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On the Ovarian Maturation of the Japanese Sea Bass, *Lateolabrax japonicus*

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Abstract The oogenesis of the Japanese sea bass, *Lateolabrax japonicus*, one of the common marine teleosts in Japanese coast, is fundamentally similar to those of the other bony fishes described so far. However, in this fish, oogenensis is marked by the characteristic pattern of distribution of the yolk vesicles and the rather shorter period needed for the maturation of the oocyte in the yolk vesicle stage into the ripe ovum. Though sufficient explanations for these characteristic patterns of maturation process are not available, the shorter period required for oogenesis seems to be closely related to the mode of their life. The follicular cells play an important role in the supply of nutrition for the growing oocyte and phagocytic function for the atretic oocyte. In this respect, the follicular cells seem to function like the seminiferous epithelial cells of the testis, intensely suggesting that their origins are homologous genetically. It was also ascertained that the seasonal change of the values of gonad index reflects somewhat precisely the fish maturity. Both a microscopical observation of ovary and the data of gonad index indicate that in Wakasa Bay spawning occurs from late December to middle of January, mostly in early January. The biological minimum size of the female is about 350 mm in body length which corresponds to the size of two or three year age group.

The pioneering researches of Yamamoto and his co-workers (1954 to 1965) on the patterns of oogenesis in fishes have stimulated many subsequent studies, and consequently a vast literature is now available in this subject. However, information on the oogenesis in marine fishes is rather scarce in comparison with that of freshwater fishes, probably owing to difficulties in regular sampling and other technical problems involved in such investigations. It is well known that marine and freshwater fishes exibit different patterns of reproductive behavior and that these patterns vary with the species. Based on this fact, it is logical to presume that the maturation pattern of gonads vary with the species and the habitat.

The author therefore undertook a detailed study on the morphology and maturation process of gonads in the Japanese sea bass, *Lateolabrax japonicus* (Cuvier), captured from Wakasa Bay. Though many aspects of the ecology of this species in Japan have been reported by various authors (Kuwatani, 1962; Hatanaka and Sekino, 1962 a, b, c; Kosaka, 1969), very little information is available on this subject and even the available information is ambiguous due to inconsistencies.

This paper deals with the oogenesis of this species; the structure of reproductive ducts, and the process of testicular maturation having been described in Hayashi (1969, 1971). The present study is chiefly concerned with the cytological characteristics of the oogenesis, though many observations clearly suggest the pattern of the reproductive cycle in this marine fish.

Materials and Methods

Materials used in this study were 143 specimens collected mostly from set net catches and line catches in Wakasa Bay, during the years 1964 to 1969. Samples were usually obtained monthly, but during the period from November to January when the spawning season is drawing near, specimens were collected every ten days. After measuring and weighing the fish,

the ovaries were dissected out, and cut into small pieces, and preserved in fixatives. The fixatives used for histological studies were Bouin's solution, Gilson's fluid, and 10 per cent neutral formalin and those for histochemical studies were Gender's solution and the osmium tetroxide (Champy's fluid). Gilson's fluid gave good results with the oocytes in advanced stages. Tissues were sectioned by the usual paraffin method at 7 to 10 μ. For general staining Mayer's acid-haemalaum and eosin were used. Mallory's triple stain was also used for oocytes at advanced stages. PAS-test according to the Lilly's method was adopted for the detection of muco-polysaccharide.

Results

1) Morphology of ovaries

Ovaries are paired elongated bodies, each suspended by a mesovarium from the ventral margins of the air bladder. They fuse with each other and are connected with a median oviduct posteriorly. At immature and fully mature conditions they are reddish orange in

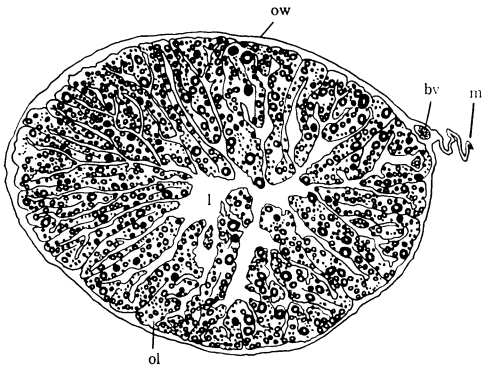

Fig. 1. Schematic drawing of ovary cross-section (×10). bv: blood vessel, l: ovarian lumen, m: mesovarium, ol: ovarian lamellae, ow: ovarian wall.

color, though during the process, i. e. when the oocytes accumulate yolk, they are yellowish-orange. The ovary is round in cross section (Fig. 1).

An ovarian wall and ovigerous lamellae are principal components of ovary. The former consists of two layers of connective tissues, interspersed with muscle-like fibers. The inner is highly vascular.

In earlier stages of ovarian maturation the ovigerous lamellae are covered with a somewhat firm membrane. A number of oocytes in various stages of growth are present in the lamellae and each of these is surrounded by the follicular cell layer. After spawning, the lamellae are considerably damaged in structure and the follicles in the lamellae are generally empty, though sporadically a few are found to retain. These oocytes are probably those which have failed to spawn, and are subsequently absorbed into the ovary. This process has been described later.

2) Oogenesis

Both in adult and immature fish, the oocytes at the early stages, e. g. chromatin-nucleolus stage and peri-nucleolus stage as defined by Yamamoto (1954, 1956) are predominant in the ovary all around the year except for a short duration before spawning. The egg cells undergo a series of morphological changes during various stages of maturation. These are described below.

The oogonia are either located singly or in groups in a cyst in the ovarian lamella. The oogonium measures less than 10 μ in diameter and has a relatively large nucleus (Fig. 2A). A thin layer of cytoplasm surrounds the nucleus, but its affinity for haematoxylin is feeble (oogonium stage according to Yamamoto, 1954, 1956). The oogonium undergoes a series of mitoses, and develops into the oocytes. At the early stage each oocyte has a more or less distinct contour and measures 15～25 μ in diameter (Fig. 2B). It has a distinct nucleus, 10 μ in diameter and bearing a deeply staining nucleolus. During further development of the oocyte this nucleolus increases in size and in affinity for haematoxylin. The thin cytoplasmic layer continues to be as indistinct as at the beginning though its affinity for the dye increases gradually with the growth of oocyte (chromatin-nucleolus

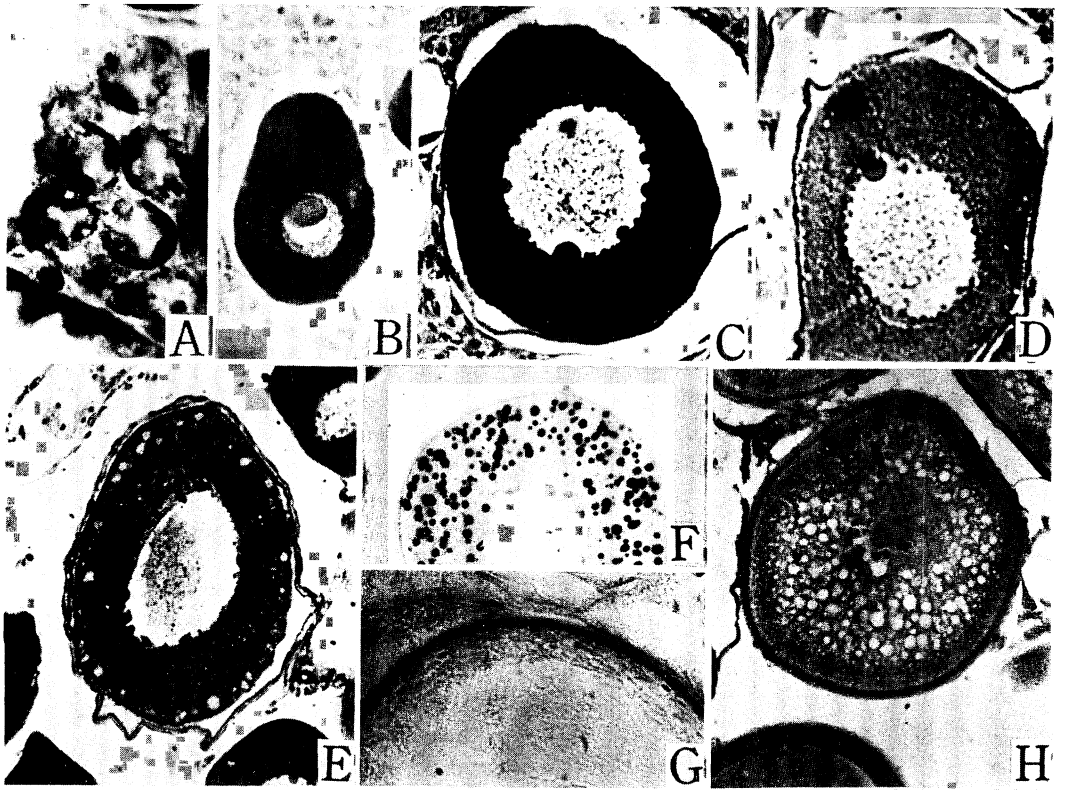

Fig. 2. Oocytes in various maturation stages of *Lateolabrax japonicus*. A: oogonium stage (×1200), B: chromatin-nucleolus stage (×400), C: peri-nucleolus state (×450), D: same stage as C showing the yolk nucleus in the peripheral cytoplasmic zone (×430), E: oil droplet or yolk vesicle stage (×290), F: same stage as E showing the osmiophilic oil droplets (×320), G: same stage as E showing the yolk vesicles treated with PAS-reagent (×320), H: primary yolk stage (×168)

stage). With further development the oocyte attains a size of about 80 μ in diameter. The nucleus also increases in size to about 30 μ in diameter. At this stage the nucleus is characterized by the presence of several nucleoli which line up along the nuclear membrane (Fig. 2C). The chromatin granules are apparent in the interior of the nucleus. The cytoplasmic layer is found to increase both in size and in its haematoxylinophilic nature. At the end of this stage the cytoplasm becomes coarse in structure, looses its affinity for haematoxylin and often contains in its peripheral region a yolk nucleus measuring 10 μ in diameter (Fig. 2D). During this phase of growth, a follicle is discernible around the oocyte, though follicle cells themselves are not conspicuous (Fig. 4B). The detailed description of follicular cell layer is dealt with in the next section. By the end of this stage the oocyte reaches a diameter of 160 μ (peri-nucleolus stage). Subsequent to these changes, a large number of oil droplets of various size make their appearance in the cytoplasm. The oil droplets appear vacuole-like in standard preparations, though are stained black with the osmium tetroxide (Fig. 2E, F). Simultaneously, another type of minute vacuoles fewer in number and smaller in size than oil droplets come into sight (Fig. 2G). These do not react with the osmium tetroxide but weakly react to PAS-test. Therefore they must be considered as the yolk vesicles which were observed in many fishes by earlier authors.

The yolk vesicles, measuring 4 μ or more in diameter, tend to aggregate more densely in a certain part of the oocyte. This polarized pattern of distribution of the yolk vesicles differs from that of other fish oocytes which show a somewhat homogeneous arrangement in the peripheral cytoplasm. The zona radiata, a precursor of egg membrane, found around the surface of oocyte, also exhibits strongly PAS-positive reaction (Fig. 2G). It is stained with aniline blue, and measures 3 μ in thickness. By the end of this phase the oocyte measures about 280 μ in diameter (oil droplet or yolk vesicle stage). Soon after the oil droplets and the yolk vesicles make their appearances in the oocytes, the yolk globules which stain reddish orange with Mallory's triple stain become appearant along the periphery of the oocyte. They measure about 6 μ in diameter (Fig. 2H). Meanwhile the nuclear membrane becomes indistinct and the nucleus shows an irregular contour. The nucleoli are still distinct along the inner surface of the nucleus though not so regularly arranged as before. The zona radiata becomes clearly visible with the gradual increase in its thickness and comes to stain deeply with acid fuchsin. Radial striations are still indistinct in it. By the end of this phase the oocyte has a diameter of 410 μ (primary yolk stage). Soon afterwards the yolk globules increase both in size and number, and disperse themselves among the yolk vesicles and oil droplets in the cytoplasm. The larger ones of these glubules measure 7 to 15 μ in diameter (Fig. 3A). Simultaneously, the oil droplets also increase in size. The yolk vesicles observed in the former stage are now hidden by the crowding yolk globules. The nucleoli become fewer in number. The zona radiata increases in thickness to about 10–15 μ and is deeply stained with acid fuchsin. By careful observation it is now possible to recognize two layers in zona radiata: (i) outer one which is weakly stained by acid fuchsin though is strongly PAS-positive in reaction and (ii) inner one which is intensely stained with acid fuchsin and shows lesser response to PAS-test. Radial striations then make their appearances in zona radiata. During this phase the oocyte grows at a remarkable rate and reaches a diameter of about 660 μ (secondary yolk stage). The yolk glubules proliferate rapidly and soon the cytoplasmic layer is completely filled with them. Late in this phase some of these in the peripheral region of oocyte begin to fuse with each other and exhibit an increased affinity for aniline blue instead of orange G. Simultaneously the oil droplets shift inward; in several cases they form a ring around the nucleus (Fig. 3B). The zona radiata does not undergo any change during this time. By the end of this stage ovo-diameter ranges from 600 to 690 μ (tertiary yolk stage). Very soon the nucleus which occupied the central portion of oocyte during the former stages, begins to shift toward the animal pole, and comes to lie close to zona radiata (Fig. 3C). The nucleoli become invisible. The yolk globules fuse with each other, so also the oil droplets, forming larger bodies within the cytoplasm. In this phase the oocytes are characterized with remarkable polarization into animal and vegetal hemispheres. The former contains the nucleus which has just moved from the central portion of oocyte and a micropyle situated in the portion of zona radiata close to the nucleus (Fig. 3D). The latter is characterized by yolk in advanced stage of fusion. This yolk is found to be aniline-blue-philic in reaction to Mallory's triple stain. During this period zona radiata seems to increase in thickness to about 30 μ and looses its affinity for acid fuchsin. By the end of this stage, the oocyte reaches 710 μ or more in diameter (migratory nucleus stage). The nucleus located at the animal pole in the oocyte soon becomes invisible. At the same time the yolk globules fuse with each other and finally form a single yolk mass which stains pale blue with Mallory's triple stain. The oil droplets also fuse into a larger ones. The egg membrane, previously noted as zona radiata and which encloses the oocyte now shrinks into a thick-

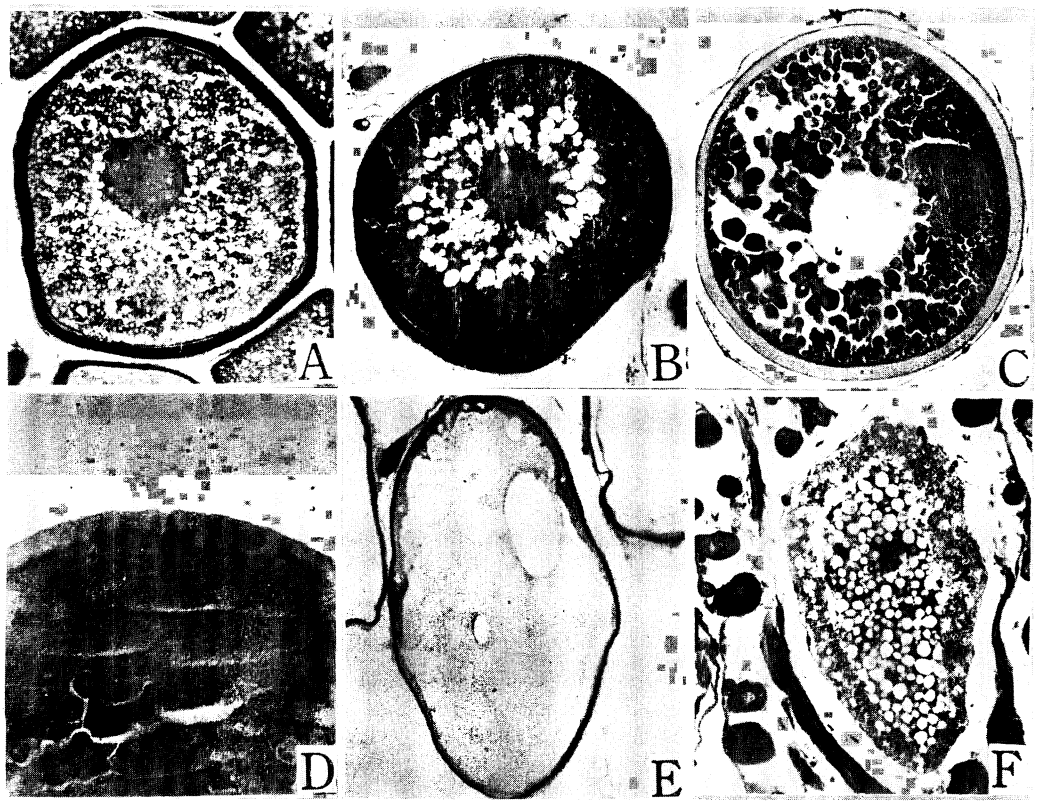

Fig. 3. Oocytes in various maturation stages of *Lateolabrax japonicus* (continued). A: secondary yolk stage (×80), B: tertiary yolk stage (×75), C: migratory nucleus stage (×60), D: same stage as C showing the micropyle at the animal pole of oocyte (×357), E: mature stage (×69), F: atretic stage of mature oocyte failed to ovulate (×78).

ness of about 12 μ. At this stage a thin nucleoplasmic layer which stains violet with Mallory's triple stain is evident in the animal pole, between the egg membrane and the yolk mass (Fig. 3E). The fully mature eggs measure about 1,100～1,300 μ in diameter (mature stage). A series of morphological changes which might have occurred in the egg cells at this stage were not completely studied due to certain technical difficulties in procedure.

The mature oocytes which continue to remain in the ovary after spawning show considerable vacuolation during the recovering process (Fig. 3F).

3) The morphological changes of follicle cells

The follicle cells also change their appearances drastically according to the stage of ovarian maturation. Fig. 4 schematically shows several stages of the changing process. Before the post peri-nucleolus stage, the follicle shows the simple membranous structure, containing only a few thecal cells with elongated nuclei (Fig. 4A). In early oil droplet stage, the follicle does not undergo any important morphological changes except that the thecal cells show cytological indications of development (Fig. 4B). Just prior to the primary yolk stage a new layer of follicle cells, viz. granulosa, make their appearance inner to the thecal cells. Though they are indistinct at the early stages of occurrence, with the advancement of ovarian maturation they become recognizable and arrange themselves into a fairly regular layer. By the secondary yolk stage the follicular cell layer markedly increases in thickness, reaching about 10 μ,

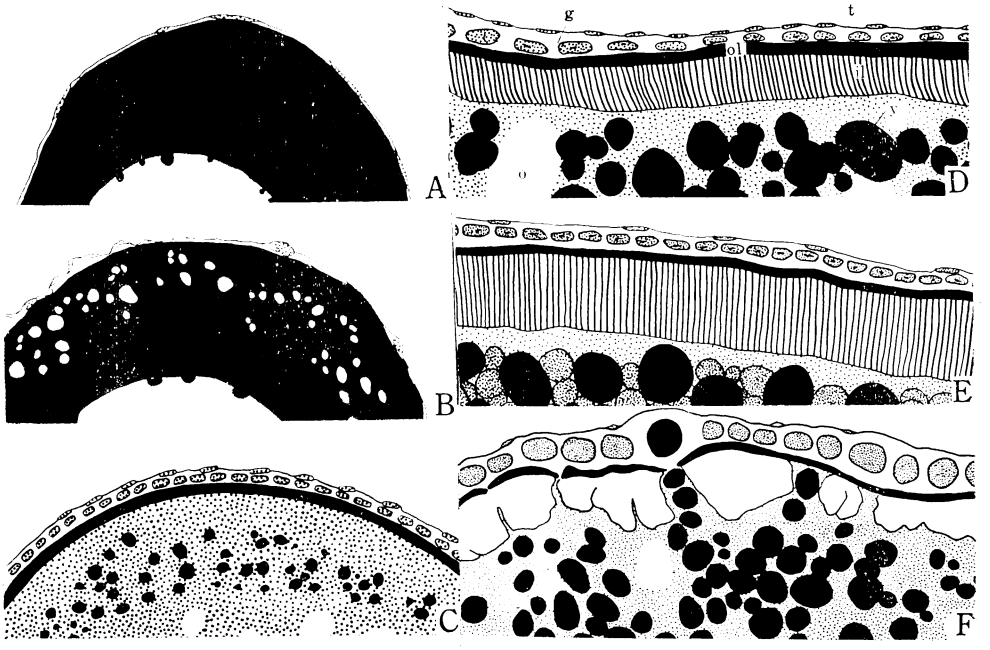

Fig. 4. Schematic drawing of morphological changes of follicular cell layers accompanied with the egg maturation. g: granulosa, il: inner layer of zona radiata, o: oil droplet, ol: outer layer of zona radiata, t: theca folliculi, y: yolk globule, A: peri-nucleolus stage of oocyte and membranous follicle with a few thecal cells (×100), B: oil droplet stage of oocyte (×70), C: primary yolk stage oocyte showing a fairly regular arrangement of follicle cells (×70), D: secondary yolk stage oocyte (×70), E: tertiary yolk stage oocyte (×70), F: atretic oocyte showing the remarkable hypertrophy of granulosa (×70).

and multilayered nature becomes clearly evident due to remarkable development of granulosa (Fig. 4C, D). In maturing conditions after the tertiary yolk stage, the follicle cells seem to show a rather relative regression in growth contrast to the remarkable development of egg cells (Fig. 4E). However, in follicles which have failed to discharge the mature oocyte, the layer of follicle cells actively develops again. Such follicle cell layer considerably thickens and often contains a few yolk globule-like substances, suggesting that the follicle cells may play an important role in the reabsorbing process just as the seminiferous epithelial cells of testis (Fig. 4F) (Hayashi, 1971).

4) Seasonal change of ovary

The gonad index, the per cent ratio of ovary weight to body weight, is commonly employed as a reliable factor in estimating the fish maturity with considerable precision. In order to evaluate this index with cytological data on maturity of gonads, gonad indices of the fishes were calculated and compared with the histological observations made in this study. The data is exclusively that of adult specimens because it was difficult to obtain sufficient number of immature specimens. The results are presented in Figs. 5 and 6 and Table 1. Fig. 5 shows the monthly values of gonad indices and Fig. 6 illustrates the relationship between the maturation stage of each ovary and its gonad index. In the latter figure the maturation stage of ovary indicates the stage of the most advanced oocyte contained in it. Table 1 indicates the stage composition of oocytes in several females which were obtained between autumn and winter. Though these values are somewhat variable in individuals, a gross analysis can be made as follows.

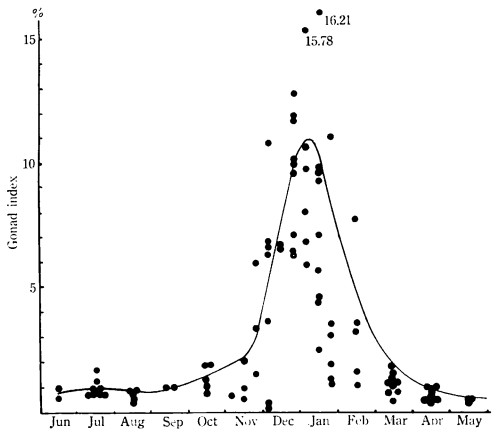

Fig. 5. Seasonal change of gonad index (percentage of ovary weight to body weight).

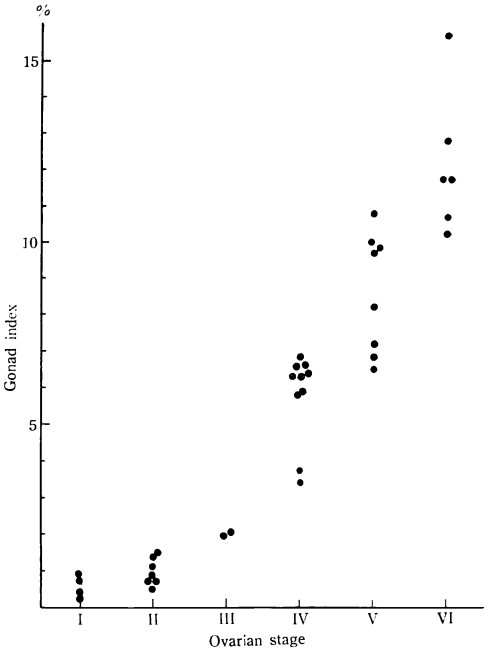

Fig. 6. Relationship between the maturation stage of ovary and its gonad index. The maturation stage of ovary indicates the stage of the most advanced oocyte contained in it. Stage I: perinucleolus stage, Stage II: oil droplet stage, Stage III: primary yolk stage, Stage IV: secondary yolk stage, Stage V: tertiary yolk stage, Stage VI: mature stage.

The gonad indices range from 0.5 to 1 per cent throughout summer when the ovary predominantly contains oocytes without yolk substances. In early October the indices rise to 1 to 2 per cent and this is correlated with the appearance of the oil droplets and the yolk vesicles in the oocytes. This condition continues till late November, when a sudden increase of index value occurs, the maximum value observed being 6 per cent. From Fig. 6 and Table 1 it is clear that this increase is due to the rapid accumulation of yolk glubules in the oocytes. Thereafter the values tend to increase steeply and after a month the majority of individuals attain indices above 7 per cent. By this time the ovaries of all adult females can be seen to contain oocytes highly rich in yolk globules, and in a few of them even oocytes approaching the migratory nucleus stage can be observed. By late December most of the oocytes in adult ovary attain the migratory nucleus stage. A few mature egg cells may even be evident in advanced ovaries. From late December to early January the oocytes grow rapidly and most of them perform their maturation process by middle of January. The final development of oocytes is associated with remarkable increase of gonad index to values above 10 per cent. Generally speaking, all adult females which are ready to spawn show 13 per cent or more in gonad index. It is noteworthy that the pre-spawning values show remarkable individual variations, in spite of the fact that the histological details of the maturation process of the ovaries are more or less uniform. The fully mature eggs are observed in the ovaries till middle of January, and their number tend to increase in course of time. Both microscopical observations of ovary and the data of gonad indices indicate that the spawning is carried out from late December to middle of January, mostly in early January. The spawning seems to occur more or less simultaneously or in a very short period of time. Microscopical observations also confirm that spawners without exception carry in their ovaries oocytes with the yolk substances by early November while non-spawners do not. Since by late

Table. 1. Stage composition of oocytes in ovaries of *L. japonicus* collected in autumn and winter.

Body length (mm)	Gonad index	Date	Number of eggs examined	Percentage of eggs at each stage					
				Peri-nucleolus	Oil droplet	Yolk stage			Mature
						Primary	Secondary	Tertiary	
472	1.07	Sep. 10	286	27.0	73.0				
500	1.00	Sep. 24	78	100					
367	0.78	Oct. 5	66	46.9	53.1				
366	1.29	Oct. 7	147	85.7	14.3				
304	0.68	Oct. 14	216	100					
513	1.90	Oct. 21	193	67.4	19.2	13.5			
460	1.95	Oct. 21	233	54.9	45.1				
329	0.70	Nov. 6	230	96.1	3.9				
356	0.79	Nov. 8	264	72.0	28.0				
445	2.07	Nov. 15	143	49.7	24.5	25.9			
308	0.54	Nov. 15	288	87.2	12.8				
347	0.87	Nov. 18	275	87.3	12.7				
341	0.91	Nov. 18	295	73.9	26.1				
410	1.56	Nov. 24	148	80.0	20.0				
394	3.40	Nov. 24	122	52.5	13.1	18.9	15.6		
406	0.69	Nov. 27	183	89.1	10.9				
379	6.30	Dec. 3	90	53.3	8.9	23.3	14.4		
350	10.81	Dec. 3	55	32.7	10.9	27.3	29.1		
520	6.83	Dec. 3	73	39.7	8.2	20.5	13.7	17.8	
225	0.20	Dec. 4	323	100					
225	0.31	Dec. 4	191	100					
528	4.39	Dec. 8	58	43.1	12.1	10.3	34.5		
361	13.9	Dec. 13	90	54.4	4.4	14.4	26.7		
402	6.55	Dec. 14	85	50.6	4.7	25.9	4.7	12.9	1.2
386	7.12	Dec. 22	88	40.8	12.5	17.0	23.9	5.7	
371	5.06	Dec. 22	64	76.6		4.7	18.8		
379	10.19	Dec. 23	51	33.3	13.7	9.8	5.9	15.7	21.6
440	11.9	Dec. 24	24	37.5	4.2	16.7	37.5	4.2	
516	13.6	Dec. 28	25	60.0	8.0		32.0		
453	15.8	Jan. 7	199	51.0	1.5	12.6	11.1	23.6	
362	16.2	Jan. 13	21	28.6	4.8	9.5	9.5	4.8	42.9
410	1.18	Jan. 21	213	100					
461	2.65	Feb. 5	63	100					
449	1.13	Feb. 5	32	100					

January none of fully mature eggs still remain in a ovary, except in a few specimens which have failed to ovulate at the proper time, showing that the ovulation has already been completed in the majority. The values of gonad indices also suddenly drop below 5 per cent in late January. At this time the number of specimens with low values ranging from 4 to 1 per cent are predominant, and by March the values decrease to below 2 per cent in all specimens. After March the values of the spent females decrease still further to about 1 per cent. Histological observations indicate that during this time the ovaries undergo recovery from spawning damage. From April onwards conspicuous changes are not either observed in the histological structure of the ovary or in the values of gonad indices. The above mentioned facts, therefore, indicate that the maturation process of the fish from the appearance of the first yolk substance in the oocytes to the formation of fully mature ova is so short as to require only about two months, and that the gonad index is a fairly effective indicator of the maturity of the female.

The findings obtained about the size of

sexual maturity is given in Fig. 7. Judging from the maturing pattern of this fish, the individuals which carry oocytes more advanced than the oil droplet or the yolk vesicle stage in their ovaries or/and indicate more than 2 per cent in gonad index by early November,

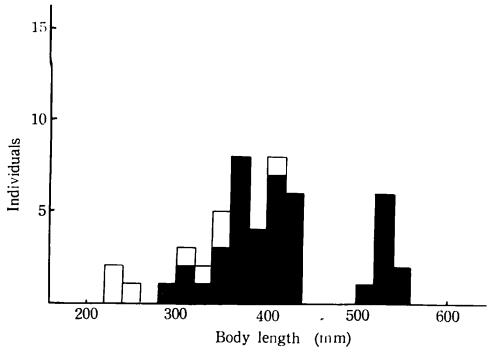

Fig. 7. Body length composition of the female collected from November to January. Solid bars show the specimens which are on the way to maturation process.

probably mature during the imminent spawning season. Fig. 7 illustrates the data classified into mature and immature forms on above criteria in relation to their body size. In this figure it is clear that most specimens less than 300 mm in body length do not mature while those more than 350 mm mature and spawn in that season. The biological minimum size of the female is thus about 350 mm in body length, which corresponds to the size of two or three year age group.

Discussion

The results obtained from this study on the egg formation of *L. japonicus*, in spite of the imperfections in some technical details, strongly suggest that the pattern of oogenesis of this fish is fundamentally consistent with that of flounder (Yamamoto, 1954; 1956). Yamamoto (1958) has previously pointed out that a wide range of variations in detail occur in the oogeneses of bony fishes, in spite of their fundamental conformity. The author also noted such differences with regard to the distribution pattern of yolk vesicles during the oogenesis of *L. japonicus*. As mentioned above, the yolk vesicles, weakly PAS-positive in reaction, are somewhat small in size, sparse in distribution, and require the considerable effort for their identification; all these being in sharp contrast to the other teleosts. Yamamoto (1955) has observed that in some fixatives the vesicle contents are not fixed entirely, and consequently some of yolk vesicles show vacuole-like features even after PAS-treatment. A similar phenomenon might have also taken place in the egg of *L. japonicus*. But the vacuolated yolk vesicles found in the oocytes are too sparse to attribute their occurrence as due to fixation. It still remains unknown what consequences such a poor distribution of yolk vesicles through the egg maturation process bring about in the embryonic development. It is of interest, however, that a similar appearance has also been noted in the pelagic eggs of yet another marine species viz. the flounder (Yamamoto, 1958). Though the vesicles disappear from sight after the yolk globules aggregate densely in the oocytes, it is probable that they still remain in a thin pre-cortex zone throughout maturation process, and give rise to the cortical alveoli in the fully mature eggs as found in a few other teleosts (Yamamoto, 1955; Kudo, 1969).

Various investigators (Beach, 1959; Kraft and Peters, 1963; Jollie and Jollie, 1963; Takano, 1964; Hurley and Fisher, 1966; Moser, 1967; Braekevelt and McMillan, 1967) have made intensive studies on the structure and functions of follicles in bony fishes. Judging from their results the zoned structure of follicle observed in *L. japonicus* seems to be common in most bony fishes, the only exception being the single layered follicle of the brook stickleback, *Eucalia inconstans* (Braekevelt and McMillan, 1967). Electron microscopic observations of Hurley and Fisher (1966) have revealed in the trout ovary the follicular cells of granulosa are connected with the ooplasm through a lot of microvilli that run

across the zona radiata. Kraft and Peters (1963) have demonstrated that granulosa develops markedly during the process of the egg maturation in the type of *Tilapia* that breed at the substratum, and that this layer produces a sort of adhesive substance.

The hypertrophic development of granulosa around atretic oocytes are also perceptible in the other teleosts and the reabsorption process seems to be similar to thet obsarved in *L. japonicus* (Beach, 1959; Moser, 1967; Braekevelt and McMillan, 1967). Beach (1959) was doubtful whether the reabsorption of the atretic oocytes by the hypertrophic granulosa cells took place through phagocytic action or enzymatic dissolution. Recent investigations seem to favor the view that the hypertrophic granulosa rather play the phagocytic role because the absorption of yolk substances has been confirmed in this layer of several species (Gokhale, 1957; Moser, 1967; Braekevelt and McMillan, 1967). These functions of granulosa thus seem to be the same as that of seminiferous epithelial cells of the male, strongly suggesting that their origins are homologous genetically (Hayashi, 1971).

Another characteristic of the oogenesis of *L. japonicus* is that it undergoes rapid development from the time the first yolk substance makes its appearance in the egg. The oogeneses of most fishes observed so far proceed rather slowly. For instance the period extends nearly a year in several salmonid fishes such as trout (Yamamoto et al., 1959), sockeye salmon and chum salmon (Ishida et al., 1961) which spawn only once in their life spans. In the goldfish which spawns a few times in a year, the period is about eleven months (Yamamoto and Yamazaki, 1961). Further in both the rainbow trout (Yamamoto et al., 1965) and the flounder (Yamamoto, 1954; 1956) which spawn once a year, and whose maturation patterns belong to the partial synchronism type the process of maturation lasts about seven months.

On the contrary, in the female of *L. japonicus* which is also an annual spawner and which has partial synchronism type of maturation, the process takes only about three months, i.e. from late September to early January, just the same duration as that of the male (Hayashi, 1971). At present, it is difficult to explain the significance of this characteristic pattern of maturation process of the species, because much more information is needed on the reproductive physiology of the fish.

However, it is great interest to note that the maturation process of the fish somewhat coincides with its life cycle. Kuwatani (1962), dealing with the ecological study of *L. japonicus* in Wakasa Bay, has described the seasonal migration of the fish as follows (Fig. 8).

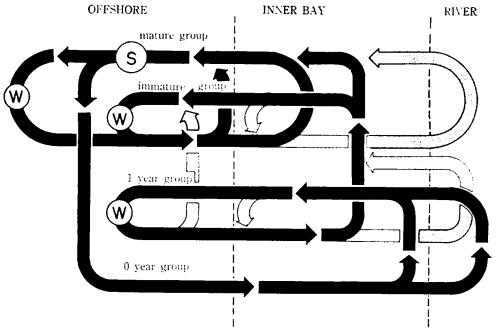

Fig. 8. A diagram of the probable course of migration of *L. japonicus* in Wakasa Bay (modified from Kuwatani, 1962). Solid bars show the main course. S: spawning, W: wintering.

The fishes which live in the offshore deep region during winter migrate into the coastal region of the bay in early spring. In most cases younger fishes even go upstream the river which flows into the bay. These fishes remain in the river and estuarine regions till late August. After September when the water temperature begins to decrease, they return from the inner bay. The adult fishes in mature condition spawn at the coastal region close to the open sea during winter. They, thereafter, move into the deeper offshore regions and stay there until spring. In addition, Kosaka (1969) has pointed out that the fish in Sendai Bay feed voraciously

from spring to autumn and feed scarcely in winter, and further that the major part of growth of the fish takes place between summer and autumn. In the light of this information it is interesting to note that it is after September that the oocytes with the oil droplet or the yolk vesicles appear in the ovary of the female spawner of the season. It is also at this time that the fish leaves the inner bay. It is, therefore, highly probable that the migration of the adult fish toward offshore region is intimately related to the performance of maturation process. The active feeding in summer and autumn certainly produces the high extent of maturation potential required for breeding purposes. The recovering period after spawning also corresponds with the offshore stay of the fish.

Thus the result obtained here shows that the maturation pattern of the species may be rather closely related to the mode of their life than that determined phylogenetically. However further discussion on this point will be meaningless unless more information is available on the maturating process of other marine fishes similar in life pattern to *L. japonicus*.

The information that the spawning time of the fish is between late December and middle of January, mostly early January, agrees with those of Hatanaka and Sekino (1962b) and Kosaka (1969). Some authors have reported that the spawning time of this fish is rather long (Mito, 1957; Watanabe, 1965). However, it seems reasonable to assume that the spawning does not vary greatly at least within a single population, as is evident from their somewhat uniform pattern of maturation process.

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スズキ卵巣の成熟過程について　林　勇夫

スズキの卵巣の成熟過程は基本的には他の硬骨魚類と大差ないようであるが，卵黄胞 (yolk vesicle) の分布が非常にまばらな点と成熟過程が速やかに進行する点が特徴的である．これらの点に関する生理学的な意義は明かでないが，成熟過程の進行はこの種の生活史と密接な関連をもっているようである．また卵胞細胞 (follicle cell) は成熟過程において顕著に変化するが，それは崩壊卵の吸収過程の際にとくに発達する．このように卵胞細胞は卵母細胞 (oocyte) に栄養を補給する機能と同時に崩壊卵の吸収にも主要な役割を果しており，精巣における精上皮細胞とその起源を同じくしていることを示唆している．顕微鏡観察および生殖腺指数の変化から推して，産卵期は 12 月下旬から 1 月中旬にかけての短期間で，成熟過程の個体差はほとんどないようである．また雌の生物学的最小形は体長 350 mm 前後で，2～3 年で成熟する．

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