**Abstract**—We studied a small artisanal fishery for the spotted eagle ray (*Aetobatus narinari*) off Margarita Island in northeastern Venezuela. We analyzed data from 413 fishing trips directed at *A. narinari* over a 29-month sampling period (August 2005–December 2007). These trips yielded 55.9 metric tons and 1352 individuals from which a subsample of 846 females and 321 males was used for biological data. Maximum fishing effort and landings occurred between February and May, and catch per unit of effort was highest between December and February and between July and October with an overall average of 3 individuals and 133 kg per trip. The overall sex ratio was significantly different from 1:1 with a predominance of females. Females ranged in size with disc widths (DW) from 64 to 226 cm. Males ranged in size between 97 and 190 cm DW. There was no statistically significant difference between male and female length-weight relationships. Mean fecundity was estimated at 3.09 embryos per female, and the largest embryo measured 44.5 cm DW. Females in different maturity stages were found in all months, except November 2007, the month when all females were immature. Postgravid females occurred mainly during the periods of January–May and July–October. Mean length ($L_{50}$) at maturity was estimated at 129.2 cm DW for males and 134.9 cm DW for females. This study provides much needed information on the biology and life history of *A. narinari* for the management of an intensive, directed, small-scale fishery for this little known species in northeastern Venezuela.

Manuscript submitted 20 October 2011.
Manuscript accepted 7 May 2012.
Fish. Bull. 110:307–316 (2012).



# Exploitation and reproduction of the spotted eagle ray (*Aetobatus narinari*) in the Los Frailes Archipelago, Venezuela

**Alejandro Tagliafico (contact author)**[1]

**Néstor Rago**[1]

**Salomé Rangel**[2]

**Jeremy Mendoza**[3]

Email address for contact author: tagliaficoa@gmail.com

[1] Instituto Nacional de Investigaciones Agrícolas
La Asunción, Isla de Margarita, Venezuela
Present address: Escuela de Ciencias Aplicadas del Mar
Universidad de Oriente
Boca de Río, Isla de Margarita, Venezuela

[2] Departamento de Ciencias
Universidad de Oriente
Isla de Margarita, Venezuela

[3] Instituto Oceanográfico de Venezuela
Universidad de Oriente, Apdo. 245
Cumaná, Venezuela

The spotted eagle ray (*Aetobatus narinari*) until recently had been considered a cosmopolitan species distributed in tropical and warm, temperate waters. However, recent genetic analysis indicates that what was thought to be a single species is actually a species complex with at least 2 separate species, 1 for the western and central Pacific and at least 1 for the eastern Pacific and central Atlantic (Richards et al., 2009; Schluessel et al., 2010a). Furthermore, White et al. (2010) in a taxonomic review of this species complex established that *Aetobatus ocellatus* is the valid species name for the Indo-West Pacific region. Both species are very similar morphologically, and the major physical difference occurs in the background dorsal coloration (White et al. 2010). Because most previous studies have been conducted in the Indo-Pacific region, this taxonomic redefinition significantly reduces the available scientific literature on the biology and fisheries of *A. narinari*. In the western Atlantic, *A. narinari* is found from Chesapeake Bay and Bermuda to the Gulf of Mexico, Caribbean Sea, and south to Brazil (Cervigón and Alcalá, 1999).

*Aetobatus narinari* is observed usually in coastal environments, such as bays and coral reefs, and occasionally in estuarine habitats. In inshore waters, it has been observed to depths of 60 m and is known to travel long distances across open waters (International Union for the Conservation of Nature [IUCN] Red List of Threatened Species, vers. 2011.2 [Available from http://www.iucnredlist.org/apps/redlist/details/39415/0, accessed July 2011]).

The spotted eagle ray is a benthic feeder with a diet consisting mainly of bivalve and gastropod molluscs (Randall, 1967, for *A. narinari*; Schluessel et al., 2010b for *A. ocellatus*), but it also consumes cephalopods, crustaceans, and teleost fishes. It is found to be solitary or to swim in large schools of up to several hundred individuals (McEachran and de Carvalho, 2002).

Little is known about the biology and reproduction of *A. narinari*. Individuals reach large sizes, and if the distance between both extremes of the pectoral fins or disc width (DW) is used as a measure of length, the maximum reported length is 230 cm DW; most reported individuals, however, are usually less than 140 cm DW (McEachran and de Carvalho, 2002). *Aetobatus narinari* has a matrotrophic mode of embryonic gestation and fetal nutrition occurs by lipid histotrophy; and this species has low fecundity with 1–4 pups per litter (McEachran and de Carvalho, 2002). Length at maturity has been estimated for *A. ocellatus* in the western Pacific and Indian Oceans, but to our knowledge there is only one previous report for *A. narinari* in the Atlantic Ocean (Dubick, 2000).

The spotted eagle ray is categorized as near threatened throughout its range by the IUCN and studies on its catch, abundance, and reproductive biology have been recommended. However, the conservation status of this species complex needs to be reviewed in light of the recent taxonomic changes (White et al., 2010).

The spotted eagle ray is considered of minor commercial importance, but it is caught as bycatch with different fishing-gear types, such as trawls, trammel nets, and longlines (Trent et al., 1997; Stobutzki et al., 2002; Grijalba-Bendeck et al., 2007). In the southeastern Gulf of Mexico, Cuevas-Zimbrón et al. (2011) reported a small-scale, directed fishery for *A. narinari*.

In Venezuela, *A. narinari* is considered a common species, particularly in insular areas with coral reef cover, such as the Los Roques Archipelago in the north central part of this country (Cervigón, 2005) and the islands of Coche, Cubagua, and Margarita off the northeastern coast. *Aetobatus narinari* is readily marketable fresh or salted and is particularly appreciated in eastern Venezuela where it is the main part of a typical dish (Cervigón and Alcalá, 1999). At Margarita Island, we studied a small, directed fishery to generate information that may contribute to the management and conservation of this little known and potentially vulnerable species.

## Materials and methods

### Study area and fishing fleet

The insular state of Nueva Esparta in northeastern Venezuela is formed by the islands of Coche, Cubagua, and Margarita. Margarita and Coche each have an important concentration of small-scale fishing communities. Puerto Fermín, also known as El Tirano, is a traditional fishing community in northeastern Margarita. Fisheries at Puerto Fermín mainly use trap gear, but a small number of boats target *A. narinari* around the nearby Los Frailes Archipelago (63°46′–63°43′N latitude, 11°14′–11°12′W longitude). This specialized fleet is composed of 6 wooden boats with outboard engines, known locally as *peñeros*, with 2 boats that fish only occasionally and the other 4 boats that fish every month. This fleet uses bottom-set gillnets that vary between 200 and 500 m in length, between 8 and 10 m in height, and between 30 and 39 cm in mesh size. Nets are set in the evening between 1600 and 1830 hours and lifted the following day between 0500 and 0900 hours. Detailed descriptions of boats and fishing gear for this area may be found in Méndez-Arocha (1963), Ginés et al. (1972), Iriarte (1997), and González et al. (2006).

### Field sampling and biological data

Fishing for the spotted eagle ray is carried out every month during a period of ~10 days around the full moon. Samples were taken during such periods over the 29 months between August 2005 and December 2007. We registered the number of boats fishing daily, the number of individuals landed, and their weight in kilograms. The retained indices of relative abundance were the number of individuals captured per trip and total kilograms collected per trip.

To determine the size of *A. narinari*, DW was measured as a proxy for total length in ray (total length cannot be reliably measured because tails can be damaged during capture) (Last and Stevens, 2009); therefore, unless otherwise specified, all subsequent references to *length* in this article refer to DW. Specimens were weighed with a field balance with a weighing capacity of 200 kg and a precision of 1 kg. Sexes were differentiated by the presence of claspers in males and their absence in females.

Male sexual maturity was verified by checking claspers visually and by touch. Individuals were considered mature when claspers were strongly calcified, rotated easily around the base, had an extensible distal extreme (Pratt, 1979; Conrath, 2005), and showed the presence of seminal fluid (Bizarro et al., 2007).

Female maturity was identified by macroscopic observation of reproductive organs in fish at the landing site in Puerto Fermín. Individuals were considered mature (nongravid) or immature based on the presence or absence of fully developed ova in the ovaries (Conrath, 2005). When possible, embryos from gravid females were counted, sex was determined, and DW measured (in centimeters). Postgravid females were recognized by the presence of a well-developed, large, highly vascularized uterus (Conrath, 2005) that, in most cases, contained intrauterine milk or histotrophe. Some of these postgravid females were considered gravid if fishermen indicated that abortions occurred during hauling of the specimens.

Other measurements, such as clasper length, follicle diameter, uterus width, gonad weight, and liver weight could not be obtained because of the speed at which animals were cut and sold on arrival at the landing site in Puerto Fermín. The swift cutting and selling of rays also prevented biological measurements of some of the landed individuals and embryos.

### Data analysis

Population structure was analyzed by sex from length-frequency data. Length-weight relationships, of the form $Wt = a\mathrm{DW}^{b}\exp^{e}$, were established for males and females separately, where $a$ is the intercept, $b$ is the slope, $\exp^{e}$ represents the residual error, and $Wt$ stands for weight. Statistical differences between these functions were established with an $F$-test from the analysis of the residual sum of squares, in a manner similar to the one proposed by Chen et al. (1992).

Differences in the proportions by sex for juveniles, adults, and embryos were estimated monthly by using a chi-square test ($\chi^2$) with Yates's correction (Zar, 1996). To determine the reproductive period for *A. narinari*, the proportions of immature and mature males and the proportions of females in different reproductive stages were examined monthly. Also, we estimated the mean and range of embryo lengths. Fecundity was determined by the number of embryos per uterus, and the size at birth was determined from the largest observed embryos.

The length at which 50% of individuals were mature was estimated for males and females by a logistic function:

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

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

Parameter estimates for $a$ and $b$ were obtained by maximizing the log-likelihood function and assuming a binomial error distribution (Welch and Foucher, 1988). Confidence intervals were estimated by joint likelihood profiles (Venzon and Moolgavkar, 1988). Parameter estimates and confidence intervals were calculated with the statistical software R, vers. 2.13.0 (R Development Core Team, 2011[1]).

## Results

### Effort, catch, and catch per unit of effort

In the 29-month sampling period, 413 fishing trips directed at *A. narinari* were analyzed. Sampling yielded 55.9 metric tons and 1352 individuals. A subsample of 1167 individuals, 846 females and 321 males, was measured for biological data.

The largest numbers of fishing trips per month, with more than 30 trips per month, were observed during the months of February, April, and May 2006 and February 2007 (Fig. 1A). For 2006 and 2007, the number of trips in the first 6 months of each year corresponded to 73% and 69% of the total number of trips made in each year, respectively. Highest catches in 2006 and 2007 occurred in months with most fishing effort (Fig. 1B). Catches in the first 6 months represented 81% and 62% of total annual catch for the years 2006 and 2007, respectively. Approximately 23% of the total number of trips during the study period resulted in no catch. In all years of this study, November was the month with the highest proportion (>50%) of trips with no catch.

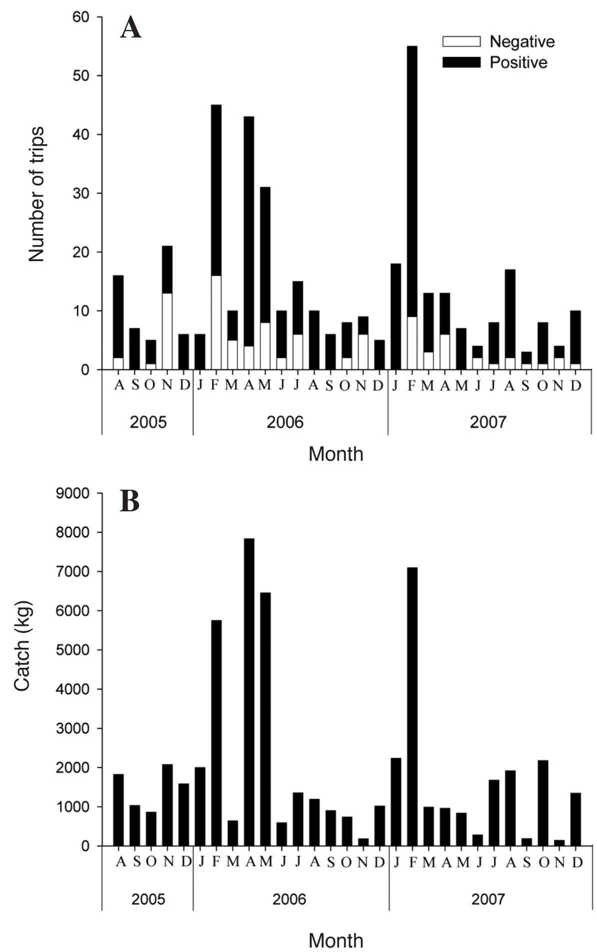


**Figure 1**

(**A**) Fishing effort in number of trips per month directed at spotted eagle ray (*Aetobatus narinari*) in the Los Frailes Archipelago in northeastern Venezuela during the period from August 2005 to December 2007. Negative=trips with no catch of *A. narinari*; Positive=trips with catch of *A. narinari*. (**B**) Catch of *A. narinari* by weight (kg) per month in the fishery in the Los Frailes Archipelago during the period from August 2005 to December 2007.

Data on catch per unit of effort (CPUE) in number of fish caught per trip did not show a clear trend during the study period. Minimum values were observed in November 2006 and 2007 (Fig. 2A), and maximum values were observed in October 2005; January, April, September, and December 2006; and July and October 2007. The overall mean CPUE for the study period was 3 individuals per trip. The distribution of numbers of fish caught per trip shows that ~85% of trips yielded 0–6 individuals, with 7–21 individuals caught during the remaining

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

15% of trips. CPUE in excess of 13 individuals per trip occurred only between February and May.

CPUE in weight (kilograms) of fish caught per trip (Fig. 2B) showed a decreasing trend during 2006 but was much more stable in 2007, albeit with a decreasing trend during the first 6 months. The months with the minimum and maximum values of CPUE by weight were the same months for which the highest and lowest CPUE in numbers of fish per trip was observed. The overall mean CPUE for the study period was 133 kg per trip. The average weight of individuals caught during the 29-month sampling period was 41.9 kg, and peaks in weight occurred in the second and last quarters of each year of study.

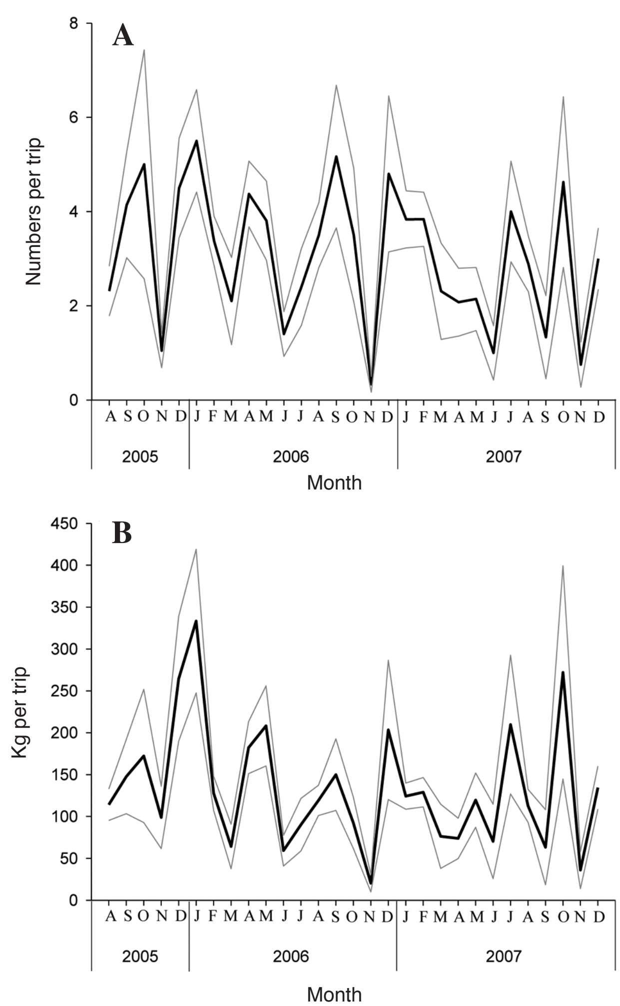


**Figure 2**

Catch per unit of effort of *Aetobatus narinari* in the Los Frailes Archipelago during the period from August 2005 to December 2007 in (**A**) numbers per trip and (**B**) weight (kg) per trip. Thick lines represent mean values, and thin lines are ±1 standard errors.

## Length structure and length-weight relationships

Measurements of length (DW in centimeters) were taken from 321 males and 846 females. Both sexes showed a unimodal length-frequency structure (Fig. 3A), and the overall range of observed lengths was 64–226 cm DW. The largest observed male was 190 cm DW. Males larger than 160 cm DW represented less than 10% of the sample. Females reached greater lengths, and the largest observed individual was a gravid female at 226 cm DW. Approximately 42% of females were larger than 160 cm DW.

Measurements of length and weight were taken from 105 males and 185 females. The comparison of male and female length-weight relationships showed no statistically significant differences ($F$=1.87; $P$=0.16). Therefore, a single length-weight relationship for both sexes was estimated (Fig. 3B). Point estimates and confidence intervals for intercept ($a$) and exponent ($b$) of this relationship were $1.824\times10^{-5}$ ($9.6\times10^{-6}$–$3.4\times10^{-5}$) and 2.95 (2.82–3.07), respectively.

## Sex ratio and reproductive period

Of 321 males, 127 were immature and 194 were mature. Males were absent in the sampled catch during November 2005; August–December 2006; and June, September, and November 2007. Mature males were observed in all remaining months, except October 2005 (Table 1).

Of the 846 female individuals examined, 481 were immature, 242 were mature nongravid, 61 were gravid, and 62 were postgravid. Females were observed in different maturity stages in all months of the study period, except in November 2007, when all were found to be immature. November 2007 also was the month with the smallest sample size obtained during this study ($n$=3). Postgravid individuals, indicating recent parturition, were present in August 2005, February–May and July–September 2006, January–April and July–October 2007, and December 2007 (Table 1).

## Fecundity and embryo lengths

Of the 61 gravid females, 75% had 3–5 embryos, and the remaining 25% of gravid females had 1–2 embryos. Seven individuals exhibited the maximum observed fecundity of 5 embryos within the uterus. Mean overall fecundity and standard deviation (SD) was estimated at 3.09 (SD=1.31) embryos. No significant relationship was observed between female length and the number of embryos for a sample of 35 gravid females ($F$=2.29; $P$=0.14).

The largest numbers of embryo samples were obtained in February 2006 ($n$=13), May 2006 ($n$=8), February 2007 ($n$=22), and July 2007 ($n$=9). Of 80 embryos observed, the length ranged from 10.1 to 44.5 cm DW (mean=31.5 cm DW) (Table 1). Eight embryos with lengths of 10.1–11.5 cm DW still had their yolk sac; in larger specimens, the yolk sac had disappeared completely and nourishment had been provided by uterine milk or histotrophe through the numerous trophonemata present in the adult uterine walls.

### Size at sexual maturity

The smallest recorded sizes at which females were nongravid, gravid, and postgravid were 106 cm, 150 cm, and 167 cm DW, respectively. The smallest mature male measured 97 cm DW.

The average length ($L_{50}$) at maturity was estimated at 129.2 cm DW for males (Fig. 4A). Joint confidence intervals (95%) for parameter estimates ranged from 125 to 134.9 cm DW for $L_{50}$ and from 0.105 and 0.195 for the slope of the regression. For females, $L_{50}$ was estimated at 134.9 cm DW (Fig. 4B), and joint confidence intervals ranged from 128.8 to 139.8 cm DW for $L_{50}$ and from 0.09 to 0.216 for the slope.

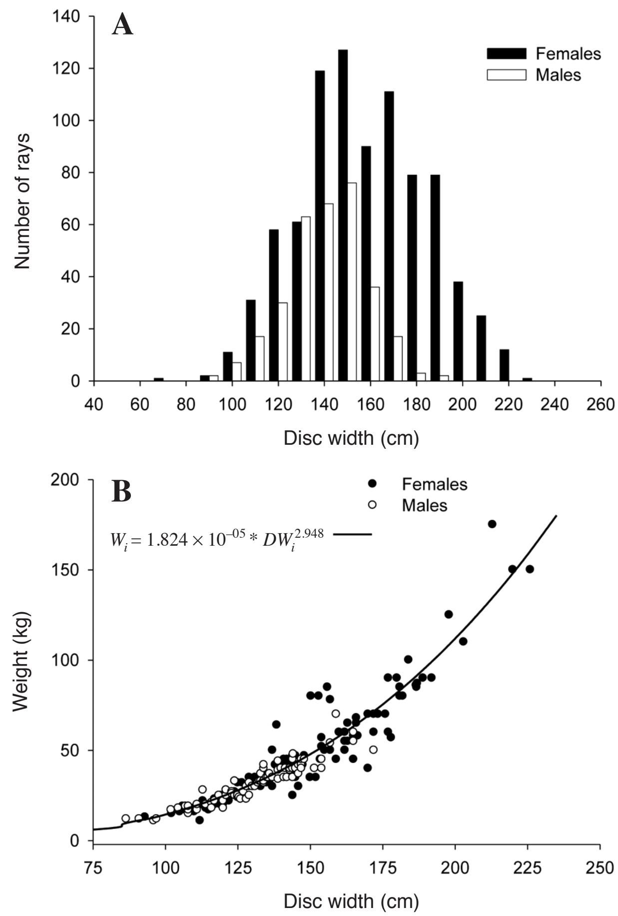


**Figure 3**

(**A**) Length-frequency histogram (cm DW) of male ($n$=321) and female ($n$=846) *Aetobatus narinari* caught in the Los Frailes Archipelago during the period from August 2005 to December 2007. (**B**) Combined length-weight relationship for male ($n$=105) and female ($n$=185) individuals of *A. narinari* sampled during the period from August 2005 to December 2007.

## Discussion

### Effort, catch, and catch per unit of effort

*Aetobatus narinari* is usually captured as incidental catch in artisanal and industrial fisheries throughout its range. Directed fisheries for this species are uncommon and, to our knowledge, this study and that of Cuevas-Zimbrón et al. (2011) are the first accounts of fisheries for which *A. narinari* is the target species.

The total catch landed during the 29-month study period from August 2005 to December 2007 was 55.9 metric tons, 64% of which was taken during the first 6 months of 2006 and 2007. In this fishery, a close relationship was observed between catch in weight and numbers and fishing effort in number of trips (coefficient of determination [$r^2$]=0.85), but peak catches did not correspond with high CPUE values. Maximum observed catches in the first months of 2006 and 2007 were preceded by high CPUE values in the months of December 2005 and January and December 2006, during which 100% of the fishing trips were positive for catch of *A. narinari*. CPUE, especially in weight per trip, tended to decrease as the fishing season progressed, which may be explained by local depletion or migration (or by both) of *A. narinari* out of the fishing area studied. It is likely that the high CPUE values and percentage of positive trips in December and January acted as a trigger for initiating the fishing season in the first months of the year. The overall estimated mean CPUE of 3 individuals caught per trip in the Los Frailes Archipelago, Venezuela, during this study was similar to values reported for Seybaplaya, Mexico, by Cuevas-Zimbrón et al. (2011) but less than the 6 individuals per trip reported for Campeche, also in the southeastern Gulf of Mexico. However, trips in Seybaplaya and in the Los Frailes Archipelago were for 1 day, whereas trips in Campeche were for 1–3 days. High numbers of fish caught per trip were observed in our study during December–February, coincident with periods of high availability of *A. narinari* reported for the southeastern Gulf of Mexico (Cuevas-Zimbrón et al., 2011). High CPUE values in our study also occurred in July–October, but they did not result in an important increase in fishing effort and catch. This lack of increase in fishing effort and catch is probably related to the existence of more lucrative alternate fisheries (*Scomberomorus* spp. and *Octopus* spp.) that are active particularly during this season of the year. A similar switch in target species (from *A. narinari* to *Octopus maya*) occurs during the second half of the year in the southeastern Gulf of Mexico (Cuevas-Zimbrón et al., 2011).

**Table 1**

Number of female and male spotted eagle ray (*Aetobatus narinari*) per maturity stage, number of female and male embryos, and mean length or disc width (DW) of embryos (cm) sampled per month between August 2005 and December 2007 in the Los Frailes Archipelago in northeastern Venezuela. Female maturity stages include nongravid (M1), gravid (M2), and postgravid (M3). Numbers in parentheses represent embryo size ranges (cm DW).

| Year | Month | Females | Immature | M1 | M2 | M3 | Males | Immature | Mature | Embryos | Females | Males | Mean DW (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | A | 29 | 18 | 5 | 2 | 4 | 6 | 2 | 4 | 2 | 2 | | 40.5 (40.0–41.0) |
| | S | 22 | 15 | 5 | 2 | | 4 | 1 | 3 | 3 | | 3 | 40.0 (39.7–40.6) |
| | O | 19 | 17 | 1 | 1 | | 2 | 2 | | 4 | 2 | 2 | 40.3 (38.5–41.5) |
| | N | 22 | 5 | 16 | 1 | | | | | | | | |
| | D | 17 | 13 | 3 | 1 | | 8 | 3 | 5 | 2 | 1 | 1 | 30.8 (21.5–40.0) |
| 2006 | J | 22 | 10 | 9 | 3 | | 8 | 2 | 6 | 3 | | 3 | 38.8 (37.0–39.8) |
| | F | 76 | 40 | 19 | 9 | 8 | 63 | 19 | 44 | 13 | 7 | 6 | 33.3 (11.5–44.5) |
| | M | 12 | 8 | 2 | | 2 | 8 | 5 | 3 | 1 | 1 | | 41.0 |
| | A | 119 | 75 | 32 | 7 | 5 | 65 | 40 | 25 | 4 | 1 | 3 | 37.6 (36.5–40.0) |
| | M | 90 | 46 | 35 | 6 | 3 | 20 | 8 | 12 | 8 | 5 | 3 | 27.9 (21.5–35.0) |
| | J | 10 | 8 | 2 | | | 4 | 1 | 3 | | | | |
| | J | 20 | 13 | 4 | 1 | 2 | 6 | 2 | 4 | 5 | 3 | 2 | 33.3 (26.0–40.0) |
| | A | 28 | 4 | 20 | 3 | 1 | | | | | | | |
| | S | 23 | 14 | 4 | 3 | 2 | | | | | | | |
| | O | 11 | 8 | 2 | 1 | | | | | | | | |
| | N | 4 | 3 | 1 | | | | | | | | | |
| | D | 21 | 16 | 4 | 1 | | | | | | | | |
| 2007 | J | 53 | 39 | 11 | 2 | 1 | 20 | 6 | 14 | 3 | 2 | 1 | 28.2 (27.5–29.2) |
| | F | 97 | 53 | 17 | 13 | 14 | 43 | 14 | 29 | 22 | 8 | 14 | 28.3 (10.8–39.0) |
| | M | 16 | 15 | | | 1 | 14 | 6 | 8 | | | | |
| | A | 11 | 7 | 3 | | 1 | 15 | 5 | 10 | | | | |
| | M | 11 | 4 | 6 | 1 | | 1 | | 1 | 1 | 1 | | 17.8 |
| | J | 4 | 2 | 2 | | | | | | | | | |
| | J | 22 | 9 | 9 | 3 | 1 | 11 | 3 | 8 | 9 | 4 | 5 | 26.7 (10.1–36.0) |
| | A | 39 | 22 | 16 | | 1 | 10 | | 10 | | | | |
| | S | 4 | 1 | 2 | | 1 | | | | | | | |
| | O | 26 | 2 | 10 | 1 | 13 | 9 | 6 | 3 | | | | |
| | N | 3 | 3 | — | | | | | | | | | |
| | D | 15 | 11 | 2 | | 2 | 4 | 2 | 2 | | | | |
| Total | | 846 | 481 | 242 | 61 | 62 | 321 | 127 | 194 | 80 | 37 | 43 | |

In our study of the small, directed fishery in northeastern Venezuela, data required to analyze fishing effort by considering the effects of net size, effective fishing time, and other factors, such as depth and location, were not collected. Hence, effort was expressed in number of trips, which is likely a biased estimate of effective fishing effort. In any case, the time series analyzed is too short to infer changes in population abundance. Almost 40 years ago, Ginés et al. (1972) mentioned that the overall abundance of rays, including the spotted eagle ray, in northeastern Venezuela had decreased. Decreases in abundance of *A. narinari* also were mentioned for the Colombian Caribbean (Correa and Manjarrés, 2004); the northern Gulf of Mexico (Shepherd and Myers, 2005), where it was last observed in 1980 in autumn demersal trawl surveys; and Campeche Bank in the southeastern Gulf of Mexico (Cuevas-Zimbrón et al., 2011), as well as globally for the *A. narinari* species complex. Nevertheless, our study area is apparently part of an important concentration area for *A. narinari* in the Caribbean. This species may do better in this area than in other areas in the western Atlantic, because large populations of bivalve and gastropod mollusks, which constitute the main food items in the diet of *A. narinari* (see Randall, 1967), are present in northeastern Venezuela (Ginés et al., 1972; Lodeiros-Seijo and Freites-Valbuena, 2008).

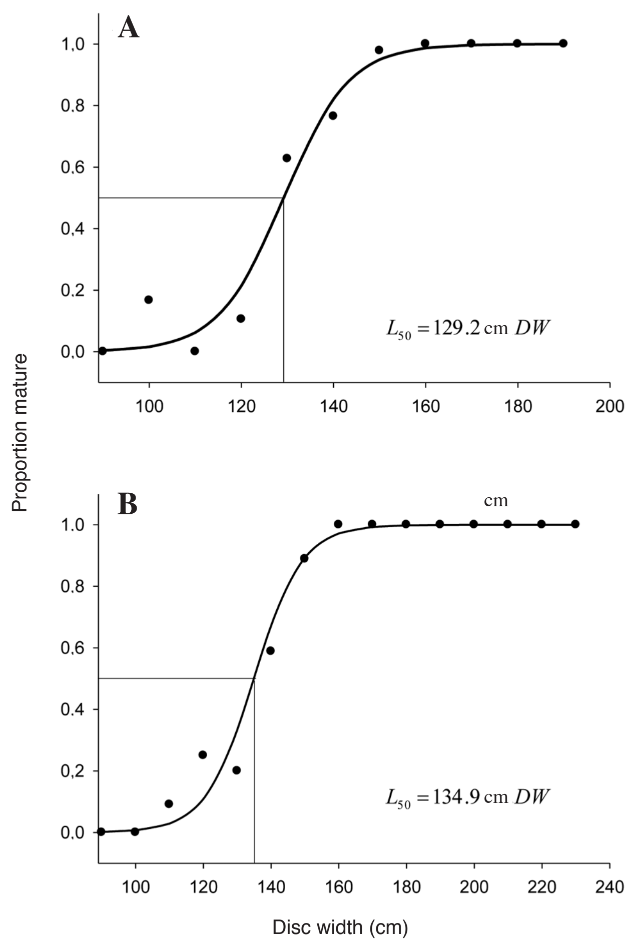


**Figure 4**

Length at maturity logistic functions for (**A**) male and (**B**) female individuals of *Aetobatus narinari* in the Los Frailes Archipelago during the period from August 2005 to December 2007. Horizontal and vertical lines indicate estimated length at 50% maturity ($L_{50}$) and value of $L_{50}$ is given.

### Length structure and length-weight relationships

In our study, females attained sizes larger than the sizes reached by males and were much more abundant than were males at lengths >160 cm DW. Differences in length distributions by sex have been reported in other areas of this species' range (Cuevas-Zimbrón et al., 2011). Additionally, growth studies on *A. narinari* indicate that females grow more slowly and reach larger sizes than do males (Dubick, 2000).

Males and females appear to be fully recruited to the fishery at 140 and 150 cm DW, respectively. Of *A. narinari* captured under 140 cm DW, ~37% were male and 19% were female. For both sexes, individuals <100 cm DW were rarely found in the fishery in the Los Frailes Archipelago. This absence may result from the selectivity of fishing gear or differential distribution of juveniles and adults. In the directed fishery in the southeastern Gulf of Mexico (Cuevas-Zimbrón et al., 2011), mesh openings (30.5–36.5 cm extended) are similar to the mesh sizes of nets used in northeastern Venezuela. However, despite the similar mesh openings used in both areas, *A. narinari* in the southeastern Gulf of Mexico, observed at lengths of 44–202 cm DW, included a higher proportion of juveniles than did the *A. narinari* observed in the Los Frailes Archipelago. Also, Cuevas-Zimbrón et al. (2011) reported size segregation in relation to distance from shore and depth in the southeastern Gulf of Mexico, with larger individuals predominating at distances of 30–50 km offshore (depths of 8–12 m) and smaller individuals predominating at distances of 8–15 km offshore (depths of 6–8 m). In northeastern Brazil, neonates and juveniles of *A. narinari* were caught close to the shore in shallow depths <10 m (Yokota and Lessa, 2006). Considering these results by Cuevas-Zimbrón et al. (2011) and Yokota and Lessa (2006) and considering that the typical height (8–10 m) of nets used around the Los Frailes Archipelago precludes their use in shallower waters, it is likely that differential distribution of juveniles and adults in relation to the fishery in northeastern Venezuela explains the absence of small individuals in our samples.

There were no significant statistical differences in the length-weight relationships of male and female *A. narinari*. To our knowledge, our study is the first reported comparison of this relationship for this species.

Our estimate of the slope (*b*) for males and females combined is similar to the one ($b$=3.13) reported by Torres (1991) for species of the *A. narinari* complex in South African waters.

### Sex ratio and reproductive period

In our study area, females were more abundant than males during most months of the period analyzed. Cuevas-Zimbrón et al. (2011) reported differences in sex ratios depending on depth and distance from shore in the southeastern Gulf of Mexico, where males were dominant in shallow waters close to shore and females were more abundant in deeper, more distant waters. Such spatial segregation by sex may explain the observed sex ratio patterns in our study. Additionally, sex ratios showed no significant differences in February, March, and June 2006 and March and April 2007; it is likely that these periods correspond to increased mating activities. Cuevas-Zimbrón et al. (2011) observed an increased proportion of adult females during March and April in the nearshore, shallow waters of Campeche Bank. These results indicate that migratory inshore–offshore movements relate to mating activity in adult *A. narinari*.

To our knowledge, this study is the first one to present *A. narinari* reproductive periodicity on an annual basis. Females in different maturity stages were found year round in the Los Frailes Archipelago. However, postgravid females were present in August 2005, February–May and July–September 2006, and January–April, July–October, and December 2007. Therefore, it appears that parturition occurs mainly during the periods of February–May and July–October. Similarly, Cervigón and Alcalá (1999) reported the presence of gravid females in March and April around the Los Roques Archipelago off central Venezuela. In India, gravid *A. ocellatus* females in "good number" were reported during April–May (Raje et al., 2007).

Schluessel et al. (2010b) observed mature oocytes and embryos in the same individual of *A. ocellatus*, and Uchida et al. (1990) reported that copulation followed immediately after parturition in aquarium conditions for *A. ocellatus*. For *A. narinari* in our study area, it is likely that mating occurs more intensely during February–May, considering the more balanced sex ratios and presence of postgravid females observed during this period.

### Fecundity and embryo lengths

Fecundity of *A. narinari* has been reported by different authors to be 1–4 embryos (Gudger, 1914; McEachran and de Carvalho, 2002), a level similar to the fecundity observed in *A. ocellatus* (*see* Devadoss, 1984; Uchida et al., 1990). In our study, 75% of gravid females had 3–5 embryos, and the remaining 25% had 1–2 embryos. These minimum values may have been caused by abortions associated with stress during the capture process. However, captive *A. ocellatus* have been observed to give birth to only 1 or 2 pups (Uchida et al., 1990). From our results, mean fecundity was 3.09 (SD=1.31) embryos per female. Additionally, no relationship was found between the length of gravid females and the number of embryos present. Gravid females of *A. narinari* had only one functional uterus in which all embryos were located—an observation also reported for *A. ocellatus* (see Schluessel et al., 2010b).

McEachran and de Carvalho (2002) indicated lengths at birth for *A. narinari* to be between 18 and 36 cm DW. In our study, the maximum embryonic length was 44.5 cm DW, and 40% of observed embryos were >36 cm DW. It is, therefore, likely that length at birth is >40 cm DW in our study area. This size is larger than the 30–40 cm DW reported for newborns in northeastern Brazil (Yokota and Lessa, 2006) but consistent with the 44 cm DW observed by Cuevas-Zimbrón et al. (2011) for neonates in the southeastern Gulf of Mexico.

### Size at sexual maturity

To our knowledge, there has been only one previous report of size at sexual maturity for *A. narinari*. Dubick (2000) estimated that size at maturity was 122 cm DW for males and 124 cm DW for females in southwestern Puerto Rico. These results are slightly lower than the lengths obtained for males in our study, $L_{50}$=129.2 cm DW (95% confidence interval [CI]=125–134.9 cm DW), and lower than the results we obtained for females, $L_{50}$=134.9 cm DW (CI=128.8–139.8 cm DW). For *A. ocellatus* in the western Pacific and Indian Oceans, size at first maturity for males has been estimated at 99.8 cm DW in Indonesia (White and Dharmadi, 2007), 130 cm DW in Australia and Taiwan (Schluessel et al., 2010b), and 135 cm DW in Madras, India (Raje et al., 2007). Female size at first maturity has been reported for Australia and Taiwan at >150 cm DW (Schluessel et al., 2010b) and for India at ~150 cm DW (Raje et al., 2007). Several factors may determine variations in estimates of length at first maturity: true differences between populations, sample size, sampling bias, differences or errors in assigning maturity stages, and estimation methods. Because *Aetobatus* spp. are captured mainly throughout their range as bycatch in industrial and artisanal fisheries, the collection of adequate sample sizes has been a major limitation in studying these species. For example, White and Dharmadi (2007) and Schluessel et al. (2010b) studied only 28 and 55 male *A. ocellatus*, respectively. In the study by Schluessel et al. (2010b) only 1 of 56 female individuals was mature and the length at maturity was estimated at >150 cm DW. The directed nature of the fishery for *A. narinari* in northeastern Venezuela allowed us to obtain a much larger sample than in previous studies of length at maturity of *Aetobatus* spp.

## Conclusions

*Aetobatus narinari* has been classified as near threatened in the IUCN Red List of Threatened Species. However, with the recent taxonomic changes within the species complex, the conservation status needs to be reviewed (White et al., 2010). For example, White et al. (2010) consider that *A. ocellatus* is more threatened than other members of this species complex, given that most threats listed for this complex have been from the Indo-Pacific region. Nevertheless, despite the paucity of data, there are indications in the western Atlantic that fishing has significantly affected the abundance of *A. narinari* (see Ginés et al., 1972; Claro et al., 2002; Correa and Manjarrés, 2004; Shepherd and Myers, 2005; Cuevas-Zimbrón et al., 2011). In particular, the small-scale, directed fisheries in the southern Gulf of Mexico and northeastern Venezuela that capture juvenile, mature, and pregnant individuals are a concern for the viability of these populations in areas where they are apparently still relatively abundant. An additional threat to *A. narinari*, which is associated with coral reefs, is habitat loss. Coral reef habitats in the western Atlantic have been declining over the most recent decades, with more than 75% of Caribbean reefs considered threatened (Burke et al., 2011).

In waters around Florida, the catch of *A. narinari* has been completely banned, but, to our knowledge, most countries of the western Atlantic have no specific regulations regarding the capture of *A. narinari*. In Venezuela, the fishery for *A. narinari* is unregulated and precautionary management measures may be necessary to assure population viability. In this study, we present results regarding length structure by sex, length-weight relationship, length at maturity, fecundity, size and sex ratio at birth, and reproductive periodicity—all of which represent important data for demographic modeling and stock assessment techniques that are required to develop management recommendations for the *A. narinari* fishery in northeastern Venezuela. However, more research is needed in this area, particularly regarding growth and mortality estimates, spatial and temporal changes in abundance, and migration patterns of *A. narinari*.

## Acknowledgments

The authors would like to thank the fishing crews that fished for spotted eagle ray in the community of Puerto Fermín for their collaboration.

## Literature cited


Bizarro, J., W. Smith, F. Márquez-Farías, and R. Hueter.
2007. Artisanal fisheries and reproductive biology of the golden cownose ray, *Rhinoptera steindachneri* Evermann and Jenkins, 1891, in the northern Mexican Pacific. Fish. Res. 84:137–146.

Burke, L., K. Reytar, M. Spalding, and A. Perry.
2011. Reefs at risk revisited, 114 p. World Resources Inst., Washington D.C.

Cervigón, F.
2005. La ictiofauna marina de Venezuela: una aproximación ecológica. Bol. Inst. Oceanogr. Venez. 44:3–28. [In Spanish.]

Cervigón, F., and A. Alcalá.
1999. Los peces marinos de Venezuela, vol. V, 230 p. Fundación Museo del Mar, Caracas, Venezuela. [In Spanish.]

Chen, Y., D. A. Jackson, and H. H. Harvey.
1992. A comparison of von Bertalanffy and polynomial functions in modeling fish growth data. Can. J. Fish. Aquat. Sci. 49:1228–1235.

Claro, R., J. A. Baisre, K. C. Lindeman, and J. A. García-Arteaga.
2002. Cuban fisheries: historical trends and current status. *In* Ecology of the marine fishes of Cuba (R. Claro, K.C. Lindeman, and L.R. Parenti, eds.), p. 194–219. Smithsonian Inst. Press, Washington, D.C.

Conrath, C.
2005. Reproductive biology. *In* Management techniques for elasmobranch fisheries (J. Musick, and R. Bonfil, eds.), p. 133–164. FAO Fish. Tech. Paper 474. FAO, Rome.

Correa, F., and L. Manjarrés.
2004. Recursos de peces demersales explotados por las pesquerías artesanales marítimas de La Guajira, Caribe Colombiano. *In* Pesquerías demersales del área norte de Colombia y parámetros biológico-pesqueros y poblacionales del recurso pargo (L. Manjarrés, ed.), p. 77–91. Univ. Magdalena, Santa Marta, Colombia. [In Spanish.]

Cuevas-Zimbrón, E., J.C. Pérez-Jiménez, and I. Méndez-Loeza.
2011. Spatial and seasonal variation in a target fishery for spotted eagle ray *Aetobatus narinari* in the southern Gulf of Mexico. Fish. Sci. 77:723–730.

Devadoss, P.
1984. On the incidental fishery of skates and rays off Calicut. Indian J. Fish. 31:285–292.

Dubick, J.D.
2000. Age and growth of the spotted eagle ray, *Aetobatus narinari* (Euphrasen, 1790), from southwest Puerto Rico with notes on its biology and life history. M.S. thesis, 158 p. Univ. Puerto Rico. Mayaguez.

Ginés, H., C. Angell, M. Méndez, G. Rodríguez, G. Febres, R. Gómez, J. Rubio, G. Pastor, and J. Otaola.
1972. Carta pesquera de Venezuela. Áreas del nororiente y Guayana, Monografía 16, 327 p. Fundación La Salle de Ciencias Naturales, Caracas. [In Spanish.]

González, L.W., N. Eslava, and F. Guevara.
2006. Catálogo de la pesca artesanal del estado Nueva Esparta, Venezuela, 222 p. Inst. Investigaciones Científicas, Univ. Oriente, Boca de Río, Venezuela. [In Spanish.]

Grijalba-Bendeck, M., C. Polo-Silva, and A. Acero
2007. Una aproximación a la abundancia de los batoideos capturados artesanalmente en Santa Marta (Colombia). Bol. Invest. Mar. Cost. 36:251–268. [In Spanish.]

Gudger, E. W.
1914. History of the spotted eagle ray, *Aëtobatus narinari*, together with a study of its external structures. Chapter XII *in* Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, vol. XI, publ. no. 183, p. 241–323. Carnegie Inst., Washington, D.C.

Iriarte, L.
1997. Embarcaciones, artes y métodos de pesca del estado Nueva Esparta, Monografía 42, 349 p. Fundación La Salle de Ciencias Naturales, Caracas, Venezuela. [In Spanish.]

Last, P. R., and J. D. Stevens.
2009. Sharks and rays of Australia, $2^{nd}$ ed., 656 p. CSIRO Publishing, Melbourne, Australia.
Lodeiros-Seijo C., and L. Freites-Valbuena.
2008. Estado actual y perspectivas del cultivo de moluscos bivalvos en Venezuela. *In* Estado actual del cultivo y manejo de moluscos bivalvos y su proyección futura: factores que afectan su sustentabilidad en América Latina (A. Lovatelli, A. Farías, and I. Uriarte, eds.), p. 135–150. Taller Técnico Regional de la FAO. 20–24 de agosto de 2007, Puerto Montt, Chile. FAO Actas de Pesca y Acuicultura, no. 12. FAO, Rome. [In Spanish.]
McEachran, J. D., and M. R. de Carvalho.
2002. Batoid fishes. *In* The living marine resources of the western Central Atlantic, vol. 1: Introduction, molluscs, crustaceans, hagfishes, sharks, batoid fishes and chimaeras (K. E. Carpenter, ed.), p. 508–589. FAO species identification guides for fishery purposes and American Society of Ichthyologists and Herpetologists, special publication no. 5. FAO, Rome.
Méndez-Arocha, A.
1963. La pesca en Margarita, Monografía 7, 267 p.Estación de Investigaciones Marinas de Margarita, Fundación La Salle de Ciencias Naturales, Caracas, Venezuela. [In Spanish.]
Pratt, H.
1979. Reproductive biology in the blue shark, *Prionace glauca*. Fish. Bull. 77:445–470.
R Development Core Team.
2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. [Available from http://www.r-project.org/, accessed May 2011.]
Raje, S. G., S. Sivakami, G. Mohanraj, P. P. Manoj-Kumar, A. Raju, and K. K. Joshi
2007. An atlas of the elasmobranch fishery resources of India, Special Publication 95, 253 p. Central Marine Fisheries Res. Inst., Indian Council of Agricultural Research, Kochi, India.
Randall, J. E.
1967. Food habits of reef fishes of the West Indies. Stud. Trop. Oceanogr. 5:665–847.
Richards, V. P., M. Henning, W. Witzell, and M. S. Shivji.
2009. Species delineation and evolutionary history of the globally distributed spotted eagle ray (*Aetobatus narinari*). J. Hered. 100:273–283.
Schluessel, V., M. B. Bennett, S. P. Collin, and J. Ovenden.
2010a. Evidence for extensive population structure in the white-spotted eagle ray within the Indo-Pacific, inferred from mitochondrial gene sequences. J. Zool.281: 46–55.
Schluessel, V., M. B. Bennett, and S. P. Collin.
2010b. Diet and reproduction of the white-spotted eagle ray *Aetobatus narinari* from Queensland, Australia and the Penghu Islands, Taiwan. Mar. Freshw. Res. 61:1278–1289.
Shepherd, T. D., and R. A. Myers.
2005. Direct and indirect fishery effects on small coastal elasmobranchs in the northern Gulf of Mexico. Ecol. Lett. 8:1095–1104.
Stobutzki, I. C., M. J. Miller, D. S. Heales, and D. T. Brewer.
2002. Sustainability of elasmobranchs caught as bycatch in a tropical prawn (shrimp) trawl fishery. Fish. Bull. 100:800–821.
Torres, F. S. B., Jr.
1991. Tabular data on marine fishes from Southern Africa, Part I. Length-weight relationships. Fishbyte 9:50–53.
Trent, L., D. E. Parshley, and J. K. Carlson.
1997. Catch and bycatch in the shark drift gillnet fishery off Georgia and east Florida. Mar. Fish. Rev. 59:19–28.
Uchida, S., M. Toda, and Y. Kamei.
1990. Reproduction of elasmobranchs in captivity. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H. L. Pratt, S. H. Gruber, and T. Taniuchi, eds.), p. 211–237. NOAA Tech. Rep. NMFS 90.
Venzon, D. J., and S. H. Moolgavkar.
1988. A method for computing profile-likelihood-based confidence intervals. Appl. Stat. 37:87–94.
Welch, D. W., and R. P. Foucher.
1988. A maximum likelihood methodology for estimating length-at-maturity with application to Pacific cod (*Gadus macrocephalus*) population dynamics. Can. J. Fish. Aquat. Sci. 45:333–343.
White, W. T., and Dharmadi [no initials].
2007. Species and size compositions and reproductive biology of rays (Chondrichthyes, Batoidea) caught in target and non-target fisheries in eastern Indonesia. J. Fish Biol.70:1809–1837.
White, W. T., P. R. Last, G. J. P. Naylor, K. Jensen, and J. N. Caira.
2010. Clarification of *Aetobatus ocellatus* (Kuhl, 1823) as a valid species, and a comparison with *Aetobatus narinari* (Euphrasen, 1790) (Rajiformes: Myliobatidae). *In* Descriptions of new sharks and rays from Borneo (P. R. Last, W. T. White, and J. J. Pogonoski, eds.), p. 141–164. CSIRO Marine and Atmospheric Res. paper no. 032. CSIRO, Australia.
Yokota, L., and R. P. Lessa
2006. A nursery area for sharks and rays in northeastern Brazil. Env. Biol. Fish. 75:349–360.
Zar, J.
1996. Biostatistical analysis, 662 p. Prentice Hall, Upper Saddle River, NJ.