

## Studies on Sharks-XI

Reproduction in Female *Heptranchias perlo*\*1

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The present report is to investigate the morphology and ecology of reproductive system of female *Heptranchias perlo* (BONNATERRE) in the southwestern waters of Kyushu. *H. perlo* belongs to the non-placental type in viviparity and does not form the uterine compartments. Both right and left ovaries of this species are functional each containing 10 mature ova measuring 35 mm to 45 mm in diameter on the average at the time of ovulation. Moreover, the ova in ovary do not develop with the growth of embryos but after the parturition. The sexual maturity of female is reached between 95 cm and 105 cm in total length as estimated from the correlation of total length with the diameter of ovum in ovary and the uterine width. It seems that this species has no specific reproductive season judging from the situations of ovaries and uterus. The embryos measuring about 240 mm in total length were similar to the adults in general body proportion and coloration, and were not enclosed in the embryonic membrane. Further, these embryos appeared to be just before parturition, since each embryo had no external yolk sac but internal yolk sac attached to the duodenum, supplying the yolk substance to the valvular intestine. The condition factor and hepatosomatic index are greatly related to the reproduction of female *H. perlo*.

*Heptranchias perlo* (BONNATERRE) belongs to Hexanchidae, and possesses seven gill openings and only one dorsal fins, for that reason *H. perlo* is very peculiar in appearance. The sharks with more than six gill openings are *Chlamydoselachus anguineus* GARMAN, *Hexanchus griseus* (BONNATERRE), *Notorhynchus platycephalus* (TENORE), *H. perlo* and *Pliotrema* sp. Of these sharks, four species except *Pliotrema* sp. have only one dorsal fin and very flexible body, and are scarcely calcified in the skeleton such as vertebrae. Therefore these four sharks are generally known to be primitive.

On the other hand, the morphology and ecology of reproductive system in female

selachians are very various in comparison with those of the teleosts, and even now hold many obscure and interesting problems. Namely, according to TESHIMA et al. (1), its morphology can be classified into oviparity and viviparity, and furthermore the viviparity is divided to placental type and non-placental type. Some oviparous species deposit an egg capsule containing a relatively grown embryo and some other species deposit an egg capsule with little or no embryonic development. The oviparity has been reported for *Scyliorhinus canicula* and *S. stellaris* by FORD (2), *Heterodontus japonicus* by SMITH (3), *H. francisci* by DEMPSTER et al. (4), and *Halaelurus bürgeri* by KUDO (5) and MAKIHATA (6).

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The viviparous placental type consists of multiple pregnancy and simple pregnancy; the former includes *Scoliodon sorrakowah* (7), *S. palasorrah* (7), *Sphyrna tiburo* (8), *Carcharhinus falciformis* (9) and *Mustelus griseus* (10), and the latter includes *C. dussumieri* (1). In the viviparous non-placental type, uterine compartments are either formed or not formed. *Mustelus manazo* (11) and *Galeorhinus japonicus* (12) form uterine compartments. These viviparous species are delivered of the embryo which is similar in most characteristics to the adult.

In this way, the reproductive morphology in female sharks is various, and its ecology has many peculiar features. Therefore, in the present report, the authors attempt to define the morphology and ecology of reproductive system in female *H. perlo*.

### Materials and Methods

The materials, *Heptranchias perlo* as shown in Fig 1, were landed at the fish

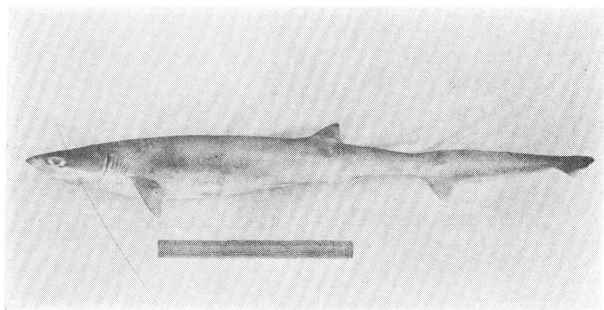


Fig. 1. Female *Heptranchias perlo*.

market in Nagasaki, Japan almost all the year around, during the period May 1974 to October 1976. As shown in Fig. 2, fishermen are catching by the bottom long line along the continental shelf of the East China Sea, that is 200 m deep contour

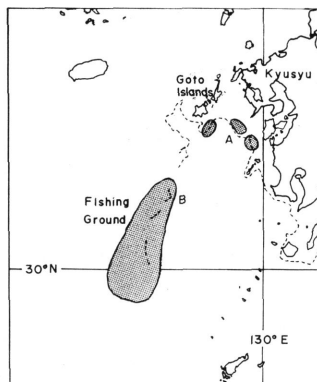


Fig. 2. Fishing ground (shaded area).  
A: Authors collected specimens.  
B: Fishermen are operating.

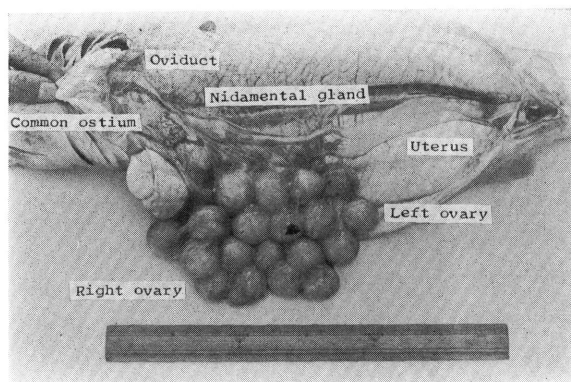
line. Furthermore, as the fishing ground is not far from Nagasaki, the authors collected some specimens by the bottom long line on board the "Kakusui", a small research vessel of Nagasaki University. This long line has 900 m buoy lines as operated 600 m in depth, and two main lines with 100 branch lines respectively. The branch line is made of wire leader so that the sharks may not bite and break it. While the operation was carried out at several depths ranging from 100 m to 600 m, the sharks were caught better at the depth between 200 m and 300 m, but not caught at the depth less than 200 m and more than 500 m.

As shown in Table 1, the specimens investigated were 218 females and 124 males, females measuring 494 mm to 1163 mm in total length. The small number of materials in August and winter does not mean that *H. perlo* migrates to other places, but it so

happened due to the fact commercial fishing is slack in August and fishermen change the fishing ground in winter. The authors could catch sharks in August like to other months. In spite of collecting throughout the year, only one gravid

Table 1. Number of specimens in each month.

Month	Male	Female	Total
Apr.	9	26	35
May	47	60	107
Jun.	9	47	56
Jul.	15	15	30
Aug.	0	4	4
Sep.	16	24	40
Oct.	2	17	19
Nov.	0	5	5
Dec.	11	2	13
Jan.	0	4	4
Feb.	0	3	3
Mar.	15	11	26
Total	124	218	342

Fig. 3. Reproductive organs of female *Hepttranchias perlo*.

female could be obtained in June.

The sharks collected were measured and dissected in the laboratory, and then were examined for gonads, stomach contents and liver weight. The gonads, as occasion demanded, were fixed in 10% formalin solution, made into paraffin sections, and stained with HANZEN'S haematoxylin and eosin.

## Result and Discussion

### 1. Reproductive Organs

In selachians, generally only the right ovary is functional and the left ovary is rudimentary. However, *Hepttranchias perlo*, as shown in Fig. 3, possesses both functional ovaries, like in *Chlamydoselachus anguineus* (13), *Squalus brevirostris* (14, 15) and *Scoliodon* (7). Moreover, in *Squalus mitsukurii* JOPDAN et FOWLER, *Centroscymnus owstoni* GARMAN, *Deania aciculata* (GARMAN) and *Etmopterus lucifer* JORDAN et SNYDER which the authors investigated, the both right and left ovaries were functional.

In immature females, ovaries consist of many tiny white ova, and mature females

appearing to be just ahead ovulation have large and small size ova in both ovaries. These large ova measuring 35 mm to 45 mm in diameter abound in yolk substance, and each ovary possesses an average of 10 ova. There was a specimen which had 16 left ova and 14 right ova of about 45 mm in diameter. On the other hand, the small ova are 8 mm or less in diameter. For the present, it is unknown whether these small ova have shrunk after the large mature ova were ovulated or they will become the ova of next ovulation.

The mature eggs ovulated in the peritoneal cavity are conveyed to each oviduct through a funnel-shaped common ostium lying in the anteroventral center of the peritoneal cavity. MATTHEWS (16) described that in *Cetorhinus maximus*, the ova discharged pass out through the pocket on the right side of the ovary and are taken up by the ostium abdominale. The oviduct separates on both sides in the common ostium and arches around laterally on the surface of the septum transversum immediately ventral to the attachments of the right and left parts of the suspensory ligament of the liver. Specimens less than 650 mm in total length possess the string-like duct following similarly from the

oviduct to the uterus. Nevertheless, in completely mature females, the oviduct is 6 mm to 8 mm in width and many ridges leading to the entrance of uterus run on the inner surface of oviduct.

The nidamental gland is not heart-shaped as *Carcharhinus dussumieri* (1) and *Galeorhinus japonicus* (12), but ovoid in shape measuring 20 mm in width and 30 mm in length at maximum though it differs by the size and reproductive state of sharks. When the sharks become more than 800 mm in total length, the width of the nidamental gland increases gradually. The inner part of uterus ranges longitudinally a large fold. The uterine wall close to parturition becomes transparent and much thinner compared with the time of ovulation. In the gravid female, the trace of placenta and uterine compartments was not observed in its uterus. Moreover, BIGELOW and SCHROEDER (17) referred to the accounts of LO BIANCO and RANZI, and mentioned that the large oval yolk sac shows no signs of any attachment to the wall of the oviduct of the mother. Trophonemata which MATTHEWS (16) has stated in *Cetorhinus maximus* were not found inside the uterus of this species.

Fig. 4 shows the relationship between

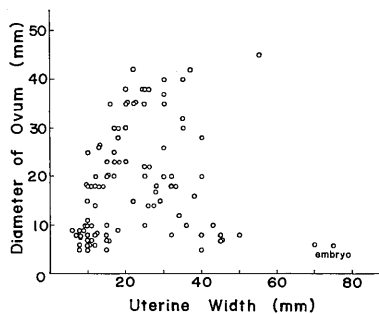


Fig. 4. Relationship between the diameter of ovum and the uterine width.

the diameter of ovum and the uterine width in female *H. perlo*, measuring more than 5

mm in diameter of ovum and 6 mm in uterine width. In this figure, the uterine width becomes greater as the diameter of ovum increases. When the ova reach 35 mm to 45 mm in diameter, the increase in the diameter of ovum nearly stops and the uterus expands rapidly. In the shark which was pregnant and appeared to be just after parturition because of the uterine width of 70 mm, the ovary contained the ova of about 6 mm in diameter. The uterus seems to shrink abruptly up to about 35 mm in width after the birth of embryo. As mentioned above, it is concluded that this species begins to develop the ova in ovary after parturition, and *H. perlo* is a curious species different from *Squalus acanthias* (2), *S. brevirostris* (14), *Mustelus manazo* (10), and *Galeorhinus japonicus* (12), in which their ova develop along with the growth of embryos. KUDO (18) described that in *Mustelus manazo* from the Bungo Channel and the sea of Iyo, the ova developed for the succeeding ovulation are not found in the ovary after parturition.

## 2. Reproductive Season

The authors mentioned in previous account (19) that *H. perlo* does not appear to have any definitive season in view of the testes and sperm sacs of males. We report again that *H. perlo* appears clearly to have no reproductive season, as a result of examination of females throughout the year. Only one female with embryos was collected in June, and no specimen with fertilized eggs was captured. Therefore, the reproductive season was studied from the monthly variations of the diameter of ovum and the uterine width.

Fig. 5 shows the monthly variation of the diameter of ovum. The ovum exceed 35

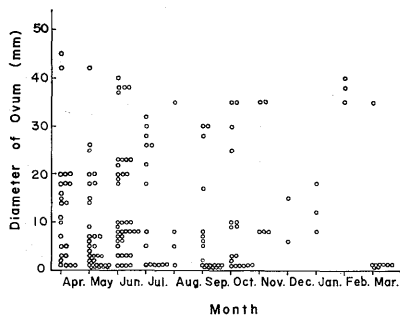


Fig. 5. Monthly variation of the diameter of ovum

mm in maximum diameter in almost all months, and it is suggested that the ovary contains mature ova ovulating at once in a whole year. The monthly variation of the uterine width is shown in Fig. 6. The uterus reaches more than 30 mm in width except in winter. This signifies that the uterus is possible to receive the fertilized eggs. The definitive situation in winter has not been grasped owing to the small number of specimens.

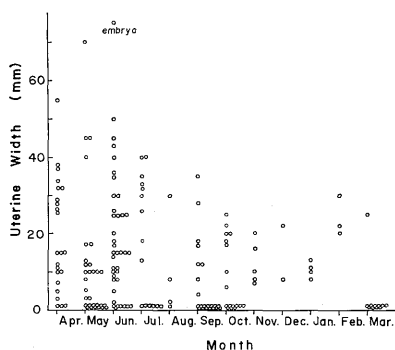


Fig. 6. Monthly variation of the uterine width.

These facts define that *H. perlo* is possible to reproduce all the year around and does not have any specific reproductive season. This may be attributable to the fact that this species inhabits at the bottom layer ranging from 200 m to 300 m in depth, where the water temperature hardly changes through the year being about 15 °C, and the amount of feed does not vary periodically. For other species

without specific reproductive season, GUDGER (13) described that *Chlamydoselachus anguineus* would presumably have no special breeding season for about the same reasons. Moreover, *Carcharhinus dussumieri* from the South China Sea was reported by TESHIMA et al. (1), and this species also dwells at the place where the water temperature, the light intensity and the amount of feed seem to be almost constant through all seasons.

### 3. Sexual Maturity

The determination of sexual maturity in female *H. perlo* was very difficult, because only one gravid female was collected. Moreover, as stated before, the development of ova in this species does not happen together with the growth of embryos. Therefore, even if the specimens possess the immature ova in the ovary, there are some specimens reaching clearly the sexual maturity judging from the uterine width. Consequently the sexual maturity of this species was determined from the diameter of ovum and the uterine width. Further, on the sexual maturity of female sharks, SPRINGER (20) determined by means of the conditions of ovary and oviduct, KIBESAKI (15) and TESHIMA et al. (21) depending on whether pregnancy occurred or not, and CHEN et al. (12) by the presence of developing ova in the ovary.

Fig. 7 shows the relationship between the diameter of ovum begins to increase when the female reaches about 80 cm in total length, and increases rapidly at the total length between 95 cm and 105 cm. Therefore, in this range, *H. perlo* appears to reach the sexual maturity. The relationship between the uterine width and the total length of female is shown in Fig. 8. In this figure as well, the uterus begins

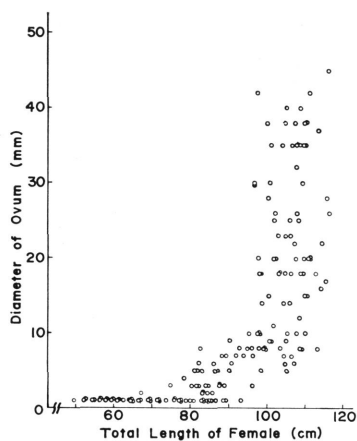


Fig. 7. Relationship between the diameter of ovum and the total length of female.

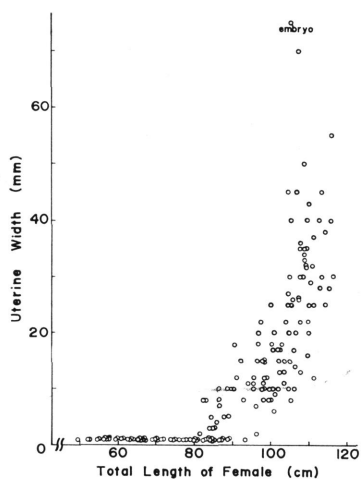


Fig. 8. Relationship between the uterine width and the total length of female.

to widen gradually at the total length of about 80 cm and this species seems to be mostly mature at the total length of 105 cm.

These 2 figures indicate that female *H. perlo* is mature from 95 cm to 105 cm in total length. Moreover, the only one gravid female measures 1052 mm in total length. BIGELOW and SCHROEDER (17) mentioned that female *H. perlo* in the Atlantic may become mature at about 3 feet or perhaps even smaller and gravid female is 932 mm in total length. As compared

with male *H. perlo* in the south-western waters of Kyushu which reaches the maturity at its total length of 70 cm to 85 cm, females reach the maturity at large total length. This phenomenon is observed also in *Squalus acanthias* (2), *S. brevirostris* (15), *S. suckleyi* (22) and *Heterodontus japonicus* (3).

#### 4. Embryo

The only female of *H. perlo* with embryos was landed at the fish market in Nagasaki, June 3, 1976. As shown in Fig. 9, 4 embryos were in the right uterus and

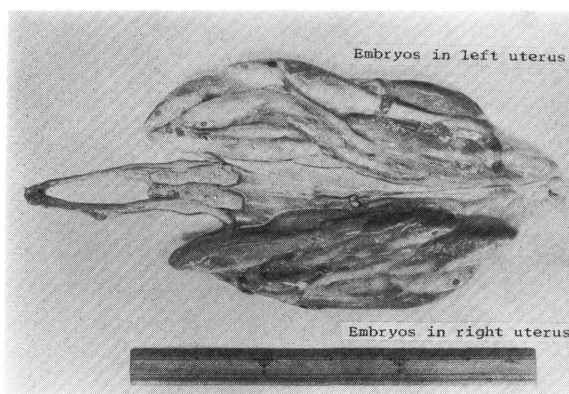


Fig. 9. Embryos in each uterus.

7 in the left uterus. Each embryo had no external yolk sac but mucus on its body, and was not enclosed in the embryonic membrane. Moreover, as shown in Fig. 10, these embryos were similar to the adults in general body proportion and coloration,

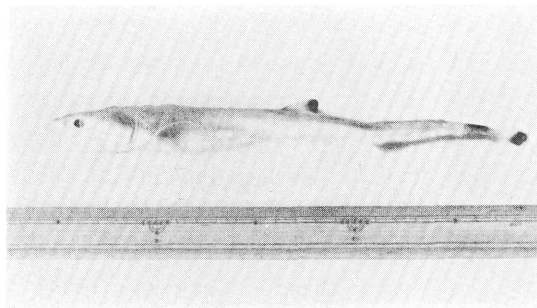


Fig. 10. Embryo measuring 242 mm in total length.

and the tip of the dorsal fin and the edge of the caudal fin were black resembling the immature sharks'. Additionally a tiny scar measuring 3 mm to 4 mm in length like an umbilical scar remained in the thoracic region.

As a result of the dissection of these embryos, some embryos retained a greatly reduced yolk duct lying between the thoracic scar and the internal yolk sac. According to IWAI (23), this yolk duct was also found in the embryo of *Etmopterus lucifer* at the last stage of gestation period. The internal yolk sac attached to the duodenum supplies the yolk substance for the valvular intestine. Table 2 shows the total length, body weight, liver weight

Table 2. Total length, body weight, and volume of internal yolk sac in each embryo.

Sex	Total Length (mm)	Body Weight (g)	Liver Weight (g)	Internal Yolk Sac (ml)	
Right Uterus	M	241	43.8	3.0	1.7
	F	242	41.0	2.5	0.3
	F	235	41.8	3.2	0.4
	F	242	45.0	2.9	1.6
Left Uterus	M	237	40.8	2.8	1.3
	M	243	41.0	2.7	0.3
	F	245	40.6	2.3	0.3
	M	246	42.3	2.3	0.9
	F	243	40.7	2.5	0.1
	M	245	41.6	2.7	0.4
	F	247	40.4	1.8	0.1
Average	242.4	41.69	2.61	0.67	

and volume of internal yolk sac in each embryo. In the volume of internal yolk sac ranging from 0.1 ml to 1.7 ml, some embryos were observed to have absorbed the great part of the yolk substance and to retain only internal yolk sac. Because of above observations, these embryos appeared to be immediately before parturition.

Furthermore, while this female examined contained 11 embryos, BIGELOW and SCHROEDER (17) cite from Luis HOWELL-RIVERO's observation that up to 20 embryos have been found in a female, in Cuban waters.

At the time of parturition, the rate of total length in these embryos collected against mother shark may be about one fourth, and this rate in other small sharks is roughly one fourth to one half. In view of these embryos, *H. perlo* indicates a lower rate among small sharks. On the other hand, small toothed whale in marine mammal bears embryo at about half size of the mother, and viviparous teleosts, such as *Ditrema temmincki* BLEEKER, breed embryos in approximately one fourth total length of the mother.

Fig. 11 shows the condition factor (Body weight x 10<sup>3</sup> / Total length<sup>3</sup>) and hepatosomatic index (Liver weight x 10<sup>2</sup> / Body

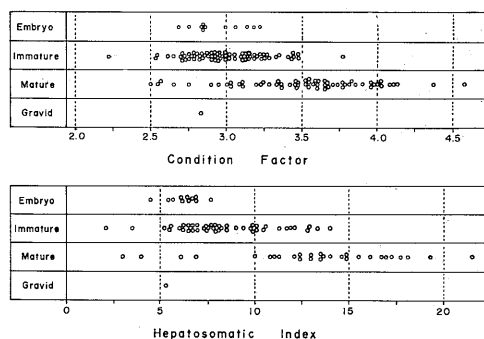


Fig. 11. Condition factor and hepatosomatic index of embryo, immature female, mature female and gravid female.

weight) of embryo, immature female, mature female and gravid female. While the values of the condition factor and hepatosomatic index are similar between embryo and immature female, these values differ distinctly between immature and mature ones. Additionally, as compared with mature female, gravid female indicates lower values, and the low values of mature

female are regarded as ones of just after parturition judging from the situation of the uterus and ovary. These facts suggest that condition factor and hepatosomatic index are greatly concerned in the reproduction of female *H. perlo*.

Lastly, in consideration as to why gravid females were not captured, it is concluded that females approaching ovulation hardly have a feed under the pressure of the ova in ovary with an average of 20 which increase the rate of space occupied in the peritoneal cavity. This opinion is supported by the fact that the sharks with the ova of more than 25 mm in diameter scarcely possess the stomach contents or have only fishing feeds. Therefore, in the future, we expect to carry out the fishing of sink gill nets and demersal seines besides bottom long lines.

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#### サメ類の研究—XI

#### エドアブラザメ *Heptranchias perlo* の雌の生殖について

田中 彰・水江 一弘

本研究では、九州南西海域のエドアブラザメ *Heptranchias perlo* の雌の生殖形態及び生態を調査した。本種は、手島らのサメ類の雌の生殖形態の分類による胎生非胎盤型に属し、子宮隔壁を形成しない種である。本種の卵巣は左右ともに機能的であり、排卵直前の成熟個体は、卵径35~45mmの完熟卵を左右平均各10個持っている。



更に、卵巢卵は、胎児の成長に伴って、発達せず、胎児の出産後に発達すると考えられる。本種の雌の成熟体長は、全長と卵巢卵の直径及び子宮幅との相関より求められ、全長95~105cmであると推測される。卵巢卵あるいは、子宮の状態から判断して、本種には、特定の生殖時期がないと考えられる。全長約240mmの胎児は、ほとんど成体と変わらない体型及び体色をし、胎児膜に包まれていない。これらの胎児は、外卵黄のうを持たず、容積0.1~1.7mlの内卵黄のうを十二指腸部に付け、腸に卵黄を供給しているため、出産間近の胎児であると考えられる。肥満度及び肝臓体重指数は、本種の雌の生殖に非常に関連している。