CRITERIA FOR THE DIFFERENTIATION OF MATURE AND IMMATURE FORMS OF CHUM AND SOCKEYE SALMON IN NORTHERN SEAS

by
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Fisheries Agency of Japan, January, 1961

I. INTRODUCTION

Accurate differentiation of mature and immature fish is one of the most important problems in the study of the ecology and life history of a fish species, particularly when considering the reproduction of the species.

For salmon found in the northern seas, Ishida and Miyaguchi (1958) studied the above problem using the seasonal changes in gonad weight, and Godfrey (1959) and Takagi (1961) made further studies, using a maturity index [(gonad weight/body weight) × 100] and also considering the age of the fish.

The authors of the present paper have studied this problem mostly by means of microscopic examination of histological sections.

Two conditions have to be met in this type of study: sampling should be on a year-round basis; and samples should be taken from the same stocks. The data and samples that can be collected from the northern seas for salmon species do not satisfy these requirements. Under the existing conditions of fishing, it is almost impossible to collect samples on a year-round basis. There are many stocks or groups of stocks for one species of salmon and the spawning seasons may differ greatly between the different groups. Strictly speaking, the spawning seasons of the different groups from which samples are taken must be known, in order to make accurate differentiation of mature and immature fish for salmon caught in offshore waters. Sufficient study has not been given to this question as yet.

In the present study, gonad samples of kokanee (land-locked sockeye) were taken from Lake Shikotsu throughout the year. Observations of the seasonal changes in the development of germ-cells of these samples, which were taken from a single stock through-out the year, gave us a basis for drawing inferences regarding the maturity of sockeye and chum salmon gonads. Although such inferences cannot be entirely correct, we feel that it is possible to determine, with considerable accuracy, whether or not a particular fish is a spawning fish of the season, by using the results of the study of the development of germ-cells of kokanee and some other fishes.

ACKNOWLEDGEMENTS

This study was made with the cooperation and assistance of many people in sampling and other phases of research. We are greatly indebted to the following inspectors and research officers for collecting samples of sockeye and chum salmon in northern seas on motherships and research vessels:

1958: Mr. Osamu Sano, Hokkaido Regional Fisheries Research Laboratory; inspector on the mothership Jinyo-maru.
Mr. Shunichi Nagata, Japan Sea Regional Fisheries Research Laboratory; research officer on the research vessel Wakashio-maru.

1959: Mr. Osamu Sano, Hokkaido Regional Fisheries Research Laboratory; inspector on the mothership Koyo-maru.
Mr. Masanao Oseko, Hokkaido Regional Fisheries Research Laboratory; research officer on the research vessel Kano-maru.
Mr. Sho Morita, Hokkaido Regional Fisheries Research Laboratory; research officer on the research vessel Wakashio-maru.
Mr. Nobuyuki Nakayama, Hokkaido Provincial Fisheries Research Station; research officer on the research vessel Wakashio-maru.
Mr. Kiichi Miyaguchi, Hokkaido Provincial Fisheries Research Station; research officer on the research vessel Hokusai-maru.

1960: Mr. Tamotsu Yonemori, Hokkaido Regional Fisheries Research Laboratory; research officer on the research vessel Etsuzan-maru.

The authors also wish to express deep appreciation to Mr. Arai, Director of the Hokkaido Salmon Hatch-
ery, Mr. Shibata, the former Chief of the Chitose Branch of the Hatchery and Mr. Ishikawa, present Chief of the same branch, for permission to collect gonad samples from the kokanee caught at the Lake Shikotsu Station of that branch; to Mr. Shozo Sasaki, Chief of the Shikotsu Station, and Messrs. Kikui Endo and Shunzo Abe, staff members of the Station, for fishing kokanee and assisting in sampling gonads; and to Mr. Takashi Kurohagi, Hokkaido Salmon Hatchery, for collaborating in sampling and measuring of kokanee.

Dr. Kiichiro Yamamoto, Professor, Faculty of Fisheries of the Hokkaido University, guided the authors in the study and also allowed them to use his histological sections and egg measurement data for sockeye and kokanee.

II. MATERIALS AND METHODS

In 1958, materials were collected from the mothership Jinyo-maru and the research vessel Wakashio-maru, operating in waters off East Kamchatka; in 1959, from the mothership Koyo-maru and the research vessel Wakashio-maru, operating in waters off East Kamchatka, the Wakashio-maru, operating in waters south of 48°N., and the Hokusei-maru of Hokkaido University, operating in Okhotsk Sea waters; and in 1960, from the research vessel Etsuzan-maru, operating in waters off East Kamchatka. Most of the materials used in the present study, however, were collected from motherships in 1958 and 1959. In 1958, gonad samples were collected from ten specimens (six females and four males) each of sockeye, chum and pink salmon taken at ten day intervals, and in 1959, from twenty specimens each of chum and sockeye salmon taken at ten day intervals and random numbers of pink salmon. The period of sampling was from mid-May to early August in 1958 and from late May to mid-July in 1959. Sampling on research vessels was only from female fish in 1958 and, in 1959, it was selective for female gonads of 10–30 g.; particularly around 20 g., and male gonads of less than 5 g. The results obtained in 1958 indicated that these gonad sizes were critical for distinguishing mature and immature fish. For studying the characteristics of the development of germ-cells of Oncorhynchus, the kokanee (land-locked sockeye) of Lake Shikotsu were sampled once or twice a month (10–40 fish each time) during the period from April, 1958, to December, 1959; except during January and February, 1959, when sampling was not possible.

The gonads thus collected were fixed mostly by Bouin's solution and partly by 10% formalin. Car- noy's solution, Zenker's solution, Flemming's strong solution and Levi's solution were also used for the kokanee of Lake Shikotsu.

The sections of testes were prepared by the paraffin method. Most of the ovaries were sectioned by the celloidin method, but those smaller than 20–30 g. were sectioned by the paraffin method. The thickness of a section was 3–8 microns for testes, 20–40 microns (mostly 30 microns) for the celloidin sections of ovaries, and 8–10 microns for the paraffin sections of ovaries.

Staining of testes sections was done mostly by a double-staining method using Heidenhain's iron-hematoxylin and light-green. In 1958, a double-staining method using Heidenhain's iron-hematoxylin and eosin and also Mallory's triple-staining method were tried, but the latter method did not give good results. Double staining with Heidenhain's iron-hematoxylin and light-green was also used for ovaries, but Mallory's triple-staining method was used for most celloidin sections. Mallory's method gave excellent results in this case in contrast with the poor results in staining testes.

For more accurate distinction of the various stages of development of oocytes, such cytochemical methods as Hotchkiss-McManus' method, Lillie's method and a double-staining method with fuchsin sulfite and 2–4 dinitrophenylhydrazine were sometimes used, together with the commonly used staining methods mentioned above.

Measurement of egg diameter was made using part of the gonad samples collected for histological observations. Therefore, nearly all of the eggs measured had been preserved in 70% alcohol after fixing with Bouin's solution. Eggs were measured along a diameter parallel to the scale of a micrometer, as proposed by Clark (1934). In Oncorhynchus, too, some extremely small eggs are observed. The eggs of species of this genera, however, seem to develop in complete synchronism (synchronisme total), as pointed out by Yamamoto and others (1959) for masu salmon. Also, histological observations indicate that these small eggs are destroyed and absorbed in the course of the development of the ovaries. Accordingly, these eggs were excluded from measurement. The number of eggs measured per fish was 30–60 in 1958, and 20 in 1959; only 10 eggs per fish were measured by Professor Yamamoto. Although the numbers of eggs measured may seem to be insufficient, the average diameters obtained from them were not greatly different from those determined by Takagi (1961), for some samples, through measurement of all eggs in ovaries. Therefore, measurement data from limited numbers of eggs were considered usable for determining general
III. RESULT AND DISCUSSION

A. FEMALES

1. Development of Oocytes (Eggs)

It is necessary to have certain criteria for indicating the degree of development of ovaries, or so-called maturity, according to the morphological changes of oocytes\(^1\) observed by histological methods. There are various descriptions of such criteria by different authors, but the method of division used by Yamamoto (1954 and 1956) for *Liopsetta obscura*, and by Yamamoto and others (1959) for *Oncorhynchus masou*, seems to be most appropriate and is used by the present authors.

The morphological changes of the eggs of various species of genus *Oncorhynchus* are, in general, very similar, as shown in Plate I, although there are some differences in detail between species. It is noted that even very small and apparently immature sockeye and chum (about 30 cm. in fork length and 400–600 g. in weight) caught in northern seas in the marine period of their life, have eggs at least as advanced as the yolk vesicle stage. Also, not only the salmon caught in northern seas, but also those found in coastal waters, do not seem to have eggs developed beyond the migratory nucleus stage. For example, the autumn chum salmon sampled in the coastal waters of Hokkaido immediately before their entrance into streams had gonad weights of 750–1050 g., which were about the same or even greater than those of fully ripe females collected at the Nishikoshi Catching Station of the Chitose Branch of the Hokkaido Salmon Hatchery, but their eggs were still at the migratory nucleus stage (Plate I–11 and 12). This indicates that the prematuration stage and more-advanced stages are reached only after salmon have entered streams. For the above reasons, our description of egg development covers the period from the yolk vesicle stage to the migratory nucleus stage.

i. *Yolk Vesicle Stage*. Eggs at this stage show yolk vesicles in the ooplasm, and yolk vesicles are the only yolk material that can be observed. Even young fish of about 30 cm. caught in northern seas show fairly well developed yolk vesicles which almost fill the ooplasm. Yolk vesicles are only slightly stained by hematoxylin, but they are strongly positive in the PAS reaction, and are stained in beautiful bluish purple by Mallory’s method. At the beginning of this stage, the nucleus is spherical with a smooth outline, and nucleoli, which are strongly stained by either hematoxylin or Mallory’s method, are observed in the nucleus along its periphery. So-called “lamp-brush” chromosomes are also visible. The outline of nucleus becomes less smooth near the end of this stage. The proportion of nucleus in the ooplasm becomes smaller as the egg becomes larger, but the actual size of the nucleus does not change greatly from this stage through the migratory nucleus stage. A thin layer of zona radiata begins to appear between the egg and the follicle layer.

At this stage, individual eggs are already clearly recognizable to the naked eye from the outside. The egg diameter is generally less than 1.0 mm., mostly 0.5–0.8 mm., for both sockeye and chum salmon (Figure 4); the ovary weight is 1–4 g. for sockeye and 5–7 g. for chum (Figure 2); and the maturity index is 0.33–0.83 for sockeye and 0.60–0.88 for chum (Figure 3). In the samples, all fish with eggs at this stage were small in size and apparently immature; 27.0–37.0 cm. in fork length and 300–600 g. in weight for sockeye, and 38.0–44.0 cm. in fork length and 600–1000 g. in weight for chum. The sockeye were one or two-ocean-year fish and the chum were three years old. (Plate I–1.)

ii. *Oil Globule Stage*. As pointed out by Yamamoto and others (1959) for masu salmon, the development of salmon eggs differs in yolk formation from flounder eggs, such as *Liopsetta obscura* (Yamamoto, 1954 and 1956) and *Hippoglossoides dubius* (Ishida, 1955). In salmon eggs, oil globules are formed in the ooplasm, particularly around the nucleus, before the appearance of yolk globules; and they increase to surround the nucleus. This stage is called the oil globule stage.

The egg diameter increases at this stage, being 1.0–1.7 mm. for sockeye and 1.1–1.6 mm. for chum (Figure 4); the ovary weight is larger than 5 g. for both species, mostly 10–15 g. (Figure 2); and the maturity index is approximately 0.6–1.0 for both species (Figure 3).

Yolk vesicles occupy the outer part of the ooplasm and are somewhat larger than at the previous stage. Oil globules occupy the inner part of the ooplasm, surrounding the nucleus, and they increase in number and size as the stage progresses. The nucleus is approximately in the center of the egg, with an irregular polyhedral shape, and strongly stained nucleoli are seen along its borderline. The zona radiata increases in thickness and becomes clearer. (Plate I—2 and 3.)

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\(^1\) Called simply “eggs” in the following paragraphs.
iii. **Primary Yolk Stage.** This is the period in which yolk globules appear in the ooplasm. Yolk globules begin to appear in the outer part of the ooplasm as very small granules, and they are stained in heavy blue-black by hematoxylin and in red by Mallory's method (Plate I—4). Thereafter, yolk globules also occur in the inner part of the egg, and they gradually increase in size. Oil globules, which were distributed around the nucleus in a circle at the previous stage, begin to scatter in the ooplasm. The nucleus is situated near the center in most cases, but it has slightly shifted from the center in a very few eggs. Its shape is a star-like polyhedral. Nucleoli are still clearly recognizable, but most of them are scattered in the nucleus instead of being distributed along its periphery as in the previous stage.

The zona radiata continues to thicken and radial striations also become recognizable. The cells of the follicular epithelium surrounding the zona radiata increase in size (Plate I—4, 5 and 6).

The egg diameter, gonad weight and maturity index further increase, being 1.9–2.4 mm., 17–35 g., and 1.25–1.75, respectively, for sockeye; and 1.8–2.0 mm., 18–30 g., and 0.9–1.6, respectively, for chum (Figures 2–4). Chum salmon show slightly smaller values in all of these measurements.

iv. **Secondary Yolk Stage.** This stage covers the period in which yolk globules develop further and occupy the greater part of an egg, pushing yolk vesicles and oil globules out toward the periphery. Particularly, the yolk vesicles are arranged in a thin layer along the periphery toward the end of this stage. One or two rows of small yolk globules are still observed in the outer part of the egg. Yolk globules in the inner part of the egg have become particularly large and have increased in number. On rare occasions, extremely large yolk globules are formed by fusion. The oil globules which were observed around the nucleus at the previous stage have largely disappeared and the inner part of the egg is filled with yolk globules. Mallory's staining method colours the yolk globules around the nucleus dark red and the outer yolk globules red. The nucleus is still in the center of the egg in most of the ovaries at this stage and is an irregular star-like polyhedron. Nucleoli are still clearly recognizable. (Plate I—7, 8 and 9.)

The egg diameter, gonad weight and maturity index, as well as their ranges of variation, increase, being approximately 2.3–2.9 mm., 33–70 g., and 1.75–3.20, respectively, for sockeye; and 2.3–3.1 mm., 26–55 g., and 1.50–3.20, respectively, for chum. It is noted that at this stage the range of gonad weight is much greater for sockeye salmon than for chum salmon (Figures 2–4).

v. **Tertiary Yolk Stage.** Yolk globules continue to increase in number and size; yolk vesicles are pushed further toward the periphery of the egg, forming a very thin layer of one or two rows of vesicles; and the small yolk globules that existed at the last stage have almost disappeared. In gross examination, accordingly, the egg appears to be almost filled with yolk globules, except for a small nucleus. Mallory's stain colours both outside and inside yolk globules an almost identical red. The nucleus is still centered in most eggs, but a slight shift from the center is apparent in some eggs. Yolk globules are small around the nucleus and increase in size toward the outer part. Sometimes adhesion is observed among the outer yolk globules. (Plate I—10.)

The egg diameter, ovary weight and maturity index, as well as their ranges, increase. They are ap-

![Figure 1](https://example.com/figure1.png)

**Figure 1.** Chronological changes, by ten-day periods, in the degree of maturation and ovary weight for the kokanee of Lake Shikotsu.
proximately 2.9–3.3 mm., 75–110 g., and 3.0–4.6, respectively, for sockeye; and 3.0–4.0 mm., 60–120 g., and 2.5–6.0, respectively, for chum. Sockeye salmon, which previously showed smaller values than chum salmon in these measurements, begin to show larger values at about this stage. Particularly, their ranges of variation are much greater in sockeye. (Figures 2–4.)

vi. Migratory Nucleus Stage. This stage is characterized by the migration of the nucleus toward one pole. The nuclei in migration can be distinguished from the nuclei at the previous stage. They are nearly hemispherical and are surrounded by very small yolk globules; in particular, the yolk globules found in the path of migration of the nucleus are extremely small. Most of the yolk globules, particu-

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**Figure 2.** Relationships between the degree of maturation and ovary weight for the sockeye and chum salmon of northern seas.

**Figure 3.** Relationships between the degree of maturation and maturity index (ovary weight/body weight × 100) for the sockeye and chum salmon of northern seas.
larly those in the outer part of the egg, adhere to each other. Yolk vesicles are present along the periphery in a layer even thinner than at the previous stage.

The egg diameter, ovary weight and maturity index increase greatly, and their ranges of variation are also very great. They are 3.5–4.5 mm., 145–325 g., and 6.0–12.5, respectively, for sockeye; and 4.2–5.8 mm., 120–590 g., and 6.5–24.58, respectively, for chum. Wide ranges of variation are notable in all these measurements. (Figures 2–4.) Due to restrictions on the fishing period and fishing grounds, samples were not obtained from salmon immediately before they entered the streams.

2. Results
i. **Kokanee**.

The histological changes in the ovarian eggs of kokanee and corresponding changes in their gonad weights are shown in Figure 1 by ten-day periods. The figure indicates the rate of development of kokanee eggs. As shown in the figure, the fish which are expected to spawn within the year (almost all four-year-olds in 1958 and 1959 and mostly four-year-olds and partly five-year-olds in 1960) have eggs as advanced as the oil globule stage as much as six to seven months before the spawning season. The length of time between the oil globule stage and actual spawning is at least five months even for the most rapidly developing ovaries. The length of time between the primary yolk stage and spawning is four to six months. Most of the fish whose eggs have reached the secondary yolk stage would be ready for spawning after three to four months; those whose eggs have reached the tertiary yolk stage would spawn after two to three months; and those whose eggs have reached the migratory nucleus stage seem to spawn in about one month.

Unusually large numbers of three and four-year-old kokanee, which were not expected to spawn in the year, were caught in November and December, 1960. Only part of these fish have been examined so far, but some results are shown in the same figure. Practically all of them had eggs at the oil globule stage, and their gonad weights were less than 2 g., mostly less than 1 g. Also, a few fish caught during the period from late July to late September had eggs at the yolk globule stage (gonad weight less than 2 g.), and these fish did not seem to be spawning fish of the season, judging from the rate of development of eggs indicated in the figure.

The above findings suggest that kokanee reach the yolk globule stage at least twelve months before spawning, and some of them reach the same stage much earlier.

Three of the immature kokanee caught in mid-November had a gonad weight of 2.4 g., and these ovaries were difficult to distinguish, by appearance and weight alone, from those at the primary yolk.
stage. One of them showed a trace of yolk globule formation near the periphery of the egg. The largest ovary sample collected in December had a weight of 3.6 g., and the weight and appearance of the ovaries indicated that they were at the primary yolk stage, although no histological observations have been made as yet. These findings suggest that in Oncorhynchus, also, some immature fish may have eggs as far advanced as the primary yolk stage, as pointed out by Hickling (1930) in his study of hake.

ii. Sockeye and Chum

a. Results of histological observations.

The period of stream migration of sockeye varies considerably from stream to stream. Most of the sockeye salmon bound for the U.S.S.R. coast and fished by Japanese vessels in offshore waters enter streams during the period from June through August, and the latest runs occur in September and October. Sockeye spawn in lakes or lake tributaries after a period of over a month from their entrance into the streams. Accordingly, the main spawning season of this species is considered to be July through September, and the latest spawning might occur in November.

The spawning season of chum salmon is more complicated, because chum salmon consist of summer chum and autumn chum. It is generally considered that the spawning season of summer chum is June through September and that of autumn chum is September through November.

In summary, the spawning season of sockeye and chum salmon extends from June through November; however, except for autumn chum salmon, spawning occurs mostly in July through September, and the latest spawning takes place around November.

For the chum salmon caught in the sea, the most advanced stage of egg development has been the migratory nucleus stage. This is true not only for chum salmon collected from the northern seas, but also for those which are caught presumably immediately before their entrance into streams. The same conclusion cannot be drawn for sockeye, because no sockeye gonad samples were obtained from coastal waters. However, for the sockeye collected from northern seas during the period of the present study, the most advanced stage of egg development was the migratory nucleus stage. Also, the length of time spent by sockeye in fresh water before spawning is generally longer than that for chum, being longer than one month. For these reasons, it is believed that the ovarian eggs of sockeye, too, do not reach stages beyond the migratory nucleus stage during the marine period of their life.

Fishing by Japanese vessels begins in mid-May or late May. It is approximately two to three months before the entrance of salmon into streams, three to four months before their spawning, and five to six months before the latest spawning. Their eggs reach the migratory nucleus stage by the time of their entrance into the streams and the maturation stage by the time of spawning. If we apply the rate of gonad development of kokanee and masu salmon to sockeye and chum in the ocean, all fish that are caught in May and whose eggs are at the secondary yolk stage or more advanced stages will have eggs as advanced as the migratory nucleus stage and the maturation stage within the above periods of time. Also, fish whose eggs are at the primary yolk stage in May may be considered spawning fish of the year, because the length of time required from this stage to the migratory nucleus stage is two to four months and that from this stage to the maturation stage is five to six months. The above inferences are endorsed by the following fact. Although the eggs of immature fish may reach the primary yolk stage, this does not happen until approximately a year before their spawning, i.e., about the spawning period of the previous year. Particularly in the case of kokanee, this stage is reached only during the latter part of the spawning season a year before. Hence, all fish whose eggs have reached the primary yolk stage or more advanced stages by late May may be considered spawning fish of the year. As mentioned before, it is obvious that the eggs of immature kokanee reach the oil globule stage. Some small and apparently immature sockeye salmon caught in northern seas (fork length, 31.5 cm., gonad weight, 4 g.; fork length 40.0 cm., weight, 640 g., gonad weight, 5 g.) had eggs at the oil globule stage. It is therefore believed that even the immature fish of genus Oncorhynchus have eggs as advanced as this stage. However, kokanee seem to develop from the latest part of the oil globule stage to the migratory nucleus stage and the maturation stage in three or four months and five or six months, respectively. It is therefore possible that the fish with eggs at the late oil globule stage in May might be spawning fish of the year, particularly if such fish belong to late-spawning stocks. Nothing definite can be said on this question.

On the other hand, all fish whose eggs are at the yolk vesicle stage must be considered immature, even if they are caught in the earliest part of the fishing season. As mentioned above, some obviously immature salmon have eggs as advanced as the oil
globule stage, and immature kokanee have reached the oil globule stage by about the spawning period a year before. Among the salmon actually sampled at sea, those with eggs at the yolk vesicle stage were 27–37 cm. in fork length and 300–600 g. in weight, and were undoubtedly immature fish.

Approximately the same criteria may be applied to the salmon caught in June. All fish having eggs at the secondary yolk stage or beyond and most of the fish having eggs at the primary yolk stage may be considered spawning fish of the year. However, the fish which belong to early-spawning stocks and whose eggs are in the early part of the primary yolk stage in June are subject to doubt. Judging from the studies on kokanee, the salmon whose eggs are at the oil globule stage at this time of the year are not likely to be spawning fish of the year, except for those belonging to the stocks which spawn in November or later.

All fish whose eggs are at the secondary yolk stage in July are assumed to be spawning fish of the year. The study of kokanee indicates that their eggs develop from this stage to the migratory nucleus stage in one or two months. Also, it is generally believed, for kokanee and many other species, that immature fish (non-spawning fish of the year) do not reach the secondary yolk stage. It takes two to three months for eggs to develop from the primary yolk stage to the migratory nucleus stage, and four to five months from the primary yolk stage to the spawning stage. Therefore, the fish whose eggs are at the primary yolk stage in July are unlikely to participate in spawning in the same year, unless they belong to late-spawning stocks. On the other hand, few immature fish have eggs at the primary yolk stage, as mentioned previously, and in kokanee this stage is reached by some immature fish only during the latter part of the spawning season a year before their spawning. Immature fish of other species may reach this stage, at the earliest, one or two months before the spawning season a year before. Hence, it seems that most of the fish whose eggs are in the latest part of the primary yolk stage in July will participate in spawning during the year.

The fish whose eggs are at the oil globule stage in July may be considered immature, except for those belonging to extremely late-spawning stocks.

For similar reasons, all fish whose eggs are at the secondary yolk stage in August may be considered mature; those whose eggs are at the primary yolk stage in August are even less likely to be spawning fish of the year than those whose eggs are at the same

<table>
<thead>
<tr>
<th>Category</th>
<th>A. Ovary weight in grams</th>
<th>B. Maturity Index</th>
<th>C. Egg diameter in mm.</th>
<th>Stage</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Definitely mature&quot;</td>
<td>40 and above</td>
<td>2.1 and above</td>
<td>2.5 and above</td>
<td>Secondary yolk stage or more advanced</td>
<td>In A: Two samples weighing 33 g. each were at the secondary yolk stage. In B and C: About half of samples of these categories were at the secondary yolk stage.</td>
</tr>
<tr>
<td>&quot;Almost certainly mature&quot;</td>
<td>33-40</td>
<td>1.5-2.0</td>
<td>2.2-2.5</td>
<td>Primary yolk stage</td>
<td></td>
</tr>
<tr>
<td>&quot;May be considered mature if caught in the early part of the fishing season&quot;</td>
<td>18-33</td>
<td>1.0-1.5</td>
<td>1.6-2.2</td>
<td>Primary yolk stage</td>
<td>In A: One sample weighing 25 g. was at the secondary yolk stage. In B: One sample was at the oil globule stage.</td>
</tr>
<tr>
<td>&quot;Possibly mature if caught in the early part of the fishing season&quot;</td>
<td>10-15</td>
<td>0.7-1.0</td>
<td>1.0-1.6</td>
<td>Oil globule stage</td>
<td>In A: Two samples weighing 15 g. and 12 g. were at the primary yolk stage.</td>
</tr>
<tr>
<td>&quot;Almost certainly immature&quot;</td>
<td>5-10</td>
<td>0.6-0.7</td>
<td></td>
<td>Oil globule stage Yolk vesicle stage</td>
<td></td>
</tr>
<tr>
<td>&quot;Definitely immature&quot;</td>
<td>Less than 5</td>
<td>Less than 0.6</td>
<td>Less than 1.0</td>
<td>Yolk vesicle stage</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 1 (continued)

B. *Chum Salmon*

<table>
<thead>
<tr>
<th>Category</th>
<th>A. Ovary weight in grams</th>
<th>B. Maturity Index</th>
<th>C. Egg diameter in mm.</th>
<th>Stage</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Definitely mature&quot;</td>
<td>33 and above</td>
<td>1.9 and above</td>
<td>2.3 and above</td>
<td>Secondary yolk stage or more advanced</td>
<td>In A, B &amp; C: Samples were about equally divided between the primary and secondary yolk stages.</td>
</tr>
<tr>
<td>&quot;Almost certainly mature&quot;</td>
<td>26-33</td>
<td>1.45-1.9</td>
<td>2.1-2.3</td>
<td>Secondary yolk stage</td>
<td>In B: One sample with an index of 1.20 was at the oil globule stage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Primary yolk stage</td>
<td>In C: Two samples with egg diameters 1.9 mm. and 1.7 mm. were at the oil globule stage.</td>
</tr>
<tr>
<td>&quot;May be considered mature if caught in the early part of the fishing season&quot;</td>
<td>18-26</td>
<td>1.0-1.45</td>
<td>1.7-2.1</td>
<td>Oil globule stage</td>
<td>In A: Part of the samples weighing 15 and 16 g. were at the primary yolk stage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>In B: Mostly oil globule stage and partly primary yolk stage; a very small number of samples at the yolk vesicle stage were also included.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oil globule stage</td>
<td>In C: Part of the samples with egg diameters 1.4-1.6 mm. were at the primary yolk stage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.8-1.0</td>
<td>0.9-1.7</td>
<td>Yolk vesicle stage</td>
<td>In A: Samples weighed 5-7 g. and were equally divided between the two stages.</td>
</tr>
<tr>
<td></td>
<td>Less than 9</td>
<td>0.5-0.8</td>
<td>0.7-0.9</td>
<td>Yolk vesicle stage or less developed</td>
<td>In C: Only oil globule stage.</td>
</tr>
<tr>
<td>&quot;Almost certainly immature&quot;</td>
<td>Less than 5</td>
<td>Less than 0.5</td>
<td>Less than 0.7</td>
<td>Yolk vesicle stage or less developed</td>
<td></td>
</tr>
</tbody>
</table>

stage in July; but the fish which belong to late-spawning stocks and whose eggs are in the latest part of this stage might possibly participate in spawning.

Thus, it can be assumed that all fish whose eggs are at the secondary yolk stage or more advanced stages are spawning fish of the year.

Summarizing the above discussion:

1. All fish whose eggs are at the secondary yolk stage or more advanced stages are spawning fish of the year.

2. All fish whose eggs are at the primary yolk stage in the early part of the fishing season are also spawning fish of the year. It is also possible that fish whose eggs are in the latest part of the primary yolk stage in July or even later may participate in spawning during the year, if they belong to late-spawning stocks.

3. The fish whose eggs are in the latest part of the oil globule stage during the early part of the fishing season and which belong to late-spawning stocks may possibly become spawning fish of the year. However, the fish whose eggs are at this stage in June or later must not be spawning fish of the year, except for those belonging to the stocks that spawn in November or later. While the oil globule stage is reached by immature fish during the year preceding their spawning year, spawning fish of the year also have eggs at this stage until five or six months prior to spawning. It is therefore difficult to determine accurately, from the degree of egg development alone, whether or not fish with eggs at the oil globule stage will spawn during the year, when the spawning seasons of the stocks to which such fish belong.
are not accurately known.

b. Relationships between the degree of gonad development as determined by histological observations and ovary weight, maturity index and egg diameter.

The degree of gonad development as determined by the above histological observations is related to such measurements as ovary weight, maturity index and egg diameter in Figures 2, 3 and 4. An attempt to establish criteria for distinguishing mature and immature fish based on these figures and on the conclusions reached in (a) is made in Table 1.

B. MALES

In most cases the testes of an individual male fish consist of germ-cells of different stages of development. Since the germ-cells in testes are extremely small and numerous, it is difficult to determine the exact proportions of cells at different stages of development. Hence, maturity (the degree of gonad development) was determined by the germ-cells of the most advanced stage observed in the testes of an individual fish.

i. Kokanee.

Seasonal changes in testis weight and maturity of germ-cells in the testes of kokanee are shown in Figure 5. Until the end of April, even supposedly mature fish (spawning fish of the year) have only primary spermatogonia in the cysts of their testes, as in the case of immature fish. In late May, some fish begin to show secondary spermatogonia in the cysts. In late June, most fish have further developed germ-cells, i.e., spermatocytes, in addition to secondary spermatogonia, and no fish which are considered mature on the basis of size have only primary spermatogonia in their testes. Already in early July, some fish show spermatids in their testes; and in mid-July, some specimens even have spermatozoa. In August and later, all fish have testes at the spermatozoan stage.

Thus, once secondary spermatogonia begin to appear, testes develop very rapidly, reaching the spermatocyte stage in about a month and shifting from the latter stage to the spermatid stage and further to the spermatozoan stage in approximately another month.

The length of time required between each of these stages and actual spawning may be estimated from Figure 5. It is three to five months from the secondary spermatogonium stage to spawning, three to four months from the spermatocyte stage to spawning, and three months from the spermatid stage to spawning. However, since testes reach an advanced period of the spermatozoan stage, in which most of the germ-cells are spermatozoa, by August, which is two months before the main spawning period, i.e., October, it is assumed that they become ready for spermatism in somewhat shorter periods of time than mentioned above. Corresponding to the very rapid development of germ-cells after the appearance of secondary spermatogonia in testes, a very sharp increase in testis weight takes place.

Testes at the secondary spermatogonium stage are already considerably larger than those at the primary spermatogonium stage, the largest of the former is several times the latter in our samples. However, a remarkable increase in weight occurs after testes have reached the spermatocyte stage. Thus, the testes (of one fish) at the primary spermatogonium stage weigh less than 0.3 g. and some less than 0.1 g., while the smallest testes (of one fish) at the spermatocyte stage weigh 2 g. and the largest, 3.7 g. The latter testes are 10 to 20 times the former in weight. The most
remarkable increase is seen after testes have reached the spermatid stage. The smallest sample at this stage, which was collected in early July, was only 2.2 g., but, in late July, even the smallest sample at this stage was over 7 g. and the largest was 13 g. This indicates a very rapid maturation of testes after the appearance of spermatids. No appreciable increase in weight was observed after testes had reached the spermatozoon stage, and there was even a general tendency of decrease in weight. At any rate, there are apparent differences in weight between testes containing only primary spermatogonia and those containing secondary spermatogonia or more advanced germ-cells. Differences are particularly great between the former testes and those containing spermatocytes or more advanced germ-cells.

ii. Sockeye and Chum Salmon.

For males, the best indication of being spawning fish of the year is, of course, the presence of large quantities of spermatozoa in the testes. However, once spermatocytes have begun to appear, maturation becomes very rapid and the formation of spermatozoa occurs within a short period of time. This is known not only for kokanee, as mentioned above, but also for many other fish species. This period is relatively long for Liopeustha obscura (Yamamoto, 1953) and Muraenox Roxine aeneus (Nishikawa, 1957), being approximately three and four months, respectively; but very short for Salmo salar (Jones, 1940), Sebastiscus marmoratus (Mizue, 1958), Perca (Turner, 1919), herring (Clupea pallasi) (Ishida, 1957 a), etc., being approximately one month, as in the case of kokanee, and sometimes even less than a month. Also, immature fish do not have germ-cells in their testes so advanced as to show large quantities of spermatocytes even during the spawning period a year before their spawning. It follows that the fish showing a formation of spermatocytes in their testes during the marine period of their life are considered spawning fish of the year. For this reason, the first criterion adopted by us for distinguishing mature and immature fish is whether or not the germ-cells in their testes have developed into spermatocytes. Furthermore, the secondary spermatogonia in the process of cell-division are large and indistinguishably resemble spermatocytes, as pointed out by Weisel (1943) for land-locked sockeye, which is similar to our kokanee, and by Jones (1940) for Salmo salar; and these spermatogonia develop into spermatocytes in a very short period of time. This is known not only for kokanee, but also for such other species as Perca, Muraenox, herring and Liopeusthaz; in all these species it takes only about one month for secondary spermatogonia to form spermatocytes.

Consequently, the fish whose testes are at the secondary spermatogonium stage are very likely to be spawning fish of the year, because such testes will probably form spermatozoa in a short period of time. This was adopted by us as the second criterion for distinguishing mature from immature salmon. However, the time of sampling is an important factor in this case. Even some of the immature fish caught approximately during the spawning season have testes at such advanced stages as to show small quantities of

![Figure 6](image-url) Relationships between the degree of maturation and testis weight for the sockeye and chum salmon of northern seas.
secondary spermatogonia. The results of studies on kokanee and Salmo salar indicate that the time interval between the appearance of secondary spermatogonia and spawning is four to five months. Accordingly, the fish which are caught towards the end of the fishing season and whose testes show only very small quantities of germ-cells as advanced as secondary spermatogonia may more appropriately be considered immature fish than mature, unless they belong to very late-spawning (November and later) stocks. Since the main spawning season for sockeye and chum salmon is July through September, it is difficult to make a clear distinction between matures and immatures for the fish whose testes remain at the secondary spermatogonium stage in July and later. It seems, however, that these fish may more appropriately be considered immature.

Based on the characteristics of spermatogenesis as outlined above, the degree of maturation of sockeye and chum salmon, as determined by histological observations, was related to their testis weights and maturity indices, and, by using such relationships, a distinction between mature and immature fish using gonad weight and maturity index was attempted.

Let us first examine the relationships between the degree of maturation and testis weight (Figure 6). As shown in the figure, the two species, sockeye and chum, show some differences in this regard, but are similar in general tendencies. Hence, they are considered together. The results are summarized according to weight classes of testes.

(1) **Fish with testes weighing 1 g. or less.** As shown in (1) and (2) of Plate II, the germ-cells in these testes remained at the primary spermatogonium stage in both chum and sockeye, and in most cases the spermatogonia in cysts formed lumps of three to over ten cells each, with no space in the centers of the cysts. The thick layers of connecting tissue surround the cysts. This condition was seen in an apparently immature fish with a fork length of 35 cm. and a body weight of 400 g., as well as in a fish with a fork length of 50 cm. and a body weight of 1600 g., the maturity of which cannot be judged from its size. Only some of the sockeye salmon showed signs of development in the spermatogonia of some of the cysts and were beginning to have a little space in the centers of the cysts.

(2) **Fish with testes weighing 2 g.** In chum salmon, except for one specimen caught on May 25, 1959 (early in the season), the spermatogonia in cysts still formed lumps, as in (1), but the testes of sockeye salmon showed slightly more advanced conditions. In general, they had somewhat larger quantities of spermatogonia than in (1) and were beginning to show many cysts with a space in the center of the lump of spermatogonia, making doughnut-like shapes. However, no germ-cells other than spermatogonia were present. (Plate II—3, 4 and 5.)

(3) **Fish with testes weighing 3–4 g.** Most of the specimens belonging to this class had testes consisting only of primary spermatogonia, as in the case of (1) and (2) (Plate II—6). However, in both chum and sockeye salmon, one specimen caught toward the end of the fishing season (testis weight 4 g.) showed secondary spermatogonia in a very small number of cysts.

(4) **Fish with testes weighing 5 g.** Most of the specimens belonging to this group had begun to form secondary spermatogonia in their testes (Plate II—8), and some sockeye even showed small quantities of primary spermatocytes. There were a few exceptions. One chum salmon caught on June 20, 1959, whose testis weight was 5 g., fork length 62 cm., and body weight 2500 g., and which in appearance seemed to be a mature fish, and two sockeye salmon caught on July 24 toward the end of the fishing season, showed only primary spermatogonia in their testes (Plate II—7).

(5) **Fish with testes weighing 6–10 g.** Most of the fish belonging to this class showed primary spermatocytes in most cysts in their testes (Plate II—9), and, in one chum salmon (testis weight 8 g.), spermatids had already been formed. One chum salmon (caught on June 4), however, had testes (6 g. in weight) consisting only of primary spermatogonia forming lumps in cysts and resembling the testes of an immature fish. This might have arisen from a mistake in sample handling.

(6) **Fish with testes weighing 10–20 g.** The fish belonging to this class, in general, had larger quantities of spermatocytes than those of (5), and many of them had begun to show secondary spermatocytes (Plate II—10 and 11). However, the spermatid stage had been reached only by one sockeye, and in all the other specimens of both species the most advanced stage of germ-cells was still that of spermatocytes.

(7) **Fish with testes weighing 20–30 g.** The germ-cells of the most advanced stages of development in the testes of this weight class had formed spermatids or spermatogonia. The quantities of the
germ-cells at these advanced stages were still very small, however. (Plate II—12, 13 and 14.)

(8) *Fish with testes weighing over 30 g.* The testes of fish belonging to this class, in general, showed increased quantities of spermatids and spermatozoa. The quantities of spermatids and spermatozoa were generally greater in the testes of larger weights, but the correlation was not very high. (Plate II—15, 16 and 17.) For comparison, the testes of autumn chum from the coast of Hokkaido and autumn chum in spermatism (caught at the Nistigoe egg-collecting station) were observed. The testes of these fish showed spermatozoa occupying the greatest portion of each cyst, but they still contained germ-cells at practically all other stages of development, including spermatogonia. Also, the testis weights of these fish were not greater than the most developed testes of the fish caught in the ocean. (Plate II—18.)

The degree of maturation, as determined by histological observations, is related to the maturity index in Figure 7.

Thus, we have determined first the criteria for distinguishing matures and immatures from the characteristics of development of germ-cells in the testes, and then the relationships between the degree of maturation, as indicated by histological examination, and testis weight and maturity index. Using such information, the following five categories may be established in an attempt to distinguish mature and immature males:

(1) The testis weights and maturity indices of the fish in this category indicate that their testes have reached the spermatocyte stage or more advanced stages. These fish are considered "definitely mature".

(2) The testis weights and maturity indices of the fish of this category indicate that their testes are at either the spermatocyte stage or the secondary spermatogonium stage. Those whose testes are at the spermatocyte stage are undoubtedly mature. Also, the testes which fall in this category and which are at the secondary spermatogonium stage have, in general, fairly large quantities of secondary spermatogonia, although definite determination cannot be made without making histological observations for individual specimens. The fish of this category are considered "almost certainly mature".

(3) The testis weights and maturity indices of the fish of this category indicate that their testes are mostly at the secondary spermatogonium stage and partly at the primary spermatogonium stage. Those with testes at the secondary spermatogonium stage can be considered mature, if they are caught in the early part of the fishing season. Those caught towards the end of the fishing season with testes at this stage are not considered spawning fish of the year, except for the fish belonging to very late-spawning stocks.

![Figure 7](image-url)
This is because the time interval between the appearance of secondary spermatogonia and spawning is about four months for kokanee, and also, some of the immature kokanee show small quantities of secondary spermatogonia in some of the cysts during the spawning season a year before their spawning, particularly during its latter part. Determination is difficult for the fish with testes at the primary spermatogonium stage, in view of the characteristics of development of germ-cells. However, if they are fish caught in the early part of the spawning season, they may be spawning fish of the year, judging from the changes (by ten-day periods) of gonad weight demonstrated by Ishida and Miyaguchi (1958) and Takagi (1961).

However, if they are fish caught toward the end of the season, they should be considered immature, because even those with testes at the secondary spermatogonium stage are doubtful of becoming spawning fish of the year, as mentioned above. In short, the fish in this category "may be considered mature, if caught in the early part of the fishing season".

(4) Fish of this category do not show germ-cells more advanced than primary spermatogonia in their testes, but many of them show some signs of development; cysts have increased in size and have a space in their centers, forming doughnut-like shapes. Since spermatogenesis is very rapid after the secondary spermatogonium stage has

<table>
<thead>
<tr>
<th>Category</th>
<th>Species</th>
<th>A. Testis weight in grams</th>
<th>B. Maturity index (GW/BW \times 100)</th>
<th>Stage of testis development</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Definitely mature&quot;</td>
<td>Sockeye</td>
<td>10 and above</td>
<td>0.4 and above</td>
<td>Spermatocyte stage or more advanced</td>
<td>In A: Seven samples at (a) and four at (b). In B: Five at (a) and five at (b).</td>
</tr>
<tr>
<td></td>
<td>Chum</td>
<td>7 and above</td>
<td>0.3 and above</td>
<td></td>
<td>In A: One at (a), three at (b) and two at (c).</td>
</tr>
<tr>
<td>&quot;Almost certainly mature&quot;</td>
<td>Sockeye</td>
<td>6-10</td>
<td>0.22-0.4</td>
<td>a. Spermatocyte stage \b. Secondary spermatogonium stage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chum</td>
<td>5-7</td>
<td></td>
<td>a. Spermatocyte stage \b. Secondary spermatogonium stage \c. Primary spermatogonium stage</td>
<td>In A: Three at (a), five at (b) and two at (c). In B: None at (a), two at (b) and one at (c).</td>
</tr>
<tr>
<td>&quot;All mature if caught in the early part of the fishing season&quot;</td>
<td>Sockeye</td>
<td>5-6</td>
<td>0.2-0.22</td>
<td>a. Spermatocyte stage \b. Secondary spermatogonium stage \c. Primary spermatogonium stage</td>
<td>In A: Three at (a) and two at (b). In B: Three at (a) and eight at (b).</td>
</tr>
<tr>
<td></td>
<td>Chum</td>
<td>5-6</td>
<td>0.2-0.3</td>
<td>a. Secondary spermatogonium stage \b. Primary spermatogonium stage</td>
<td></td>
</tr>
<tr>
<td>&quot;Possibly mature if caught in the early part of the fishing season&quot;</td>
<td>Sockeye</td>
<td>2-5</td>
<td>0.1-0.2</td>
<td>Primary spermatogonium stage</td>
<td>All germ-cells in testes are still primary spermatogonia, but in many samples cysts containing spermatogonia have a space in their centers and form doughnut-like shapes, indicating some development.</td>
</tr>
<tr>
<td></td>
<td>Chum</td>
<td>2-5</td>
<td>0.1-0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Almost certainly immature&quot;</td>
<td>Sockeye and Chum</td>
<td>Less than 2</td>
<td>Less than 0.1</td>
<td>Primary spermatogonium stage</td>
<td>In all samples cysts containing spermatogonia have no space in their centers and spermatogonia in a cyst form a lump.</td>
</tr>
</tbody>
</table>
been reached, there is a possibility that the fish whose testes are at this stage at the beginning of the fishing season might participate in spawning during the year. Nothing definite can be said for the fish of this category. They are classified as "possibly spawning fish of the year, if caught in the early part of the season".

(5) Only primary spermatogonia are present in the testes of the fish of this category; the spermatogonia in cysts form lumps; and the thick layers of connecting tissue surround the cysts. This condition is commonly observed in apparently immature fish. It is very unlikely, if not impossible, that the fish with testes at this stage, even at the beginning of the fishing season, will become spawning fish of the year. Fish in this category are considered "almost certainly immature".

The results of our observations are summarized in Table 2 according to the above categories.

SUMMARY

An attempt is made to distinguish mature and immature fish for the salmon caught during the marine period of their life, i.e., to determine whether or not they would be spawning fish of the year. The study is principally based on the histological observations of gonads, and the characteristics and rate of gonad development of other fishes, particularly kokanee, as well as the maximum degree of gonad development for their immatures.

1. FEMALES

(1) Female fish reach the maturation stage within approximately three or four months after ovarian eggs have reached the secondary yolk stage. Also, immature kokanee and other species can, at most, reach the primary yolk stage in gonad development, and most of them remain at the oil globule stage. Hence, all fish whose eggs are at the secondary yolk stage or beyond can be considered mature.

(2) It takes four months or more for ovarian eggs to develop from the primary yolk stage to the maturation stage. However, considering the maximum degree of gonad development in immature fish, as mentioned above, the fish whose eggs are at the primary yolk stage are assumed to be spawning fish of the year, except for those caught at the end of the fishing season. Those caught towards the end of the fishing season with ovaries at this stage are more appropriately considered immature, except for fish which belong to late-spawning (November and later) stocks and whose eggs are so advanced as to be close to the secondary yolk stage.

(3) The oil globule stage may well be reached by immature fish of Oncorhynchus approximately one year before their spawning; and the time interval between the late oil globule stage and the maturation stage is five to six months. Accordingly, most of the sockeye and chum salmon with eggs at this stage are presumably immature fish, judging from the spawning seasons of these species. However, it is possible that fish whose eggs are so advanced as to be close to the primary yolk stage in the early part of the fishing season might participate in spawning during the year. Nothing definite can be said in this respect.

(4) Fish whose eggs are at the yolk vesicle stage can definitely be considered immature. Immature specimens of Oncorhynchus may well reach the oil globule stage, which is a more advanced stage, and all the fish in samples whose eggs remain at the yolk vesicle stage are apparently immature, judging from their lengths and weights.

(5) Summarizing the relationships between the results of histological observations, as reviewed above, and gonad weight and maturity index, an attempt to distinguish mature and immature fish may be made as in Table 1.

2. MALES

(1) All fish whose testes contain germ-cells at the spermatocyte stage or further advanced stages can be considered mature, because the testes as advanced as these stages would reach the spermatozoon stage within a month.

(2) Since testes develop from the secondary spermatogonium stage to the spermatozoon stage in one to two months, fish whose testes are at the secondary spermatogonium stage are presumably mature. However, it is noted for kokanee that the time interval between the appearance of germ-cells of this stage and the spawning season is as long as approximately four months. Also, even immature fish may have very small quantities of secondary spermatogonia in some of the cysts in their testes during the spawning season a year before their spawning. Hence, it is assumed that the fish caught toward the end of the fishing season with testes at this stage are not spawning fish of the year, unless they belong to late-spawning stocks.

(3) It is possible that even fish whose testes are at the late primary spermatogonium stage may be
spawning fish of the year, if they are caught at the beginning of the fishing season and if they belong to late-spawning stocks, because the testis development from the secondary spermatogonium stage onward is very rapid. Nothing definite can be said on this question, however.

(4) Based on the results of histological observations, as mentioned above, criteria for distinguishing mature and immature fish from gonad weight and maturity index may be proposed as in Table 2.

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PLATES

METHOD

Plate I. (2), (4), (5) and (6) are paraffin sections double-stained by Heidenhain’s iron-hematoxylin and light-green; others are cellodin sections stained by Mallory’s triple-staining method.

Plate II. All paraffin sections. (11) to (14) were double-stained by Heidenhain’s iron-hematoxylin and eosin; others were double-stained by Heidenhain’s iron-hematoxylin and light-green.

All samples in Plates I and II were fixed by Bouin’s solution.

ABBREVIATIONS

Plate I. Eggs

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>y. v.</td>
<td>yolk vesicle</td>
</tr>
<tr>
<td>g. v.</td>
<td>germinal vesicle</td>
</tr>
<tr>
<td>z. r.</td>
<td>zona radiata</td>
</tr>
<tr>
<td>y. g.</td>
<td>yolk globule</td>
</tr>
<tr>
<td>n.</td>
<td>nucleolus</td>
</tr>
<tr>
<td>f. d.</td>
<td>fatty droplet (oil globule)</td>
</tr>
</tbody>
</table>

Plate II. Testes

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I s. p. g.</td>
<td>primary (resting or first) spermatogonium</td>
</tr>
<tr>
<td>II s. p. g.</td>
<td>secondary spermatogonium</td>
</tr>
<tr>
<td>I s. c.</td>
<td>primary (first) spermatocyte</td>
</tr>
<tr>
<td>II s. c.</td>
<td>secondary spermatocyte</td>
</tr>
<tr>
<td>s. t. d.</td>
<td>spermatid</td>
</tr>
<tr>
<td>s. p. z.</td>
<td>spermatozoon</td>
</tr>
<tr>
<td>c. w.</td>
<td>cyst wall</td>
</tr>
</tbody>
</table>
PLATE I. EGGS OF SOCKEYE AND CHUM SALMON (Continued on page 44)

(1) Chum. Immature, yolk vesicle stage. Collected on August 9, 1958, by the *Fuyo-maru* at 50°37'N.—171°07'E. F. L. 48.0 cm., B. W. 1,450 g., G. W. 9 g., egg diameter 1.27 mm., age 3.

(2) Chum. Immature, oil globule stage. Collected on August 9, 1958, by the *Fuyo-maru* at 50°37'N.—171°07'E. F. L. 51.0 cm., B. W. 1,800 g., G. W. 15 g., egg diameter 1.60 mm., age 4.

(3) Sockeye. Immature, oil globule stage. Collected on May 25, 1959, by the *Koyo-maru* at 48°11'N.—165°58'E. F. L. 48.0 cm., B. W. 1,300 g., G. W. 9 g., age 4.

(4) Chum. Mature, primary yolk stage. Collected on June 12, 1958, by the *Wakashio-maru* at 52°57'N.—177°38'E. F. L. 55.0 cm., G. W. 27 g., age 5.

(5) Sockeye. Mature, primary yolk stage. Collected on June 11, 1958, by the *Wakashio-maru* at 53°00'N.—177°30'E. F. L. 50.5 cm., G. W. 32 g., egg diameter 2 mm., age 5.

(6) Sockeye. Mature, primary yolk stage. Collected on May 25, 1959, by the *Koyo-maru* at 48°11'N.—166°58'E. F. L. 48.0 cm., B. W. 1,300 g., G. W. 15 g., egg diameter 1.98 mm., age 4.
(7) Chum. Mature, secondary yolk stage. Collected on July 24, 1958, by the Jinyo-maru at 49°05'N.—165°40'E. F. L. 55.0 cm., B. W. 2,000 g., G. W. 30 g., egg diameter 2.35 mm., age 4.

(8) Sockeye. Mature, secondary yolk stage. Collected on June 24, 1958, by the Jinyo-maru at 53°32'N.—166°39'E. F. L. 52.0 cm., B. W. 1,850 g., G. W. 43 g., egg diameter 2.5 mm., age 5.

(9) Sockeye. Mature, secondary yolk stage. Collected on July 6, 1958, by the Jinyo-maru at 51°25'N.—163°30'E. F. L. 59.0 cm., B. W. 2,600 g., G. W. 75 g., egg diameter 2.94 mm., age 7.

(10) Chum. Mature, tertiary yolk stage. Collected on June 24, 1958, by the Jinyo-maru at 53°32'N.—166°39'E. F. L. 56.0 cm., B. W. 2,250 g., G. W. 120 g., egg diameter 3.96 mm., age 4.


(12) Part of (11).
PLATE II. TESTES OF SOCKEYE AND CHUM SALMON (Continued on pages 46 and 47)

(1) Sockeye. Immature, primary spermatogonium stage. ×400. Collected June 24, 1959, by the Koyo-maru at 51°15′N.—165°15′E. F.L. 35.0 cm., B.W. 400 g., G.W. less than 1 g., age unknown.

(2) Sockeye. Immature, primary spermatogonium stage. ×400. Collected June 24, 1959, by the Koyo-maru at 51°15′N.—165°15′E. F.L. 48.2 cm., B.W. 1,300 g., G.W. 1 g., age 5.

(3) Chum. Immature, primary spermatogonium stage. ×400. Collected on August 9, 1958, by the Jinjo-maru at 50°37′N.—171°07′E. F.L. 54.0 cm., B.W. 2,100 g., G.W. 2 g., age 4.

(4) Chum. Part of (3). ×1000.

(5) Sockeye. Immature, primary spermatogonium stage. ×400. Collected on July 6, 1958, by the Jinjo-maru at 51°25′N.—163°30′E. F.L. 54.0 cm., B.W. 1,900 g., G.W. 2 g., age 5.

(6) Chum. Immature, primary spermatogonium stage. ×400. Collected on June 24, 1958, by the Jinjo-maru at 53°32′N.—166°39′E. F.L. 52.0 cm., B.W. 1,550 g., G.W. 3 g., age 5.
(7) Sockeye. Immature, primary spermatogonium stage. ×400. Collected on July 24, 1958, by the Jisyo-maru at 49°05′N.—165°40′E. F.L. 50.0 cm., B.W. 1,400 g., G.W. 5 g., age 7a.

(8) Sockeye. Mature, secondary spermatogonium stage. ×600. Collected on May 27, 1958, by the Jisyo-maru at 46°52′N.—168°09′E. F.L. 56.0 cm., B.W. 2,300 g., G.W. 5 g., age 6a.

(9) Sockeye. Mature, beginning of primary spermatocyte stage. ×100. Collected on May 17, 1958, by the Jisyo-maru at 51°15′N.—171°45′E. F.L. 54.0 cm., B.W. 2,800 g., G.W. 8 g., age 7a.

(10) Sockeye. Mature, primary spermatocyte stage. ×600. Collected on June 7, 1958, by the Jisyo-maru at 52°21′N.—168°36′E. F.L. 58.0 cm., B.W. 2,300 g., G.W. 10 g., age 6a.


(12) Sockeye. Mature, spermatocyte stage. ×400. Collected on June 7, 1958, by the Jisyo-maru at 52°21′N.—168°36′E. F.L. 55.0 cm., B.W. 2,000 g., G.W. 21 g., age 5a.
(13) Chum. Mature, spermatozoa begin to appear. × 100. Collected on July 6, 1958, by the *Juyo-maru* at 51°25'N—163°30'E. F.L. 48.0 cm, B.W. 1,300 g, G.W. 26 g, age 3.

(14) Chum. Part of (13). × 600.

(15) Chum. Mature, spermatozoa stage. × 100. Collected on August 9, 1958, by the *Juyo-maru* at 50°37'N—171°07'E. F.L. 56.0 cm, B.W. 2,300 g, G.W. 50 g, age 3.


(17) Chum. Mature, spermatozoa stage. × 400. Collected on July 5, 1959, by the *Koyo-maru* at 53°31'N—167°37'E. F.L. 58.0 cm, B.W. 3,050 g, G.W. 185 g, age 4.

(18) Autumn chum. Mature, testis in spermatism. × 100. Sampled at the Chitose hatchery, Hokkaido. F.L. 67.5 cm, B.W. 4,100 g, G.W. 130 g, age unknown.