INTRODUCTION INTO AYSEN CHILE OF PACIFIC SALMON

No. 6

Some Biological Observations of Wild Brown Trout *(Salmo trutta)* in the Aysén and Salto Rivers, Southern Chile

By

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and

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Some Biological Observations of Wild Brown Trout *(salmo trutta)* in the Aisén and Salto Rivers, Southern Chile.

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ABSTRACT

Seventy-seven brown trout were captured in the Aisén and Salto Rivers, southern Chile, between March and June 1980 to 1982. Variation in monthly catch, length frequency (total length - TL), sex ratio, maturity, age, growth and stomach contents of trout collected were studied. Most fish obtained from both rivers were on spawning runs from fiord water. Pre-spawning movement to upper streams appeared to be more active in March and April than in May and June. The TL of fish ranged from 25.8 to 69.0 cm, showing a mode between 55 and 60 cm in both male and female. More females than males were collected in both rivers, but there was no statistically significant difference from a sex ratio of 50% females. All the smaller fish examined up to 41 cm TL and some of the larger fish had immature gonads with the gonadal indices less than 0.56. Maturing males (gonad index: 2.50 to 5.78) showed a decrease of gonad index from March to April, while in maturing females the gonadal indices, which ranged between 6.51 and 19.42. increased rapidly during March to May. Twenty-five scale samples revealed that the fish (29.5 to 65.5 cm TL) had ages of II+ to VI+ and spent one or two complete years in fresh water. About 15 circuli were formed on the scales of trout during each of the first and second years in fresh water. All scales showed a sudden, well marked increase in number of circuli and in width of radius when the fish are presumed to have entered the fiord, but thereafter annual increments diminished with year. The total length at smolt maigration of the second- and third- year migrants are estimated to be about 12 and 17 to 18 cm respectively. The annual increment in size of the second-year migrants in the fiord life is considered to be larger than that of third-year migrants. Brown trout which go down to the fiord appear to become mature at the end of their third or fourth year of life at 40 to 45 cm TL. Fish, snails and squat-lobsters formed important foods for the trout in the Aisén River, and fish were exceedingly important as food for the Salto River trout.

INTRODUCTION

The brown trout *(Salmo trutta* Linnaeus) was introduced into Chile from Germany in 1905, and has become acclimated to central and southern Chile (Golusda, 1927: Valenzuela, 1961; MacCrimmon and Marshall, 1968). This trout is the most dominant species at least in the Simpson river-system and commonly occurs also in Aisén Fiord, southern Chile. However, no information is available on biological aspects of brown trout naturalized in Chile so far as we know, except Zama and Cárdenas (1982).

The introduction of Pacific salmon into the XI Region, Chile, has been conducted by the cooperative project between Chile and Japan. Juveniles of chum salmon, *Oncorhynchus keta* (Walbaum), have been released into the Simpson and Salto Rivers and Ensenada Baja. We have found that the released juvenile salmon are eaten by the brown trout, which are regarded as the heaviest predador on juvenile salmon in the rivers and fiord. In order to effectively complete our project, it is important to have a thorough knowledge of the biology of the brown trout, in particular predation or competition for food between the wild brown trout and released salmon.

In the autumn and winter, 1980 to 1982, we carried out surveys to capture returning chum salmon by means of gill nets in the lower reaches of the Aisén (Simpson) and Salto Rivers. During these surveys we also obtained the brown trout, mainly made up of spawning runs, from the two rivers. This paper presents some biological observations on the trout collected.

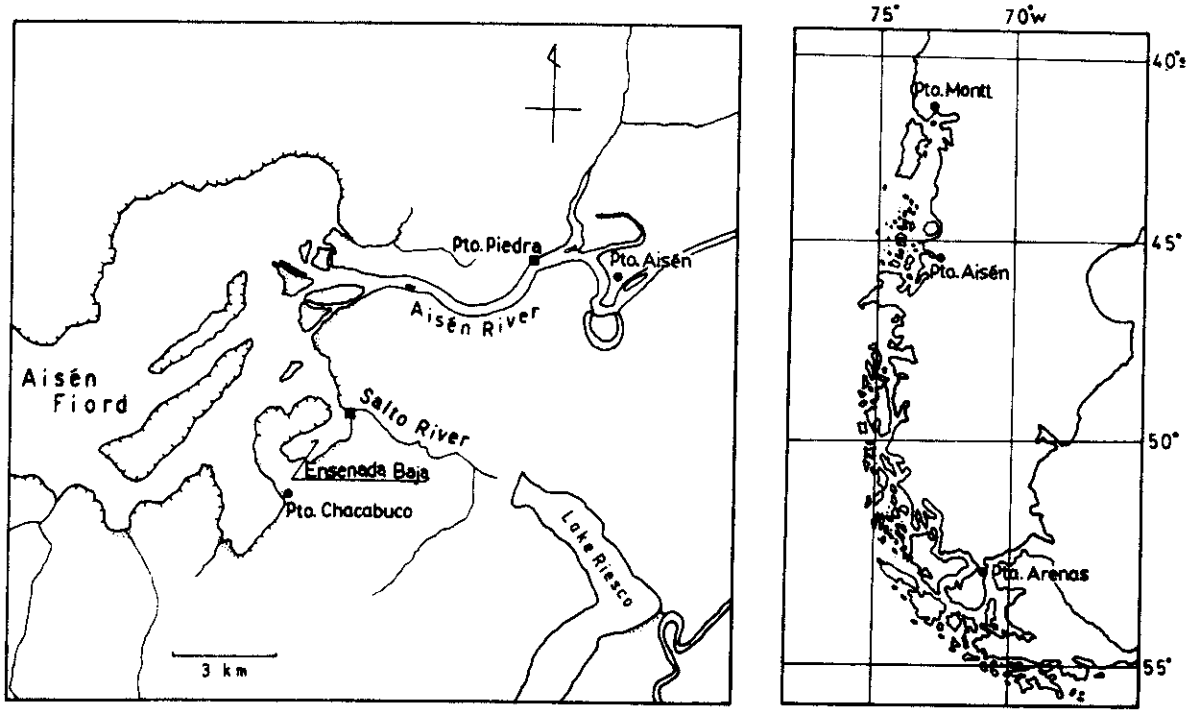

Fig. 1. Maps of southern South America (right) and the innermost part of Aisén Fiord (left), showing sampling spots indicated by black squares in the Aisén and Salto Rivers.

MATERIAL AND METHODS

The Simpson River, which is one of the longest rivers in southern Chile, flows northwest to Aisén Fiord from near the border between Chile and Argentine. It has a length of about 200 km and a width of 200 to 300 m at the lower reaches, where it is known as the Aisén River. The Salto River, about 10 km long and 45 m wide at its mouth, runs into the passage of Ensenada Baja which is situated at the innermost part of Aisén Fiord (Fig. 1).

Between mid-March and June 1980 to 1982, for the capture of the returning salmon, gill nets were set at Pto. Piedra (in 1980 and 1981), 6.5 km above from the estuary of the Aisén River (Fig. 1 and Pl. I, A), and at hte mouth of the Salto River (in 1981 and 1982) (Fig. 1 and Pl. I, B). During these surveys a total of 77 brown trout were captured in the two rivers.

All fish were caught by surface gill nets of 2 m high, 30 m long and 135 mm stretched mesh per unit. One to three units of net were used at different times in the Aisén River, and one throughout in the Salto River. In each river one end of the nets was attached to the shore and the other end anchored to the bottom at a depth of 3 to 5 m. The gill nets were checked every day as long as there were neither heavy freshets nor other problems. Surface water temperatures of the Aisén and Salto Rivers and meteorological conditions were observed on nearly all days between 08:30 and 18:30 when the nets were checked. These data are shown in Appendix Tables 1 and 4.

The total length (TL) and body weight of all the fish collected were measured immediately after sampling, and their stomach contents were examined. No effort was made to identify the organisms eaten to the specific level except in the case of lamprey and fishes. The gonads of 44 fish, except for all specimens obtained from the Aisén River in 1980 and several others of which almost all were immature, were weighed when fresh. The gonad index (GI) was

calculated with the following formula:

$$GI = \frac{\text{Gonad weight (g)}}{\text{Body weight (g)}} \times 100$$

In consideration of the fish size from small to large, 11 scale samples of brown trout from the Aisén River and 14 from the Salto River were obtained selectively among the fish caught in 1981. The scales of each fish were taken from one to five rows above the lateral line between the dorsal and adipose fins, and the age and number of circuli in each year of growth were recorded with a microprojector at 33 magnifications. The radius of each year ring was also measured from the focus along the longest axis of the scale to the outer edge of the ring under the same microprojector. From both mean total length at capture and scale radius for each age group, the proportionate calcuclation of total lengths at previous ages was made with the Fraser's formula (Kubo and Yoshihara, 1979): The size at squamation of brown trout was regarded as 3.5 cm TL, judging from the figures for other salmonids (Shiraishi *et al.*, 1958; Kobayashi, 1961).

RESULTS

Catch and total length

Of 77 brown trout examined 46 were obtained from the Aisén River and 31 from the Salto River; 32 were male and 45 female (Table 1). According to the gonad examation and scale check, most trout collected in each river were fish running upstream from Aisén Fiord to spawn (Pl. I, C).

The number of the fish captured every ten days for each sex and daily mean catch per month are shown in Fig. 2. In March and April the daily mean catch in each river was more than in May and June except for in the case of May (1981) when number of days surveyed in the Salto River was few. The number of the gill nets used in the Aisén River was not constant through

Table 1. Number, total length and body weigth for each survey of brown trout collected in the Aisén and Salto Rivers between 1980 and 1982.

River	Date	Sex	No.	Total length(cm)	Body weight(g)
Aisén River	Mar. 27 - May 28 1980	Male	9	42.0 ~ 69.0	1,100 ~ 3,800
		Female	17	30.0 ~ 68.0	700 ~ 3,800
Aisén River	Mar. 15 - Jun. 25 1981	Male	9	47.3 ~ 63.0	1,200 ~ 3,260
		Female	11	37.0 ~ 64.0	500 ~ 3,530
Salto River	Mar. 31 - May 2 1981	Male	8	51.0 ~ 65.5	1,400 ~ 3,300
		Female	10	29.5 ~ 60.0	350 ~ 2,550
Salto River	Apr. 20 - Jun. 30 1982	Male	6	25.8 ~ 60.5	190 ~ 2,370
		Female	7	26.8 ~ 57.5	215 ~ 2,100
TOTAL			**77**	**25.8 ~ 69.0**	**190 ~ 3,800**

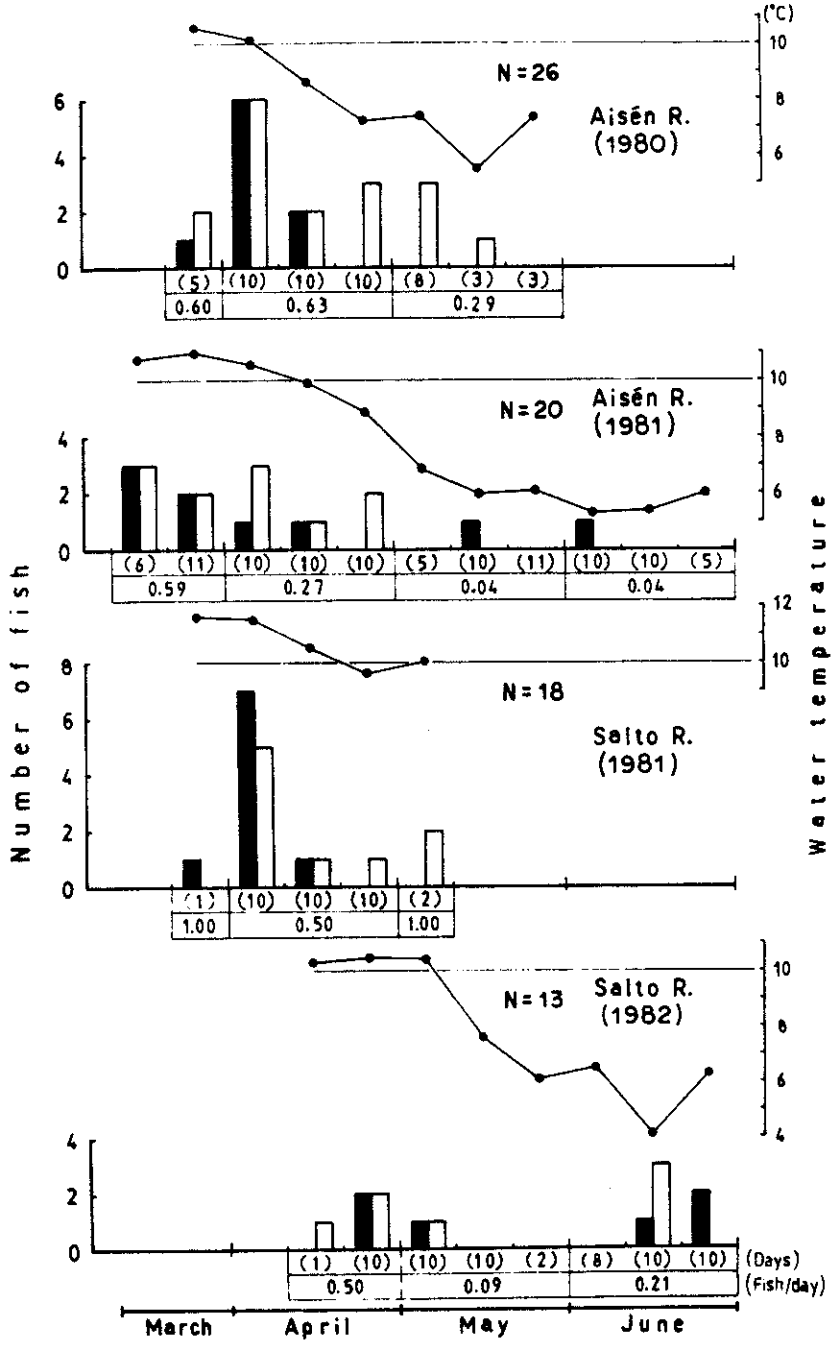

Fig. 2. Number of males (dark bar) and females (open bar) captured every ten days and daily mean catch per month of brown trout collected in the Aisén and Salto Rivers between March and June 1980 to 1982. Number of days during which the gill nets were checked indicated in parentheses. Mean surface water temperature for each river averaged every ten days.

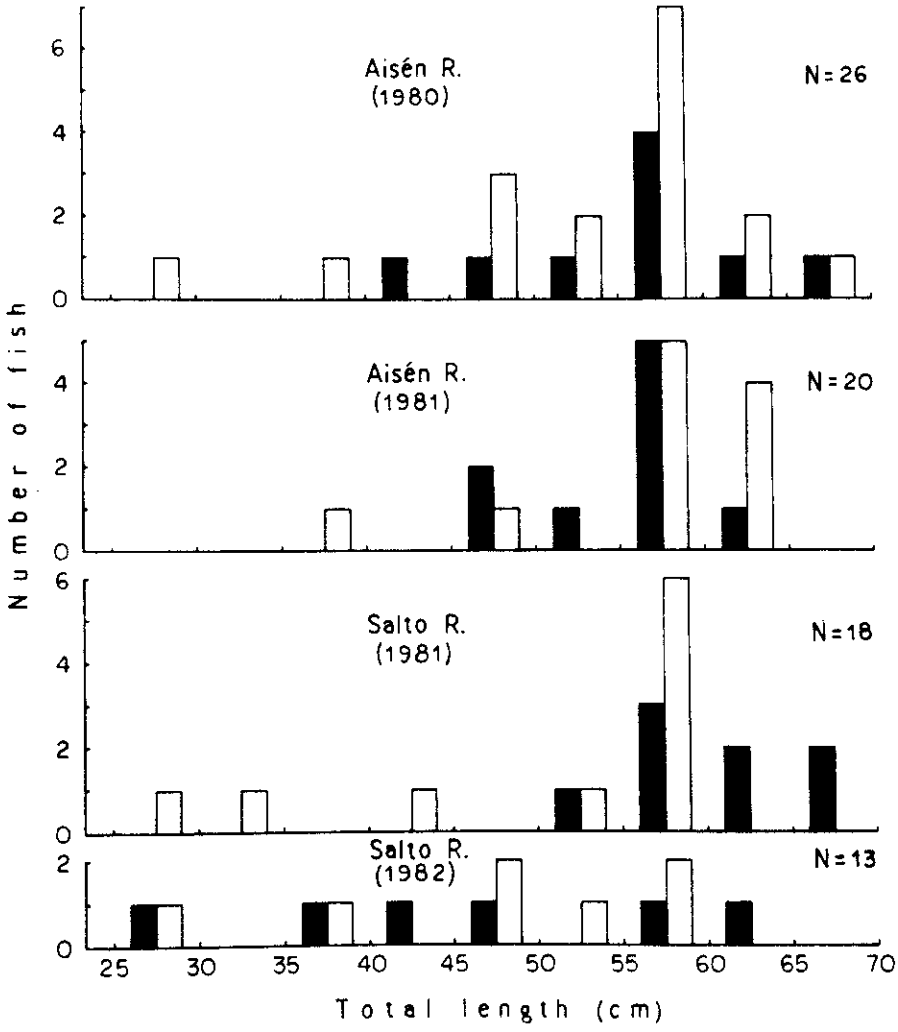

Fig. 3. Total length composition of males (dark bar) and females (open bar) of brown trout collected in the Aisén and Salto Rivers, 1980 to 1982.

the whole survey. It was unlikely, however, that the numerical differece of net disorted the figures of total monthly catch because the great majority of the fish obtained from the Aisén River, as well as from the Salto River, were netted in the part near to the shore. Males and females collected until mid-April were almost equal in number, but thereafter females were dominant over males, when the data were combined in each river (Figs. 2 and 4).

Between March and May the surface water temperature of the Salto River was 1 to 2°C higher than that of the Aisén River (Fig. 2). In June, however, the water temperature decreased to 5 to 6°C in these rivers. It appeared that the upstream movements of the brown trout in the lower reaches of the rivers were more active until the water temperature dropped to about 7°C.

The total length of the fish examined in this study ranged from 25.8 to 69.0 cm (Table 1). The mode (TL) occurred at the interval between 55 and 60 cm in each river, and another minor mode was found at the size of 45 - 50 cm (Fig. 3). There was no distinct difference in size

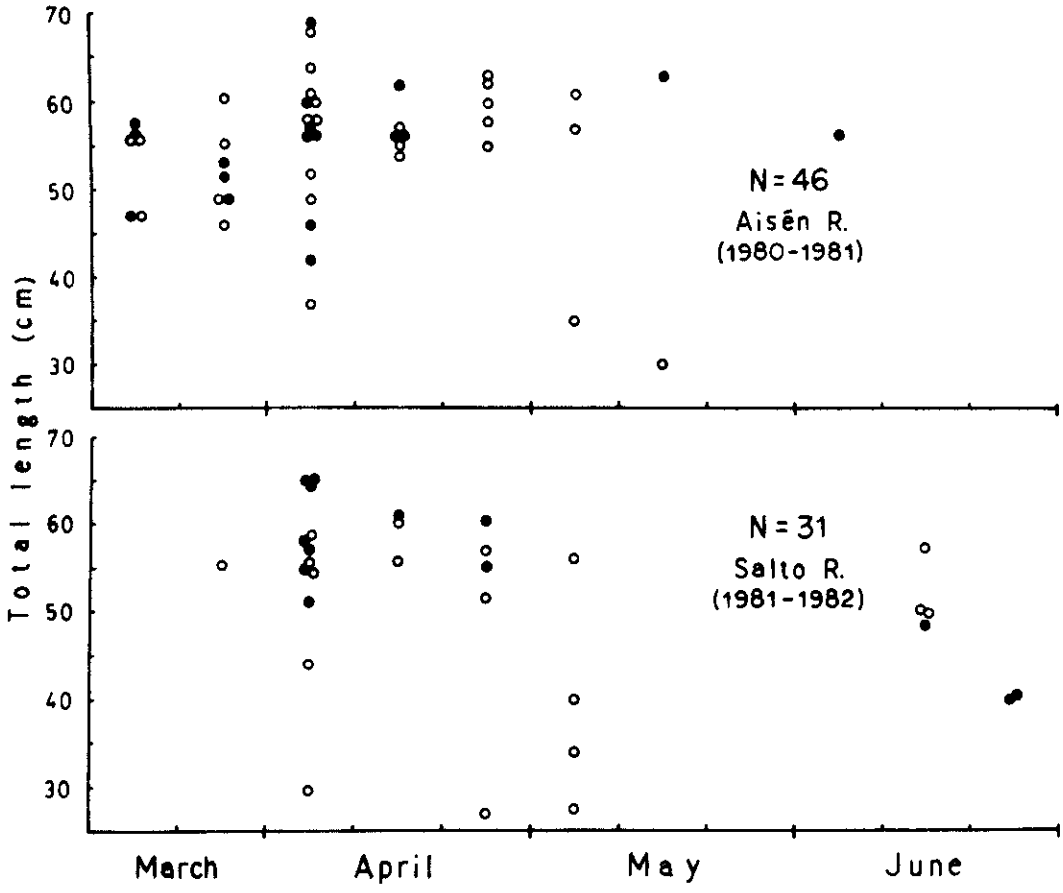

Fig. 4. **Distribution of total length for each sex of brown trout collected in the Aisén and Salto during each ten days between March and June 1980 to 1982. Dark cirde, male; open cirele, female.**

composition between the trout from the Aisén and Salto Rivers although mesh selectivity might work on the length compositions examined because a single mesh size (135 mm) of net was applied in both rivers. No great difference in the size composition was found between the sexes, but , if anything, as a whole males tended to be a little larger (Fig. 3). As shown in Fig. 4, most of the fish up to 54 cm TL in the Aisén River were captured until early April. However, such a tendency did not occur in the Salto River trout.

Relationship between total length and body weight of all the fish obtained from the two rivers are plotted in Fig. 5. It can be said that the growth rates of body weight to the total length of fish from both rivers are similar.

Sex ratios and maturity

It is mentioned above that the numbers of males and females of the brown trout caught were even from March to mid-April, but thereafter the females were dominant. Table 1 shows an excess of females over males in each survey. As for the maturing fish from both the Aisén and Salto Rivers, noted below, the females (15 fish) also exceeded the males (11). In each case, however, there was no significant difference from a hypothetical sex ratio of 50% females at the 5% probability level by means of Chi-square, even if all data in the two rivers were combined.

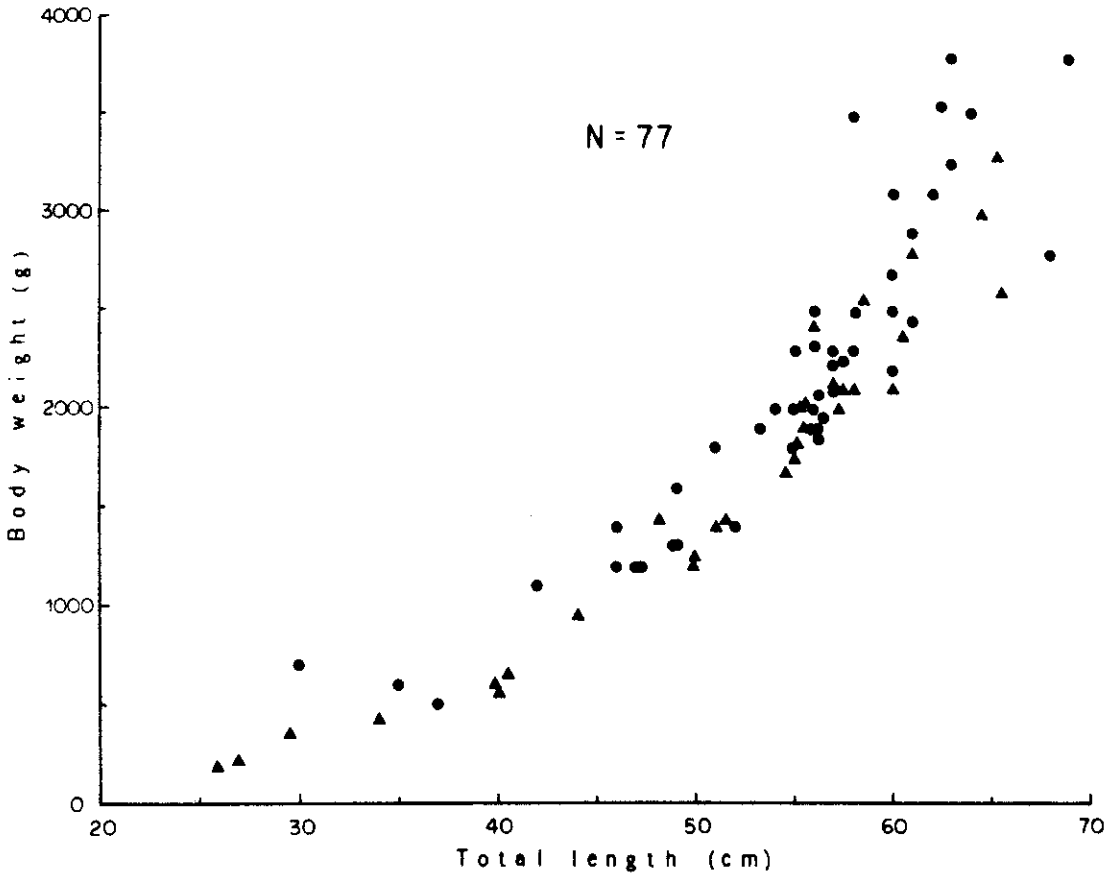

Fig. 5. **Relationship between total length and body weight of brown trout from the Aisén (circle) and Salto (triangle) Rivers, 1980 to 1982.**

In Fig. 6 the gonad index (GI) for each fish is plotted against total length. All the fish examined, up to 40.5 cm TL, were immature irrespective of sex, showing gonadal indices less than 0.48. Larger males and females, 44.0 cm TL and longer, were respectively separated into two distinct groups containing maturing and immature (or spent) gonads. In particular the females revealed a remarkable distinction of gonad index between the two groups, *i.e.*, most of the larger females yielded developing ovaries with gonadal indices from 6.51 to 19.42; in the other few (including the fish after spawning) the values of gonad index were very low (GI: 0.09 to 0.30). Maturing males showed gonadal indices between 2.50 and 5.78, while immature males which were fewer than the maturing ones had small testes (GI: 0.04 to 0.56).

From March to May maturing females showed a rapid growth of gonad index (Fig. 7). On the other hand, such an increment of the gonad index was not found in maturing males, or rather their gonadal indices decreased from March to April. The undeveloped gonads of males and females occurred in all the months surveyed regardless of the fish size, but the distribution of gonad index for the immature gonads remained apart from that for the maturing gonads. The brown trout in the Simpson river-system and adjacent rivers are said to spawn about June. It is likely that fish belonging to the maturing groups were migrating upstream to spawn, but that those in the immature groups were not on spawning runs.

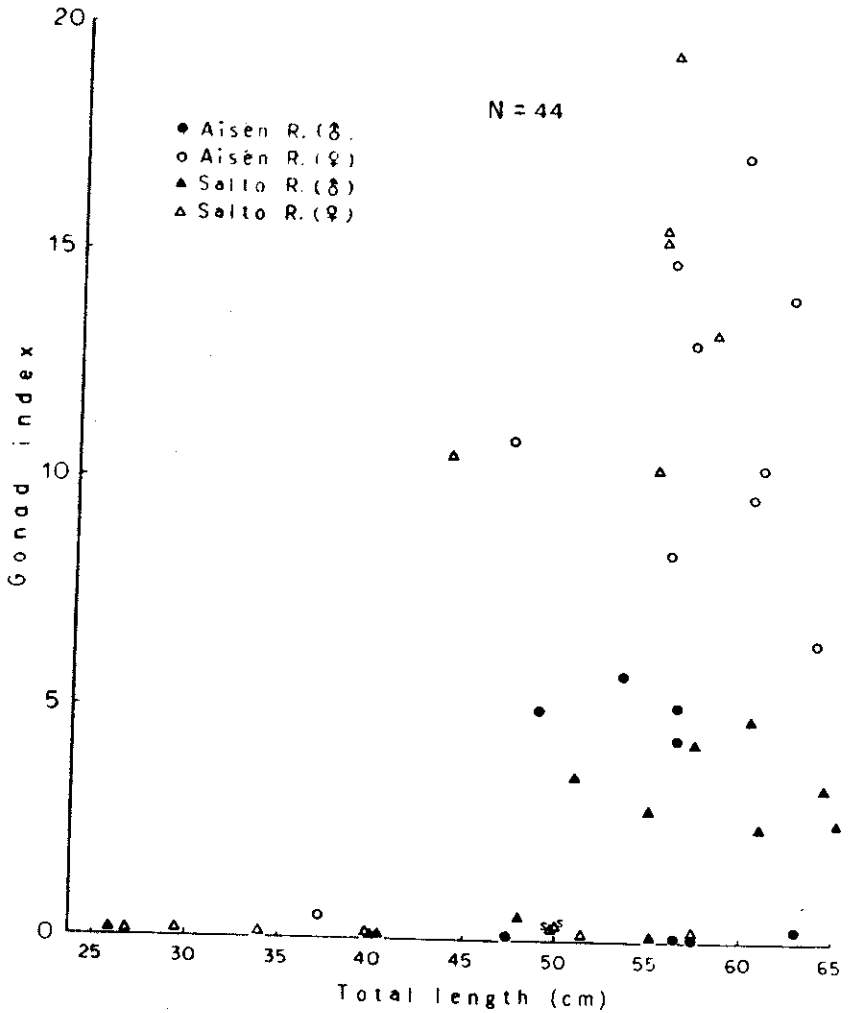

Fig. 6. Relationship between gonad index and total length for each sex of brown trout from the Aisén (in 1981) and Salto (in 1981 and 1982) Rivers. "S" indicates spent gonads.

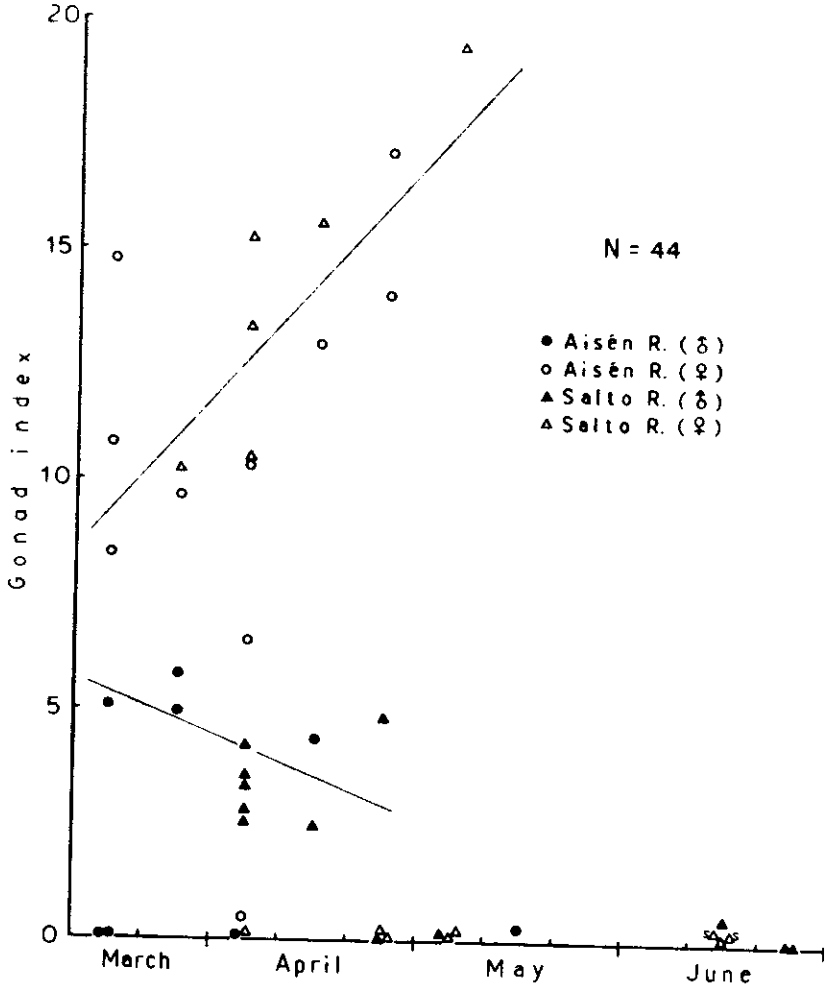

Fig. 7. Change of gonadal indices for each sex of brown trout in a period between March and June. The gonadal indices were plotted every ten days of the month. "S" indicates spent gonads.

Age and growth

Twenty-five brown trout (29.5 to 65.5 cm TL) sampled from the Aisén and Salto Rivers in 1981, for which the age determination was made, consisted of a mixture of year classes, ranging in age from three (II+) to seven (VI+) years (Table 2). All scales showed two distinguishable growth zones of both fluvial and sea (fiord) lives. Each year class except for seven year class was made up of two age groups including fish which spent either one and two complete years in fresh water. In each river fish which spent two years in fresh water were more numerous than those with one-year fluvial life. The proportion of the fish with one-year fluvial life in the Salto River (42.9% of total) was higher than in the Aisén River (18.2%) (Table 2). The two fish in the three-year (II+) class were still immature without previous spawning information although some of the other fish examined, including the immature fish of four (III+) year old at capture, had spawned in their third year of life.

About 15 circuli were formed on the scales of trout during each of the first and second years in fluvial life, when the annual number of circuli in the fish from the Salto River were somewhat more than those from the Aisén River (Table 3). In each year before or after the seaward migration, the fish migrating in their second year showed more annual number of circuli than the third-year migrants did. During the first year after migration the scales revealed a noticeable increment not only in number of circuli but in radius, and afterward the annual growth rate of these characters diminished with age (Tables 3 and 4). In the other words, apparently, the brown trout commence to grow rapidly after the seaward migration. According to the scale observations, however, the growth of scale in the fiord life was not uniform. Compared with the scales showing a typical sea growth, the circuli of some scales were closely spaced during one to four years after the fish had run into the fiord or a distinction between growth and resting zones of the scale was unclear. These effects may be due to the life in the estuarine water (which is included in the category of the fiord for convenience) or a probable, seasonal migration in the fiord.

Table 5 summarizes the estimated mean total length for each age group of trout from the Aisén and Salto Rivers at the end of each year of growth. Lee's phenomenon (Kubo and Yoshihara, 1979) can be detected in the estimated figures which were obtained by the back

Table 2. Age composition in number and total length of brown trout sampled from the Aisén and Salto Rivers, 1981. Number of immature fish in parentheses; an asterisc showing the fish of which maturity was not observed.

Age group	Aisén River		Salto River		TOTAL	Total length (cm)
	Male	Femele	Male	Femele		
3_2		(1)			1	37.0
3_3				(1)	1	29.5
4_2		1	1*	1	3	55.5~58.0
4_3	(1)	1+1*	1		4	47.2~55.3
5_2			1	2	3	54.5~60.0
5_3	1*	2		2*	5	44.0~56.6
6_2			1		1	65.3
6_3		2	2+1*		5	55.0~65.5
7_3		1		1	2	55.3~62.5
TOTAL	2	9	7	7	25	
Total length (cm)	47.3~56.6	37.0~64.0	51.0~65.5	29.5~60.0		29.5~65.5

Table 3. Mean number of circuli in each year (Cn) of growth on the scale of brown trout from the Aisén (AR) and Salto (SR) Rivers, 1981. The total mean of all age groups for each migrant is calculated excluding the number of circuli (in paretheses) after the last annulus. See Table 2 as to the number of fish examined for each river.

(A): Second-year migrant.

Age group	Fluvial life				Fiord life							
	C_1		C_2		C_3		C_4		C_5		C_6	
	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR
3_2	18.0	–	28.0	–	(21.0)	–						
4_2	12.0	18.5	30.0	32.5	29.0	16.5	(4.0)	(12.0)				
5_2	–	14.7	–	27.7	–	23.0	–	18.7	–	(8.0)		
6_2	–	15.0	–	31.0	–	18.0	–	18.0	–	17.0	–	(3.0)
TOTAL	**15.0**	**16.1**	**29.0**	**30.4**	**29.0**	**22.5**	–	**18.4**	–	**17.0**	–	–
MEAN	**15.6**		**29.7**		**25.8**		**18.4**		**17.0**			

(B): Third-year migrant.

Age group	Fluvial life				Fiord life									
	C_1		C_2		C_3		C_4		C_5		C_6		C_7	
	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR
3_3	–	15.0	–	18.0	–	(23.0)								
4_3	15.3	19.0	14.3	15.0	26.7	23.0	(17.7)	(16.0)						
5_3	13.3	9.5	14.7	15.0	33.3	23.0	18.7	24.0	(10.7)	(10.5)				
6_3	11.5	14.0	9.5	17.0	27.0	23.0	20.5	21.3	15.0	14.7	(7.0)	(5.3)		
7_3	14.0	18.0	14.0	15.0	17.0	17.0	18.0	22.0	18.0	13.0	20.0	10.0	(13.0)	(11.0)
TOTAL	**13.5**	**15.1**	**13.1**	**16.0**	**26.0**	**21.5**	**19.1**	**22.4**	**16.5**	**13.9**	**20.0**	**10.0**	–	–
MEAN	**14.3**		**14.6**		**23.8**		**20.8**		**15.2**		**15.0**			

Table 4. Mean radius (in mm) to the end of each year ring (Rn) for each age group on the scale of brown trout from the Aisén (AR) and Salto (SR) Rivers, 1981. The scale radius (in parentheses) to the posterior end is not included in the calculation of the total mean of all age groups for each migrant. See Table 2 as to the number of fish examined for each river.

(A): Second-year migrant.

Age group	Fluvial life		Fiord life									
	R_1		R_2		R_3		R_4		R_5		R_6	
	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR
3_2	0.54	–	1.27	–	(1.95)	–						
4_2	0.39	0.48	1.25	1.59	2.27	2.53	(2.53)	(3.01)				
5_2	–	0.44	–	1.18	–	2.02	–	2.71	–	(2.99)		
6_2	–	0.41	–	1.31	–	1.98	–	2.55	–	3.11	–	(3.22)
TOTAL	0.47	0.44	1.26	1.36	2.27	2.18	–	2.63	–	3.11	–	–
MEAN	0.46		1.31		2.23		2.63		3.11			

(B): Third-year migrant.

Age group	Fluvial life				Fiord life									
	R_1		R_2		R_3		R_4		R_5		R_6		R_7	
	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR
3_3	–	0.43	–	0.74	–	(1.51)								
4_3	0.42	0.50	0.85	0.83	1.75	1.65	(2.59)	(2.39)						
5_3	0.42	0.33	0.81	0.73	2.00	1.56	2.67	2.40	(3.04)	(2.78)				
6_3	0.49	0.44	0.79	0.82	2.00	1.72	2.68	2.54	3.15	3.08	(3.36)	(3.29)		
7_3	0.39	0.60	0.74	0.97	1.45	1.51	2.03	2.07	2.97	2.45	3.93	2.75	(4.56)	(3.13)
TOTAL	0.43	0.46	0.80	0.82	1.80	1.61	2.46	2.34	3.06	2.77	3.93	2.75	–	–
MEAN	0.45		0.81		1.71		2.40		2.92		3.34			

Table 5. **Estimated mean total length (CLn) at the end of each year ring for each age group of brown trout from the Aisén (AR) and Salto (SR) Rivers, 1981. The mean total length at capture for each age group is indicated in parentheses. See Table 2 as to the number of fish examined for each river.**

(A): Second-year migrant.

Age group	Fluvial life		Fiord life									
	CL_1		CL_2		CL_3		CL_4		CL_5		CL_6	
	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR
3_2	12.8	–	25.3	–	(37.0)	–						
4_2	11.6	12.0	29.4	31.2	50.6	44.2	(56.0)	(56.8)				
5_2	–	11.4	–	24.8	–	39.9	–	52.2	–	(57.3)		
6_2	–	11.3	–	28.6	–	41.5	–	52.4	–	63.2	–	(65.3)
TOTAL	12.2	11.6	27.4	28.2	50.6	41.9	–	52.3	–	63.2	–	–
MEAN	11.9		27.8		46.3		52.3		63.2			

(B): Third-year migrant.

Age group	Fluvial life				Fiord life									
	CL_1		CL_2		CL_3		CL_4		CL_5		CL_6		CL_7	
	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR	AR	SR
3_3	–	10.9	–	16.2	–	(29.5)								
4_3	11.0	13.4	18.7	20.0	34.9	36.3	(49.9)	(51.0)						
5_3	11.2	9.2	18.3	16.0	40.2	30.3	52.5	44.7	(59.3)	(51.2)				
6_3	11.8	11.3	16.8	18.0	37.2	33.9	48.7	48.4	56.6	58.0	(60.1)	(61.7)		
7_3	8.6	13.5	13.0	19.7	22.3	28.7	29.8	38.1	41.9	44.5	54.4	49.5	(62.5)	(55.8)
TOTAL	10.7	11.7	16.7	18.0	33.7	32.3	43.7	43.7	49.3	51.3	54.4	49.5	–	–
MEAN	11.2		17.4		33.0		43.7		50.3		52.0			

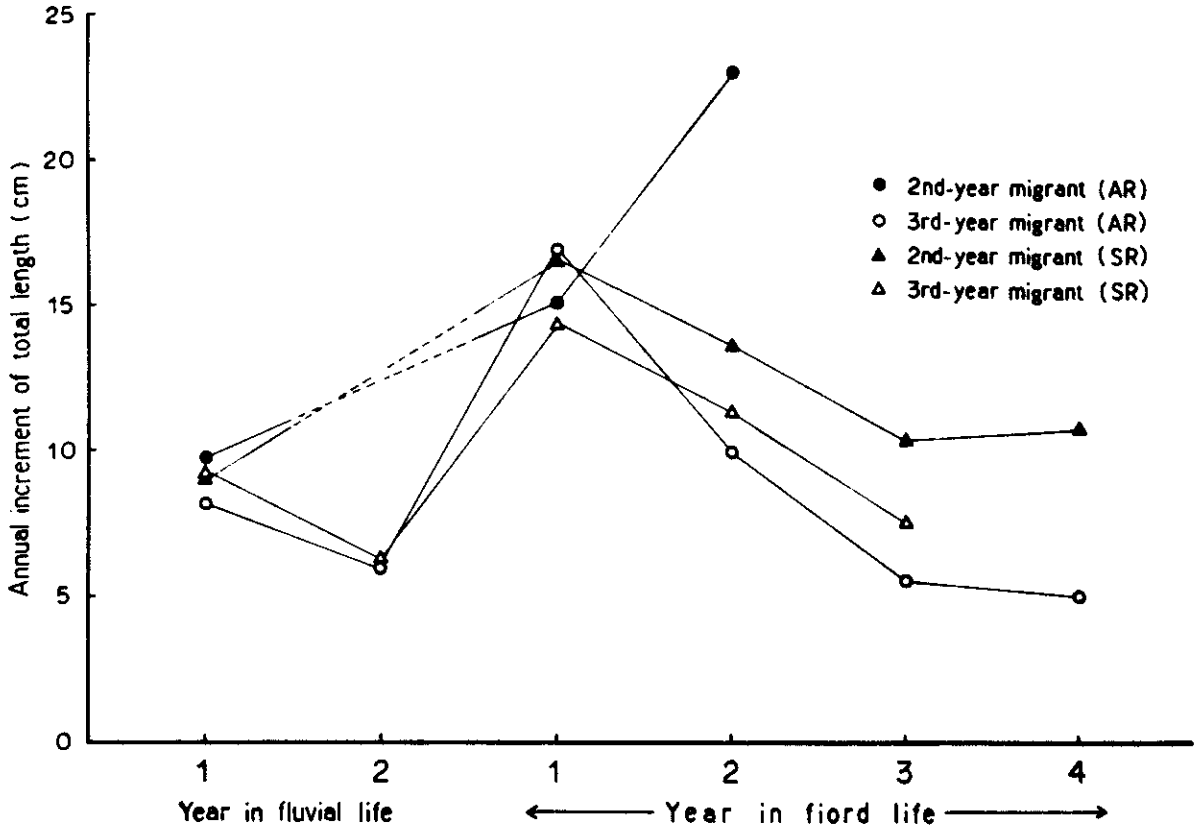

Fig. 8. **The calculated annual increments of total length for each migrant of brown trout sampled from the Aisén (AR) and Salto (SR) Rivers, 1981. The mean total length of hatched fry was regarded as 2.5 cm (Thomas, 1964) for the first year increment.**

calculation of lengths from the scales. In the present instance, therefore, the estimated lengths for each age group may be less than the true values, particularly those of third-year migrants at age III to VI. The total length at smolt migration of the second-and third-year migrants are considered to be about 12 and 17 to 18 cm TL respectively. At the end of the first year in fresh water the second-year migrants of the Aisén River seem to be larger than third-year migrants. The annual growth rates of total length for each migrant were remarkable during the first two years after the seaward migration, and diminished with the number of years spent in the fiord (Fig. 8). The annual increments of total length in the fiord life for the second-year migrants seem to be larger than those for the third-year migrants. These results on the growth rate are correlated to the number of scale circuli. The relationship between age and total legnth of fish at capture is shown in Fig. 9, which indicates rapid growth in an early period of the fiord life. The total length of the second-year migrants will reach about 40 cm TL in the third year of life with the third-year migrants being over 40 cm in the fourth year (Table 5 and Fig. 9). Considering also the results of the gonad examination and scale check, the brown trout which enter the fiord appear to become mature at the end of their third or fourth year of life at the size of 40 to 45 cm TL, and do not always spawn every year after the first spawning.

Stomach contents

The food organisms observed in stomachs of brown trout from the Aisén and Salto Rivers for each survey are given in Table 6. As a whole the stomach contents of the trout from both rivers were made up of 14 organisms in six higher taxonomic categories. Although the com-

Table 6. Stomach contents of brown trout collected in the Aisén and Salto Rivers, showing number (No) of food organisms and frequency of occurrence (Oc).

River	Aisén River				Salto River			
Date	Mar. 27 – May 28 1980		Mar. 15 – Jun. 25 1981		Mar. 31 – May 2 1981		Apr. 20 – Jun. 30 1982	
No. of fish examined	26		20		18		13	
No. of stomachs with food	14		8		9		5	
% of empty stomachs	46.2		60.0		50.0		61.5	
Food organism	No (%)	Oc (%)	No (%)	Oc (%)	No (%)	Oc (%)	No (%)	Oc (%)
Seed of plant	–	–	–	–	3(12.0)	1(8.3)	–	–
Gastropoda	30(51.7)	7(31.8)	2(12.5)	1(9.1)	–	–	–	–
Crustacea TOTAL	**19(32.8)**	**9(40.9)**	**4(25.0)**	**3(27.3)**	**14(56.0)**	**3(25.0)**	–	–
Galatheidae (*Aegla* sp.)	19(32.8)	9(40.9)	3(18.8)	2(18.2)	3(12.0)	1(8.3)	–	–
Grapsidae	–	–	1(6.3)	1(9.1)	11(44.0)	2(16.7)	–	–
Insecta								
Tricoptera	3(5.2)	1(4.5)	–	–	–	–	–	–
Cyclostoma								
Geotria australis	–	–	3(18.8)	1(9.1)	–	–	–	–
Pisces TOTAL	**6(10.3)**	**5(22.7)**	**7(43.8)**	**6(54.5)**	**8(32.0)**	**8(66.7)**	**17(100.0)**	**7(100.0)**
Aplochiton taeniatus	6(10.3)	5(22.7)	2(12.5)	2(18.2)	–	–	–	–
Galaxias maculatus	–	–	–	–	–	–	2(11.8)	1(14.3)
Macruronus magellanicus	–	–	–	–	1(4.0)	1(8.3)	7(41.2)	3(42.9)
Merluccius sp.	–	–	–	–	1(4.0)	1(8.3)	–	–
Odontesthes smitti			1(6.3)	1(9.9)	2(8.0)	2(16.7)	–	–
Normanichthys crockeri	–	–	–	–	–	–	4(23.5)	1(14.3)
Eleginops maclovinus	–	–	2(12.5)	1(9.1)	–	–	1(5.9)	1(14.3)
Fish unidentified	–	–	2(12.5)	2(18.2)	4(16.0)	4(33.3)	3(17.6)	1(14.3)
Total number of preys	58		16		25		17	
Total occurrence of preys		22		11		12		7

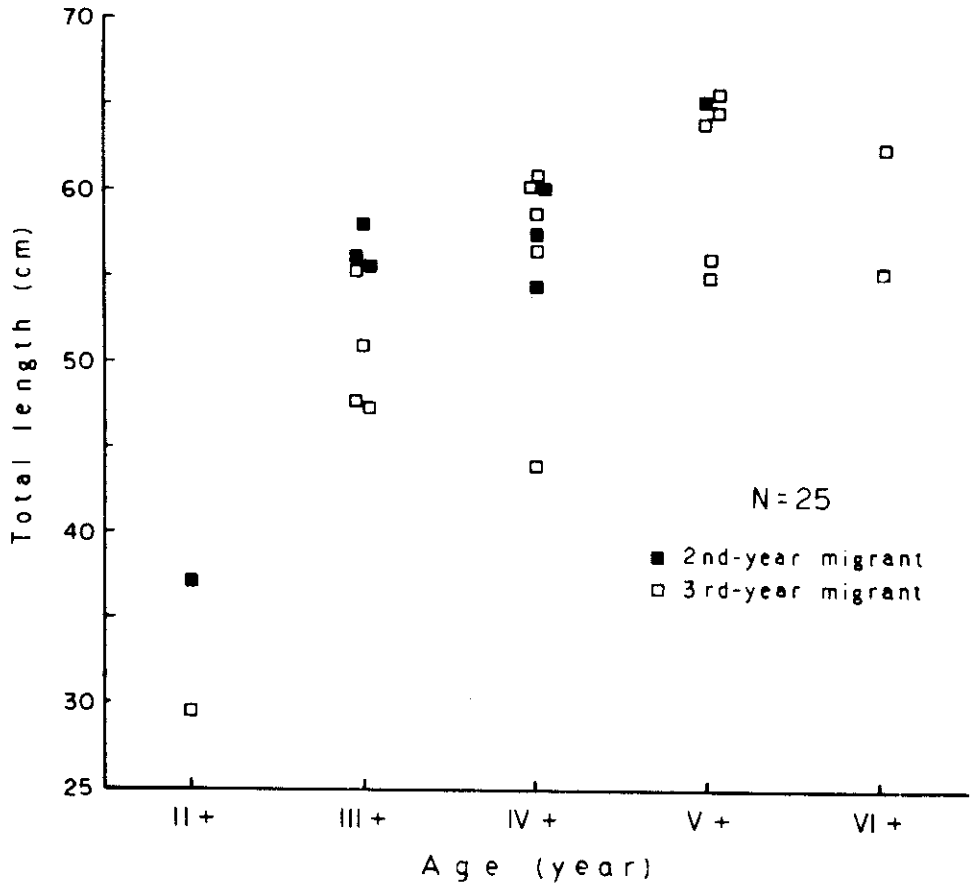

Fig. 9. Relationship between age and total length at capture for each migrant of brown trout sampled from the Aisén and Salto Rivers.

position of the food organisms eaten varied to some extent in each river year by year, fish formed a significant proportion of food of the trout from the rivers, and in partiuclar were exceedingly important for the Salto River trout. The trout in the Aisén River tended to subsist on various kinds of food. In addition to fish snails (Gastropoda) and freshwater squat-lobsters (Galatheidae) were also important for Aisén River trout. The rates of empty stomachs of the trout from the two rivers ranged from 46.2 to 61.5%, showing no difference between the rivers (Table 6).

DISCUSSION

The river-resident brown trout may be identified with *Salmo fario* Linnaeus and the sea-run brown trout with *S. trutta,* but both types can be recognized as one species *S. trutta* (Trewavas, 1953; MacCrimmon and Marshall, 1968; McDowall, 1978). Although the native range of the trout is confined to the northern hemisphere from North Africa through Eurasia to Scandinavia and Iceland, naturalized populations have been established through introduction in many countries in both hemispheres (Mason, 1953; Trewavas, 1953; MacCrimmon and Marshall, 1968; MacCrimmon *et al.,* 1970).

Spawning of this trout occurs in the autumn to winter, commonly in late October to December in the northern hemisphere (Needham *et al.,* 1945; Horton, 1961; Thomas, 1964; Moyle, 1976) and in late May to July in the southern hemisphere (Hobbs, 1937; Hopkins, 1970; McDowall, 1978). Hobbs (1937) and Moyle (1976) stated that the upstream movement to the

spawning grounds of trout is stimulated by a temporary rise of water level or temperature, and the spawning is more active when the water temperature drops to 6 to 10°C. In this study the catches of the brown trout mainly made up of spawning runs in the lower reaches of the rivers were more abundant until the water temperature decreased to about 7°C. We (unpublished) observed that the brown trout in the Lake General Carrera spawn at Pto. Ibañez (46° 16'S and 71° 58'W) in June and July. The spawning behavior and season of the brown trout established in southern Chile must be essentially similar to those found in other countries.

The female brown trout collected in the present surveys were more abundant than the males, particularly in the latter period of the survey, although there was no statistically significant difference between the sexes. The sex ratio of the brown trout (22.0 to 58.2 cm TL) found in Ensenada Baja is significantly different, showing a predominance of females (Zama and Cárdenas, 1982). Hobbs (1937) observed that there is an excess of females over males in the spawning runs of lake-living brown trout in New Zealand. In the spawning grounds, however, it is known that the males exceed females or sex ratios are even (Hobbs, 1937; Hopkins, 1970).

In the steelhead runs, *Salmo gairdneri* (Richardson), the females are predominant over the males or make up nearly half of the total (Briggs, 1953; Maher and Larkin, 1954). Briggs (1953) noted an example that the males predominate in the early stages of the California steelhead run and are in the minority in the latter portion. In the British Columbia, Maher and Larkin (1954) showed that in older fish or fish which have spent more years in salt water, females make up of a greater portion of the total for each age group. Judging from their table, the sex ratios inclusive of all age group are constant at about 60% females month by month.

It is likely that the incidence of seaward migration in female of brown and steelhead trouts is higher than in male as in the case of the *Oncorhynchus* species, *e.g.*, *O. masou* (Brevoort) (Oshima, 1957; Sano, 1959; Kato, 1971; Kubo, 1980) and *O. rhodurus* Jordan and MacGregar (Shiraishi and Suzuki, 1957; Kato, 1973; Kato, 1975), and the male trout begin to ascend the rivers prior to the females as known in the *Oncorhynchus* salmon (Kato, 1971; Matsubara and Ochiai, 1977).

According to Nomura (1963), Yamamoto *et al.* (1965) and Kato (1975), the ovaries of maturing rainbow trout increase rapidly in weight during the months preceding spawning when the gonadal indices reach the maximum of between 15 and 20. On the other hand, the maturing males show the maximum gonad index (GI: 5 to 13) in a few months before spawning, followed by a gradual decrease of gonad index (Nomura, 1963; Kato, 1975). These data agree well with the present observations on the brown trout (Fig. 7).

The brown trout reach maturity in their second to fifth year or more, usually in the third or fourth year (Trewavas, 1953; Lake, 1957; Burnet, 1959; Beyerle and Cooper, 1960; Horton, 1961; Thomas, 1964; Hopkins, 1970; Moyle, 1976). In general it is known that fish size is an important factor for maturation of the first spawning fish (Kato, 1975). In hatchery-reared rainbow trout the larger fish generally reach maturity at an earlier age than the smaller and spawn for the first time at a standard length of about 28 cm (Nomura, 1963; Yamamoto et al., 1965; Kato, 1975).

Apart from this study we sampled two maturing brown trout (29.2 and 36.8 cm TL) of fluvial form in the Simpson River in May 1982. Lake (1957) stated that in most streams, New South Wales, Australia, river-living trout first spawn when larger than 30 cm (TL?). Hopkins (1970) reported that average fork length of the spawning runs derived from larger rivers, New Zealand, is 42.7 cm, the rang being 30.1 to 56.0 cm. Judging from other workers (Burnet, 1959; Thomas, 1964; Moyle, 1976) who indicated a relationship between age and growth of the trout, in addition to the above-mentioned sampling, it appears that the river residents of brown trout usually spawn at a size larger than 30 cm TL.

The lake or sea migrants of brown trout grow up faster and to larger size than the river residents (Trewavas, 1953; Burnet, 1959; Moyle, 1976; McDowall, 1978). Burnet (1959)

observed that in the spawning run from lake in New Zealand most fish are between 35.5 and 55.0 cm long (45.6 cm on the average). Trewavas (1953) stated that the brown trout in a Swedish lake spawn at the average length of 57 cm (TL?) and the ages of the first spawning in the lake and sea habitants are higher than in the river trout. In the steelhead run, Maher and Larkin (1954) pointed out that the length (47.2 cm average fork length) at maturity is determined by the number of years spent in salt water and fork length is a function of the period of ocean life rather than total age.

Thus the sea-run brown trout, as well as the lake-living brown trout and the steelhead, must attain maturity at larger size (probably more than 40 cm TL) due to a faster growth in salt water than the river residents. It would be interesting to determine whether there is a difference of age at maturity between the two forms of brown trout.

In chum salmon scales the annual decrease of circulus number and growth rate of radius with age were studied in detail by Kobayashi (1961). Although no reference is available as to the annual formation of circuli on the brown trout scales, the number of circuli will be useful as an index for age determination. The brown trout presently studied had about 15 circuli in each year of fresh water life. Oshima (1957) and Kubo (1966) found the 12 to 14 circuli on the cherry salmon *(O. masou)* scales within the first year ring. The scale photos of sea-run *O. rhodurus* given by Kato (1973; 1975) show an annual formation of 12 to 17 circuli in fresh water. It seems that salmonids form 12 to 16 circuli on their scales during one year in fresh water life although, of course, the range and mode of circulus number may vary according to species or populations.

Allen (1938) estimated that brown trout migrate to the lake in English population in their second to fourth year, the larger fish at an earlier age. Kubo (1974; 1980) also pointed out a similar migratory tendency of cherry salmon smolts to the sea. In the present study the second-year migrants of brown trout in the Aisén River are estimated to be larger at the end of the first year than the third-year migrants are. However, both migrants in the Salto River are calculated to be equal in size at the same period. The actual or estimated lengths of four salmonid species at smolt migration are shown in Table 7 where the smolts of the *Oncorhynchus* which spend one year or more in fresh water may be larger than the *Salmo* smolts.

Many studies on the food of brown trout have been made in various countries, *e.g.*, in England and Ireland (Clarke, 1924; Southern, 1932; Allen, 1938; Horton, 1961; Thomas, 1962; Thomas, 1964), in New Zealan and Australia (Lake, 1957; Lane, 1964; Hospkins, 1965;

Table 7. **Comparison of lengths at smolt migration among five salmonid species, *Salmo trutta, S. gairdneri, Oncorhynchus masou, O. rhodurus* and *O. nerka*. An asterisc indicates that the length was estimated from the scale.**

Species	*S. trutta*		*S. gairdneri*	*O. masou*		*O. rhodurus*	*O. nerka*
Author	Present study	Allen (1938)	Maher and Larkin (1954)	Oshima (1957)	Kubo (1966; 1974; 1980)	Kato (1973; 1975)	Tokui (1970)
Country	Chile	England	Canada	Japan	Japan	Japan	Japan
Age at smolt migration	Total length* (cm)	Total length(?)* (cm)	Fork length* (cm)	Standard length (cm)	Standard length (cm)	Standard length (cm)	Total length (cm)
I+	11.6~12.2	7.0	11.1	More than 14	14~15	15	-
II+	16.7~18.0	13.4	16.5				18.2
III+		18.2	20.0				
IV+			22.9				

Hopkins, 1970), in Japan (Shiraishi and Tanaka, 1967), in Canada (Idyll, 1942) and in Chile (Zama and Cárdenas, 1982). The brown trout feed on a wide range of animals such as aquatic and terrestrial insects, mollusc, crustacea and fish: The small aquatic insects (as larvae) are the most important food for fry and young trout, while larger insects and the latter three for greater trout (Allen, 1938; Allen, 1961; Idyll, 1942; Horton, 1961; Thomas, 1962; Lane, 1964; Thomas, 1964; Hopkins, 1965; Shiraishi and Tanaka, 1967; Hopkins, 1970; McDowall, 1978). Zama and Cárdenas (1982) reported that the brown trout (23.0 to 58.2 cm TL) obtained from Ensenada Baja subsist mainly on fish, followed by terretrial insects and snails. Lane (1964) stated that the brown trout from a lagoon (adults) feed almost totally on Mollusca and Tricoptera and this probably reflects food availability. A difference of food composition of the brown trout presently studied was found between the Aisén and Salto Rivers (Table 6). At any rate the brown trout in the estuarine water of these rivers surely predate the fish as the most important food.

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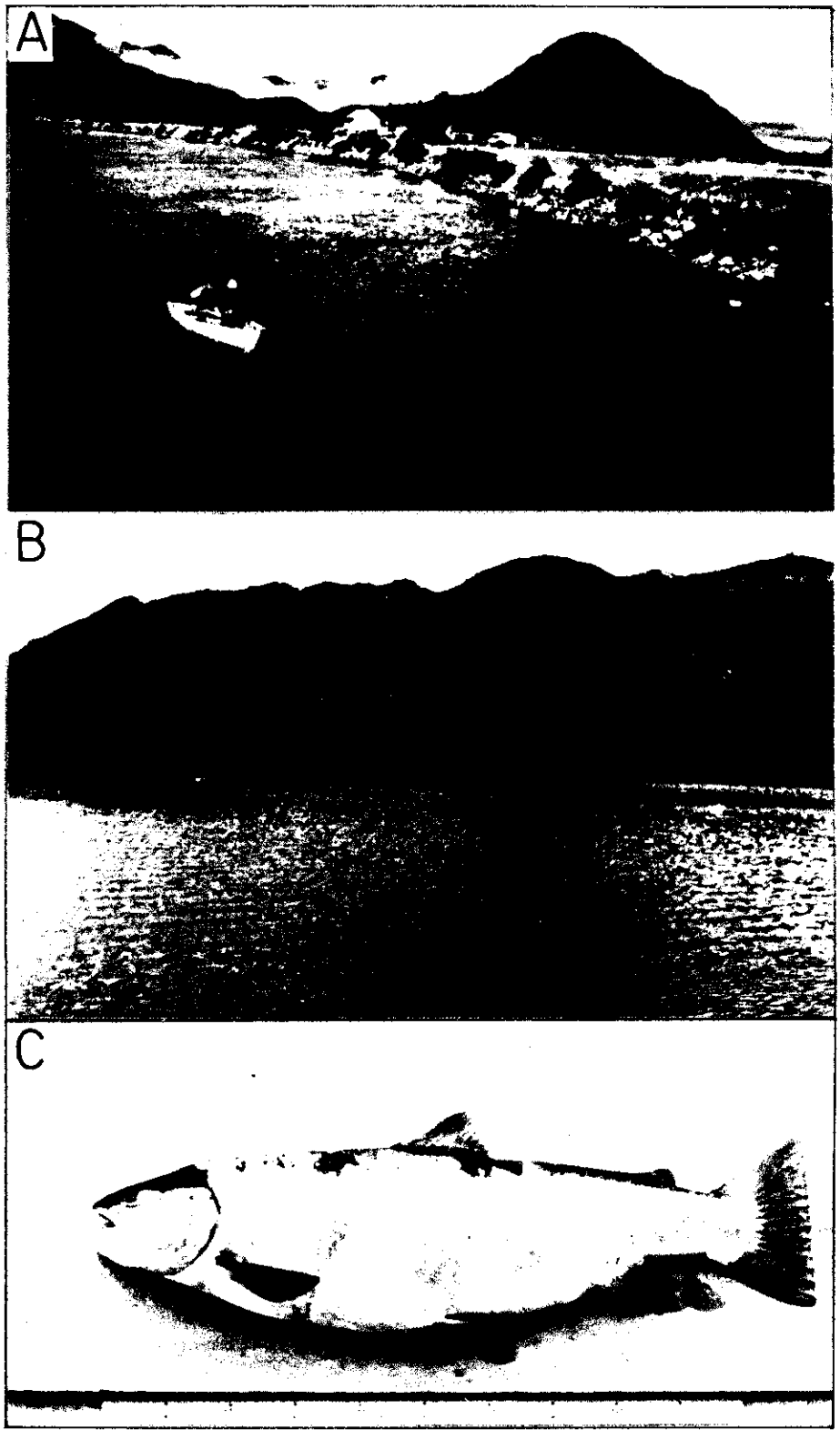

Explanation of PL. I:
A, checking the gill nets at Pto. Piedra in the Aisén River; B mouth of the Salto River; C, brown trout of spawning rum, female, 56.1 cm in total length from the Aisén River in March 16, 1981.

Appendix Table 1. Daily observation of weather, air and surface water temperatures and number of brown trout collected in the Aisén River, 1980.

Date	Time	Weather	Air temp. (°C)	Water Temp. (°C)	No. of trout collected
Mar. 27	10:30	c	11.0	13.0	2
28	10:10	bc	12.0	9.0	
29	10:10	bc	17.0	10.0	
30	10:20	bc	12.0	9.5	
31	09:30	c	12.0	11.5	1
Apr. 1	09:45	r	12.0	11.0	4
2	10:00	c	14.0	10.5	2
3	11:30	c	9.5	10.0	
4	12:10	bc	10.0	9.5	
5	11:55	c	12.0	11.0	
6	13:00	r	12.0	9.5	1
7	12:40	c	11.5	9.5	2
8	12:00	c	7.0	11.0	1
9	15:00	bc	8.5	8.8	2
10	12:00	bc	8.0	–	
11	12:00	c	8.0	8.0	1
12	13:00	bc	9.0	–	
13	13:30	bc	9.0	–	1
14	12:30	bc	9.0	–	1
15	12:00	c	9.0	9.5	
16	12:10	bc	7.5	7.5	
17	18:10	c	8.0	7.7	
18	14:00	c	8.0	7.5	1
19	18:00	b	8.0	12.6	
20	18:30	b	5.0	7.2	
21	12:00	b	5.0	6.5	
22	12:00	c	8.5	8.5	1
23	09:00	c	6.0	6.5	
24	12:30	r	6.0	6.7	2
25	18:15	c	8.0	6.8	
26	12:30	b	6.0	7.5	
27	15:00	c	6.0	6.5	
28	11:45	bc	7.0	7.2	
29	12:30	bc	6.0	7.5	
30	12:30	bc	8.0	8.0	
May 1	12:00	bc	9.0	7.6	
2	12:00	bc	8.0	7.4	
3	13:30	bc	9.5	7.5	1
4	15:30	bc	9.0	7.7	
5	12:00	c	10.0	8.0	1
8	12:00	c	8.5	7.1	1
9	12:30	r	8.0	7.3	
10	12:40	r	7.0	6.9	
13	12:15	b	4.5	5.0	
14	12:00	bc	3.5	4.5	
19	12:00	bc	6.0	7.0	1
24	11:15	bc	7.0	7.5	
25	11:30	r	7.5	7.0	
28	12:15	bc	7.0	7.5	

Appendix Table 2. Daily observation of weather, air and surface water temperatures and number of brown trout collected in the Aisén River, 1981.

Date	Time	Weather	Air temp. (°C)	Water temp. (°C)	No. of trout collected
Mar. 15	10:00	c	7.5	10.8	1
16	09:15	r	7.5	11.1	2
17	09:15	c	7.5	10.2	1
18	09:15	bc	12.0	10.7	2
19	09:15	c	12.0	11.4	
20	09:15	r	10.5	10.6	
21	10:15	r	8.0	10.4	1
22	10:00	r	8.5	10.3	
23	09:15	bc	8.5	10.7	
24	09:30	r	7.5	10.9	
25	09:30	bc	14.5	10.4	2
26	09:30	bc	9.5	10.7	
27	09:15	c	13.0	11.6	
28	09:45	bc	14.0	11.3	
29	09:45	bc	11.0	11.4	
30	09:15	c	12.0	11.4	
31	09:10	c	13.0	11.5	1
Apr. 1	09:15	c	12.0	11.1	1
2	09:10	c	12.0	10.8	
3	09:30	c	11.0	10.8	1
4	10:50	b	14.0	10.3	
5	10:30	b	10.0	10.4	2
6	09:30	c	10.0	10.8	
7	09:00	c	12.0	10.6	
8	09:20	c	11.0	10.6	
9	09:30	r	9.5	10.7	
10	09:30	c	8.5	9.7	
11	10:40	c	11.5	9.7	
12	10:20	bc	11.5	10.0	
13	09:20	bc	9.0	9.5	
14	10:00	bc	11.5	9.8	
15	09:15	c	11.0	9.9	1
16	09:30	bc	9.0	9.9	1
17	10:30	bc	11.5	9.9	
18	10:30	bc	13.0	9.9	
19	10:30	bc	13.5	10.3	
20	09:45	r	11.5	10.3	
21	09:45	c	9.5	10.2	
22	09:30	c	9.0	9.6	
23	09:40	c	9.5	9.5	
24	09:30	c	4.0	8.9	1
25	09:30	f	3.0	8.5	
26	10:00	bc	7.0	8.1	1
27	10:00	bc	10.5	8.2	
28	09:30	r	8.5	8.6	
29	09:15	r	10.0	9.0	
30	09:30	r	9.5	8.0	

(continued)

Date	Time	Weather	Air temp. (°C)	Water temp. (°C)	No. of trout collected
May. 1	10:40	r	9.5	8.0	
7	09:30	r	4.0	7.0	
8	09:15	r	6.8	6.3	
9	09:50	bc	3.5	6.6	
10	10:30	b	2.0	6.4	
11	09:50	c	1.5	5.5	
12	09:30	bc	5.0	5.7	
13	10:30	r	4.5	5.3	
14	09:30	r	8.0	6.0	
15	09:30	r	4.5	6.0	
16	10:20	r	5.5	6.2	
17	10:30	r	4.5	6.6	1
18	09:40	r	3.5	5.8	
19	09:50	c	2.5	5.9	
20	09:25	c	9.0	6.6	
21	10:05	c	7.0	6.7	
22	09:30	r	9.0	6.1	
23	10:30	r	8.2	6.6	
24	10:00	c	5.0	6.2	
25	09:30	c	3.0	5.9	
26	10:00	bc	4.0	5.3	
27	09:30	c	5.0	5.7	
28	09:30	c	7.0	5.8	
29	09:30	c	7.5	5.9	
30	09:15	r	5.0	6.4	
31	10:30	c	4.5	6.2	
Jun. 1	09:15	f	2.0	5.7	
2	09:30	c	5.0	5.9	
3	09:15	bc	6.0	5.9	
4	09:45	f	−0.5	5.5	
5	09:20	b	1.5	4.1	
6	09:45	c	3.0	4.6	
7	09:30	c	3.5	4.9	
8	09:25	c	4.5	4.7	
9	09:15	r	3.5	5.7	
10	09:20	c	4.0	5.5	1
11	09:20	c	4.0	5.7	
12	09:15	c	3.5	5.6	
13	09:30	r	3.0	5.5	
14	10:30	c	10.5	5.2	
15	09:30	c	5.0	5.7	
16	09:30	c	4.0	5.8	
17	09:15	b	2.0	5.1	
18	09:30	f	1.5	5.1	
19	09:35	f	2.0	5.4	
20	09:45	c	2.5	5.3	
21	10:00	c	4.0	5.4	
22	09:25	r	8.0	5.8	
23	09:30	r	10.5	6.5	
24	09:40	r	6.5	6.5	
25	09:30	c	5.0	5.7	

Appendix Table 3. Daily observation of weather, air and surface water temperatures and number of brown trout collected in the Salto River, 1981.

Date	Time	Weather	Air temp. (°C)	Water temp. (°C)	No. of trout collected
Mar. 31	09:30	c	11.0	11.6	1
Apr. 1	09:20	c	10.0	12.1	3
2	09:20	c	9.5	12.0	1
3	09:10	c	9.5	11.8	1
4	12:00	b	11.0	12.0	1
5	08:30	bc	5.0	10.6	
6	10:00	c	9.0	11.4	2
7	10:40	c	10.0	11.9	2
8	10:00	c	9.0	11.3	
9	10:00	r	10.0	11.5	1
10	10:00	c	8.0	10.1	1
11	08:30	c	11.0	–	
12	09:30	bc	9.0	–	
13	09:00	bc	7.5	10.1	
14	10:30	bc	10.0	10.0	1
15	09:00	c	10.0	10.1	1
16	09:00	bc	12.0	11.0	
17	08:35	bc	9.5	–	
18	10:00	bc	11.0	10.0	
19	08:30	c	10.0	10.8	
20	09:30	r	11.0	11.2	
21	09:40	r	11.0	11.0	1
22	09:30	c	8.0	10.6	
23	09:15	c	8.0	9.8	
24	09:30	c	5.0	8.8	
25	09:00	f	3.0	7.9	
26	12:00	c	9.0	–	
27	09:30	c	10.0	8.6	
28	09:00	r	8.0	9.9	
29	09:30	r	10.0	9.8	
30	09:30	r	10.0	9.7	
May. 1	10:30	r	11.0	10.6	2
2	08:30	r	8.5	9.4	

Appendix Table 4. Daily observation of weather, air and surface water temperatures and number of brown trout collected in the Salto River, 1982.

Date	Time	Weather	Air temp. (°C)	Water temp. (°C)	No. of trout collected
Apr. 20	08:40	bc	10.0	10.3	1
21	08:40	f	10.5	10.0	1
22	09:10	c	10.0	10.4	
23	10:10	c	11.0	10.0	1
24	10:10	c	13.0	11.2	1
25	10:10	bc	8.0	10.4	
26	10:10	c	10.5	10.1	1
27	09:20	c	11.5	9.9	
28	09:10	r	13.0	11.1	
29	09:20	c	13.0	11.2	

(continued)

Date	Time	Weather	Air temp. (°C)	Water temp. (°C)	No. of trout collected
30	10:10	bc	13.0	11.1	
May 1	09:10	bc	10.0	10.2	1
2	09:10	c	10.0	10.3	
3	09:40	f	10.5	10.6	
4	09:10	r	12.5	10.9	1
5	09:10	r	12.5	10.8	
6	10:40	c	9.5	10.2	
7	11:10	r	8.5	10.3	
8	09:40	r	10.0	9.9	
9	10:40	c	10.0	10.2	
10	14:00	c	11.0	–	
11	09:10	c	10.0	8.9	
12	09:10	r	9.0	8.5	
13	09:40	c	8.0	8.3	
14	09:10	c	7.0	7.0	
15	10:25	r	7.0	7.5	
16	10:10	r	7.5	7.8	
17	09:10	c	11.0	7.7	
18	09:40	r	7.0	8.0	
19	10:10	r	4.0	6.0	
20	11:40	c	5.0	5.9	
21	10:10	c	7.0	6.2	
22	09:00	r	7.0	6.0	
Jun. 3	09:30	r	6.0	7.2	
4	09:30	r	9.0	7.7	
5	10:30	c	7.0	6.9	
6	11:30	r	9.0	7.0	
7	09:30	r	5.5	5.8	
8	09:30	r	7.0	6.0	
9	08:30	c	6.5	5.9	
10	09:00	c	1.0	5.2	
11	09:00	r	5.0	4.3	
12	11:00	c	5.0	4.5	
13	14:30	c	2.0	4.0	
14	10:00	c	0.5	3.7	
15	10:30	c	−1.0	3.1	
16	10:30	bc	−1.5	2.9	
17	10:00	bc	0.0	4.0	1
18	09:30	bc	2.5	3.4	2
19	08:30	bc	−2.0	4.2	
20	10:30	bc	2.0	6.7	1
21	09:45	bc	0.0	8.2	
22	09:30	bc	1.0	6.7	
23	15:00	c	2.5	8.1	
24	09:30	c	3.0	8.0	
25	09:30	c	2.5	6.8	
26	16:30	bc	4.0	6.6	
27	11:30	c	2.5	4.0	
28	09:30	bc	2.0	5.5	
29	09:30	c	3.0	4.8	1
30	09:15	c	1.0	4.4	1