Biology of *Myliobatis goodei* (Springer, 1939), a widely distributed eagle ray, caught in northern Patagonia

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ARTICLE INFO

ABSTRACT

Chondrichthyans play an important role in structuring marine communities. *Myliobatis goodie* is an eagle ray reported from South Carolina in the USA (35°N) to Santa Cuz, Argentina (44°S), however little is known about this species, which is considered data deficient by the IUCN. In order to create adequate management strategies for this species, biological information is sorely needed. The objective of this study was to describe the biology of the population of *M. goodei* and its relationships with season, sex and the geographic features of Anegada Bay, Argentina (from 39.96°S to 40.60°S and from 62.10°W to 62.46°W) in 2008. Specifically, the population structure of *M. goodie* was studied by sex, seasons and sites, its food habits by seasons and sites, and the reproductive biology by seasons and sex. The results show that *M. goodei* exhibits seasonal migrations. Young-of-the-year remain in the bay all year long, while adults enter during spring and summer. Juveniles in spring are likely to become first-time mating individuals that migrate into open sea at the end of summer. These individuals would return to give birth for the first time and mate for the second time during the next year at summer. Anegada Bay would then be a mating and nursery area for the species. *M. goodei* behave as a generalist feeder with a uniform diet composed mainly of bivalves. Seasonal differences in the diet found arise from differences in prey diversity between summer and spring. Spatial differences, however, arise from the different abundances of caprellids and bivalves. Trophic level was 3.2 and it constitutes the first reference for this species, characterizing it as a secondary consumer.

1. Introduction

Chondrichthyans are a relatively conserved group of fishes that have successfully functioned in diverse marine ecosystems for over 400 million years (Camhi et al., 2007). Rays and skates play an important role in structuring marine communities by influencing mortality rates and behavior of mesoconsumers and other organisms (Heithaus et al., 2008) and are also mesoconsumers or primary consumers, feeding on planktonic organisms (Ebert and Stehmann, 2013; McEachran and de Carvalho, 2002), as well as top predators, in the case of some skate species (Ebert and Bizzarro, 2007). The life history of these fishes is characterized by late maturity, long life spans, long gestation periods and few well developed offspring (Dulvy et al., 2008; Estalles et al., 2011; Mabragaña et al., 2002). Additionally, some rays gather in schools by age, sex and reproductive states, while others have restricted distributions (Barker and Schluessel, 2005). These life history traits confer a low intrinsic rate of population increase and growth, rendering rays and skates extremely vulnerable to fishing mortality (Bonfil, 1994; Brander, 1981; Cedrola et al., 2005; Dulvy et al., 2008). From the 150 species of rays and skates monitored by the International Union for the Conservation of Nature (IUCN), 12.67% were reported to be Near Threatened, 17.34% Vulnerable, 6% Endangered and 2% Critically Endangered. This means that approximately 38% of the total ray and skates species are facing major conservation threats, while only 20% is presented as Least Concern. However, these numbers might be offset by the greater proportion of species declared data deficient (48%), for which there is simply insufficient validated information available about their status and threats (based on an analysis conducted by J. Molina on May 15, 2013)[1]. This is the case for *Myliobatis goodie*, commonly known as Atlantic eagle ray.

The bibliography available about *M. goodei* consists of a taxonomic description published by Refi (1975) and a biological study conducted by Ruocco (2012). Other information available are about uterine dynamics (Colonello et al., 2013), the species bycatch levels (Mendoza et al., 2003; Vooren and Klippel, 2005) and parasitic fauna (Brooks et al., 1981; Ivanov and Campbell, 1998). The existing literature reports

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[1] All batoidea species listed in the IUCN red list of endangered species until 2012 were analyzed. Species conservation category, population status and threat information were extracted and used to create a database, from which percentage of each threat category was calculated to assess the state of knowledge on rays biology.

110 cm maximum disc width, 130 cm maximum length (Ruocco, 2012) and a distribution that ranges from South Carolina in the United States of America (35°N) to Santa Cruz, Argentina (44°S) (Stehmann, 2009). It tolerates wide ranges of salinity, being reported in both estuarine and marine waters (Lopez Cazorla, 1987; Refi, 1975). In order to create adequate management strategies for this species, biological information is sorely needed. This article aims to provide up to date information on the diet, reproduction and other important population variables of *M. goodei* in a location of its southern distribution. Threats to these species and the state of its populations have not been evaluated by the IUCN, but Ruocco (2012) reports a decrease in its abundance in the last ten years.

We hypothesize that the population of *M. goodei* from Anegada Bay presents seasonal and spatial variations in its population parameters. In order to test this hypothesis, the objectives of this study were to describe the seasonal occurrence and population structure, estimate some reproductive parameters and study the diet composition of the population of *M. goodei* from Anegada Bay. Specifically, we aim to explore the population structure of *M. goodie* by sex, seasons and sites, the reproductive parameters by seasons and sex, and its food habits by seasons and sites.

2. Materials and methods

2.1. Study area

Anegada Bay, located in the south of Buenos Aires province, Argentina (from 39.96°S to 40.60°S and from 62.10°W to 62.46°W), is an integral natural reserve under the multiple usage category. It has an important ecological value due to great biodiversity and high environmental complexity, composed of diverse aquatic environments, with wide muddy intertidals, sandy bottom beds, islands and sand and gravel beaches. Commercial and sport fishing and tourism are the principal human activities in the Bay. However in recent years, commercial fishing has been prohibited within the boundaries of the reserve.

This study was conducted in the southern part of the Bay, characterized by San Blas tidal channel, where three sampling stations were placed. This channel is 2.5 km wide and 12 km long and has a maximum depth of 28 m. "San Blas" station (40.5307°S, 62.2249°W) was close to

Omega island, on the northern flank of the channel, where the sampling depth ranged from 3 to 4.5 m. "Ría" station (40.5211°S, 62.3182°W) was placed at the mouth of Jabalí stream, with depths ranging from 0.8 to 3 m. "Los Pocitos" station (40.466° S, 62.366° W) was placed on the southern flank, near the fisher's village with the same name, on the inner part of the Bay. In this site, the samples were obtained from depths ranging from 2.8 to 6.4 m. Bottom sediments at San Blas are comprised of unconsolidated sand, while at Los Pocitos, they are consolidated fine-sand sediment. Bottom sediments at Ría share characteristics with the other two sites (Fig. 1) (Cuadrado and Gómez, 2010). Distance between San Blas–Ría and Ría–Los Pocitos was approximately 8 km, and between San Blas–Los Pocitos it was close to 14 km.

2.2. Sampling methods and data collection

Specimens of *M. goodei* were collected with seasonal frequency from February (summer) to November (spring) of 2008. The fishing gear consisted of two batteries of seven gill nets. Each net was 25 m long and 2 m height with different mesh sizes (64, 70, 80, 105, 135, 150 and 170 mm stretched). Nets were placed parallel to the coast at the bottom in each of the sample stations described in Section 2.1, at dusk, and retrieved 12 h later, at dawn.

Disc width (Dw) of all rays was measured in situ to the nearest cm and subsequently individuals were grouped into 1-cm size classes. A subsample composed of ten randomly selected specimens of each size-class was used for further analysis. Each specimen was measured (Dw, in mm), weighed (total weight, W, in g), sexed and the maturity stage was determined macroscopically (immature or mature; Sidders et al., 2005). Females were classified as mature when the ovaries exhibited yellow follicles. Males were considered mature if they showed totally calcified claspers. Gonads were weighted (Gw, in g) with a 0.1 g precision. Stomachs were taken from each fish, kept in plastic bags and frozen at −15 °C for subsequent examination in the laboratory. Evidence of regurgitation was not observed in any of the fish sampled.

In the laboratory, the samples of the day were defrosted to be analyzed. Each stomach content was sorted, counted, weighed and identified to the lowest possible taxon using identification keys (Boschi et al., 1992). The unidentifiable material was weighed and labeled "Remains" and was not used for further analysis.
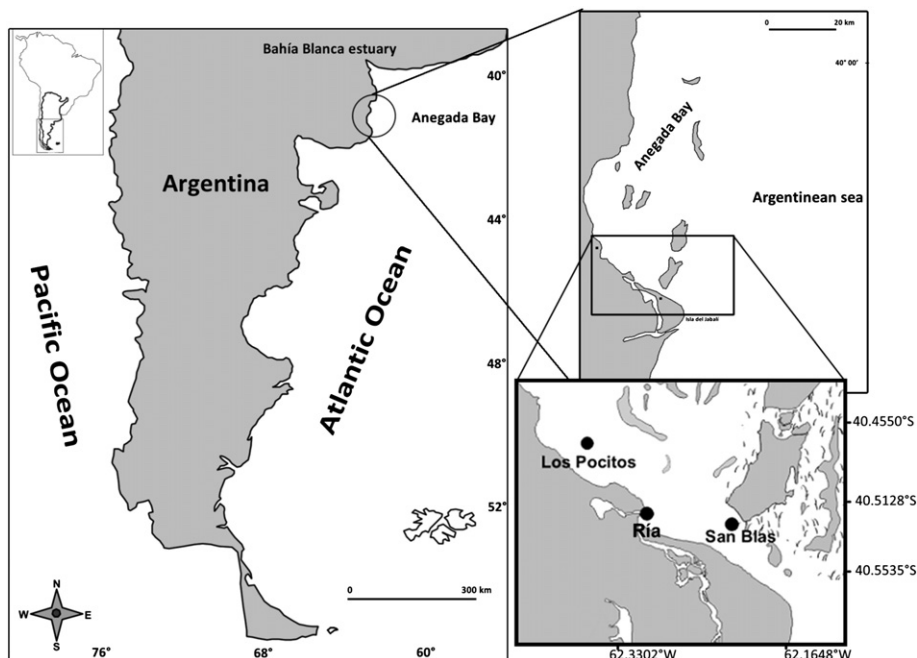

Fig. 1. Study site in Anegada Bay, Buenos Aires, Argentina.

2.3. Morphometrics

Mean, standard deviation and mode of the Dw for each season and sample site were calculated for the entire sample and for the subsample. Given a normal fit of data (Shapiro–Wilk test, P > 0.05), two-way ANOVA test was used to assess differences in mean Dw between seasons and sites using the total sample data. Summer and spring size frequency distributions were compared with a two-sample Kolmogorov–Smirnov test (Crawley, 2007). Disc width–weight relationship was obtained for each sex and season applying the following model:

$$W = a \cdot Dw^b$$

where a is the intercept and b is the allometry coefficient or slope. These parameters were determined by means of nonlinear least squares method (Bates and Chambers, 1992). Differences on the Dw–W relationship between sexes and seasons were tested with ANCOVA (Zar, 1999).

2.4. Reproductive parameters

Gonadosomatic index (GSI) was employed to describe the reproductive seasonal behavior of M. goodei. This index was calculated for each fish following Vazzoler (1981):

$$GSI = 100 \cdot Gw/W - Gw.$$

Mean GSI was calculated for each sex and season. Seasonal differences in mean GSI for each sex were analyzed with t-student test (Zar, 1999).

To determine if a given individual has attained sexual maturity as a function of body size, Dw at first maturity (Dw_{50}) was estimated fitting a logistic model to binomial-maturity data (immature = 0, mature = 1):

$$Y = \left(1 + e^{(-a+bDw_{50})}\right)^{-1}$$

where Y is the proportion of mature individuals, a and b are the position and slope parameters, estimated by a numerical search algorithm that maximized the logarithm of the likehood function assuming a normal error distribution (Welch and Foucher, 1988). Dw_{50} is given by $-a/b$ (Mollet et al., 2000). Chi-square statistic was used to test differences between sexes (Zar, 1999). Specimens with sizes corresponding to less than Dw_{50} size were referred to as juveniles and specimens larger than Dw_{50} as adults. The relative abundance of each group was estimated for each sex and season.

2.5. Trophic ecology

Cumulative prey curves were used to determine whether an adequate number of stomachs had been examined to describe the diet precisely. The order in which stomachs were analyzed was randomized 500 times to minimize bias resulting from sampling order. Shannon diversity index and its standard deviation were plotted against the total number of stomachs analyzed (Bizzarro et al., 2007). The asymptote of the curve indicated the minimum sample size required to adequately describe the diet (Ferry and Cailliet, 1996). These calculations were performed using EstimateS software (Colwell, 2013). The curves were generated to the lowest taxonomic level of the prey.

2.5.1. Dietary structure

Diet composition was examined using the Prey-Specific Index of Relative Importance (PSIRI) (Brown et al., 2012) which summarizes the information obtained by three different quantification methods:

$$PSIRI = 0.5 \cdot \%O \cdot (\%Ni + \%Wi)$$

where $\%O$ is the percentage frequency of occurrence of each item, meaning the number of times that a given prey item appears in the total number of stomachs with content, expressed as a percentage, $\%Ni$ is the prey specific numeric abundance of food items (defined as the percent numerical abundance of a prey item averaged over the stomach samples in which it occurs) and $\%W$ is the prey specific wet weight abundance calculated for each food item. These indices were calculated for the lowest possible taxon identified and were also calculated for the main prey categories: Amphipoda, Isopoda, Stomatopoda, Decapoda, Polychaeta, Gasteropoda and Bivalvia.

Normality of diet composition data was tested with a Shapiro–Wilk test (Shapiro and Wilk, 1965). Given the lack of a normal fit (Shapiro–Wilk test, P < 0.001), dietary composition shifts among seasons and sites were analyzed with a two way permutation multivariate analysis of variance (PERMANOVA) (Anderson et al., 2006). The binomial dissimilarity index was selected for constructing the distance matrix, as it accounts for the deficiencies in normality that abundance data often exhibits (Anderson, 2004). Weight data was used to calculate the binomial dissimilarity matrix. The P-values were obtained after 4999 random permutations of the data matrix. If significant differences were found, permutational pairwise comparisons were performed (Anderson et al., 2006; Crawley, 2007). Where no significant differences were found, data were grouped for further analysis. All tests used a significance level of α ≤ 0.05.

2.5.2. Feeding strategy and trophic level

The feeding behavior of M. goodie was evaluated according to a modification of the Costello graphic method, in which the percentage prey specific abundance ($\%Pi$) was plotted against the percentage frequency of occurrence ($\%F$) (Amundsen et al., 1996). The $\%Pi$ was calculated as the wet weight of a prey item i divided by the total weight of prey in the stomachs that contained prey item i, expressed as percentage. Preys located at the upper right of the diagram would indicate a narrow niche breadth (i.e. a specialized predator), but if most prey points were located along or below the diagonal from the upper left to the lower right of the plot, the trophic niche breadth would be broad (i.e. generalist predator). Preys located on the upper left corner of the graph indicate specialized individual predators, while preys on the lower right corner will have been eaten occasionally by most individuals in the population. This graphical representation was also used to analyze prey importance.

The trophic level (TL) of M. goodei was calculated according to Cortés (1999).

$$TL = 1 + \left(\sum_{j=1}^{n} Pj \cdot TLj\right)$$

where Pj is the proportion of prey taxon j in the predator stomach, calculated as weight, TLj is the trophic level of each prey taxon j (taken from Cortés, 1999) and n is the number of prey taxon recorded in the predator stomach.

Estimations and statistical analysis were performed using R statistical software (R Development Core Team, 2013).

3. Results

3.1. Morphometrics

A total of 248 individuals of M. goodie were captured, only in summer in Los Pocitos and San Blas and in spring in the three sampling sites. Some individuals have been partially eaten by isopods when the nets were retrieved (n = 39), these specimens were not considered in subsequent analyses, except in Fig. 2. Dw for the sample ranged from 200 to 700 mm (mean ± s.d: 462.2 mm ± 85.8 mm; mode: 470 mm). Range, mean and standard deviation of the Dw for each season and
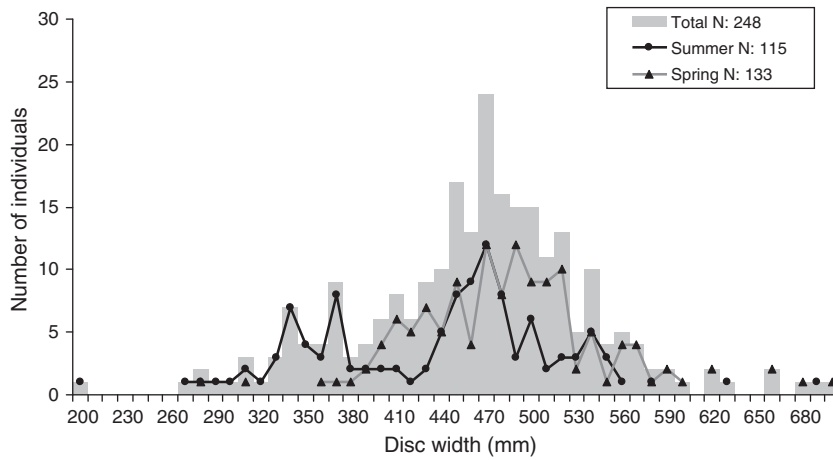
Fig. 2. Total and seasonal size frequency distribution of *Myliobatis goodei* in Anegada Bay during February–November 2008.

sampling site are presented in Table 1. Spring showed a significantly higher mean than summer (P < 0.05), while there were no differences in mean Dw between sites (P > 0.05; Table 1). Smaller sizes were better represented in summer while size distribution in spring showed a higher frequency of larger eagle rays (Fig. 2). These differences were highly significant (Kolmogorov–Smirnov statistic = 0.2976, P < 0.001).

Within each season, there were no differences in the Dw–W relationship between sexes (ANCOVA test, summer: $F = 3.99$, $DF = 54$, $P = 0.09$; spring: $F = 0.62$, $DF = 120$, P = 0.43). The relationship in summer was isometric for both sexes of *M. goodei* (t-test, males: $t = 1.31 < t_{0.05, n: 48} = 2.022$; females: $t = 1.94 < t_{0.05, n: 18} = 2.093$) (Fig. 3a) while in spring it was positive allometric for males (t-test, males: $t = 3.12 > t_{0.05, n: 76} = 1.992$) and isometric for females (t-test, females: $t = 1.24 > t_{0.05, n: 48} = 2.022$) (Fig. 3b).

Total population showed seasonal differences in the Dw–W relationship (ANCOVA test,: $F = 8.19$, $DF = 178$, P < 0.05). The growth in summer was positive allometric (t-test, $t = 2.91 > t_{0.05, n: 66} = 2.008$) while in spring it was isometric (t-test, $t = 1.94 < t_{0.05, n: 124} = 1.980$; Fig. 3c).

3.2. Reproductive biology

Mean GSI of *M. goodei* presented significant seasonal variations in both sexes (t-test, males: $t = 2.419 > t_{0.05, n: 109} = 2.364$; females $t = 2.871 > t_{0.05, n: 48} = 2.021$), where the higher values were registered in summer (males: 1.5 vs 0.58; females: 1.25 vs 0.68). Dw_{50} estimated on the basis of maturity stages was 487 and 450.2 mm Dw for females and males respectively. Size intervals used for these estimations were 350–697 mm and 350–605 mm for females and males respectively. No differences in DW_{50} were found between sexes (P > 0.05). Juveniles were smaller and more abundant in summer than in spring. The percentage of juveniles determined with the Dw_{50} was 75% for females (mean ± s.d Dw: 366.8 ± 57.2 mm) and 32% for males (mean ± s.d Dw: 389.8 ± 48.8 mm) in summer and 41.3% for females (mean Dw ± s.d: 424.6 ± 48.1 mm) and 22.9% for males (mean Dw ± s.d: 408.7 ± 37.1 mm) in spring.

We found pregnant females carrying highly developed pups in their uteri and two recently born specimens (205 and 220 mm DW) in summer.

3.3. Torphic ecology

We analyzed 144 stomachs of *M. goodie* from which 33 (22.9%) were empty (Table 2).

The minimum number of samples required to adequately describe the diet of *M. goodei* in summer was 10 in Los Pocitos and 11 in San Blas and in spring was 13 in Los Pocitos and 11 in San Blas (Fig. 4).

3.3.1. Dietary structure

The diet of *M. goodei* was composed of 16 items of which 9 were identified to species level, 5 to genera level and 2 to family level.

The total diet was mainly composed of bivalves, followed by amphipods and polychaetes (Table 3). Diet composition showed significant differences between seasons ($F = 5.47$; $P = 0.034$) and sites ($F = 5.70$; P = 0.031). Interactions between factors presented no differences ($F = 2.15$; $P = 0.191$). Summer prey composition was dominated by bivalves in Los Pocitos and San Blas (mainly *Lasaea* sp. and *Solen techuelchus*), but for San Blas site amphipods rose in importance (Table 3). In spring, *Lasaea* sp. and *S. techuelchus* were also dominant in Los Pocitos, while in San Blas bivalves were less important and showed more diversity, with polychaetes and amphipods being the second and third most important items (Table 3). Other prey items presented less than 5% of PSIRI.

3.3.2. Feeding strategy and trophic level

M. goodei presented an individual specialization strategy, with high %Pi and low %Fi for the majority of preys (Fig. 5), related with a high between phenotype contribution to the niche width. There was a weak population specialization for *S. techuelchus* at Los Pocitos in both seasons and for *Lasaea* sp. at San Blas in summer (Fig. 5a, b and c). *S. techuelchus*, *Lasaea* sp. and Caprellids presented high %Pi at all sites in both seasons

Table 1
Disc width (Dw) range, mean Dw and standard deviation (s.d.) of *Myliobatis goodei* sample and subsample for each season and site in Anegada Bay during February–November 2008. n: number of individuals. Different lower case letters indicate significant differences in mean Dw (P < 0.05).

Season	Site	Sample (n: 209)			Subsample (n: 190)		
		Range	Mean Dw ± s.d	n	Range	Mean Dw ± s.d	n
Summer	Los Pocitos	200–630	427.3 ± 104.1	23a	266–565	430.9 ± 77.1	18
	San Blas	275–697	449.6 ± 80.3	53a	275–697	449.6 ± 80.3	48
Spring	Los Pocitos	280–605	470 ± 76.2	32b	294–605	482.3 ± 79.9	30
	Ría	310–680	497.4 ± 91.2	50b	322–680	505.2 ± 66.5	48
	San Blas	360–700	473.3 ± 77.4	51b	382–671	479.5 ± 51.7	46

a)

Females W = 4×10^{-6}Dw$^{3.23}$
R^2 = 0.89 n:18

Males W = 4×10^{-5}Dw$^{3.05}$
R^2 = 0.96 n:48

b)

Females W = 2×10^{-5}Dw$^{3.01}$
R^2 = 0.97 n:48

Males W = 3×10^{-6}Dw$^{3.29}$
R^2 = 0.92 n:76

c)

Summer W = 5×10^{-6}Dw$^{3.21}$
R^2 = 0.92 n: 66

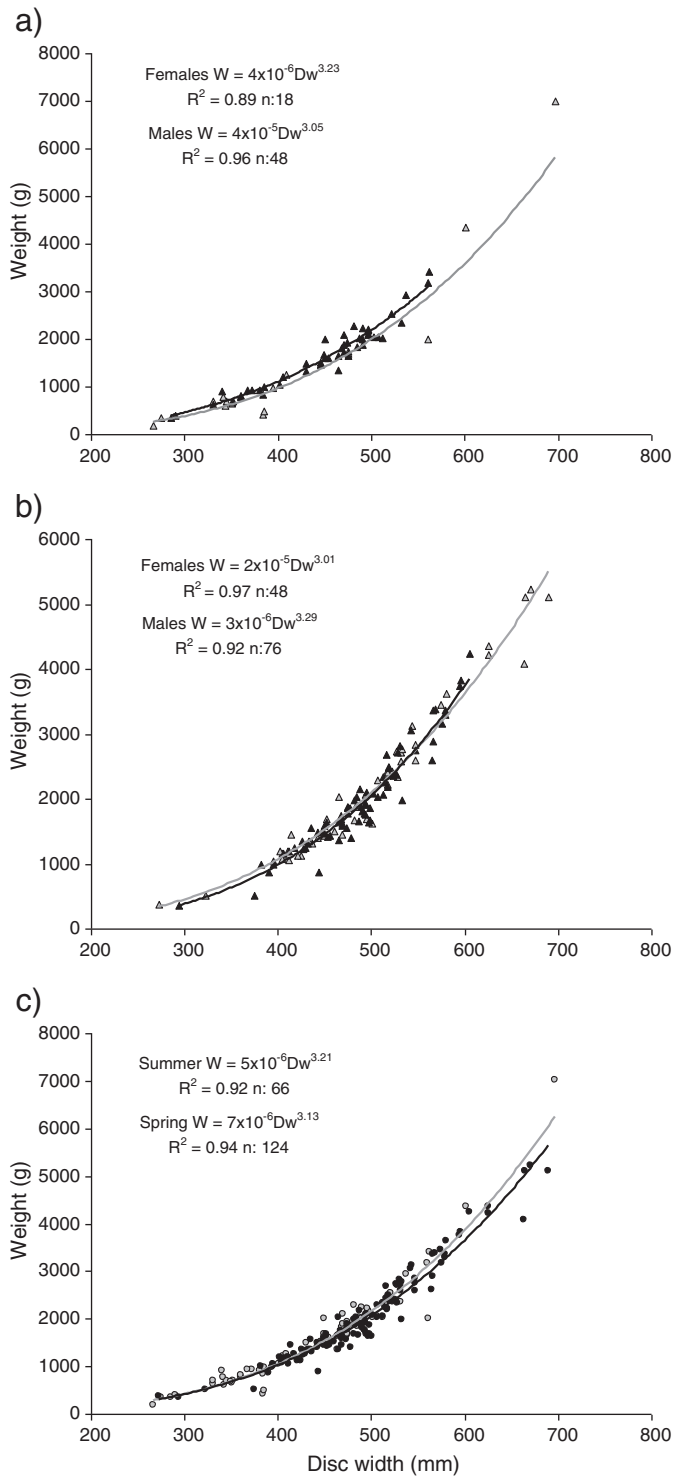Spring W = 7×10^{-6}Dw$^{3.13}$
R^2 = 0.94 n: 124

Fig. 3. Disc width–weight relationship by sex in summer (a) and spring (b) and by season (c) of *Myliobatis goodei* in Anegada Bay during February–November 2008. Females: ▲—; males: ▲—; summer: ○—; spring: ●—.

(>60%; Fig. 5). Individuals captured at San Blas in spring were characterized by a high abundance of different preys in their stomachs, as evidenced by the low frequency and high %Pi values (Fig. 5d).

Trophic level for *M. goodie* in Anegada Bay was 3.2.

4. Discussion

M. goodei was present in Anegada Bay only in spring and summer, suggesting that it spends the other seasons away from this region.

Table 2
Number of stomachs of *Myliobatis goodie* analyzed during February–November 2008 in Anegada Bay, discriminated by season and location. n_c: number of stomachs with content; n_e: number of empty stomachs; n_{c+v}: total number of stomachs.

Seasons	Summer		Spring		Total
Locations	Los Pocitos	San Blas	Los Pocitos	San Blas	
n_c	19	18	21	53	111
n_e	3	8	12	10	33
n_{c+v}	22	26	33	63	144

Migration to protected areas, like bays and estuaries, allows neonates and juveniles to easily find food and shelter, providing effective protection against predators and optimum conditions for development (Castro, 1993; Simpfendorfer and Milward, 1993). This migrating behavior of *M. goodei* was also reported by Jaureguizar et al. (2003) and Lopez Cazorla (1987) in Río de la Plata and Bahía Blanca estuaries respectively, also within the warm seasons (spring and summer). Ruocco (2012) reports the greatest peak of abundance, along the coastal waters of Buenos Aires province, between November and the end of December (spring).

Size range of *M. goodei* in Anegada Bay was different from what is presented by Ruocco (2012). This author presents maximum Dw of 1100 mm, while in our study the maximum Dw observed was 700 mm. Regardless of this difference, in both studies female *M. goodei* presented larger size and weight than males (In this study, males = Dw: 285–600, W:340–4240 and females = DW: 266–700, W: 188–7010; in Ruocco, 2012, males = Dw: 211–645, W:200–6000 and females = DW: 198–1100, W: 200–19,000). Differences in size between sexes are a widespread sexual dimorphism type in elasmobranches (Bullis and Struhsaker, 1961; Capapé, 1993; Pierce et al., 2009; Santos and de Carvalho, 2004; Seck et al., 2004). As in the present study, no differences in Dw–W relationship between sexes were found by Ruocco (2012). Additionally, the allometry coefficient presented by this author is similar to the one estimated in the present study.

Larger juveniles found in spring suggest that the young of the year remains in Anegada Bay all year long, as happens in other protected areas for other species of elasmobranches inhabiting Bahía Blanca estuary, Río de la Plata estuary and Anegada Bay (Colautti et al., 2010; Jaureguizar et al., 2003; Lopez Cazorla, 1987; Molina and Lopez Cazorla, 2011), while adults of *M. goodie* enter the bay during spring and summer. By means of the GSI values it can be inferred that the mating and spawning season for *M. goodei* in Anegada Bay may occur in summer, although a complete series of GSI values for a complete year would be needed to accurately demonstrate this. The presence of mature males and pregnant females with highly developed embryos in the uterus in summer, and recently born pups would imply that they became pregnant immediately after parturition, given that the Myliobatidae family is not known to present sperm reserves (Hamlett, 1999). Additionally, other species such as *Myliobatis californica* is known to have gestation periods of one year (Martin and Cailliet, 1988), therefore, it is likely that *M. goodei* behave similarly. Gestation period has not yet been determined for this species; however Ruocco (2012) presents evidence that would support our conclusions.

The disc width seasonal progression of juveniles and the size of first maturity estimated, close to the mean Dw of spring juveniles, would suggest that some of these could be considered as first-time mating individuals that migrate into open sea during late summer and early autumn. These individuals would return to give birth for the first time and mate for the second time during the next year at summer. The greater number of juvenile fish captured in summer strengthens the conclusion of this as the spawning season for the species. The information so far presented suggests that Anegada Bay represents a mating and nursery area for *M. goodei*.
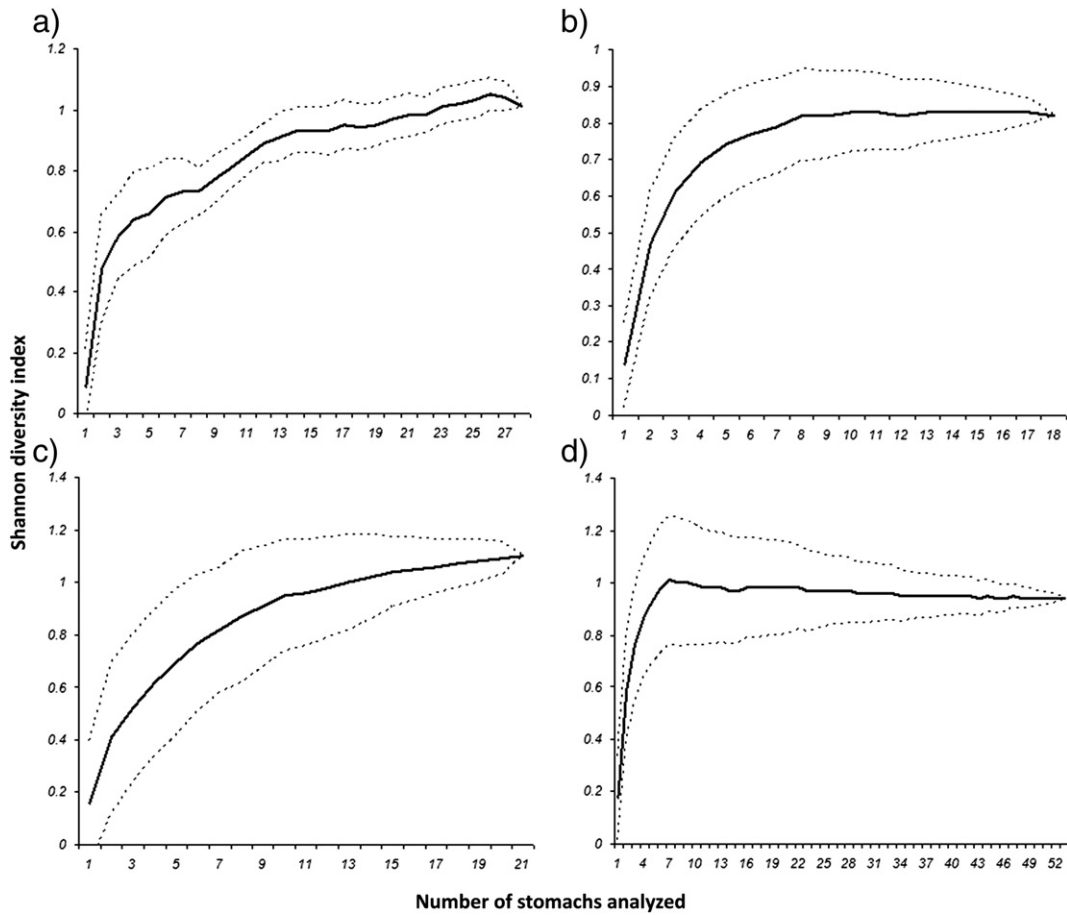
Fig. 4. Cumulative prey curves for *Myliobatis goodei* in Anegada Bay in summer at Los Pocitos (a) and San Blas (b) and in spring at Los Pocitos (c) and San Blas (d). The black line is the Shannon diversity index and the dashed lines are standard deviations.

Table 3
Percentage of frequency of occurrence (%O), prey-specific number abundance (%Ni), prey-specific weight abundance (%Wi) and Prey-Specific Index of relative Importance (%PSIRI) for each prey item by season, location and the total sample of *Myliobatis goodei* in Anegada Bay during February–November 2008.

| | Summer | | | | | | | | Spring | | | | | | | | Total | | | |
| | Los Pocitos | | | | San Blas | | | | Los Pocitos | | | | San Blas | | | | | | | |
	%O	%Ni	%Wi	%PSIRI	%O	%Ni	%Wi	%PSIRI	%O	%Ni	%Wi	%PSIRI	%O	%Ni	%Wi	%PSIRI	%O	%Ni	%Wi	%PSIRI
Crustacea																				
Amphipoda	6.9	96.4	97.7	6.7	29.4	93.4	83.8	26.1	14.3	92.9	82.2	12.5	20.8	98.1	79.8	19.7	17.5	96.3	81.6	15.6
Caprellidae	6.9	96.4	97.7	6.7	29.4	93.4	83.8	26.1	14.3	92.9	82.2	12.5	20.8	98.1	79.8	19.7	17.5	96.3	81.6	15.6
Isopoda	3.4	0.8	1.3	<0.1	11.8	4.1	2.3	0.4	4.8	4.1	0.4	0.1	3.8	7.0	16.9	0.5	5.0	3.7	4.3	0.2
Cirolana sp.	3.4	0.8	1.3	<0.1	11.8	4.1	2.3	0.4	4.8	4.1	0.4	0.1	3.8	7.0	16.9	0.5	5.0	3.7	4.3	0.2
Stomatopoda	3.4	50.0	79.2	2.2													0.8	50.0	79.2	0.5
Pterygosquilla armata	3.4	50.0	79.2	2.2													0.8	50.0	79.2	0.5
Decapoda	13.8	6.4	13.5	2.0	5.9	12.8	30.5	1.3	14.3	3.4	5.6	1.1	13.2	7.8	10.1	4.4	12.5	7.3	11.5	2.3
Artemesia longinaris	6.9	5.7	1.5	0.2	5.9	12.8	30.5	1.3	4.8	2.3	1.8	0.1	1.9	1.7	1.7	<0.1	4.2	5.3	6.3	0.2
Corystoides abbreviatus													3.8	18.2	7.0	0.5	1.7	18.2	7.0	0.2
Cyrtograpsus angulatus									4.8	7.7	16.4	0.6	3.8	75.0	28.3	2.1	2.5	23.5	21.7	0.6
Neohelice granulata													3.8	66.7	20.7	1.8	1.7	66.7	20.7	0.7
Loxopagurus sp.	6.9	28.6	23.8	1.8					4.8	14.3	2.4	0.4					2.5	21.4	20.2	0.5
Anelida																				
Polychaeta	13.8	28.6	52.5	5.6	17.6	16.7	40.6	5.1	14.3	5.1	7.6	0.9	26.4	73.2	87.4	22.4	20.0	27.0	60.7	9.0
Phyllodocidae	13.8	28.6	52.5	5.6	17.6	16.7	40.6	5.1	9.5	6.0	11.1	0.8	22.6	72.7	86.8	19.2	17.5	29.6	66.1	8.4
Namanereis sp.									4.8	3.4	1.9	0.1	5.7	50.0	57.5	3.2	3.3	17.1	18.2	0.6
Mollusca																				
Gasteropoda									4.8	100	100	4.8	3.8	25.0	43.1	1.4	2.5	33.3	57.0	1.1
Unidentified gastropod									4.8	100	100	4.8	3.8	25.0	43.1	1.4	2.5	33.3	57.0	1.1
Bivalvia	79.3	95.6	93.4	74.8	64.7	98.0	98.9	61.7	71.4	96.9	97.9	68.4	56.6	76.0	94.2	51.7	67.5	92.1	95.9	57.9
Amiantis purpurata	3.4	9.1	5.7	0.3	11.8	100	100	11.8					5.7	73.7	70.9	4.4	5.0	57.1	54.7	2.8
Brachidontes rodriguezii													3.8	27.3	29.6	1.1	1.7	27.3	29.6	0.5
Solen techuelchus	27.6	92.9	90.9	25.3	52.9	88.6	87.9	46.7	14.3	80.0	95.8	12.6	26.4	77.0	93.7	24.0	28.3	82.7	92.4	24.8
Lasaea sp.	51.7	95.2	94.9	49.2	5.9	44.4	63.4	3.2	71.4	88.8	67.5	55.8	11.3	96.3	94.3	11.5	30.8	89.3	75.5	25.4
Mytilus edulis platensis													13.2	55.8	96.0	10.7	5.8	55.8	96.0	4.4
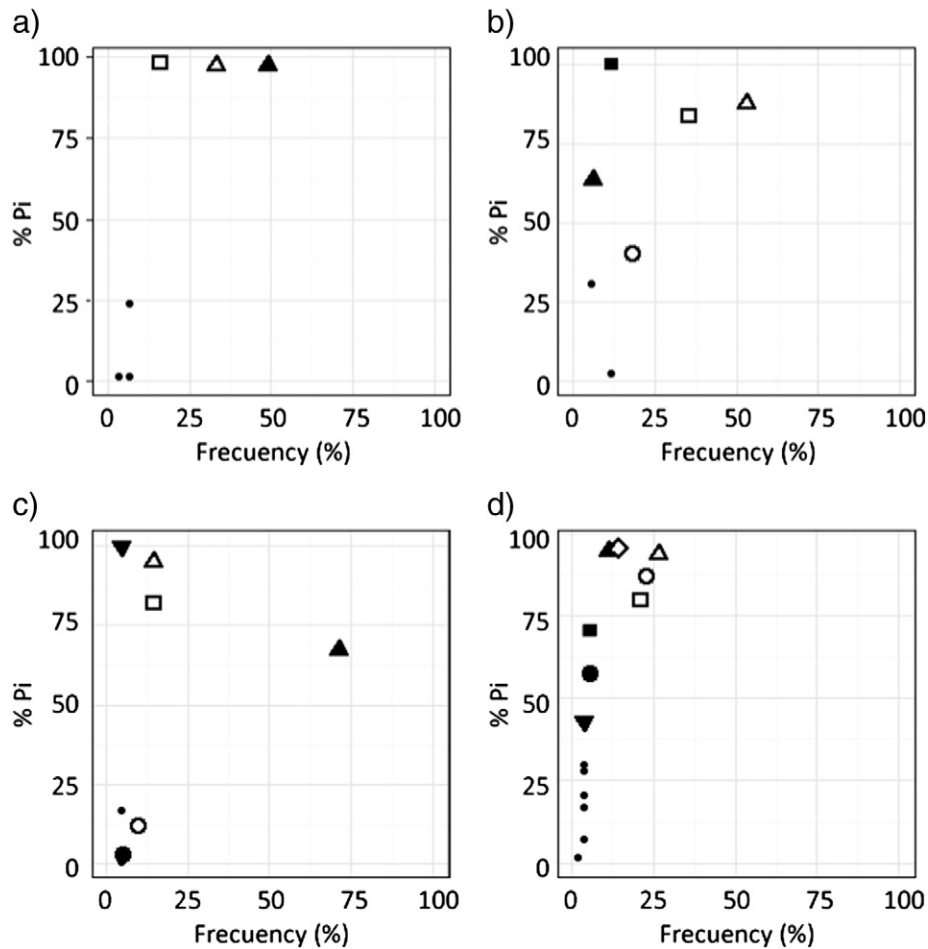
Fig. 5. Feeding strategy of *Myliobatis goodei* in Anegada Bay during February–November 2008. a) Los Pocitos in summer, b) San Blas in summer, c) Los Pocitos in spring, d) San Blas in spring. %*Pi*: prey specific abundance in percentage. Prey items: *Amiantis purpurata* (■), Phyllodocidae (○), *Namanereis sp.* (●), *Solen techuelchus* (△), *Lasaea sp.* (▲), Gasteropoda (▼), Caprellidae (▢), *Mytilus edulis platensis.* (◇), other items (●).

Estimated Dw_{50} for both females and males of *M. goodie* in Anegada Bay was smaller than what Ruocco (2012) presents in her work (Dw_{50} for males: 498.8 mm, and females: 598.7 mm). This could be due to differences in Dw range of the sample, as Dw_{50} estimations based on proportion of mature individuals may be affected by this. Alternatively, given that the samples used by Ruocco (2012) were taken from 2005 to 2008, it could imply a rejuvenation of the reproductive stocks of *M. goodei*.

M. goodei in the study area behave as generalist feeders, with a uniform diet composed mainly of bivalves. The predominance of these items was also observed by Gray et al. (1997) in *M. californica*, while Ruocco (2012) found the diet of *M. goodei* in the coastal waters of Buenos Aires province to be composed mainly of polychaetes and decapods. Elasmobranches are often considered opportunistic predators, usually with an electivity index around zero, and with wide trophic spectrum, as Lucifora et al. (2006) report. It is then likely that the differences found in the diet of *M. goodei* are due to prey assemblage differences between studies rather than active selection by the predator. Such phenomena have been suggested for *M. schmitti* in Anegada Bay by Molina and Lopez Cazorla (2011) and for other elasmobranches by Barry et al. (2008).

The seasonal differences in the diet found in the present study arise from the inclusion of a greater variety of prey by *M. goodei* in spring (e.g., *Cyrtograpsus angulatus*, *Corystoides abbreviatus* or *Neohelice granulata*, *Amiantis purpurata*, *Mytilus edulis platensis*). In contrast, summer prey composition shows a narrower trophic spectrum. However, spatial differences arise from the different abundances of

caprellids and bivalves. In Los Pocitos, diet was clearly dominated by *S. tehuelchus* y *Laesea* sp., while in San Blas, caprellids were highly important. Caprellid abundance was probably due to the higher abundance of these crustaceans among the rocky shores of San Blas site. Given that rays feed hovering over the substrate and sucking preys from it (Hines et al., 1997), it is likely that *M. goodei* have sucked high quantities of caprellids while feeding on other prey.

It must be noted that seasonal differences discussed above might have been due to differences in the size composition. Juvenile individuals were more predominant in summer, while adults dominated in spring. It is possible that as the individuals grow they develop the ability to seize decapods like *Cyrtograpsus angulatus*, *Corystoides abbreviatus* or *Neohelice granulata*, or the strength to crush shells of harder bivalves like *Amiantys purpurata* or *Mytilus edulis platensis*, explaining the consumption of these preys in spring. Information on seasonal availability of benthic invertebrates is lacking for the study area, and would be needed to test this assumption. If so, the seasonal differences observed might represent ontogenetic shifts in the diet, as have been reported for other elasmobranches (Bethea et al., 2007; Chiaramonte and Pettovello, 2000; Lucifora et al., 2006, 2009; Molina and Lopez Cazorla, 2011).

Trophic level of *M. goodie* in Anegada Bay (TL:3.2) constitutes the first reference for this species, characterizing it as a secondary consumer. For direct comparison, TL was estimated from feeding ecology data of this species presented by Ruocco (2012), obtaining a TL of 3.3. Both estimations are similar. Other species of the genus, as *M. californica* (TL = 3.5; Talent, 1982), *M. chilensis* (3.86; Ballón, 2005), *M. australis*

(3.55; Last and Stevens, 1994) and *M. aquila* (3.61; Jardas et al., 2004) have similar, if slightly higher, TL. These species are also secondary consumers.

Acknowledgments

References

Amundsen, P.A., Gabler, H.M., Staldvik, F.J., 1996. A new approach to graphical analysis of feeding strategy from stomach contents data—modification of the Costello (1990) method. J. Fish Biol. 48, 607–614.

Anderson, M., 2004. Spatial variation and effects of habitat on temperate reef fish assemblages in northeastern New Zealand. J. Exp. Mar. Biol. Ecol. 305, 191–221.

Anderson, M.J., Ellingsen, K.E., McArdle, B.H., 2006. Multivariate dispersion as a measure of beta diversity. Ecol. Lett. 9, 683–693.

Ballón, R.M., 2005. Comparative Analysis of the Community Structure and Trophic Relations of the Peruvian Hake *Merluccius gayi peruanus* and its By-catch of the Years 1985 and 2001(PhD thesis) University of Bremen, Bremen.

Barker, M.J., Schluessel, V., 2005. Managing global shark fisheries: suggestions for prioritizing management strategies. Aquat. Conserv. Mar. Freshw. Ecosyst. 15, 325–347.

Barry, K.P., Condrey, R.E., Driggers, W.B., Jones, C.M., 2008. Feeding ecology and growth of neonate and juvenile blacktip sharks *Carcharhinus limbatus* in the Timbalier–Terrebone Bay complex, LA, U.S.A. J. Fish Biol. 73, 650–662.

Bates, D.M., Chambers, J.M., 1992. Statistical models in S. In: Chambers, J.M., Hastie, T.J. (Eds.), Comp. Sci. and Stat., Proc. 19th Symp. on the Interface. Wadsworth & Brooks, California.

Bethea, D.M., Hale, L., Carlson, J.K., Cortés, E., Manire, C.A., Gelsleichter, J., 2007. Geographic and ontogenetic variation in the diet and daily ration of the bonnethead shark, *Sphyrna tiburo*, from the eastern Gulf of Mexico. Mar. Biol. 152, 1009–1020.

Bizzarro, J.J., Robison, H.J., Rinewalt, C.S., Ebert, D.A., 2007. Comparative feeding ecology of four sympatric skate species off central California, USA. Environ. Biol. Fish 80 (2/3), 197–220.

Bonfil, R., 1994. Overview of word elasmobranch fisheries. FAO Fisheries Technical Paper No. 341(119 pp.).

Boschi, E.E., Fishback, C.E., Iorio, M.I., 1992. Catalogo ilustrado de los crustáceos estomatopodos y decapodos marinos de Argentina. Frente Marítimo 10, 8–94.

Brander, K., 1981. Disappearance of common skate *Raia batis* from Irish Sea. Nature 290, 48–49.

Brooks, D.R., Mayes, M.A., Thorson, T.B., 1981. Cestode parasites in *Myliobatis goodei* Garman (Myliobatiformes: Myliobatidae) from Río de la Plata, Uruguay, with a summary of cestodes collected from South American elasmobranches during 1975–1979. Proc. Biol. Soc. Wash. 93, 1239–1252.

Brown, S.C., Bizzarro, J.J., Cailliet, G.M., Ebert, D.A., 2012. Breaking with tradition: redefining measures for diet description with a case study of the Aleutian skate *Bathyraja aleutica* (Gilbert 1896). Environ. Biol. Fish 95, 3–20.

Bullis, H.R., Struhsaker, P., 1961. Life history notes on the roughtail *Dasyatis centroura* (Mitchell). Copeia 2, 232–234.

Camhi, M.D., Valenti, S.V., Fordham, S.V., Fowler, S.L., Gibson, C., 2007. The Conservation Status of Pelagic Sharks and Rays. IUCN Species Survival Commission's Shark Specialist Group, University of Oxford, Newbury.

Capapé, C., 1993. New data on the reproductive biology od the thorny stingray, *Dasyatis centroura* (Pisces: Dasyatidae) from the Tunisian coast. Environ. Biol. Fish 38, 73–80.

Castro, J.I., 1993. The shark nursery of Bulls Bay, South Carolina, with a review of the shark nurseries of the southeastern coast of the United States. Environ. Biol. Fish 38, 37–48.

Cedrola, P.V., González, A.M., Pettovello, A.D., 2005. Bycatch of skates (Elasmobranchii: Arhynchobatidae, Rajidae) in the Patagonian red shrimp fishery. Fish. Res. 71 (2), 141–150.

Chiaramonte, G., Pettovello, A.D., 2000. The biology of *Mustelus schmitti* in southern Patagonia, Argentina. J. Fish Biol. 57, 930–942.

Colautti, D., Baigun, C., Lopez Cazorla, A., Llompart, F., Molina, J.M., Suquele, P., Calvo, S., 2010. Population biology and fishery characteristics of the smooth-hound *Mustelus schmitti* in Anegada Bay, Argentina. Fish. Res. 106, 351–357.

Colonello, J.H., Christiansen, H.E., Cousseau, M.B., Macchi, G.J., 2013. Uterine dynamics of the southern eagle ray *Myliobatis goodei* (Chondrichthyes: Myliobatidae) from the southwest Atlantic Ocean. Ital. J. Zool. 80, 187–194.

Colwell, R.K., 2013. EstimateS: statistical estimation of species richness and shared species from samples. Version 9. User's Guide and Application (published at: http://purl.oclc.org/estimates).

Cortés, E., 1999. Standardized diet compositions and trophic levels of sharks. ICES J. Mar. Sci. 56, 707–717.

Crawley, M.J., 2007. The R Book. Wiley, West Susex.

Cuadrado, D.G., Gómez, E.A., 2010. Geomorfología y dinámica del canal San Blas, Provincia de Buenos Aires (Argentina). Lat. Am. J. Sedimentol. Basin Anal. 17, 3–16.

Dulvy, K.N., Baun, J.K., Clarke, S., 2008. You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. Aquat. Conserv. Mar. Freshw. Ecosyst. 482, 459–482.

Ebert, D.A., Bizzarro, J.J., 2007. Standardized diet composition and trophic levels in skates. Environ. Biol. Fish 80, 221–237.

Ebert, D.A., Stehmann, M.F.W., 2013. Sharks, batoids, and chimaeras of the North Atlantic. FAO Species Catalogue for Fishery Purposes 7. FAO, Rome, Italy (523 pp.).

Estalles, M., Coller, N.M., Perier, M.R., Di Giácomo, E.E., 2011. Skates in the demersal trawl fishery of San Matías Gulf: species composition, relative abundance and maturity stages. Aquat. Living Resour. 24, 193–199.

Ferry, L.A., Cailliet, G.M., 1996. Sample size and data analysis: are we characterizing and comparing diet properly? Feeding Ecology and Nutrition in Fish, Symposium Proceedings, pp. 71–80.

Gray, A.E., Mulligan, T.J., Hannah, R.W., 1997. Food habits, occurrence, and population structure of the bat ray, *Myliobatis californica*, in Humboldt Bay, California. Environ. Biol. Fish 49, 227–238.

Hamlett, W.C., 1999. Sharks, Skates, and Rays: The Biology of Elasmobranch Fishes. The Johns Hopkins University Press, Maryland.

Heithaus, M.R., Frid, A., Wirsing, A.J., Worm, B., 2008. Predicting ecological consequences of marine top predator declines. Trends Ecol. Evol. 23, 202–210.

Hines, A.H., Whitlatch, R.B., Thrush, S.F., Hewitt, J.E., Cummings, V.J., Dayton, P.K., Legendre, P., 1997. Nonlinear foraging response of a large marine predator to benthic prey: eagle ray pits and bivalves in a New Zealand sandflat. J. Exp. Mar. Biol. Ecol. 216, 191–210.

Ivanov, V.A., Campbell, R.A., 1998. *Echinobothrium megacanthum* sp. n. (Cestoda: Diphyllidea) from the eagle ray *Myliobatis goodei* (Chondrichthyes: Rajoidei) from the Patagonian shelf of Argentina. Folia Parasitol. 45, 225–229.

Jardas, I., Santic, M., Pallaoro, A., 2004. Diet composition of the eagle ray, *Myliobatis aquila* (Chondrichthyes: Myliobatidae), in the eastern Adriatic sea. Cybium 28, 372–374.

Jaureguizar, A., Menni, R., Bremec, A.C., Mianzana, H., Lasta, C., 2003. Fish assemblage and environmental patterns in the Río de la Plata estuary. Estuar. Coast. Shelf Sci. 56, 921–933.

Last, P.R., Stevens, J.D., 1994. Sharks and rays of Australia. Copeia 1994, 1055–1057.

Lopez Cazorla, A.C., 1987. Contribución al conocimiento de la ictofauna marina del área de Bahía Blanca(PhD thesis) Universidad Nacional del Sur, Bahía Blanca.

Lucifora, L.O., García, V.B., Menni, R.C., Escalante, A.H., 2006. Food habits, selectivity, and foraging modes of the school shark, *Galeorhinus galeus*. Mar. Ecol. Prog. Ser. 315, 259–270.

Lucifora, L.O., García, V.B., Menni, R.C., Escalante, A.H., Hozbor, N.M., 2009. Effects of body size, age and maturity stage on diet in a large shark: ecological and applied implications. Ecol. Res. 24, 109–118.

Mabragaña, E., Lucifora, L.O., Massa, A.M., 2002. The reproductive ecology abd abundance of *Sympterigia bonapartii* endemic to the southwest Atlantic. J. Fish Biol. 60, 951–967.

Martin, L.K., Cailliet, G.M., 1988. Aspects of the reproduction of the bat ray, *Myliobatis californica*, in central California. Copeia 3, 754–762.

McEachran, J.D., de Carvalho, M.R., 2002. Batoid fishes. In: Carpenter, K.E. (Ed.), Introduction, Molluscs, Crustaceans, Hagfishes, Sharks, Batoid Fishes and Chimaeras. The Living Marine Resources of the Western Central Atlantic vol. 1. FAO, Rome, Italy, pp. 507–589.

Mendoza, J., Booth, S., Zeller, D., 2003. Venezuelan marine fisheries catches in space and time: 1950–1999. Fish Cent. Res. Rep. 11, 171–180.

Molina, J.M., Lopez Cazorla, A., 2011. Trophic ecology of *Mustelus schmitti* (Springer, 1939) in a nursery area of northern Patagonia. J. Sea Res. 65, 381–389.

Mollet, H.F., Cliff, G., Prat Jr., H.L., Stevens, J.D., 2000. Reproductive biology of the female shortfin mako *Isurus oxyrinchus* Rafinesque, 1810, with comments on the embryonic development of lamnoids. Fish. Bull. 98, 299–318.

Pierce, S.J., Pardo, S.A., Bennett, M.B., 2009. Reproduction of the blue-spotted maskray *Neotrygon kuhlii* (Myliobatoidei: Dasyatidae) in south-east Queensland, Australia. J. Fish Biol. 74, 1291–1308.

R Development Core Team, 2013. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Refi, S.M., 1975. Myliobatidae y Dasyatidae del litoral bonaerense de la República Argentina y estudio comparado del mixopterigio (Chondrichthyes, Myliobatoidea). Physis 34, 121–136.

Ruocco, M.C., 2012. Ecología y conservación de los chuchos (Chondrichthyes, Myliobatiformes) del ecosistema costero Bonaerense y uruguayo(PhD thesis) Universidad Nacional de Mar del Plata, Mar del Plata.

Santos, H.R.S., de Carvalho, M.R., 2004. Description of a new species of whiptail stingray from the southwestern Atlantic Ocean (Chondrichthyes, Myliobatiformes, Dasyatidae). Bol. Mus. Nac. Zool. 516, 1–24.

Seck, A.A., Diartta, Y., Dio, M., Guélorget, O., Reynaud, C., Capapé, C., 2004. Observations on the reproductive biology of the blackchin guitarfish, *Rhinobatos cemiculus* E. Geoffroy Saint-Hilaire, 1817 (Chondrichthyes, Rhinobatidae) from the coast of Senegal (Eastern Tropical Atlantic). Sci. Gerundensis 27, 19–30.

Shapiro, S.S., Wilk, M.B., 1965. An analysis of variance test for normality (complete samples). Biometrika 52, 591–611.

Sidders, M.A., Tamini, L.L., Perez, J.E., Chiaramonte, G.E., 2005. Biología reproductiva del gatuzo *Mustelus schmitti* Springer, 1939 (Chondrichthyes, Triakidae) en el área de Puerto Quequén, Provincia de Buenos Aires. Rev. Mus. Argent. Cienc. Nat. 7, 89–101.

Simpfendorfer, C.A., Milward, N.E., 1993. Utilisation of a tropical bay as a nursery area by sharks of the families Carcharhinidae and Sphyrnidae. Environ. Biol. Fish 37, 337–345.

Stehmann, M., 2009. *Myliobatis goodei*. IUCN 2013. IUCN Red List of Threatened Species (Version 2013.2. <www.iucnredlist.org>. Downloaded on 18 March 2014).

Talent, L.G., 1982. Food habits of the gray smoothhound, *Mustelus californicus*, the brown smoothhound, *Mustelus henlei*, the shovelnose guitarfish, *Rhinobatos productus*, and

the bat ray, *Myliobatis californica*, in Elkhorn Slough, California. Calif. Fish Game 68, 224–234.

Vazzoler, A.E.A. de M., 1981. Manual de métodos para estudos biológicos de populacones de peixes; reproducao e crescimiento. CNPq. Programa Nacional de Zoología, Brasilia.

Vooren, C.M., Klippel, S., 2005. Açoes para a conservaçao de tubaroes e raias no Sul do Brasil. Igaré, Porto Alegre.

Welch, D.W., Foucher, R.P., 1988. A maximun-likehood methodology for estimating length at first maturity with application to Pacific cod (*Gadus macrocephalus*) population dynamic. Can. J. Fish. Aquat. Sci. 45 (2), 333–343.

Zar, J.H., 1999. Biostatistical Analysis, 4th ed. Prentice Hall, New Jersey.