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Studies on the Seasonal Migration and Reproduction of the Spotted Mackerel, *Pneumatophorus tapeinocephalus* (BLEEKER)

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Abstract

The studies on the ecology and the fishing condition of the spotted mackerel have been made by the writer in the coastal sea of Japan and the East China Sea since 1961.

In the following papers some descriptions have been made of the migration of the fish, 4~450mm. in fork length, distributing in the sea areas mentioned above, the sex differentiation and growth of the gonads of the young fish, 5~300 mm. in fork length and the seasonal changes in the gonads of the adult fish caught in the southwestern sea of Kagoshima and its vicinity.

Contents

Introduction

The mackerels found swimming in the waters adjacent to Japan can be divided into two species, namely, the common Japanese mackerel, *Pneumatophorus japonicus* (HOUTTUYN), and the spotted mackerel, *Pneumatophorus tapeinocephalus* (BLEEKER). Hitherto the swim-

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ming areas of the former have been fixed as the Japan Sea, the Pacific coastal waters of Tohoku district and the northern region of the East China Sea, while that of the latter, as the coastal waters of Chiba Prefecture and the Pacific Ocean south of Chiba Prefecture.

As the spotted mackerel is one of the fishes important to the coastal fisheries in Japan, numerous investigations on the ecology of this fish have been made until now by many researchers. According to the reports of TANOUE (1952, '57),[1),2)] MORITA (1953, '54),[3),4)] TSUJITA (1954),[5)] MORI and NISHIKAWA (1955),[6)] UDA and ŌTSUBO (1956),[7)] and KANAMORI (1956),[8)] the distribution pattern of *P. tapeinocephalus* in the East China Sea shows a relationship to temperatures between 18.0～24.0°C, formed when the Kuroshio current flowing northward along the continental slope is mixed with the cold water coming from the Yellow Sea. TANOUE (1958),[9)] showed that schools of *P. tapeinocephalus* migrated in the Tsushima warm current northward or northeastward from the southern regions of the East China Sea, following a gradual rise in the surface water temperature in the north sea during the spring. In summer they arrived at the eastern sea area off Saishu Island and off the San-in district.

Some observations were made on the seasonal changes in the gonads of *P. tapeinocephalus* caught in the waters around the Ōsumi islands and the East China Sea by KOKUBU (1954),[10)] MURAKAMI (1954),[11)] KOKUBU and TAKAHASHI (1955),[12)] TANOUE (1956),[13)] ENAMI (1958, '61)[14),15)] and TANOUE, KURATA and TOKUDOME (1960).[16)] These authors have clarified that the spawning begins in the southern part (30～27°N. lat.) of the fishing ground of the East China Sea at the end of January and continues to take place along the continental shelf until May ; and that in the sea around the Ōsumi Islands it takes place from the end of January to June. According to TATEISHI (1956),[17)] TATEISHI, Ko and MIZUE (1957),[18)] the ovaries of *P. tapeinocephalus* caught in the East China Sea in May contain a large number of oocytes of nearly full size. In the ovaries of the fish caught in June young oocytes and empty follicles are found. Concerning the relation between the distribution of the larvae of the spotted mackerel and the water temperature, YABE (1957),[19)] HOTTA (1957),[20)] IMAI (1958)[21], UCHIDA (1958),[22)] TANOUE (1960, '61)[23),24)] reported that in the East China Sea and the sea area around the Ōsumi Islands the larvae were collected only at the waters where the temperature was higher than 17°C. In spite of numerous reports on the ecology of *P. tapeinocephalus*, only a little has been elucidated as to the habits, migration and spawning of this fish. Moreover, on the ecology of this fish in the Pacific Ocean no investigations have been done so far, except those of the present author. In order to clarify the seasonal migration and the spawning behavior of *P. tapeinocephalus* the present author has made studies since 1961 on the sea conditions of fishing grounds, the fork length composition in every fishing ground, and the distribution of larvae. In addition to these, anatomical and histological observations were done by him on the fish, 4～450mm. in fork length, in order to clarify the growth and differentiation as well as the seasonal change of their gonads.

Before going further, the writer wishes to express his hearty gratitude to Prof. T. KAWAMURA, Faculty of Science, Hiroshima University, for his kind guidance in this study, and the revisory reading of the manuscripts, and to Dr. H. SANBUICHI, Dr. S. NADAMITSU and Dr. M. NISHIOKA of the same university for their support in carrying out the present work. He also is deeply grateful to Dr. T. MORIWAKI, Suzugamine Womens Collage and to Dr. S. TATEISHI, Faculty of Fisheries, Nagasaki University for assistance on the histological study, to Prof. T. TANAKA, Prof. T. FUJITA, Prof. S. IMAI, Prof. T. MORITA, Assist. Prof. S. ENAMI, and Inst. N. HIGO, Faculty of Fisheries, Kagoshima University, for their valuable aid in many ways. Furthermore thanks should be offered to Mr. T. HASHIGUCHI, Miyazaki Fisheries Exp. Station, Mr. Y. KURATA, Tokyo Fish. Exp. Station, Mr. T. HANADO, Chiba Fish. Exp. Station, Mr. S. YAMASAKI, Shimane Fish. Exp. Station, Mr. T. NAKAHARA, Yamaguchi Fish. Exp. Station and Mr. S. UENO, Kagoshima Fish. Exp. Station for their kind help in collecting material, and to captain S. UEDA and the first officer T. IMAI of the 'Kagoshima Maru', and to captain T. HENMI of the 'Keiten Maru', and to captain K. TAKAHASHI and the members of the 'Shiroyama Maru', the training ships belonging to the Faculty of Fisheries, Kagoshima University, for their co-operations in the present study.

I. Migration

1. Methods of investigation

In order to clarify the seasonal migration of the spotted mackerel in the sea area adjacent to the sea of Japan, oceanographical observations have been carried out on the training ships of the Faculty of Fisheries Kagoshima University, 'Kagoshima Maru' (1037 gross tons), 'Keiten Maru' (267 gross tons) and 'Shiroyama Maru' (18 gross tons) in the Pacific Ocean off Shionomisaki and southward, the sea around the Ōsumi Islands and in the East China sea since February, 1961. About 7000 specimens of the spotted mackerel were

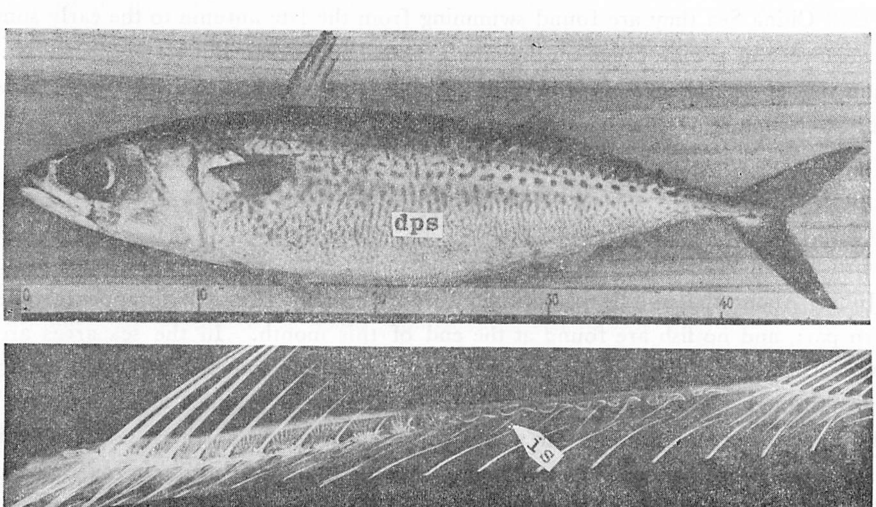


Fig. 1. Dark pigment spots (dps) of the ventral portion and interneural spines(is) of *Pneumatophorus tapeinocephalus*.

collected in Amami Ōshima, Kagoshima, Aburatsu, Goto, Senzaki, Tosa-shimizu, Muroto, Wakayama, Shizuoka, the Izu Islands, Tateyama and Katsu-ura. These specimens were identified as this species by the presence of one or both of the following two morphological characteristics : 1) dark pigment spots over the ventral portions and 2) more than 17 interneural spines (Fig. 1). Measurments were made on the fork length, body weight and gonad weight.

As an instrument for the research of the swimming layer, the fish finder of Furuno Electrical Co. Ltd. having 28 KC. frequency and equipped with a wet paper recording system was used.

2. Geographical distribution

The distribution of spotted mackerels, as shown in figure 2, covers the following sea areas: the northern land shelf of Formosa, the East China Sea, the sea areas around the Ōsumi Islands and Kyushu, the eastern sea area of Saishu Island, the sea area along the San-in district, the Pacific Ocean area spreading along the shore from Chiba Prefecture to Shikoku and around the Izu Islands. Spotted mackerels are caught with the following kinds of fishing tackle : a purse seine, a long line, a Hanezuri pole line and a lift net. The southern limit of adults caught by a long line and a purse seine lies at the sea area near Kameyama Island off Formosa (CHEN, LIN and SHEU, 1959).[25]

a. Fishing Season

i) Adult fish

The fishing season of each fishing ground is presented in figure 3. In the eastern sea of Formosa and in the sea area around the Uotsuri Islands, spotted mackerels appear late in autumn, remain there during winter and spring and then disappear. In the southern parts of the East China Sea they are found swimming from the late autumn to the early summer of the next year in a wide range on the continental shelf between 30° and 26°N. lat. It is certain that spotted mackerels appear first in the northern part of this range, between 29° and 30°N. lat., early in October.

During the following three months, November to January, they are found everywhere in the range of 27° 30′～28° 30′N. lat. and 123°～125°E. long. While in February they are still found in the southern end of this range, in March they begin to migrate northward and in April they appear in the northern part, where they remain until the early June. About the middle of this month they usually begin to disappear from the northern part, and no fish are found at the end of this month. In the sea areas around the Ōsumi Islands and along the shore of Kagoshima district spotted mackerels are found swimming through the four seasons, although the catches in summer and winter are less than those in spring and autumn. In spring they appear in the northern sea area of Yaku Island and in the area around Tane Island. Early in summer they approach the coast near Sata Cape. In midsummer they are caught in the deep layer of the northern sea area of Yaku Island and on the bank situated west of Kuchino-erabu Island. In autumn and winter they are found swimming in the northern sea areas of Yaku Island and on the

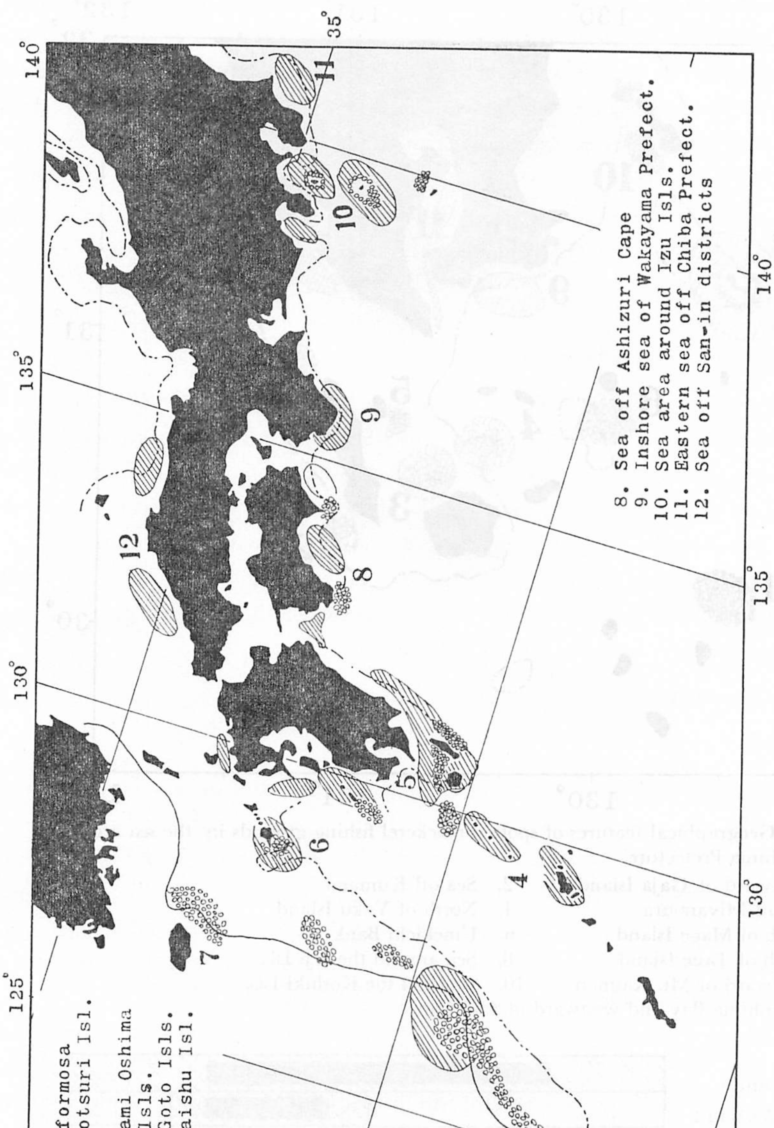


Fig. 2-1. Geographical features of spotted mackerel fishing grounds.

: Juvenile mackerel fishing ground

: Adult mackerel fishing ground

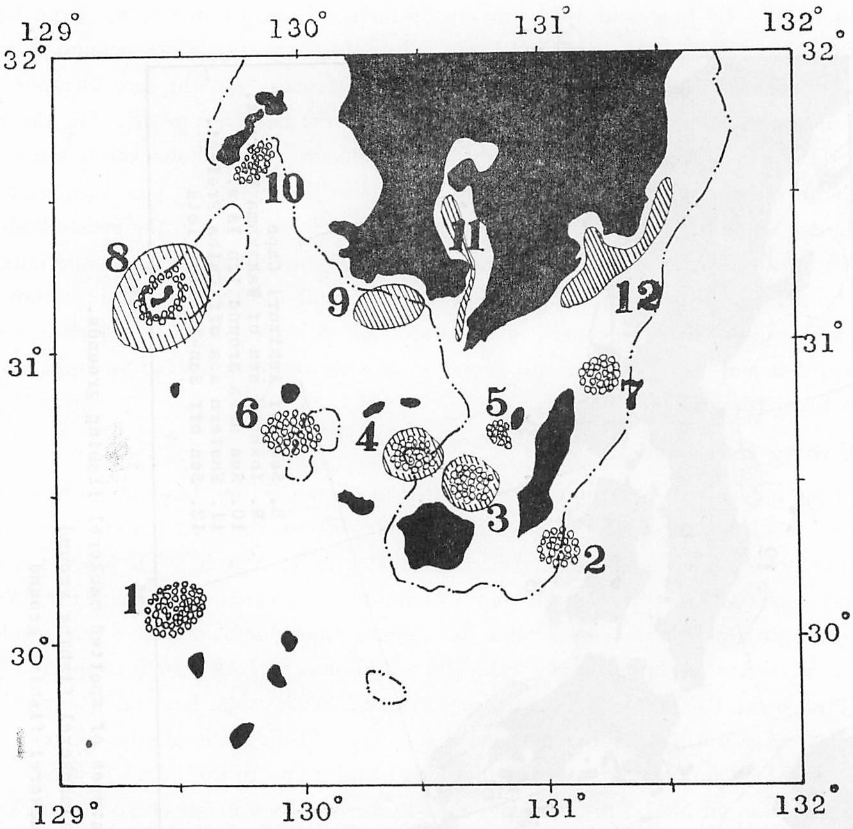


Fig. 2-2. Geographical features of spotted mackerel fishing grounds in the sea around Kagoshima Prefecture.

1. Westward of Gaja Island
2. Sea off Kumano
3. Sea off Miyanoura
4. North of Yaku Island
5. South of Mage Island
6. Umekichi Bank
7. North of Tane Island
8. Sea around the Uji Isls.
9. Westward of Mt. Kaimon
10. South of the Koshiki Isls.
11. Kagoshima Bay and westward of Sata Cape

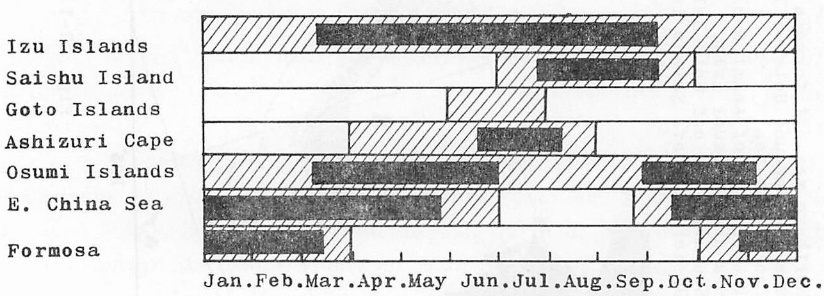


Fig. 3. Fishing season in every fishing ground

: Chief fishing period

Sub-fishing period

Umekichi Bank. In June and July they are in the southern sea area of the Goto Islands and in the waters around the Danjo Islands. In July, they are found swimming in the eastern sea area of Saishu Island, staying there until October. In the late October, they begin to disappear from that area ; no fish remain in the late November. On the other hand, in the Pacific Ocean area along the coast of Shikoku, spotted mackerels are caught during the term from April to August ; they are done with a Hanezuri pole line and a long line in the sea area off Ashizuri Cape and with a Hanezuri pole line in the area off Muroto Cape. From the middle of June to the beginning of August the catches are especially rich there. In the sea around the Izu Islands, they are found through the four seasons. In autumn and winter they are caught in the waters off Miyake Island and Hachijo Island, while in spring and summer they are found in a wide sea area spreading from Ōshima Island to Kozu Island.

ii) Young fish

One of the habits most characteristic of spotted mackerels is that they are apt to associate in a dense school. Very young fiish which are 30～60 mm. in fork length aggregate in schools and swim along the shore of Amami Island early in March. They are found in the coastal waters of Kagoshima in the mid-March ; they are caught with a dip net. Young fish are often caught in waters very close to a shore line ; occasionally, even inside of harbours. Early in summer, young fish, 100～200 mm. in fork length, appear around Kyushu and in the Pacific Ocean areas along Shikoku, Wakayama, Izu and Chiba. They seem to stay there until December or somewhat later. Throughout all the winter season they are caught in the coastal waters of southern Kyushu and in the East China Sea.

In the sea areas off San-in district and Chiba Prefecture, two Kinds of young mackerels, *P. japonicus* and *P. tapeinocephalus* are caught with a fishing net. The numerical ratios of *P. tapeinocephalus* to *P. japonicus* in the catches which were caught with a purse seine in the sea area off San-in district and with a pole-held-dip-net in the waters off Chiba Prefecture in 1962 and 1963 are presented in table I. The ratio in the sea area off San-in district is about 5 : 95 from July to November, while about 20 : 80 in the waters off Chiba Prefecture in spring, summer and autumn.

b. Age composition of the fish in each fishing ground

The fork lengths of spotted mackerels caught in each fishing ground are shown with histograms in figure 4. According to previous papers of the present author (1955, '56)[26),27)] and those of TAKESHITA and MIO (1958)[28)] and TAKANO (1961),[29)] the age of spotted mackerels can be presumed from their fork lengths, as shown in table 2.

In the southern area of the East China Sea from autumn to spring most fish are composed of 1-year-old fish ; a small number of them are of 2-year-old ones. Late in autumn some young fish born this year make their appearance. In spring in the sea area around Kagoshima and the Ōsumi Islands the fish are mostly 1 or 2 years old; there are a small number of 3–or 4–year old fish among them. During the months from summer to winter in the same area spotted mackerels are mostly 1 year old and a small number of them are 2 years old. In spring young fish born this year appear inshore and remain there

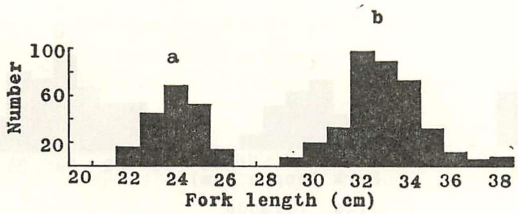
Table 1. Percentages of the number of *P. tapeinocephalus* to that of *P. japonicus* among fishes caught with a purse seine in the sea area off Hamada, San-in district and that caught with a pole-held-dip net in the sea area off Katsu-ura.

	The sea off Hamada			The sea off Katsu-ura		
Month	Number of fish	Range of fork length (mm.)	T/J %	Number of fish	Range of fork length (mm.)	T/J %
'62 Apr.	100	220～260	0 100	100	250～320	5 95
May	120	230～265	0 100	100	280～320	8 92
June	200	245～270	2 98	150	200～350	12 88
July	150	250～280	6 94	120	210～320	16 84
Aug.	200	240～300	3 97	100	200～260	22 78
Sep.	250	230～290	4 96	150	200～270	14 86
Oct.	200	260～285	7 93	100	210～300	20 80
Nov.	150	245～280	0 100	150	200～300	16 84
Dec.	100	250～290	0 100	100	280～350	0 100
'63 Jan.	300	220～245	0 100	200	300～380	0 100
Feb.	450	230～280	0 100	200	300～380	0 100
Mar.	300	250～270	0 100	200	300～380	0 100
Apr.	600	230～260	0 100	200	250～350	10 90
May	450	250～270	0 100	200	200～300	15 85
June	300	250～280	0 100	200	200～340	15 85
July	450	260～295	2 98	200	200～335	20 80
Aug.	450	210～315	4 96	400	200～250	20 80
Sep.	300	210～310	3 97	400	200～250	20 80
Oct.	450	225～250	5 95	400	200～300	20 80
Nov.	450	235～250	2 98	200	200～350	10 90
Dec.	300	240～255	0 100	200	300～350	0 100

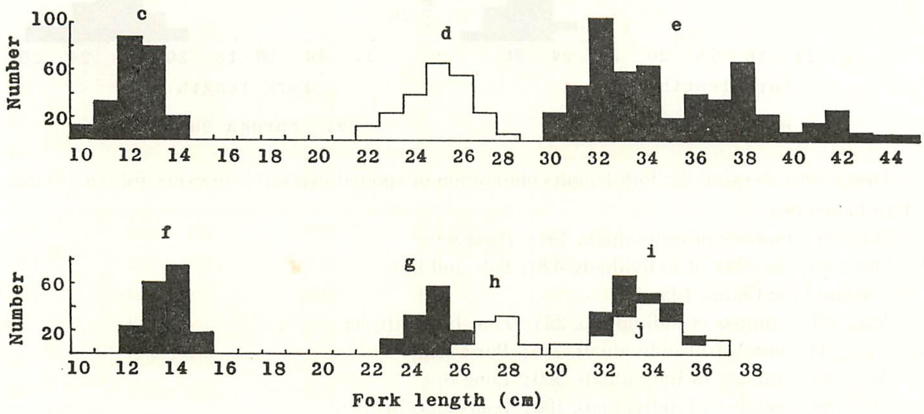
T, *Pneumatophorus tapeinocephalus* J, *Pneumatophorus japonicus*

Table 2. Ranges in fork length of *P. tapeinocephalus* in each age group.

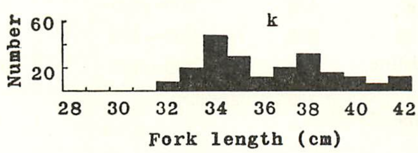
Age	Range of fork length (mm.)
1	281～350
2	351～400
3	401～428
4	429～



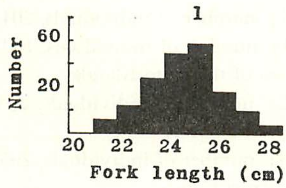
1. East China Sea



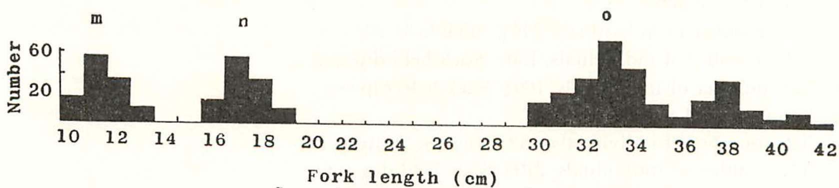
2. Osumi Islands



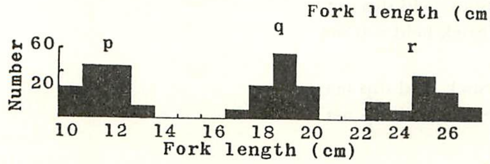
3. Goto Islands



4. San-in district



5. Ashizuri Cape



6. Wakayama

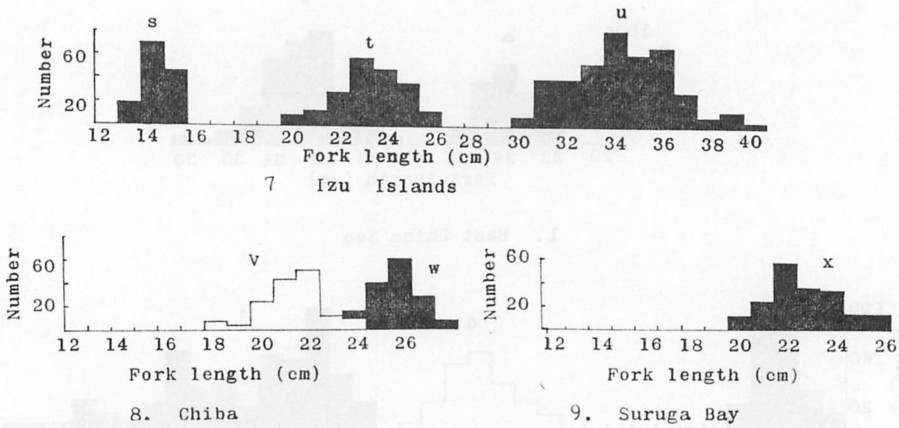


Fig. 4. Histograms showing the fork length composition of spotted mackerels in every fishing ground.

1. East China Sea
   - a. Oct., '64; number of individuals, 194; Purse seine
   - b. Mar., '63; number of individuals, 420; Pole and line
2. Sea around the Ōsumi Islands
   - c. Apr., '63; number of individuals, 225; Four-boats lift net
   - d. Nov., '63; number of individuals, 275; Purse seine
   - e. Apr., '63; number of individuals, 560; Long line
   - f. May. '64; number of individuals, 180; Four-boats lift net
   - g. Oct., '64; number of individuals, 124; Purse seine
   - h. Nov., '64; number of individuals, 80; Pole and line
   - i. July, '64; number of individuals, 204; Long line
   - j. Dec., '64; number of individuals, 160; Long line
3. Southern sea of the Goto Islands
   - k. June, '62; number of individuals, 220; Pole and line
4. Sea off San-in districts
   - l. June, '63; number of individuals, 295; Purse seine
5. Sea off Ashizuri Cape
   - m. May, '63; number of individuals, 132; Four-boats lift net
   - n. July, '63; number of individuals, 127; Four-boats lift net
   - o. july, '63; number of individuals, 346; Pole and line
6. Inshore sea of Wakayama
   - p. May, '62; number of individuals, 144; Stick held dip net
   - q. Aug., '62; number of individuals, 130; Stick held dip net
   - r. Oct., '62; number of individuals, 100; Stick held dip net
7. Sea area around the Izu Islands
   - s. June, '62; number of individuals, 132; Stick held dip net
   - t. Oct., '62; number of individuals, 210; Stick held dip net
   - u. May, '62; number of individuals, 350; Stick held dip net
8. Eastern sea off Chiba
   - v. July, '62; number of individuals, 156; Stick held dip net
   - w. Sep., '63; number of individuals, 150; Stick held dip net
9. Suruga Bay
   - x. July, '62; number of individuals, 200; Purse seine

until winter. In the sea area around the Goto Islands, the fish found in June and July are mostly 1 year old. There are also a small number of 2-year-old fish and a few 3-year-old ones. From summer to autumn some young fish born this year appear. From summer to autumn young fish born this year are found swimming in the sea area off San-in district. Off Ashizuri Cape from late spring to summer most fish are composed of 1-year-old fish ; a small number of them are of 2-year-old fish and a few 3-year-old fish. From spring to late autumn young fish born this year are found. In the inshore sea of Wakayama Prefecture from spring to autumn all the spotted mackerels are those born this year. In spring, in the sea area around the Izu Islands the fish are mostly 1 year old ; there are a small number of 2-year-old ones among them. From summer to late autumn young fish born this year are found swimming in the same area. In the eastern sea off Chiba Prefecture spotted mackerels are mostly composed of new born fish ; a few of them are 1 year old.

As the conclusion of the results obtained through the above mentioned investigations, the geographical distribution of spotted mackerels of each age can be summarized as follows ; new born fish appear in spring both in the sea area around Kyushu, in the Pacific Ocean along Shikoku district, Wakayama Prefecture, Shizuoka Prefecture and Chiba Prefecture and Chiba Prefecture and around the Izu Islands, and stay there until autumn. From late autumn to winter they are found in the inshore sea area off Kyushu and in the East China Sea. From winter to spring 1-year-old fish appear in the southern East China Sea, the Ōsumi Islands and the Izu Islands. From summer to early autumn they are found in the eastern sea area off Saishu Island, in the sea area around the Ōsumi Islands and the Izu Islands and in the sea area off Ashizuri Cape ; late in autumn they are found around the Ōsumi Islands, in the southern East China Sea and around the Izu Islands. 2-year-old fish are swimming from winter to spring in the southern East China Sea, around the Ōsumi Islands and the Izu Islands. In summer they are found in the sea areas around the Ōsumi Islands, south of the Goto Islands, east of Saishu Island, off Ashizuri Cape and around the Izu Islands. 3-year-old fish and those of somewhat older age are found swimming around the Ōsumi Islands from spring to early summer ; a few of them are found in the sea areas south of the Goto Islands, off Ashizuri Cape and around the Izu Islands.

3. Vertical distribution

a. Seasonal change

The vertical distribution of spotted mackerel schools in each fishing ground was explored with a fish finder attached to a training or fishing ship. It was also determined by measuring the depth of the hooks of a long line through the catenary counting equation (YOSHIHARA, 1954)[30] and the length of the line of a line and hook.

The vertical distributions recorded with a fish finder in the sea area around Kagoshima district and the Ōsumi Islands in different months are shown in figure 5 and table 3. The vertical distributions found with a pole and line, a long line and a trawl net in different months were as follows. In the sea area, 90$\sim$110 m. in depth, lying in the north of Yaku

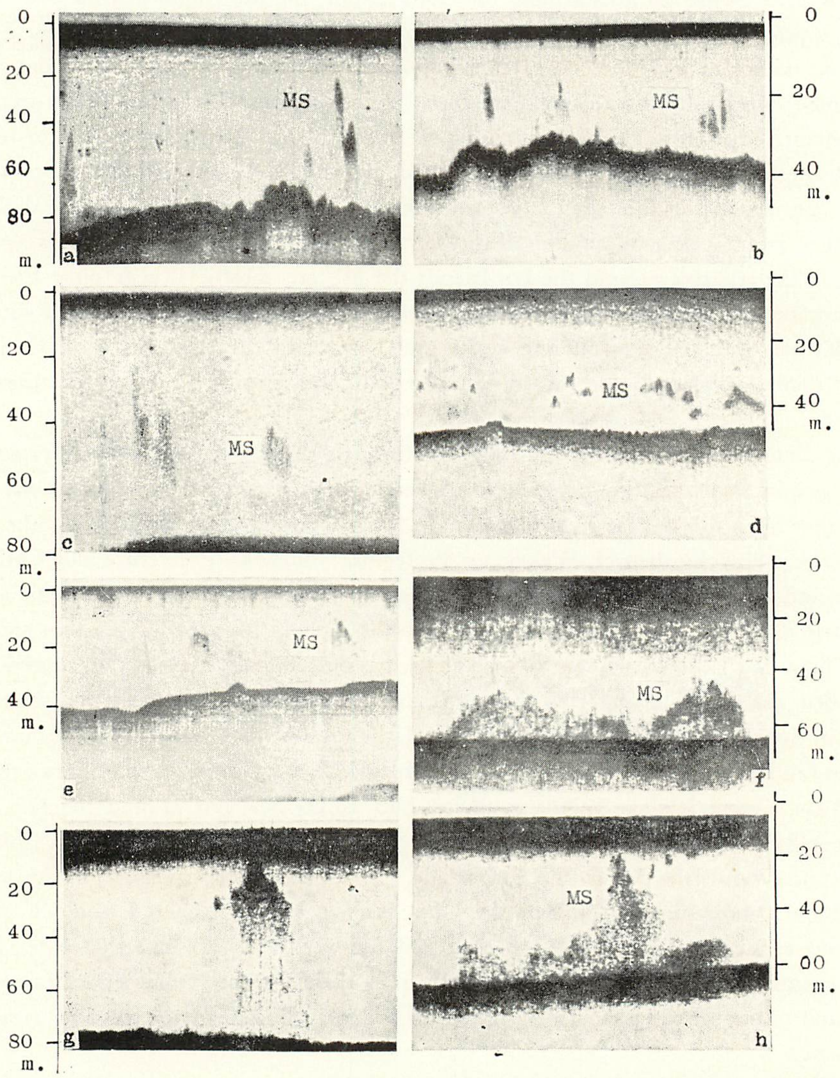


Fig. 5. Vertical distributions of the schools of spotted mackerels (MS) recorded with a fish finder at daytime in the sea area around the Ōsumi Islands and the sea off Mt. Kaimon in different months.

a. The vertical distributional range recorded on the 8th April, 1962, showing the schools distributed in the layer between 20 m. and 70 m. in depth, in the sea area of 80~90 m. in depth, in the north of Tane Island. These schools were composed of fish which were 360 ~420 mm. in fork length.

b. The vertical distributional range recorded on the 15th June, 1964, showing the schools distributed in the layer between 12 m. and 25 m. in depth, in the sea area of 30~40 m. in depth, in the south of Mage Island. These schools were composed of fish which were 300 ~380 mm. in fork length.

c. The vertical distributional range recorded on the 18th October, 1963, showing the schools distributed in the layer between 40 m. and 60 m. in depth, in the sea area of 80 m. in depth, in the north of Yaku Island. These schools were composed of fish which were

300~360 mm. in fork length.

d. The vertical distributional range recorded on the 28th June, 1964, showing the schools distributed in the layer between 30 m. and 45 m. in depth, in the sea area of 50 m. in depth, in the west of Sata Cape. These schools were composed of fish which were 340~430 mm. in fork length.

e. The vertical distributional range recorded on the 12th September, 1963, showing the schools distributed in the layer between 18 m. and 25 m. in depth, in the sea area of 45 m. in depth, in the west of Mt. Kaimon. These schools were composed of fish which were 200~260mm. in fork length.

f. The vertical distributional range recorded on the 20th December, 1964, showing the schools distributed in the layer between 45m. and 60m. in depth, in the sea area of 60m. in depth, in the west of Mt. Kaimon. These schools were composed of fish which were 240~300mm. in fork length.

g. The vertical distribution of the schools recorded with a fish-finder in the sea area near Mage Island at a. m. zero o'clock in May 10th, 1964. The distributional range was situated between 20m. and the 40m. in depth. These schools were composed of fish which were 300~400mm. in fork length,

h. The vertical distribution of the schools recorded at the sea area westward of Mt. Kaimon at p. m. ten o'clock in October 20th, 1963. The distribution range was situated between 15m. in depth and the bottom. These schools were composed of fish which were 220~290mm. in fork length.

Island, schools of spotted mackerels, 300~360 mm. in fork length, were caught in September, 1962~1964, with a pole and line in the layer between 80m. and 90m. in depth. In the same season on the sea bank situated west of Gaja Island, schools of spotted mackerels, 340~370mm. in fork length, were caught with a bottom long line in the layer between 80m. and 90m. in depth. In the sea area off Kumano at the east side of Tane Island, schools of fish, 330~400mm. in fork length, are caught with a long line in March and April every year. These schools are distributed in the layer between 50m. and 80m. in depth. At 28°N. lat. 124 E. long. in the East China Sea, schools of fish, 260~330mm. in fork length, were caught with a trawl net near the bottom in June and August, 1963 and 1964. In the sea area 100~150m. in depth, lying in the west of Ashizuri Cape, schools of fish, 320~390mm. in fork length, are caught from May to July every year with a long line. These schools are distributed in the layer between 40m. and 60m. in depth.

Table 3. Vertical area in which spotted mackerels were recorded with a fish finder or caught with a long-line, at day time in each fishing ground.

Fishing ground	DePth of water (m.)	Fishing season	Number of times	Vertical area (m.)	Fork length (mm.)
North of Tane Island	80~110	Mar.~April	26	40~70	340~425
North of Yaku Island	85~115	April~May	25	28~45	295~400
		Oct. ~Nov.	10	40~65	325~380
South of Mage Island	25~60	May ~June	20	20~40	320~415
West of Mt. Kaimon	50~75	Sept. ~Oct.	8	45~60	250~300
West of Sata Cape	40~55	May ~June	15	20~35	340~435

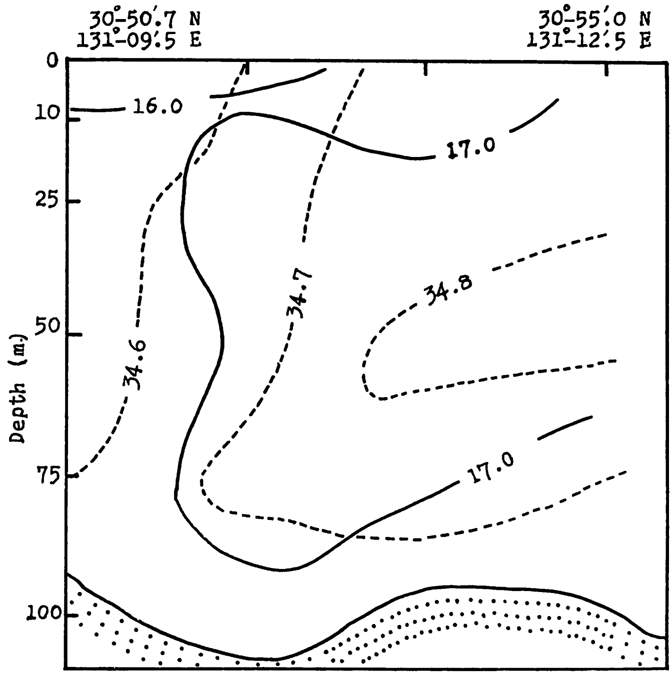


Fig. 6-a. Fishing ground north of Tane Island

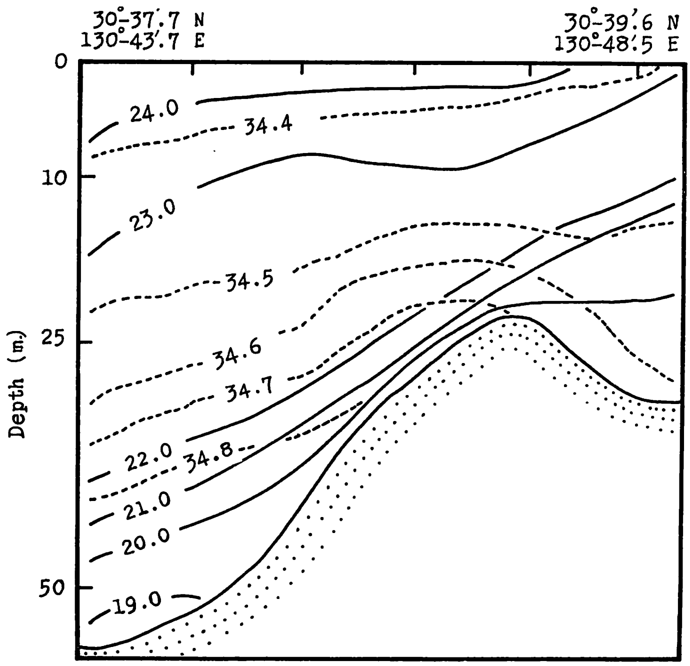


Fig. 6-b. Fishing ground south of Mage Island

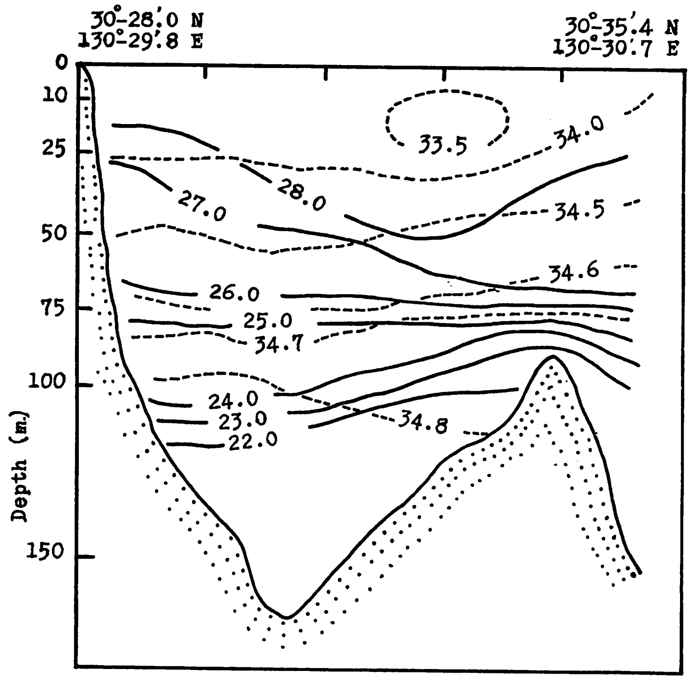


Fig. 6-c. Fishing ground north of Yaku Island

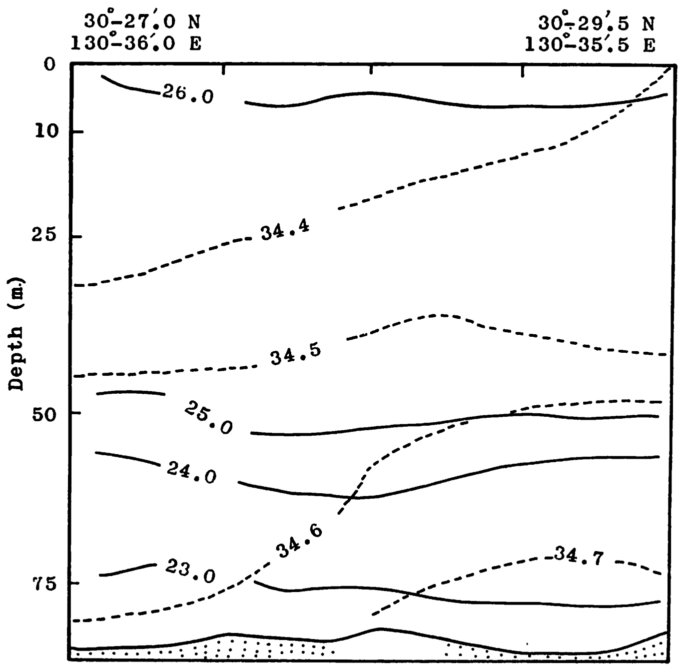


Fig. 6-d. Fishing ground north of Miyanoura

Fig. 6. Vertical distributions of water temperature and salinity in the fishing grounds, lying north of Tane Island and north of Yaku Island.
—— : Isotherm ---- : Isohaline
a. The spotted mackerels in this fishing ground were distributed in the range between 50m. and 70m. in depth April 8th, 1962.
b. The spotted mackerels were distributed in the range between 12m. and 25m. in depth June 15th, 1964.
c. The spotted mackerels were distributed in the range between 80m. and 90m. in depth September 6 th, 1963.
d. The spotted mackerels were distributed in the range between 50m. and 70m. in depth October 20th, 1963.

The vertical distribution of young fish, 100～150mm. in fork length, seems to be near the sea surface, as they are nearly always found swimming in the regions where the water is about 5 meters deep.

Judging from the above mentioned results, in spring the range of vertical distribution of the adult fish is situated in the layer between 40m. and 70m. in depth, and from late spring to early summer the schools are distributed in the layer between 20m. and 40m. in depth. In summer some schools are distributed near bottom, about 80～90m. in depth. From autumn to winter the schools are found in the layer between 50m. and 60m. in depth.

The vertical distribution of schools of spotted mackerels at night was recorded with a fish finder. It is shown in figure 5. In spring the vertical distribution found with a pole and line in the fishing ground, north of Yaku Island is in the layer between the surface and 30m. in depth ; in autumn it is between 10m. and 45m. in depth. Besides this, in the seas areas north of Tane Island and off Sata Cape, schools of spotted mackerels are distributed at night in spring in the layer between the surface and 30m. in depth.

b. Water temperature and salinity

The vertical shifting of water temperature and salinity in the fishing grounds north of Tane Island, south of Mage Island, north of Yaku Island and off Miyanoura is shown in figure 6. The ranges of water temperature and salinity in the vertical area where schools of spotted mackerels were recorded with a fish finder or found with a pole and line in each fishing ground are presented in table 4. In the waters north of Tane Island the lowest

Table 4. Ranges in water temperature and salinity in the vertical area where spotted mackerels were recorded with a fish finder or caught with a pole and line in each fishing ground.

Fishing ground	Number of times	Vertical area (m.)	Water temp. (°c)	Salinity (‰)
North of Tane Island	15	50～70	17～20	34. 5～34. 8
North of Yaku Island	30	30～70	20～23	34. 4～34. 7
South of Mage Island	20	20～40	22～25	34. 6～34. 8
The sea off Miyanoura	6	30～60	23～25	34. 4～34. 7

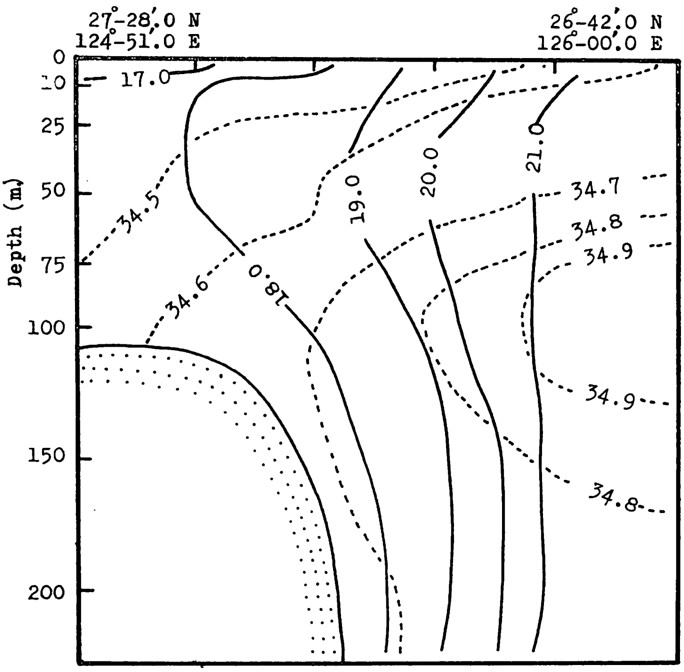


Fig. 7-a. Fishing ground of East China Sea

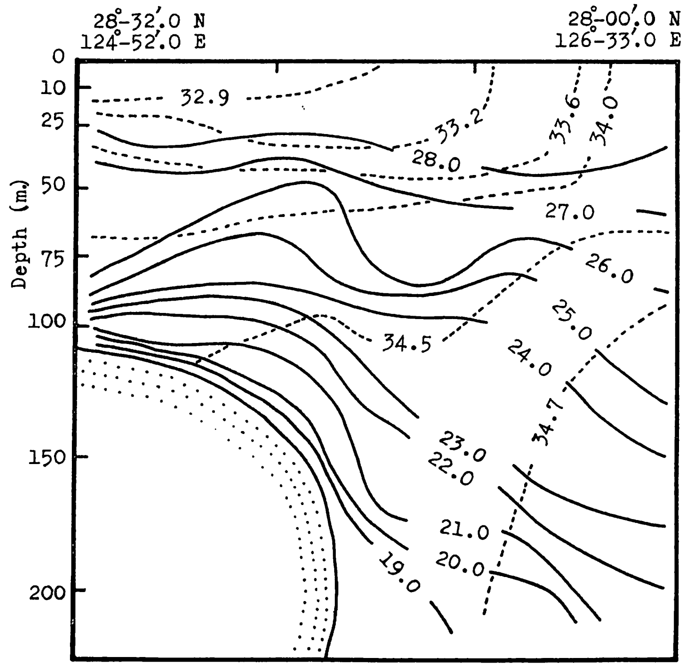


Fig. 7-b. Fishing ground of East China Sea

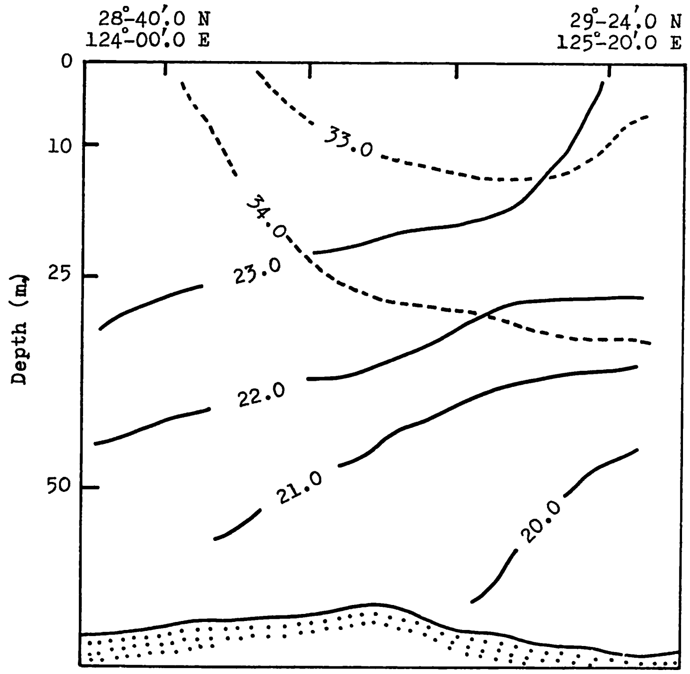


Fig. 7-c. Fishing ground of East China Sea

Fig. 7. Vertical distributions of water temperature and salinity in the fishing grounds lying south of the East China Sea.

—— : Isotherm ---- : Isohaline

a. The spotted mackerels were distributed in the range between 25m. in depth and the bottom, and caught by a pole line in Februaly., 1961.

b. The spotted mackerels were distributed in the range near the bottom in July, 1961.

c. The spotted mackerels were distributed in the range near the bottom in June, 1964.

water temperature was 17°C in the beginning of April. The range in water temperature in the other three fishing grounds was from 20 to 25°C, the deviation being small. The range in salinity in each of the four fishing grounds was from 34.4 to 34.8‰. The vertical distribution of water temperature and salinity in the southern fishing ground of the East China Sea and the waters off Ashizuri Cape is shown in figures 7 and 8, respectively. The ranges of water temperature in these two fishing grounds were from 17 to 23°C, and from 17 to 19°C, respectively. The ranges of salinity were 34.0～34.6‰ and 34.5～34.6‰, respectively.

Judging from these results, it is clear that the spotted mackerels are distributed in the area where the water temperature is 17～25°C, and the salinity 34.0～34.8‰.

II. Spawning period and spawning ground

1. Methods of investigation

As it is very difficult to observe the spawning of spotted mackerels in the sea, the present

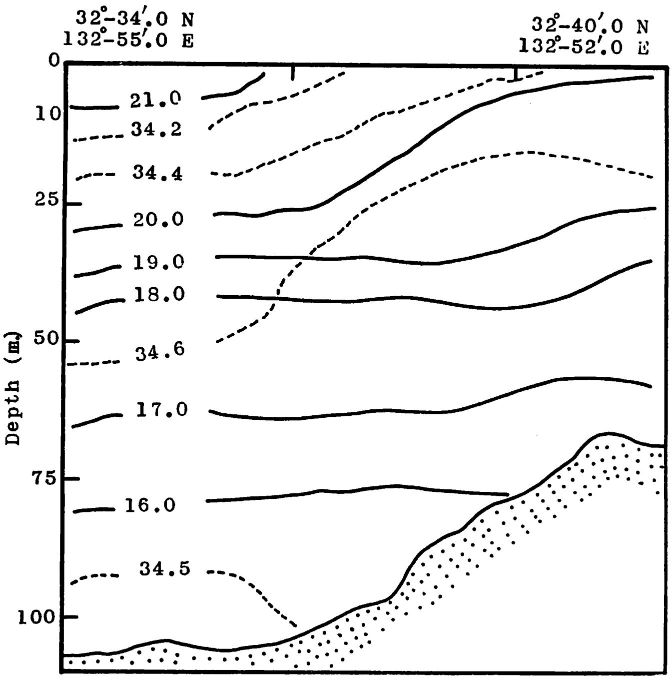


Fig. 8. Vertical distributions of water temperature and salinity in the fishing ground off Ashizuri in May, 1962.

—— : Isotherm ---- : Isohaline

The spotted mackerels in this ground were distributed in the layer between 40m. and 80m. in depth. The schools were composed of fish which were 300~410mm. in fork length.

author assumed the spawning period and spawning ground on the basis of the appearance period and distribution range of larvae, correlating these with the area where adult fish were caught. Two types of larvae nets were used for the purpose of collecting larvae smaller than 25mm. in total length. One was 1.5m. in diameter and 3.5m. in length (the cod-end was 1m. in length and composed of a silk netting No. 54 GG). This 1.5m. net was hauled in the surface layer. The other was 1.0m. in diameter and 2.8m. in length (the cod-end was 0.8m. in length and composed of the same kind of silk netting). This 1.0m. net was hauled in the middle layers, 10m., 20m., 30m., 40m. and 50m. in depth. When hauling, the larvae nets were used in the combination of 2 or 3 sets ; the middle layer net being submerged with a 21kg. depressor. Nets were hauled for 20 minutes at a speed of 2~2.5 knots. The depth of a sunken net was measured with a depth counter, type A-295 made by Tsurumi Seiki Machine Manufacturing Factory or with the equation related to the rope length hauling the net and the angle of the rope line to the horizontal line (TANOUE, 1960).[23]

The larvae which were more than 25mm. in total length were caught with a seine or a dip net. They were also collected even from the stomachs of skipjacks, *Katsuwonus pelamis.*

2. Results of larva collecttion

Results of collecting larvae are presented in table 5 ; the hauling and collecting points are shown in figure 9. In the sea near Kagoshima collection of larvae was possible from the middle of February to late in June. They were collected from every layer between surface and 40m. in depth, while they were not found at the depth of 50m. In February and March, almost the same number of larvae was caught at each of the surface and the depths of 10m. and 20m. But from April to June the number of larvae caught at the depths of 10m. and 20m. was bigger than that of larvae caught at the surface. The distribution of the total lengths of these larvae is shown in figure 10 ; the total lengths was between 4.6～25mm. More than 85% of them were those with total lengths of less than 15mm., while those with total lengths of more than 20mm. were very few. Almost no difference was found among the total lengths of larvae caught at different depths.

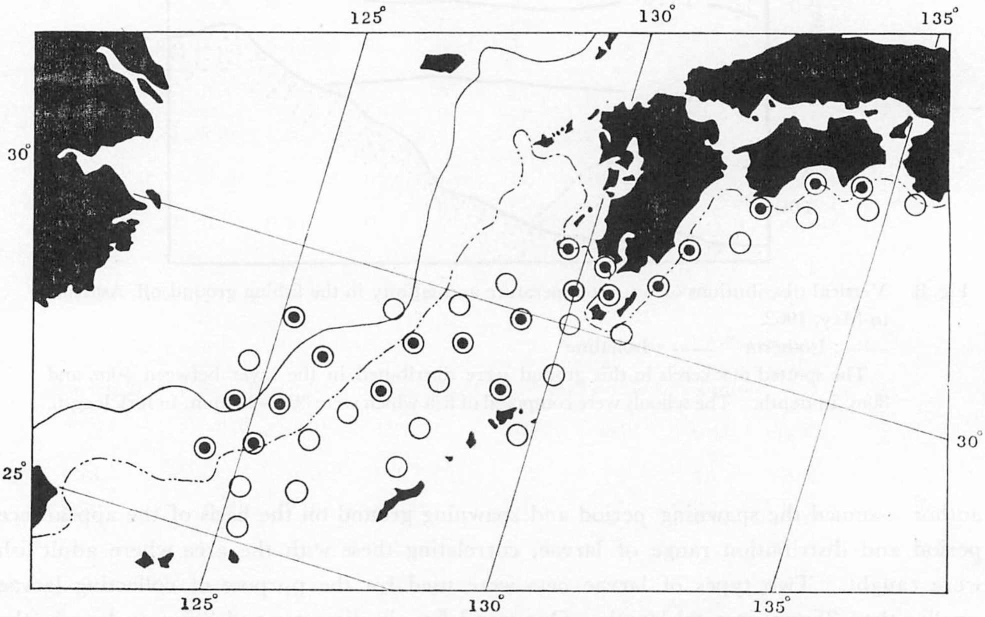


Fig. 9. Sea areas (circlets) where a larva net was towed and the areas (black spots) where larvae were collected.

In the sea areas lying from Kagoshima to Shionomisaki a larva net was hauled early in March, 1962. In the sea area between Tane Island and Aburatsu, larvae with total lengths of 6.0～11.0mm. were collected at the surface and the depth of 10m. No larvae were collected in the sea north of Aburatsu. In May, 1961, in the sea off Aburatsu and Ashizuri and in Tosa bay a larva net was hauled at the depths of 10m. and 20m., and larvae with the total lengths of 6～20mm. were collected, the largest number being at the 20m. depth. In the southern East China Sea, larvae with the total lengths of 4.8～20mm. were collected both at the surface and the 20m. depth ; the number of larvae

Table 5. Results of larva collections and the ranges in water temperature in the sea area where larvae were collected, during the months from February to June, 1961～1964.

a. The coastal sea of Kagoshima Prefecture

	Number of individuals							Range of total length (mm.)			Water temp. (°c)
	Depth	Surf.	10 m.	20 m.	30 m.	40 m.	50 m.	Surf.	10 m. 20 m.	30 m. 40 m.	
Feb.	Total	98	85	30	32	9	0	4. 8	5. 0	5. 0	17. 0
	Times	30	30	30	20	20	15				
	Means	3. 3	2. 8	2. 0	1. 6	0. 5	0	12. 0	12. 0	12. 0	19. 1
Mar.	Total	116	223	67	39	17	0	5. 0	4. 8	5. 5	16. 8
	Times	45	40	30	30	30	20				
	Means	2. 9	5. 6	2. 1	1. 3	0. 6	0	16. 0	17. 0	10. 5	20. 4
Apr.	Total	44	67	59	28	5	0	6. 0	5. 2	6. 0	18. 6
	Times	32	32	30	25	25	18				
	Means	1. 4	2. 1	1. 1	1. 1	0. 2	0	11. 0	15. 4	13. 0	21. 6
May	Total	30	81	102	23	8	0	5. 6	4. 8	6. 2	19. 6
	Times	35	35	35	30	30	15				
	Means	0. 8	2. 3	2. 9	0. 8	0. 2	0	16. 4	20. 2	18. 0	23. 6
June	Total	18	50	61	33	4	0	6. 2	6. 0	5. 0	21. 0
	Times	25	25	25	25	20	20				
	Means	0. 7	2. 0	2. 4	1. 3	0. 2	0	12. 0	12. 0	11. 5	24. 0

b. The sea off Ashizuri Cape

	Number of individuals				Range of total length (mm.)			Water temp. (°c)
	Depth	Surf.	10 m.	20 m.	Surf.	10 m.	20 m.	
May	Total	11	20	26	4. 3	6. 0	6. 0	19. 4
	Times	8	8	8				
	Means	1. 4	2. 5	3. 2	16. 7	13. 5	12. 0	21. 1

c. The East China Sea (N. lat. 28～29°, E. long. 124～127°)

	Number of individuals			Range of total length (mm.)		Water temp. (°c)
	Depth	Surf.	10 m.	Surf.	10 m.	
May	Total	12	94	4. 8	6. 0	17. 0
	Times	7	7			
	Means	1. 7	13. 4	17. 0	20. 0	22. 3
June	Total	23	15	4. 8	6. 0	20. 0
	Times	9	9			
	Means	2. 6	1. 7	20. 0	18. 0	23. 0

Total : total number of larvae
Times : number of times of collections performed
Means : average number of larvae per one collection

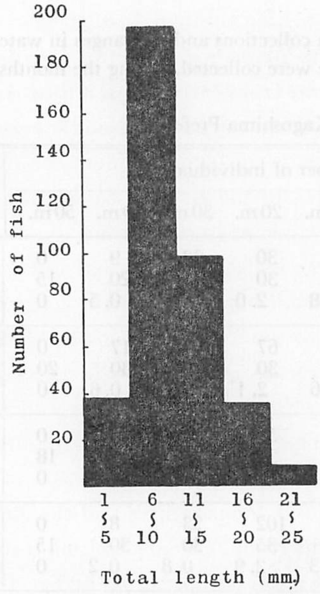
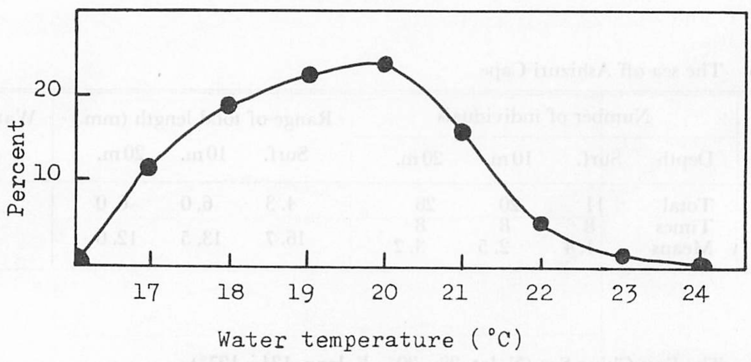


Fig. 10. Histogram represents the distribution of lengths of the larvae collected with a larva net.



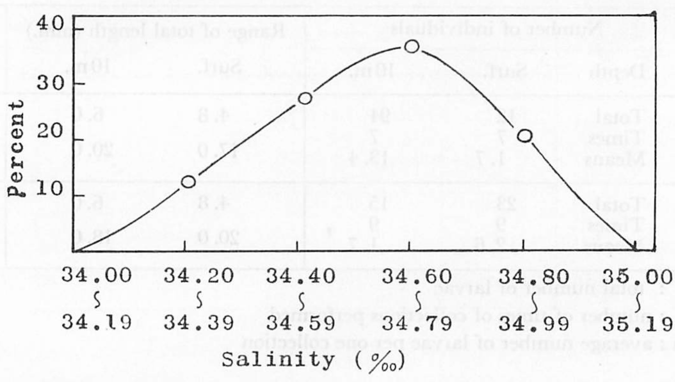


Fig. 11. Ranges of water temperature and salinity in the sea areas where larvae were collected.

collected at the 20m. depth was bigger than that at the surface. In the sea area around the Tokara Islands, schools of larvae with the total lengths of 30～60mm. were collected with a dip net during the period from early in March to April. These schools were found in shallow water near seashores. In the same season they were found around Amami Island. In the bay of Shibushi, larvae with the total lengths of 30～40mm. were caught with a seine net in March and April. In the coastal sea of Aki, Kochi Prefecture, larvae with the total lengths of 20～30mm. were caught with a seine net early in April. On the other hand, a larger number of larvae with the total lengths of 15～40mm. were collected from the stomachs of some skipjacks, *Katsuwonus pelamis*, caught in the sea area lying from the west of the Okinawa Islands to the Tokara Islands in March and June.

The ranges of water temperature and salinity in the coastal sea of Kagoshima, where larvae were collected, are shown in figure 11. The water temperature range was within 16～24°C and the salinity range 34.2～34.9‰ the monthly difference in salinity being small.

The relationship between water temperatures and the percentages of the largest catches of larvae in each of five months from February to June is shown in figure 12. The majority of larvae were collected at the water temperature higher than 17°C, though in February and March they were collected at such a low temperature as 16°C. A large number of larvae were collected at the water temperature 18～20°C in April and at 21～23°C in May and June. In the East China Sea and the sea off Ashizuri Cape, larvae were collected at 16～23°C and 20～21°C, respectively.

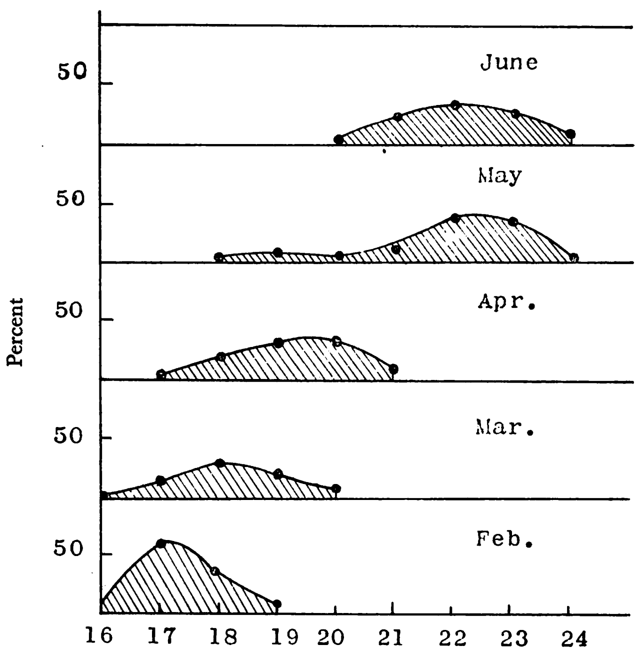


Fig. 12. Percentage of the water temperatures when larvae were collected in each month.

3. Spawning period and conditions of spawning grounds

Judging from the location where adult fishes were caught and the area where larvae were found, the geographical distribution of spawning grounds of spotted mackerels is considered to be as shown in figure 13. The spawning begins to occur in the northern sea area of Formosa, the sea around Uotsuri Island and the sea area of the continental shelf spreading between N. lat. 26° and 29°, from January to March. Afterwards, the spawning ground moves gradually to the northern sea area ; spawning takes place in the sea area spreading from N. lat. 28° to N. lat. 30°, from May to June. The spawning ground is 70～100m. in depth of water. In the coastal sea area of Kagoshima Prefecture, schools of adult fish are found in the north of Yaku Island, on the bank lying west of Yaku Island and in the southern sea off Tane Island, from January to March. Therefore, it is assumed that spawning begins in these sea areas. In March large fish appear in the north of Tane Island and spawning takes place. From May to June, schools of adult fish stay and their spawning takes place in the waters near shores in the west and south of Mage Island, west of Sata Cape, around the Uji Islands and south of the Koshiki Islands. The spawning grounds of the Uji and Koshiki Islands are 80～100m. in depth, while those of Mage Island and Sata Cape are 40m. in depth.

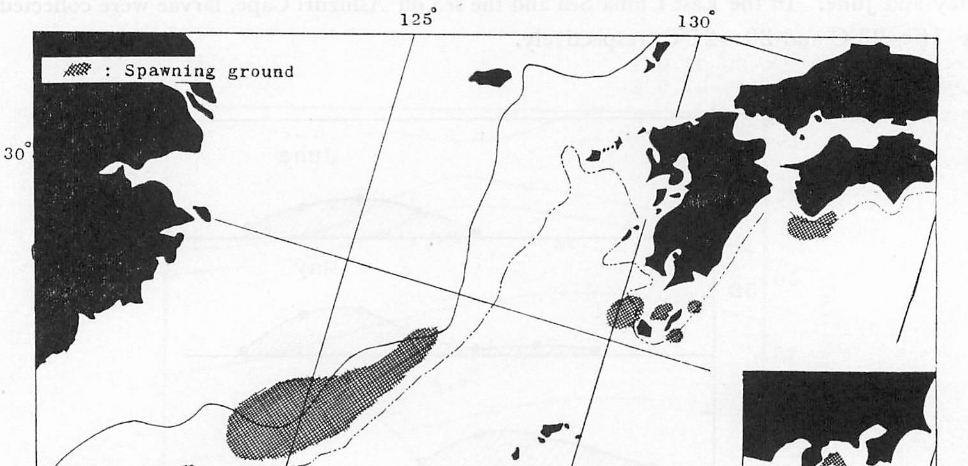


Fig. 13. Geographical features of the spotted mackerel spawning grounds.

As shown in figure 14, these spawning grounds are confined to the sea area where a comparatively rapid tidal current runs towards the land shelf.

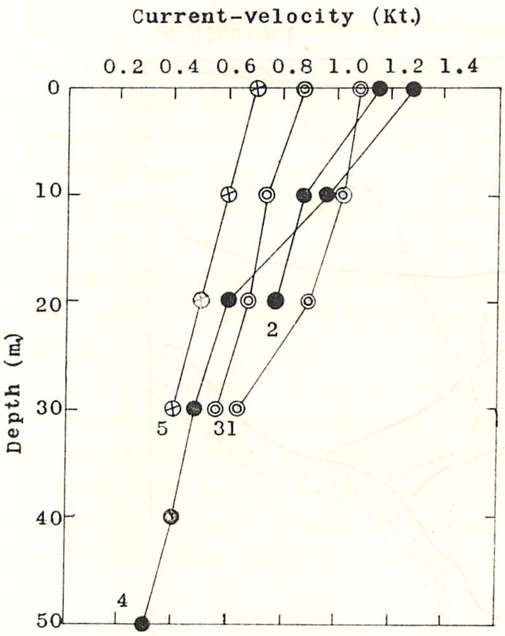


Fig. 14. Vertical distributions of the current velocities in three fishing grounds situated north of Yaku Island (2, 4), south of Mage Island (1, 3) and west of Sata Cape (5).
2 : April, '63 1 and 5 : May, '63
3 and 4 : June, '63

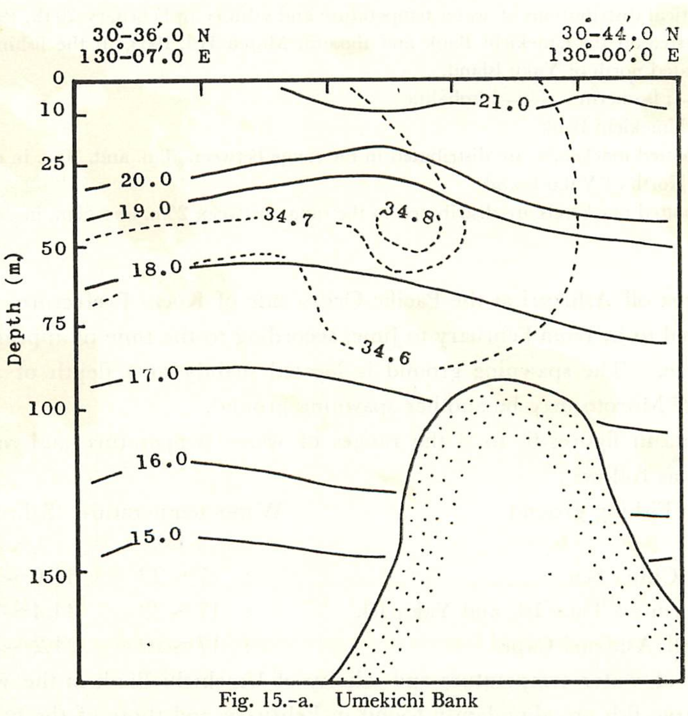


Fig. 15.-a. Umekichi Bank

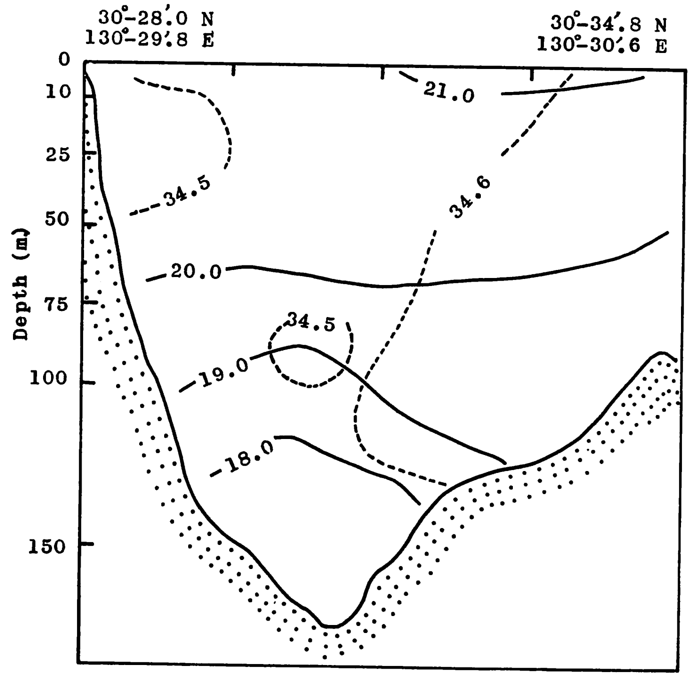


Fig. 15.-b. North of Yaku Island

Fig. 15. Vertical distributions of water temperature and salinity in February 20 th, 1963, in the sea area on the Umekichi Bank and those in March 3rd, 1963, in the fishing ground situated north of Yaku Island.

—— : Isotherm ---- : Isohaline

a. Umekichi Bank

Spotted mackerels are distributed in the range between 30m. and. 70m. in depth.

b. North of Yaku Island

Spotted mackerels are distributed in the range between 25m. and 50m. in depth.

In the sea area off Ashizuri at the Pacific Ocean side of Kochi Prefecture, the spawning period is assumed to be from February to June, according to the time of appearance of both adults and larvae. The spawning ground is located mainly at a depth of about 100m. The sea area off Muroto may be another spawning ground.

From the data in figures 6, to 8 the ranges of water temperature and salinity in the spawning areas as follows;

Fishing ground		Water temperature (°C)	Salinity (‰)
The East China Sea	:	17～23	34.0～34.6
The sea around Tane Isl. and Yaku Isl.	:	17～23	34.4～34.8
The sea off Ashizuri Cape	:	17～19	34.2～34.6

The records of water temperature and salinity of Umekichi Bank in the west of Yaku Island where large fish are abundantly found in February and those of the fishing grounds in the sea around Yaku Island in March are shown in figure 15. In these fishing grounds, the water temperature and salinity of the sea area shallower than 100m. were 17～21°C, 34.5～34.8‰, respectively.

According to the above observations, it is presumed that the spawning of spotted mackerels takes place in the sea area where the water temperature is 17～23°C and the salinity is 34.0～34.8‰.

III. Sex differentiation and growth of gonads

1. Material and methods

For the purpose to examine the sex differentiation and growth of the gonads of spotted mackerels, histological observations were made by the use of fish which were more than 5mm. in total length. These fish were collected with a larva net, a stick-held dip net, a dip net, a purse seine and a beach seine. Some of them were preserved in 15～20% formalin solution, and the others were done in 70% alcohol after being fixed with Bouin's fluid for 12 hours. The gonads of young fish which were more than 30mm. in total length were fixed with Bouin's fluid for 24 hours. By the ordinary paraffin method serial sections were made at 8 to 10 μ in thickness. The sections were stained with Delafield's hematoxylin and eosin. The size of the gonads of fish, 5～299mm. in fork length are shown in table 6.

2 Indifferent gonads

The gonads of larvae immediately after hatching are quite minute, transparent and invisible to the naked eye. By microscopic observation, it was ascertained that the gonads are of cylinder shape. They are symmetrically coupled at both left and right sides and suspended with their mesogonium from the dorsal coelomic wall into the coelom; they are situated at the dorsal side of the intestine and along both sides of the rudiment of air bladder. The posterior ends of both gonads are united into one and connected to the cloaca. The surface of the gonad is covered with coelomic epithelium. This epithelium and primordial germ cells adjoined at the inner side of the epithelium make up the germinal epithelium. The interior part is filled with stroma cells.

a. The gonads of the larvae, 5～30mm. in total length

The indifferent gonads of the larvae, 5～9mm. in total length, are very slender. Each of them is suspended in the coelom by a comparatively thick mesogonium. In a transverse section it is ellipsoidal; there is a primordial germ cell having clear cytoplasm. The primordial germ cell is surrounded with stroma cells. The primordial germ cell is about 13 μ in diameter (Plate I, Fig. 1).

The indifferent gonads of larvae, 10～30mm. in total length, are generally larger than those of the above described ones (Plate I, Figs. 2 to 3). They are lanceolate in a transverse section. Germ cells are two or three in number. At the interior of the end-tip portion of the gonad, a vigorous increase of stroma cells is occurring. Moreover, germ cells are found at the base of the mesogonium and at the part adjoining the inner side of the peritoneal

Table 6. Ranges in length, width and thickness of the gonads of fish, 5~299mm. in fork length.

a. Indifferent gonads of fish, 5~99mm. in total length

Total length (mm.)	Number of fish	Length		Width		Thickness	
		Range (mm.)	Mean (mm.)	Range (μ)	Mean (μ)	Range (μ)	Mean (μ)
5~ 9	25	— —	—	18~ 25	21	7~11	8
10~19	28	— —	—	22~ 53	39	7~13	9
20~29	26	— —	—	34~ 78	61	10~14	12
30~39	35	— —	—	68~110	83	10~16	13
40~49	36	— —	—	78~130	113	12~18	16
50~59	47	7.6~12.5	9	100~125	110	14~21	17
60~69	53	11.0~16.2	13	130~162	140	16~25	21
70~79	55	13.0~19.0	15	141~184	159	18~34	28
80~89	45	16.0~22.0	19	130~188	165	26~48	34
90~99	35	18.0~24.6	21	150~220	194	36~52	38

b. Testes and ovaries of fish, 80~229mm. in fork length

Total length (mm.)	Sex	Number of fish	Length		Width	Thickness
			Range (mm.)	Mean (mm.)	Range (mm.)	Range (mm.)
80~ 99	♀	15	14~23	21	0.1 ~0.3	0.02~0.05
	♂	20	15~25	23	0.05~0.1	0.01~0.02
100~119	♀	40	20~29	24	0.1 ~0.5	0.05~0.2
	♂	50	22~31	26	0.05~0.2	0.01~0.08
120~139	♀	34	25~36	33	0.3 ~0.8	0.1 ~0.3
	♂	30	27~37	31	0.2 ~0.4	0.05~0.1
140~159	♀	25	34~41	38	0.6 ~1.5	0.1 ~0.5
	♂	30	32~43	39	0.3 ~0.6	0.05~0.2
160~179	♀	25	40~51	45	1.0 ~2.0	0.3 ~1.0
	♂	25	38~53	46	0.5 ~1.0	0.1 ~0.3
180~199	♀	30	43~57	51	1.5 ~2.3	0.5 ~1.5
	♂	35	41~58	53	0.5 ~1.5	0.1 ~0.5
200~219	♀	50	48~64	55	1.5 ~3.5	1.0 ~1.5
	♂	50	50~62	55	1.0 ~2.0	0.3 ~0.6
220~239	♀	50	55~71	63	2.0 ~4.0	1.0 ~2.5
	♂	50	56~73	64	1.0 ~3.0	0.3 ~0.7
240~259	♀	30	59~78	71	2.0 ~4.0	1.0 ~2.5
	♂	25	62~80	73	1.0 ~3.0	0.4 ~0.8
260~279	♀	40	68~89	80	3.0 ~5.0	1.0 ~3.0
	♂	45	66~91	79	1.5 ~4.0	0.5 ~1.0
280~299	♀	26	78~100	87	3.0 ~6.0	1.0 ~3.0
	♂	25	75~96	85	2.0 ~4.0	0.6 ~1.5

epithelium which covers the abdominal wall of the rudiment of air bladder. The surface of the indifferent gonad is wrapped with flat peritoneal epithelium, and the germ cells are obviously situated at the inner side of it and covered with the epithelium which is flattened considerably. As the germ cells are found at the part near the base of the gonad and the number of germ cells in the gonad is very few at this stage, it is assumed that germ cells wander into the gonad from other parts than the area where the gonads are to be formed. The germ cells at this stage are about 6～7μ in diameter.

b. The gonads of larvae, 40～90mm. in fork length

As compared with the gonads described above, those of the larvae with the fork lengths of 40～50mm., are enlarged both in length and width and show an increase in the number of germ cells; in a cross section there are several germ cells. The germ cells are about 4～6μ in diameter (Plate I, Figs. 4 to 5). In the gonad it becomes possible to discern the peritoneal epithelium, the germ cells, the follicular cells surrounding the germ cells and the stroma cells filling up the inner portion of the gonad. The increase of the stroma cells is not so vigorous at the part near the mesogonium but it is quite active at the part far from the latter. In the gonads of larvae which are more than 60mm. in fork length, an increase can be seen not only in length and width but also in thickness, reaching 10mm. in length, 0.1mm. in width and 0.02mm. in thickness. In a cross section of the gonad in this stage the germinal epithelium becomes distinctly noticeable, and the gonad is observed to be constituted with the peritoneal epithelium, germ cells and the follicular cells surrounding the latter. The peritoneal epithelium consists of cuboidal cells, and the follicular cells are extremely flattened. The germ cells are widely scattered; they are large and approximately global. The cytoplasm is abundant and clear, and the nucleus is generally large and polymorphic, and not densely stained with hematoxylin.

During this stage, at the part near the mesogonium on the surface facing the mesentely of the gonad, a longitudinal depression of the peritoneal epithelium into the interior takes place (Plate I, Figs. 6 to 7). The gonocoel proceeds to be formed from this depression. A remarkable increase of stroma cells is brought forth out of this part towards the circumference, and causes almost all the increase in the thickness of the gonad. The nuclei of stroma cells are oval in shape, the nuclear membrane is densely stained with hematoxylin, while the cytoplasm is not so dense.

In a cross section, the width of mesogonium is one-fourth to one-third of that of the gonad, while the former is about the same as the latter in thickness. The peritoneal epithelium of the mesogonium is connected with that of the air bladder; a small number of stroma cells are contained in the interior of the mesogonium and the differentiation into a connective tissue is observed. A lot of blood capillaries are contained in this tissue. The stroma cells in the mesogonium are connected with those in the gonad. When spotted mackerels reach the fork lengths of 70～80mm., or the fork lengths of more or less 100mm. in some cases, the differentiation of the gonad into an ovary or a testis begins to take place. When this stage is reached, the gonocoel is developed in the interior of the gonad, the longitudinal mouth of which becomes fused and the connection between the gonocoel and coelom is thus cut out by this fusion (Plate I, Fig. 8). In some cases, the gonocoel is extremely enlarged, and in others it is left as a slit-like cavity. The former is considered to be the first step in the differentiation of an ovary, and the latter, of a testis.

3. Ovary

a. The first stage

This stage can be seen in the ovaries of spotted mackerels with the fork lengths of 80～115mm. (Plate II, Figs. 9 to 10). The gonad is a short cylinder; in a transverse section it is elliptically elongated and contains a wide ovocoel. The epithelial cells surrounding the ovocoel form a one-layered cuboidal epithelium, which has no folds at the inner surface. Oogonia are arranged at the outside of this epithelium. Each oogonium is a large-sized cell of almost spherical shape, being about 4～6μ in diameter, and has a polymorphic nucleus. Each oogonium is surrounded with one layer of follicular cells. The oogonia contained in each cross section of the gonad are ten or thereabouts in number at first, but gradually the number increases. The layer containing oogonia is surrounded with stroma cells which constitute a connective tissue. Many blood vessels are distributed in this layer of the connective tissue, while no oogonia are contained in this layer. Accordingly the oogonia containing layer and the connective tissue layer can be discerned clearly from each other. The surface of the ovary is wrapped with one layer of flattened peritoneal epithelium. With the gradual growth of the ovary, the ovocoel becomes extremely enlarged, leaving the wall even and smooth; in accordance with this, the number of the oogonia increases.

b. The second stage

This stage is shown by the ovaries of spotted mackerels with the fork lengths of 80～130mm. (Plate II, Figs. 11 to 13). The ovary and the ovocoel become enlarged, with a simultaneous increase of oogonia in size and number. The wall of the ovocoel forms some small protuberances thrusting into the cavity. During this stage, the cuboidal epithelial cells surrounding the ovocoel become flattened cells. The formation of protuberances has almost nothing to do with the connective tissue layer surrounding the layer of oogonia. There is a distinct difference between these two layers. Near the mesovarium, this connective tissue layer is connected with the connective tissue in the mesovarium. While the number of protuberances in the ovocoel is small, being about ten at first in a transverse section, this number conspicuously increases in accordance with the growth of the ovary. The number of oogonia increases through vigorous divisions. The oogonia during this stage are about 6～8μ in diameter.

c. The third stage

This is the stage to be applied to the ovaries of young fish with the fork lengths of 130～150mm. (Plate III, Figs. 14 to 15). The ovaries are still semitransparent and of thread-like shape, when observed with the naked eye. In a cross section, the gonad is elliptical and the ovocoel is large. In this stage, the protuberances thrusting into the ovocoel are not so high, their height being nearly the same as the width at their basal parts. Transformation of some oogonia into oocytes occurs here and there. One to eight oocytes contained in one protuberance or lobe and besides them there are a few oogonia in the same lobe. Each oocyte has a spherical nucleus, in which a network of chromatin is observable. One or two oocytes begin to swell up, when observed in a transverse section of each lobe. The ooplasm of such oocytes is densely stained with hematoxylin. This shows that yolk formation has started. The oocytes at this stage is about 12〜20μ in diameter.

d. The fourth stage

This is the state to be applied to the ovaries of the young fish with the fork lengths of 160〜200mm. (Plate III, figs. 16 to 17). The ovaries are milky white and a little cylindrical, being larger then the testes of fish of the same fork length. The interior of the ovary is filled up with hypertrophied oocytes which are on their way to the yolk formation. The ovocoel becomes narrow, owing to the vigorous stretching of protuberances into the cavity. Each lobe contains hypertrophied oocytes which are arranged in orderly fashion and closely upon the wall. The space between the lobes becomes extremely narrow and looks like a slit. The nucleus of each oocyte becomes a large vesicle and has minute chromatin grains in chromatin filaments. The ooplasm is densely stained with hematoxylin. A small number of oogonia are observed at the tip and the side wall in each protuberance. The surface of the ovary is covered with a membrane consisting of the peritoneal epithelium and a connective tissue. Each oocyte is about 20〜50μ in diameter. The follicle cells of the oocyte become clearly visible.

e. The fifth stage

This is the state to be applied to the ovaries of fish which are more than 210mm. in fork length. (Plate IV, Figs. 18 to 19). A cross section of the ovary shows nearly the same structures as was observed in the former stage. But oocytes are larger; some of them are approximately 0.07mm. in diameter. The nucleus of oocytes is vesicular and contained a lot of peripheral nucleoli which are attached to the nuclear membrane. The interior of the nucleus is clear. Ooplasm is densely stained with hematoxylin.

In the ovaries of young females with the fork lengths of 240〜270mm., oocytes reach 0.18〜0.25mm. in diameter. Yolk vesicles begin to appear in the ooplasm, while the ooplasm is not stained as densely as was in the former stage. The egg membrane (zona radiata) becomes thickened. In the ovaries of young fish with the fork lengths of 280〜290mm., oocytes become 0.3〜0.5mm. in diameter, and yolk globules are observed in those ooplasm (Plate IV, Fig. 20). The yolk globules are quite minute at first and stained with Haidenhain's iron hematoxylin. They are distributed in the outer region of the ooplasm of a few large oocytes. These large oocytes are found among numerous younger ones contained in each lobe. The nucleus is spherical and contained peripheral nucleoli densely stained with hematoxylin. The chromatin filaments are becoming achromatic. The egg membrane (zona radiata) is clearly composed of two layers.

In the ovaries of females with the fork lengths of more than 300mm., oocytes sometimes reach 0.5〜0.65mm. in diameter. (Plate IV, Fig. 21). The nuclei of these oocytes are moved toward the periphery of the oocyte and take an eccentric position. They become semi-lunar in shape. Yolk globules in the ooplasm are on the way to fusion. These are matured ova.

f. Ovarian eggs

Eggs found in the ovaries of matured females are divided into seven stages, according to the degree of maturation. Eggs of these stages are shown in plate V, figures 22 to 30.

i) Chromatin nucleolus stage.

The eggs of this stage belong to the smallest oocytes in the ovaries of matured females. They are less than 0.07mm. in diameter. The ooplasm around the globular nucleus is rather thin. Although chromatin nucleoli are found in the nucleus, no true nucleoli are observable. The ooplasm is densely stained with hematoxylin.

ii) Peripheral nucleolus stage.

The oocytes of this stage are 0.07～0.15mm. in diameter. The ooplasm becomes enlarged, and is densely stained with hematoxylin early in this stage at least. True nucleoli are arranged in contact with the inner surface of the nuclear membrane. The nucleus is almost globular, although the shape of oocytes is polygonal. When oocytes grow larger than 0.1mm. in diameter, the outer layer of ooplasm is not so densely stained with hematoxylin as in the above described oocytes, while the inner layer is still densely stained. The oocytes become almost globular.

iii) Yolk vesicle stage.

The oocytes of this stage are 0.16～0.25mm. in diameter. Yolk vesicles are observed in the ooplasm. They appear near the peripheral portion of the ooplasm at first, and soon increase in number and become enlarged, filling up the ooplasm. The egg membrane begins to become thickened. The ooplasm is not densely stained with hematoxylin. The nucleoli situated along the nuclear membrane increase in number.

iv) Early yolk globule stage.

The oocytes are 0.25～0.5mm. in diameter. Some yolk globules appear in the peripheral portion of the ooplasm and gradually increase in number and size. Eventually they are distributed all over the ooplasm. They are quite densely stained with Haidenhain's iron hematoxylin. The nucleoli are found even in the interior of the nucleus, besides the peripheral position. The egg membrane becomes more thickened.

v) Late yolk globule stage.

The oocytes are 0.45～0.7mm. in diameter. Large yolk globules completely fill up the ooplasm. The egg membrane becomes thickened and makes distinct double layers. In this stage, there are some oocytes containing large vesicles in the ooplasm.

vi) Migrating nucleus stage.

The oocytes are 0.5～0.75mm. in diameter: they are nearly the same in size as in the previous stage. The nucleus is found near of the pole of the oocyte, and shows a semi-lunar shape. The yolk globules become enlarged.

vii) Matured stage.

The eggs are 0.7～1.15mm. in diameter. The yolk globules begin to be resolved into liquid. The nuclear membrane disappears. The follicles become exfoliated from the surface of the egg membrane. The eggs squeezed out of the abdomen of an adult female fish are global and semi-transparent.

4. Testis

a. The first stage

In the gonads of larvae, 80~90mm. in fork length, a slit-like testocoel, which is regarded as the first symptom of a testis, appears in the part between the mesogonium and the central line of an indifferent gonad (Plate VI, Fig. 31). The wall of this testocoel is made up of one layer of cuboidal epithelial cells. A cross section of the testis of this stage, is lanceolate in shape and shows that the testis is covered with peritoneal epithelium and contains numerous stroma cells and a small number of spermatogonia which are scattered among them.

b. The second stage

In the testes of young fish, 100~120mm. in fork length, the stroma cells are exceedingly multiplied. A few branches are stretched out of the testocoel (Plate VI, Figs. 32 to 33). The walls of these branches are made up of cuboidal epithelium. The branches gradually increase in number and are branched again, in accordance with the development and differentiation of the testis. They form a net-work of ducts among stroma cells, although their position is confined within the inner part of the testis. Each spermatogonium is surrounded by stroma cells (accompanying cells). Most spermatogonia are arranged directly beneath the peritoneal epithelium. A small number of spermatogonia are buried deep in the testis and scattered among the branches of the testocoel. The spermatogonia are still comparatively small in number at this stage. The peritoneal epithelium consists of cuboidal cells and is somewhat wavy in accordance with the arrangement of cells in the inner part of the testis. Differing from the structures of ovaries, there is no distinct layer consisting of stroma cells under the peritoneal epithelium. There are sometimes a few degenerating cells which are considered to be abortive oocytes among spermatogonia.

c. The third stage

In the testes of young male fish, 130~200mm. in fork length, spermatogonia considerably increase in number. (Plate VI, Figs. 34 to 35,). The spermatogonia are about 8~10μ in diameter. In a cross section the testis is lanceolated in shape. The mesorchium is well developed; its width and thickness are about one half the width of the testis. The branches of the testocoel are repeatedly branched and extended toward the peripheral part of the testis. The small branches surrounded with spermatogonia become seminiferous tubules, while the larger branches become the rete apparatus constructed of collecting ducts and the testocoel becomes the main collecting duct.

A lot of spermatogonia are distributed in the outer part of the testis; they are isolated or forming small masses. In the inner part of the testis, the spermatogonia are small in number; they are generally isolated. The testocoel can be clearly observed in the central part near the base of the testis. The surface of the mesorchium is covered with peritoneal epithelium. In the interior there is a well developed connective tissue.

d. The fourth stage

A remarkable multiplication of spermatogonia occurs in the testes of male fish, 210～270mm. in fork length (Plate VII, Figs. 36 to 37). They are grouped surrounding the branches of testocoel which run toward the periphery of the testis. The nuclei of them are polymorphic. There are two sorts of spermatogonia; one has a large quantity of cytoplasm and its nucleus is not densely stained with hematoxylin, while the other has a comparative small amount of cytoplasm and the nucleus is somewhat densely stained with hematoxylin. The latter sort of spermatogonia arises by active divisions of the former. Both sorts of germ cells belong to primary spermatogonia, as they have polymorphic nuclei.

e. The fifth stage

In the testes of male fish, more than 280mm. in fork length, spermatogenesis is taking place (Plate VII, Figs. 38 to 39). The spermatogonia increase in number by rapid divisions and form many masses which are globular in shape, as observed in a cross section. The nuclei of spermatogonia composing globular masses are spherical and densely stained with hematoxylin. These cells are secondary spermatogonia; they are about 6～6.5μ in diameter. These masses of secondary spermatogonia grow larger in accordance with an increase in the number of germ cells. Secondary spermatogonia turn into first spermatocytes, about 4.5μ in diameter. There are some masses of spermatocytes which are smaller than the first spermatocytes. They are about 3.5μ in diameter; they have a smaller amount of cytoplasm, and their nuclei are spherical and densely stained with hematoxylin. These spermatocytes are the secondary spermatocytes, arising from the first maturation division. Besides them, there are extremely small sized germ cells, about 2.5μ in diameter. They have spherical nuclei stained very densely with hematoxylin and an extremely little amount of cytoplasm. These are spermatid, arising from the second maturation division. The spermatids turn afterward into spermatozoa, which are made up of a head and comparatively long tail.

5. Sex ratio and gonad length

The sex ratio of young and adult fish, 150～400mm. in fork length, caught by a purse seine and a long line is presented in table 7. The sex ratio of young fish, 150～250mm. in fork length, changes from school to school, although there is no tendency for preponderance of females above males. The sex ratio of the fish of the total schools is approximately I : I. In the spawning season, females are apt to be more numerous than males among fish which are more than 300mm. in fork length.

The gonad length was measured as that from the tip of the gonad to the anterior end of vas deferens or oviduct. At first, the gonad lengths of 30 spotted mackerels, 200～209mm. and 350～359mm. in fork length, were measured. There were both males and females. The difference in length between testes and ovaries was examined by means of "students" t test.

The results obtained are presented in table 8. The gonad lengths are looked upon as showing a normal distribution type; with the confidence limit of 95%, there is no significant difference in gonad length between males and females. Accordingly, it was ascer-

Table 7. Sex ratio of spotted mackerels caught with a purse seine, a blanket net and a long line.

a. Young fish

Date	Fork length (mm.)	Male (%)	Female (%)	Date	Fork length (mm.)	Male (%)	Female (%)
1963 Aug. 18	190~230	27 (42.2)	37 (57.8)	1963 Dec. 10	250~290	26 (44.8)	32 (55.2)
Sep. 27	200~235	44 (56.4)	34 (43.6)	1964 Aug. 5	170~215	47 (60.3)	31 (39.7)
Dec. 28	220~250	32 (45.7)	38 (54.3)	Sep. 12	200~228	50 (46.3)	58 (53.7)
1964 Feb. 18	240~290	21 (52.5)	19 (47.5)	Oct. 10	210~240	60 (52.2)	55 (47.8)
Aug. 30	180~220	33 (44.0)	42 (56.0)	Nov. 20	260~296	35 (44.3)	44 (55.7)
Nov. 5	230~260	30 (51.7)	28 (48.3)	Dec. 4	280~320	25 (44.6)	31 (55.4)

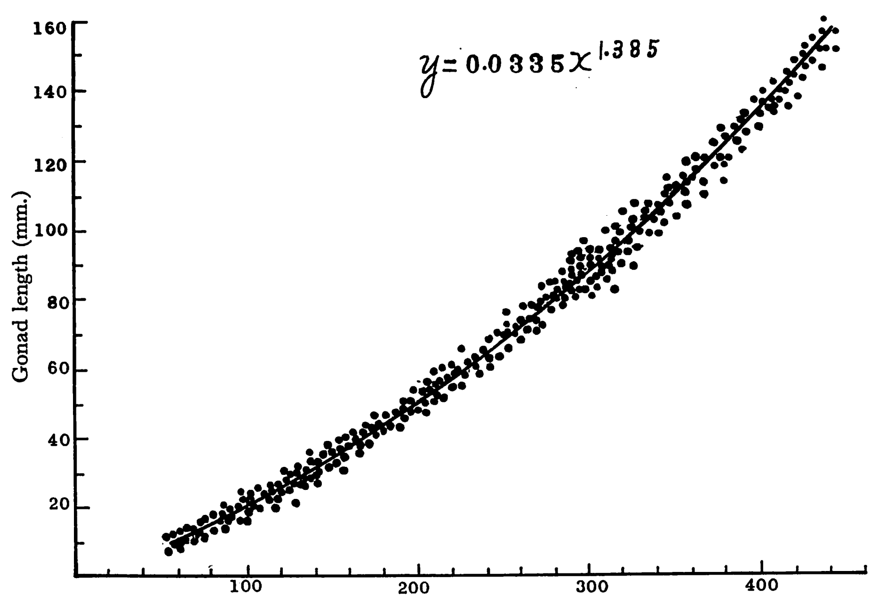
b. Adult fish

1963				1964			
Date	Fork length (mm.)	Male (%)	Female (%)	Date	Fork length (mm.)	Male (%)	Female (%)
Jan. 24	300~350	30 (40.5)	44 (59.5)	Jan. 26	320~400	30 (44.1)	38 (55.9)
Feb. 26	315~385	26 (43.3)	34 (56.7)	Feb. 26	300~360	22 (36.7)	38 (63.3)
Mar. 25	340~420	23 (38.3)	37 (61.7)	Mar. 10	320~415	33 (42.3)	45 (57.7)
Apr. 23	325~430	32 (51.6)	30 (48.4)	Apr. 15	300~430	34 (44.7)	42 (55.3)
May. 24	320~415	36 (40.0)	54 (60.0)	May. 20	330~400	25 (41.7)	35 (58.3)
June 8	332~400	28 (41.2)	40 (58.8)	June 4	325~385	31 (44.3)	39 (55.7)
Jul. 16	320~358	32 (50.0)	32 (50.0)	Jul. 10	310~365	30 (44.1)	38 (55.9)
Aug. 20	315~360	44 (52.4)	40 (47.6)	Aug. 20	330~350	33 (55.0)	27 (45.0)
Sep. 19	320~360	40 (69.0)	18 (31.0)	Sep. 28	328~356	40 (52.6)	36 (47.4)
Oct. 27	318~365	50 (56.8)	38 (43.2)	Oct. 15	325~370	28 (48.3)	30 (51.7)
Nov. 20	320~350	44 (58.7)	32 (41.3)	Nov. 23	330~380	26 (51.0)	25 (49.0)
Dec. 26	340~375	48 (52.2)	44 (47.8)	Dec. 15	320~360	22 (55.0)	18 (45.0)

tained that in the fish having the same fork length there is statistically no difference in the length of gonads between both sexes. Based on these results, the relationship between gonad lengths and fork lengths was calculated without discriminating ovaries and testes from each other. The relationship between gonad lengths and fork lengths in different stages of growth from young fish to adult fish, 60~420mm. in fork length, is shown in figure 16. The relationship between gonad lengths and fork lengths shows an exponential function. It may be approximately indicated by the following equation; $\log y = 1.385 \log x + \log 0.0335$ or $y = 0.335X^{1.385}$. In the equation y indicates a gonad length and X a fork length. It is ascertained that the gonad lengths of fish, more than 300 mm. in fork length, reaches more than one-third of the fork lengths.

Table 8. Lengths of the gonads of fish, 200~209 mm., and 350~359 mm. in fork length, and the value of "Student's" t test of the difference in length between the testes and the ovaries

Fork length (mm.)	Sex	Number of fish	Gonad length			t
			Range (mm.)	Mean (mm.)	Standard deviation	
200~209	♀	30	49 ~ 58	53.3	2.33	1.81
200~209	♂	30	49 ~ 58	54.8	2.40	
350~359	♀	30	106 ~122	115	4.57	1.66
350~359	♂	30	105 ~122	113	4.69	



Flg. 16. Relationship between the gonad length and the fork length.

IV. Seasonal variations in the gonads of adult fish

1. Material and methods

As material for this study, the gonad of spotted mackerels which were caught with a fishing gear and a fishing net in the coastal sea area of Kagoshima and its vicinity and in the sea area around the Ōsumi Islands, from May, 1962 to April, 1965 were used. The length, width and thickness of the gonads are measured on board immediately after fishing. But in summer when scanty fish catch makes it impossible to get living fish, the gonads of the fish obtained from fish markets were used as material. Twenty spotted mackerels were measured at a time, the measuring was made more than one time in every month. For histological observations their gonads were taken out and cut into anterior, middle and posterior portions. Small fragments of each portion were fixed in Bouin's fluid for 24 hours and then preserved in 70% alcohol. As there is no noticeable difference between right and left gonads both in morphological and histological characters, the left gonads were usually used as material for microscopic observations. The flagments of gonads were cut into sections at $8 \sim 10\mu$, mostly at 10μ by the paraffin method. The sections were usually stained with Delafield's hematoxylin and eosin, and sometimes with Haidenhain's iron hematoxylin.

2. Anatomical features of gonads

The right and left gonads are symmetrically arranged; the anterior ends approximately reach the middle level between the sixth and the seventh vertebra. The posterior end of each gonad is connected with a short gonad tube, an oviduct or a sperm duct. The right and left gonad tubes are fused into a common tube and connected with the cloaca. The shape of testes and ovaries are shown in plate VIII, figures 40 to 42.

In the spawning season, the gonads become extremely large and fill up the abdominal cavity. On the surfaces of the ovary there are many distinct blood vessels which mostly run transversally. The surfaces of mature ovaries are pale yellow brown, while those of mature testes are milky white. On the surfaces of testes no distinct blood vessels are found. In a cross section the ovary is mostly of elliptical shape, and becomes gradually flattened in the posterior portion. In a cross section, the testis is more flattened than the ovary. After spawning, both kinds of gonads become slender and dark brown; there is scarcely any morphological difference between the ovary and the testis.

a. Variations in the length of gonads

The seasonal variations in the length of gonads were observed on 376 spotted mackerels, 330 mm., 360 mm., 380 mm. and 390 mm. in fork length. These mackerels represent the majority of fish collected through the whole year.

The variations in the mean value of gonad lengths are shown in table 9, and the differences in each season are shown in figure 17. The gonads of spotted mackerels, 330mm. and 360mm. in fork length, reach their maximum in length in March and April, and fall to their minimum in September and October. The gonad lengths of 380mm. and 390mm.

Table 9. Seasonal variations in length of the gonads of adult fish

Month	330~339mm. in F. l.*			360~369mm. in F. l.		
	Number of fish	Range in length (mm.)	Mean (mm.)	Number of fish	Range in length (mm.)	Mean (mm.)
Jan. ~Feb.	20	96~130	107	16	126~138	131
Mar. ~Apr.	25	102~125	114	20	128~140	134
May.~June	30	98~126	110	20	115~139	128
July ~Aug.	25	90~116	104	16	112~128	122
Sep. ~Oct.	20	92~114	101	17	118~126	120
Nov. ~Dec.	20	95~110	103	15	112~126	123
	380~389mm. in F. l.			390~399 mm. in F. l.		
Jan. ~Feb.	15	124~144	138	10	136~157	142
.Mar.~Apr.	20	125~150	144	16	132~154	146
May.~June	20	130~168	143	20	130~155	143
July ~Aug.	16	118~138	133	15	120~140	134

*F. l. : fork length

fish are almost constant from March to June and decrease suddenly in July and August. Accordingly, it is ascertained that the gonad length reaches its culmination during the spawning period, is sharply reduced afterwards and begins to swell up late in autumn or early in winter. The seasonal difference in length of the gonads of spotted mackerels, 330mm. and 360mm. in fork length, is 13~14mm., or about 3.9% of the fork length; that of 380mm. and 390mm. fish is 10~12mm. or about 2.6% of the fork length. Generally speaking, the gonads of adult fish are enlarged about 9~13% of the original length during the spawning season.

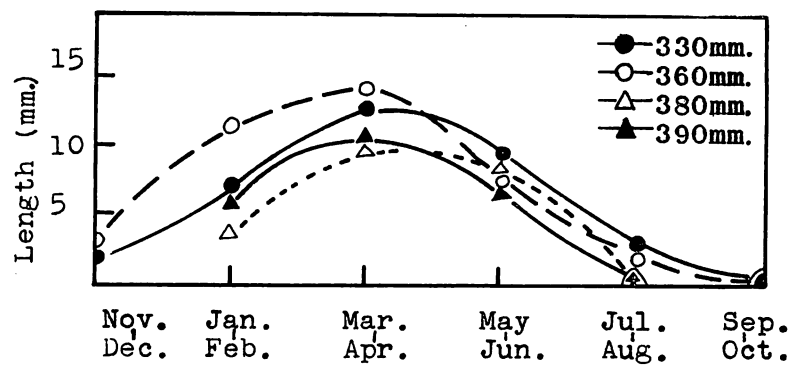


Fig. 17. Seasonal variations of mean values in length of the gonads of adult fish.

b. Variations in the width, thickness and weight of gonads

The largest widths and thickness of gonads in their mid-portions, were measured. The monthly variations in width, thickness and weight of the testes and ovaries of adult fish, 310~350mm. and 360~390 mm. in fork length, are shown in table 10. The mean value of the widths of testes and ovaries of adult fish begins to increase in January, reaches the maximum in April and becomes rapidly small in July. The maximum mean value of the widths of testes and that of ovaries reach 7 and 5 times the minimum mean value, respectively. The maximum width of an ovary and that of a testis are 50 and 31mm., respectively. Generally speaking,the testes are wider than those of the ovaries in adult fish with the same fork length, during the months from January to June. The testes and ovaries of adult fish are thick during the same period; they reach their maximum in April and become rapidly smaller in July. The maximum values in thickness of the testes and ovaries are 11.8 and 15.0mm., respectively; they are 6 and 7.5 times the minimum, respectively. Therefore, the ovaries are thicker than the testes in adult fish with the same fork length, during the months from January to June.

As shown in figure 18, the percentages in weight of gonads to bodies are less than 1% during the months from July to November. The percentages in big males and females, more than 360mm. in fork length, become 3% in December. During the months from January to June, the percentages in large males and females amount to 6~13%. In big male and female fish, 360~440mm. in fork length, the percentages are 11~13% and

Table 10. Seasonal variations in width, thickness and weight of the gonads of adult fish
a. 310~350mm. in fork length

Month	Sex	Number of fish	Width		Thickness		Weight	
			Range (mm.)	Mean (mm.)	Range (mm.)	Mean (mm.)	Range (mm.)	Mean (mm.)
Jan.	♀	22	6~ 9	7.2	2~ 5	8.0	2~15	8.0
	♂	15	4~ 7	5.4	1~ 2	1.5	2~18	10.0
Feb.	♀	15	8~20	11.6	5~18	9.0	15~30	22.4
	♂	16	5~25	14.0	3~10	6.2	14~33	24.8
Mar.	♀	16	16~24	18.0	6~16	11.0	10~25	18.4
	♂	11	18~26	22.0	5~12	8.0	5~30	20.0
Apr.	♀	12	15~22	20.0	8~14	12.0	20~30	23.3
	♂	12	20~40	25.5	5~12	9.1	15~60	34.3
May	♀	17	8~18	13.5	3~12	6.8	5~35	11.6
	♂	19	12~30	17.0	4~ 8	6.0	6~40	16.7
June	♀	11	12~20	15.2	5~12	6.4	12~26	22.4
	♂	10	9~23	16.2	3~ 8	5.0	12~40	19.5
July	♀	16	6~10	7.8	2~ 3	2.5	1~ 3	2.0
	♂	14	5~ 8	6.8	1~ 3	2.0	1~ 3	2.0
Aug.	♀	18	4~ 7	5.6	2~ 3	2.5	1~ 2	1.5
	♂	10	4~ 8	5.4	2~ 3	2.5	0.5~ 2	1.0
Sep.	♀	11	4~ 8	6.8	1~ 3	2.0	1~ 2	1.0
	♂	15	3~ 8	5.3	1~ 3	2.0	0.5~ 2	1.0
Oct.	♀	7	3~ 6	4.8	1~ 3	2.0	1~ 2	1.0
	♂	10	4~ 7	5.5	1~ 2	1.5	0.5~ 2	1.0
Nov.	♀	9	3~ 6	4.1	1~ 3	2.0	1~ 4	2.3
	♂	31	2~ 6	4.0	1~ 1.5	1.2	1~ 2	1.5
Dec.	♀	12	3~ 6	4.2	1~ 3	2.0	1~ 6	3.0
	♂	15	2~ 6	4.0	1~ 2	1.5	1~ 8	3.4

b. 360~390 mm. in fork length

Month	Sex	Number of fish	Width		Thickness		Weight	
			Range (mm.)	Mean (mm.)	Range (mm.)	Mean (mm.)	Range (mm.)	Mean (mm.)
Jan.	♀ ♂	7 7	16~26 20~27	20.6 23.4	6~13 5~ 7	9.1 6.3	7~ 39 11~ 46	19.0 21.0
Feb.	♀ ♂	8 10	20~28 24~30	23.0 27.0	10~14 8~12	12.2 9.6	30~ 98 50~105	49.7 63.4
Mar.	♀ ♂	10 8	25~30 26~34	26.5 29.7	14~18 10~14	15.0 11.8	45~110 50~100	72.0 87.0
Apr.	♀ ♂	12 14	15~28 20~45	23.3 30.6	5~16 5~13	10.6 9.4	17~105 15~ 63	34.4 39.3
May.	♀ ♂	12 10	22~31 30~50	27.2 36.0	8~11 9~12	9.6 10.6	17~ 65 30~ 70	35.8 39.1
June	♀ ♂	16 14	14~26 18~28	20.1 22.1	8~12 6~12	8.5 7.4	20~ 78 18~ 62	37.1 28.8
July	♀ ♂	12 15	6~ 8 6~ 7	7.4 6.5	1.5~ 3 1~ 2	2.4 1.8	1~ 3 1~ 3	2.0 2.0
Aug.	♀ ♂	10 9	6~14 7~18	9.1 8.0	2~ 3 2~ 3	2.0 2.5	1~ 3 1~ 3	2.0 2.0
Sep.	♀ ♂	10 13	6~10 5~ 8	8.0 7.0	2~ 3 1~ 2	2.2 1.0	1~ 3 1~ 3	2.0 2.0
Oct.	♀ ♂	14 15	4~ 7 4~ 7	5.0 5.0	2~ 3 1~ 2	2.2 1.8	1~ 3 1~ 3	2.0 2.0
Nov.	♀ ♂	15 13	6~ 8 5~ 8	7.4 6.7	1.5~ 4 1~ 3	2. 0 2. 0	1~ 3 1~ 3	2.0 2.0
Dec.	♀ ♂	16 13	6~10 7~16	8. 1 11.1	3~ 6 2~ 4	4.3 2.6	2~ 13 2~ 8	4.0 5.0

less than 11%, respectively. In this season there are some big fish, having testes or ovaries which are more than 100g. in weight. In some adult fish, 300~350mm. in fork length. caught during the months from February to June, the percentages in weight of testes and ovaries to bodies are at 7~10 and less than 7.5, respectively. Therefore, it is clear that in the spawning season the percentage in weight of testes to bodies is generally larger than that of ovaries to bodies in both sexes having the same fork length.

c. The size and number of ovarian eggs

Three fragments, an anterior, a middle and a posterior, were get out of each ovary fixed in 10% formalin, by cutting the latter transversely. Each fragment was 2mm. in height. After the weight of each fragment was measured, all the eggs contained in this fragment were separated from one another. The number of the eggs was counted and the diameters were measured. Then the total number of eggs contained in each ovary was calculated on the basis of the ratio of the total weight of the three fragments to the weight of the whole ovary.

The number of eggs contained in the two ovaries of each female fish and the distribution of different egg diameters are presented in table 11. In the ovaries of all female fish, the eggs which are less than 0.2mm. in diameter are 60～80% of the total eggs in number.

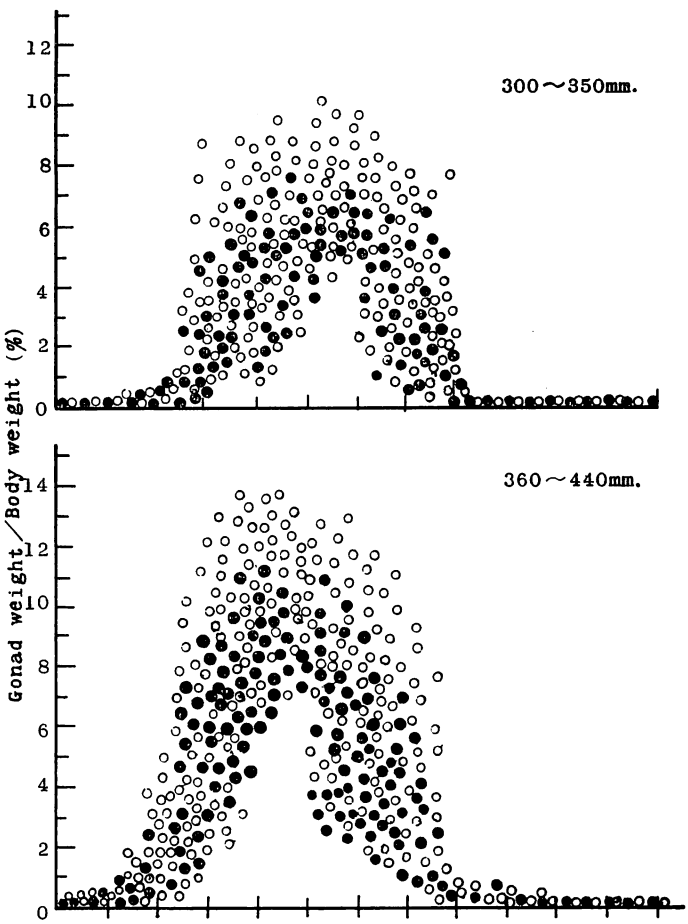


Fig. 18. Relationship between the gonad weight and the body weight.
○ : male ● : female

This percentage is comparatively constant during the months from January to June. The seasonal fluctuations in the distribution of egg diameters in the ovary is as follows: in a large fish, 370mm. in fork length, the eggs in December are less than 0.2～0.3mm. in diameter. In another fish, 337mm. in fork length, the eggs are less than 0.15mm. in diameter. In the ovaries of an adult female, 380mm. in fork length, caught late in January there were some large eggs with a diameter of 0.5～0.6mm., and in the ovaries of another large fish of the same fork length, a clear mode of distribution is made with eggs having a diameter of 0.5～0.55mm. On the other hand, in the ovaries of a fish, 340mm. in fork length, the eggs with a diameter more than 0.5mm. are few. In February, a small number of large eggs with a diameter larger than 0.7mm. appear in the ovaries. These large eggs are always observable until June. The mode of distribution of egg diameters is 0.5~0.55mm. in February, while it is 0.6~0.65mm. in March and April, that is, the mode is

Table 11. Number of ova contained in a pair of ovaries and distribution of different egg diameters

Date	Fork length (mm.)	Gonad weight (gr.)	Number of eggs	Percentage of each egg diameter								
				0.02 ~ 0.09 mm.	0.10 ~ 0.19 mm.	0.20 ~ 0.29 mm.	0.30 ~ 0.39 mm.	0.40 ~ 0.49 mm.	0.50 ~ 0.59 mm.	0.60 ~ 0.69 mm.	0.70 ~ 0.79 mm.	0.80 ~ 0.89 mm.
Dec. 20	337	8	181000	66	34							
	370	13	380000	66	27	5.0	2.0					
Jan. 28	340	20	296000	42.5	33	14	5.0	3.5	2.0			
	380	35	550000	52.0	21	8	5.5	4.0	6.5	3.0		
Feb. 12	338	30	321000	36.8	31.7	10	5.0	7.0	5	4	0.5	
	390	52	680000	54	23	3.1	6.1	3	6	3	1	0.2
Mar. 20	342	16	260000	49	20	4	8	5	4	7	3	
	402	76	863000	58	13.5	6	5	6	3.2	7.5	1.5	0.3
Apr. 15	340	25	225000	51	18	11	6	5.0	3	5	1	
	415	62	795000	57	9	8	5	3.4	4	8.5	4.6	0.5
May 22	333	20	204000	56	16	6	7	4.5	7	3	0.5	
	386	50	508000	60	11	5	5	7	3	6	3	
June 13	338	13	153000	45.4	26	6	6	5	8	3.5	0.1	
	365	24	440000	57	18	3	5	5	6.5	4	1.5	

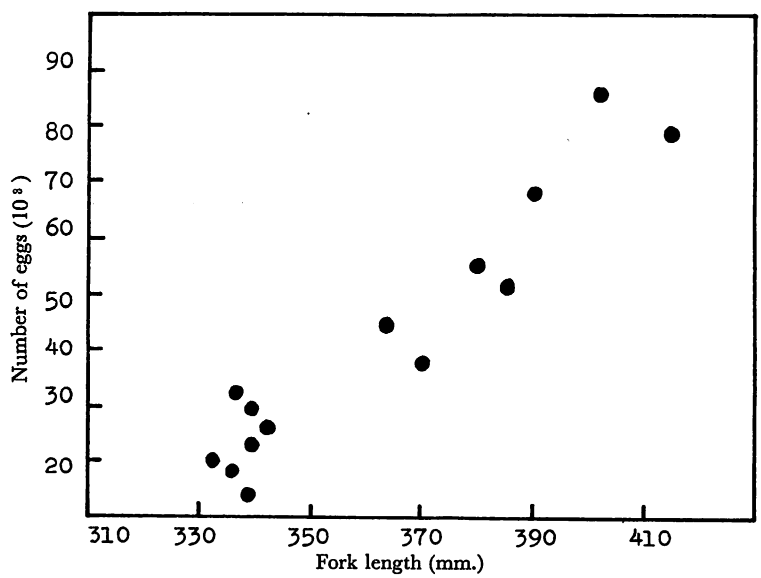


Fig. 19. Relationship of the number of the ovarian eggs contained in a pair of ovaries to the fork length.

shifted toward a larger diameter. In June, large eggs decrease in number and the mode generally move toward a smaller diameter. In the ovaries of female fish caught late in July no large eggs are observed ; all the eggs are less than 0.2mm. in diameter.

The eggs in a pair of ovaries of each of fish, 336～342mm. in fork length, are calculated to be 153.000～290.000 in number. In the ovaries of fish, 365～415mm. in fork length, they are calculated to be 380.000～863.000 in number. The relationship of the fork length with the egg number is shown in figure 19.

3. Histological features of ovaries

In order to clarify the seasonal change of the ovary, microscopic observations were made every month on the three parts of each ovary, namely, the anterior, the middle and the posterior. It is ascertained that there is no difference in the maturation stage of eggs among these three parts during the months from March to November. But in December, a lot of eggs of the yolk globule stage are observed in the posterior part, while such eggs are very small in number in the other parts. Late in January some empty follicles begin to appear in the posterior part, while they are not observed in the other parts. This shows that the

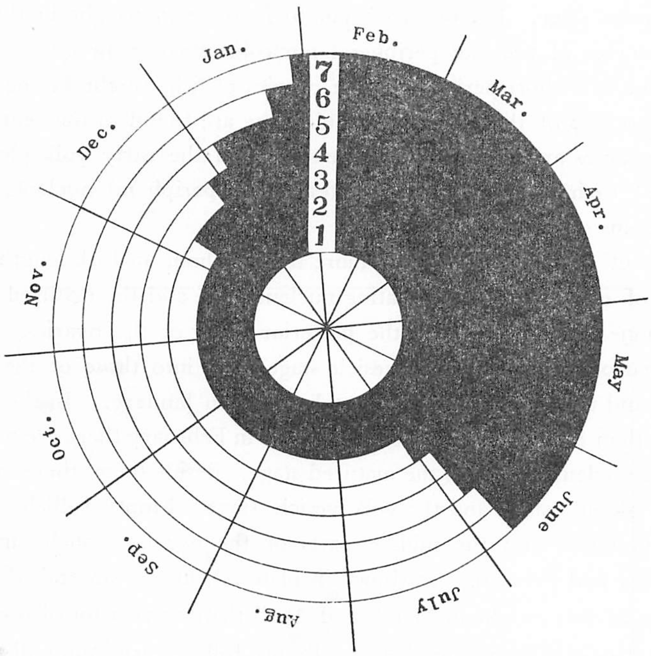


Fig. 20. Duration of the appearance of eggs at each stage in the ovary.
1, chromatin nucleolus stage
2, peripheral nucleolus stage
3, yolk vesicle stage
4, early yolk globule stage
5, late yolk globule stage
6, migrating nucleus stage
7, matured stage

eggs in the anterior part are generally matured earlier than those in the other parts. The eggs contained in an ovary in every month are shown in plates IX and X, figures 43 to 54. The developmental stages of eggs found in the ovaries in every month are shown in figure 20. In the ovaries in the latter half of July, all the eggs are at the chromatin nucleolus stage and the peripheral nucleolus stage; the ovaries are in the so-called spent state. The ovaries almost composed of empty follicles, although a few mature eggs are still retained here and there. Much stroma tissues are found around the eggs. These tissues may have be derived from follicle cells left in the ovaries after ovulation. In the inner part of each lobe there are many eggs of the peripheral nucleolus stage, and near the periphery of each lobe there are groups of minute eggs of the chromatin nucleolus stage.

In August and September, no increase in diameter is observed in oocytes. The oocytes in each ovary in October are larger in number than those in September; reproduction begins to occur in this month. In the latter part of November, oocytes of the late peripheral nucleolus stage are found in the central part of each lobe. In the ovaries of adult fish caught in the latter part of December, oocytes of the early yolk globule stage are observed in the central part of each lobe, and near the periphery there are a lot of eggs of the peripheral nucleolus stage. The ovaries begin to increase in weight in this season. It is assumed that oocytes of the late peripheral nucleolus stage grow into those of the early yolk globule stage in a short period. In the ovaries of fish caught in the middle part of January, large oocytes of the late yolk globule stage are found in the central part of each lobe, but most oocytes are at the yolk vesicle stage and the early yolk globule stage. In the periphery of each lobe there are oocytes of the peripheral nucleolus stage and the chromatin nucleolus stage.

In the ovaries of adult fish, which are more than 380mm. in fork length, caught late in January, a lot of oocytes of the migrating nucleus stage and the matured stage are found and there are some empty follicles in the posterior parts of the ovaries. Accordingly, it seems certain that oocytes of the yolk vesicle stage grew into those of the matured stage, in a short time, and the spawning begins to take place in January. In the ovaries of some adult fish, more than 350mm. in fork length, caught in February there are numerous oocytes of the migrating nucleus stage and the matured stage. Beside them, there are many oocytes of the late yolk globule stage and the yolk vesicle stage. Empty follicles are clearly observed in the posterior and the middle parts of the ovaries. Such empty follicles of ovaries in January and February are shown in plate XI, figures 55 and 56.

In the ovaries of fish caught in March and April there were a lot of oocytes of the migrating nucleus stage and the matured stage. Empty follicles are found all over the ovaries. In this season, they are also found in the ovaries of fish, which are less than 340mm. in fork length. In the ovaries of fish caught in May and June, there are many oocytes of the migrating nucleus stage and the matured stage, as well as a lot of empty follicles. However, the eggs seem to have decreased in number. These large oocytes begin to atrophy late in June. In the ovaries of fish caught late in June, as shown in plate XI, figures 57 and 58, oogonia become easily observable at the periphery of each lobe, while they are hardly observable at other times. They are comparatively abundant at the basal part of the lobe.

Oogonia are also found in the ovaries of fish in July when the spawning has been finished.

In the ovaries of fish which have finished their spawning, there are some residual oocytes, so-called closed eggs. Of these residual oocytes, those of the yolk vesicle stage, the yolk globule stage and the migrating nucleus stage are degenerated and absorbed afterwards. But oocytes of the peripheral nucleolus stage and the chromatin nucleolus stage remain till the next spawning season and are made use of for reproduction. Some degenerating oocytes are shown in plate XI, figures 59 and 60. The degenerating process of residual oocytes may be summarized as follows. First, yolk globules are fused into large masses, and then vacuoles appear in these masses. The vacuoles gradually become larger and fused with one another. By such a way all the ooplasm and yolk collapse, become liquefied and are absorbed. It is estimated that large residual oocytes are absorbed within a month.

4. Histological features of testes

It is clear that, as was in ovaries, spermatogenesis occurs in the posterior parts of testes somewhat earlier than in the anterior. The structures of the testes of fish caught in every month are shown in plates XII to XIV, figures 61 to 79. In the testes of fish caught in June, the walls of seminiferous tubules become thickened in accordance with ejection of spermatozoa. When a lot of spermatozoa are still left in the cavities of seminiferous tubules, primary spermatogonia become arranged along the walls of the tubules. As the ejection of spermatozoa advances further, the spermatogonia begin to increase rapidly. The testes become in a short time filled up with spermatogonia. The multiplication of spermatogonia occurs at first in the outer part of the testis near the epithelium, and then extended towards the central part. In a cross section, the spermatogonia in each seminiferous tubule are arranged around slit-like cavities. They are about 20~30 in number and are very similar to each other in shape and size. Concerning the destiny of spermatozoa remaining in the cavities no special research has been made. But it is assumed that they are degenerated and absorbed sooner or later as was seen in case of the immature ovarian eggs. In the latter part of July, there are no spermatozoa in the testes; the latter are filled up with new spermatogonia which immediately begin to grow and become about 8~10μ in diameter. In the nuclei of spermatogonia during this growth period, there are one or two nucleoli and a chromatin network gathered to the central region. The nuclei are surrounded with clear cytoplasm. These spermatogonia are observed during the months from July to November. In this period, divisions of spermatogonia occur here and there in the testes. In the testes of fish caught in December, spermatogonia remarkably increase in number by active mitoses and they become smaller in size; they are transformed into secondary spermatogonia. These secondary spermatogonia become somewhat larger and changed into primary spermatocytes. This transformation process of secondary spermatogonia into primary spermatocytes does not simultaneously proceed in each seminiferous tubule. It generally occurs earlier in the inner part of the testis. Primary spermatocytes become spermatids through the first and second maturation divisions. In a little while, spermatids are changed into spermatozoa.

Spermatozoa begin to appear late in December. The spermatozoa are gathered in bundles; in each bundle they are arranged in the same direction. Besides them, numerous spermatids and spermatocytes are simultaneously found in the testes of every adult males caught in this season. This situation continues until June.

When spermatozoa are matured, they are carried through the cavities of seminiferous tubules, the rete apparatus and the main collecting duct towards the vas deferens. In large male fish which are more than 380mm. in fork length, spermatozoa are ejected from the cloaca when their abdomen is pushed in the latter part of January. It is probable that the first ejection of spermatozoa occurs in this month. The formation of spermatozoa occurs most actively in the testes of fish in March and April. The testes increase in weight until April. In May and June, they are filled with spermatozoa, while the spermatogenesis becomes less frequent than in March and April. In these months the testes decrease gradually in weight as a result of ejection of spermatozoa. It may be concluded that the ejection of spermatozoa takes place from late in January to June.

V. Discussion

1. Migration

a. Migration of young and adult fish

Although no investigations have been made as to the northern limit of the distribution area of spotted mackerels, it was reported by KOJIMA (1952)[31] that some schools of spotted mackerels were found off San-in district in summer. There is no catch record hitherto at the sea off Ishikawa and Fukui Prefectures, situated in the north of San-in district. In the Pacific Ocean, it was recorded by the Ibaraki Fisheries Experiment Station (1964)[32] that a small number of spotted mackereles were caught in Kashima nada. It seems that this kind of fish has not yet been caught in the north of Kashima nada. It was clarified by the present author that at the sea off Yamaguchi Prefecture and at the sea off Choshi district some schools of young spotted mackerels are found in summer.

Judging from these investigations, it is assumed that the northern limit of the distribution area of spotted mackerels is the sea off San-in district and the sea off Choshi district. The schools found in these sea areas are obviously those which are on their feeding migration. As to the schools of spotted mackerels in the East China Sea and in the southern part of Japan Sea, the following assumption was made by AIKAWA (1958)[33] and TANOUE (1958) that the schools of these two sea areas are of the same group. In summer some schools of the this group come to the sea area around Saishu Island or in the northern sea area near by. From late autumn to winter schools of the this group gather in the sea area around South Kyushu and in the southern part of the East China Sea. The present investigation presumes that spotted mackerels belonging to the same group are making a seasonal migration of a much wider range: the schools appearing in the sea area off Ashizuri belong to the same group as those swimming north of the sea area around the Ōsumi Islands, and they are also of the same group as the schools of the East China Sea.

Concerning adult spotted mackerels found in the sea area around the Izu Islands, it was reported by KASAHARA and ITO (1953)[34] that they seem to be of a different group from those in the East China Sea. By repeated observations made by the present author on a lot of spotted mackerels found in the southern sea area of the Izu Islands in winter season, the same conclusion as that of KASAHARA and ITO is induced. However, as young spotted mackerels swimming in the sea area around the Izu Islands are supplied by some schools belonging to the group of the East China Sea and of the sea area around the Ōsumi Islands, it may be too hasty to conclude that the group of the Izu Islands and that of the East China Sea are completely isolated from each other.

As to the swimming layer, a lot of schools of spotted mackerels were observed in the layer from the surface to 30m. in depth in the East China Sea in winter and spring by TANOUE (1958). Schools were also observed in the bottom layer during the same season by TSUJITA and KONDO (1958)[35]. In the present research, it was clarified that some schools were swimming near the bottom layer in summer in the East China Sea and in the sea area around the Ōsumi Islands. Judging from these facts it is assumed that the range of swimming layer of spotted mackerels is somewhat different with a season. Generally speaking, the swimming layer is situated at 20～60m. in depth, and they are swimming in a comparatively shallow layer near the beach during and immediately after the spawning season.

The optimum water temperature of the swimming layer is assumed to be within the range of 17～26°C, as reported by TANOUE (1952), MORI and NISHIKAWA (1955), TSUJITA and KONDO (1958), MORITA (1958)[36], TAKESHITA (1958)[37], TANOUE (1958, '62)[38),39], TANOUE, KURATA and TOKUDOME (1960). As to the salinity, while MORITA (1958) reported that it was within the range of 34.3～34.6‰, the present author observed spotted mackerels even in the range of 34.0～34.3‰. The optimum water temperature of the swimming layer of common mackerels, *Pneumatophorus japonicus*, lies within the range of 10～20°C, according to KATAYAMA (1940)[40], KASAHARA and ITO (1953), HARA (1958)[41], UDA (1961).[42] Hence, it is ascertained that the optimum water temperature of spotted mackerels, *P. tapeinocephalus* is higher than that of the common ones.

b. Distribution of larvae

As to the distribution of larvae, it has been known that they are found in the surface (YABE, 1953) and in the current rip (IMAI, 1958) in the East China Sea around the Ōsumi Islands. Some larvae were detected by HOTTA (1957) in the stomachs of skipjacks, *Katsuwonus pelamis*. TANOUE reported in previous papers (1960, 1961) that they were observed swimming densely in the layer, 10～30m. in depth. KAMIYA (1925)[43] reported that a larva, 4.04mm. in total length, was observed to be positively phototactic. SETTE (1943)[44] reported that larvae of *Scomber scombrus* in the Atlantic Ocean appeared in a deep layer in the daytime, and floated up to the surface in the night. ODATE (1961)[45] reported that larvae of the common mackerel, *P. japonicus*, swimmed up to the surface in the night. EHRENBAUM (1923)[46] ascertained that larvae of *Scomber scombrus* were swimming in a deep layer, 100～200m. in wire length. Larvae of the spotted mackerel are distributed in the range from surface to 40m. in depth in the East China Sea, the sea area around the Ōsumi Islands, and the sea area off Ashizuri. They generally become fewer near the surface during the months from April to June. This seems atributable to changes of sea conditions, chiefly to elevated water temperature and increased illumination in these months. Generally speaking, the larvae of the spotted mackerel are floating at the surface or swimming in the middle layer, and are brought by a sea current or a tide current.

2. Spawning

As to the spawning period of spotted mackerels, KOKUBU (1954), MURAKAMI (1955), TANOUE (1958) and TSUJITA and KONDO (1958) reported that spawning took place from late in January to May in the southern part of the East China Sea. And also it was reported by TANOUE (1956), TANOUE, KURATA and TOKUDOME (1960) that spawning took place from late in January to June in the sea around the Ōsumi Islands, and from late in February to June around the Izu Islands. In the present research, it is ascertained that in the East China Sea spawning continues until June. In the sea off Ashizuri, spawning is assumed to take place from late in February to June. In the sea areas around the Izu Islands and Ōsumi Islands, the same results as mentioned above are obtained.

The ranges of the water temperature and salinity in spawning ground are 17～23°C and 34.0～34.8‰, respectively, as were reported by the above investigators. There is no considerable difference in water temperature and salinity among the above-mentioned sea areas. It is generally recognized that *Scomber scombrus* (SETTE, 1943)[47] and *P. japonicus* (SANO and TAMURA, 1958)[48] gather in a shallow sea area for spawning. The spawning of spotted mackerels mostly occurs at the sea near beaches. In the sea less than 150m. in depth, spawning takes place in areas washed by a comparatively rapid current running towards land shelf. This may be due to the fact that there is an up-welling, in these sea areas, since there are probably abundant food and oxygen which make it possible that the fish stay in a narrow place to lay eggs, as mentioned by HALL (1930)[49].

3. Sex differentiation

In Amphibia, Aves and Mammalia it is already well known that the primordial germ cells migrate in tha gonads from the other places. In fishes, JOHNSTON (1951)[50]reported that the primordial germ cells in the largemouth black bass, *Micropterus salmoides salmoides* LACEPEDE, reach the primordial gonads by amoeboid movement. In the present study, the same process as was found in the largemouth black bass is pressumed to take place, judging from the fact that some primordial germ cells are found not only in indifferent gonads, but also in neighborhood of the latter. Although the earlier history of the primordial germ cells were not examined well.

The indifferent gonads of teleosts are constituted of the peritoneal epithelium, the primordial germ cells covered by the peritoneal epithelium and the stroma cells (JOHNSTON, 1951; SWARUP, 1958)[51]. In this respect those of the spotted mackerel are nearly of the same structure.

As to the process in which the sex is separated into the male and the female, JOHNSTON (1951) described in *Micropterus salmoides* as follows. The formation of a gonocoel occurs in the primordial gonad by the separation of a part of the epithelial layer along the long axis of the gonad, leaving the germ cells contained within the remaining epithelial layer.

The organization of the testis in the *Micropterus salmoides* apparently proceeds at a slower rate than does that of the ovary; the gonocoel remains small in size. Moreover, the testis is lacking in the thickened tunica which covers the ovary. At the first stage of the differentiation of ovaries in *Salmo irideus* (PADOA, 1939)[52] and *Oncorlynchus Keta* (ROBERTSON, 1952)[53] there is a remarkable multiplication of germ cells composing nests inside the gonad and less conspicuous growth of stroma cells. On the other hand, in testes there is scarcely any multiplication of germ cells. In *Gasterosteus aculeatus* (SWARUP, 1958) the ovarian features are found in the characteristic stages of oogenesis and the formation of the oviduct; the ovarian cavity and oviduct are formed by the fusion of the edges of a groove on the surface of the gonad, as is the case in *Cottus bairdii* (HANN, 1927)[54].

In the spotted mackerel the formation of gonocoel begins by the fusion of the edges of a groove on the surface of the gonad, as in *G. acculeatus*, *Cottus bairdii*, *Acerina* and *Perca* (GOODRICH, 1958)[55]. However, such a groove is formed prior to sex differentiation. The gonad in which the gonocoel is greatly enlarged becomes an ovary, whereas the gonad in which the gonocoel is left narrow grows into testis. Concerning sex differentiation, there are two types of fishes. In one type indifferent young fish become directly males and females, as in *Belone* (MACLEOD, 1880)[56], *Cottus* (HANN, 1927), Blackbass (JOHNSTON, 1951), Pacific salmon (ROBERTSON, 1952) and *G. aculeatus* (SWARUP, 1958). In the other type, indifferent young fish become indirectly males and females, passing through juvenile hermaphrodes, as in *Anguilla* (GRASSI, 1919)[57], *Xiphophorus* (ESSENBERG, 1923)[58], *Lebistes* (DILDINE, 1936)[59], (MIYAMORI, H. 1964)[60] and Black bream (KINOSHITA, 1953)[61]. The spotted mackerel belongs to the former type; the pocess of sex differentiation is very similar to that of *Micropterus salmoides.*

4. Seasonal change in the gonad of adult fish

As to the seasonal change of the gonad length of the adult fish, HONMA and TAMURA (1962)[62] reported that during the spawning time of *Plecoglossus altivelis* their ovaries are elongated twice as long as the ordinary length. The elongation ratio of the gonad length of the spotted mackerel is, both in males and females, at 9～13% of the shortest length in other than the spawning season. The gonads become exceedingly large in width and thickness in the spawning season. Concerning the number of eggs in the ovary, the fact that the larger the fork length the bigger the number of ovum was ascertained in the Ayu, *Plecoglossus altivelis* by MATSUI (1940)[63], in Herring, *Cupea pallasi* by SAKANO (1952)[64], *Percina caprodes* by C. HUBBS (1958)[65] and *P. japonicus* by ENAMI (1958), *Seriola quinqueradiata* by MITANI (1960)[66]. The same tendency is observed in the spotted mackerel.

A comparatively sharp mode of distribution in diameter can be seen among the ovarian-eggs of the spotted mackerel and a shifting of this mode is assumed to have some intimate relationship with the number of ova spawned at one time, though no authentic information was obtained. About the maturing process of the ovary, HICKLING (1930)[67] reported in the hake that it was divided into four stages; the spent, the recovery, the ripe and the running. YAMAMOTO (1956)[68] in accordance with the morphological variations of the eggs in the ovaries of adult fish of *Liopsetta obscura* classified them into 10 stages: the spent phase, the yolkless phase, the yolk vesicle phase, the primary yolk phase, the secondary yolk phase, the tertiary yolk phase, the migrating nucleus phase, the pre-maturation phase, the maturation phase and the ripe phase. In the case of the spotted mackerel it is assumed to be proper, in accordance with the morphological variations of the eggs in the ovaries to classify them into the following eight stages: the spent phase, the yolkless phase, the yolk vesicle phase, the early yolk phase, the later yolk phase, the migrating nucleus phase, the maturation phase and the ripe phase. As to the frequency of the spawning, ISHIDA, UGAWA and ARITA (1959)[69], judging from ripened ova and empty follicles found in an ovary, assumed that the spawning of *Sardinops melanosticta* takes place more than twice. On the same basis as this, it is presumed that the spotted mackerel is a poly-spawning fish.

Concerning the degeneration and the absorption of ovarian eggs and empty follicles after spawning, TATEISHI (1956)[70] reported that the eggs were absorbed in a month, while the empty follicles disappeared about ten days in the ovaries of *Cyprius acreatus*. However, according to YAMAMOTO and YOSHIOKA (1964)[71], the empty follicles in the ovaries of *Oryzias latipes* disappear in three days. It was ascertained by TATEISHI (1958) in the common mackerel and by HONMA and TAMURA (1962) in *Plecoglossus altivelis* that the remaining ova in the ovaries after spawning were degenerated and wholly absorbed. In the spotted mackerel large remaining oocytes in the stages later than the yolk vesicle are absorbed in a month after spawning.

After spawning younger oocytes at the chromatin nucleolus stage and peripheral nucleolus stage remain in the ovaries of perennial fishes, for example, the genuine cod by GOKHALE (1957), the herring, *Clupea pallasi* by POLDER (1961)[72], *Liopsetta obscura* by YAMAMOTO (1960), the gold fish, *Carassius auratus* by YAMAMOTO and YAMAZAKI(1961)[73]. In the gold fish and the herring these oocytes were assumed to be ripenned by the next spawning season. According to SUZUKI (1937)[74] and HONMA (1961), such small oocytes found in the ovaries of the sweet fish, *Plecoglossus altivelis* after spawning might be those which were newly formed from oogonia during the spawning season. YAMAMOTO (1962)[75] reported that the new oocytes of *oryzias latipes* were derived from oogonia appearing in the ovarian folds after spawning. In the ovaries of the spotted mackerel, young oocytes at the chromatin nucleolus stage and the peripheral nucleolus stage as well as a few oogonia are found after spawning. It is assumed that they become mature ova by the next spawning season.

The fact that the growth of spermatogonia occur at the stage of the first spermatogonia has been ascertained by FOLEY (1926)[76] in *Umbra limi*, by YAMAMOTO (1953) in *Liopsetta obscura*, by GOKHALE (1957)[77] in *Godus merlangus*, by HONMA and TAMURA (1962) in *Plecoglossus altivelis*. The same is applicable to the case of the spotted mackerel, too.
In *Fundulus*, MATHEWS (1938)[78] reported that spermatogenesis varies in each seminiferous tubule. In the *Heteropneustes fossilis*, GHOSH (1952)[79] reported that the spermatogenesis continued throughout the year with an equal tempo. YAMAMOTO (1953) in *Liopsetta obscura*, HONMA and TAMURA (1962) in *Plecoglossus altivelis*, and TAKADA (1955)[80] in *Clupea pallasii* reported that the spermatogenesis is carried out in each seminiferous tubule almost simultaneously. The spermatogenesis of the spotted mackerel is nearly the same as

that of *Fundulus*.

Spermatogonia and migrating cells (presumable precursors of spermatogonia) are recognized in the testes during spermatogenesis by POLDER (1961) in *Clupea harengs*, by GOKHALE (1957) *in Godus merlangus*, and by FOLEY (1926) *in Umbra limi*, by NISHIKAWA (1956)[81] in *Orizias tatipes* and *Misgurnus anguillicaudatus*. In *Liopsetta obscula*, YAMAMOTO (1953) reported that in the testis where a lot of spermatozoa were left inside the seminiferous tubules, there were primary spermatogonia. The same character as in *Liopsetta obsculla* is observed in the testes of spotted mackerels, however so-called migrating cells were not found there.

VI. Summary

1. The migration of the spotted mackerel, *Pneumatophorus tapeinocephalus* distributing in the coastal sea of Japan was investigated in relation to the geographical distribution of the fishing grounds, seasonal change of fishing condition, sea conditions and fork length. Secondarily, some anatomical and histological observations were carried out on spotted mackerels caught in the coastal sea area around Kagoshima and its vicinity to clarify the sex differentiation and the seasonal cycle of the gonads.

2. Spotted mackerels are distributed throughout a wide sea area stretching from north of Formosa to the south of Japan Sea, including the Pacific coastal sea from Kyushu to Chiba Prefecture. The northern limit of the distribution area is assumed to be the sea areas off San-in and Chosi.

3. The schools of adult fish make a feeding migration to the circumference of Saishu Island and to the sea area off Ashizuri cape in summer, and these schools make a spawning migration toward the sea area around the Osumi Islands and the southern area of the East China Sea in winter.

4. In winter some schools of adult fish remain living in the sea area south of the Izu Islands. These schools belong to a group isolated incompletely from that of the East China Sea, as some of them are those which came from the East China Sea.

5. The larvae grow while they are being brought by the sea current or tide current. When they have reached 50∼60mm. in total length, they aggregate in schools and approach the coast. In spring they swim in the coastal nursery grounds.

6. From summer to autumn, the schools of the young fish make a feeding migration to the sea off San-in and to the eastern coastal sea of Chiba Prefecture. In winter, they make a seasonal migration to the coastal sea of South Kyushu, the East China Sea and the southern sea area of the Izu Islands.

7. The range of vertical distribution of the larvae is supposed to be the layer from the surface to 40m. in depth. The vertical distribution of the adult fish is chiefly in the layer, 40∼70m. in depth, during the period from late autumn to early spring. It becomes shallower in late spring and summer, the depth being about 20∼40m.

8. The ranges of water temperature and salinity in the sea where the adult fish schools are distributed are 17.0∼26.0°C and 34.0∼34.8‰, respectively.

9. The spawning takes place during the period from the end of January to June in the southern part of the East China Sea and the sea areas around the Ōsumi Islands, off Ashi-zuri Cape and around the Izu Islands. These spawning grounds are sea areas where a comparatively rapid current is running towards a land shelf.

10. The ranges of the optimum water temperatures and salinities for the spawning are assumed to be 17〜23°C and 34.0〜34.8‰, respectively.

11. The primordial germ cells seem to migrate to the gonad by amoeboid movement from other places than the gonad.

12. The early indifferent gonad is very slender and suspended with a mesogonium, in the coelom. It is composed of peritoneal epithelium, stroma cells and primordial germ cells.

13. The formation of the gonocoel begins as a longitudinal depression on the surface of the gonad, facing the mesentery. This depression takes place in the gonad of the fish, about 60mm. in fork length, prior to the sex differentiation.

14. The sex differentiation occurs directly without a phase of a juvenile hermaphrodite.

15. The gonad in which the gonocoel is greatly enlarged becomes an ovary, while that in which the gonocoel is left narrow becomes a testis.

16. In the early ovary the layer containing oogonia is surrounded with stroma cells. The surface of the ovary is covered with cuboidal epithelium.

17. In the ovary of the fish, 100〜130mm. in fork length, the wall of the ovocoel forms small protuberances, which become the lobes of the ovary. The oocytes are situated in these lobes. The yolk formation begins in the oocytes, 15〜20μ in diameter,

18. The maturing process of eggs is clasified into the following 7 stages; the chromatin nucleolus, the peripheral nucleolus, the yolk vesicle, the early yolk globule, the late yolk globule, the migrating nucleus and the matured stage. Ovarian eggs at the migrating nucleus stage and the matured stage are observed in the fish, more than 300mm. in fork length.

19. The surface of the early testis is covered with peritoneal epithelium. The interior is filled up with the multiplied stroma cells and the spermatogonia scattered among them. In the testis of a somewhat later stage, a lot of branches are stretched out of the testocoel. Some of the spermatogonia are arranged directly beneath the peritoneal epithelium and the others are buried deep in the testis. The testis lacks a layer of stroma cells under the peritoneal epithelium.

20. In the testis of young male fish the spermatogonia increase in number and surround the small branches of testocoel; they form seminiferous tubules. The testocoel and its large branches become the rete apparatus constructed of collecting ducts.

The maturation division appears in the testes of the fish more than 280mm. in fork length.

21. The sex ratio of the young fish is approximately 1 : 1. The ratio between the gonad length and the fork length shows an exponential increase. The gonads of adult fish are enlarged about 9〜13% of the original length during the spawning season.

22. During the months from July to November the oocytes in the ovaries of adult female fish are at the chromatin nucleolus stage and the peripheral nucleolus stage. During the same season there are only spermatogonia in the testes of adult male fish.

The gonads of adult fish begin to increase in size in December and become the largest in March and April. The increase in size of the ovary is chiefly due to the enlargement of ova on account of yolk deposition. The increase in size of the testis is due to accumulation of spermatozoa.

23. A few oogonia can be seen in the ovaries of adult female fish during and immediately after spawning.

Numerous spermatogonia appear along the inner walls of the seminiferous tubules late in the spawning season.

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PLATE I～XIV

Plate I

Microphotographs of cross sections of indifferent gonads

Explanation of figures

sc, stroma cell ; in, intestine ; mg, mesogonium ; pgc, primordial germ cell ; dpe, depression of the peritoneal epithelium ; gon, gonocoel

Fig. 1 A cross section through the middle part of a larva, 5.5mm. in total length, showing a primordial germ cell near the base of the mesogonium. ×600

Fig. 2 A transverse section of the gonad of a larva, 11. 0mm. in total length, showing primordial germ cells. ×600

Fig. 3 A cross section of the gonad of a larva, 20mm. in total length. A germ cell is found near the base of the mesogonium. ×1000

Fig. 4 A cross section of the gonad of a fish, 46mm. in total length, showing the some cells. ×1000

Fig. 5 A cross section of the gonad of a fish 53mm. in total length, showing some germ cells and stroma cells. ×600

Fig. 6 The gonad of a fish, 60mm. in total length; showing the first stage of the depression of the peritoneal epithelium. ×1000

Fig. 7 The gonad of fish, 65mm. in total length, showing a groove which arose from the depression of the peritoneal epithelium. ×600

Fig. 8 The gonad of a fish, 83mm. in total length, having a gonocoel formed in the gonad. ×400

Plate I

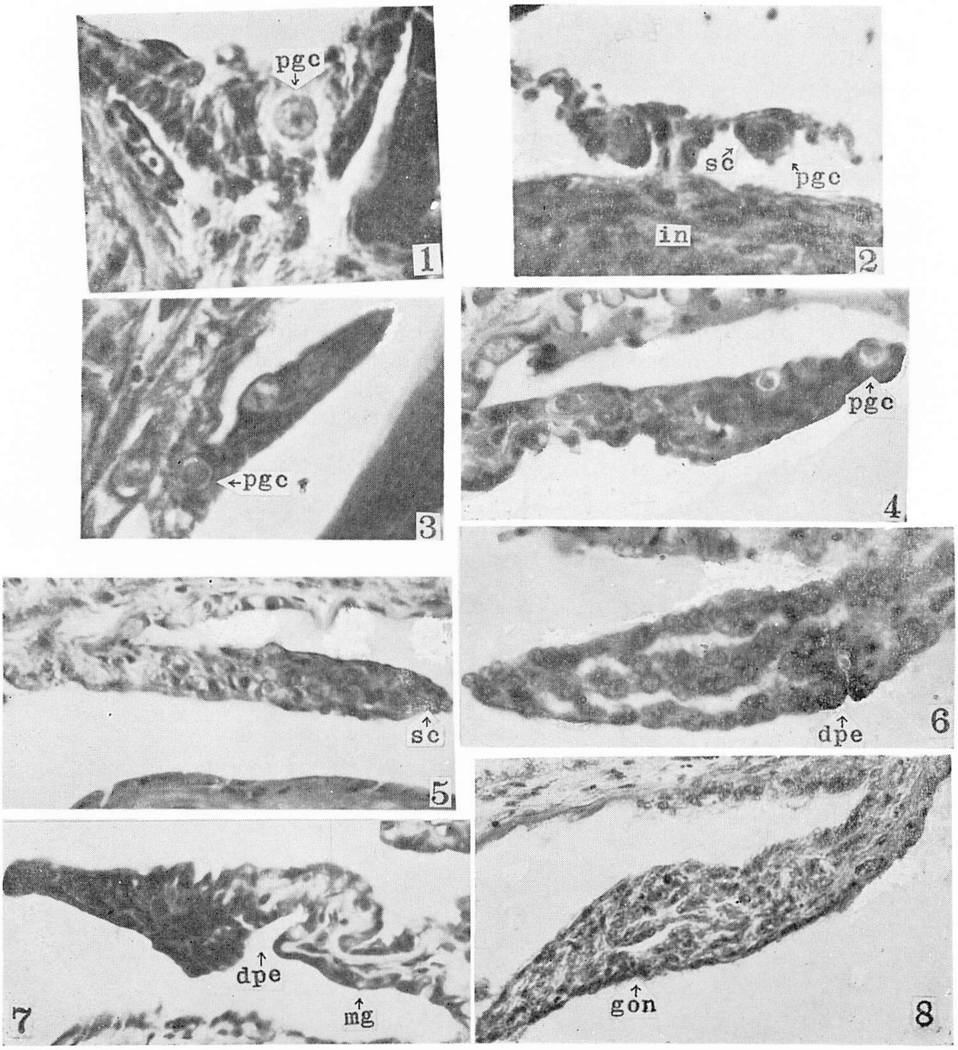


Plate II

Microphotographs of cross sections of ovaries.

Explanation of figures

ovc, ovocoel ; cel, cuboidal epithelium ;

og, oogonium ; pr, protuberance

Fig. 9 The ovary of a fish, 85mm. in fork length, showing the ovocoel. ×600

Fig. 10 The ovary of a fish, 105mm. in fork length, having a wide ovocoel. ×600

Fig. 11 The ovary of a fish, 130mm. in fork length. ×150

Fig. 12 An enlarged photograph of Fig. 11, showing many protuberances and oogonia. ×600

Fig. 13 An enlarged photograph of oogonia of Fig. 12. ×1500

Plate II

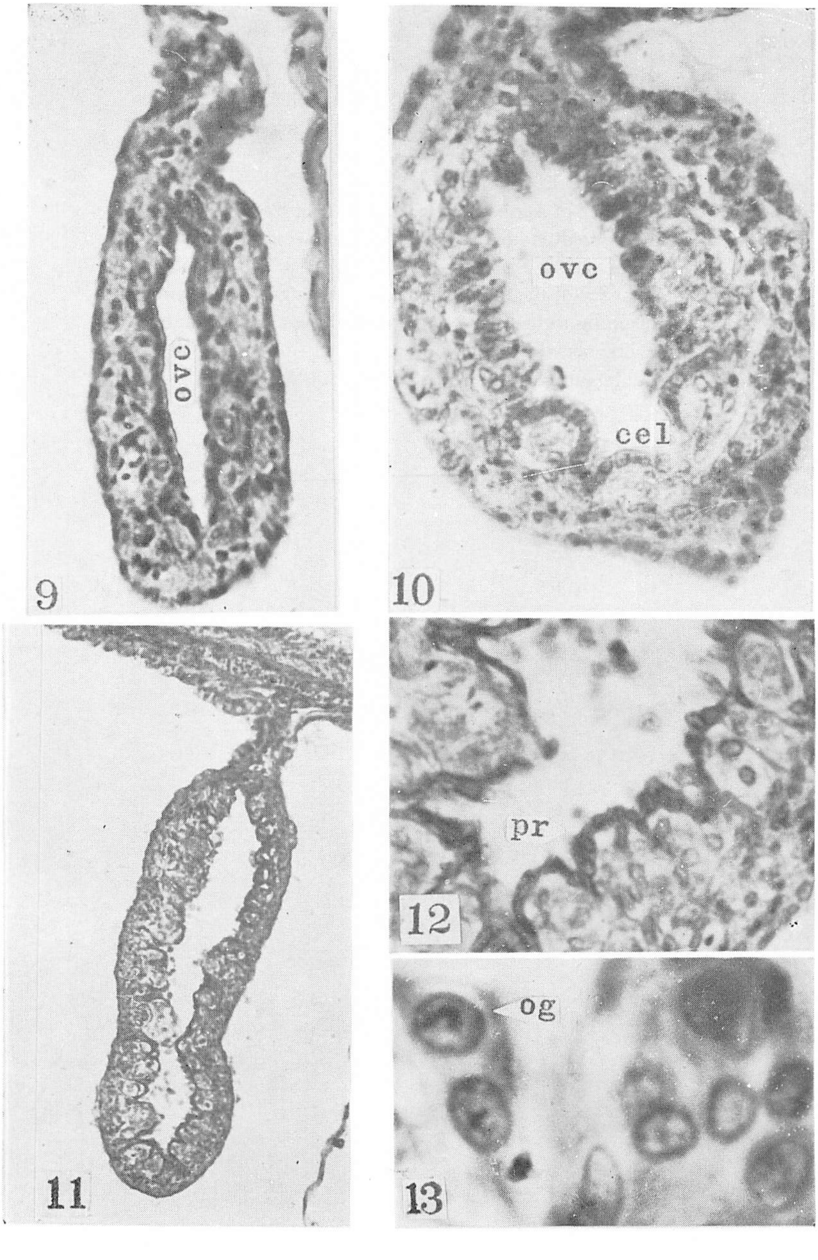


Plate III

Microphotographs of cross sections of ovaries.

Explanation of figures

oc, oocyte ; lb, lobe

Fig. 14 The ovary of a fish, 150mm. in fork length. ×150

Fig. 15 An enlarged photograph of Fig. 14, showing primary oocytes. ×600

Fig. 16 The ovary of the fish, 180mm. in fork length, with many lobes protruding in the ovocoel and containing a large number of growing oocytes. ×100

Fig. 17 An enlarged photograph of Fig. 16. ×400

Plate III

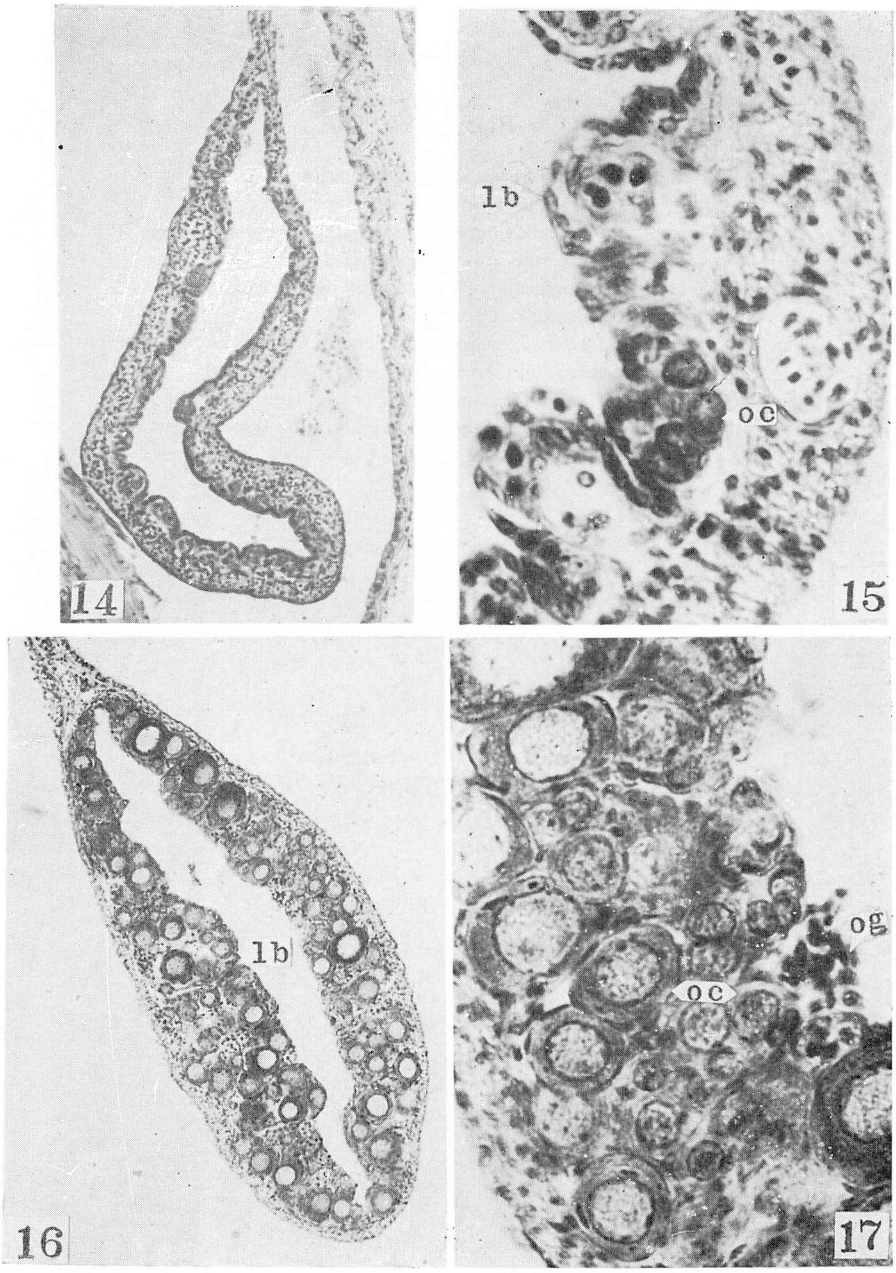


Plate IV

Microphotographs of cross sections of ovaries.

Explanation of figures

Fig. 18 The ovary of a fish, 220mm. in fork length, having a slit-like ovocoel and numerous growing oocytes. ×40

Fig. 19 An enlarged photograph of Fig. 18, showing oocytes at the peripheral nucleolus stage. ×150

Fig. 20 The ovary of a fish, 275mm. in fork length, having oocytes at the yolk vesicle stage and the early yolk globule stage. ×40

Fig. 21 The ovary of a fish, 300mm. in fork length, having large oocytes at the late yolk globule stage and the migrating nucleus stage. ×28

Plate IV

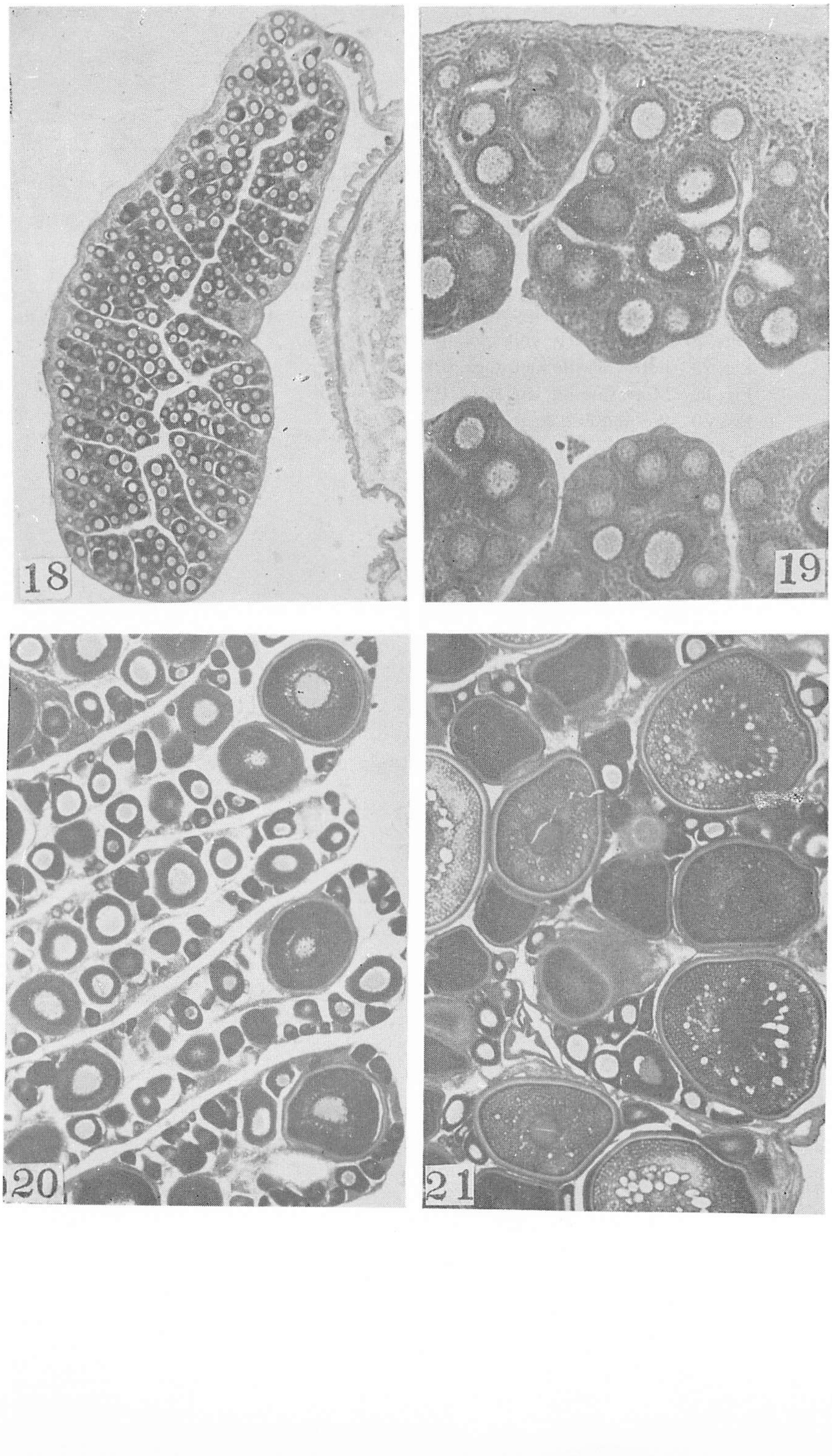


Plate V

Microphotographs of cross sections of eggs in every stage.

Explanation of figures

Fig. 22 Chromatin-nucleolus stage, 0. 05mm. ×600

Figs. 23 and 24 Peripheral nucleolus stage, 23 : early stage, 0. 07mm. ×600 24 : late stage, 0. 12mm. ×340

Fig. 25 Yolk vesicle stage, 0. 23mm. ×170

Figs. 26 and 27 Early yolk globule stage, 0. 32mm. ×130 0. 50mm. ×90

Fig. 28 Late yolk globuel stage, 0. 68mm. ×65

Fig. 29 Migrating nucleus stage, 0. 68mm. ×70

Fig. 30 Pre-matured stage, 0. 75mm. ×57

Plate V

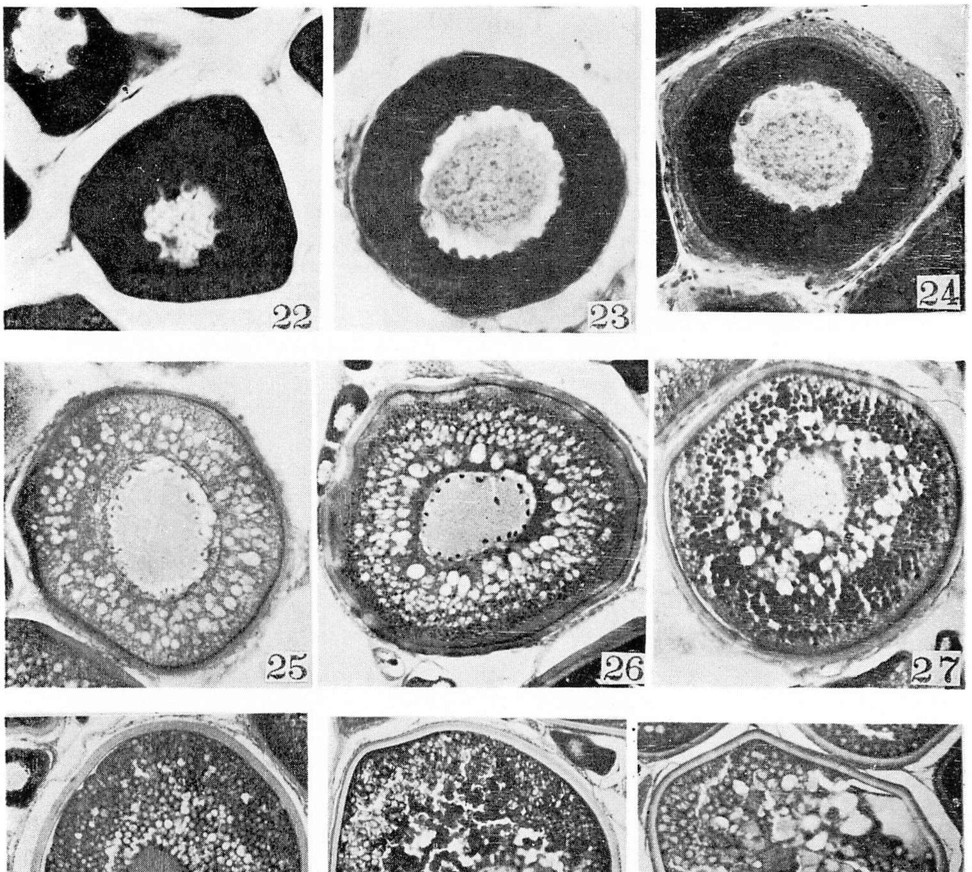


Plate VI

Microphotographs of cross sections of testes.

Explanation of figures

spg, spermatogonium ; tec, testocoel

teb, a branch of the testocoel

Fig. 31 The testis of a fish, 85mm. in fork length, having a small number of spermatogonia and a slit-like testocoel. ×600

Fig. 32 The testis of a fish, 105mm. in fork length. ×150

Fig. 33 An enlarged photograph of Fig. 32, showing spermatogonia surrounded by stroma cells. ×1000

Fig. 34 The testis of a fish, 135mm. in fork length. ×150

Fig. 35 An enlarged photograph of Fig. 34, showing the testocoel and its branches. ×600

Plate VI

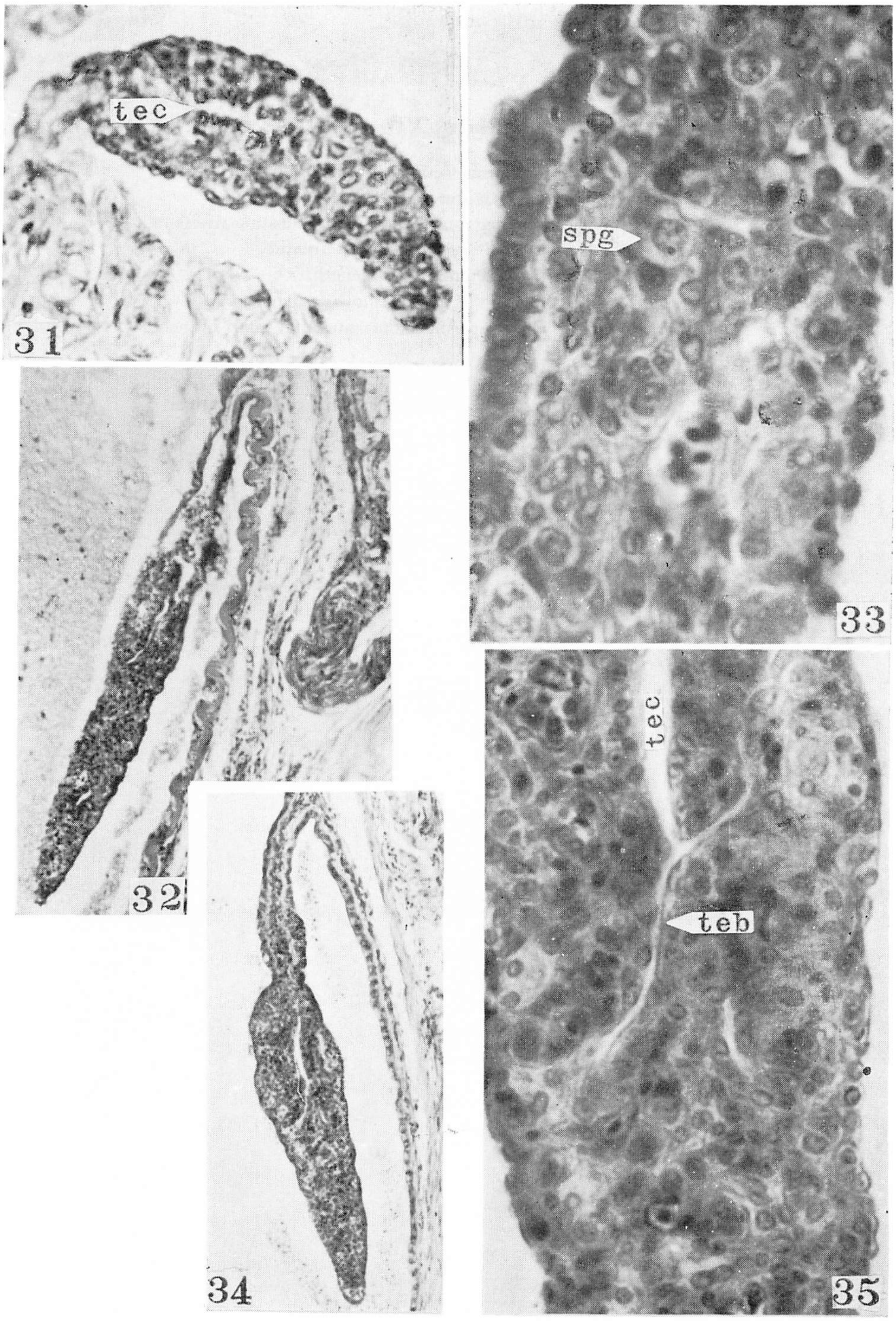


Plate VII

Microphotographs of cross sections of testes.

Explanation of figures

seg, secondary spermatogonia ; fmd, first maturation division smd, second maturation division ; tid, spermatid

Fig. 36 The testis of the fish, 220mm. in fork length. ×60

Fig. 37 An enlarged photograph of Fig. 36, showing many large spermatogonia. These spermatogonia surround small branches of the testocoel. ×600

Fig. 38 The testis of a fish, 285mm. in fork length. ×28

Fig. 39 An enlarged photograph of Fig. 38, showing the maturation divisions. ×600

Plate VII

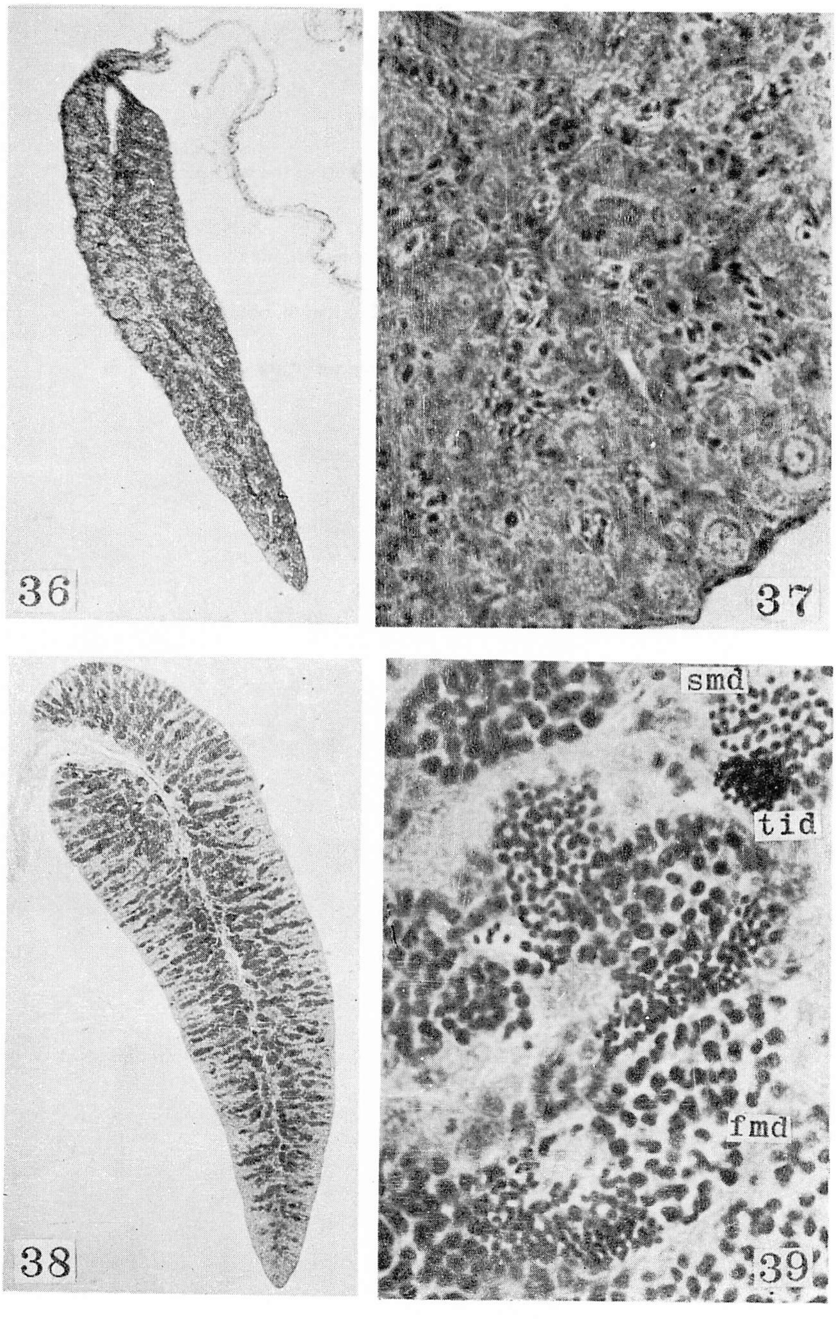


Plate VIII

The gonads of adult spotted mackerels in the spawning season.

Explanation of figures

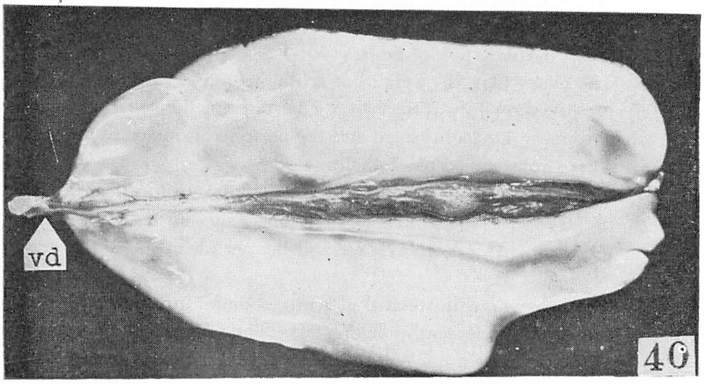
ov, oviduct ; vd, vas deferens

Fig. 40 The testis of a fish, 340mm. in fork length, obtained on April 10th, 1964.

Fig. 41 The ovary of a fish, 335mm. in fork length, obtained on April 10th, 1964.

Fig. 42 An enlarged photograph of the interior of the ovary shown in Fig. 41.

Plate VIII



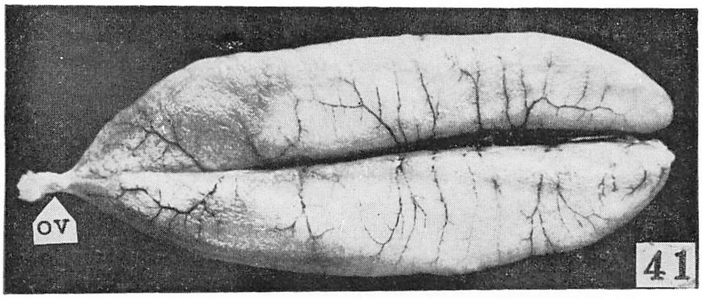


Plate IX

Microphotographs of cross sections of the ovaries of adult fish, 340~415mm. in fork length.

Explanation of figures

Fig. 43 The ovary (3gr. in weight) of a fish, 360mm. in fork length, preserved on July 18th, 1964. The stages of the oocytes are at the chromatin nucleolus stage and the peripheral nucleolus stage. There are some empty follicles. ×28

Fig. 44 The ovary (2gr. in weight) of a fish, 346mm. in fork length, preserved on August 22nd, 1964. The stages of the oocytes are at the chromatin nucleolus stage and the peripheral nucleolus stage. ×28

Fig. 45 The ovary (2gr. in weight) of a fish, 350mm. in fork length, preserved on September 20th, 1964. The stages of the oocytes are at the chromatin nucleolus stage and the peripheral nucleolus stage. ×28

Fig. 46 The ovary (3gr. in weight) of a fish, 360mm. in fork length, preserved on October 29th, 1964. The stages of the oocytes are at the chromatin nucleolus stage and the peripheral nucleolus stage. ×28

Fig. 47 The ovary (3gr. in weight) of a fish, 365mm. in fork length, preserved on November 18th, 1964. The stages of the oocytes are at the chromatin nucleolus stage and the later peripheral nucleolus stage ×28

Fig. 48 The ovary (12gr. in weight) of a fish, 360mm. in fork length, preserved on December 26th, 1964. ×28
Various stages of oocytes are observed, namely, the chromatin nucleolus stage, the peripheral nucleolus stage, the yolk vesicle stage and the early yolk globule stage.

Plate IX

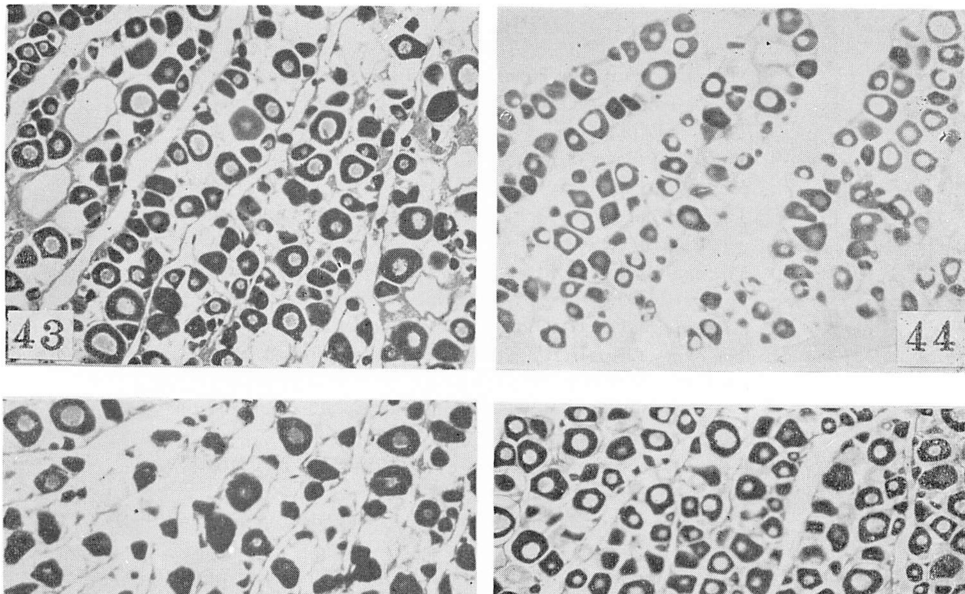


Plate X

Microphotographs of cross sections of the ovaries of adult fish in the spawning season.

Explanation of figures

Fig. 49 The ovary (35gr. in weight) of a fish, 380mm. in fork length, preserved on January 18th, 1964. ×28
There are large oocytes in late yolk-globule stage and many oocytes in early stages.

Fig. 50 The ovary (50gr. in weight) of a fish, 370mm. in fork length, preserved on February 15th, 1964, containing oocytes at the migrating nucleus stage and earlier stages. ×28

Fig. 51 The ovary (75gr. in weight)of a fish, 388mm. in fork length, preserved on March 20th, 1964. ×28
There are many oocytes at the late yolk globule stage and the migrating nucleus stage.

Fig. 52 The ovary (60gr. in weight) of a fish, 365mm. in fork length, preserved on April 15th, 1964. ×28
The stages of the oocytes are at the late yolk globule stage and the migrating nucleus stage.

Fig. 53 The ovary (46gr. in weight) of a fish, 360mm. in fork length, preserved on May 22nd, 1964. The stages of the oocytes are at the late yolk globule stage and the migrating nucleus stage. ×28

Fig. 54 The ovary (20gr. in weight) of a fish, 360mm. in fork length, preserved on June 13rd, 1964. The stages of the oocytes are as the same as in Fig. 53. ×28

Plate X

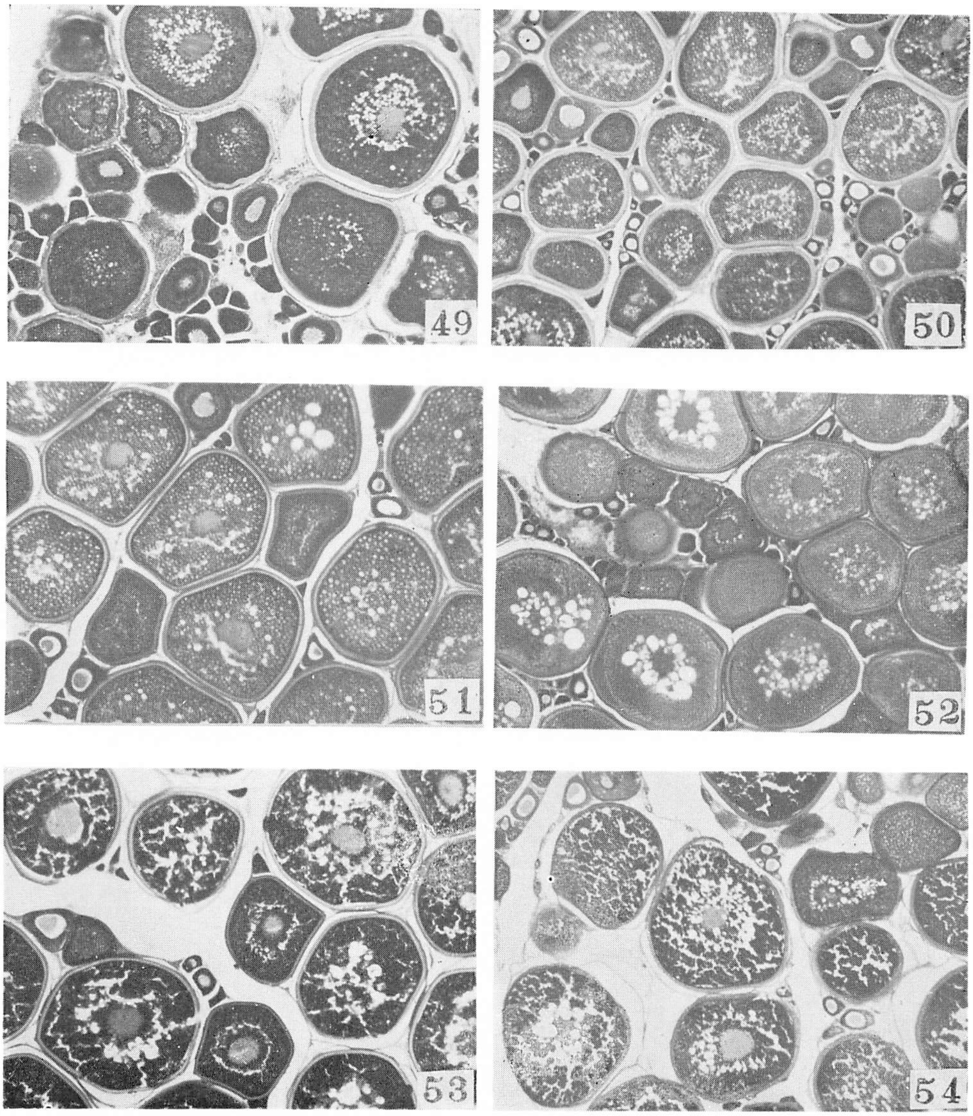


Plate XI

Microphotographs of cross sections of ovaries.

Explanation of figures

Fig. 55 The ovary of a fish, 380mm. in fork length, preserved on January 28th, 1964. having an empty follicle. ×100

Fig. 56 The ovary of a fish, 350mm. in fork length, preserved on February 20th, 1964, having two empty follicles. ×100

Fig. 57 The ovary of a fish, 365mm. in fork length, preserved on July 10th, 1964, having oogonia in the periphery of a lobe. ×1500

Fig. 58 The ovary of a fish, 380mm. in fork length, preserved on June 20th, 1964, having oogonia at the base of a lobe. ×1500

Fig. 59 The ovary of a fish, 350mm. in fork length, preserved on July 10th, 1964, having degenerating oocytes and empty follicles. ×40

Fig. 60 The ovary of a fish, 380mm. in fork length, preserved on June 22nd, 1963, having a degenerated oocyte. ×40

Plate XI

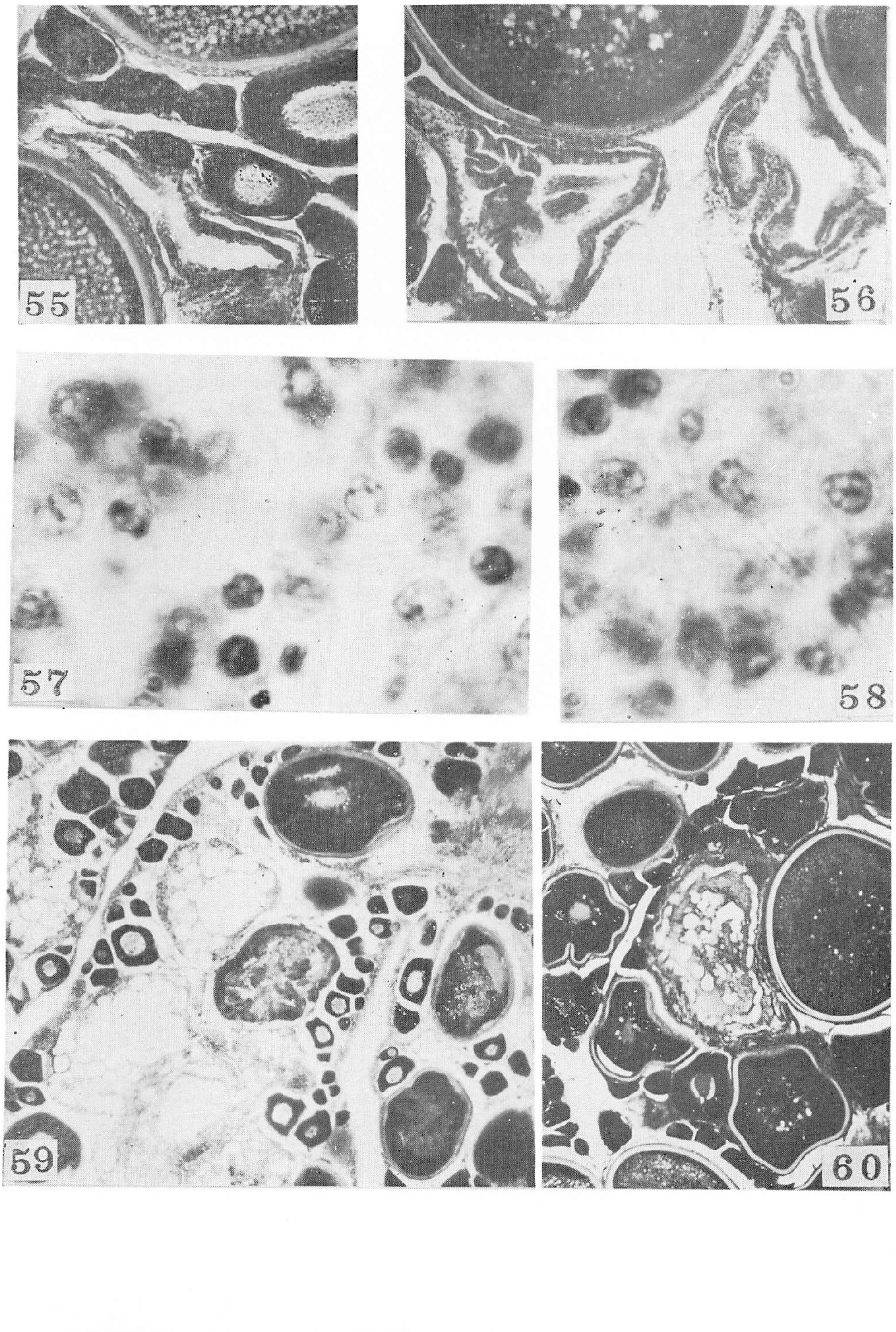


Plate XII

Microphotographs of cross sections of testes.

Fig. 61 The testis of a fish, 360mm. in fork length, preserved on June 18th, 1964, showing swollen cyst walls. ×28
Seminiferous tubules are filled with spermatozoa and their walls are somewhat hypertrophied.

Fig. 62 An enlarged photograph of Fig. 61 showing primary spermatogonia (psg) lodged along the wall of a seminiferous tubule. ×600

Fig. 63 The testis of a fish, 365mm. in fork length, preserved on July 10th, 1964, having newly formed seminiferous tubules. ×150

Fig. 64 An enlarged photograph of a part of seminiferous tubules shown in Fig. 63. There are multiplied spermatogonia. ×600

Fig. 65 A lobe in the testis of a fish, 342mm. in fork length, preserved on July 21st, 1963, having the lobe is closely packed with newly formed seminiferous tubules. ×28

Fig. 66 An enlarged photograph of a part of the lobe shown in Fig. 65. The spermatogonia are at their growing stage. ×600

Plate XII

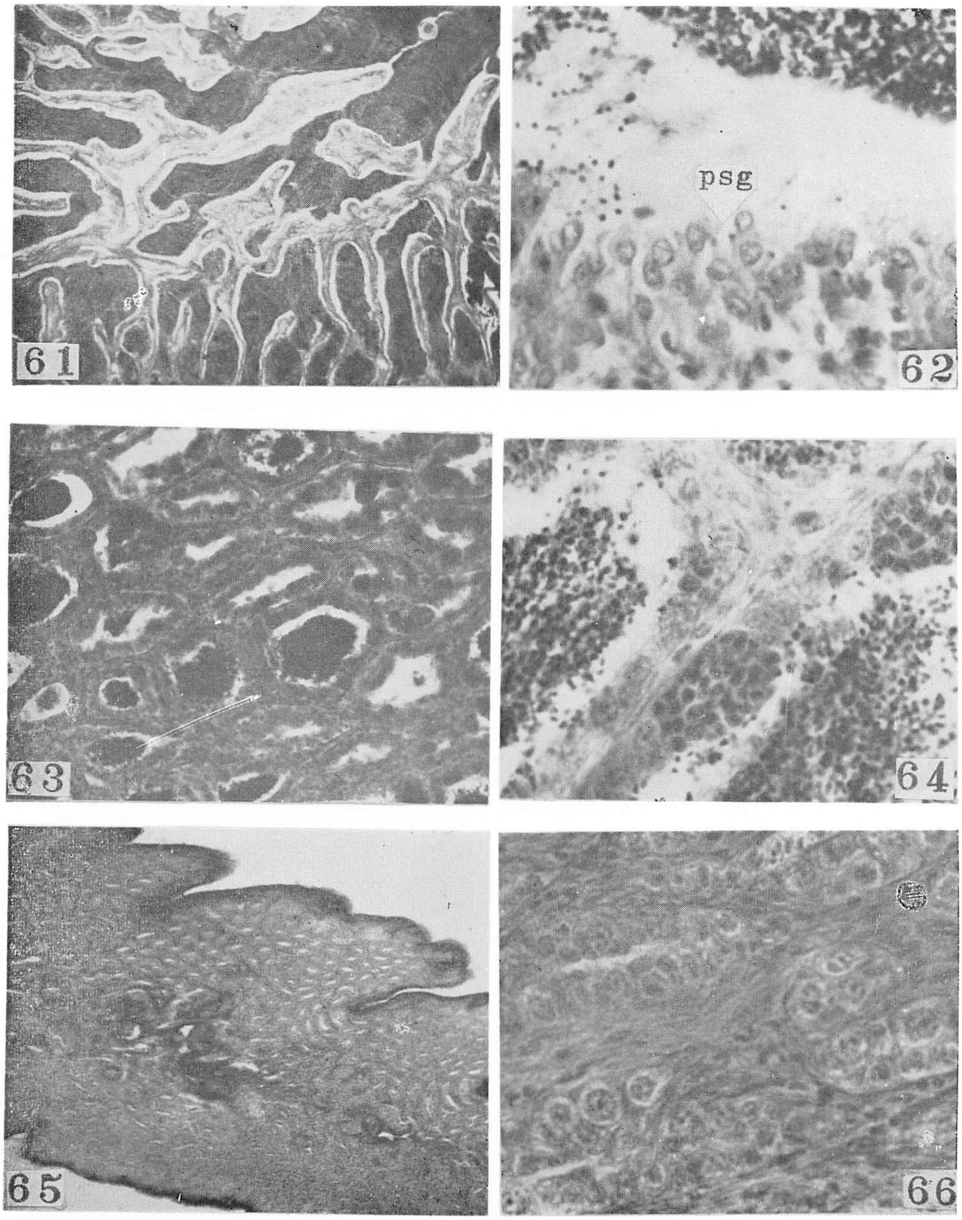


Plate XIII

Microphotographs of cross sections of testes

Explanation of figures

Fig. 67 The testis of a fish, 352mm. in fork length, preserved on Sept. 24th, 1963, showing the rete apparatus (ra) in the center part of the testis.

Fig. 68 An enlarged photograph of a part of the testis shown in Fig. 67. Spermatogonia are arranged along the walls of seminiferous tubules. ×600

Fig. 69 The testis of a fish, 346mm. in fork length, preserved on August 20th, 1963, showing spermatogonia arranged along the walls of seminiferous tubules. ×600

Fig. 70 The testis of a fish, 350mm. in fork length, preserved on October 21st, 1963, showing two small masses of multiplied spermatogonia. ×600

Fig. 71 The testis of a fish, 380mm. in fork length, preserved on November 19th, 1964, showing the rete apparatus and seminiferous tubules. ×28

Fig. 72 An enlarged photograph of a part of the testis shown in Fig. 71. There are some masses of multiplied spermatogonia. ×600

Plate XIII

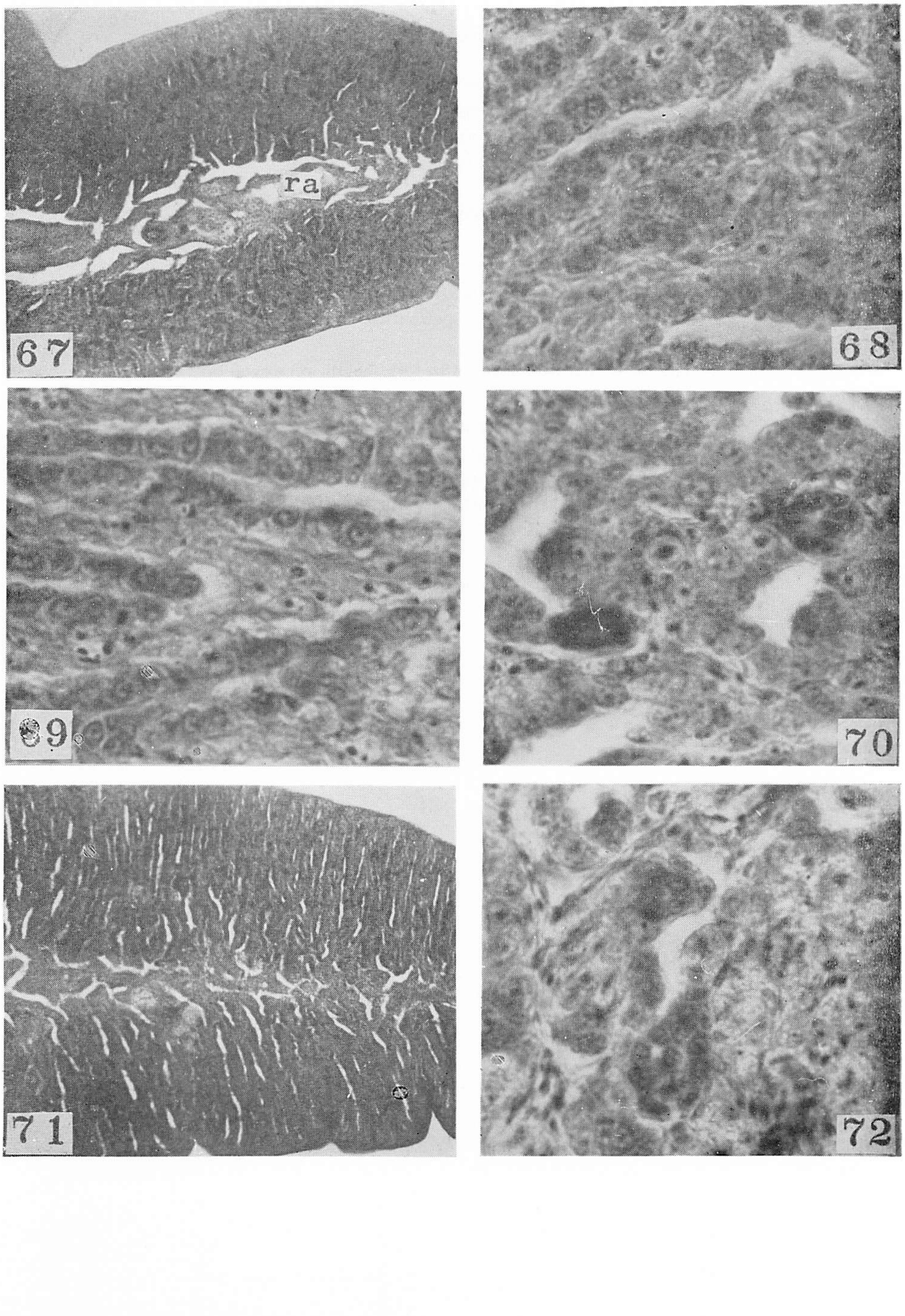


Plate XIV

Microphotographs of cross sections of testes

Explanation of figures

Fig. 73 The testis of a fish, 365mm. in fork length, preserved on December 22nd, 1964, seminiferous tubules and collecting ducts are filled with spermatozoa. ×28

Figs. 74～77 Enlarged photographs of a part of the testis shown in Fig. 73. ×600

Fig. 74 First spermatocytes, spermatids and spermatozoa.

Fig. 75 First and second spermatocytes and spermatids (tid).

Fig. 76 Second spermatocytes and spermatids.

Fig. 77 Spermatozoa.

Fig. 78 The testis of a fish, 362mm. in fork length, preserved on February 20th, 1964, showing the rete apparatus filled with spermatozoa and seminiferous tubules in which spermatogenesis is actively taking place. ×28

Fig. 79 The testis of a fish, 380mm. in fork length, preserved on April 15th, 1964. All the cavities are filled up with matured spermatozoa. ×28

Plate XIV