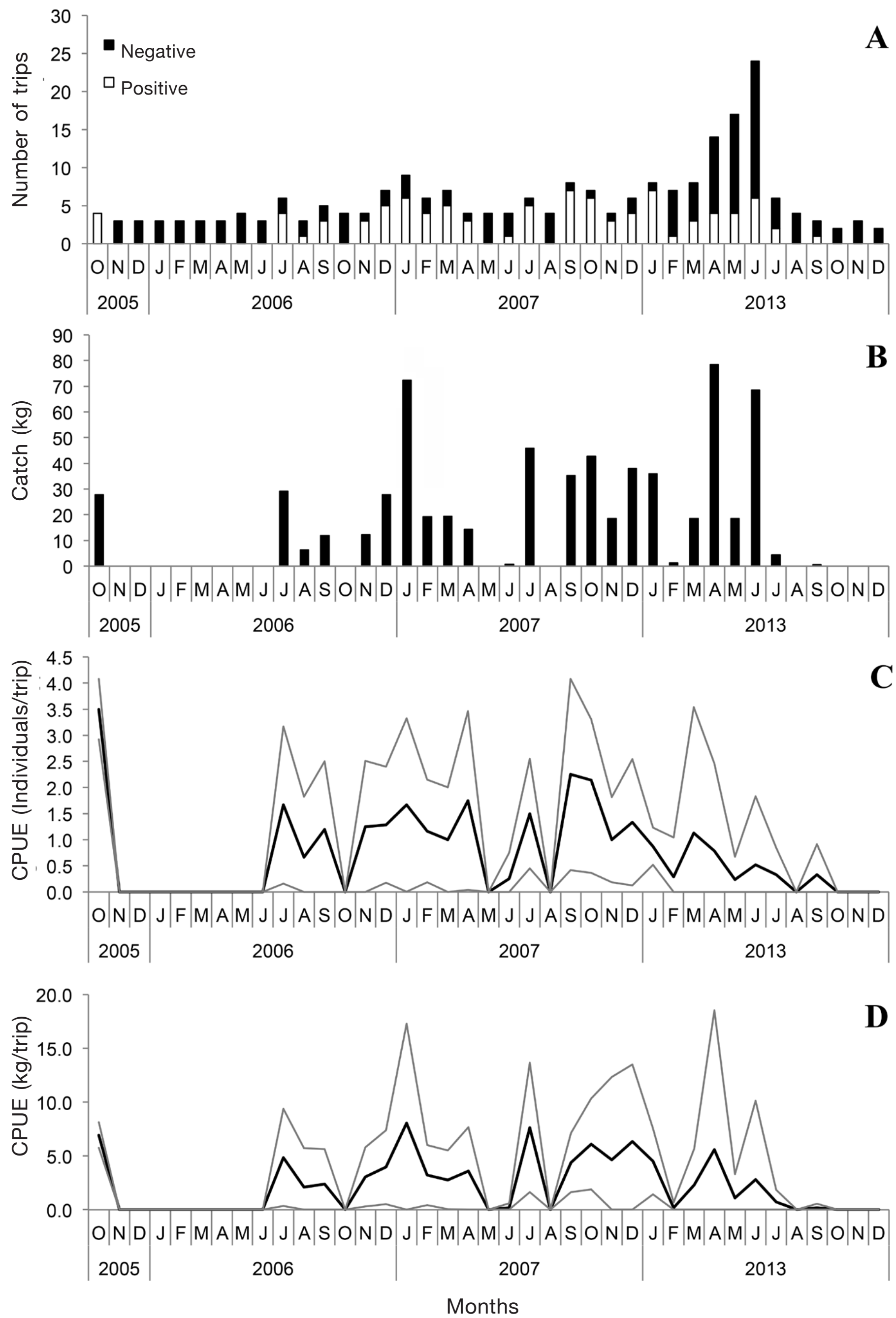

Figure 2

Monthly fishing effort in (**A**) number of trips and (**B**) catch by weight; and (**C**) monthly catch per unit of effort (CPUE) in individuals per trip and (**D**) weight per trip for bullnose ray (*Myliobatis freminvillei*) caught by the artisanal fishery of La Pared, Venezuela, during 2 periods, 2005–2007 and 2013. In panels C and D, thick lines represent mean values, and thin lines indicate the respective standard deviations of the means.

size and weight of captured specimens of bullnose ray in our study. Furthermore, fishing effort at La Pared can be influenced by the abundance of other species, such as tuna and deep sea sharks (Tagliafico et al., 2013a), as well as by natural events, such as strong wind, waves, or even local festivities, all of which can reduce landings, and with them, the data available for fishery-dependent research.

Table 3

Results of analysis of variance of catch per unit of effort, measured as individuals per trip of bullnose ray (*Myliobatis freminvillei*) captured in La Pared, Venezuela, during 2 periods, 2006–2007 and 2013, with the year and month used as sources of variation. An asterisk (*) indicates statistical difference at a level of significance (α) of 0.05. df=degrees of freedom; SS=sum of squares; MS=mean squares; *F*= *F*-test; CV=coefficient of variation.

Source	df	SS	MS	*F*	*P* (perm)	CV
Year	2	19.40	9.70	6.95	0.004*	0.16
Month	11	21.42	1.95	1.40	0.191	0.00
Year×Month	22	36.30	1.65	1.18	0.281	0.00
Residual	179	249.63	1.39			1.39
Total	214	336.16				

Table 4

Results of analysis of variance of CPUE, measured as kilograms per trip of the bullnose ray (*Myliobatis freminvillei*) captured in La Pared, Venezuela, during 2 periods, 2006–2007 and 2013, with the year and month used as sources of variation. An asterisk (*) indicates statistical difference at a level of significance (α) of 0.05. df=degrees of freedom; SS=sum of squares MS=mean squares; *F*= *F*-test; CV=coefficient of variation.

Source	df	SS	MS	*F*	*P* (perm)	CV
Year	2	240.7	120.4	3.948	0.025*	1.68
Month	11	296.6	27.0	0.884	0.514	0.00
Year×Month	22	534.9	24.3	0.797	0.641	0.00
Residual	179	5457.4	30.5			30.49
Total	214	6705.9				

Current literature on the sex ratio of bullnose ray comes from only a few studies: an 8-month study from Brazil, in which 6 females and 2 males were analyzed (Schmidt et al., 2012) and a 38-year study from North Carolina in which a 1:1 sex ratio was reported (Schwartz, 2011). For another species of this genus, the bat ray (*M. californica*), Hopkins and Cech (2003) found that females were more common than males (21:5) in California. The total sex ratio of all 187 organisms examined for our study was 4:5 (females to males), which indicates no significant difference between sexes and that spatial segregation by sex does not exist for the bullnose ray. However, when the data were analyzed over shorter time periods, significant differences occurred in sex ratios between different years (Table 1), highlighting the importance of collecting data over time periods greater than 1 year.

Future studies of the bullnose ray need to take into account the short, medium, and long-term population dynamics of this species. Our data, and previous work by Schmidt et al. (2012), indicate the likelihood of complex population dynamics and variable sex ratios, yet the data are not adequate to accurately describe the factors that affect sex ratios over different temporal scales or to provide information that is imperative for the management of this species. Additionally, it has been proposed that different sampling techniques can result in variable sex ratios (Hopkins and Cech, 2003). Therefore, bias from different sampling methods, biologically driven spatiotemporal segregation, and the overall mobility of elasmobranchs could hinder efforts to improve understanding of population-level attributes that create differences in the distribution of individual animals and observed sex ratios.

To our knowledge, only 2 reports describe size at sexual maturity for this species. McEachran and de Carvalho (2002) suggest that males reach maturity between 60.0 and 70.0 cm DW, yet they include no estimate for females. Gómez et al. (2010) indicate that females reach maturity when they are greater than 58.0 cm DW and males reach maturity when they are above 45.0 cm DW. By comparison, our data indicate that the average size at sexual maturity for this species occurs at a DW of 53.3 cm for both sexes—a size that is slightly lower than most of the previous estimates. Recently, Molina and Lopez (2015) estimated that the

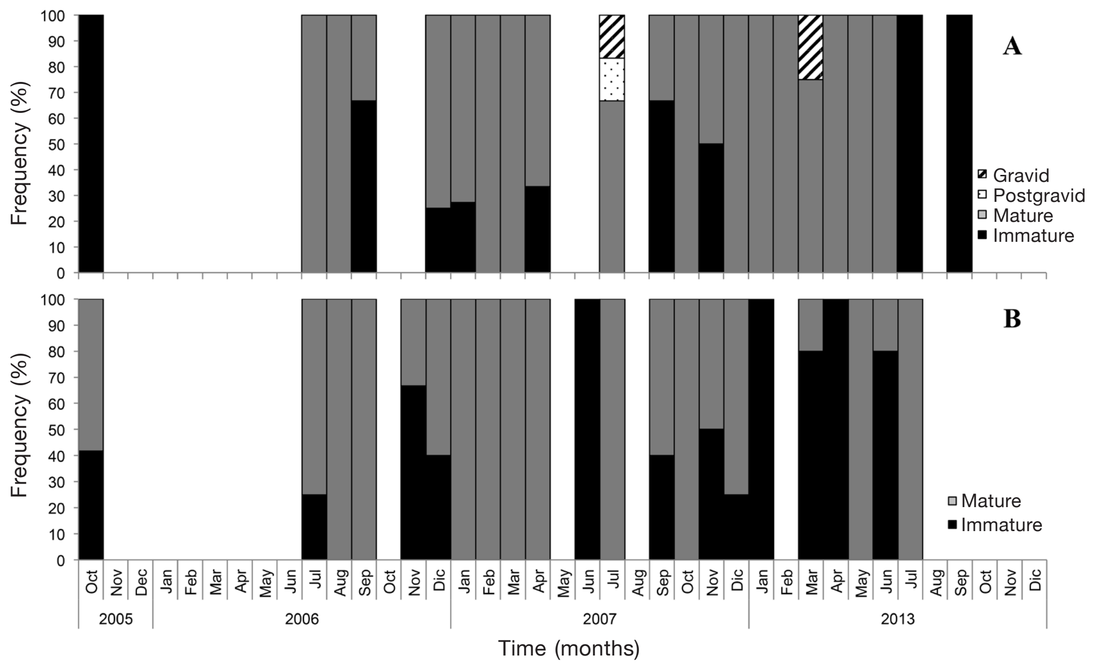

Figure 3

Monthly proportion of sexual maturity stages for (**A**) female and (**B**) male bullnose ray (*Myliobatis freminvillei*) captured by the artisanal fishery of La Pared, Venezuela, during 2 periods: 2005–2007 and 2013.

size at sexual maturity for the southern eagle ray in Northern Patagonia was 48.7 and 45.0 cm DW for females and males, respectively. In central California, for the bat ray, sexual maturity has been estimated to occur at 45.0–62.2 cm DW for males and 50% maturity of females has been reached at an estimated 88.1 cm DW (Martin and Cailliet, 1988). Differences in DW at sexual maturity for species occurring in diverse regions have also been reported for other species of Myliobatidae, and several factors may determine such disparities, such as real variations in populations, sample size, sampling bias, as well as errors in the assignation of maturity stages and the use of different estimation methods (Tagliafico et al., 2012).

No patterns were detected in the reproductive cycle of bullnose ray. As with our observations of gravid and postgravid females in July, Cervigón and Alcalá (1999) reported capture of gravid females in June and October. The low numbers of gravid females in our study may indicate a spatial segregation of the sexes, with females giving birth in waters outside the operational area of the fishery.

The maximum size of embryos registered in this study (20.6 cm DW) is similar to the previously reported range (21.5–21.7 cm DW; Cervigón and Alcalá, 1999) and to the size of neonates (25.0 cm, McEachran and de Carvalho, 2002; 22.0–23.0 cm, Gómez et al., 2010). Also, the maximum fecundity encountered in this study (n=6) is comparable to the previously reported numbers of 6–8 embryos (Cervigón and Alcalá, 1999; McEachran and de Carvalho, 2002). An outlier specimen, a female captured with a single embryo of 9.0 cm, is suspected to have aborted pups during its capture as a result of stress. Similar values for size and number of embryos have been indicated for the bat ray (n=2–5; size: 22.0–30.5 cm) (Martin and Cailliet, 1988).

Venezuelan fishery resources are showing signs of overexploitation (Mendoza[2]), and a lack of management for Myliobatiformes (i.e., the spotted eagle ray [*Aetobatus narinari*], southern stingray [*Dasyatis americana*], and longnose stingray [*D. guttata*]) has been reported previously (Tagliafico et al., 2012, 2013b). Precautionary management measures may be necessary to ensure ongoing population viability of the bullnose ray. In this study, we provide results regarding CPUE, DW at maturity, size structure by sex, and the sex ratio for this species, all of which are important parameters for demographic modeling and stock assessment that are necessary in order to develop management recommendations.

Previous studies have highlighted that most of the elasmobranchs accessible to the world's fisheries are under threat (Dulvy et al., 2014), and this group, with low resilience to fishing (Cheung et al., 2005) and a protracted period of 14 years for a stock to rebuild

[2] Mendoza, J. J. 2015. Rise and fall of Venezuelan industrial and artisanal marine fisheries: 1950–2010. Fish. Cent., Univ. British Columbia, Work. Pap. Ser. #2015-27, 16 p. [Available at website.]

(Froese and Pauly, 2015), may be considered highly vulnerable. However, the bullnose ray has shown signs of recovery since the implementation of shark-specific management strategies in the southeastern United States (Ward-Paige et al., 2012). Additional fishery-independent research is needed on the bullnose ray to develop effective conservation measures, particularly with regard to mortality, growth estimates, and migration patterns, and to detect temporal and spatial changes in abundance.

Currently, no law is in place to directly regulate catch of bullnose ray. However, this species was previously reported as bycatch in the industrial shrimp trawl fishery (Cervigón et al., 1992), and the total ban of this fishery in Venezuela that began in March 2009 (Article 23, Law of Fisheries and Aquaculture) may be contributing to the conservation of the bullnose ray. In addition, the fishing community in the area of our study has implemented self-management strategies, such as rotation of target species, fishing methods, and locations throughout the year (Tagliafico et al., 2013a). Such local adaptations of fishing practices can provide effective management strategies that would benefit fisheries and endemic marine populations.

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