RECORDS ON THE HERRING SHARK *LAMNA DITROPIS* (LAMNIDAE) AND ITS EMBRYOS IN THE SURF ZONE OF KUNASHIR ISLAND (SOUTH KURIL STRAIT) IN FEBRUARY 2024

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The discovery of a female salmon shark *Lamna ditropis* and two its embryos in the surf zone of Kunashir Island is reported. Data of morphometric measurements of the female are presented. *TL* of the female was 216 cm; *aC*, 195 cm. Cephalopod (Cephalopoda) beaks and codfish (Gadidae) otoliths have been found in the stomach of the shark. It is assumed that the stress trigged premature parturition.

Keywords: salmon shark *Lamna ditropis*, morphometry, feeding, premature parturition, Kunashir Island, South Kuril Strait, Pacific Ocean.

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INTRODUCTION

The currently existing representatives of the genus *Lamna* – the Pacific *L. ditropis* Hubbs et Follett, 1947 and the Atlantic *L. nasus* (Bonnaterre, 1788) porbeagle sharks – belong to the family Lamnidae, which also includes the genera *Carcharodon* and *Isurus* (Reshetnikov, Kotlyar, 2022; Fricke et al., 2024). The Pacific salmon shark is distributed in coastal and oceanic waters of the northern Pacific Ocean: from Japan (including the Sea of Japan), the Korean Peninsula and the Pacific coast of Russia (including the Sea of Okhotsk and the Bering Sea) to the USA, Canada (from Alaska south to British Columbia, Washington, Oregon and Southern California) and possibly Mexico (Compagno, 2001) , as well as near the Hawaiian Islands (Weng et al., 2005). It is an ovoviviparous species (Gubanov et al., 1986). The study of its distribution patterns and biology has been conducted primarily by foreign researchers (Tanaka, 1980, 1986 – cited from: Nagasawa, 1998; Nakano, Nagasawa, 1996; Nagasawa, 1998; Compagno, 2001; Hulbert, Rice, 2002; Weng et al., 2005; Goldman, Musick, 2006; Kubodera et al., 2007; Gallucci et al., 2008; Last, Stevens, 2009; Conrath et al., 2014). Until 2005, morphometric descriptions were known for only three specimens (Nakaya, 1971 – cited from: Dolganov, 2005). Russian researchers have studied the seasonal distribution and some biological features of the shark (Blagoderov, 1993), and also conducted an analysis of morphometric measurements of 75 specimens (Dolganov, 2005) from the northwestern Pacific Ocean. It is believed (Blagoderov, 1993) that the Pacific waters near the Southern Kuril Islands are a permanent habitat for some salmon sharks and their breeding area. The current understanding of parturition in females of this species in the South Kuril waters during the winter period is based on indirect information. Premature parturition of salmon sharks in Russian waters has not been previously documented. In our work, we describe the first such case.

MATERIAL AND METHODS

On the Pacific side of Kunashir Island, 200 m south of the Sernovodka River mouth, at coordinates 43°54′02″ N, 145°38′09″ E, on February 22, 2024, local residents discovered a female shark next to two of her dead embryos (Fig. 1, 2). The female was alive, her gills were moving. She was lying half in the water about 4 m from the surf line on her right side with her belly toward the sea, embryos were in the surf line about 8 m apart from each other on their left side also with bellies toward the sea (Fig. 2a). The embryo lying on the right was about 6 m from the shark, the one on the left was about 4 m away. No other sharks were visually observed nearby. The embryos were not measured, but one of them was photographed in close-up (Fig. 2c). Morphometric measurements according to the previously published (Dolganov, 2005) measurement scheme and detailed photography of the female were carried out the next day. At that time, the embryos were no longer near her, possibly carried away by the ebb tide into the sea. To determine the species of fish whose otoliths were found in the shark's stomach, we used previously obtained values of the length-to-width ratio of Pacific cod *Gadus macrocephalus* otoliths from waters near the northern Kuril Islands (730 pairs), walleye pollock *G. chalcogrammus* (25 pairs) and Far Eastern navaga *Eleginus gracilis* (25 pairs) from waters near the southern Kuril Islands (own data). Fish species names are given according to Eschmeyer's catalog (Fricke et al., 2024).

RESULTS AND DISCUSSION

The appearance of the examined female matched the description of the Pacific salmon shark (Mecklenburg et al., 2002): dark bluish-gray back, white belly with dark spots and "blots," robust body; short, conical snout; first dorsal fin positioned above the pectoral fin (Fig. 2b), small secondary keel at the base of the caudal fin (Fig. 2g), elongated and smooth teeth, accessory cusps on most teeth, height of middle teeth on upper jaw less than half the height of anterior teeth (Fig. 2d). The belly of the examined specimen was gray, and accessory cusps on most teeth were not visible. The upper and lower jaws had three rows of teeth each. In the other two species of the family Lamnidae found in Pacific waters – the white shark *C. carcharias* and the shortfin mako shark *I. oxyrinchus* , the pectoral fin is positioned in front of the first dorsal fin, and the secondary keel and accessory cusps on teeth are absent (Mecklenburg et al., 2002). The pups had light gray bodies, sac-like bellies, and, judging by the photo of one of them, a crescent-shaped caudal fin and projections above the gill slits.

The absolute length (*TL*) of the porbeagle shark female found on the shore was 216 cm. The maximum *TL* of this species, according to some data, is 305 cm (Compagno, 2001), according to others - 350 cm (Gubanov et al., 1986), and according to unconfirmed isolated cases - 370-430 cm (Compagno, 2001) . In the South Kuril region from June -November , specimens with *TL* of 41-230 cm were encountered (Blagoderov, 1993), while information on shark length from this region for the winter period was absent.

Based on the occurrence of small-sized specimens, it was assumed that for the northwestern part of the Pacific Ocean, the birthing places are limited to waters near Japan and the southern Kuril Islands, as well as the open waters of the northern Pacific Ocean (Blagoderov, 1993). However, according to observations by V.N. Dolganov (personal communication), during the hydrological winter, porbeagle sharks stay in waters near the southeastern coast of Honshu Island and the southern coast of Hokkaido Island, and the appearance of a female of this species near the coast of Kunashir during this time is unusual.

The plastic characteristics of the studied specimen are presented in the table. The values of our measurements either fall within the ranges or are close to their boundaries obtained by Dolganov (2005) for 75 specimens with *TL* of 909-2470 mm from waters east of Japan (40°13′-45°57′ N, 147°09′-166°02′ E (in the cited publication incorrectly indicated as W)) in 1977-1979.

Plastic characters of the Pacific herring shark *Lamna ditropis* according to literature and our data

Character	Dolganov, 2005		Our data
	$M \pm m$	min–max	
TL , mm	1468.0 ± 0.04	909.0–2470.0	2160
In % *TL*			
Distance from the tip of the snout to:			

– eye	5.4 ± 0.05	4.0–6.3	5.6
– nostril	3.7 ± 0.05	2.8–4.7	4.4
– mouth	4.7 ± 0.06	3.3–5.9	6.0
– 1st gill slit	21.3 ± 0.18	18.1–24.8	20.8
Head length	29.4 ± 0.22	24.9–33.8	30.0
Distance from the tip of the snout to the beginning of the fin:			
– pectoral	27.8 ± 0.27	23.3–31.5	29.9
– pelvic	55.3 ± 0.35	49.2–61.4	62.0
– 1st dorsal	33.9 ± 0.22	30.4–37.9	35.2
– 2nd dorsal	71.3 ± 0.30	66.7–77.6	78.7
– anal	70.9 ± 0.34	65.8–77.7	
– caudal	79.6 ± 0.30	74.7–85.4	90.3
Length of pectoral fin base	8.3 ± 0.06	7.6–9.7	9.7
Height of the outer edge of the pectoral fin	18.2 ± 0.15	16.0–21.0	21.3
Length of 1st dorsal fin base	10.8 ± 0.06	9.7–12.2	9.7
Height of 1st dorsal fin	11.3 ± 0.12	9.2–13.5	13.7
Length of 2nd dorsal fin base	1.4 ± 0.02	1.1–1.8	1.4
Height of 2nd dorsal fin	1.6 ± 0.02	1.4–2.0	1.4
Length of anal fin base	1.6 ± 0.02	1.2–2.0	1.9
Height of anal fin	2.0 ± 0.02	1.7–2.5	2.8
Length of upper lobe of caudal fin	25.2 ± 0.12	22.9–27.0	23.6
Length of lower lobe of caudal fin	18.5 ± 0.15	16.1–20.7	17.1
Distance between:			
– eye and 1st gill slit	13.5 ± 0.07	12.4–14.8	14.3
– nostrils	3.5 ± 0.04	3.0–4.3	4.4
– eyes	5.9 ± 0.07	4.9–7.3	6.9
– 1st and 2nd dorsal fins	27.2 ± 0.13	25.2–29.6	30.6
– 2nd dorsal and caudal fins	8.4 ± 0.08	7.0–9.9	8.8
– anal and caudal fins	8.5 ± 0.07	7.3–9.6	6.9
Distance from beginning to beginning of fins:			
– pectoral and pelvic	27.8 ± 0.19	24.5–34.4	27.8
– pelvic and anal	16.0 ± 0.18	13.1–22.5	19.9
Eye diameter	1.7 ± 0.03	1.4–2.2	1.7
Length of gill slit:			
– 1st	7.7 ± 0.07	6.8–9.3	7.9
– 2nd	7.8 ± 0.07	6.8–9.1	8.3
– 3rd	7.8 ± 0.08	6.3–8.9	8.3
– 4th	7.8 ± 0.15	6.8–9.0	7.4
– 5th	8.0 ± 0.07	6.8–9.1	7.4

Note. *TL* – absolute body length, $M \pm m$ – mean value and its error,

min–max – limits of character variation.

Sexual maturity of males and females occurs when the body length from the tip of the snout to the beginning of the caudal fin (*aC* or in foreign literature *PCL*) reaches 140 and 170–180 cm respectively at the age of 5 and 8–10 years in the western waters of the North Pacific Ocean (Tanaka, 1980, 1986 – cited from: Nagasawa, 1998) and 124.0 and 164.7 cm at the age of 3–5 and 6–9 years in the eastern waters (Goldman, Musick, 2006). The female we studied had an *aC* of 195 cm, which is consistent with the data mentioned above. Based on research in the waters of the western and eastern Pacific Ocean (Goldman, Musick, 2006), her age could have been from 10 to 16 years. Studies in Alaskan waters (Conrath et al., 2014) revealed the gestation period for females of the species to be 9–10 months. In this case, the mating period for the female we examined was during the summer months. The results of studying the seasonal distribution of the porbeagle shark in the northwestern Pacific Ocean (Blagoderov, 1993) showed that during the summer period, individuals concentrate mainly in the South Kuril region (mixing zone of the Oyashio and Kuroshio currents) and in the northern part of the Sea of Japan near the Primorye coast, including the Tatar Strait. It is possible that the female mated in the waters of one of these regions.

Lamnid sharks reproduce via aplacental viviparity with intrauterine cannibalism (oophagy) (Compagno, 2001). Embryos in the uterus hatch from egg capsules after depleting yolk reserves and begin consuming unfertilized eggs, which are continually ovulated into the oviducts throughout part or most of the pregnancy (Gilmore et al., 2005 - cited in: Conrath et al., 2014) from the ovary (Tanaka, 1980, 1986 - cited in: Nagasawa, 1998). In December 2006, a pregnant 15-year-old female *TL* 256.5 cm from Alaskan waters had such an ovary, nourishing two embryos in each the right and left uteri, weighing 7.5 kg and measuring 42 cm in diameter (Gallucci et al., 2008) . The sac-like organ approximately 35 cm long filled with yellow fat-like substance (Fig. 3a) found in the body cavity of the shark we examined was such an ovary, the contents of which nourished the embryos. As a result of feeding on unfertilized eggs, the internal yolk stomach of embryos expands to large sizes (Jensen et al., 2002). Studies of the sand tiger shark *Carcharias taurus* showed that in late pregnancy stages, the ovary is no longer vitellogenic and the embryo feeds on yolk from its distended yolk stomach (Wyffels et al., 2022). It appears that the embryos were discovered at this developmental stage. Since the birth was premature and the embryos had not completed their intrauterine development cycle, they were non-viable. The number of offspring born is, according to some data, four to five (Nagasawa, 1998), according to others - three to four, predominantly four (Conrath et al., 2014), and according to third sources - two -five (Compagno, 2001). In our case, two embryos were recorded. Cases of premature birth in sharks under stress situations, particularly during capture, are known and described (Adams et al., 2018). Premature birth due to beaching has been documented for the bluntnose sixgill shark *Hexanchus griseus* in Puget Sound (USA) (Williams et al., 2010).

Stress-induced parturition is presumed to have adaptive significance, and two hypotheses have been proposed for the emergence of this phenomenon in cartilaginous fishes (Adams et al., 2018). The first is self-sacrifice, where a pregnant female stranded by storm or tidal waves gives birth to increase the survival chances of her offspring and ensure the continuation of the species. The second is predation/self-preservation, where a stressed pregnant female disposes of her offspring to facilitate her escape. According to Low (1978), a female who deliberately abandons her offspring has a better chance of escaping predators by distracting them with the abandoned young. However, the shark we studied was not washed ashore by waves - there was no sea disturbance. At the time of discovery, it was halfway in the water, which would not have prevented it from returning to the sea if it were in normal physical condition. Disposing of non-viable embryos does not ensure the continuation of the species. The predation hypothesis also finds no confirmation. It is known that sharks, including white sharks (Towner et al., 2024), are attacked by killer whales *Orcinus orca* . In particular, there is a documented case where, as a result of killer whale attacks on a group of broadnose sevengill sharks *Notorhynchus cepedianus* off the coast of Argentina, two of them beached themselves and died (Reyes, García-Borboroglu, 2004). There is also a known case of killer whales attacking a porbeagle shark (Ford, Ellis, 2014 - cited in: Mucientes, Gonzles-Pestana, 2020). But there were no killer whales in the area where the shark was found.

There are also different opinions about the breeding period: February-March (Lindberg, Legeza, 1959), winter -spring (Blagoderov, 1993), spring (Compagno, 2001), March-May (Nagasawa, 1998), May-June (Conrath et al., 2014). All of them are based on catches of already born individuals or females with late-stage embryos. Different timing of the appearance of offspring, it seems, is due to the characteristics of the birthing areas. If we accept the view that the shark we studied had a premature birth, then they would most likely have been born in March. According to published data, *TL* of newborn sharks ranges from 40-50 to 85 cm (Compagno, 2001). The embryos found on the Kunashir coast were not measured, but according to one witness, their *TL* was 60-70 cm.

The porbeagle shark is a predator that consumes various prey and occupies the highest trophic level in the food chain (Nagasawa, 1998). For the Aleutian Islands and Gulf of Alaska region during the summer period, its main food objects are Pacific salmon (*Oncorhynchus*) (Compagno, 2001). In the Pacific waters east of the Kuril Islands, the porbeagle shark was regularly encountered in drift net catches along the migration routes of Pacific salmon from June to September (Poltev, 2020). In addition to these, the species' diet also includes squids (Myopsida + Oegopsida (= Teuthoidea)), sablefish *Anoplopoma fimbria* , Pacific herring *Clupea pallasii* , rockfish *Sebastes* sp., eulachon *Thaleichthys pacificus* , Pacific capelin *Mallotus villosus* , spiny dogfish *Squalus acanthias* , arrowtooth flounder *Atheresthes stomias* and cod fishes (Gadidae) (Hulbert, Rice, 2002). In the summer-autumn period, some porbeagle sharks, mainly large ones, migrate to the waters of the northern part of the Sea of Japan and the southern part of the Sea of Okhotsk, as well as to the waters near the Southern Kurils to feed on Japanese sardine *Sardinops* *sagax* , and in autumn - to more distant areas of the Sea of Okhotsk and the Bering Sea to feed on Pacific herring and walleye pollock (Blagoderov, 1993). In particular, most of the sharks studied in the Bering Sea and Gulf of Alaska in autumn 2002 and 2009-2010 were caught during walleye pollock fishing (Conrath et al., 2014). The diet of a female *TL* 256.5 cm from Alaskan waters during winter consisted of Pacific herring, during the fishing of which the predator was caught (Gallucci et al., 2008). Individuals *TL* 69-157 cm in the waters of the northwestern Pacific Ocean in April-May 1999 and 2000 predominantly consumed mesopelagic squids *Gonatopsis borealis* , *Onychoteuthis borealijaponica* and *Okutania anonycha* (= *Berryteuthis anonychus*) (Kubodera et al., 2007). In the stomach of the female we examined, only six beaks of cephalopods (Cephalopoda) (presumably squids) and 19 otoliths of cod fish (Fig. 3b) were found. The average and extreme values of the length-to-width ratio of these otoliths are 2.7 (2.3-3.0). For Pacific cod otoliths, these values are 2.0 (1.6-2.6), which excludes the possibility that the examined otoliths belong to this species. The values obtained for walleye pollock otoliths (2.6 (2.2-3.1)) and saffron cod (2.8 (2.5-3.0)) are close to those examined. However, considering that saffron cod is a coastal demersal species, while walleye pollock is a demersal-pelagic species forming dense aggregations offshore, and based on the facts presented above about sharks feeding on walleye pollock, we assume that the examined otoliths belong to this species. In addition to food remains, unidentified roundworms (Nematoda) and tapeworms (Cestoda) were observed in the shark's stomach.

During examination of the shark, large healing cuts and wounds resembling bites were noted in the tail area (Fig. 3c). They may have been inflicted by larger conspecifics. Since the female appeared healthy externally, her death was unlikely related to the consequences of these injuries. We consider it more realistic that the shark died from a hidden, latent infectious disease or infection (viral, bacterial) with a fulminant course. In both cases, clinical signs of the disease do not manifest, and the fish externally does not differ from healthy individuals. The weakening female headed to shallow water as a safer place, where, while dying, she ended up in a shallow area, and the stress accompanying the events caused premature birth.

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COMPLIANCE WITH ETHICAL STANDARDS

The already deceased individual was studied. No permission is required for such work.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflict of interest.

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FIGURE CAPTIONS

Fig. 1. Location of discovery (●) of the female salmon shark *Lamna ditropis* and her embryos ; (—) – isobaths.

Fig. 2. Position of the female salmon shark *Lamna ditropis* (↑) and her embryos(↓) during discovery (a), external appearance of the shark (b) and one of her embryos (c), (↗) – additional keel (d), jaws (e). Photos 2a–2c courtesy of S.S. Bobryshev.

Fig. 3. Ovary (a) and food remains from the stomach (b) of the female salmon shark *Lamna ditropis* , (↖) – wounds on her body (c). Photo 3c courtesy of S.S. Bobryshev.