Reproductive biology of the crocodile shark

Pseudocarcharias kamoharai

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From February 2005 to September 2007, a total of 490 crocodile sharks Pseudocarcharias kamoharai, caught as by-catch in the swordfish and tuna longline fishery that operates in the tropical western Atlantic Ocean, was studied in regard to their reproductive biology. Maximum observed total lengths (LT) were 1220 and 1090 mm for females and males respectively, with a high proportion of the catch being composed of mature specimens. Sexual maturity was attained at 760–810 mm LT for males (LT50 = 800 mm) and 870–980 mm LT for females (LT50 = 916 mm). The size at birth was estimated at 415 mm LT. Temporal variation in gonad morphology and mass suggests that in this region P. kamoharai, an aplacental viviparous species with oophagy, does not show a well-defined reproductive seasonality, with mating and parturition occurring possibly over an extended period of the year. Mean ± s.d. fecundity was estimated to be 3·9 (±0·6) pups per reproductive cycle.

Key words: fecundity; Lamniformes; life history; maturity; oophagy; reproductive strategy.

INTRODUCTION

The crocodile shark Pseudocarcharias kamoharai (Matsubara) is a small shark belonging to the order Lamniformes, family Pseudocarchariidae. It is an epipelagic and mesopelagic species, occurring from the surface down to depths of at least 590 m, in tropical and subtropical waters of the Atlantic, the Indian and the Pacific Oceans (Compagno, 2001). It is usually found offshore, although it sometimes occurs inshore and near the bottom (Compagno, 2001).

Pseudocarcharias kamoharai are caught worldwide predominantly as by-catch in pelagic longline fisheries targeting other species, such as swordfish Xiphias gladius L. and tunas (Scombridae) (Hazin et al., 1990), although the species is also

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occasionally caught by other fishing methods, such as gillnets (scombrid fishery) and squid jigs (Compagno, 2001). Given its low commercial value, captured specimens are usually discarded. Abe et al. (1969) reported that although this species is usually treated as trash fish in the central wholesale market of Tokyo, the liver is proportionately very large, weighing >20% of the whole fish and the squalene content is also very high, comprising 60–70% of the liver oil by mass. Thus, in some parts of the world, the liver may be retained for sale (White et al., 2006).

Even though *P. kamoharai* is globally widespread, it is reported to have a patchy distribution in most areas of occurrence (Béarez et al., 2001; Stewart, 2001; Meléndez et al., 2006). The first records for the Atlantic Ocean came from the eastern Atlantic (Cadenat, 1963), and since then the species has been regularly recorded as by-catch of commercial pelagic longliners operating along Brazilian oceanic waters, being particularly abundant in the tropical western Atlantic (north-eastern Brazil) (Hazin et al., 1990).

In spite of its worldwide distribution, *P. kamoharai* has been poorly studied and not much is known about its biology. The species is reported to have an aplacental viviparous reproductive strategy with oophagy (Fujita, 1981; Gilmore, 1993), where embryos feed on unfertilized yolked ova in the uteri to complete their embryonic development. Recent studies have mentioned that the terminology aplacental viviparity should be abandoned, and that matrotrophic viviparity with oophagy would best describe the reproductive mode of most Lamniformes (Hamlett et al., 2005; Musick & Ellis, 2005). Aplacental viviparity with oophagy, however, is still widely used and accepted to describe this type of reproductive strategy (Snelson et al., 2008), and hence it is used here, whilst acknowledging that it can be considered synonymous with matrotrophic viviparity with oophagy.

Most of what is currently known about the reproductive biology of this species comes from studies carried out in the Indo-Pacific Ocean. Fujita (1981) reported the catch of 11 specimens in the central Pacific Ocean, including one pregnant female that had four embryos from 401 to 428 mm total length ($L_T$) and considered that these were probably full-term embryos, therefore providing an approximate size at birth. Compagno (2001) stated that this is the smallest of the living lamnoids. White (2007) recorded the largest specimens so far, a female caught in eastern Indonesia measuring 1181 mm $L_T$, and stated that males in the Indonesia region were maturing at c. 725 mm and females from 870 to 1030 mm $L_T$. Currently, there are no biological data for this species from the equatorial Atlantic Ocean. Given that the species is usually discarded, there are no catch data that can be analysed from commercial landings and it is impossible to estimate population trends based on commercial fisheries catches.

In 2000, the Shark Specialist Group (SSG) of the International Union for the Conservation of Nature (IUCN) assessed *P. kamoharai* as ‘Lower Risk/Near Threatened’. This evaluation was based on the fact that this was an uncommon oceanic shark, with low fecundity and probable life-history characteristics that made it vulnerable as by-catch of expanding high-seas longline fisheries (Compagno & Musick, 2000).

The lack of biological data on this species, its possible biological vulnerability and the fact that it is being taken as by-catch from several oceanic pelagic fisheries reinforces the need for accurate reproductive data. The current paucity of life-history data hinders scientific assessments of *P. kamoharai* population trends. Therefore,
the goal of this study was to gather reproductive data on this fish in the tropical western Atlantic Ocean, specifically size at maturity, fecundity and reproductive seasonality.

MATERIALS AND METHODS

SAMPLE COLLECTION

The fish were caught from February 2005 to September 2007 by commercial longline fishing vessels operating in oceanic waters of the equatorial and tropical western Atlantic Ocean (latitude: 6° N to 23° S; longitude: 21° W to 39° W) (Fig. 1). These fishing vessels target tunas and X. gladius with drifting pelagic longlines, usually set at depths from 100 to 300 m. Once caught, P. kamoharai were stored frozen aboard the fishing vessels and transported whole to the laboratory at the Federal Rural University of Pernambuco, Brazil. Specimens remained frozen for a few days or a few months, depending on the time that a particular vessel remained at sea after each specimen was caught. Each specimen was sexed, measured for total length ($L_T$; all measurements taken with the caudal fin in its natural position) and weighed for total mass ($M$) and eviscerated mass ($M_E$).

For females, the ovary and oviducal glands were measured for width and weighed (gonad mass, $M_G$), and both uteri were measured for width along the median section, at the largest width. Liver masses were also recorded ($M_L$). Following dissection, the contents of the uteri were observed, and any developing embryos were counted, sexed (embryos $>100$ mm $L_T$), and measured and weighed. For males, the claspers were measured for inner and outer length, according to the definitions provided by Compagno (2001), the testes were measured along the median section at the largest width excluding the epigonal gland, weighed ($M_G$) and the presence of semen in the seminal glands recorded. All organs were measured to the nearest 0.1 mm using a digital calliper. All material was weighed using digital scales: material weighing $>3000$ g was weighed with a scale of 10 g precision, between 2000 and 3000 g was weighed with a scale of 1 g precision and $<$2000 g was weighed with a scale of 0.1 g precision.

DATA ANALYSIS

Sexual differences in the size and mass distribution of the samples between sexes were assessed with a non-parametric Mann–Whitney U-test. Samples were tested for normality with a Kolmogorov–Smirnov test (with Lilliefors’ correction), and parametric tests were used when the samples were normally distributed while non-parametric statistics were used when the samples lacked a normal distribution.

The gonado-somatic index ($I_G$) and the hepato-somatic index ($I_H$) were calculated for all specimens and the mean ± s.d. for each maturity stage was plotted. These indices were calculated as: $I_G = 100M_GM_E^{-1}$ and $I_H = 100M_LM_E^{-1}$. ANOVA followed by Tukey’s pair-wise comparisons or Kruskal–Wallis tests followed by Dunn pair-wise comparisons (depending on whether parametric or non-parametric approaches were chosen) were used to assess differences in those indices between maturity stages.

Each specimen was assigned to a specific maturity stage by macroscopically observing the condition of the reproductive system. For males, maturity was assigned based on the calcification and size of the claspers. For females, maturity was assigned based on the presence of uterine contents and the dimensions of the reproductive organs such as the ovary, oviducal glands and uterus.

For the purpose of the size at maturity estimations, and considering that a mature specimen is a specimen that is able to reproduce or has done so in the past (Conrath, 2004), the various reproductive stages previously assigned to the specimens were grouped as either mature or immature. The proportion of mature individuals by 20 mm $L_T$ size class was used to fit length-based maturity ogives and to estimate the size at maturity ($L_T$ at which 50% of the...
Fig. 1. Positions of *Pseudocarcharias kamoharai* caught in the tropical western Atlantic Ocean off the north-eastern Brazilian coast.

Individuals are mature, $L_{T50}$. The logistic curve was fitted by non-linear least squares by:

$$P_{Li} = \left[1 + e^{-b(L_{Ti} - L_{T50})}\right]^{-1},$$

where $P_{Li}$ is the proportion of mature individuals in size class $L_{Ti}$ and $b$ is the slope. The s.e. and the lower and upper limits of the 95% CI were calculated for each estimated coefficient. Maturity ogives were only fitted to females due to the small sample size of males.
Reproductive seasonality was assessed by plotting the frequency of occurrence of the different maturity stages of females, and the variation in embryo length throughout the year, to determine whether specific maturity stages were occurring predominantly during a specific season or period of the year. Uterine fecundity was estimated by direct methods, counting the number of developing embryos occurring in each female during pregnancy. Numbers of developing embryos occurring in the left and right uteri were compared with a Mann–Whitney $U$-test (given that the samples were not normally distributed). The sex ratio of the embryos was calculated and tested for equal proportions with a two proportion $z$-test. Numbers of unfertilized ova in the left and right uteri were compared with a $t$-test.

RESULTS

SAMPLE CHARACTERISTICS

A total of 490 specimens was caught during the sampling period, with the sex ratio biased towards females (1:1.8). Males ranged in size from 655 to 1090 mm $L_T$ ($n = 177$) and females from 750 to 1220 mm $L_T$ ($n = 313$). Males ranged in $M$ from 900 to 4420 g and females from 1200 to 7820 g. The largest female was 130 mm longer than the largest male, and the mean ± s.d. $L_T$ for females (965 ± 95 mm) was almost 50 mm longer than that for males (918 ± 81 mm) (Fig. 2). The sampled fish showed significant differences between sexes in terms of $L_T$ (Mann–Whitney $U$-test, $n_{\text{females}} = 313$, $n_{\text{males}} = 177$, $P < 0.05$) and $M$ (Mann–Whitney $U$-test, $n_{\text{females}} = 283$, $n_{\text{males}} = 155$, $P < 0.05$).

![Fig. 2. Total length ($L_T$) frequency distribution (50 mm intervals) of Pseudocarcharias kamoharai caught in the tropical western Atlantic Ocean (■, males $n = 177$; □, females $n = 313$).](image)
MATURITY

According to the calcification and size of the claspers, males were divided in three maturity stages: juvenile, maturing and adult (Table I). A significant growth in clasper length was observed when males grew from juveniles to adults, with juvenile specimens having claspers <60 mm inner length and adult specimens having claspers >80 mm inner length (Fig. 3). The best criterion to define male maturity was clasper calcification, with mature specimens having calcified claspers, while juvenile and maturing specimens did not have calcified claspers. Based on these characteristics, it was possible to estimate that males were mature at c. 760–810 mm $L_T$, with immature (including juvenile and maturing) males in the sample ranging from 655 to 810 mm $L_T$, and mature (adult) males ranging from 760 to 1090 mm $L_T$. Of the 177 males caught during this study, 91.5% were mature.

For males, a trend of increasing $I_G$ was observed between the different maturity stages, and those differences were statistically significant (ANOVA, d.f. = 2,146, $P < 0.05$). With the pair-wise Tukey’s multiple comparison tests, it was possible to determine that a homogeneous group is formed for the juvenile and maturing specimens (Tukey’s, $P > 0.05$), which is different from the adult specimens (Tukey, $P < 0.05$ in all cases). In terms of $I_H$, no statistical differences were detected (Kruskal–Wallis, d.f. = 2, $P > 0.05$).

For females, the ovary, the oviducal gland, the uterus and the presence of developing embryos were suitable structures for assessing maturity stage. Based on observation of these structures, females were divided into: juvenile, early pregnancy I, early pregnancy II, intermediate pregnancy, late pregnancy and resting (Table II). The ovary was very small (<15 g in mass) in juvenile specimens and enlarged in mature fish during gestation, being particularly enlarged (>150 g) during the intermediate pregnancy stage. Resting specimens had a small ovary similar to the juveniles (Fig. 4). The oviducal gland was small (<2 g) in immature fish, and large (>2 g) in mature specimens. The uteri were very narrow (<15 mm in width) in juveniles and enlarged in mature fish during pregnancy, particularly during the late pregnancy stage (50–125 mm width) (Fig. 4). Based on these observations, it was possible to estimate that females were maturing between 870 and 980 mm $L_T$, with immature (juvenile) specimens ranging from 750 to 980 mm $L_T$ and mature (including pregnant and resting) specimens ranging from 870 to 1220 mm $L_T$. By fitting a logistic maturity ogive it was possible to estimate that mean $\pm$ s.e. $L_{T50}$ 916 ± 4 mm, and that females achieve maturity at 75.1% of the maximum observed size. Of the 313 females caught during this study, 66.5% were mature.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juvenile</td>
<td>Small and un-calcified claspers, &lt;60 mm inner and 35 mm outer length</td>
</tr>
<tr>
<td>Maturing</td>
<td>Claspers developing, with 80–105 mm inner length and 50–75 mm outer length, but still not fully calcified</td>
</tr>
<tr>
<td>Adult</td>
<td>Large, developed and calcified claspers, usually with &gt;80 mm inner and 65 mm outer length</td>
</tr>
</tbody>
</table>
An increase in $I_G$ was observed throughout the initial pregnancy stages followed by a decrease towards late-term pregnancy. For resting females, the $I_G$ was low and relatively similar to the values of the juvenile specimens (Fig. 5). Statistical differences were found between the $I_G$ values of the different maturity stages (Kruskal–Wallis, d.f. = 5, $P < 0.05$). With the Dunn pair-wise multiple comparison tests, it was possible to determine that a homogeneous group is formed for the pregnant specimens (Dunn, $P > 0.05$ in all cases), which is significantly different from the juvenile and resting specimens (Dunn, $P < 0.05$ in all cases). A trend was also observed in $I_H$.
Table II. Characteristics of maturity stages for female *Pseudocarcharias kamoharai*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juvenile</td>
<td>Small and underdeveloped ovary, usually with &lt;15 g in mass and 30 mm in width. Small oviducal glands, with &lt;2 g in mass. Uteri narrow, with &lt;15 mm in width</td>
</tr>
<tr>
<td>Early pregnancy I</td>
<td>Presence of fertilized ova or very small embryos in the uteri. Ovary enlarged, showing vitellogenic activity, weighing from 30 to 200 g. Enlarged oviducal glands, 2 to 4 g in mass. Uterus enlarged, 20 to 50 mm in width</td>
</tr>
<tr>
<td>Early pregnancy II</td>
<td>Presence of small-sized embryos, with &lt;100 mm total length, $L_T$, and unfertilized ova (usually &gt; 10) in each uterus. Ovary enlarged, weighing from 150 to 600 g. Uterus enlarged, with 40 to 85 mm in width</td>
</tr>
<tr>
<td>Intermediate pregnancy</td>
<td>Presence of developing embryos, between 10 and 30 mm $L_T$, and a few unfertilized ova (usually &lt; 10) in the uteri. Ovary enlarged, weighing usually from 150 to 800 g. Uterus enlarged, with 40–90 mm in width</td>
</tr>
<tr>
<td>Late pregnancy</td>
<td>Presence of late-term embryos with &gt;30 mm $L_T$ and absence of unfertilized ova in the uteri. At this stage, all the unfertilized ova have been consumed by the embryos. Ovary less enlarged than in previous pregnancy stages, weighing from 10 to 400 g. Uterus highly enlarged, with 50–125 mm in width</td>
</tr>
<tr>
<td>Resting</td>
<td>Evidence of recent parturition activity, with enlarged uteri, up to 80 mm in width. Ovary without evidence of vitellogenic activity, weighing &lt;80 g</td>
</tr>
</tbody>
</table>

along the different female maturity stages, with the early I, early II and intermediate pregnant females having relatively high $I_H$ values, but the late-term pregnant females showing lower values. $I_H$ values increased slightly in resting specimens (Fig. 5). Statistical differences were found between $I_H$ values of the different maturity stages (ANOVA, d.f. = 5.279, $P < 0.05$), with significant differences occurring between juveniles and early pregnant I and intermediate pregnant females (Tukey, $P < 0.05$ in both cases).

**SEASONALITY**

By analysing the frequency of occurrence of the different maturity stages in the year, it was noted that both juveniles, pregnant and resting females occurred in all months of the year, with pregnant females occurring in higher numbers from May to July and juveniles in September and October (Fig. 6). No clear seasonal pattern in embryonic growth was detected (Fig. 7).

**FECUNDITY**

*Pseudocarcharias kamoharai* is an aplacental viviparous shark and the specimens analysed showed evidence of oophagy. Direct observations of dissected specimens showed that during gestation the embryos had yolked ova inside their stomachs. No differences were found in the mean number of embryos counted in each
Intensive vitellogenic activity was observed during the early pregnancy stages, with a relatively high number of unfertilized ova present in each uterus. The number of ova then decreased for the intermediate pregnant females and completely disappeared in late-term pregnant females, having all been presumably consumed by the developing embryos (Fig. 8). Typically, pregnant females had two embryos in each uterus, although some exceptions of either one (n = 17, representing 12.3% of all uterus with embryos) or three embryos (n = 1, representing 0.7% of all uterus with embryos).
Fig. 5. Differences in the mean ± s.d. \((n, \text{sample size})\) (a) gonado-somatic index \((I_G)\) and the (b) hepatosomatic index \((I_H)\) for the different maturity stages of female *Pseudocarcharias kamoharai*.

embryos) were found. The species’ mean ± s.d. uterine fecundity, based on the count of fully developed late-term embryos, was calculated to be \(3.9 \pm 0.6\) (\(n_{\text{females}} = 20; n_{\text{embryos}} = 77\)). The sex ratio of the embryos was close to 1:1, but slightly favoured females (53.7% females v. 46.3% males), although no significant statistical differences were detected (two proportion \(z\)-test, \(n_{\text{females}} = 101, n_{\text{males}} = 87, P > 0.05\)). The most typical situation observed was for a pregnant female to have one male and one female embryo in each uterus, totalling two males and two females per reproductive cycle.

**DISCUSSION**

Even though it is a widely distributed species, *P. kamoharai* seems to be relatively uncommon in many areas where it has been described (Béarez *et al.*, 2001;
Stewart, 2001; Meléndez et al., 2006). Hazin et al. (1990), however, provided the first evidence that this species is relatively common in the tropical western Atlantic Ocean. In the present study, it was observed that while the fish was caught over a relatively extensive latitudinal range, the higher density of catches came almost exclusively from the equatorial area. Further to the south, *P. kamoharai* appears to become again a rare species, as previously described by Amorim et al. (1998) for the southern Brazil (latitudes: 17° S to 35° S).

In this study, females attained larger sizes than males. This may indicate sexual dimorphism in terms of maximum size, or may be the result of segregation in the population or fishing bias. The maximum $L_T$ values presented in this study are slightly larger than what has been previously described in the literature (White,
One limitation of the present study was the lack of specimens <655 mm $L_T$ in the sample. The largest fully developed embryo observed in the present study measured 415 mm $L_T$, a size consistent with Fujita (1981) who reported that size at birth for this species should be c. 400–420 mm $L_T$ based on observations of full-term embryos. The present study lacked specimens from 400–420 mm to 655 mm $L_T$ and at this stage two hypotheses for this can be suggested: (1) that small specimens were not caught due to size selectivity of the fishing gear and (2) that small specimens were not caught because they were absent in the study area, meaning that the juveniles of this species are occurring at either a different geographical location or at different depth ranges. Future studies will need to address this issue, either by using smaller sized hooks or by sampling different geographical and depth areas.

For male *P. kamoharai*, clasper calcification and length seemed to be the best characteristics to evaluate maturity stage. Testis mass did not show a clear pattern with some large males showing small and light testis, possibly due to being at a resting stage. For females, the ovary mass, the oviducal gland mass and the uterus width were all suitable for assessing the maturity stage. Those structures are commonly used to assess elasmobranch maturity (Chen *et al.*, 1997; Mollet *et al.*, 2000; Jensen *et al.*, 2002).

Female *P. kamoharai* mature at larger sizes than males, a pattern common with many elasmobranchs (Cortés, 2000). The size at maturity ($L_{50}$) estimates of 760–810 mm for males and 916 mm for females indicate that both sexes are maturing at c. 75% of the maximum observed $L_T$, again a common value for elasmobranchs (Cortés, 2000). White (2007) reported that *P. kamoharai* males in Indonesia mature at c. 725 mm $L_T$, lower than what was estimated in the present study for the tropical western Atlantic Ocean. Alternatively, White (2007) reported that females in Indonesia matured between 870 and 1030 mm $L_T$, sizes similar to those presented in this study.

Reproductive seasonality is one of the most difficult variables to estimate, and although the results are inconclusive and it was not possible to determine how often a single female reproduces, this study provided some insights regarding this issue. Early pregnant females occurred throughout the year, with a slight peak from May
to July, indicating that mating might be occurring predominantly during this period, even though part of the population might be mating over the rest of the year. On the other hand, late-term pregnant females seemed to occur mainly from May to November, and this may reflect an extended parturition season for *P. kamoharai* in the equatorial and tropical western Atlantic Ocean. Finally, embryos were found in different development stages throughout the year without any clear growth seasonality, suggesting that *P. kamoharai* does not have a defined reproductive seasonality in the south-west Atlantic Ocean. This seems to agree with Fujita (1981) who also suggested that the mating season for this species in the central Pacific Ocean seemed to extend over a long period, even though he based his conclusions on a very limited dataset. Since there is vitellogenic activity in the ovary during pregnancy leading to production of ova for feeding the developing embryos, it was not possible to determine whether, by the end of their pregnancy, females are ready to immediately start another cycle. By observing the *I*_H variation along the different reproductive stages, it is interesting to note the progressive decrease in this index through the pregnancy stages, which suggests that females are spending high quantities of energy during pregnancy, probably due to the continuing production of ova for the oophagous embryos. Likewise, the decrease in *I*_G towards the end of pregnancy appears linked to the oophagous reproductive strategy, indicating that by the end of the pregnancy the embryos have already received all the energy they need to complete their development and that the production of oocytes in the ovary decreases. These observations imply that females may need a relatively prolonged resting phase to accumulate enough energy to undergo another reproductive cycle and is supported by the hypothesis posed by Gilmore *et al.* (2005) that oophagous species such as *P. kamoharai* probably do not mate and become impregnated every year, but would skip years.

The most common pattern found in late-term pregnant females was the presence of four embryos, usually one male and one female in each uterus, nourishing through oophagy. Pregnant females of some elasmobranch species are known to lose embryos during the capture process (Coelho & Erzini, 2008) and this issue was not accounted for in this study. Only a few elasmobranch species have been documented to have oophagy or adelphophagy, all from the order Lamniformes (Gilmore, 1993). Oophagy seems to be the most common of these two strategies and has been previously described for the bigeye thresher *Alopias superciliosus* (Lowe) (Gilmore, 1983; Moreno & Morón, 1992; Chen *et al.*, 1997), the pelagic thresher *Alopias pelagicus* Nakamura (Liu *et al.*, 1999), the shortfin mako *Isurus oxyrinchus* Rafinesque (Stevens, 1983; Mollet *et al.*, 2000), the longfin mako *Isurus paucus* Guitart Manday (Gilmore, 1983) and the porbeagle *Lamna nasus* (Bonnaterre) (Francis & Stevens, 2000; Jensen *et al.*, 2002). Adelphophagy seems to be a much rarer strategy and has in fact been described for only one species, the sand tiger *Carcharias taurus* Rafinesque (Gilmore *et al.*, 1983). Of particular interest is the fact that among the oophagous species, *P. kamoharai* has usually four pups per reproductive cycle, differing from what is observed for thresher sharks (*Alopias* spp.) where only two pups (one embryo per uterus) are successful (Gilmore, 1983), and *I. oxyrinchus* where fecundity is much higher, from four to 25 and seems to be correlated with female size (Mollet *et al.*, 2000). One species similar to *P. kamoharai* in this aspect is *L. nasus*, where four embryos also develop successfully during pregnancy (Francis & Stevens, 2000; Jensen *et al.*, 2002).
The ecological advantage of such a reproductive strategy remains unclear. One possibility is that by having a lower fecundity, the females are able to nourish their embryos at a faster rate, meaning that embryos reach larger sizes in shorter periods of time, and that might be a competitive ecological advantage for the species. Another hypothesis is that by having a lower fecundity the females can hold their embryos until they reach a larger size. In fact, if *P. kamoharai* is compared with another pelagic shark with a much higher fecundity, such as the blue shark *Prionace glauca* (L.), whose litter size can reach 135 pups (Compagno, 2001), it is noticeable that while *P. kamoharai* pups are born at c. 35% of the maximum size of the species (assuming the maximum size of 1220 mm and the size at birth of 415 mm observed during the present study), *P. glauca* pups are born at only 10% of the maximum size of the species [assuming a maximum size of 3830 mm and a size at birth of 400 mm documented by Compagno (2001)]. By being born at relatively larger sizes, the juvenile *P. kamoharai* are better prepared for their predatory lifestyle, not only because they can more easily find and hunt for larger and faster prey, but also because they are less vulnerable to predation from larger sharks. On the other hand, the demographic disadvantage of such a reproductive strategy is that the species fecundity is much lower. By having a mean fecundity of approximately four pups every reproductive cycle, this species’ intrinsic rate of increase may be very low. This fact is not a problem in areas without significant fisheries, where only natural mortality affects the populations, but once fishing mortality increases, the low fecundity will probably have the consequence of the species declining very rapidly, without being able to recover easily.

Future studies addressing this species, life history should include the estimation of growth variables and determination of age at maturity. Like other pelagic species’ *P. kamoharai* might be easily affected and affected by fishing mortality, particularly due to its low fecundity.

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