Biomass and Production of Rose Bitterling in the Shin Tone River

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Rose bitterling *Rhodeus ocellatus ocellatus* gained most of its annual growth in both length and weight from April to early autumn, with little or no growth during winter. The growth rate was highest in the younger fish groups, and, the mean daily growth rate in weight was 0.015%, 0.011%, and 0.006% per day for 20-30 mm, 30-40 mm, and greater than 40 mm SL fish groups, respectively. The decline in the growth rate with size is clearly marked in spring and summer when growth was most rapid.

Seasonal changes in biomass and production occur, and in general, biomass and production are maximum in summer when growth is also maximum. The monthly mean individual weight range was 784-1,230 mg. The monthly mean biomass was 11.7-35.0 kg for a 200-meter shoreline. The daily production range was 85-689 g/day. The monthly production range was 2.4-16.3 kg/month and the total annual production for a growth period of 209 days was 61.3 kg for the above mentioned area or 307 kg/hectare.

It is concluded that, in summer, as a result of recruitment, the population size increases and higher individual weight due to the high growth rate during this season results in higher fish biomass and production.

It was reported that the rose bitterling *Rhodeus ocellatus ocellatus* population undergoes a seasonal change in its abundance.¹⁾ This conclusion was made from analyses of the fish catch in the Shin Tone River where the fish catch was observed to be high in summer and very low in winter. To explain this seasonal pattern in the fish abundance, a comprehensive study on the fish distribution and movement, reproduction, age and growth, and feeding habit was made.¹⁻⁴⁾ The results from these studies showed the existence of a seasonal pattern in the fish catch which coincide with the seasonal change in the fish abundance. The spawning season extends from early spring to late summer,²⁾ and most of the fish growth takes place during this period³⁾ and also feed most actively.⁴⁾ On the other hand it was found that the fish movement is very limited throughout the year and was found to be only 200-700 m during a period of more than five months when the fish were most active, and, it was much lower in winter. Thus fish migration does not seem to contribute much to the seasonal change in the fish abundance. The continuous recruitment of young fish to the population in summer and autumn has been suggested as the main factor for the seasonal change in the

fish abundance, but the effect of natural mortality to this seasonal change is not known.

In this paper the seasonal biomass changes and production of the rose bitterling population is described. Population size estimates from mark and recapture experiments, growth rates from field growth experiments, and, data on mean weights are used to calculate a series of biomass and production estimates.

Materials and Methods

Production

The estimation of biomass and production of rose bitterling was made following those of CHAPMAN.⁵⁾ Population estimates were made using the Petersen-type mark-recapture method.⁶⁾ The monthly production was estimated as $P = G\bar{B}$ where,

P = production during Δt in weight ($\Delta t = t_1 - t_0$).

$G = (\ln W_1 - \ln W_0) / \Delta t$ where, W_0 , W_1 are weights of each individual fish at the beginning and the end of the interval on a daily basis.

G = instantaneous rate of increase in weight (monthly average).

$\bar{B} = (B_0 + B_1) / 2$ where

$\bar{B}$ = mean biomass in weight present during Δt .

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B_0 =biomass at the beginning of the interval.

B_1 =biomass at the end of the interval.

Growth Rate

Monthly growth rates were measured by keeping fish in nylon net cage about a meter square. The cage was kept in a free floating position in the river by using floats and anchors. During each month, fish were collected from the river and were measured at the site using a measuring board and a portable balance and kept in a cage. During each succeeding visit, all fish in the cage were removed and measured. On the same day, new collections were made and fishes were measured and kept in the cage. Every month the cage was taken out of the river and cleaned thoroughly. The instantaneous growth rates were calculated each month for each individual fish stocked in the cage. This was made by measuring the length and weight of fish at the beginning and end of each interval. The difference in growth between the beginning and end of intervals were calculated for each individual fish by comparing the length of individuals of the two intervals arranged in ascending order. Mean instantaneous growth rates were obtained each month from these data for four separate size classes; 1) 10–20 mm (standard length), 2) 20–30 mm, 3) 30–40 mm, and 4) larger than 40 mm.

Fish Biomass

To estimate the fish biomass, data from monthly mark-recapture experiments and length frequency distributions were utilized. The data on mark-recapture experiments were from May 1981 to May 1982. The population number was calculated using the Petersen-type estimate for a length of 200 meters of the river shoreline. Since no mark-recapture experiments could be made in winter, data on population size are not available for November, December, January, and February months. Monthly length-weight data were used to estimate the mean weight for the different size groups of fish as well as for the total fish population. The monthly population size for each size group or for the total population was multiplied by the corresponding mean individual weight of the size group or of the total population to estimate the biomass of the month.

Results

Growth Rates

The daily growth rates of the fish in the river which were kept in cages are shown in Fig. 1. The

figure shows the daily growth rate of fish in weight (%/day) between the monthly sampling intervals from May 1981 to May 1982. In general, the growth rates of smaller fish were much higher than those of the larger fish. The growth rates sharply decline with increasing length or weight and this trend is clearly marked in spring and summer when the growth rate was most rapid, while it is not so clear during winter when the growth rate was minimum or nil. This trend is clearly shown in Fig. 2 where the 20–30 mm size groups show the highest growth rate during the high growth season followed by the 30–40 mm size groups. The largest size group had the lowest growth rate.

The monthly calculated mean growth rate is shown in Table 1. For the 20–30 mm fish the growth rates ranged as follows: 0.0148–0.0413% per day in spring and summer; 0.0086–0.0237% in autumn; and 0.0015–0.0070% in winter. The mean growth rate was 0.0147% per day. For the 30–40 mm fish group the range was 0.0078–0.0222 in spring and summer; 0.0103–0.0152% in autumn; and 0.0021–0.0068% in winter. The mean growth for this group is 0.0112% per day. For fish greater than 40 mm the range was 0.0031–0.0158% in spring and summer; 0.0087–0.0119% in autumn; and –0.0002–0.0061% in winter. The mean growth rate for this group is 0.0064% per day.

Biomass

Table 2 shows the monthly population size, mean individual weight, and biomass of fish by size group. The monthly population size shows large variations from as low as 3,213 fish in June to as high as 56,436 fish in September of 1981. The population size ranges of 20–30 mm; 30–40 mm; and greater than 40 mm size groups of fish were, 1,263–27,823; 1,812–25,566 and 80–3,348 fish, respectively. The monthly biomass ranges for 20–30 mm, 30–40 mm, and greater than 40 mm size groups were, 0.66–15.7 kg, 1.66–25.8 kg and 0.15–7.2 kg, respectively, where the 30–40 mm size group shows the highest monthly biomass.

Seasonal change in the total monthly fish biomass takes place. The biomass was high during mid and late summer with a peak in September. The fish biomass in spring and summer had a range of 2.6–23.6 kg, and while it was at its highest in September it was 48.4 kg. The low values in June and July are probably due to the bad weather conditions (heavy rain and floods) during these sampling periods which had affected

Fig. 1. Daily growth rate (in weight) of fish kept in cage. The growth rates of fish for each sampling interval are shown.

Fig. 2. Daily growth rate of fish by size group (% Body weight/day).

the fish catch and thus resulting population size estimates during these months.

Production

Table 2 shows the monthly fish biomass and production. The monthly biomass, mean weight, and growth rate, as well as the number of days the fish are grown for each monthly interval are also indicated. The monthly production (per day level) ranges were 27.0–284.6 g, 51.0–242.4 g, and 2.2–83.3 g for fish in size groups 20–30 mm, 30–40 mm, and greater than 40 mm, respectively, where the 30–40 mm fish group shows the highest production.

Marked seasonal variations occurred in the fish production with the highest rates being 309–689 g/day from August to October and lower rates in the other months with values between 115–250 g/day. The highest production was by the 30–40 mm size groups. For the monthly calculated production, the highest rates were 12.1–16.3 kg per month from August to October, and the lowest were with values between 2.3–8.8 kg per month in the other months. The total annual

Table 1. Growth rate observed between two successive sampling dates expressed as percent/day ($\times 100$)

Date	10–20 mm	20–30 mm	30–40 mm	40 < mm	Total
27 May					
30 June		2.25	1.68		1.97
28 July		1.86	2.21	1.16	2.09
25 Aug.		4.13	1.61		2.95
2 Sept.					
24 Sept.		2.37	1.52	1.19	1.97
28 Oct.		0.86	1.03	0.87	0.96
26 Nov.		0.40	0.68	0.42	0.56
25 Dec.		0.50	0.46	0.30	0.47
26 Jan.		0.44	0.37	0.03	0.41
24 Feb.	0.04	0.15	0.21	–0.02	0.14
25 Mar.	0.43	0.70	0.67	0.61	0.61
28 Apr.		1.48	0.78	0.31	0.89
27 May		2.53	2.22	1.58	2.06
Mean	0.23	1.47	1.12	0.64	1.26

production for the growth period of 209 days was 61.3 kg.

Fig. 3 is the summary of the above results showing the overall trends in monthly growth rates, population size, biomass, and production. It can be seen that in summer, higher population size and higher individual body weights result in higher fish biomass. In general, the high fish biomass coupled with high growth rate in summer result in high production during this season, which is being reflected by the high fish catch in summer.

Discussion

The production of the rose bitterling population in the Shin Tone River is limited to the spring, summer and autumn seasons. In most months, the largest contribution to the monthly fish production was made by the 30–40 mm size group followed by the 20–30 mm size group. In the size groups where production is highest, it is associated with highest growth rate and/or highest fish biomass (Table 2). Biomass and production changes reflect the seasonal interaction of growth and recruitment. These seasonal changes in biomass and production are similar to those reported for temperate fish species by GERKING,⁹⁾ KELSO *et al.*¹⁰⁾, and ALEXANDER *et al.*¹⁰⁾

In this study, CHAPMAN's definition of production¹¹⁾ is considered, where it is defined as the total elaboration of tissue during any time interval Δt , including what is formed by individuals that do not survive to the end of Δt .¹²⁾ When produc-

Table 2. Monthly fish biomass and production by size group

Date	Size class	Mean wt. (mg)	Pop. size N	Biomass B (kg)	Mean biomass	Growth rate (G)	Production (gr)
1981							
27 May	20-30	659	11,913	7.85			
	30-40	1,001	14,843	14.86			
	40<	2,280	380	0.87			
	total	869	27,136	23.58			
30 June	20-30	526	1,263	0.66	4.26	2.25	95.8
	30-40	915	1,812	1.66	8.26	1.68	138.7
	40<	1,761	138	0.24	0.55		
	total	812	3,213	2.61	13.09	1.97	257.8
28 July	20-30	389	5,780	2.25	1.45	1.86	27.0
	30-40	909	3,267	2.97	2.31	2.21	51.0
	40<	1,860	80	0.15	0.19	1.16	2.2
	total	551	10,053	5.54	4.07	2.09	85.1
25 Aug.	20-30	445	18,611	8.28	5.26	4.13	217.0
	30-40	1,027	5,943	6.10	4.53	1.61	72.9
	40<	2,154	3,348	7.21	3.68		
	total	772	27,902	21.54	13.54	2.95	399.4
2-24 Sep.	20-30	566	27,823	15.75	12.01	2.37	284.6
	30-40	1,009	25,566	25.80	15.95	1.52	242.4
	40<	2,270	2,991	6.79	7.00	1.19	83.3
	total	858	56,430	48.42	34.98	1.97	689.1
25 [*] Oct.	20-30	558	6,939	3.87	9.81	0.86	84.4
	30-40	877	12,956	11.36	18.58	1.03	191.4
	<40	2,070	368	0.76	3.77	0.87	32.8
	total	784	20,468	16.05	32.23	0.96	309.4
1982							
24 Feb.-	20-30	505	6,787	3.43		0.70	
25 Mar.	30-40	993	10,011	9.94		0.67	
	40<	2,248	1,051	2.36		0.61	
	total	879	17,813	15.66		0.61	
28 Apr.	20-30	700	1,526	1.07	2.25	1.48	33.3
	30-40	1,237	6,354	7.86	8.90	0.78	69.4
	40<	2,738	511	1.40	1.88	0.31	5.8
	total	1,230	8,383	10.31	12.98	0.89	115.5
27 May	20-30	566	8,510	4.82	2.94	2.43	74.4
	30-40	1,120	5,879	6.58	7.22	2.22	160.3
	40<	2,000	774	1.55	1.47	1.58	23.2
	total	841	15,472	13.01	11.66	2.06	240.2

Note: 2-24 Sept., and 24 Feb.-25 March are dates of growth intervals during these months. Dates of growth intervals are consecutive for the other months.

tion is estimated at a yearly interval, the inclusion of the product of the non-surviving members might have considerable effect on the total biomass and production estimates. Since the sampling interval in this study is made on a monthly basis, the effect of the inclusion of the product of the non-surviving members is believed to be slight. Furthermore, there would be no change in the trends, and therefore the conclusions drawn are thereby largely unaffected by possible errors brought about by overlooking the natural mortality. However, the consideration of the sexual

products (released eggs and sperms) are overlooked and its effect on the estimate is not known.

The annual production is estimated for a growth period of 209 days. Production estimates for winter could not be made mainly due to the difficulty in estimating the population size during winter. The original production estimates are in kg wet weights for a 200 meters' river shoreline. However, the river has an average width of 40 m and most of the fish catch is distributed within 10 m from the river shoreline which in this part has a depth of about 2 m. This width is con-

Fig. 3. Seasonal changes in the rose bitterling population size, biomass, growth rate, and production in the Shin Tone River.

sidered most appropriate for calculating the area along the river which was sampled. Thus the sampling area would be 200×10 m or 0.2 hectare. From this the annual production will be 307 kg/ha. This value is quite high for a single species production in a temperate region. Many workers^{8,13-19} have worked on estimating the production of several fish species. However, studies on productivity by cyprinid fish are sparse. Some examples of annual production estimates reported for other species include, "trouts": 26-129 kg/ha; bullhead: 6.2-43.1 g/m²; ¹⁶ charr: 163-191 kg/ha; ²⁰ juvenile rainbow trout in Georgia Bay: 111.6 kg/ha; ¹⁰ and Bluegill in Wyland Lake: 625 kg/ha. ¹⁹ A very high value of 1,554 kg/ha is reported for the amargosa pupfish *Cyprinodon nevadensis* in a hot desert stream in California. ¹⁷ Fish production reported from temperate standing waters range up to 150 kg/ha. ²¹ Annual production for North American lakes are 143-170 kg/ha; ²² 208 kg/ha for 127 North American reser-

voirs; ²³ and 382 kg/ha for 42 Oklahoma ponds. ²³ For tropical standing waters a multi-species annual fish production of 230 kg/ha for Lake George, ^{24,25} and a high value of 1223 kg/ha for Lake Kariba are reported. ¹⁹ Thus from these values it can be seen that the production of rose bitterling is in the higher production range, especially for single species production.

The important reasons for the high production of fish in the tropics is cited to be the generally earlier maturity and more rapid succession of generations that occur in the tropics. Longevity is also generally short. ²⁶ It is considered that these reasons could be used to explain the high production of rose bitterling.

From the results of this study it is suggested that if a fishery that removes larger fish is taking place, the rose bitterling population would be most efficiently exploited in late summer and early autumn. During the period of rapid production on the other hand, a late spring and early summer

fishery might remove fish before they had contributed significantly to new biomass.

Lastly, measurement of production is being increasingly used as an indicator of the health of an ecosystem, assessing the effects of environmental pollution or other problems. For example, CRISP *et al.*²⁷⁾ provided data of measurement of fish production in a proposed impoundment in order to compare with subsequent production data after impoundment. Thus the present work might provide some information for future monitoring of the health of the ecology of the Shin Tone River.

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