BIOLOGICAL OBSERVATIONS ON SEA-RUN BROWN TROUT IN FIORDO AYSEN, SOUTHERN CHILE (PISCES: SALMONIDAE).

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ABSTRACT. Biological observations on sea-run brown trout in Fiordo Aysén, southern Chile (Pisces: Salmonidae).

The sex ratio, gonadaldevelopment and stomach contents of sea-run brown trout were studied in material obtained from Fiordo Aysén. The proportion of females was found to be greater than that of males, about 60%. The gonad indices of maturing males attained the highest level in March, but thereafter decreased progressively until spawning, which began in May. Maturing females showed a remarkable, steady increase in gonad index from January to May. In males and females, maturation usually occurred after the fish reached about 350 mm SL although there were a few maturing males measured at a little over 200 mm SL. Pisces, followed by Crustacea, were the most important food sources for the Fiordo Aysén brown trout and the importance of these animal groups as food was almost constant all year-round. The brown trout established in Fiordo Aysén seems to show a sex ratio, reproductive characteristics and food habits essentially similar to those observed in other countries.

Key words: Sea-run brown trout, sex ratio, gonadal development, food habits, Fiordo Aysén.

RESUMEN. Observaciones biológicas en trucha café migrante del mar en el fiordo Aysén, Chile austral (Pisces: Salmonidae).

Se estudió la proporción numérica de sexos, el desarrollo gonadal y el contenido estomacal en material de trucha café migrante del mar obtenido en el fiordo Aysén. Se encontró que la proporción de hembras era mayor que la de machos, siendo alrededor del 60%. Los índices gonádicos de machos en maduración alcanzaron su nivel más alto en marzo, pero de ahí en adelante decrecieron progresivamente hasta el desove, el que comenzó en mayo. Las hembras en maduración mostraron un notable aumento continuo en el índice gonádico desde

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enero a mayo. En machos y hembras, la maduración usualmente tuvo lugar después que los peces alcanzaron alrededor de 350 mm LS, aunque hubo algunos machos en maduración que midieron un poco más de 200 mm LS. Las fuentes más importantes de alimento para la trucha café del fiordo Aysén fueron Pisces seguido de Crustacea y la importancia como alimento de estos grupos animales fue casi constante a lo largo de todo el año. La trucha café establecida en el fiordo Aysén parece mostrar una proporción de sexos, características reproductivas y hábitos alimentarios esencialmente similares a aquellos observados en otros países.

INTRODUCTION

The native range of the brown trout, **Salmo trutta** Linnaeus, is confined to the northern hemisphere from Scandinavia and Iceland throughout other European regions and western Asia southward to northern Africa, but naturalized populations have been established through introduction in many countries in both hemispheres (Mason 1953, Frost & Brown 1967, MacCrimmon & Marshall 1968, MacCrimmon **et al.** 1970, Mills 1971). In the southern hemisphere, the brown trout populations introduced into New Zealand and Australia have been studied in detail by workers such as Hobbs (1937), Allen (1951), Lake (1957), Nicholls (1958) and Hopkins (1970).

In 1905, the brown trout was transplanted to Chile from Germany and has acclimated extensively to rivers and lakes in the central and southern regions (Golusda 1927, Fowler 1940, Mann 1954, Campos 1970, Duarte **et al.** 1971, Zeiss **et al.** 1973, Leible & Alveal 1982, Ojeda & Santelices 1982). This trout is now one of the most popular freshwater game fishes in the country (Subsecretaría de Pesca 1981). In southern Chile, the trout has become the most dominant species, at least in the Simpson River system and an anadromous form also commonly occurs in Fiordo (Fiord) Aysén (Zama & Cárdenas 1984a). However, very little information is available on the biology of the brown trout naturalized in Chile. The only record of sea-run brown trout from central Chile (about 37ºS) was reported by Leible & Alveal (1982). Zama & Cárdenas (1982, 1983, 1984b) reported on some biological aspects of the brown trout collected in Fiordo Aysén. Aguirrebeña (1986) noted the stomach contents of brown trout from Río (River) Simpson, which runs into Fiordo Aysén as Río Aysén, and compared the

stomach contents with those of released juvenile chum salmon **Onchorhynchus keta** (Walbaum).

During the course of various investigations on salmon propagation in southern Chile, I had an opportunity to examine brown trout obtained from Fiodo Aysén. This paper presents the sex ratio, gonadal development and stomach contents of the trout examined.

MATERIAL AND METHODS

Fiordo Aysén, about 60 km long and 3 to 6 km wide, is located at 45°20'S and 73°00'W. A total of 616 brown trout was obtained from six sites in the fiord from 1980 to 1984 (Fig. 1, Table 1). Of these fish, 542 (88%) were collected in Ensenada Baja, a small inlet at the innermost part of Fiordo Aysén. All but five were captured by surface gill nets of 60 to 135 mm stretched mesh at depths between the surface and 6.5 m near the shore. Four were taken from Ensenada Acantilada by

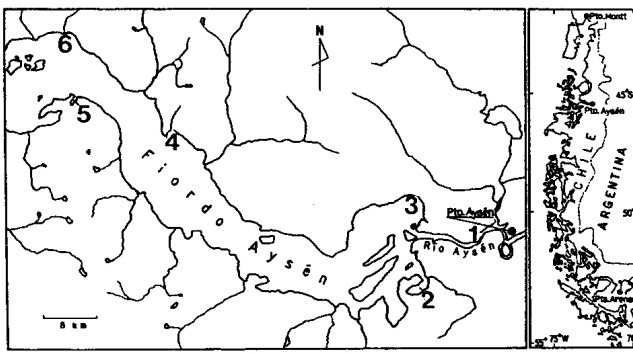

Fig. 1. Pacific side of southern South America (right) and Fiordo Aysén (left), indicating sampling sites. 1. Puerto Piedra; 2. Ensenada Baja; 3. Ensenada Acantilada; 4. Punta Tortuga; 5. Puerto Gato; 6. Puerto Pérez.

purse seine and one from Ensenada Baja by hook and line. Puerto Piedra is located at the lowest part of Río Aysén (Fig. 1). Most of the fish collected there with well-developed gonads were on spawning runs from Fiordo Aysén and some with immature gonads were regarded as the sea-run form because of the presence of both river- and sea-life zones on their scales (Zama & Cárdenas 1983).

Standard length (SL) and body weight of all the fish collected were measured immediately after capture and their stomach contents were examined in the field. No attempt was made to identify the organisms eaten to the specific level except in the case of lamprey and fishes. The gonads of 91 males and 209 females were also weighed when fresh. The gonad index (GI) was calculated as follows: GI = (gonad weight in g/body weight in g) x 100. Developmental stages of the gonads were determined by macroscopic appearance following the description given by Frost & Brown (1967). In this study, however, all males and females with a gonad index of less than 1.0, which were not expected to spawn during the following spawning season, were treated as immature even if some appeared to have previously experienced spawning. The sex ratio was tested for difference from a hypothetical sex ratio of 50% females by means of the Chi-square test and expressed as percentage of females. Some of the fish dealt with in this paper were used for previous reports by Zama & Cárdenas (1982, 1983, 1984b).

RESULTS

Sex ratio

The standard length of 616 brown trout examined in this study ranged from 151 to 640 mm and the body weight from 59 to 4700 g (Table 1). Of these fish, females numbered 364 (59.1% of the total catch), showing a significant difference from the hypothetical 50% females at the 1% probability level. As shown in Table 1, more females than males were collected at all sampling sites although only small numbers of specimens were available from sites other than Ensenada Baja. Two samples from Ensenada Baja ($p < 0.01$) and Puerto Pérez ($p < 0.05$) showed a significant predominance of females. Table 2

summarizes the percentages of females obtained from all sites in each year. From 1980 to 1982, there were statistically more females at the 1% (1980 and 1981) and 5% (1982) probability levels. The sex ratio was not significantly different from the 50% level in 1983 and 1984.

When the data were arranged by season, the proportion of females in all seasons (52.2 to 64.5%) was greater than that of males, showing a significant difference ($p < 0.01$) in spring and autumn (Fig. 2). Fig. 2 also shows the length composition

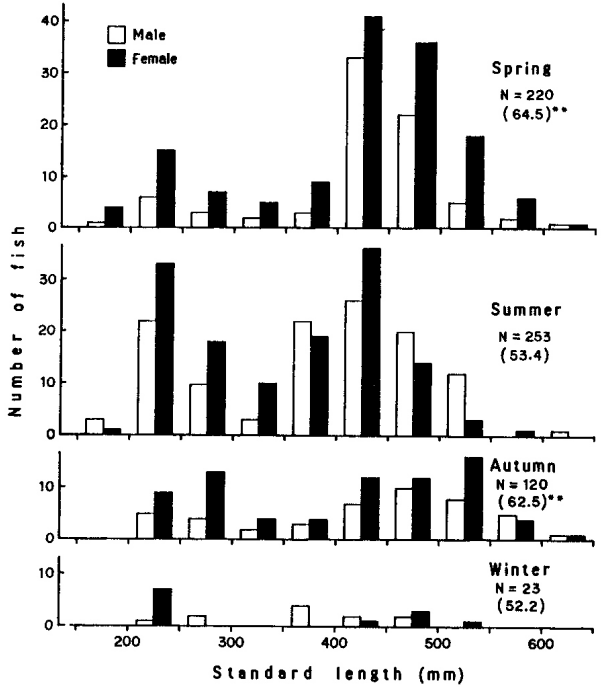

Fig. 2. Length composition for each sex of brown trout from Fiordo Aysén during each season. Specimens were divided into 50 mm length groups. Figures in parentheses indicate percentages of females. **, $P < 0.01$.

of males and females by season. There was no difference in length range between the sexes in each season, but the females were dominant in number at most 50 mm-length intervals, particularly in spring and autumn.

In the above analysis, at no time were males found in significantly greater numbers than females. I presume, as a whole, that in the brown trout inhabiting Fiordo Aysén, the proportion of females is greater than that of males, about 60%, although the sex ratio may vary according to seasons or years.

Gonadal development

In Fig. 3, the gonad index of each fish is plotted according to month. From January to May, both males and females were separated into two groups containing immature and maturing gonads. This separation was clearer between March and May than in January. Therefore, the immature group, showing a range of gonad indices up to 0.8, was not expected to spawn during the following spawning season, while the maturing group with gonad indices of 1.0 and higher was considered ready to ripen the gonads for spawning. The numerical criterion for separating immature and maturing gonads was a gonad index of 1.0. The separation, particularly in females, probably began in December although unfortunately, December data were not available.

Different characteristic changes in gonad index were recognizable between the maturing males and females. Only one maturing male with a gonad index of 1.0 occurred in January. In March, the gonad indices of maturing males reached their highest levels, ranging from 3.2 to 5.8 (4.2 on the average), but thereafter, decreased progressively, i. e., the average gonad index was 3.5 in April and 2.9 in May. On the other hand, maturing females had gonad indices between 1.1 and 3.6 (2.1 on the average) in January and then showed remarkable, steady growth until May. Their gonad indices were 2.8 to 14.8 (8.8) in March, 6.5 to 17.2 (12.4) in April and in May, increased to higher values varying from 10.5 to 19.4 (15.5). In June, a few spent females were caught in Ensenada Baja. During and after June, all males and females had immature (and spent) gonads, which failed to reach the 1.0 level on the gonad index (Fig. 3). It appears, therefore, that the pre-

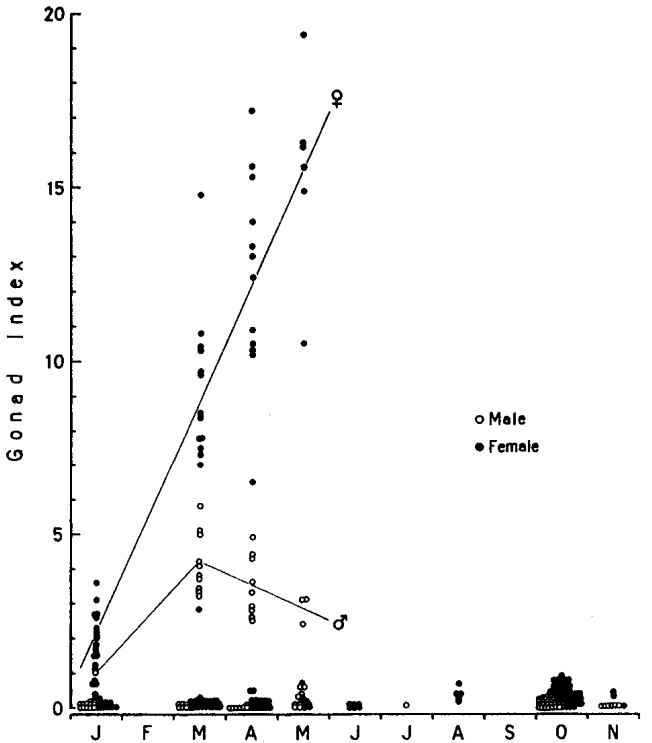

Fig. 3. Monthly change in gonad index for each sex of brown trout from Fiordo Aysén.

spawning upstream migration of the brown trout from Fiordo Aysén lasts until May (late autumn) and spawning takes place in late autumn and winter.

Fig. 4 shows the relationship between standard length and gonad index for the fish collected between January and May when the pre-spawning increase in gonad index was observed. Males and females with immature gonads ranged in length from 151 to 560 mm SL. As noted above, they were presumed to be

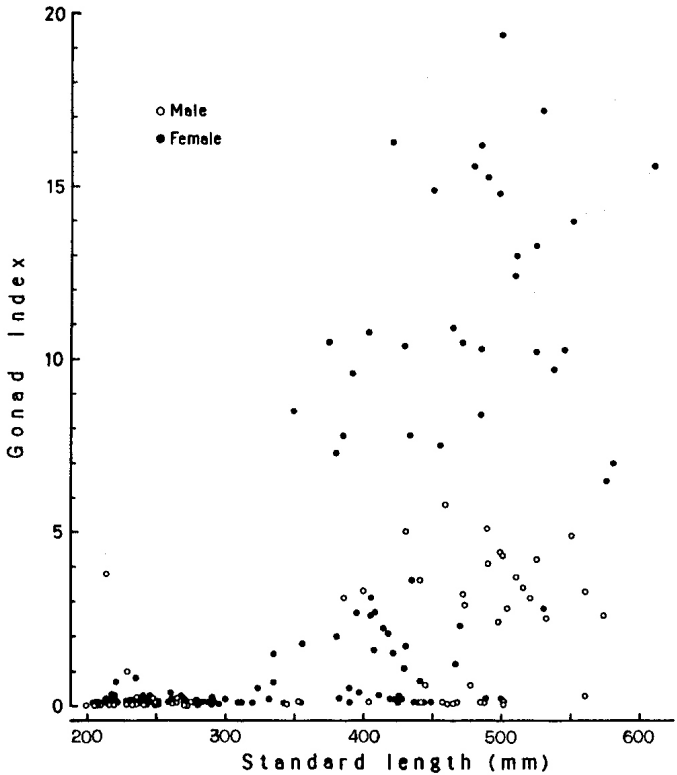

Fig. 4. Relationship between standard length and gonad index for each sex of brown trout from fiordo Aysén from January to May.

non-spawners during the following spawning season although some of them may have previously spawned. Two males measuring 213 and 228 mm SL were regarded as maturing because their gonad indices measured 1.0 or higher. Other maturing males were 386 mm SL and longer. The occurrence of maturing females was confined to standard lengths of 335 mm and longer. This data suggests that the first maturation occurs in males and females after the fish attain about 350 mm SL, except for some precocius males beginning to mature at a smaller size.

Stomach contents

The stomach contents of the brown trout presently examined were classified into 25 prey items in eight higher taxonomic categories (Table 3). Although 425 young chum and 21 young pink (**Oncorhynchus gorbuscha**) salmon were contained in stomachs of the brown trout from Ensenada Baja, they were not from a natural population, but had been released into the bay from ponds and floating pens. Therefore, these salmon are excluded from the present analysis.

The occurrence of empty stomachs was lowest in spring at 32.3% and increased in winter to 60.9% (Table 3). The variety of prey items numbered 17 or 18 during spring to autumn, but decreased to only five in winter. The number of preys per stomach was highest in summer (2.0), followed by spring (1.7), and dropped to its lowest level in winter (0.5) (Table 3).

The galatheid **Aegla** sp., the normanichthyid **Normanichthys crockeri** and the nototheniid **Eleginops maclovinus** were found during all seasons (Table 3). Pelagic polychaetes, snails, grapsid crabs, terrestrial insects, the clupeid **Spratus fuegensis** and the atherinid **Austromenidia smitti** occurred from spring to autumn, but disappeared in winter. **Aegla** sp. and snails, both of which are found in fluvial waters (personal observation), were available to the brown trout from Puerto Piedra and Ensenada Baja. A large number of **S. fuegensis** were eaten in spring. As a whole, **E. maclovinus**, **N. crockeri**, **S. fuegensis**, snails, **Aegla** sp., gammarids and terrestrial insects were considered to be the main diet for the brown trout in Fiordo Aysén.

Seasonal composition of the stomach contents, grouped into seven higher taxonomic categories for convenience, is depicted

in Fig. 5. Between spring and autumn, preys eaten by the brown trout were of many varieties, but confined to Pisces and Crustacea in winter. During each season, Pisces made up the greatest part of the stomach contents in both frequency of occurrence and number, usually accounting for 60 to 75%, while Crustacea accounted for 15 to 25%. There is little doubt that Pisces are an exceedingly important food source for the Fiordo Aysén brown trout, followed by Crustacea. The importance of these two groups as food is constant all year-round as they account for as much as or more than about 80% of all stomach contents (in numerical and frequency of occurrence compositions). Gastropoda and Insecta may be not negligible from spring to autumn.

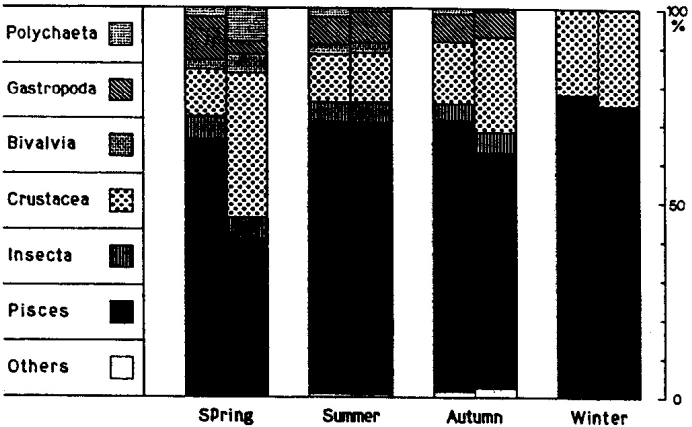

Fig. 5. Seasonal composition expressed as percentage of stomach contents grouped into higher taxonomic categories for brown trout from fiordo Aysén. See Table 3 as to the detailed figures for each category. Left column in each season, frequency of occurrence; right column, the number eaten.

DISCUSSION

According to remarkable variation in features such as color, form and habit, many scientific names were given to the brown trout from different rivers, lakes and seas, but all populations of the trout should be recognized as one species, **S. trutta** (Trewavas 1953, Frost & Brown 1967, MacCrimmon & Marshall 1968, Mills 1971).

The present study suggests that the proportion of females is higher than that of males in the brown trout from Fiordo Aysén. In rivers containing no anadromous populations of brown trout, males and females are almost balanced in number (Allen 1951, McFadden **et al.** 1962, Lusk 1968). As is the case with the present study, however, females in populations migrating into the sea or lakes tend to predominate over males (Hobbs 1937, Alm 1950, Gustafson 1951, Khalturin 1970, Treasurer 1976). The predominance of females is also seen in sea-migrants of some salmonid species (Okazaki 1984).

In brown trout inhabiting rivers, Lusk (1969) reported that females show a rapid increase in gonad index during the five months preceding spawning, while in males, a peak in gonad index occurs three months before spawning, followed by a gradual decrease. These observations agree well with those presented here for the sea-run brown trout. Similar changes in gonad weight have been observed on reared rainbow trout **Salmo gairdneri** (Richardson) (Nomura 1963, Yamamoto **et al.** 1965, Kato 1975). The gonad index of female brown trout is known to attain the highest values (15.0 to 20.0 or a little more) just before spawning (Lusk 1968, 1969, Amanov & Khakimova 1979). According to Lusk (1968, 1969), as well as the present findings, males show a peak in gonad index at about 5.0. The highest male gonad index was recorded by Amanov & Khakimova (1979) at 10.0.

In this study, the distinction between immature and maturing gonads were determined by whether the gonad index reached 1.0 or not and males and females with immature gonads during the five months (January to May) before spawning season were presumed to be non-spawners for the season. In accordance with the present observation, Lusk (1969) reported that after spawning, the gonad indices of males and females decrease to less than 1.0 until gonad weight starts increasing again before the next spawning. Frost & Brown (1967) and Mills

(1971) noted that some fish living in large lakes do not always spawn every year after the first spawning. This behavior has been ascertained for the brown trout in Fiordo Aysén through scale examination by Zama & Cárdenas (1983). Brown & Kamp (1942) reported that in brown trout collected above a reservoir, the average gonad index of females increased from 0.6 to 10.8 during one month just before spawning season. It seems to me, however, that the initial value Brown & Kemp (1942) obtained is too low and that the fish (368 to 406 mm SL) examined at that time might have been out of a spawning group.

Males usually reach maturity at an earlier age than females (Lake 1957, Horton 1961, Frost & Brown 1967, Campbell 1971, Amanov & Khakimova 1979). Among the present maturing fish, there were two males which measured 213 and 228 mm SL, while the smallest females was 335 mm SL. It is likely that in Fiordo Aysén, males tend to mature at an earlier age than females. As noted earlier, in the brown trout from the fiord, spawning appears to take place in late autumn and winter. Brown trout is known to spawn during autumn and winter in the northern hemisphere (Frost & Brown 1967, Mills 1971, Moyle 1976) and also in the southern hemisphere where the trout has been introduced (Hobbs 1937, Hopkins 1970, Scott **et al.** 1974, McDowall 1978).

A great number of studies on the food habits of brown trout have been done in various countries. Food organisms fed upon by brown trout differ widely in kind according to locality (Lane 1964, Frost & Brown 1967). Aquatic and terrestrial insects are very important foods for brown trout living in rivers and lakes (e. g., Clark 1924, Allen 1938, Idyll 1942, Thomas 1964, Shiraishi & Tanaka 1967, Tusa 1968, Hopkins 1970, Amanov & Khakimova 1973, Aguirrebeña 1986). In estuarine and sea waters, fishes, crustaceans and molluscs become important food sources (Lane 1964, Frost & Brown 1967, Mills 1971, McDowall 1978, Leible & Alveal 1982).

Intertidal and benthic communities along the shore of Fiordo Aysén are considered to be impoverished because of the strong influence of freshwater inflow from rivers (Zama & Cárdenas 1982, 1984c). The present study confirms that fishes are an exceedingly important food source for the Fiordo Aysén brown trout. Among the fishes eaten by the present brown trout, **E. maclovinus** was most frequently observed in their stomachs throughout the year, while **S. fuegensis** became of increasing

importance in spring. It is known that the former is the most common species among Fiordo Aysén ichthyofauna and the latter migrates into the fiord to spawn in spring (Zama & Cárdenas 1982, 1984a). Zama & Cárdenas (1984d) found that the brown trout is the most voracious predator of juvenile salmon released into Ensenada Baja.

The present analysis of the stomach contents suggests that food organisms available to the brown trout in Fiordo Aysén may be comparatively abundant in spring and summer, but become scarce in winter. According to Hirakawa (1984) and Zama & Cárdenas (1984e), the kinds and biomass of zooplankton in Fiordo Aysén are much greater during spring and summer than in winter. There were few planktonic animals in the brown trout stomachs presently examined. It is likely, however, that seasonal changes in the quality and quantity of preys eaten were connected with those of the zooplankton fauna in the fiord, even if indirectly.

Comparing these results with other studies, the sex ratio, reproductive characteristics and food habits of the brown trout in Fiordo Aysén are considered to be essentially similar to those observed in other countries. The brown trout is among the more common fishes in Fiordo Aysén and there is probably no species competing with this trout for food, except the steelhead trout (**S. gairdneri**) which is very rare in this area (Zama & Cárdenas 1982, 1984a, 1984b). In addition, the water temperature of the fiord, varying seasonally at the surface from 6° to 16°C, usually 8° to 14°C (Zama & Cárdenas 1984c), is optimal for the growth of the brown trout (Frost & Brown 1967, Moyle 1976). The almost complete absence of competitors for food and the suitable water temperature seem to have assured a successful establishment of the brown trout in Fiordo Aysén and probably in adjacent waters.

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TABLE 1. Number and size of brown trout collected in Fiordo Aysén from 1980 to 1984. Asterisks indicate a significant difference from the hypothetical 50% females at the 1 (**) and 5 (*) % probability levels.

LOCALITY	Nº fish	% females	Standard length (mm)	Body weight (g)
1. Puerto Piedra	46	60.9	264 - 607	500 - 3800
2. Ensenada Baja	542	57.9**	182 - 640	112 - 4700
3. Ensenada Acantilada	3	66.7	151 - 157	59 - 66
4. Punta Tortuga	6	83.3	167 - 575	59 - 2580
5. Puerto Gato	1	100.0	472	1900
6. Puerto Pérez	18	77.8*	297 - 590	470 - 3200
Total or range	616	59.1**	151 - 640	59 - 4700

TABLE 2. Total number and relative appearance of females in the brown trout from Fiordo Aysén in each year from 1980 to 1984. Asterisks as in Table 1.

YEAR	1980	1981	1982	1983	1984
Nº of fish	68	223	100	83	142
% of females	66.2**	63.7**	61.0*	55.4	49.3

TABLA 3. Seasonal change in the stomach contents of brown trout from Fiordo Aysén, showing frequency of occurrence (Oc) and the number (Nº) of food organisms expressed as % of each seasonal total. For pink and chum salmon eaten, the actual numbers are given, but not included in the total. The four seasons are recognized as follows: Spring (September to mid-December), Summer (mid-December to March), Autumn (April and May), and Winter (June to August).

SEASON	Spring		Summer		Autumn		Winter		TOTAL	
Nº of fish examined	220		252		121		23		616	
Nº of stomachs with all contents digested	16		7		1		1		25	
% fish with empty stomachs	32.3		51.2		52.1		60.9		43.8	
PREY ITEM	Oc	Nº	Oc	Nº	Oc	Nº	Oc	Nº	Oc	Nº
Seeds of plant					1.4	2.2			0.3	0.3
Polychaeta (pelagic)	2.4	8.6	2.2	0.8	1.4	0.7			2.0	3.7
Gastropoda										
Snails	9.8	3.2	7.2	7.9	7.2	6.7			7.7	6.0
Slug	1.2	0.3							0.3	0.1
Bivalvia	2.4	4.6	2.2	2.6					1.7	3.0
Crustacea										
Gammaridae	4.9	34.6	2.2	7.9					2.3	16.6
Euphausiidae			0.7	1.0	1.4	3.0			0.7	0.9
Galatheidae (**Aegla** sp.)	3.7	0.8	5.0	2.2	11.6	13.4	11.1	16.7	6.4	3.4
Macrura			0.7	0.2			11.1	8.3	0.7	0.2
Grapsidae	2.4	0.8	3.6	1.4	2.9	8.2			3.0	2.1
Brachyura (larvae)	1.2	1.4							0.3	0.5
Insecta										
Terrestrial insects	3.7	1.1	5.0	5.1	2.9	3.0			4.0	3.3

TABLA 3. (continuación)

PREY ITEM	Oc	Nº	Oc	Nº	Oc	Nº	Oc	Nº	Oc	Nº
Aquatic insects	2.4	4.3			1.4	2.2			1.0	1.9
Cyclostoma										
Geotria australis										
Pisces										
Sprattus fuegensis	18.3	21.4	2.9	1.8	1.4	0.7			6.7	8.8
(Oncorhynchus gorbuscha)			(4)	(21)					(4)	(21)
(Oncorhynchus keta)	(73)	(425)							(73)	(425)
Aplochiton taeniatus			2.2	0.6	5.8	3.7			2.3	0.8
Galaxias maculatus			2.2	1.0	1.4	1.5			1.3	0.7
Macruronus magellanicus	1.2	0.3			13.0	17.9			3.3	2.5
Merluccius sp.					1.4	0.7			0.3	0.1
Austromenidia smitti	1.2	0.3	1.4	0.6	4.3	2.2			2.0	0.7
Normanichthys crockeri	3.7	4.6	6.5	10.6	14.5	14.2	11.1	25.0	7.7	9.0
Eleginops maclovinus	7.3	3.0	15.8	14.1	1.4	0.7	22.2	16.7	10.4	8.2
Notothenia tessellata			0.7	0.8					0.3	0.4
Stromateus stellata	1.2	0.3							0.3	0.1
Unidentified fishes	32.9	10.5	38.8	40.5	26.1	18.7	44.4	33.3	34.4	26.5
Total occurrence of preys	82		139		69		9		299	
Total number of prey items	17		18		17		5		25	
Total number of preys		370		491		134		12		1007
Number of preys per stomach		1.7		2.0		1.1		0.5		1.6