J. Fac. Fish. Anim. Husb.
Hiroshima Univ. (1962), **4**:47~79.

Fecundity and Spawning of a Puffer, *Fugu rubripes* (T. et S.) in the Central Waters of the Inland Sea of Japan

Daijiro KUSAKABE, Yutaka MURAKAMI & Takashi ONBE

Department of Fisheries, Faculty of Fisheries and Animal Husbandry, Hiroshima University, Fukuyama, Japan

(Pls. 1–8; Text-figs. 1–8; Tables 1–8)

INTRODUCTION

The puffer, *Fugu rubripes* (T. et S.) is distributed throughout the coasts of Japan except northern Hokkaido, the distribution being further extended to the coasts of Korea, Formosa, China and as far north as Peter the Great Bay (MATSUBARA, 1955).

Despite of its notorious toxic substance, tetrodotoxin, the puffer is one of the most important fishes in this country and it claims a very high market price. In recent years, the stock culture of the puffer has been gradually developed in the coastal regions of the Inland Sea of Japan (YASUDA, 1959, 1960). However, Several problems are pending in the present puffer culture, such as an unusually high death rate during the period. As there has been no substantial knowledge on the biology and ecology of the puffer, many of these problems remain unsettled at the present time.

The purpose of the present paper is to describe some of the results of the investigations made on the problems concerning the spawning of the puffer in the central waters of the Inland Sea in 1960 and 1961.

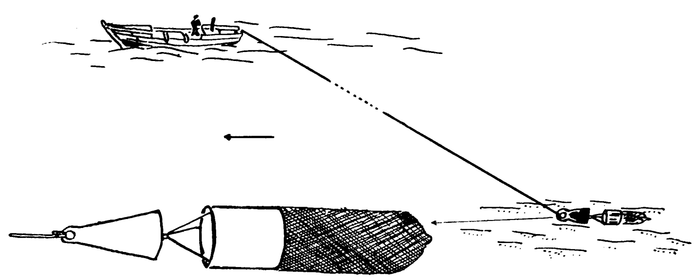
We wish to express our cordial thanks to Prof. Yasuo MATSUDAIRA, Hiroshima University, who was kind enough to give us some valuable advices concerning collecting method of the eggs of the puffer from the spawning bed. We are also grateful to Mr. S. HOSHINO, Director of Okayama Prefectural Fisheries Experimental Station and Mr. R. NAKANO, the fisheries technical expert, Okayama Prefecture, who were kindly provided facilities in the course of the present investigation. In both 1960 and 1961 our studies have been aided by a grant of Scientific Testing Research from the Ministry of Education, for which we are very grateful.

MATERIALS AND METHODS

The investigation of the spawners of *Fugu rubripes* was carried out at Tanoura, Kojima City, Okayama Pref., on April 29–May 2, 1960. The fish were caught by seine nets operated in the Bisan Strait. The nets are operated for catching the sea-bream, *Chrysophrys major*, during the season from April to June.

A number of the puffer were landed 3–4 hours after capture, of which random samplings were made. The length from the tip of the snout to the tip of the longest caudal fin-ray and the total weight were measured immediately after landings with fresh specimens. Ovary samples were taken at random for the fecundity examination. Ovaries were fixed in 10% formalin and preserved for later observation.

The investigations of the spawning grounds were made in May, 1960–1961, mainly in the central part of the Bisan Strait, especially around Ushi-Shima off Marugame City, Kagawa Pref. Bottom deposits were collected from a 3 Hp Diesel-engined boat by dragging a milk-can (10 cm. in diameter) with a lead (3 kg. in weight) near its mouth and a net in the rear (Text-fig. 1).



Text-fig. 1. Bottom-sampler used in the investigation.

Dredgings were made at the mercy of currents. The number of eggs found in each bottom sample was counted. The sand was sieved through wire gauzes with meshes of varing in size and the size-composition of sand particles was determined (for details, see text).

RESULTS AND DISCUSSION

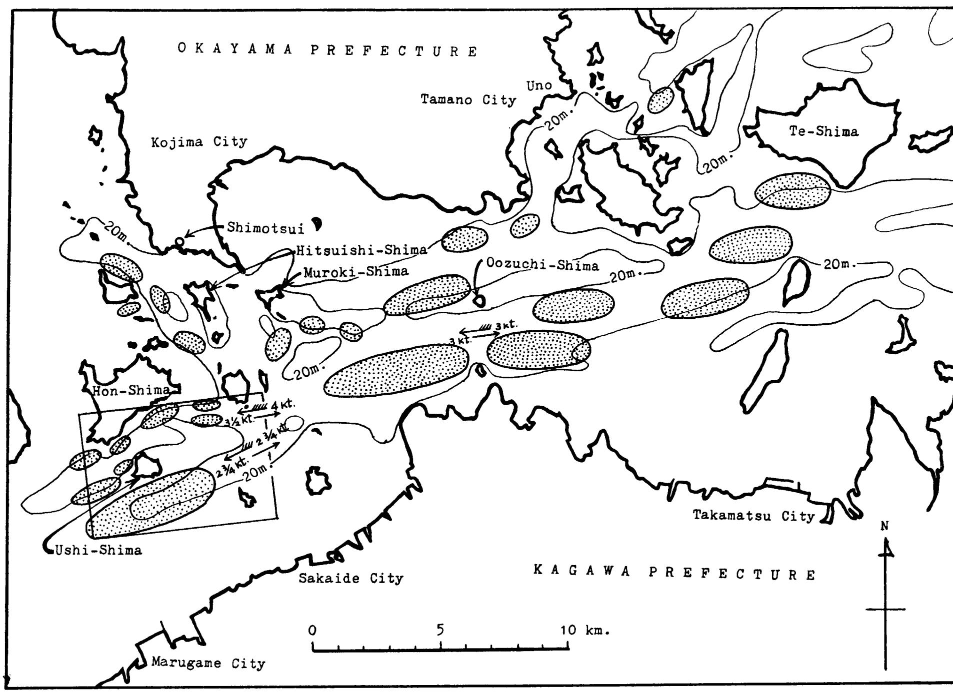
I. Fishing Season and Fishing Grounds of *Fugu rubripes* in the Central Part of the Inland Sea.

It is said among Japanese fishermen that the fishing season of the puffer, *Fugu rubripes*, begins in the autumn equinox and ends in the spring equinox. In the waters of western Japan, Suô Nada, Bungo Strait and Genkai Nada, are known as good fishing grounds of the puffer. Accordingly, Shimonoseki City is the most famous center of the puffer landings in Japan.

On the contrary, in the waters of the central part of the Inland Sea, such as Hiuchi Nada, Bingo Nada and Bisan Strait, the puffer is captured only in spring season, having its peak landings from late April to early May. Major catch of the puffer in these areas are taken by long-line and a unique fishing-tackle and line with many lead (Pl. 8, Fig. 15).

The period from spring to summer are not the season of the puffer, and they have no market value. So the puffer caught during the period are usually used as seed fish for stock culture (YASUDA, 1959, 1960). They are kept alive for seven to eight months till the year's end when the market price of the puffer is raised ten to thirty times higher.

Distribution of the principal fishing grounds of the puffer in the central part of the Inland Sea, Bisan Strait, is illustrated in Text-fig. 2.



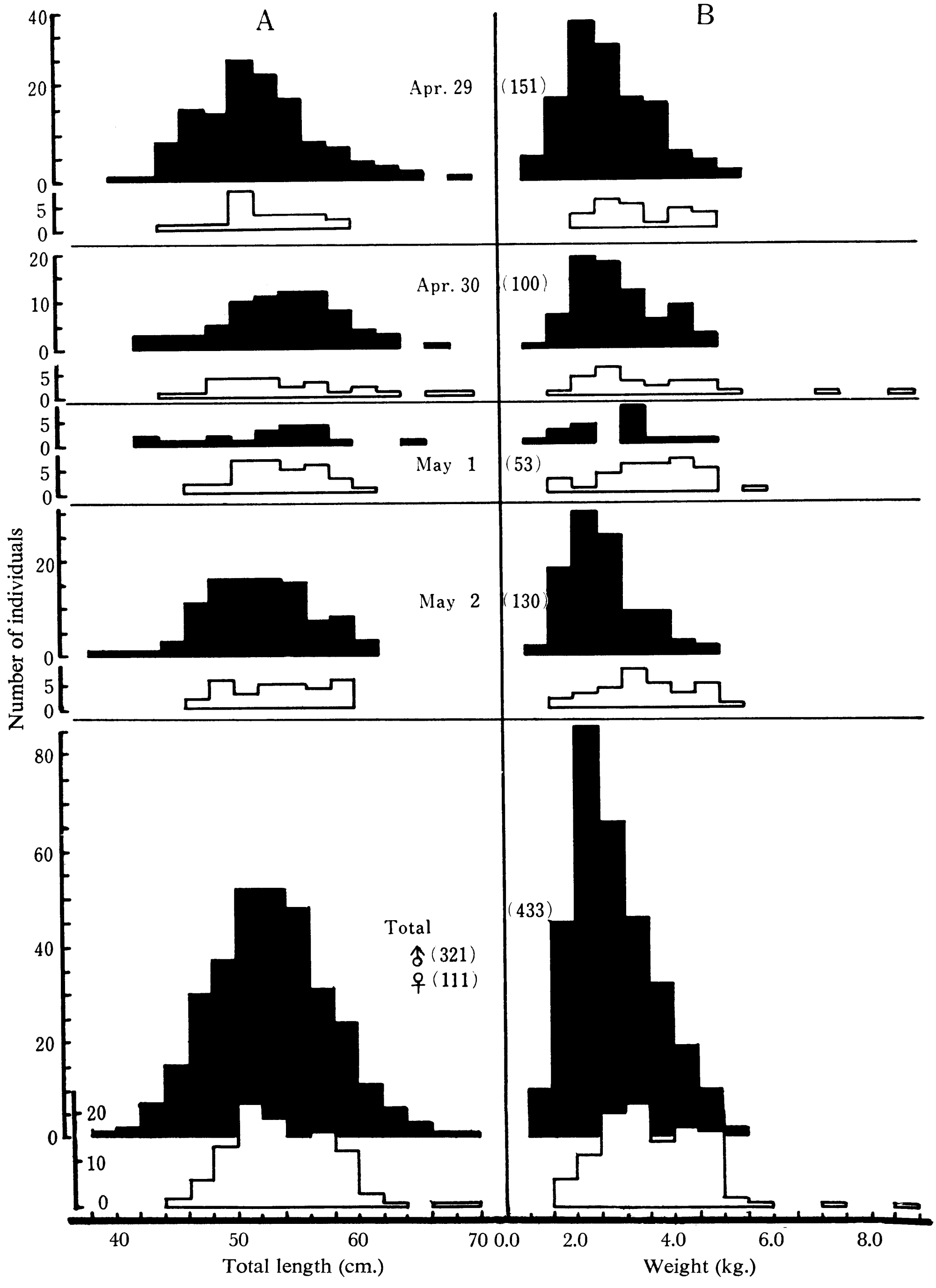
Text-fig. 2. Distribution of the fishing grounds of *Fugu rubripes* in the central part of the Inland Sea of Japan (Bisan Strait). Dotted areas represent the fishing grounds. For area enclosed in a square, see Text-fig. 8.

From the figure we can find that all the fishing grounds are situated in the region below 20 m. depth contours of the strait where the current speed is relatively fast.

II. Morphological Characteristics of the Spawners of *Fugu rubripes*.

As mentioned previously, the puffer used in this investigation were caught by the sea-bream seine nets. They were composed of larger fish with well-developed gonads, a considerable number of which had shed fully matured ova and semen by pressing the abdomen slightly. From these observations together with the results obtained on the spawning-ground investigations described in later pages, it might safely be said that they were caught from the spawning population.

The fish measured during the 4-day period were totaled up to 434, of which 321 were males, 111 females and 2 unsexed younger individuals. Sex ratios (♀ : ♂) are thus calculated as approximately 1 : 3. As no information on the age and



Text-fig. 3. Length-weight composition of the spawners of *Fugu rubripes*.
A: Length frequency distribution
B: Weight freqency distribution
Number in brackets shows sample size; solid part indicates males and open one, females.

growth has been known in this puffer, it must be admitted here that the following accounts can only give an external characteristics of the spawner of the puffer.

1) Size composition.

The size frequency distribution is shown in Text-fig. 3A. The total length ranges from 391 to 690 mm. (excluding young) with an average length of 530 mm. The most conspicuous is lying between 490 and 600 mm., 87.2% of the total being included in the range.

The sexual difference in total length is not clear. Males ranged from 391 to 683 mm., with an average of 527 mm. In females, the range and the mean of total length are 445–690 mm. and 537 mm. respectively. Females are 10 mm. larger than males in mean length, but the difference is denied by *t*-test at 95 % fiducial limit (Table 1A).

Table 1. Test of difference between length and weight of both sexes of the spawners of *Fugu rubripes*.
A: Test of difference in total length
B: Test of difference in weight.

A

Sex	Numbr	*d. f.*	Mean	Sum of square
Male	321	320	52.74	7743.0776
Female	111	110	53.74	2071.4236
	432	430	1.00	9814.5012

$t = 1.901$

$t_{0.05} = 1.966$ $\quad t < t_0$
$d.f. = 400$

B

Sex	Numbr	*d. f.*	Mean	Sum of square
Male	321	320	2,767	227,655,769
Female	111	110	3,556	136,085,596
	432	430	789	363,741,365

$t = 7.791$

$t_{0.01} = 2.588$ $\quad t > t_0$
$d.f. = 400$

2) Weight composition.

The weight frequency distribution shows that the samples are consisted of fishes weighing from 1,220 to 8,590 g., being 2,970 g. in average (Fig. 3B). Out of 434 fishes, 355 are within the range of 1,500–4,000 g., comprising 81.7% of the total.

The difference in weight of both sexes is very conspicuous. Males have an average weight of 2,767 g. ranging from 1,220 to 5,210 g., while the females have an average of 3,556 g. with the range of 1,820–8,590 g. Weight difference between males and females is significant by t-test at 99% fiducial limit (Table 1B).

3) Weight-length relationship.

Mean weight was calculated for each 20-mm. interval of total length (Table 2). The relationship of total length with weight is shown in Text-fig. 4. A clear linear relation can be noted between the logarithms of the two variables. By the method of least squares, the following empirical formulae are obtained:

Males: $W=0.304L^{2.281}$, and

Females: $W=0.0278L^{2.949}$, where W indicates the body weight in g. and L, total length in cm.

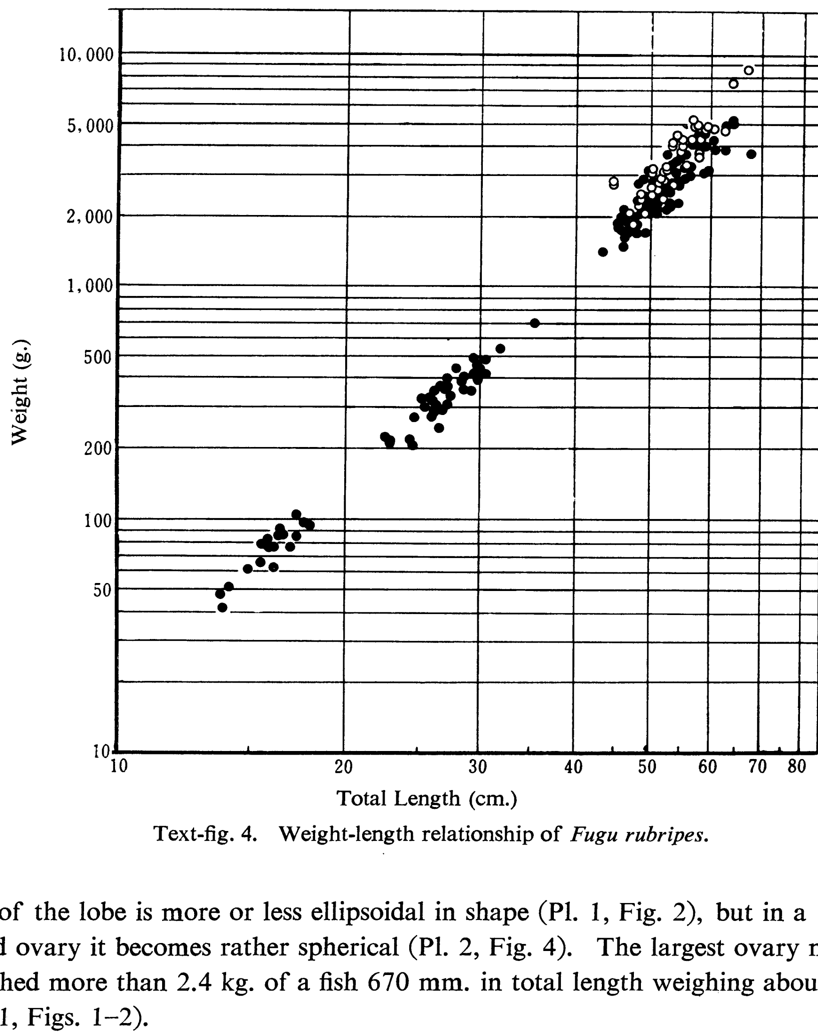
In Text-fig. 4, values of young fish (sex unknown) obtained in May, 1960 and Sept., 1961 are also plotted.

Table 2. Weight-length relationship of the spawners of *Fugu rubripes*.

Total length (mm.)	Male				Female			
	Number	%	Weight (kg.) Range	Weight (kg.) Mean	Number	%	Weight (kg.) Range	Weight (kg.) Mean
380—400	1	0.3	—	1.220	—	—	—	—
400—420	2	0.6	1.23—1.42	1.325	—	—	—	—
420—440	7	2.2	1.40—1.78	1.540	—	—	—	—
440—460	15	4.7	1.30—3.56	1.861	2	1.8	2.74—2.77	2.755
460—480	30	9.3	1.47—2.43	1.912	6	5.4	1.84—2.50	2.047
480—500	37	11.5	1.68—3.20	2.310	13	11.7	1.94—3.20	2.434
500—520	52	16.2	1.90—3.34	2.418	22	19.8	1.82—3.76	2.918
520—540	52	16.2	1.56—3.80	2.827	19	17.1	2.38—4.20	3.331
540—560	48	15.0	1.79—4.16	3.104	15	13.5	2.70—4.48	3.775
560—580	31	9.7	1.67—4.52	3.329	16	14.4	3.25—5.23	4.384
580—600	24	7.5	1.53—4.90	3.180	12	10.8	4.04—5.20	4.612
600—620	11	3.4	3.90—4.82	4.332	3	2.7	3.43—5.78	4.660
620—640	6	1.9	3.12—4.90	4.055	1	0.9	—	4.630
640—660	3	0.9	4.53—5.21	4.933	—	—	—	—
660—680	1	0.3	—	3.510	1	0.9	—	8.590
680—700	1	0.3	—	3.740	1	0.9	—	7.470
Total	321	100.0		2.767	111	100.0		3.556

III. Fecundity of *Fugu rubripes*.

The ovary of *Fugu rubripes* is constituted of two lobes, both very large in size and weight. In a full matured individual, it weighs as much as one third of the body weight. Macroscopic observation shows that a large blood vessel runs dorso-laterally along its full length of each lobe with many capillary networks. Each lobe is connected together with thin membrane. At the posterior end, both left and right lobes unite together into an oviduct. The cross section perpendicular to the median



Text-fig. 4. Weight-length relationship of *Fugu rubripes.*

line of the lobe is more or less ellipsoidal in shape (Pl. 1, Fig. 2), but in a full matured ovary it becomes rather spherical (Pl. 2, Fig. 4). The largest ovary measured weighed more than 2.4 kg. of a fish 670 mm. in total length weighing about 8.6 kg. (Pl. 1, Figs. 1–2).

It is generally known that when ovaries become ripe and spawning approaches, the ovarian eggs increase in size and weight. Therefore, the size-frequency distribution of the ovarian eggs together with the ratio of ovary weight to body weight have been used as an indicator of gonad maturity in many fishes. Furthermore, if frequency of size of ovarian eggs shows bimodal or trimodal curve, the spawning of the fish can be considered to be done twice or thrice in its spawning season.

Information on the ovarian eggs of *Fugu rubripes* has been scanty, except FUJITA and UENO's (1956) description of fecundity of only one specimen. In order to get some basic knowledge on the ovarian eggs of the puffer, examinations were made on the ovary samples taken when the measurement investigations of the spawners had been carried out.

1) Test of difference in size of ovarian eggs taken from different parts of the ovary.

In order to examine whether or not the difference in ova-diameter exists within one ovary, samples of ova were taken from six different parts of the left lobe. The lobe was cut at three different parts pallalel to one another. The resulting three sections were named as sections A, B and C. Section A is located at the anterior part of the lobe, section B, the middle part and section C, the posterior part. From the central and the peripheral parts of each section, ova samples were cut out. Diameters of 30 ova were measured in each sample (60 ova from each section) with eyepiece micrometer mounted in microscope.

An example of the results of such measurements is shown in Tables 3 and 4. From these tables it can be seen that no statistically significant difference is detected in size of the ovarian eggs within one section and between sections. It is supposed from these results that the development of ovarian eggs might be advanced uniformly throughout the ovary. Accordingly, the spawning of the puffer is considered to be done at a time or at least in a very short period of time. The evidence is clearly shown in Pl. 2, Figs. 3 and 4 and Pl. 3, Figs. 5 and 6. It is noted from these figures that in a full matured ovary it is filled with ripe ova remaining no immature ones.

Table 3. Test of difference in ova-diameter within one section. For explanation, see text.

	Section A		Section B		Section C	
	Central part	Marginal part	Central part	Marginal part	Central part	Marginal part
Mean	65.90	65.77	66.20	66.00	64.23	65.73
Variance	6.01	6.18	7.41	8.97	12.39	8.82
F-test	$F_0=0.18<F^1_{58}(0.01)=7.09$		$F_0=0.07<F^1_{58}(0.01)=7.09$		$F_0=3.18<F^1_{58}(0.01)=7.09$	

Unit of the mean of ova-diameter; 1/55 mm.; 18. 1μ.

Table 4. Test of difference in ova-diameter between two sections. For explanation, see text.

	Section A	Section B	Section C
Mean	65.83	66.10	64.98
Variance	6.06	8.06	11.00

F-test:

Between Sections A and B.	$F_0=0.31<F^1_{118}(0.01)=6.85$
Between Sections B and C.	$F_0=3.95<F^1_{118}(0.01)=6.85$
Between Sections A and C.	$F_0=2.54<F^1_{118}(0.01)=6.85$.

2) *Relation of length and weight with fecundity of Fugu rubripes.*

One gram of ova weighed to nearest 0.1 g. was counted. The samples of these ova were taken from six different portions of the ovary as already described. Mean number per 1 g. of ova was then calculated from these counts (Table 5). The coefficient of variation of these counts was comparatively small, so they were probably representative.

Total eggs were estimated by a simple multiplication. Such fecundity estimates

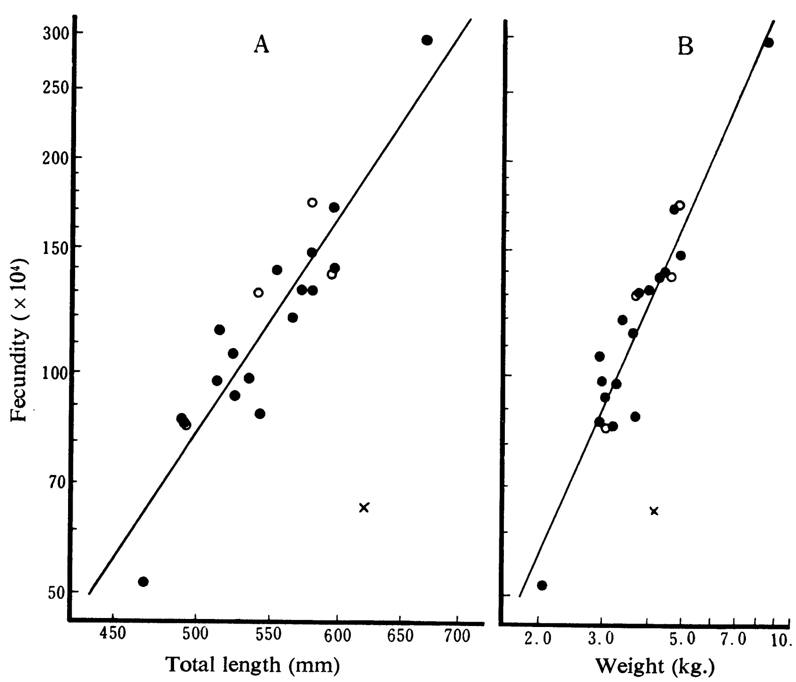
Table 5. Results of ovarian egg counts of *Fugu rubripes*.

B. W. (g.)	T. L. (mm.)	Gonad weight (g)	Gonad index	Number of ovarian eggs per g.			Estimated number of total ovarian eggs	Remark
				Range	Mean	Coef. var.		
8, 590	670	2, 435	28. 3	1, 164—1, 287	1, 214± 44	3. 5	2, 956, 493±17, 052	Samplings of ova made from six different parts of ovary.
4, 920	578	1, 480	30. 1	952—1, 088	1, 000± 52	5. 0	1, 479, 280±12, 868	
4, 700	595	1, 067	22. 7	1, 446—1, 688	1, 609±108	6. 4	1, 716, 978±19, 144	
4, 450	553	1, 404	31. 6	932—1, 052	995± 44	4. 2	1, 396, 512±10, 258	
4, 280	595	1, 211	28. 3	1, 049—1, 174	1, 136± 47	4. 0	1, 374, 762± 9, 556	
3, 710	542	510	13. 7	1, 361—2, 130	1, 715±294	16. 3	874, 480±25, 010	
3, 380	565	734	21. 7	1, 470—1, 780	1, 632±126	7. 3	1, 197, 762±15, 386	
3, 260	513	642	19. 7	1, 422—1, 632	1, 514± 80	5. 0	971, 988± 8, 553	
3, 200	492	811	25. 3	981—1, 094	1, 046± 45	4. 1	848, 578± 6, 068	
2, 960	535	647	21. 9	1, 205—1, 733	1, 517±219	13. 7	981, 172±23, 606	
2, 940	490	491	16. 7	1, 614—1, 903	1, 754±120	6. 5	861, 132± 9, 859	
2, 050	468	{ 360	(20. 7)	{ 1, 131—1, 246	1, 205± 66	5. 2	433, 860± 3, 971 } 505, 647	
		·64*		1, 104—1, 145	1, 122± 22	1. 9	71, 787± 473	
3, 620	514	1, 050	29. 0	—	1, 093	—	1, 147, 125	Samplings of ova made from two parts of ovary.
3, 030	525	596	19. 7	—	1, 560	—	929, 462	
4, 020	580	893	22. 2	—	1, 462	—	1, 305, 120	
3, 760	572	779	20. 7	—	1, 679	—	1, 307, 552	
2, 930	524	975	33. 3	—	1, 092	—	1, 064, 700	
4, 160	620	910	21. 9	—	708	—	644, 707	FUJITA and UENO (1956)

* Eggs shed out during preservation.

were made for 17 famales ranging in total length from 468 to 670 mm. and in weight from 2,050 to 8,590 g. (see also Table 5). The fecundity estimates ranged from 50.6×10^4 to 295.6×10^4 showing an increase in egg number with increasing length and weight of fish.

Regressions of the number of eggs on length and weight of fish were calculated by least squares with the resulting formulae: $N = 0.0000312\, L^{3.862}$ and $N = 0.0120\, W^{1.161}$, where N represents number of eggs; L, total length in millimeters and W, weight in grams. When the logarithm of the fecundity is plotted against the logarithms of the total length and the weight, the straight lines shown in Text-figs. 5A and 5B are obtained. In these figures, FUJITA and UENO's (1956) count on a single specimen is also shown. The value they obtained is noticeably smaller than those obtained here for the corresponding length and weight. Since the specimen they treated with was fully matured, it is presumed that some free flowing eggs had perhaps been shed out of the body before capture.

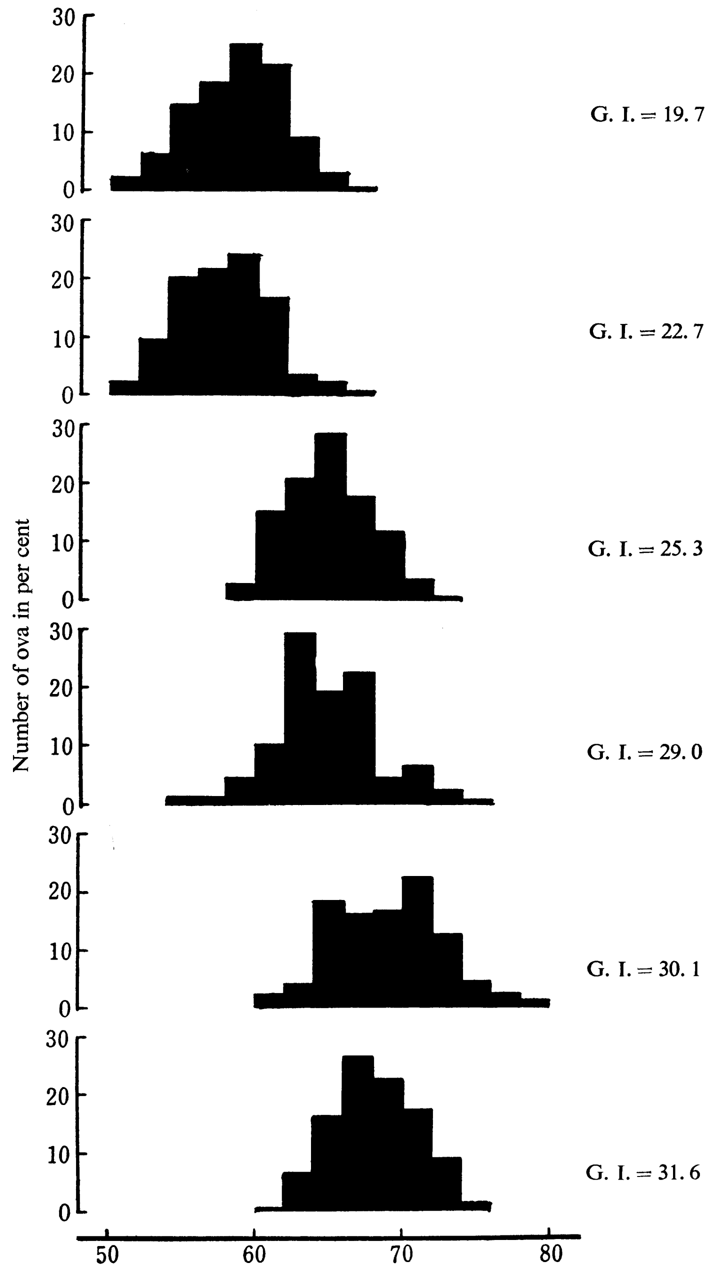


Text-fig. 5. Fecundity-length and fecundity-weight relationships of *Fugu rubripes*. FUJITA & UENO's (1956) count is shown with a cross.

3) Relation of size and weight with gonad index.

As mentioned already, the ovarian eggs increase in size and weight as spawning approaches. Gonad indices were calculated on females, the ovaries of which had been used for the fecundity studies. Gonad index was expressed as G.I. = (ovary weight in grams/body weight in grams) $\times$ 100.

The ova-diameter measurements and the number of ova per gram were correlated with gonad index. The relationship of size and number per g. of ovarian eggs with gonad index is clearly demonstrated in Table 5 and Text-fig. 6. In full-matured specimens, the ova-diameters become as large as about 1.4 mm. and the number of ova decreases to 1,000–1,100 per gram. (Pl. 4, Fig. 7).



Text-fig. 6. Frequency distribution of ova-diameter in relation to gonad index.
G. I.: gonad index (gonad weight/body weight × 100).

IV. Spawning Grounds of *Fugu rubripes* in the Central Waters of the Inland Sea.

On the habit of spawning of Japanese puffers, there is only a report by UNO (1955), working with *Fugu niphobles*. He described that this species spawns on sandy beaches of the spray zone.

No information has hitherto been known on the spawning of *Fugu rubripes*. FUJITA & UENO (1956) succeded in carrying out artificial insemination of the eggs of the puffer, giving detailed description on the early development, the fry and the post-larvae. According to them, the eggs of *Fugu rubripes* have strong adhesive power. Hatching occurs about 10 days after insemination at 16°–19°C.

Judging from these findings together with the nature of the eggs of puffer in general (FUJITA, 1958), it was possible for us to think that the eggs of *Fugu rubripes* might be deposited somewhere on the bottoms of the sea. In an endeavor to find the eggs deposited on bottoms, thus making clear the actual spawning ground of the puffer, efforts were concentrated in collecting bottom deposits of the fishing grounds, where abundant spawners had been caught.

On May 5, 1960 we succeeded in collecting 22 eggs of the puffer for the first time in the Noti Strait off Mihara City, Hiroshima Pref. Three to seven days later of this success, collections were also made in the waters off Shimotsui, Okayama Pref., and in the waters around Ushi-Shima, Kagawa Pref. with greater success; this time hundreds of eggs were collected (Pl. 4, Fig. 8).

In the 1961 season, the same successful collection of the eggs was attained in the waters near Ushi-Shima (Pl. 8, Fig. 16) and in Shimonoseki Strait, the most western part of the Inland Sea.

Details of these investigations are as follows.

Investigation No. 1. May 5, 1960.

Locality: Noti Strait, off Mihara City, Hiroshima Pref.

Bottom deposits were collected from 7 stations. Eggs collected from 2 stations; 4 at St. 1 and 18 at St. 2.

Investigation No. 2. May 8, 1960.

Locality: Near Muroki-Shima off Shimotsui, Kojima City, Okayama Pref.

Bottom deposits collected from 4 stations, depth, 20-30 m. At St. 2, 396 eggs collected, depth 21 m.

Investigation No. 3. May 10, 1960.

Locality: Noti Strait.

Collections made at 14 stations, eggs found at Sts. 12, 13 and 14, the numbers of which were 1, 14 and 3 respectively.

Investigation No. 4. May 13～14, 1960.

Locality: In the waters from the east of Oozuchi-Shima, off Takamatsu City, to Ushi-Shima, off Marugame City, Kagawa Pref.

Eggs collected abundantly. For details, see Table 6.

Investigation No. 5. May 7, 1961.
Locality: In the waters around Ushi-Shima.
For details, see Table 7.

Investigation No. 6. May 10, 1961.
Locality: Shimonoseki Strait, the westernmost part of the Inland Sea of Japan.
Collections made at 4 stations, 4 eggs found at St. 1.

Investigation No. 7. May 16–17, 1961.
Locality: In the waters around Ushi-Shima.
For details, see Table 8.

Bottom sediments collected by dredging were put into a small bucket and about $3l$ of sea water was poured into it. When stirred up with hand, the eggs were easily caused to float and the floating eggs were picked up quickly. These procedures were repeated severally until all the eggs were recovered. Bottom sediments excluding the puffer eggs and other organisms were dried and passed through six sieves

Table 6. Relation between particle size of the sediment and the number of eggs found in it. Investigation No. 4, May 13–14, 1960.

St.	Particle size (mm.)							Number of eggs found
	<1	1～2	2～4	4～6	6～8	8～10	10<	
	%	%	%	%	%	%	%	
1	97.0	2.2	0.5	0.3	—	—	—	0
2	50.4	3.3	3.4	4.8	7.8	5.2	25.2	0
3	76.3	4.0	3.1	1.7	1.7	0.9	12.1	0
4	90.5	4.6	3.6	1.2	0.2	—	—	0
5	93.8	3.1	2.0	0.2	0.7	0.2	—	0
6	90.3	5.3	2.2	1.6	0.6	—	—	0
7	98.5	1.1	—	0.4	—	—	—	0
8	99.2	0.5	—	0.3	—	—	—	0
9	16.9	14.9	34.3	20.0	8.2	2.0	3.5	372
10	34.7	16.9	18.0	12.7	10.0	4.1	3.6	128
11	2.1	14.1	51.2	26.5	1.9	1.6	2.6	94
12	1.8	5.7	17.4	17.9	10.6	9.9	36.8	6
13	3.0	4.8	14.2	13.2	16.1	12.2	36.5	0
14	1.4	3.5	10.3	7.9	8.1	3.7	65.1	3
15	—	0.3	3.1	3.3	4.0	2.5	86.8	0
16	0.4	0.8	2.4	2.4	2.8	1.8	89.3	6
17	16.7	15.6	17.7	13.4	10.5	3.5	22.8	7
18	9.5	15.0	15.4	11.2	6.9	3.3	38.7	17
19	4.6	11.6	25.5	14.3	2.7	2.6	38.6	2
20	10.8	12.7	23.0	14.0	10.5	3.4	25.5	24
21	1.9	4.4	11.4	7.2	6.6	1.6	6.7	1
22	18.5	17.3	20.7	9.5	5.4	2.1	26.7	0
23	4.6	10.0	16.9	10.5	7.7	3.9	46.4	0
24	7.1	13.2	15.9	8.8	7.8	4.4	42.7	4
25	10.4	14.8	18.4	8.4	8.8	2.7	36.8	0

Table 7. Relation between particle size of the sediment and the number of eggs found in it. Investigation No. 5, May 7, 1961.

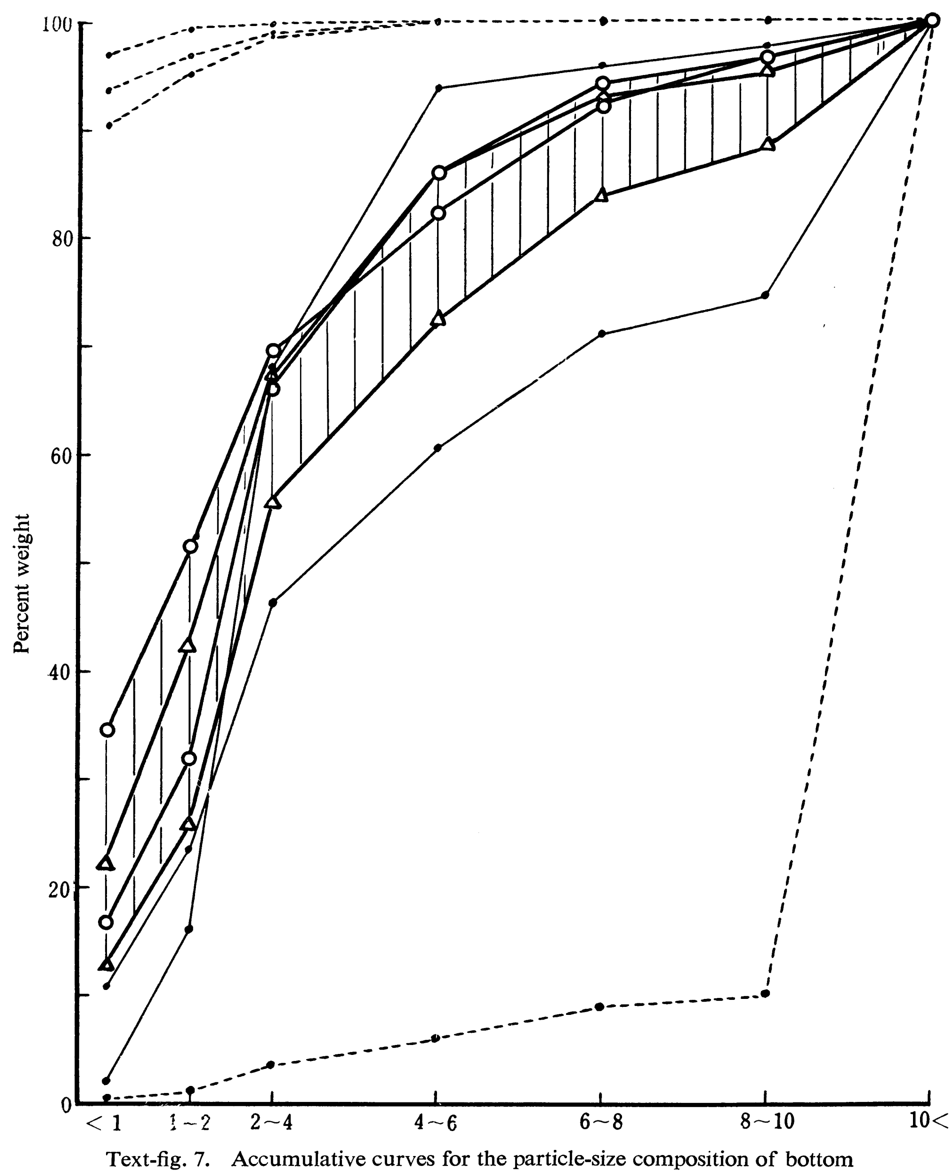
St.	Particle size (mm.)							Number of eggs found
	>1	1~2	2~4	4~6	6~8	8~10	10<	
1	21.0%	32.5%	23.1%	8.9%	6.9%	2.7%	5.0%	13
2	10.4	22.7	28.0	14.8	9.7	4.6	9.8	4
3	15.0	24.9	29.7	10.8	7.7	2.5	9.4	0
4	0.5	7.5	15.5	8.3	9.3	7.0	51.9	1
5	0.6	6.1	13.1	13.3	14.6	11.0	41.3	0
6	0.4	1.8	6.8	6.8	7.0	0.0	77.2	0
7	0.1	0.4	1.5	1.5	1.8	0.3	94.4	0
8	0.2	0.4	5.1	6.8	6.9	6.9	73.7	0
9	12.6	12.9	30.2	16.9	11.4	4.7	11.3	229
10	17.6	18.2	23.1	14.0	13.6	4.5	9.0	62
11	6.4	17.0	39.1	19.2	10.3	2.5	5.5	17
12	81.2	2.6	2.8	0.9	1.0	1.5	10.0	0

Table 8. Relation between particle size of the sediment and the number of eggs found in it. Investigation No. 7, May 16–17, 1961.

Date	St.	Particle size (mm.)							Number of eggs found
		<1	1~2	2~4	4~6	6~8	8~10	10<	
May 16, 1961. a. m.	1	0.3%	0.8%	1.5%	1.9%	2.0%	2.4%	91.1%	10
	2	66.4	15.2	9.1	2.1	1.1	0.5	5.6	2
	3	0.9	3.9	19.5	17.9	17.6	12.7	27.5	1
	4	1.1	3.6	28.0	20.8	9.4	3.9	33.2	16
	5	83.3	10.3	5.1	0.8	0.2	0.1	0.2	1
	6	75.3	16.1	6.4	1.0	0.5	0.2	0.5	0
	7	24.1	16.6	21.5	10.1	8.0	3.8	15.9	20
	8	2.5	6.0	16.7	12.0	11.4	7.2	44.2	7
	9	4.5	16.6	41.0	16.8	9.7	4.5	6.9	3
	10	16.3	13.7	22.1	10.3	9.3	5.9	22.4	2
	11	18.3	15.6	24.3	13.7	12.0	5.8	11.3	17
	12	36.6	31.6	20.7	7.2	2.3	0.5	1.1	51
	13	64.7	19.8	10.8	2.2	1.2	0.5	0.8	1
	14	—	—	—	—	—	—	—	0
	15	12.5	23.2	31.6	16.9	7.7	0.7	7.4	43
	16	32.0	15.4	20.9	14.6	7.5	3.8	5.8	0
	17	20.7	9.9	13.8	8.1	6.6	4.2	36.7	20
	18	23.7	29.0	36.7	7.5	2.2	0.5	0.4	1
May 16, 1961. p. m.	1	34.7	42.5	18.4	1.6	0.3	0.5	2.0	0
	2	87.6	7.5	3.4	0.5	0.4	0.1	0.5	0
	3	62.1	32.7	4.6	0.4	0.2	—	—	0
	4	14.9	15.9	22.8	19.0	8.6	3.5	15.3	0
	5	10.5	10.6	17.2	12.1	11.6	5.6	32.4	0
May 17, 1961.	1	19.6	25.4	31.7	11.9	4.4	1.4	5.4	2
	2	23.3	19.2	24.8	18.8	6.9	2.4	3.9	223
	3	31.5	21.0	25.6	12.8	3.8	1.7	3.6	2
	4	44.3	17.0	16.7	12.2	5.1	1.6	3.2	20

with meshes of 1, 2, 4, 6, 8 and 10 mm., respectively. Each of the resultant seven components, having particle size of less than 1, 1–2, 2–4, 4–6, 6–8, 8–10 and larger than 10 mm., was weighed.

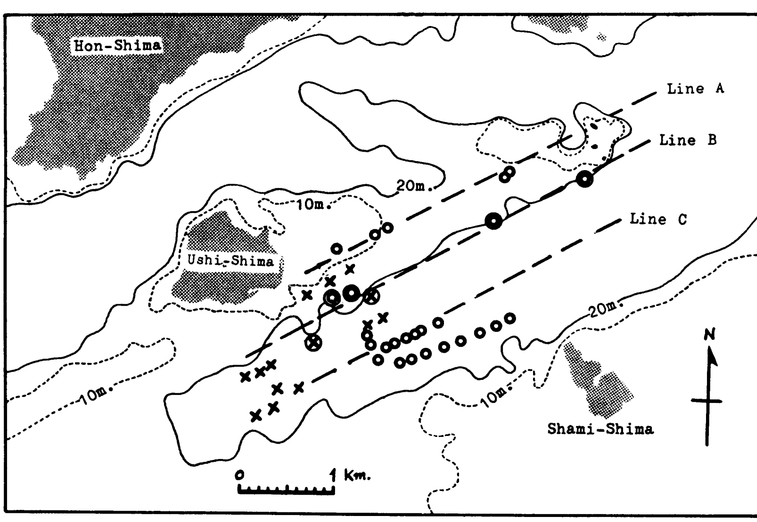
The results of sediment analyses of the Investigation Nos. 4, 5 and 7 done in the Ushi-Shima fishing ground in May 1960–1961 are shown in Tables 6, 7 and 8, respectively, with the counts of the eggs found within these sediments. From these tables it can be seen that bottom sediments of the stations where abundant eggs were collected are composed chiefly of sand of 2–4 mm. in diameter. In Text-fig. 7, ac-



Text-fig. 7. Accumulative curves for the particle-size composition of bottom sediments in relation to number of eggs found.

cumulative weight frequency curves for the sediments from which abundant eggs were collected are shown with thick solid lines. In both 1960 and 1961 seasons, the sediments from which abundant eggs were taken are similar in particle-size composition. In comparison with these curves, those for the sediments in which considerable number of eggs (thin solid lines) and practically no egg (dotted lines) were found are also illustrated.

Some of the stations where bottom sediments were taken in Investigation Nos. 4 and 5 in the Ushi-Shima fishing ground are shown in Text-fig. 8. The bottom sediments of the stations situated around the line A (Sts. 1–8, Investigation No. 4) are consisted chiefly of fine sand (Pl. 5, Fig. 9). These stations are in shallower region between 10–20 m. in depth, where no egg was found. Stations around the line C (Sts. 14–16, Investigation No. 4) are located in the region deeper than 20 m. where bottom sediments are composed of large pebbles (Pl. 5, Fig. 10) and a small number of eggs were sporadically taken. The stations where abundant eggs were collected are concentrated on the line B. Being situated between the lines A and C, these stations are located along the 20 m. depth line, where the bottom contours slope downwards. The bottom sediments of these stations are shown in Pl. 6, Figs. 11 and 12; Pl. 7, Figs. 13 and 14.



Particle size (mm.)

Text-fig. 8. Stations where bottom sediments were collected. Open circles show stations in Investigation No. 4, and crosses, those of Investigation No. 5.

The characteristic features of the spawning grounds of *Fugu rubripes* are thus made clear. The results obtained above show that the spawning grounds of the puffer lie on the bottoms having particle-size of sediments 2–4 mm. in diameter where current velocity is relatively fast.

It should be added here that on May 6, 1962, NAKANO and HOSHINO (personal communication) succeeded in collecting the eggs of the puffer deposited on the bottom of a puffer-culture ground, Hitsuishi-Shima, off Kojima City, Okayama Prefecture. This is perhaps the first record of collection of the eggs deposited outside of the natural spawning beds.

SUMMARY

1) In order to make clear the fecundity and spawning of a puffer, *Fugu rubripes* T. et S., investigations were carried out in the central waters of the Inland Sea of Japan in April-May, 1960–1961.

2) Distribution of the fishing grounds of *Fugu rubripes* in Bisan Strait was shown.

3) Morphological characteristics of the spawners of *Fugu rubripes* were clarified. Sex-ratio (female: male) of the spawners caught by seine-nets was approximately 1:3. Females were significantly greater in weight than in males, while the difference in total length between both sexes was not significant.

4) Development of ovarian eggs seems to be advanced uniformly within an ovary, which makes reasonable to consider that the spawning may occur at a time or at least in a very short period.

5) Relationships of fecundity with total length and weight of body were clarified.

6) Successful collection of the eggs deposited on natural spawning beds was made. The data obtained in the present investigation show that the spawning beds of *Fugu rubripes* lie in the bottoms having particle-size of sand 2–4 mm. in diameter.

REFERENCES

FUJITA, S. & UENO, M. 1956. On the egg development and prelarval stages of *Fugu* (*Torafugu*) *rubripes* (TEMMINCK et SCHLEGEL). Sci. Bull. Fac. Agr., Kyushu Univ., **15** (4): 519–524. (In Japanese with English summary).

TAKAI, T., MIZOUE, A. & MATSUI, I. 1959 a. Study on the fisheries biology and culture of the puffer, *Fugu rubripes* (TEMMINCK et SCHLEGEL). I. On the pond-culture of the puffer. J. Shimonoseki Coll. Fish., **8** (1): 91–99. (In Japanese with English summary).

——— ——— ——— 1959 b. Study on the fisheries biology and culture of the puffer, *Fugu rubripes* (TEMMINCK et SCHLEGEL). II. On the growth and decreasing rate of the fingerling fish. *Ibid.*, **8** (1): 101-104. (In Japanese with English summary).

——— ——— ——— 1959 c. Study on the fisheries biology and culture of the puffer, *Fugu rubripes* (TEMMINCK et SCHLEGEL). III. The constitution of total length and the feeding habit of the fingerling fish. *Ibid.*, **8** (1): 105–112 (In Japanese with English summary).

UCHIDA, K., et al. 1958. *Studies on the Eggs, Larvae and Juvenile of Japanese Fishes.* Series I., viii+89 p., 84 pls. 2nd Lab. Fish. Biol., Fish. Dept., Fac. Agr., Kyushu Univ., Fukuoka. (In Japanese).

UNO, Y. 1955. Spawning habit and early development of a puffer, *Fugu* (*Torafugu*) *niphobles* (JORDAN et SNYDER). J. Tokyo Univ. Fish., **41** (2): 169–183.

YASUDA, J. 1959. Commercial rearing of the puffer (*Sphaeroides rubripes*) in the Seto Inland Sea and the prospects of the enterprise. The Aquiculture, **7** (2): 24–38. (In Japanese).

———, 1960. (Commercial rearing of the puffer). The aquiculture, **7** (4): 31–40. (In Japanese).

瀬戸内海中央部におけるトラフグの産卵に関する研究

日下部台次郎・村上　豊・遠部　卓

トラフグの産卵については従来まったく知られていなかった．われわれは，1960年および1961年の4～5月，瀬戸内海中央部において，本種の産卵に関する研究を行ない，次の結果をえた．

1)　備讃瀬戸におけるトラフグ漁場は，水深20m以上の比較的潮流の早い場所に局在している．漁期は4月中旬～5月中旬であり，産卵群を漁獲の対象としている．従って，これら漁場は同時にトラフグの産卵場である．

2)　産卵群の形態的特徴を明らかにした．タイ縛網に混獲される産卵群の性比は，雄3：雌1の割合であった．全長平均値間の雌雄差は認められなかったが，体重平均値間にみられる両者の差は極めて有意であり，雌が大きい．

3)　卵巣内における卵の発達は，一様に進行する．このことから，放卵は一回あるいはきわめて短期間に完了するものと推定される．

4)　孕卵数（N）と全長（L，mm）および体重（W，g）との関係は，それぞれ次の指数式で表わすことができる。

$$N = 0.0000312 \cdot L^{3.862}\,;\ N = 0.0120\,W^{1.161}.$$

5)　トラフグ漁場の底質中より，天然に産着された多量のトラフグ卵の採集に成功し，産卵場を確認することができた．

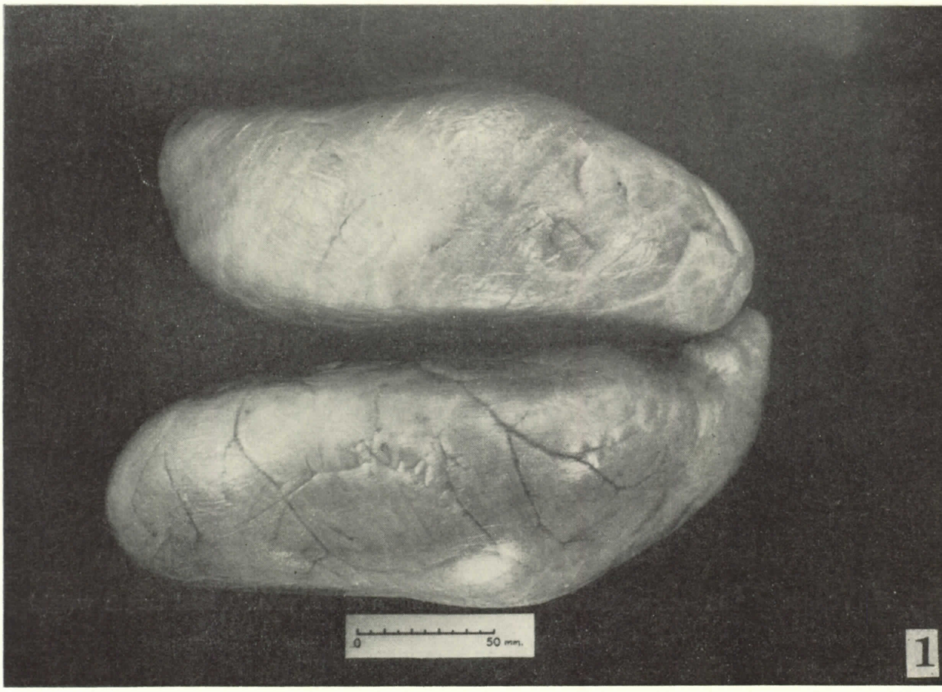
6)　産着卵数と底質の粒子組成との間にみられる関係から，産卵床の特徴を明らかにすることができた．卵の最も多く見出された場所は，径2～4mmの粒子の卓越する（重量組成）場所であった．底質が細砂，粗礫よりなる場所からは，殆んどあるいは全く産着卵は採集できなかった．

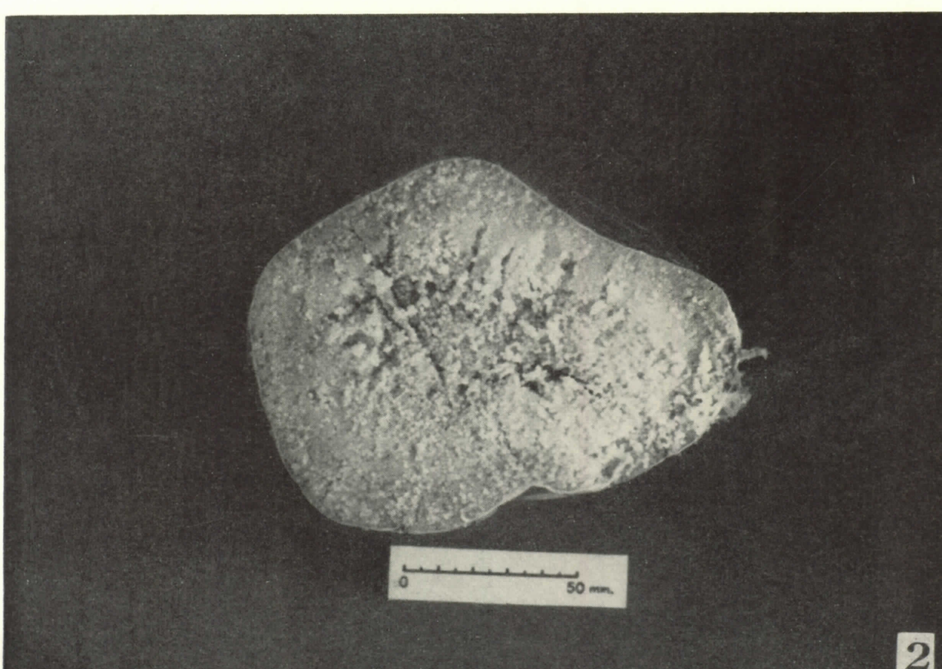
EXPLANATION OF PLATES

Plate 1.

Fig. 1. The largest ovary taken from a fish of 670 mm. in total length weighing 8,590 g. (ovary weight: 2,435 g.), captured on April 30, 1960. Dorsal view.

Fig. 2. Cross section of the lobe of the same ovary shown above.





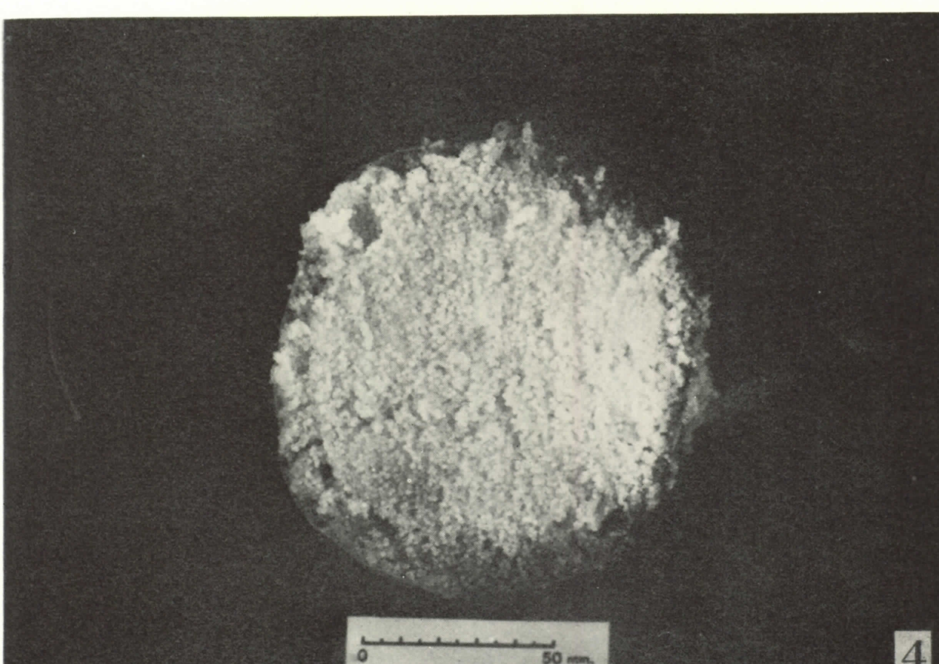
KUSAKABE, MURAKAMI & ONBE : Fecundity and Spawning of *Fugu rubripes*

Plate 2.

Fig. 3. Left lobe of a full-matured ovary taken from a fish of 594 mm. in total length weighing 4,580 g., captured on May 2, 1960.

Fig. 4. Cross section of the same.

3



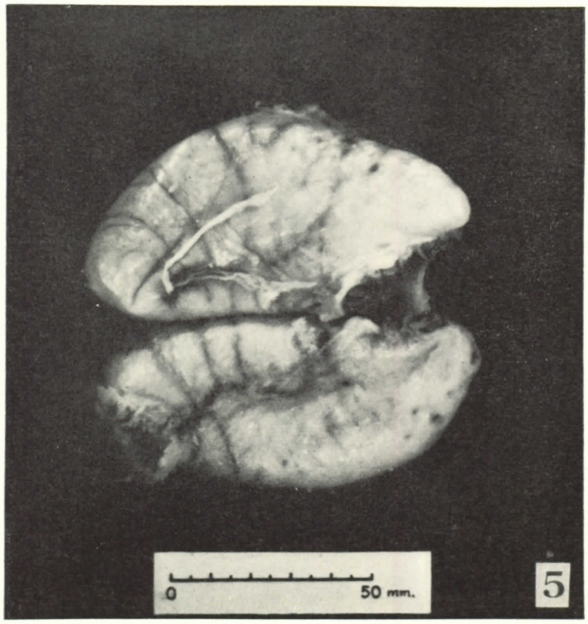
4

KUSAKABE, MURAKAMI & ONBE : Fecundity and Spawning of *Fugu rubripes*

Plate 3.

Fig. 5. A spent ovary of a fish of 537 mm. in length weighing 2,540 g., captured on May 2, 1960.

Fig. 6. Sagittal section of the same, showing no ova within.


0
50 mm.
5

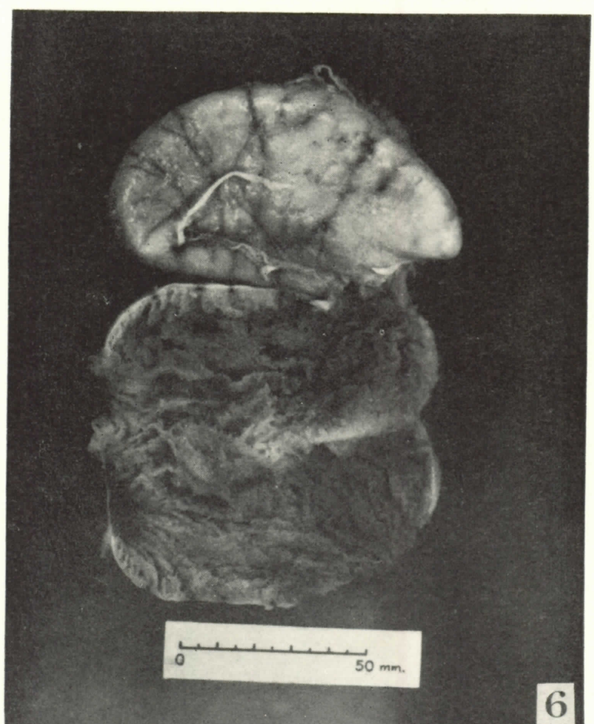
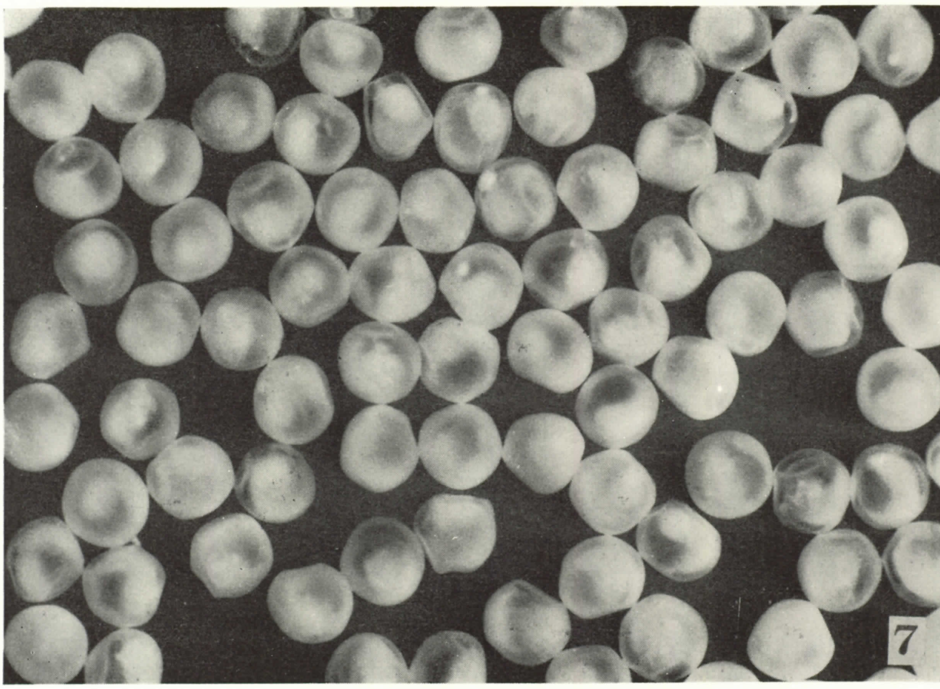
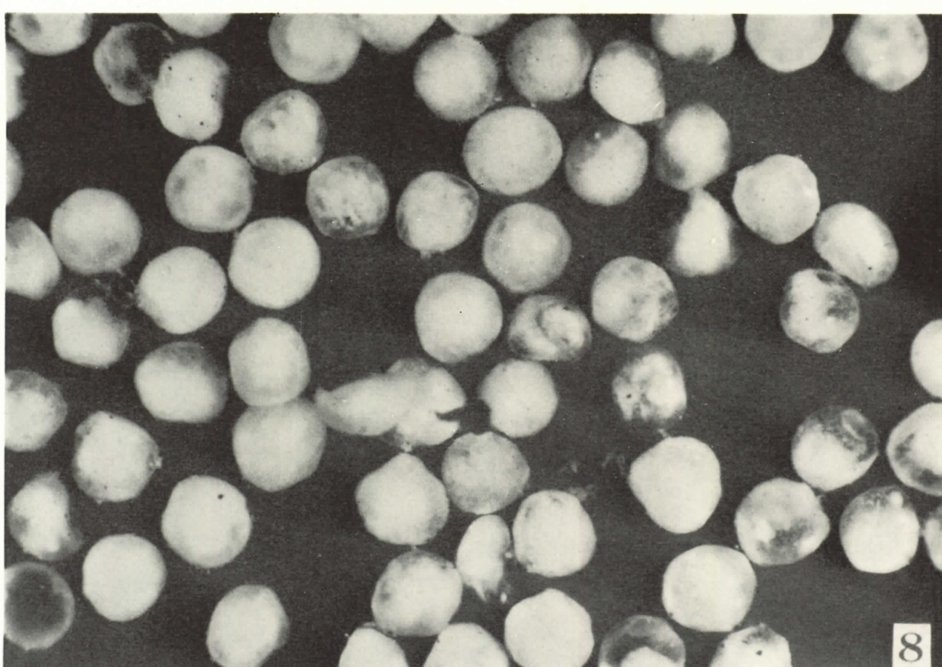

0
50 mm.
6

Plate 4.

Fig. 7. Full-matured ovarian eggs, taken from the ovary shown in Plate 2, dispersed in water. Deformation due to preservation. Diameter: 1.14～1.30 mm. (mean: 1.21mm).

Fig. 8. Eggs spawned in nature, collected in the waters around Ushi-Shima on May 14, 1960. Depth: 20–30 m. Diameter: 1.16～1.44 mm. (mean: 1.32 mm).



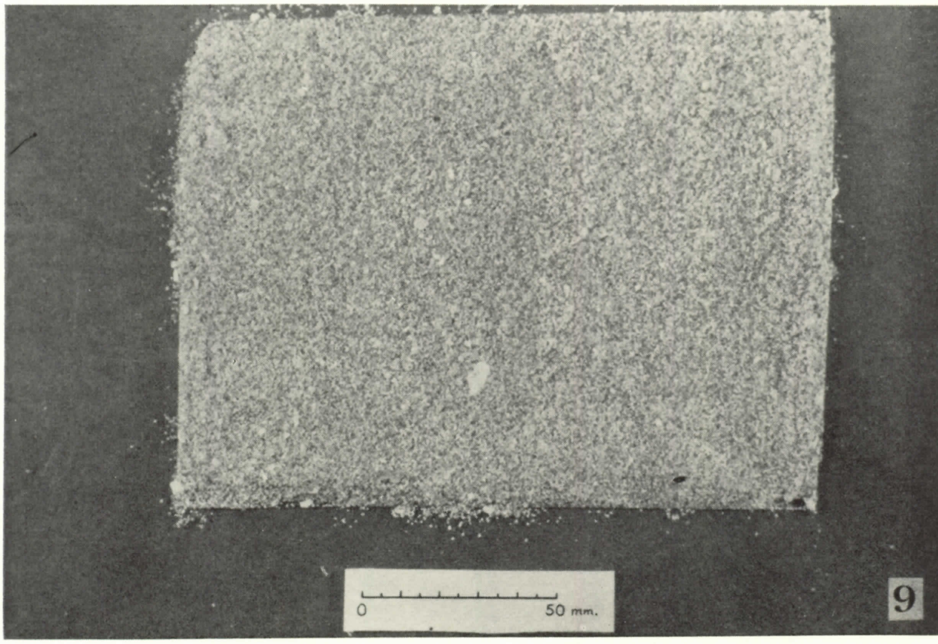


KUSAKABE, MURAKAMI & ONBE : Fecundity and Spawning of *Fugu rubripes*

Plate 5.

Fig. 9. Bottom sediment consisted of fine sand. No egg found.

Fig. 10. Bottom sediment consisted chiefly of pebbles. No egg found.


0
50 mm.
9

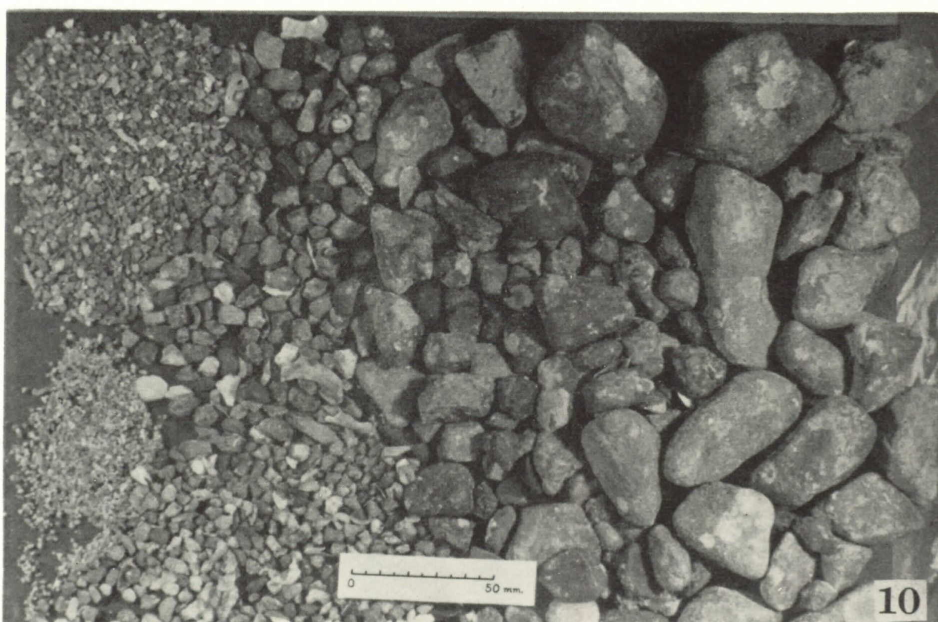
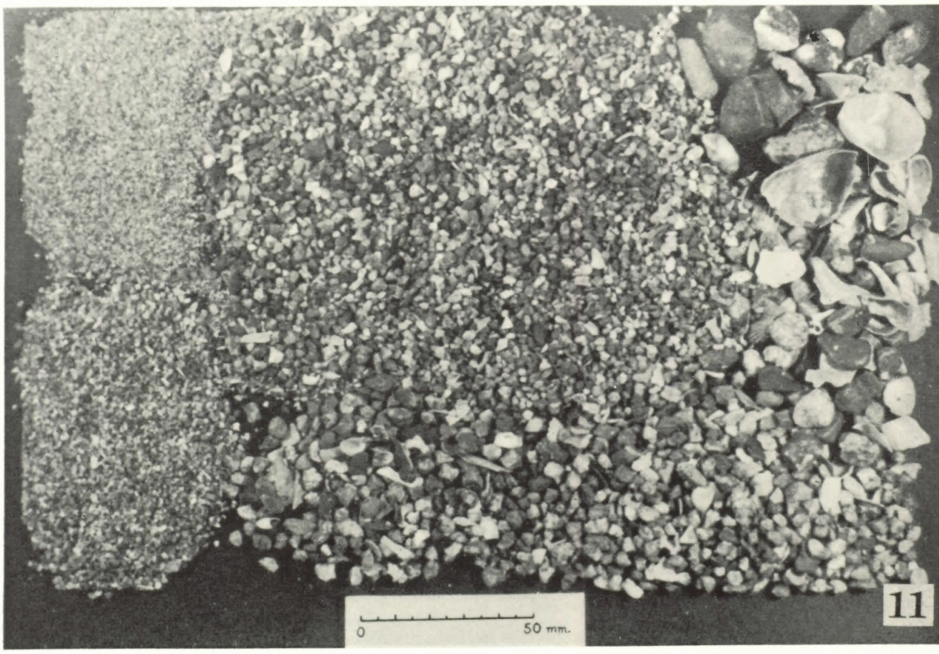
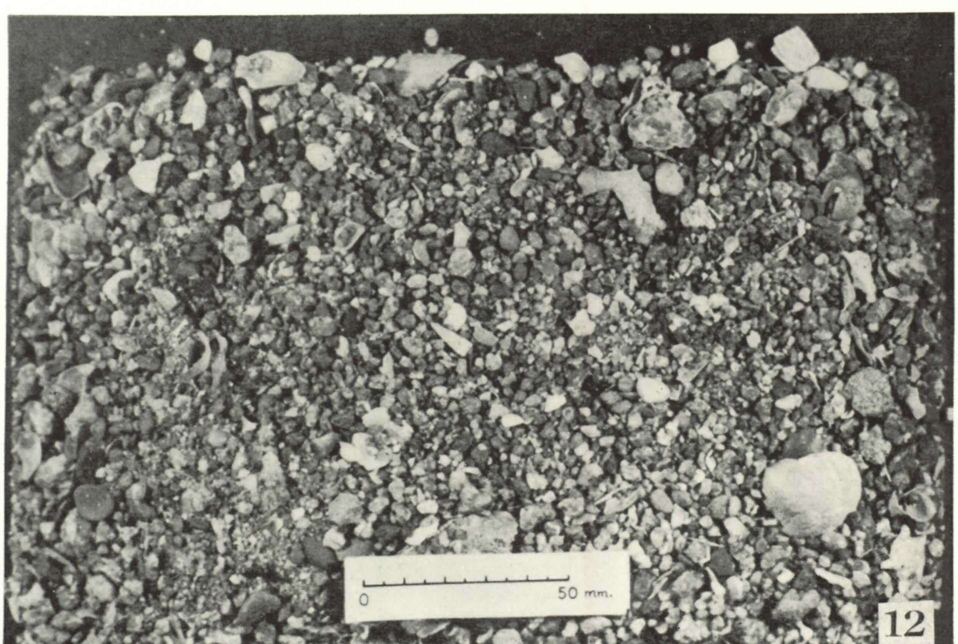

0
50 mm.
10

Plate 6.

Fig. 11. Bottom sediment in which 372 eggs were found, showing particle composition.

Fig. 12. The same as above, mixed.



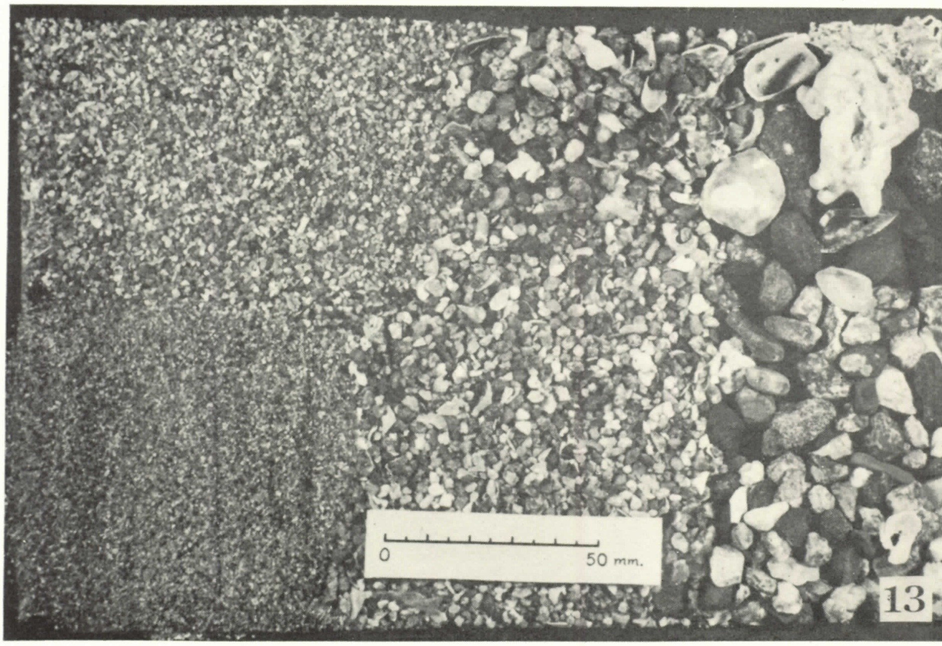


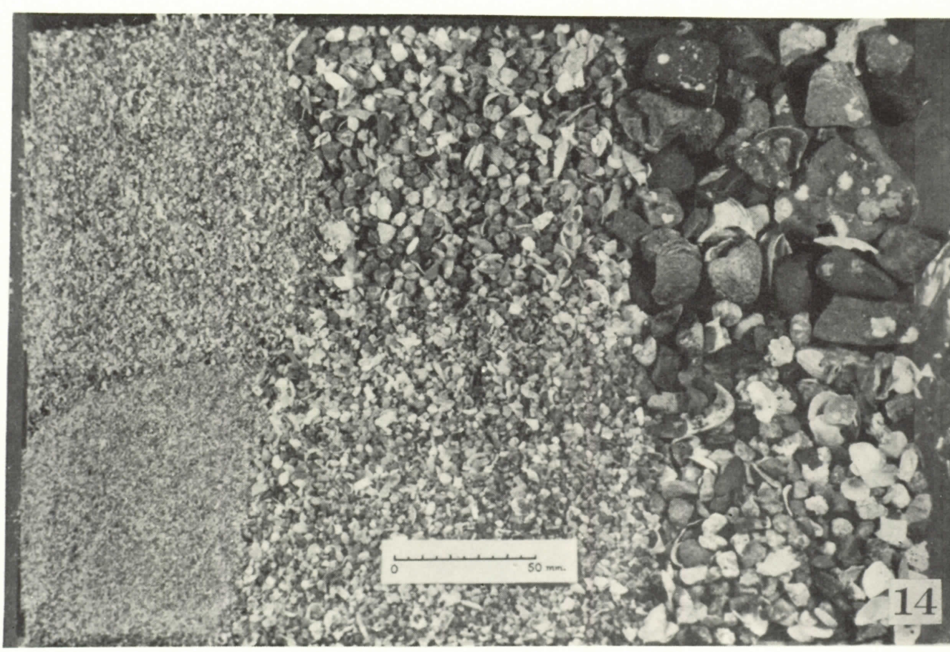
KUSAKABE, MURAKAMI & ONBE : Fecundity and Spawning of *Fugu rubripes*

Plate 7.

Fig. 13. Bottom sediment in which 128 eggs were found.

Fig. 14. Bottom sediment in which 50 eggs were found.



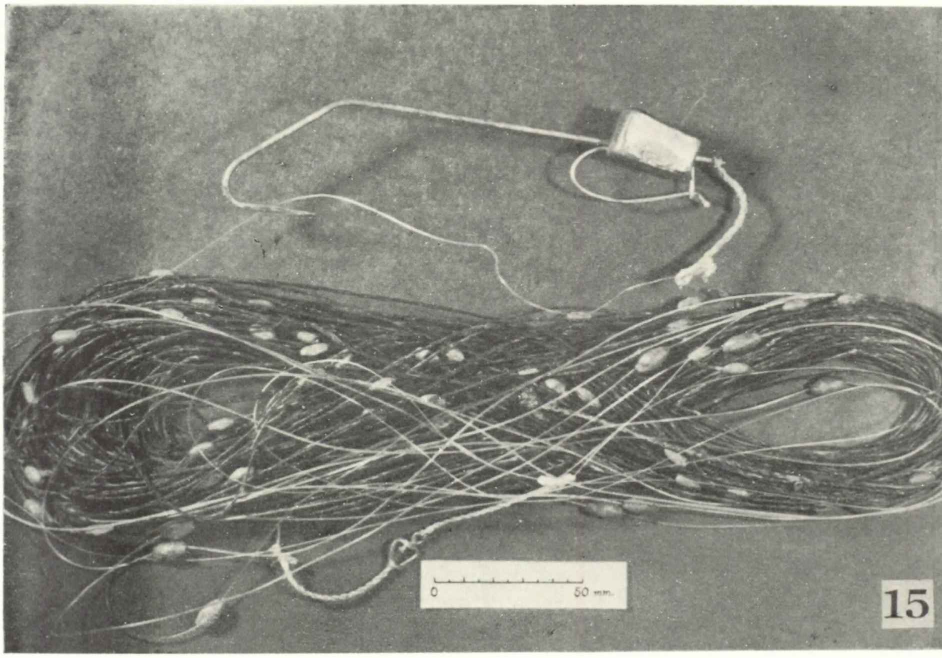


KUSAKABE, MURAKAMI & ONBE : Fecundity and Spawning of *Fugu rubripes*

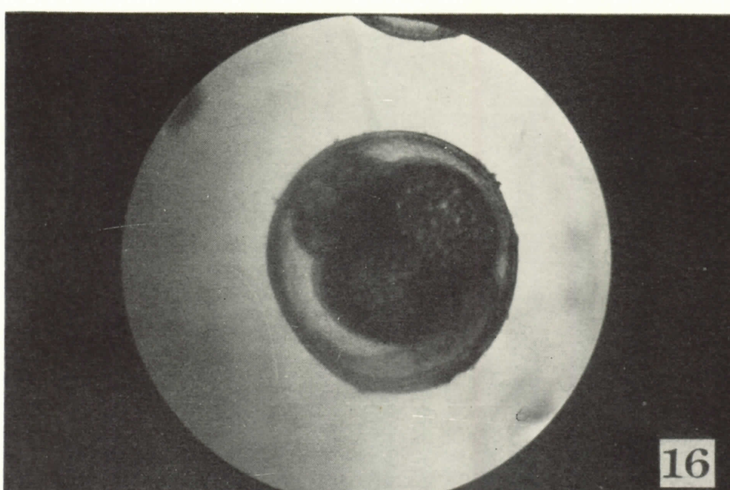
Plate 8.

Fig. 15. Fishing-tackle used for fishing spawners of *Fugu rubripes* in the central waters of the Inland Sea.

Fig. 16. An egg collected on May 16, 1961, showing advanced embryonic development.



15



16