# Reproduction, abundance and feeding habits of the broadnose sevengill shark *Notorynchus cepedianus* in north Patagonia, Argentina

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ABSTRACT: Broadnose sevengill sharks *Notorynchus cepedianus* caught in a recreational fishery during a 3 yr period in Anegada Bay, Argentina were examined. Monthly variations in abundance were found, with the highest mean abundance in April. Neonates and juveniles were common in the study area, indicating that Anegada Bay is a nursery area of *N. cepedianus*. Male and female sizes at maturity were 170 and 224 cm total length (TL), respectively, similar to other studied regions. Liver size was sexually dimorphic, with adult females having larger livers, which might allow for the maximization of oocyte size/number. Individuals <100 cm TL fed mainly on teleosts, sharks 100 to 170 cm TL consumed mainly cartilaginous fishes and less teleosts, and sharks >170 cm fed mostly on cartilaginous fishes and marine mammals. All size groups preyed on marine mammals, which may be a result of the local availability of small calves of La Plata River dolphins *Pontoporia blainvillei*. Possibly, the pattern of habitat use of Anegada Bay by *P. blainvillei* is affected by *N. cepedianus*. The proportion of individuals with prey within the stomach was negatively correlated with TL. As indicated by prey remains found within stomachs (most were in pieces) and by the location of the fishing hook in sharks (most were hooked in the mouth), *N. cepedianus* extensively handles its prey with the mouth before swallowing it, which is consistent with previous observations. Anegada Bay may be an important area for conservation of *N. cepedianus* in the SW Atlantic given the high abundance of juveniles and subadults.

KEY WORDS: Elasmobranch · Maturity · Nursery · Predation · Marine mammals

## INTRODUCTION

The broadnose sevengill shark *Notorynchus cepedianus* is the only species within the Hexanchidae inhabiting exclusively coastal and shelf waters (Compagno 1984), where it completes its entire life cycle (Ebert 1986a, 1989, 1996). The ecology and life history of *N. cepedianus* have been studied only off California (USA) (Ebert 1986a, 1989) and southern Africa (Ebert 1996). Females mature at much larger total lengths (TL) than males; the female reproductive cycle is biennial and the fecundity is one of the highest among elasmo-branchs (Ebert 1986a, 1989, 1996). Shallow bays are an important habitat for reproduction of *N. cepedianus*. High abundances of *N. cepedianus* within or adjacent to shallow bays have been reported in California (Ebert 1986a, 1989), northern New Zealand (Cox & Francis 1997), and northern Argentina (Otero et al. 1982, Menni & García 1985). Females bearing tooth marks (indicative of mating activity) were also observed inside shallow bays (Ebert 1986a, 1989, 1996). The seasonal abundance of *N. cepedianus* in San Francisco and Humboldt Bays (California) appears to be related to their reproductive cycle (Ebert 1986a,b, 1989).

*Notorynchus cepedianus* is an apex predator (Compagno 1984). In California, its diet is composed mainly of teleosts and cartilaginous fishes, and secondarily of marine mammals (Ebert 1986a, 1989); off the western and southern coasts of South Africa and the central coast of Namibia, cartilaginous fishes are the main prey, and off southern Namibia, marine mammals are the most common prey (Ebert 1991a). This is presumably due to different relative abundances of prey among different regions (Ebert 1991a). The diet of *N. cepedianus* shifts with ontogeny (Ebert 2002). Juveniles feed mainly on teleosts and, as they grow, they prey more upon cartilaginous fishes and marine mammals and less upon teleosts (Ebert 2002).

In this paper we analyze the reproductive biology, and seasonal relative abundance, and feeding habits of *Notorynchus cepedianus* in Anegada Bay, Argentina. We hypothesize that Anegada Bay is a nursery area for *N. cepedianus* in the SW Atlantic.

## MATERIALS AND METHODS

**Study area.** Anegada Bay (39° 50′ to 40° 40′ S) is a shallow and highly productive area with many small islands and sand/mud banks shallower than 2 m during high tides. The banks and islands are covered with halophytes and the area has high densities of benthic invertebrates (Esteves et al. 2000). Depth is usually 10 to 14 m, but can be up to 24 m in some places. Water temperature is about 12°C in winter and 16 to 17°C in summer (Martos & Piccolo 1988). The area is an important nursery area for teleosts (Macchi & Acha 1998) and some elasmobranchs (Cousseau 1986, Mabragaña et al. 2002).

**Abundance.** A shark recreational fishery occurs in Anegada Bay every year between October and late April. Sharks are caught from small boats (<7 m long) with rod and reel. Samples for this study were taken from this fishery during the fishing seasons 1998 to 1999, 1999 to 2000, and 2000 to 2001. The relative abundance of *Notorynchus cepedianus* in Anegada Bay was estimated as catch per unit of effort (CPUE) as the number of sharks caught per boat per fishing trip per day. Mean monthly CPUE were compared by means of the Kruskal-Wallis test (Conover 1980). When significant differences were detected, pairwise comparisons were made by means of the non-parametric multiple comparisons test (Conover 1980). The proportion of neonates, juveniles and adults of each sex was quantified monthly. Differences in the sex ratio per month were assessed by means of the $\chi^2$ test with the Yates' correction (Zar 1984).

**Reproduction.** Samples were taken within 3 h of landing. Sharks were measured for TL and precaudal length (PCL). A relationship between PCL and TL was calculated in order to estimate TL for specimens with the caudal fin removed.

In males, the inner length (Compagno 1984) and the degree of calcification of the claspers were recorded. Also, the status of the inner reproductive organs of males (i.e. testes, epididymides and efferent ducts, and seminal vesicles) was noted. Males with calcified claspers and highly convoluted epididymides were classified as mature.

In females, the width of the uteri and oviducal glands was recorded. Females with wide, pendulous uteri were classified as mature, whereas females with thin uteri well attached to the dorsal surface of the body cavity were regarded as juveniles. The number and size (in mm) of ovarian follicles were recorded.

The length at which 50% individuals are mature ($TL_{50}$) was calculated by fitting a logistical curve to proportions of mature individuals in every 5 cm size class interval.

Gonad and liver weight was recorded for individuals of both sexes. The gonadosomatic index (GSI) was calculated, following Taniuchi (1988), as GSI = (gonad weight [in g]/$TL^3$) × 100. Monthly GSI were compared for assessing possible temporal variations. The relationship between liver weight and TL was estimated separately for each sex. The relationship was linearized by applying a ln-transformation and the slopes were compared between sexes for evaluating sexual dimorphism in liver size.

**Feeding habits.** Individuals were grouped in 15 cm TL intervals and the proportion of individuals with prey in the stomach was calculated for every size interval. The relationship between the proportion of individuals with stomach content and TL was assessed by testing the significance of the Spearman rank correlation coefficient (Conover 1980).

For dietary analyses, sharks were grouped into 3 size classes: <100 cm TL, 100 to 170 cm TL, and >170 cm TL. The stomach contents were identified to the lowest possible taxonomic level, weighed, and counted. Frequency of occurrence of prey *i* ($F_i$) was defined as the number of stomachs containing prey *i* divided the total number of stomachs examined. Numeric frequency of prey *i* ($N_i$) was the total number of specimens of prey *i* found in the analyzed stomachs divided by the total number of all prey specimens found in the stomachs. Weight frequency of prey *i* ($W_i$) was defined as the weight (in g) of prey *i* divided by the total weight of the stomach contents. The index of relative importance of prey *i* ($IRI_i$) was then calculated as $IRI_i = F_i \times (N_i + W_i)$. $IRI_i$ were recalculated dividing each $IRI_i$ by the sum of all $IRI_i$ and multiplying by 100 in order to obtain the proportional IRI (%IRI, Cortés 1997), which is precise and unbiased (Liao et al. 2001). The dietary composi-

tions of the 3 shark size groups were compared with the *G*-test (Cortés 1997), with prey sorted into 4 groups: teleosts, cartilaginous fishes, marine mammals, and invertebrates.

The pattern of prey capture and handling was evaluated by quantifying both the number of prey found whole, sectioned (i.e. several pieces of the same individual prey) and headless (i.e. only the posterior two-thirds of the body found in the stomach), and the proportions of sharks hooked in the mouth and in inner parts of the digestive tract (i.e. from the first branchial arc backwards). The frequencies of whole, sectioned and headless prey in the stomachs, and mouth-hooked and inside-hooked individuals were compared with the *G*-test (Zar 1984).

## RESULTS

### Abundance

The CPUE varied significantly between October and April (Kruskal-Wallis test, H = 27.26, k = 6, n = 166, p < 0.001, Fig. 1). The lowest abundance of *Notorynchus cepedianus* was during December and January, in February CPUE began to increase and attained its maximum in April (Fig. 1). Juveniles dominated the catches in all months (63.6 to 80 % of the catch). During October and November catches were composed mainly of juveniles of both sexes, with a few adult males. Neonates with healed umbilical scars were present from January to March (9.1 to 15.4 % of the catch). The low numbers of neonates is most likely due to sampling bias because anglers tend to release neonates.

The sex ratio of juveniles was not significantly different to 1:1 from October to January (October to December:

ber: ratio = 0.71:1, n = 12, $\chi^2$ = 0.08, p = 0.773; January: ratio = 2.50:1, n = 7, $\chi^2$ = 0.57, p = 0.450). Females outnumbered males from February to April (February: ratio = 2.75:1, n = 30, $\chi^2$ = 5.63, p = 0.018; March: ratio = 5:1, n = 30, $\chi^2$ = 12.03, p = 0.0005; April: ratio = 4:1, n = 20, $\chi^2$ = 6.05, p = 0.014). The adult sex ratio could not be assessed statistically due to low sample size, but all adults found in December were males, and from January to March all adults were females, while both sexes were present in April.

### Reproduction

A total of 136 individuals (43 males and 93 females) were examined. The relationship between TL and PCL was linear (slope = 1.3845, intercept = 8.8284, $R^2$ = 0.995, range = 45.2 to 253 cm TL, n = 120).

The smallest juvenile male was 53.2 cm TL and the largest adult male 217 cm TL. The largest juvenile male was 167 cm TL and the smallest adult male was 173 cm TL (Fig. 2). There were significant differences in male GSI between October–November and April, with minimum GSI in April (Mann-Whitney test, October to November mean GSI = $5.9 \times 10^{-3}$, April mean GSI = $2.1 \times 10^{-3}$, n = 4 and 5, p = 0.014).

The smallest examined female was 45.2 cm TL and the largest was 253 cm TL. The largest juvenile female was 222 cm TL and the smallest adult was 214 cm TL (Fig. 3A). Female $TL_{50}$ was 223.98 cm TL (Fig. 3B). Data on fecundity were obtained from 3 adult females, measuring 220, 243, and 237 cm TL, which had 107, 59, and 94 mature oocytes in the ovaries, respectively. The mean maximum diameter of ovarian follicles in adult
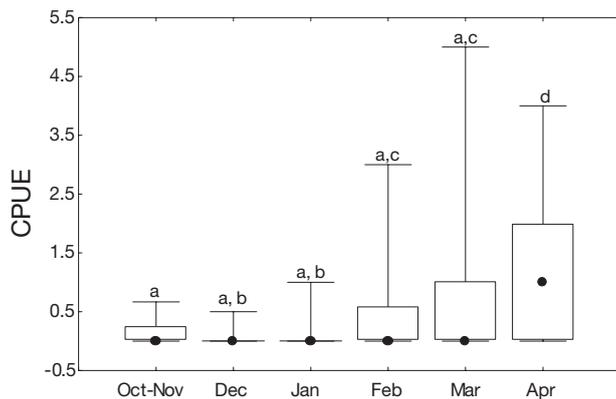


Fig. 1. *Notorynchus cepedianus*. Monthly catch per unit of effort (CPUE = sharks caught per fishing boat per trip per day) in Anegada Bay, Argentina. Dot = median, boxes = 25–75th percentiles, whiskers = minimum and maximum values. Months with the same letter are not significantly different (non-parametric multiple comparisons test, p < 0.05)
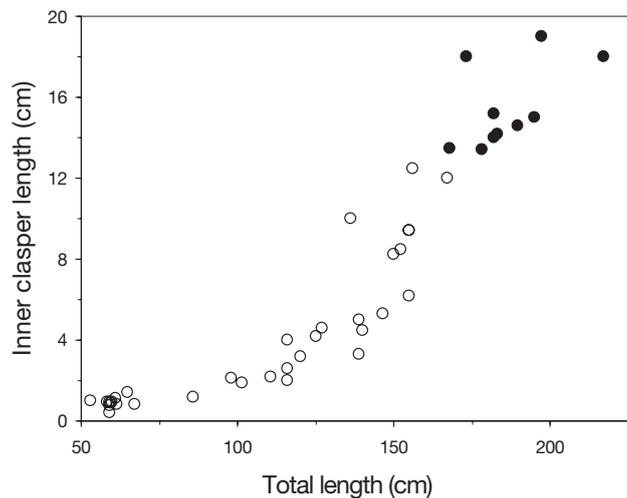


Fig. 2. *Notorynchus cepedianus*. Total length–inner clasper length relationship of males from Anegada Bay, Argentina. O: juvenile males, ●: adult males
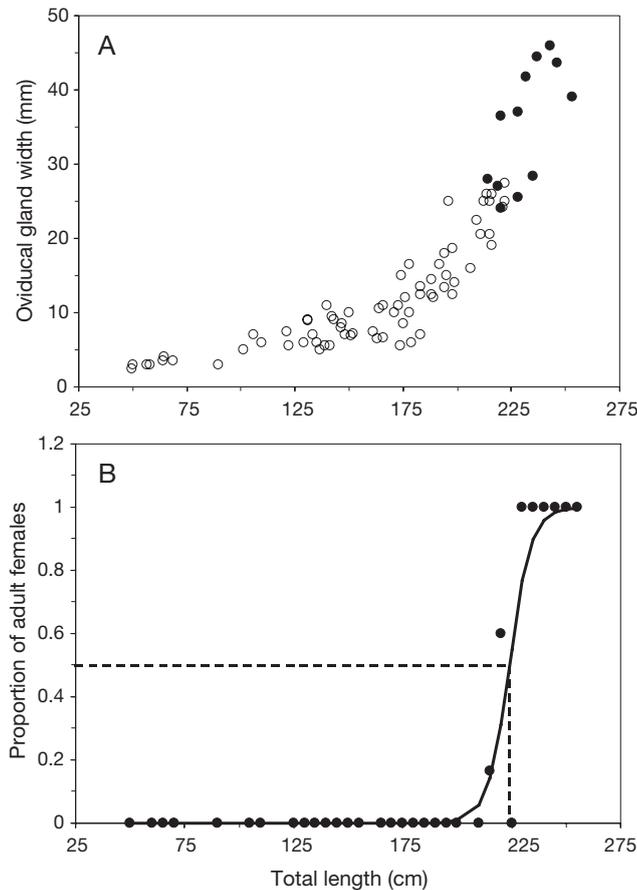
Fig. 3. *Notorynchus cepedianus*. Maturity of females from Anegada Bay, Argentina. (A) Relationship between oviducal gland width and total length; ○: juvenile females with undeveloped gonads and uteri, ●: adult females with fully developed gonad and uteri. (B) Proportion of mature females in 10 cm size intervals, dashed lines mark the size at which 50% females reached adulthood

females was 31.98 mm ± 19.49 SD (range = 11 to 69 mm). No pregnant females were recorded.

A sexual dimorphism in liver size was observed. The slope of the relationship between TL and liver weight was significantly higher in females than in males (Fig. 4, Student's *t*-test, $t = 4.824$, df = 131, $p \ll 0.0001$), which indicates a larger liver in adult females than in adult males.

The length frequency distribution shows 4 relative modes, the largest ones due mainly to the presence of females, and a mode for neonates is apparent (Fig. 5).

### Feeding habits

A total of 138 individuals were examined for stomach contents. Prey were found in 45 individuals (12 individuals in the <100 cm TL group, 21 in the 100 to 170 cm TL group, and 12 individuals in the >170 cm
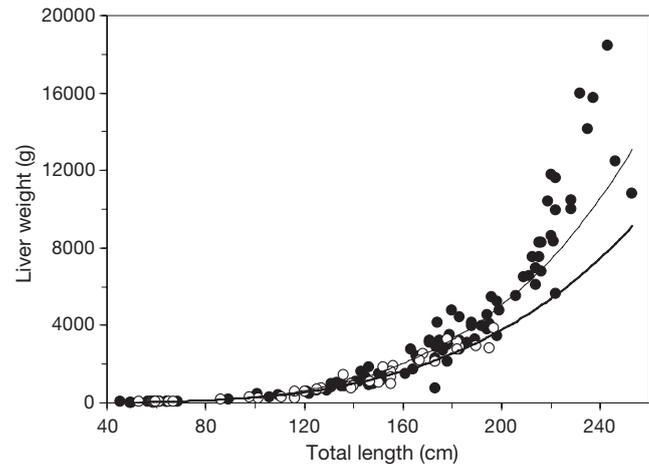


Fig. 4. *Notorynchus cepedianus*. Liver weight–total length relationship in females (●, thin line) and males (○, thick line) from Anegada Bay, Argentina
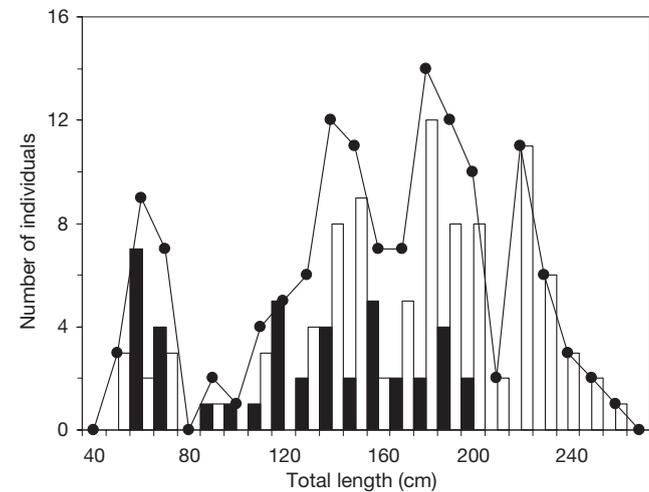


Fig. 5. *Notorynchus cepedianus*. Size frequency distribution from Anegada Bay, Argentina. Filled bars: males, empty bars: females, dots and line: males and females

TL group). The proportion of individuals with stomach contents decreased significantly with TL (Spearman $r = -0.610$, n = 13, $t = 2.55$, $p = 0.027$).

The dietary composition differed significantly among the 3 size groups ($G = 157.84$, df = 6, $p < 0.001$). Individuals <100 cm TL consumed almost exclusively unidentified teleosts, while unidentified cartilaginous fishes, small La Plata River dolphins *Pontoporia blainvillei*, and invertebrates were secondary prey (Table 1). Sharks 100 to 170 cm TL shifted their diet and consumed mainly cartilaginous fishes (especially narrownose smoothhound sharks *Mustelus schmitti*), secondarily teleosts, and cetaceans and invertebrates were of less importance (Table 1). Individuals >170 cm TL preyed on cartilaginous fishes (mainly eagle rays

Table 1. *Notorynchus cepedianus*. Diet composition of 3 size classes of broadnose sevengill sharks in Anegada Bay, Argentina. $F_i$: frequency of prey (*i*) occurrence, $N_i$: frequency in prey (*i*) number, $W_i$: frequency in prey (*i*) weight, IRI: proportional index of relative importance (in **bold**), TL: total length. Italicized values refer to IRI calculations with individual prey grouped

| Group | Common name | $F_i$ <100 cm TL | $N_i$ | $W_i$ | IRI | $F_i$ 100 to 170 cm TL | $N_i$ | $W_i$ | IRI | $F_i$ >170 cm TL | $N_i$ | $W_i$ | IRI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Actinopterygii** | | *0.67* | *0.57* | *0.74* | ***86.4*** | *0.43* | *0.31* | *0.31* | ***25.6*** | *0.25* | *0.21* | *0.02* | ***7.94*** |
| Atherinopsidae | | | | | | | | | | | | | |
| *Odonthestes argentinensis* | Silverside | | | | | 0.05 | 0.03 | 0.10 | **2.24** | 0.08 | 0.07 | 0.01 | **2.34** |
| Carangidae | | | | | | | | | | | | | |
| *Parona signata* | Leatherjacket | | | | | | | | | | | | |
| Sciaenidae | | | | | | | | | | | | | |
| *Cynoscion guatucupa* | Weakfish | | | | | 0.14 | 0.10 | 0.18 | **13.9** | | | | |
| Unidentified teleosts | | 0.67 | 0.57 | 0.74 | **92.0** | 0.23 | 0.17 | 0.02 | **15.5** | 0.17 | 0.14 | 0.01 | **8.73** |
| **Chondrichthyes** | | *0.25* | *0.21* | *0.20* | ***10.2*** | *0.67* | *0.52* | *0.62* | ***72.7*** | *0.50* | *0.50* | *0.51* | ***68.3*** |
| Squatinidae | | | | | | | | | | | | | |
| *Squatina guggenheim* | Angel shark | | | | | | | | | 0.08 | 0.07 | 0.01 | **2.21** |
| Triakidae | | | | | | | | | | | | | |
| *Mustelus schmitti* | Smoothhound | | | | | 0.23 | 0.17 | 0.15 | **25.6** | 0.08 | 0.07 | 0.00 | **2.05** |
| *Galeorhinus galeus* | School shark | | | | | | | | | 0.08 | 0.07 | 0.07 | **3.92** |
| Rajidae | | | | | | | | | | | | | |
| *Sympterygia acuta* | Skate | | | | | 0.05 | 0.03 | 0.03 | **1.08** | | | | |
| *Sympterygia bonapartii* | Skate | | | | | | | | | 0.08 | 0.07 | 0.05 | **3.38** |
| *Atlantoraja castelnaui* | Skate | | | | | | | | | 0.08 | 0.07 | 0.06 | **3.76** |
| Unidentified Rajidae | Skate | | | | | 0.09 | 0.07 | 0.08 | **4.91** | | | | |
| Myliobatidae | | | | | | | | | | | | | |
| *Myliobatis* spp. | Eagle ray | | | | | 0.14 | 0.10 | 0.22 | **15.8** | 0.08 | 0.07 | 0.29 | **10.2** |
| Unidentified cartilag. fish | | 0.17 | 0.14 | 0.08 | **3.91** | 0.19 | 0.14 | 0.13 | **17.2** | | | | |
| Unidentified batoid | | 0.08 | 0.07 | 0.12 | **1.67** | | | | | 0.08 | 0.07 | 0.05 | **3.34** |
| **Mammalia** | | *0.08* | *0.07* | *0.06* | ***1.06*** | *0.09* | *0.07* | *0.06* | ***4.22*** | *0.25* | *0.21* | *0.46* | ***22.9*** |
| Platanistidae | | | | | | | | | | | | | |
| *Pontoporia blainvillei* | Dolphin | | | | | 0.05 | 0.03 | 0.01 | **0.80** | | | | |
| Unidentified cetacean | | 0.08 | 0.07 | 0.06 | **1.13** | 0.05 | 0.03 | 0.05 | **1.31** | | | | |
| Otariidae | | | | | | | | | | | | | |
| *Otaria flavescens* | Sea lion | | | | | | | | | 0.21 | 0.46 | 0.17 | **58.0** |
| **Invertebrates** | | *0.17* | *0.14* | *0.01* | ***2.36*** | *0.05* | *0.10* | *0.01* | ***0.48*** | *0.08* | *0.07* | *0.01* | ***0.80*** |
| Cnidaria | | | | | | | | | | | | | |
| Amphisbetiidae | | | | | | | | | | | | | |
| *Amphisbetia operculata* | | 0.08 | 0.07 | 0.01 | **0.63** | | | | | | | | |
| Unidentified cnidarian | | 0.08 | 0.07 | 0.01 | **0.63** | | | | | | | | |
| Mollusca | | | | | | | | | | | | | |
| *Buccinanops duartei* | Sea snail | | | | | 0.05 | 0.10 | 0.01 | **1.70** | | | | |
| Crustacea | | | | | | | | | | | | | |
| Paguridae | Hermit crabs | | | | | | | | | 0.08 | 0.07 | 0.00 | **2.03** |

*Myliobatis* spp.), and marine mammals. However, the main individual prey of this group were South American sea lions *Otaria flavescens*, which were the only marine mammal consumed by these large sharks (Table 1). All *O. flavescens* remains found within the stomachs belonged to hind parts of the body (e.g. hind flippers). No significant differences were detected among the diet of the 3 size groups when teleosts and cartilaginous fishes were removed from the analysis ($G = 5.34$, df = 2, p = 0.069). Significant differences were also found when *N. cepedianus* <100 cm TL were excluded ($G = 25.96$, df = 3, p $\ll$ 0.001). This was due to differences in the consumption of teleosts and carti-

laginous fishes. The 2 smallest size groups had also significantly different diets ($G = 81.09$, df = 3, p $\ll$ 0.001), with the differences due to the different consumption of cartilaginous fishes.

The proportion of sectioned prey in the stomachs of *Notorynchus cepedianus* was higher than the proportion of whole and headless prey (whole: 18.5%, headless: 3.7%, sectioned: 77.8%, n = 27, $G = 12.86$, df = 2, p = 0.002). Only 1 out of 8 teleost prey was found whole, all marine mammals were found sectioned, and 10 out of 14 cartilaginous fishes were found sectioned. All cartilaginous fishes consumed whole were small (i.e. *Mustelus schmitti*, juvenile

smallnose fanskate *Sympterygia bonapartii*, and juvenile eagle rays).

A total of 74 individuals were examined to determine the hooking location. The hook was located in the mouth in 63 individuals without affecting any internal organ; 1 individual was hooked in the mouth, but the hook perforated the musculature and skin between the neurocranium and the palatoquadrate behind the right eye; 10 individuals swallowed the hook and it perforated the esophagus or stomach wall, and sometimes affected the heart and/or liver. The proportion of mouth-hooked and inside-hooked individuals was significantly different from the proportion 1:1 (mouth-hooked: 86.3 %, inside-hooked: 13.7 %, $G$ = 22.91, df = 1, p $\ll$ 0.001).

## DISCUSSION

The seasonal pattern of abundance found in this study is remarkably similar to other bays in regions 1000s of km away in a different ocean (i.e. San Francisco and Humboldt Bay, California, Ebert 1986a,b, 1989), with the highest abundance found in late summer to early autumn.

Sizes at maturity of *Notorynchus cepedianus* estimated here (i.e. males: 170 cm TL, females: 224 cm TL) are consistent with data from other regions. Males mature over 150 cm TL in California (Ebert 1986a, 1989), between 155 and 180 cm TL in southern Africa (Ebert 1996), and at 150 cm TL in Australia (Last & Stevens 1994). Females have a larger size at maturity than males, they become adult between 230 and 250 cm TL in California (Ebert 1986a, 1989), and at 220 cm TL in SW Africa (Ebert 1996) and Australia (Last & Stevens 1994). The fecundity range recorded in this study is consistent with previous observations indicating a high fecundity for *N. cepedianus* (Ebert 1986a, 1989, 1996).

A larger liver in females than in males is common among elasmobranchs (Rossouw 1987, Silva & Lessa 1991, Lucifora et al. 2002, Mabragaña et al. 2002), and it could have an adaptive value because a large liver could allow females to maximize yolk production and then to produce more or larger oocytes.

The smallest individuals examined in this study are in the range of neonate size (45 to 53 cm TL, Compagno 1984, Ebert 1986a, 1989) and they had umbilical scars, which (though healed) indicate a recent birth. This suggests that *Notorynchus cepedianus* gives birth during spring/summer in north Patagonia. The presence of neonates and juveniles <100 cm TL is an indicator that Anegada Bay is a nursery area for *N. cepedianus* in the SW Atlantic. These results are consistent with previous records of neonates of *N. cepedianus* off

Samborombón Bay, Argentina (Menni & García 1985), and other bays elsewhere (Ebert 1986a,b, 1989), suggesting that other Patagonian bays might be important nursery areas for this species.

There are similarities in the temporal variation of male GSI between males from Anegada Bay and southern Africa. In both regions, GSI is much lower in April than in October and November (Ebert 1996). This suggests that male reproductive activities might occur at the same time in both margins of the South Atlantic.

The high number of individuals with prey within their stomach among the smallest size classes is expected if small sharks feed more frequently and/or have lower metabolic rates. In the case of ectotherm sharks (like *Notorynchus cepedianus*) metabolic rates decrease with size (Sims 1996). Thus, this pattern can be explained by a higher rate of prey consumption by small sharks. This is consistent with observations in captive individuals of *N. cepedianus* (Van Dykhuizen & Mollet 1992). A higher rate of prey consumption for the smallest ontogenetic stages can be adaptive because these individuals have high energy requirements for growth. This suggests that using a highly productive environment, such as Anegada Bay (Esteves et al. 2000), during the most energy-demanding ontogenetic stage might have some advantage. Also, the highly female-biased sex ratio of juveniles suggests that juvenile females might use Anegada Bay as a rich foraging area allowing them to increase their growth rate, and then acquire a larger size at maturity (Klimley 1987).

The diet of *Notorynchus cepedianus* in Anegada Bay changes ontogenetically as reported earlier (Ebert 2002). Teleosts are the main prey of *N. cepedianus* <100 cm TL (Menni et al. 1986, Ebert 2002, this study). Individuals between 100 and 170 cm TL prey mainly on cartilaginous fishes, especially *Mustelus schmitti*, which is abundant in the region (Cousseau 1986), and is also consumed by *N. cepedianus* in other areas (Praderi 1985, Chiaramonte & Pettovello 2000). The consumption of cartilaginous fishes larger than 100 cm TL (i.e. angular angel shark *Squatina guggenheim*, school shark *Galeorhinus galeus*, spotback skate *Atlantoraja castelnaui*, and eagle rays *Myliobatis* spp.) is highest among individuals larger than 170 cm TL, which suggests a higher capacity for preying on larger cartilaginous fishes as *N. cepedianus* grows. This pattern is consistent with patterns recorded in California (Ebert 1986ab, 1989) and South Africa (Ebert 1991a). The high incidence of cartilaginous prey in the diet of large *N. cepedianus* is possibly related to high relative abundance of this kind of prey (Ebert 1991a).

In Anegada Bay, *Notorynchus cepedianus* begins to prey on marine mammals at a smaller size (i.e. >80 cm TL) than in California or SW Africa (i.e. >120 cm TL,

Ebert 2002). The most common cetacean in Anegada Bay is the La Plata River dolphin *Pontoporia blainvillei* (L. O. Lucifora, pers. obs.). The birth season of *P. blainvillei* in Anegada Bay is concentrated in spring and summer (Bordino et al. 1999), which suggests that calves as small as 75 cm TL (Jefferson et al. 1994) may be present in the area by the end of summer, when the abundance of *N. cepedianus* is highest. Thus, it is highly likely that the consumption of cetaceans by small juveniles of *N. cepedianus* is a result of the availability of very small cetaceans in Anegada Bay. A similar pattern has been observed among tiger sharks, *Galeocerdo cuvier*, which normally prey on cetaceans only after reaching 200 cm TL (Lowe et al. 1996). However, when small cetaceans are available, tiger sharks < 200 cm TL prey on them (Mann & Barnett 1999).

During spring and summer, *Pontoporia blainvillei* is present in shallow waters of Anegada Bay, while during autumn and winter it uses deeper waters off the bay (Bordino et al. 1999). This shift in habitat use has been interpreted as a strategy for avoiding predation by sand tiger *Carcharias taurus* and copper sharks *Carcharhinus brachyurus* (Bordino et al. 1999), which are most abundant during summer months (Lucifora et al. 2002, Lucifora 2003). However, neither *C. taurus* nor *C. brachyurus* from Anegada Bay feed on marine mammals (Lucifora 2003). In contrast, *Notorynchus cepedianus* has its lowest abundance in Anegada Bay during most of the summer and preys heavily on marine mammals. This suggests that *P. blainvillei* is using the habitat of Anegada Bay most extensively when its main shark predator (*N. cepedianus*) is absent.

Only the largest individuals of *Notorynchus cepedianus* feed on South American sea lions *Otaria flavescens*. This is consistent with previous observations (Ebert 1986a, 1989, Long & Spencer 1995). The high incidence of *O. flavescens* as a prey of adult *N. cepedianus*, the fact that *N. cepedianus* has been witnessed attacking sea lions (Ebert 1991b), and the occurrence of hind parts of sea lions within stomachs suggest that *N. cepedianus* preys rather than scavenges on sea lions. The occurrence of hind parts of *O. flavescens* within stomachs suggests that *N. cepedianus* attacks *O. flavescens* from behind, as suggested for other sea lion–shark predatory interactions (Stewardson 1999).

Most prey of *Notorynchus cepedianus* are sectioned before being swallowed. This indicates that in spite of having a non-protrusible mandibular arc and serrated teeth only on the Meckel′s cartilage (i.e. lower jaw), the jaws of *N. cepedianus* are highly effective in sectioning. This is consistent with the observed prey capture behavior (Ebert 1991b). When attacking cartilaginous fishes or marine mammals, *N. cepedianus* usually cuts its prey in several pieces (Ebert 1991b). This can be explained by the size of the prey relative to that of the predator, because among cartilaginous fishes, only the smallest are consumed whole. The high incidence of mouth-hooked individuals is also consistent with a common use of jaws in prey handling, given that a high number of mouth-hooked individuals is expected if they bite several times the bait. In addition, the high incidence of mouth-hooked sharks suggests that, if lesions on mouth are not serious, the release of hooked sharks might contribute to reduce recreational-fishing mortality.

The results presented here indicate that Anegada Bay is a nursery area for *Notorynchus cepedianus*. The presence of large numbers of juveniles >100 cm TL suggests that this could be an important area for the conservation of *N. cepedianus* in the SW Atlantic.

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