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Seasonal Migration and Gonadal Changes in the Hagfish *Eptatretus burgeri*

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Abstract The hagfish, *Eptatretus burgeri*, were collected from late October to next July in Kamo Bay situated in one of the Oki Islands in the Japan Sea. They were absent from the Bay in August and September. Instead, the hagfish were found outside the bay at depths of about 50 m in August and early October. The relative ovary weight and the size of maturing eggs drastically decreased between August and early October. The ovary of the hagfish collected in early October contained large postovulatory follicles. It was estimated that the hagfish breed in September somewhere outside the bay. There were 44 maturing eggs per female on the average. The relative testis weight did not show clear seasonal changes. The testis of males captured in August contained mainly spermatogonia, but few sperm. Fully mature males about to participate in reproduction were not collected. Males were significantly longer (50.8 cm) than females (48.9 cm).

The Japanese hagfish, *Eptatretus burgeri* (Girard), is the only hagfish so far known that seasonally migrates for breeding between shallow and deep water (Kobayashi et al., 1972; Fernholm, 1974; Patzner, 1977b, 1978; see also Dean, 1904; Conel, 1931). However, this migration has been studied only in one locality in Japan, at the Misaki Marine Biological Station situated on the Pacific coast. *Eptatretus burgeri* is widely distributed in the southern part of Japan (Strahan, 1962). We found that individuals of this species are abundant near the Oki Marine Biological Station in the Oki Islands of the Japan Sea. In this locality, we have studied whether this hagfish migrates between shallow and deep water. Annual changes of the gonads were also examined, and spawning time was estimated.

Material and methods

Eptatretus burgeri were collected at Kamo Bay located at the south end of the main island (Dogo) of the Oki Islands (36°11′N latitude, 133°17′E longitude) (Fig. 1). Traps were set on a day in the latter one third of every month (20th～30th) from November 1980 to October 1981. In August and September, however, the fish were not found in the bay. Instead, in August and early October, they were captured in a region about one kilometer south of the bay. In September, we did set traps in this spot outside the bay, but we lost all of the traps because of a heavy storm. The traps used were 12 mm-mesh cages, which were baited with frozen sardines, mackerel, or cuttlefish. The traps were placed on the sea bottom at depths of about 20 m in the bay (from late October to July), and about 50 m outside the bay (August and early October). Each month, eight to ten traps were kept in the sea for one to three nights each. The water temperaute was recorded at the time of collection. In addition to hagfish,

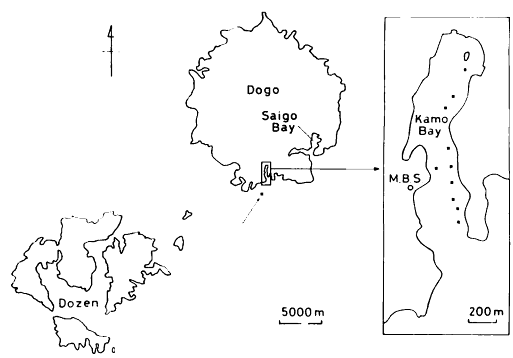

Fig. 1. Locations of spots where *Eptatretus burgeri* was collected. Specimens were collected in Kamo Bay from late October to July. In August and early October, they were captured outside the bay (small arrow). Places where traps were set are shown by x marks. M.B.S., Oki Marine Biological Station.

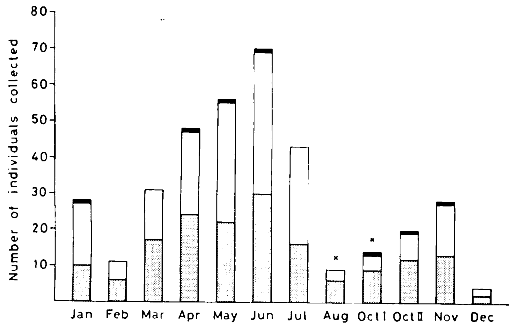

Fig. 2. Number of *Eptatretus burgeri* collected in each month. Stippled areas represent males, open areas represent females, and filled areas represent hermaphrodites. In August and early October (Oct. I) (x), the hagfish were collected only from outside of the bay.

the conger eel (*Conger myriaster*) and the octopus (*Octopus vulgaris*) were occasionally trapped in the bay.

The hagfish were anesthetized with 0.05% MS 222 in sea water. Total length, body weight, and gonadal weight were recorded. From these measurements, the gonado-somatic index was calculated for each individual (GSI = (gonadal weight/body weight) × 100).

In females, the long axis of maturing eggs was measured in each individual. Eggs larger than 10 mm in the long axis were counted. The presence or absence of postovulatory follicles (corpora lutea) was noted. Correlation between total length and ovarian weight or number of eggs larger than 10 mm was also determined.

In males, the posterior part of the testis was fixed in Bouin's solution, embedded in paraffin, cut at 6 μm, and stained with hematoxylin and eosin. The testis of the hagfish does not consist of seminiferous tubules, but instead consists of round balls termed testicular follicles or spermatic ampullae. The percentages of testicular follicles containing spermatogonia, primary spermatocytes, spermatids, or maturing sperm were calculated in a randomly chosen section of the testis of each individual. Secondary spermatocytes were much fewer in number, and here they were included in the category of spermatids. The developmental stage of spermatogenetic cells in each testicular follicle was quite uniform. However, a few follicles contained cells of two succeeding stages such as spermatogonia and spermatocytes. Such follicles were divided in half, and added to the number of the preceeding stage and the succeeding stage, respectively. Correlation between total length and percentage of follicles containing spermatogonia also was determined. Totally, 14,659 testicular follicles were examined. This means that on an average 131 follicles were examined in each animal.

In months when relatively large numbers of the fish were collected, some individuals were only sexed, or at most externally measured without internal inspection. This procedure was performed randomly. Two-sample t-test was applied for statistical analysis, unless otherwise stated.

Results

The total number of *Eptatretus burgeri* collected in each month is shown in Fig. 2. The bait and the number of traps used, and the period of immersion of traps in the sea were different among months. Therefore, the number shown may not exactly reflect the population density in a manner comparable among months. However, we noticed that many hagfish were collected in Kamo bay in late spring and early summer. The fish were not found in the bay in August and September. Instead, they were found outside the bay on the sea bottom at about 50 m depth in August and early October (Fig. 1).

The sea bottom of both the bay and the location outside the bay at 50 m depth consisted of sand and mud. Temperature of the surface water of the bay is given in Table 1. Temperature of the bottom of the bay, where the hagfish live from late October to July, may not be very different from the surface temperature, since the depth of the bay is only about 20 m. On October 6th, the temperature of the sea water at 50 m depth, where hagfish lived, was 21.6°C.

Total number of hagfish collected through the year was 362. There were 167 males (46%), 188 females (52%), and 7 hermaphrodites (2%). Females were more abundant than males, but with the binomial test we could not reject H_0 that the sex ratio is one ($P > 0.2$). At the depth of 50 m, more males were collected than females. However, the sex ratio in the population in deeper waters did not depart from unity with the binomial test ($P>0.05$). On the other hand, sex ratio between July and August combined with early October trappings was different with χ^2-test ($P<0.05$).

Mean length of males and females collected in each month is given in Table 1. Monthly fluctuation was not significant with analysis of variance. Mean length of all males measured was 50.8±0.7 cm (mean±S.E.M.) ($n=144$). That of females was 48.9±0.5 cm (mean ± ±S.E.M.) ($n=142$). Males were larger than females ($P<0.05$). Size frequency histograms of April and May are given in Fig. 3. Several low peaks appeared, but the distribution pattern of these peaks was different between April and May. With the Kolmogorov-Smirnov one-sample test, we could not reject H_0 that the histograms of both April and May do not depart from normal distribution.

The mean total length of seven hermaphrodites was 50.0±2.7 cm (mean±S.E.M.). Among these hermaphrodites, five possessed a well-developed ovary except for the posterior tip of the gonad where tiny testicular tissues were found. Since they contained both maturing eggs and postovulatory follicles, they might have been functional females. The tiny testis contained testicular follicles consisting mainly of spermatogonia, or spermatocytes, or both. One hermaphrodite caught in early October possessed a degenerating ovary anteriorly and a well-developed testis posteriorly. The ovarian portion contained postovulatory follicles of considerably old age and the testicular portion contained some sperm in addition to many deteriorated follicles. Another hermaphrodite caught in late October possessed a well-developed ovary and a tiny testis. However, the ovarian portion did not contain any postovulatory follicles, and testicular follicles consisted of spermatogonia exclusively.

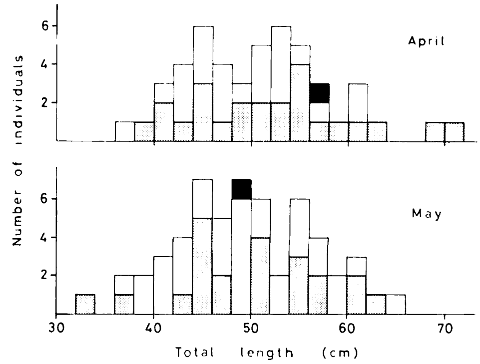

Fig. 3. Size frequency histogram in April and May. Total lengths are expressed in 2 cm intervals. Stippled areas represent males, open areas females, and filled areas hermaphrodites.

Females. Ovarian weight suddenly decreased in early October (Fig. 4). From late October onwards, it gradually increased, reaching the peak in next August. The ovary in early October was significantly heavier than that in late October

Table 1. Water temperature and total length and number of *Eptatretus burgeri* collected in each month.

Month (water temperature in °C[1])	Mean±standard error in cm (number)	
	♂[4]	♀[5]
January (10.0)	52.5±2.6 (10)	54.2±2.3 (10)
February (9.0)	51.6±1.9 (6)	46.6±1.4 (5)
March (11.5)	46.2±2.3 (17)	46.9±1.4 (14)
April (12.0)	51.7±1.8 (24)	48.9±1.3 (23)
May (17.0)	49.6±1.6 (22)	48.9±1.2 (33)
June (21.5)	48.4±2.2 (14)	48.3±1.5 (12)
July (24.0)	55.2±1.2 (9)	48.7±2.1 (15)
August[2] (26.0)	54.8±1.7 (6)	43.0, 54.5, 58.5 (3)
early October[2] (24.5[3])	48.7±1.3 (9)	50.9±2.5 (4)
late October (19.8)	55.2±2.2 (12)	47.6±1.6 (7)
November (16.0)	50.5±3.5 (13)	47.3±1.7 (14)
December (14.0)	44.0, 55.2 (2)	50.0, 61.2 (2)

1, Temperature of surface water of the bay; 2, In these months, the hagfish were collected outside the bay; 3, Value in late September; 4, Fcal=1.4244 ($P>0.1$); 5, Fcal=1.1996 ($P>0.25$).

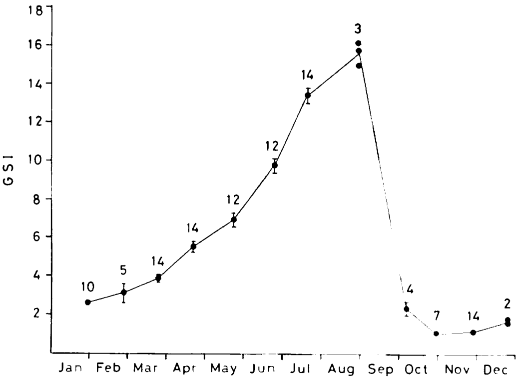

Fig. 4. Annual change of gonado-somatic index in females. Numbers of individuals studied in each month are shown. One female in April and one female in July were apparently immature, and excluded from calculation. Standard errors in January, late October, and November are so small that they are included in the size of the mean data points.

($P<0.05$). Postovulatory follicles measured approximately 11 mm in early October, and 5 mm in late October. Large postovulatory follicles apparently contributed to the relatively high ovarian weight in early October.

The ovary of most of the females contained numerous small eggs (oocytes) not exceeding 1 to 2 mm in length. In addition to these small eggs, maturing eggs were also found. The long axis of maturing eggs was on the average 2.3 mm in early October. It gradually increased, culminating in August in fully grown eggs measuring more than 20 mm (Fig. 5). Only one female possessed fully shelled eggs. She was caught in July. The ovary contained 50 maturing eggs without shells and 8 shelled eggs anchored to each other by terminal filaments. Both maturing eggs and shelled eggs measured 21 mm in the long axis. Only one female possessed an apparently degenerated ovary. She was caught in April and was considered to be "sterile".

The number of eggs larger than 10 mm in each month is shown in Fig. 6. Eggs attained this size in January, when maturing eggs larger than 10 mm averaged 63 per female. From February to August, the number of maturing eggs was constant (44.0±1.8, mean ±S.E.M.). From February to August, small eggs not exceeding 2 mm and large maturing eggs exceeding

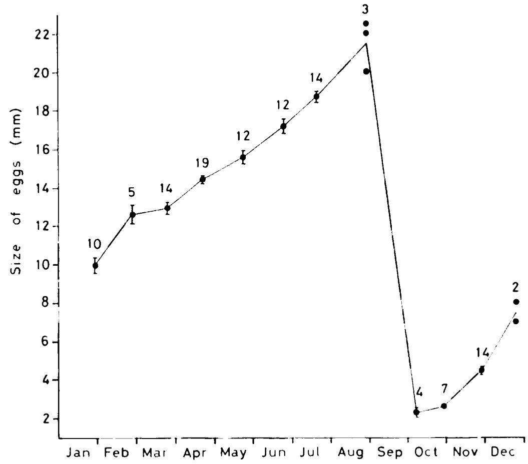

Fig. 5. Annual growth curve of maturing eggs. Numbers of individuals studied are shown. One female in April and one female in July were apparently immature, and excluded from calculation. The size of maturing eggs was quite uniform in each individual. The mean was taken from each individual. Standard errors are those among individuals. Standard error in late October is so small that it is included in the size of the mean data point.

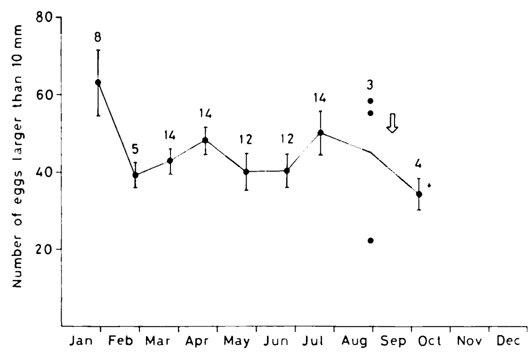

Fig. 6. Number of eggs larger than 10 mm in each month. Numbers of individuals studied and standard errors are shown. Maturing eggs approximate 10 mm in length in January. Two females in January, one female in April, and one female in July did not possess eggs larger than 10 mm. They were excluded from calculation. From October to December, females do not contain any eggs larger than 10 mm. The value in early October (+) represents number of postovulatory follicles. An arrow indicates estimated spawning time.

Table 2. Regression equation of ovarian weight (Y) against total length (X) and correlation coefficient (r) in each month.

Month	Regression equation	r	Number
January	$Y=0.326X-11.022$	0.961**	10
February	$Y=0.047X+3.583$	0.047	5
March	$Y=0.360X-10.419$	0.824**	14
April[1]	$Y=0.529X-15.434$	0.758*	14
May	$Y=1.086X-39.120$	0.952**	12
June	$Y=1.076X-35.286$	0.929**	12
July[1]	$Y=1.975X-69.056$	0.850**	14
August	—	—	3
early October	$Y=0.089X-1.087$	0.432	4
late October	$Y=0.059X-1.249$	0.453	7
November	$Y=0.167X-6.040$	0.884**	14
December	—	—	2

1, One female in April and one female in July were apparently immature, and they were excluded from calculation; *, $P<0.005$; **, $P<0.001$.

10mm predominated. Eggs of intermediate size were few. In early October, all mature eggs had been spawned, and postovulatory follicles numbered 34 on an average.

Correlation between ovarian weight and total length is shown in Table 2 for each month. Coefficients were high except for February and October, when only small numbers of females were available. There was also a good correlation between number of eggs larger than 10 mm (Y) and total length (X). The correlation coefficient was 0.834 ($P<0.001$) and the regression equation was $Y=2.213X-62.974$ for 74 individuals caught from February to August (Fig. 7). Therefore, it may be concluded that the ovarian weight of an individual in each month is mainly attributable to the number of maturing eggs, which increases according to the

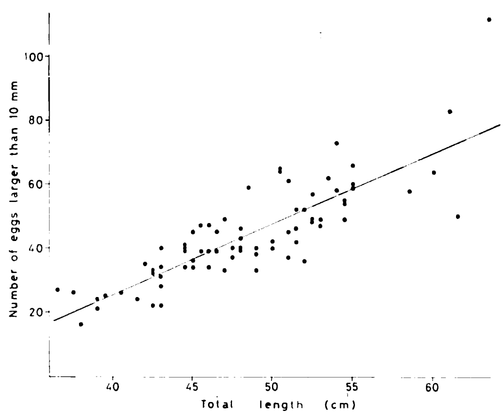

Fig. 7. Regression line between number of eggs larger than 10 mm and total length in 74 females examined from February to August ($r=0.834$).

Table 3. Number and total length of females of different ovarian conditions.

Month	Females with two generations of postovulatory follicles	Females with one generation of postovulatory follicles	Females without postovulatory follicles
January	9	1	0
February	4	1	0
March	7	7	0
April[1]	14		1
May[1]	11		1
June[1]	10		2
July[1]	13		2
August[1]	3		0
early October	3	1	0
late October	6	1	0
November	9	1	4
December	2	0	0
Total length (mean$\pm$S.E.M., cm)	51.0 ± 0.9* ($n=40$)	44.4 ± 1.4 ($n=12$)	41.0 ± 1.5[2] ($n=10$)

1, From April to August, generations of postovulatory follicles were not clearly determined in some individuals. In these months, females with postovulatory follicles were grouped, irrespective of their generations; 2, 41.8 ± 2.4 for four individuals caught from October to March; *, Significantly larger than females with one generation of postovulatory follicles ($P<0.001$).

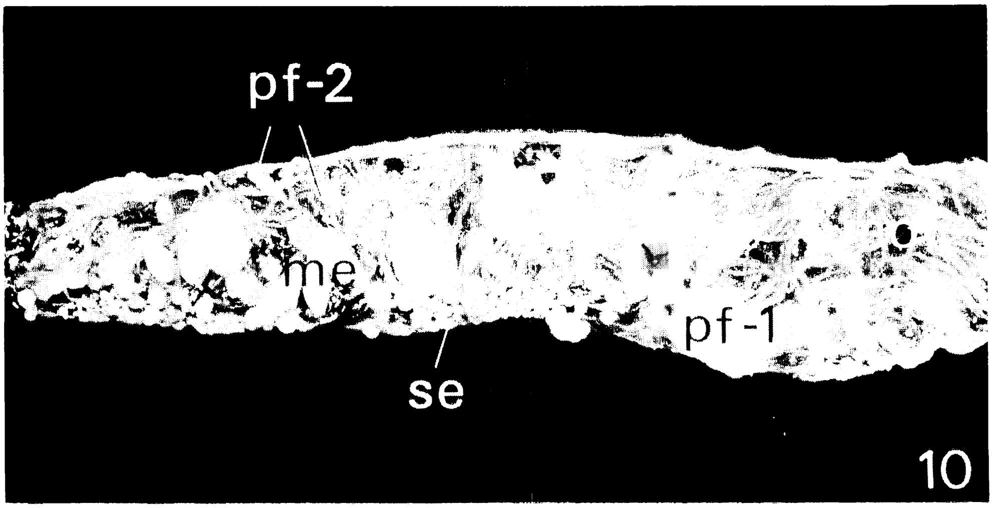

Fig. 8. Dissected ovary of a hagfish collected in late October. In addition to maturing eggs (me), postovulatory follicles of two different kinds are found on the mesovarium (mo). One group (pf–1) represents freshly ovulated follicles, and another (pf–2) represents remnants of ovulation in preceeding year(s). Numerous small eggs (se) are located on the free margin of the mesovarium. ×2.3.

size of the individual.

Females who did not contain any postovulatory follicles were considered to be individuals without spawning experience. They were only ten in number (8.8% of total females examined) (Table 3). Their occurrence was not restricted to a certain season. From October to March, at least two generations of postovulatory follicles were observed in the ovary (Fig. 8). One generation consisted of relatively large bags, which are considered as remnants of spawning in the previous September. Another generation(s) consisted of small yellow-brown structures (brown bodies), which are considered as remnants of spawning in the preceeding year(s). From October to March, a total of 56 females were examined. Forty females (71%) showed

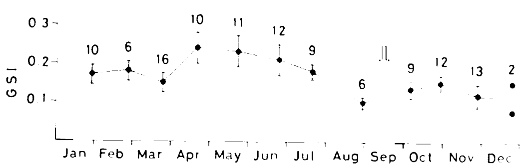

Fig. 9. Annual change of gonado-somatic index in males. Numbers of individuals studied and standard errors are shown. GSI increases in April and decreases in August. Note the difference of scale in the ordinate between this figure and Fig. 4.

at least two generations of postovulatory follicles, 12 females (21%) contained only one generation of postovulatory follicles, and 4 females (7%) were individuals without spawning experience (Table 3). Total lengths of females classified into these three categories are also given in Table 3. The total length of females with two generations of postovulatory follicles was significantly larger than that with one generation of postovulatory follicles. The females with one generation of postovulatory follicles were larger than those without postovulatory follicles, but the difference was not significant. From April onwards, two generations of postovulatory follicles approached each other in size and appearance. It was not always possible to differentiate them. However, such a distinction was still clear in some individuals collected as late as in July. The rate of absorption of postovulatory follicles is apparently different among individuals.

The largest female collected was 68.0 cm in total length. The smallest measured 34.0 cm.

Males. Although the gonado-somatic index increased in April and decreased in August, annual changes of the index were not conspicuous as compared with those of females (Fig. 9).

Testicular follicles of different developmental stages are shown in Fig. 10. Percentages of

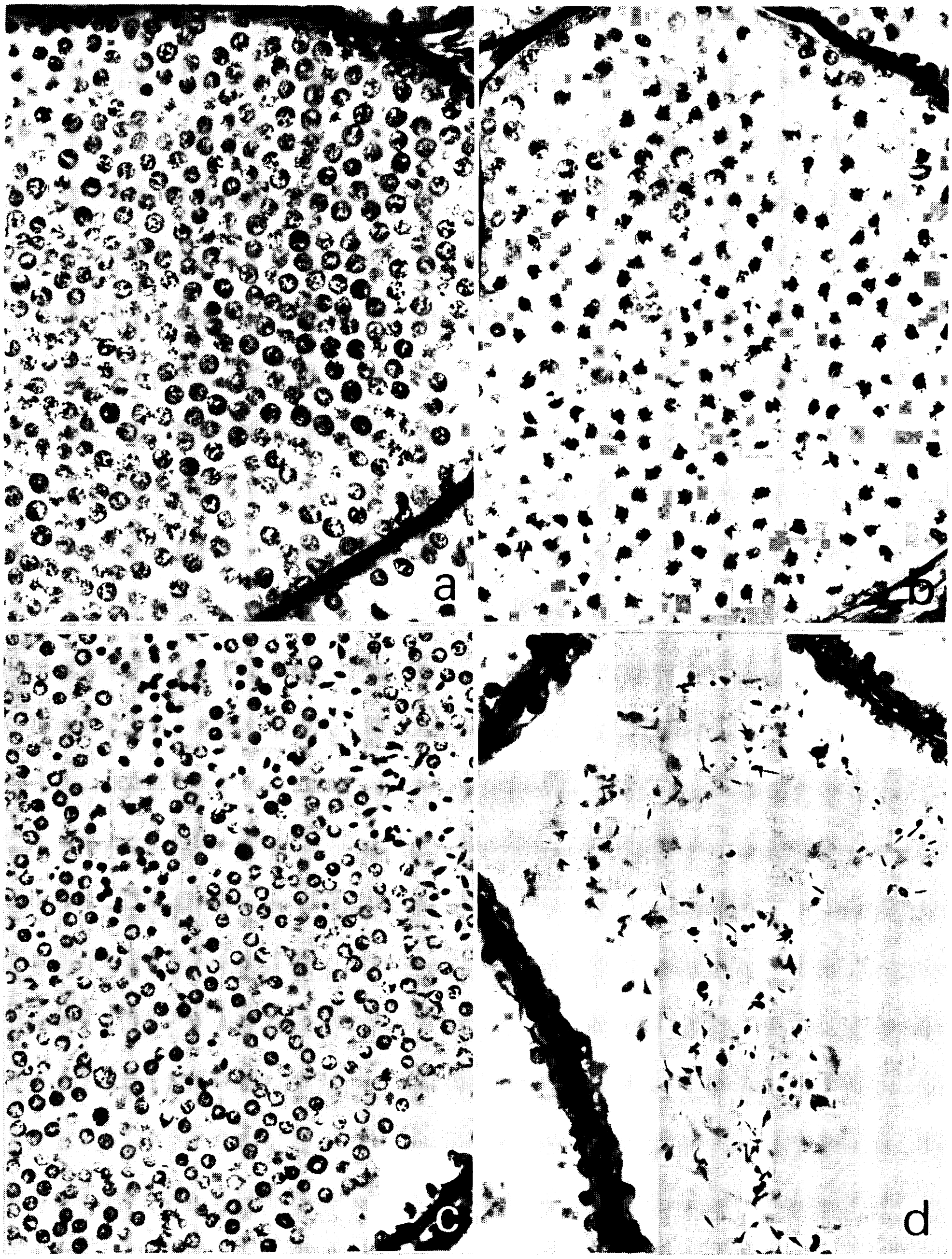

Fig. 10. a: Follicle containing spermatogonia. b: Follicle containing primary spermatocytes. c: Follicle containing spermatids of varying developmental stages. d: Follicle containing maturing sperm. ×72.

follicles containing spermatogonia, primary spermatocytes, spermatids, maturing sperm, and "unidentified" structures are shown in Figs. 11 to 13. Individual differences were so large that the original values are given. The percentages of follicles containing spermatogonia were high from August to December (Fig. 11). They significantly decreased in April ($P<0.05$,

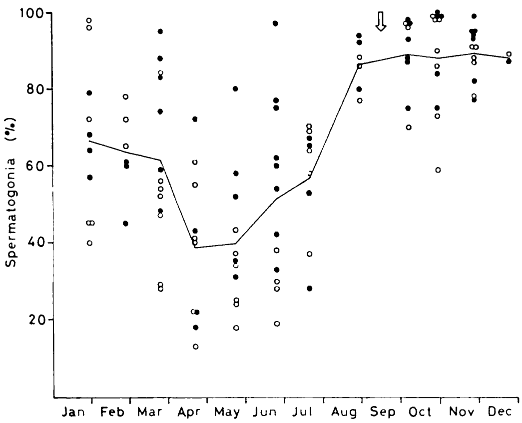

Fig. 11. Percentage of follicles containing spermatogonia in each month. All individuals possessed follicles with spermatogonia. Therefore, the number of circles indicates the number of individuals studied in each month. The line connects the mean in each month. Open circles represent individuals larger than the mean total length in each month. Solid circles represent individuals smaller than the mean total length in each month. An arrow indicates estimated spawning time.

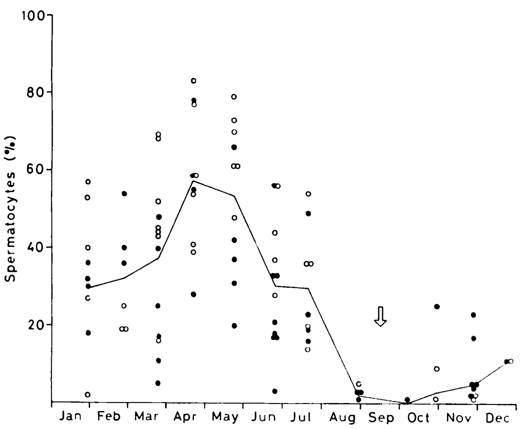

Fig. 12. Percentage of follicles containing spermatocytes in each month. Some individuals did not possess follicles with spermatocytes, especially in autumn. The line, circles and arrow are figured as in Fig. 11.

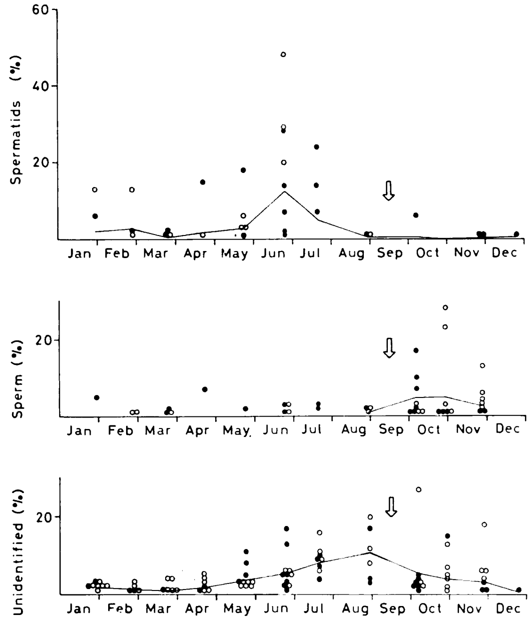

Fig. 13. Top: Percentage of follicles containing spermatids. Many individuals did not possess any follicles with spermatids. Middle: Percentage of follicles containing maturing sperm. Many individuals did not possess any follicles with sperm. Bottom: Percentage of follicles containing "unidentified" structures. See the text for a description of unidentified structures. The line, circles and arrow are figured as in Fig. 11.

Mann-Whitney *U* test). The percentages of follicles containing spermatocytes were roughly in the mirror image of those containing spermatogonia (Fig. 12). They significantly increased in April ($P<0.05$, Mann-Whitney *U* test). From August to December, there were few follicles containing spermatocytes. Follicles containing spermatids were much fewer than those containing cells in the preceding stages (Fig. 13). They increased in June, although the difference was not significant ($P>0.1$, Mann-Whitney *U* test). Follicles containing maturing sperm were few except for October and November (Fig. 13). In addition to these follicles, there were some follicles which could not be identified. They were "unidentified" because: (1) they contained no cells, but just flocculent material; (2) they contained only leucocytes; (3) they contained cells of irregularshape enmeshed in a network of fibers; and (4) they contained cells in the course of spermatogenesis, but the cells were either highly pycnotic or abnormally swollen. The number of "unidentified" follicles slightly

Table 4. Kendall's rank correlation coefficient (τ) between total length and percentage of follicles containing spermatogonia.

Month	τ	Number
January	−0.045	10
February	0.400	6
March	−0.256	13
April	0.045	10
May	−0.709*	11
June	−0.713*	12
July	0.282	9
August	−0.467	6
early October	0.086	9
late October	−0.413	12
November	−0.217	12
December	—	2

* $P<0.005$

increased towards the end of summer (Fig. 13).

There was no clear relation between total length and the degree of progress of spermatogenesis (Figs. 11∼13). Correlation between total length and the percentage of follicles containing spermatogonia is shown in Table 4. Kendall's rank correlation coefficient was significant in May and June, when large individuals possessed small numbers of follicles containing spermatogonia. This means that only in these months initiation of meiosis is related to the size of the individual.

There were three males larger than 70 cm in total length among 144 individuals measured during the year. The largest measured 75.5 cm. The smallest was 32.5 cm.

Discussion

Hagfish, *Eptatretus burgeri,* were found in Kamo Bay from late October to July. They were absent in the bay in August and September, but were found in 50 m deep water in August and early October. The ovary showed striking changes between August and early October both in weight and in the size of eggs. These observations confirm that this species seasonally migrates between shallow and deep water, and lays eggs in deep water. Three females caught in August (29th) all possessed large eggs exceeding 20 mm, but these eggs had not yet been shelled. Four females caught in early October (6th) all possessed postovulatory follicles measuring approximately 11 mm. Considering the time required for shell formation and the time required for regression of follicles to about half size, the spawning time can be estimated to be sometime in September, at latest in very early October. The hagfish were also absent in August and September in Saigo Bay, which is located about seven kilometers north-east of Kamo Bay (Fig. 1) (personal communication from Dr. T. Ayama).

The hagfish, *Eptatretus burgeri,* around the Misaki Marine Biological Station (Kanagawa Prefecture; Pacific coast of central Honshu) show a breeding migration similar to that at Oki, but they leave shallow water (Koajiro Bay) as early as June at least in available observations (Kobayashi et al., 1972; Fernholm, 1974; Patzner, 1977b, 1978; see also Dean, 1904). The Oki population stayed in the bay in July not only in 1981, when the systematic search was done, but also in the preceding year (1980) (personal observation). One of the reasons to leave shallow water may be the rising temperature in early summer, as suggested by Fernholm (1974) for the Misaki population. If water temperature was lower in Oki than in Misaki, this could explain the observation that the Oki population stays longer in the bay. It should also be considered that Kamo Bay in Oki is about 20 m deep and Koajiro Bay in Misaki is only about 10 m deep. The upper limit of temperature endurable for *Eptatretus burgeri* seems to be around 22°C. The surface temperature of the bay water was 24°C in late July, when the hagfish were still collected in the bay. However, the bottom temperature must be somewhat lower, since it is generally believed in Japan that the vertical temperature change is the greatest in July.

The exact spot and the manner of reproduction are unknown both in the Oki population and the Misaki population (Fernholm, 1975). Patzner (1978) estimated that the Misaki population breed in October on the basis of studies of the ovary.

In the Misaki population, both Dean (1904) and Patzner (1978) reported that females were collected more than males in the late autumn and early winter. However, such a tendency was not evident in the Oki population, although much large numbers of individuals should be examined before any generalized statement is made. The preponderance of males in deep water was noted not only in the Misaki population (Patzner, 1978), but also in the Oki population. However, it is uncertain whether the preponderance of males really reflects the sex ratio of the population in deep water. It is possible that mature females are not attracted by bait or that most of them live in much deeper regions.

The average total length of the Misaki population is 42 cm for males and 41 cm for females (Dean, 1904) or 42.0 cm for males and 42.8 cm for females (Kobayashi et al., 1972). Individuals of the Oki population are larger than those of the Misaki population (50.8 cm for males and 48.9 cm for females). However, it should be mentioned that the traps used in Oki consisted of 12 mm mesh and very small individuals might escape through mesh of this size. Therefore, the average total length of the Oki population might be slightly overestimated. However, the Oki population is larger also in the largest individual (75.5 cm in males and 68.0 cm in females) than the Misaki population (54.5 cm (Dean, 1904) or 66 cm (Patzner, 1977b) in males, and 60 cm in females (Dean, 1904; Patzner, 1978)). The Misaki region is irrigated solely by the warm Kuroshio current. The Oki region also is irrigated by the warm Tsushima current. However, low temperature regions are found near the Oki Islands (Shimomura and Miyata, 1957). The influence of cold water may be involved in promoting growth in the Oki population.

The development of the ovary is almost linear both in terms of the relative weight and the size of eggs. The number of eggs larger than 10 mm is high in January (63 per female). The number of such eggs decreases in February and fluctuated around 44 per female until the breeding season. It is apparent that about 20 eggs degenerate between January and February and the remaining eggs consistently develop for later spawning. The number of postovulatory follicles, which are direct proof of ovulation, was only 34 in early October. However, it must be remembered that this value is the mean of only four females. In the Misaki population, Dean (1904) reported that maturing eggs numbered about 18 per female. This is still a much smaller value than the number of postovulatory follicles of the Oki population in early October.

Since postovulatory follicles represent spawnings, it is easy to distinguish females which have not yet spawned from females which have spawned in previous years. From October to March, it is also easy to distinguish females with one generation of postovulatory follicles from females with two generations of postovulatory follicles. In this period, the number of females with one generation of postovulatory follicles is much smaller than that of females with two generations of postovulatory follicles. This may indicate that females with apparently two generations of postovulatory follicles actually consist of at least two different age classes. From these observations, it may be inferred that the hagfish live at least four years, and probably more than five years. Females with one generation of postovulatory follicles were larger by 3.4 cm than females without postovulatory follicles, although the difference was not significant. Patzner (1978) estimated that the Misaki population grows 4 to 5 cm per year, and this value is roughly compatible with the value mentioned above.

Considering this annual growth rate, it is peculiar that the length of individuals that have just returned from deep water (late October) is not less than that of individuals just returning to deep water (July). If much larger numbers of individuals are examined, a significant difference in total length might be revealed. However, this is a complicated problem, since we do not know whether the hagfish migrate to the shallow water all at once in October or whether some individuals migrate to the shallow water much later, thus consistently supplying the bay population towards the summer. If relatively large individuals came back to the bay earlier and they also left the bay earlier, then it would be reasonable that the average total length is not less in late October than in July. The possibility that large individuals migrate earlier than small individuals was indeed suggested by Kobayashi et al. (1972). The fact that the hagfish is collected abundantly in the bay in late spring and early summer may indicate that the migration into the bay has not been completed in the late autumn.

The seasonal change in the relative weight of the testis is minor as compared with the ovary. The increase in the gonado-somatic index in April may be related to the simultaneous increase of the percentage of testicular follicles containing spermatocytes, and the decrease in August may be correlated with the concomitant increase in the percentage of follicles containing spermatogonia. In the Misaki population, Patzner (1977b) showed an increase in the relative testis weight and in the percentage of follicles containing spermatids of late developmental stages towards the end of summer. He distinguished "normal" males from "undeveloped" males, and excluded undeveloped males from the calculation of the gonado-somatic index. In the Oki population, it was easy to differentiate immature females from maturing females, since there were few intermediate females. In males, however, without drawing an arbitrary line it was impossible to differentiate immature males from maturing males both in terms of the gonado-somatic index and in terms of the total length. The gonado-somatic index and the total length changed gradually without any appreciable interruption. In any case, the testis weight should be carefully interpreted as an indicator of the maturity of males.

Spermatogenesis proceeded from October to June in a predictable way, although individual differences were large. From October to March, follicles containing spermatogonia predominated, but in April and May follicles containing spermatocytes predominated, and finally in June the number of follicles containing spermatids apparently increased. However, the testes of individuals collected in July and August mainly contained follicles with spermatogonia. They were approaching the breeding season, but possessed apparently immature testes. At present, we do not know the reason why fully mature males are not captured immediately before the breeding season. In any case, the total length did not necessarily relate to the degree of progress of spermatogenesis. The "unidentified" follicles increased near the end of summer. The reason is unknown. Some increase of follicles with sperm in October may be due to individuals which only partially released sperm in September.

Hermaphrodites represented about 2% of the Oki population. This is a much higher percentage than in the Misaki population, where hermaphrodites were 0.4% (Kobayashi et al., 1972) or 0.1% (Patzner, 1977a) of the total. However, it should be kept in mind that the posterior testicular portion of the hermaphrodite gonad is frequently so tiny that it might be easily overlooked. Walvig (1963) and Patzner (1977a) may be consulted for references on hermaphroditism in other species of hagfish.

Eptatretus burgeri is the only hagfish so far known to show seasonal migration with a limited period of reproduction during the year. Another Japanese hagfish, *Paramyxine atami,* is claimed to live at a depth of about 54 m from April to June, but live at a depth of 180 m from July to September (Okada et al., 1948). However, it is unknown whether this apparent migration is related to reproduction. In addition to *Eptatretus burgeri,* the New Zealand hagfish, *Eptatretus cirrhatus,* is known to live in exceptionally shallow water (Fernholm and Holmberg, 1975). However, *Eptatretus cirrhatus* was also caught at depths of 300 to 700 m off the coast of New South Wales of Australia (Strahan, 1975). They may migrate between shallow and deep water, but have not yet been studied in detail as far as we know.

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ヌタウナギの季節的移動と生殖腺の周年変化

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日本海西部に位置する隠岐諸島の道後の加茂湾付近で，年間にわたり各月 1 回ずつヌタウナギの採集を行った．10 月下旬より翌 7 月下旬までは深さ約 20 m の湾内で採集できたが，8 月と 9 月は湾内では採集できなかった．しかし 8 月下旬と 10 月上旬には湾外の深さ約 50 m の地点で採集された．卵巣の相対重量および卵径は 8 月下旬から 10 月上旬の間で著しい減少を示した．一方，10 月上旬に採集された雌の卵巣には放卵後の大きな濾胞がみられた．これらの事実から，ヌタウナギの産卵はおそらく 9 月，遅くとも 10 月の第 1 週に，しかも湾外で行われることが推定される．一方，精巣の相対重量には顕著な周年変化はみられなかった．繁殖期直前の 8 月下旬に採集された雄の精巣は主に精原細胞からなる濾胞でできており，精子はほとんどみられなかった．これらの事実は，繁殖に参加する雄は採集されなかったことを示している．雄の平均全長は 50.8 cm，雌のそれは 48.9 cm であり，統計的に有意な差があった．

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(October 8, 1983)

Masaru Tanaka: Overview of recent works in organogenesis of young fishes.

Kaneyoshi Yamashita: Differentiation of epidermis, gill and swimbladder.

Kenichi Ishida: Development of sensory organs.

Masanobu Matsuoka: Developement of locomotor organs.

Noritomo Komada: Dentition and mouth shape in young ayu, *Plecoglossus altivelis*.

Kosaku Yamaoka: Development of some trophic organs in cichlids, with reference to feeding behavior.

編集後記・Editorial notes

原図の大きさはＡ4版くらいにして下さい．どんなに大きくとも全体がＢ4版を越えることがないようにして下さい．大き過ぎる図は郵送中に損傷しやすく，縮小率の関係で図中の文字が見えにくくなります．また，図中のそれぞれの文字の大きさには十分注意して下さい．一般に図中の文字が大き過ぎる傾向があります．小さい文字と大きな文字を組み合わせて使うときには刷り上りの図を想定し，よく吟味して下さい．

英語で論文を書いた場合は，英語を母国語とする人に校閲してもらうよう勧めます．不十分な表現によって，著者の考えが正確に伝わらない事もあります．多少の手間をかけることによって論文が読みやすくなることを考えれば，校閲を頼むことを逡巡する必要はないでしょう．

訂　正　Erratum

Japanese Journal of Ichthyology, 29 (4), p. 437, right column, line 17: "see also Dean" should read "see, however, Dean".

(K. M.)