EFFECTS OF X-IRRADIATION UPON RAINBOW TROUT (*SALMO IRIDEUS*)

III. Ovary Growth in the Stages of Fry and Fingerling*

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There have been published numerous papers on the effects of the various kinds of radiations upon the ovary in a number of species of animals. It has generally been accepted that, in comparison with other organs, the ovary is highly sensitive to the radiations.[1] A few studies have also been reported on the effects of X-irradiation upon the ovary in the salmonid fishes as noted in the paper of Welander *et al.*[2] However, most of these studies were made on irradiated fishes reared for a relatively short period. From the biological and fisheries standpoints the authors have been of opinion that it is important to study in what manner an ovary injured by a low but effective dosage of radiation may develop throughout the whole course of the fish's life and whether such an ovary has any hereditary influence on the descendants. To clarify such effects, rainbow trout fry exposed to X-ray have been reared, and a few studies related to this problem have already been reported.[3,4] In the course of the present study, the growth of the ovary in both control and irradiated fishes was measured. A histopathological analysis of them is in progress, but only the study made concerning the growth of the ovary in the fishes is presented in this paper.

MATERIALS AND METHODS

A detailed description of the fishes used and the irradiation procedure have already been presented in the preceding papers.[3,4] Briefly speaking, the fishes used were 2550 in number which were artificially fertilized on January 23, 1956 and hatched on March 31, 1956; the exposure of fry to X-ray of 100r and 500r was made on August 10, 1956; the body length and weight of 12 fishes sampled at random at the time of irradiation were respectively 4.2-7.2 cm and 1.3-3.5 g on average.

After irradiation the three groups of fishes, the control, the 100r and the 500r, were reared separately; about 15 - 50 fishes of each group were sampled at given intervals for the present experiment and also for the other purposes in this series of studies.

The ovaries of both sides were sampled, and the weight and length of each side one were measured respectively; the weight was obtained by use of a torsion balance. Although in most cases the ovaries of both sides were different in weight and also in length from each other even in the same fish, the measurements of the right side one only were used to analyze their growth throughout the present experiment. The values of the relative weight and length of the ovary and of the coefficient of fatness of the fishes

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indicated in the present paper were calculated from the following formulae: relative weight of ovary = ovary weight (mg) / body weight (g) × 10; relative length of ovary = ovary length (mm) / body length (mm) × 100; coefficient of fatness = body weight (g) / body length $(cm)^3$ × 1000.

Sex-ratio of the fishes sampled at each time was not always the same. As the fishes examined were sometimes biassed in number to male, the number of ovaries available for the measurements was often too small to enable one to analyze the significancy of difference between the control and irradiated fishes. Under these circumstances, the statistical test was made on the data of a convenient period which summed up the measurements of the neighbouring 2 or 3 sampling times to increase the reliability of significancy.

RESULTS

The ovary weight was measured first on the 110th day after irradiation at which time the sexes of the gonad in fry became easy to discriminate and also the gonad was easy to weigh. The ovary length was measured first on the 20th day. The ovary growth

Table 1. Seasonal changes in the relative weight of the ovary (mean ± standard error of the mean), ovary weight and body weight in the rainbow trout fry and fingerling

Group	OW mg	BW g	OW/BW×100	*t*	*P* [2]
		Nov. 28 – Dec. 24			
Control	12.0–20.0	10.5–37.2	8.7±0.74 (15)[1]	1.78	<0.1
100r	13.0–47.0	10.0–75.5	7.2±0.40 (14)	4.33	<0.001
500r	4.0–19.0	9.5–37.0	5.1±0.39 (15)	3.81	<0.001
		Jan. 23 – March 7			
Control	15.0–34.0	12.5–50.5	9.5±0.83 (11)	0.51	>0.5
100r	16.5–36.0	17.0–55.0	9.0±0.53 (16)	2.91	<0.01
500r	10.0–33.0	14.0–70.0	6.5±0.61 (15)	3.21	<0.005
		May 10 – June 21			
Control	28.0–56.0	26.0– 71.0	9.4±0.44 (13)	0.14	>0.5
100r	25.0–72.0	27.0–113.0	9.3±0.52 (15)	3.60	<0.005
500r	9.0–53.0	29.0– 92.0	7.2±0.43 (20)	3,13	<0.005

(1) Figures in the parentheses indicate the number of ovaries measured.

(2) Probability was calculated from the table of Student's *t*, using the equations: $t = m_1 - m_2 / \sqrt{SE_1^2 + SE_2^2}$ and $n = (n_1 - 1) + (n_2 - 1)$, where m_1 and m_2 represent the two means, SE_1 and SE_2 the two standard errors, and n_1 and n_2 are the number of ovaries from which the respective means are obtained.

thus measured was analyzed in connection with the coefficient of fatness of the fishes sampled in each period.

Relative weight of ovary Fig. 1 and Table 1 show the changes of the relative weight of the ovary in each group in the seasons from the early winter to the early summer of the next year. In the period from the 110th to the 136th day after irradiation, the difference between the control and 500r groups and also that between the 100r and 500r groups are both highly significant, showing $P < 0.001$ respectively. The difference

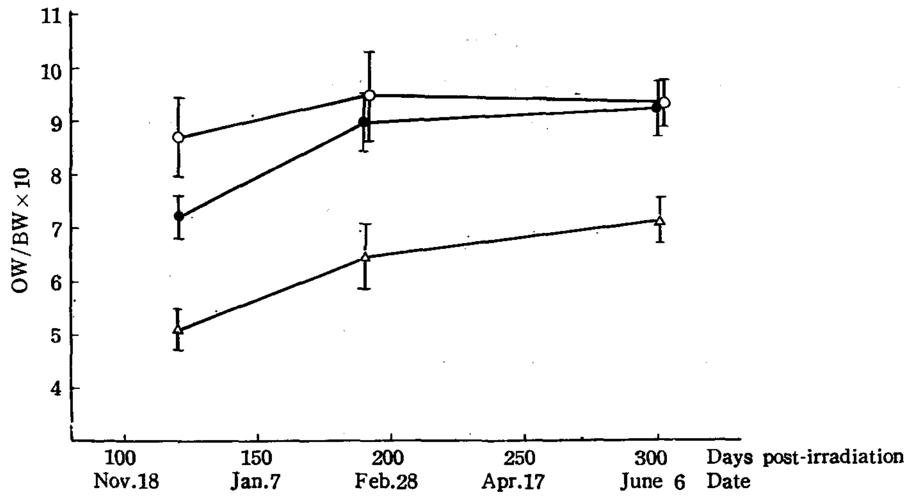

Fig. 1. Seasonal changes in the relative weight of the ovary in the rainbow trout fry and fingerling
Each bar indicates the standard error of the mean ; ○ control, ● 100r and △ 500r

between the control and 100r groups is probably non-significant ($P < 0.1$). In the period from the 166th to the 209th day, no significant difference of the relative weight of the ovary is found between the control and 100r groups, while the differences between the 500r and each of the above cited two groups are both highly significant ($P < 0.01$ and $P < 0.005$). Such a retardation of the ovary growth in the 500r group is found to continue even in the period from the 273rd to the 315th day after the exposure of X-ray. It indicates a striking recovery that the relative weight of the ovary in the 100r group attained enough the control level by the period from the 166th to the 209th day after irradiation.

Relative length of ovary It is presumable from the results shown in Fig. 2 and Table 2 that in the seasons of the autumn and winter no increase of the ovary length is found in proportion to that of the body length. However, it appears that the ovary begins to increase its length in the spring or in the early summer.

Table 2. Seasonal changes in the relative length of the ovary (mean ± standard error of the mean), ovary length and body length in the rainbow trout fry and fingerling

Group	OL mm	BL mm	OL/BL×100	*t*	*P*
			Aug. 30 – Sep. 20		
Control	6.0–17.0	51–75	17.4±0.88 (17)	0.59	>0.5
100r	5.5–14.0	54–79	16.7±0.78 (13)	0.81	<0.5
500r	7.0–12.5	51–69	16.5±0.68 (14)	0.19	>0.5
			Oct. 1 – Oct. 24		
Control	10.0–22.0	68–128	16.4±0.39 (17)	0.52	>0.5
100r	12.0–19.0	80–111	16.1±0.42 (17)	3.37	<0.005
500r	8.0–19.0	69–108	13.7±0.70 (12)	2.96	<0.01
			Nov. 28 – Dec. 24		
Control	13.0–19.0	90–137	14.8±0.52 (14)	1.22	<0.25
100r	7.0–29.0	84–164	15.9±0.74 (15)	0.36	>0.5
500r	10.0–21.5	84–131	15.1±0.64 (15)	0.82	<0.5
			Jan. 23 – March 7		
Control	10.5–28.0	96–143	14.4±0.91 (12)	0.47	>0.5
100r	14.0–22.0	100–150	14.9±0.55 (16)	0.26	>0.5
500r	13.0–28.0	95–170	14.7±0.71 (15)	0.22	>0.5
			May 10 – June 21		
Control	21.0–33.0	121–170	17.2±0.68 (13)	0.21	>0.5
100r	17.0–35.0	120–195	17.0±0.64 (15)	2.75	<0.025
500r	18.0–30.0	127–180	15.0±0.43 (18)	2.59	<0.025

In the period from the 52nd to the 75th day post-irradiation the relative length of the ovary in the 500r group is significantly smaller than that in both control and 100r groups ($P < 0.005$ and $P < 0.01$). The similar relation is also found in the period from May to June; especially, it is noteworthy that the relative length of the ovary of both control and 100r groups shows a distinct increase in this period, while that of the 500r group is only nearly equal value to that of the preceding period from January to March.

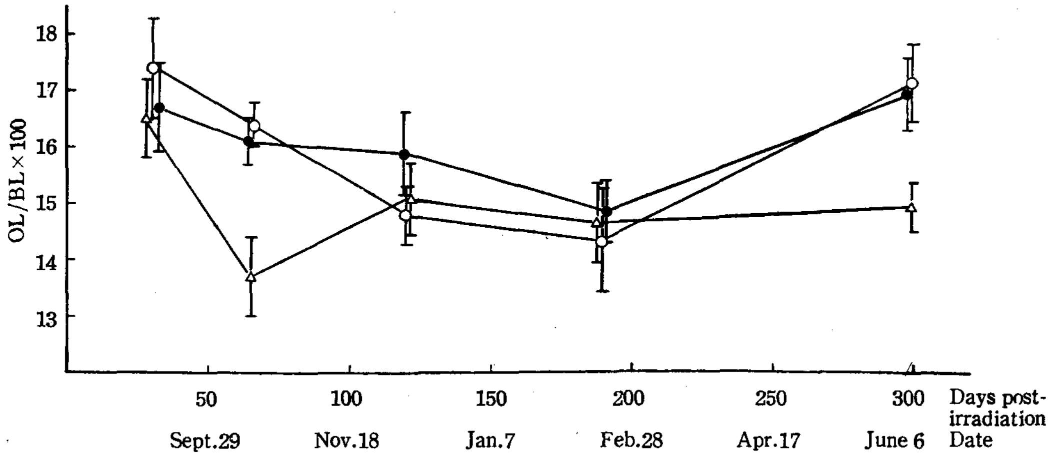

Fig. 2. Seasonal changes in the relative length of the ovary in the rainbow trout fry and fingerling Each bar indicates the standard error of the mean ; ○ control, ● 100r and △ 500r

DISCUSSION

Effective damage of the ovary by radiation, if it occurs, is to be demonstrated positively by some histological or histochemical observations. However, evidence as to the approximate degree of the injury seems to be afforded even by comparison of the ovary growth as tested in the present experiment. That is, the low and effective dosage of

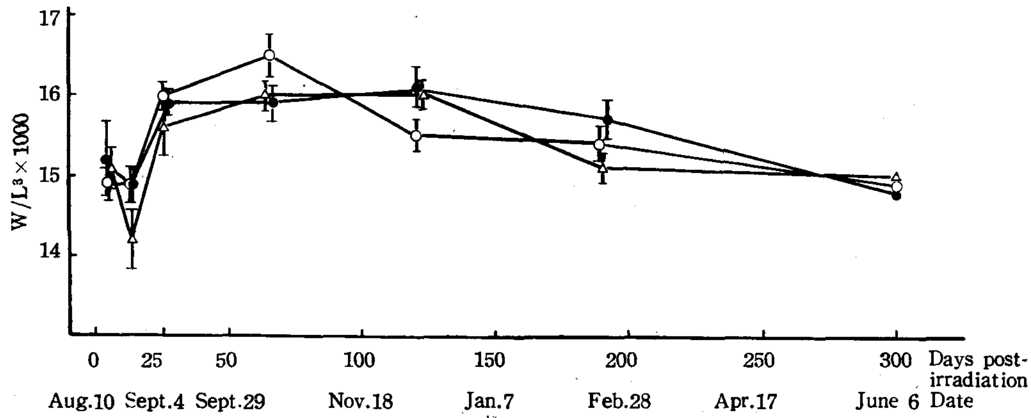

Fig. 3. Seasonal changes in the coefficient of fatness in the rainbow trout fry and fingerling Each bar indicates the standard error of the mean ; ○ control, ● 100r and △ 500r

X-ray on the ovary of the rainbow trout in the stages of fry and fingerling may be said to be between 100r and 500r.

The seasonal changes of the coefficient of fatness in the three groups of the sample fishes are shown in Fig. 3 to make it easy to understand the comparison of the ovary growth with the body growth. The change of this value in the control group is found to be rather more distinct than changes in the irradiated groups, the maximum occurring in the autumn. Although in some periods examined significant differences of this value were found among the three groups, no difference was found, at least, in the period from May to June. It is noticeable that although an identical value of the coefficient of fatness was found in all groups, both the relative weight and the length of the ovary in the 500r group showed a significant depression in this period (cf. Figs. 1 and 2).

The coefficient of fatness in the 500r group showed a significant lowering in the period from the 10th to the 15th day after irradiation. That may possibly be caused by a continuous depresison of the feeding in this period which was caused by X-irradiation as already reported[3].

Considering from the present analysis of the ovary growth, it is conceivable that the injury of the ovary occurs in an early period post-irradiation as in the cases of the domestic animals[1] and that recovery is slow when the dosage received is as low as 100r, but that the recovery is incomplete and the growth inhibition and degenerative effects on the ovary continue when the roentgen received is as high as the order of 500r. Such a supposition will perhaps be substantiated by the histopathological study of the ovary in the near future.

SUMMARY

1. The growth of the ovary of the rainbow trout fry exposed to the X-ray of 100r and 500r was compared with that of the control.

2. The low and effective dosage of X-ray on the ovary of the rainbow trout in the stages of fry and fingerling is between 100r and 500r.

3. The relative weight of the ovary in the 100r group attains the control level by the period from the 166th to the 209th day after irradiation. But, in the 500r group the significant lowering is found to remain even in the period from the 273rd to the 315th day.

4. In the seasons of the autumn and winter no increase of the ovary length is found in proportion to that of the body length. During such a period the effect of X-irradiation upon the relative length of the ovary does not stand out distinctly, but a highly significant difference in that respect between the 500r and each of the control and 100r groups is found in the later period from spring to early summer.

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