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ECOLOGICAL ASPECTS OF NEMATODE PARASITES OF INTRODUCED SALMONIDS FROM VALDIVIA RIVER BASIN, CHILE

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Between 1986 and 1987, 666 fishes distributed among the following species introduced in Chile, and from different sectors of the Valdivia river basin (39°30' – 40°00'S, 73°30' – 71°45'W), were examined: 348 Salmo trutta, *242* Salmo gairdneri, *24* Cyprinus carpio *and 52* Gambusia affinis holbrooki. *The presence of* Camallanus corderoi *and* Contracaecum *sp. in* S. gairdneri *and of* C. corderoi *in* S. trutta *is recorded in Chile for the first time.* Cyprinus carpio *and* G. a. holbrooki *did not present infections by nematodes.*

The prevalence and mean intensity of the infections by nematodes presented significant differences among some sectors of the Valdivia river basin. In general, the prevalence and intensity of the infections by C. corderoi *were greater than those by* Contracaecum *sp. The infections in* S. gairdneri *were higher than in* S. trutta.

The sex of the hosts had no influence on the prevalence and intensity of the infections by both nematodes. The length of the hosts did have an influence, except in the case of the infections by Contracaecum *sp. in* S. gairdneri. *The infrapopulations of both nematode species showed overdispersion in most cases. The diet of the examined salmonids suggests that they would become infected principally through the consumption of autochthonous fishes.*

Key words: parasitism – Nematoda – *Camallanus corderoi* – *Contracaecum* sp. – salmonids – freshwater ecosystems – Chile

Research carried out on parasitic nematodes of introduced fishes in Chile is limited to the data on infections by *Contracaecum* sp. in *Salmo trutta* (L.) and *Oncorhynchus kisutch* Walbaum (Torres & Cubillos, 1987; Torres, 1990) and *Camallanus* sp. in *O. kisutch* (Torres, 1990). The importance of parasitological research on the fishes introduced in Chile, particularly salmonids, lies in the harm that may be caused to these hosts since they are feasible to be exploited through sport fishing, promotion of tourism or development of fish hatcheries.

The present research work refers to data on prevalence and intensity of the infections by nematodes in introduced fishes of the Valdivia river basin (39°30' – 40°00'S, 73°30' – 71°45'W), the degree of aggregation of the infrapopulations and the influence of factors of the host on parasitism.

MATERIALS AND METHODS

Between 1986 and 1987, a total of 666 fishes were examined for nematode parasites. These were distributed among the following introduced species: 348 *S. trutta*, 242 *Salmo gairdneri* Richardson, 24 *Cyprinus carpio* (L.) and 52 *Gambusia affinis holbrooki* Girard. The fishes were caught by means of nets and/or electric fishing in different sectors of the Valdivia river basin (Figure, Table I) and in different periods: summer (21 Dec. – 20 Mar.), autumn (21 Mar. – 20 Jun.), winter (21 Jun. – 20 Sep.) and spring (21 Sep. – 20 Dec.) (Table I).

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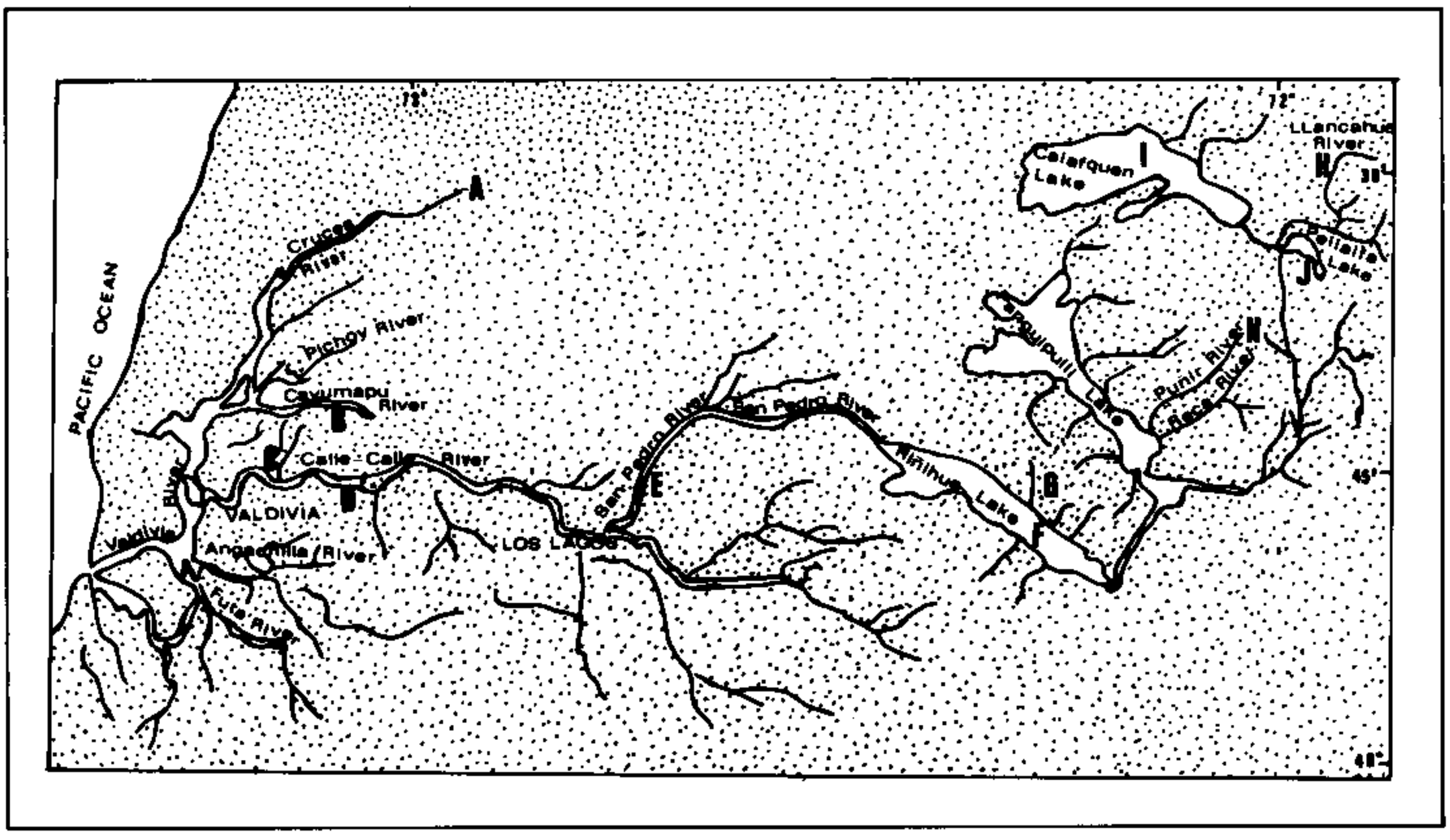

Sampling sectors of introduced fishes from Valdivia River Basin, Chile. A: Dollinco Stream. B: Cayumapu River. C: Santa Elvira Stream. D: Calle-Calle River. E: San Pedro River. F: Riñihue Lake. G: Riñihue Streams. H: Reca, Puñir and Llancahue Rivers. I: Calafquén Lake. J: Pellaifa Lake.

TABLE I

Characteristic of hosts and prevalence, mean intensity and variance/abundance of *Camallanus corderoi* and *Contracaecum* sp. in introduced salmonids from different sectors of Valdivia River Basin

Sector[a]	Fishes						*C. corderoi*[e]			*Contracaecum* sp.[e]		
	Species	Examined/ seasons[b]	Standard lenght[c]	Sex[d] F	M	ND.	P	I	S/A	P	I	S^2/A
Dollinco (S)	*S. gairdneri*	1/A	35	1	0	0		f			*f*	
	S. trutta	60/Su-A-W-S	17.5 ± 6.3	33	12	15	3.3	1.5 (1-2)	1.6		*f*	
Cayumapu (S)	*S. trutta*	8/0	13.4 ± 5.7	4	0	4		f			*f*	
Sta. Elvira (S)	*S. gairdneri*	1/S	30.5	0	1	0		f		100	34 (34)	
	S. trutta	61/S-A	11.5 ± 5.2	33	6	22	4.9	14 (11-18)	14.2	3.3	16 (13-19)	16.3
Calle-Calle (R)	*S. gairdneri*	11/A-W	19.8 ± 6.8	9	1	1	18.2	7.5 (1-14)	12.9	18.2	3.0 (1-5)	4.2
	S. trutta	76/Su-A-W-S	12.8 ± 5.4	33	17	26	9.2	4.9 (1-12)	7.3	1.3	13 (13)	13.0
San Pedro (R)	*S. gairdneri*	18/SU-W	16.5 ± 7.8	5	4	9		f			*f*	
	S. trutta	69/Su-A-W-S	13.2 ± 5.5	39	7	23		f			*f*	
Riñihue (L)	*S. gairdneri*	89/Su-A-W-S	28.5 ± 8.7	70	12	7	36.0	6.5 (1-37)	12.9	2.3	1.5 (1-2)	0.2
	S. trutta	8/Su-A-W	20.4 ± 19.5	4	0	4	12.5	33 (33)	33.0		*f*	
Riñihue (S)	*S. gairdneri*	40/Su-A-W-S	10.1 ± 4.8	17	7	16	2.5	2.0 (2.)	2.0		*f*	
	S. trutta	39/Su-A-W-S	12.9 ± 6.3	18	11	10	5.1	3.5 (1-6)	5.2		*f*	
Reca, Puñir and Llancahue (R)	*S. gairdneri*	56/A-W-S	25.7 ± 10.8	31	13	12	8.9	7.2 (1-14)	11.5	1.8	1 (1)	1.0
	S. trutta	27/A-W	14.1 ± 5.3	11	6	10	3.7	5.0 (5.0)	5.0		*f*	
Calafquén (L)	*S. gairdneri*	23/A	27.0 ± 6.3	11	10	2	43.5	18.7 (3-74)	32.1	8.7	1 (1)	1.0
Pellaifa (L)	*S. gairdneri*	3/A	41.3 ± 2.9	3	0	0	100	3.0 (2-4)	0.33		*f*	

a: S = stream; R = river; L = lake. *b:* Su = summer; A = autumm; W = winter; S = spring. *c:* Mean ± standard deviation. *d:* M = males; F = females. ND: not determined. *e:* prevalence. I: mean intensity (range). S^2/A: variance/abundance. *f:* not present.

The dead fishes were preserved at $-4\,^{o}C$ until their parasitological examination within 48 h. The fishes caught alive were kept in aquariums until their necropsy. In each fish, sex and standard length were determined, and stomach, intestine, liver, gonads, spleen, brain, gas bladder, eyes, peritoneum and corporal musculature were examined. Isolation, fixation and study of the nematodes were carried out by means of conventional methodology (Bylund et al., 1980; Torres & Cubillos, 1987).

The analyses of prevalence and mean intensity respectively were made with the proportion equality test (Domenech, 1980) and the Mann Whitney U test (Siegel, 1972). Analysis of the mean intensity in sectors with low frequency of parasites per host was not carried out, to avoid error type II. A significance level of 5% was used in all the analyses. The terms prevalence, mean intensity, abundance and infrapopulation were applied as proposed by Margolis et al. (1982). The ratio variance/abundance (Scott, 1987) was used as a measure of the degree of aggregation or overdispersion of the nematode infrapopulations in their hosts.

RESULTS

In *S. trutta* and *S. gairdneri,* adults and larvae of *Camallanus corderoi* Torres, Teuber & Miranda, were found in the intestine, and larvae of *Contracaecum* sp. were found in the peritoneum and/or intestinal wall. For the first time, *C. corderoi* was recorded in both salmonid species and *Contracaecum* sp. in *S. gairdneri* from Chile. Infection by nematodes was not present in *C. carpio* specimens collected in the summer period in Lake Riñihue (n = 7; standard length: 33.8 ± 4.6 cm) and in the Cayumapu river (n = 17; standard length: 31.9 ± 4.6 cm), neither in the *G. a. holbrooki* specimens caught in the latter sector in summer-winter (n = 52; standard length; 2.4 ± 0.9 cm).

Prevalence of the infections. The prevalence of *C. corderoi* was greater in the *S. gairdneri* specimens collected in the different lakes and in the Calle-Calle river (Table I). The prevalence of the infections in the fishes of the streams of Lake Riñihue and of the Reca, Puñir and Llancahue rivers (the data of the fishes of these three rivers are presented as a whole for they exhibit characteristics of a biotope of rithrom) showed significant differences with respect a those of the hosts of the three sampled lakes, where they were greater (Tables I, II). However, the prevalence of *C. corderoi* in *S. gairdneri* of the Calle-Calle river only showed significant differences with that of the fishes of Lake Pellaifa (Tables I, II).

The prevalence of *C. corderoi* in *S. trutta* was lower than that observed in *S. gairdneri,* and no significant differences were found between the different sampled sectors (Tables I, II).

Gravid females of *C. corderoi,* provided with first-stage larvae, were found only in the fishes of Lake Calafquén. In the other cases, female worms presented only occasionally a scarce quantity of eggs.

Infection by *Contracaecum* sp. in salmonids was evident in few sectors compared to *C. corderoi* (Table I).

Intensity of the infections – The greatest mean intensity of *C. corderoi* was observed in *S. gairdneri,* in Lake Calafquén (Table I). The statistical analysis was only possible for the intensities of *C. corderoi* in *S. gairdneri* of three sectors, and significant differences were only observed in the infections of the fishes of Lake Calafquén with respect to Lake Riñihue ($Z = -3.25$; $P < 0.01$) and the Reca, Puñir and Llancahue ($Z = -3.47$; $P < 0.01$).

In general, the intensity of the infections by *Contracaecum* sp. in *Salmo* spp. was lower than by *C. corderoi* (Table I). However, a high intensity was observed in the few infected *S. trutta* specimens as well as in the *S. gairdneri* specimens of the Santa Elvira stream (Table I). The intensity was found to be lower in the infected *S. gairdneri* specimens of Riñihue and Calafquén Lakes and of the Reca, Puñir and Llancahue rivers than in the above-mentioned sectors (Table I).

Variance/abundance ratio – The *C. corderoi* infrapopulations of *Salmo* spp. showed, in general, overdispersion in the different sectors sampled (Table I). There was a low dispersion in Lake Pellaifa, but the sample was scarce. The *Contracaecum* sp. infrapopulations of the fishes of the Santa Elvira stream and Calle-Calle river showed higher overdispersion (Table I).

Influence of sex and standard length of the hosts on parasitism – No influence of sex on

TABLE II

Z statistic for multicomparison of prevalence of *Camallanus corderoi* in introduced salmonids from different sectors of Valdivia River Basin

Sector[a] Host	Riñihue (S)	Riñihue (L)	Reca, Puñir and Llancahue (R)	Calle-Calle (R)	Santa Elvira (S)	Pellaifa (L)
Calafquén (L)						
S. gairdneri	– 4.23[b]	– 0.67 NS	– 3.38[b]	1.45 NS		– 1.84 NS
Dollinco (S)						
S. trutta	– 0.45 NS	– 1.24 NS	– 0.10 NS	– 1.34 NS	– 0.45 NS	
Riñihue (S)						
S. gairdneri		– 4.13[b]	– 1.3 NS	– 1.94 NS		– 3.36[b]
S. trutta		– 0.80 NS	– 0.28 NS	– 0.77 NS	0.045 NS	
Riñihue (L)						
S. gairdneri			3.04[b]	1.10 NS		– 2.21[c]
S. trutta			1.60 NS	0.66 NS	1.76 NS	
Reca, Puñir and Llancahur (R)						
S. gairdneri				– 0.91 NS		– 4.52[b]
S. trutta				– 0.90 NS	– 0.27 NS	
Calle-Calle (R)						
S. gairdneri						2.62[b]
S. trutta					1.00 NS	

a: L = lake; S = stream; R = river. Significant difference: *b* ($P < 0.01$); *c* ($P < 0.05$). NS: not significant ($P > 0.05$).

TABLE III

Prevalence, mean intensity and variance/abundance of *Camallanus corderoi* and *Contracaecum* sp. in introduced salmonids of different sexes

	Hosts			
	S. gairdneri		*S. trutta*	
	Females	Males	Females	Males
Examined fishes	147	48	175	59
Infected with				
C. corderoi	38	15	11	5
Contracaecum sp.	5	3	2	1
Prevalence (%)				
C. corderoi	25.9	31.3	6.3	8.5
Z value	– 0.77 (P >0.05)		– 0.58 (P >0.05)	
Contracaecum sp.	3.4	6.3	1.1	1.7
Z value	– 0.85 (P >0.05)		– 0.36 (P >0.05)	
Mean intensity				
C. corderoi	5.6	16.5	9.2	4.6
Z value	– 0.44 (P >0.05)		– 0.44 (P >0.55)	
Contracaecum sp.	1.8	12.3	13.0	19.0
Z value	ND		ND	
Variance/abundance				
C. corderoi	9.1	31.4	17.6	8.7
Contracaecum sp.	3.2	31.3	13.0	19.1

Not significant ($P > 0.05$). ND = not determined.

TABLE IV

Prevalence, mean intensity and variance/abundance of *Camallanus corderoi* and *Contracaecum* sp. in introduced salmonids of different lengths

	Host lengths (in cm)					
	S. gairdneri			*S. trutta*		
	< 15	15-28	> 28	< 15	15-28	> 28
Examined fishes	68	78	96	225	111	12
Infected with						
C. corderoi	3	12	38	3	9	4
Contracaecum sp.	0	1	7	0	1	2
Prevalence (%)						
C. corderoi	4.4	15.4	39.6	1.3	8.1	33.3
Contracaecum sp.	0	1.3	7.3	0	0.9	16.7
Mean intensity						
C. corderoi	3.0	6.4	9.9	5.0	4.3	17.5
Contracaecum sp.	0	1.0	6.4	0	13.0	16.0
Variance/Abundance						
C. corderoi	2.3	12.8	23.0	7.3	6.9	18.9
Contracaecum sp.	0	1.0	26.3	0	12.7	15.1

TABLE V

Z statistic for multicomparison of the prevalence and mean intensity of the infections by *Camallanus corderoi* in hosts of different lengths

Lenght (cm)	15 – 28	> 28
< 15		
S. gairdneri		
Prevalence	– 2.20^a	– 5.17^b
Mean Intensity	– 2.80^b	– 5.20^b
S. trutta		
Prevalence	– 3.57^b	– 6.53^b
Mean Intensity	– 2.60^b	– 2.43^b
15 – 28		
S. gairdneri		
Prevalence		– 3.51^b
Mean Intensity		– 3.30^b
S. trutta		
Prevalence		– 3.50^b
Mean Intensity		– 0.73 NS

Significant differences: *a* ($P < 0.05$); *b* ($P < 0.01$). NS = not significant ($P > 0.05$).

the prevalence and mean intensity of the infections by *C. corderoi* and prevalence of *Contracaecum* sp. was observed in both salmonid species. The mean intensity of the infections by *Contracaecum* sp. was not analyzed, to avoid error type II (Table III).

The prevalence and intensity of the infections by *C. corderoi* showed significant differences, in general, among the different length intervals of *Salmo* spp., and their values increased with this variable (Tables IV, V). The prevalence of *Contracaecum* sp. also showed significant differences with respect to the length of *S. trutta* ($Z = -3.43$; $P < 0.01$) but not in *S. gairdneri* ($Z = -1.88$; $P > 0.05$). No analysis was carried out for the mean intensity of *Contracaecum* sp. (Table IV).

The infrapopulations of both nematodes showed overdispersion in males and females of the two host species (Table III) and it was higher in the fishes of greater length (Table IV).

Table VI outlines the prey consumed by the salmonids of the different sectors of the Valdivia river basin. The consumption of fishes by *S. gairdneri*, in most cases, was evident in specimens that were over 15 cm long. In *S. trutta*, the presence of fishes in the diet was found in specimens of different lengths, although the frequence and number of prey was greater in the fishes that were over 15 cm long (Table VI). The consumption of copepods was only observed in *S. gairdneri* of the Reca and Puñir rivers, probably because they returned from Lake Panguipulli, where these rivers flow into

TABLE VI

Diet of introduced salmonids of different lengths and sectors from Valdivia River Basin

Examined Fishes				Prey		
Species	Sector[a]	Total	Standard length	Total[d]	Fishes[e] (*Galaxias* spp. principally)	Other[e]
S. gairdneri						
Calle-Calle (R)	7	*b*	66	28.6/ND	100/100	(I, A, D)
San Pedro (R)	4	*c*	13	*f*	100/100	(G, I, A, D)
	4	*b*	22	25.0/4.5	100/95.5	(I, D)
Riñihue (S)	22	*c*	148	*f*	100/100	(O, G, I, D, Am)
	2	*b*	6	*f*	100/100	(I)
Riñihue (L)	5	*c*	33	40.0/30.3	80/69.7	(I)
	59	*b*	1765	33.9/14.5	100/85.5	(G, I, Ac, A, N)
Calafquén (L)	20	*b*	397	90.0/76.3	55/23.7	(I, A, D)
Reca, Puñir	12	*b*	199	41.6/43.2	58.3/55.3	(B, I, C, N)
Llancahue (R)	6	*c*	168	*f*	100/100	(G, I, Am)
S. trutta						
Dollinco (S)	4	*b*	345	25/ND	100/100	(O, I)
	32	*c*	2100	3.1/0.1	100/99.9	(O, G, I, D)
Santa Elvira (S)	38	*b*	460	10.5/1.3	100/98.7	(G, I, A, D, Am, N)
	15	*c*	302	6.7/0.3	100/99.7	(G, I, A, D, Am, N)
Calle-Calle (R)	12	*b*	81	16.7/2.5	100/97.5	(O, G, I, D)
	26	*c*	328	15.4/1.2	100/98.8	(O, G, B, I, A, D, Am, N)
San Pedro (R)	14	*b*	75	14.3/2.7	100/97.3	(G, I, A, D, N)
	25	*c*	136	4.0/0.7	100/99.3	(G, I, A, D, Am, N)
Riñihue (S)	13	*b*	90	*f*	100/100	(O, G, I, A, D, N)
	17	*c*	139	5.9/2.2	100/97.8	(O, G, I, Ac, A, D)
Riñihue (L)	1	*b*	5	*f*	100/100	(I)
	4	*c*	11	*f*	100/100	(I)
Reca, Puñir and	12	*b*	52	8.3/3.9	100/96.1	(I, D)
Llancahue	4	*c*	16	*f*	100/100	(G, I)

a: R = river; S = stream. L = lake. *b:* 15 or more cm *c:* < 15 cm. *d:* no. of prey in the total of fishes. *e:* fish percentages with prey/Prey percentages from total. Insecta (I). Araneae (A). Decapoda (D). Gastropoda (G). Oligochaeta (O). Amphipoda (Am). Acari (Ac). Nemata (N). Bivalvia (B). Copepoda (C). *f:* not present.

(Table VI). In general, the frequence and number of fishes in the diet of *S. gairdneri* were greater than those observed in *S. trutta* (Table VI). The other prey consumed by both salmonid species, in general, turned out to be similar (Table VI).

DISCUSSION

In Chile, the introduction of some fresh water fishes was started from Germany in 1875 for *C. carpio* and in 1905 for *S. gairdneri* and *S. trutta* (Golusda, 1927; Campos, 1970). *Gambusia affinis holbrooki* was introduced from the United States in 1927 (Campos, 1970). The differences observed in the prevalence and mean intensity of the infections by parasitic nematodes in the different sectors of the Valdivia river basin may be related with the abiotic characteristics of the biotopes and with the type of prey consumed by the salmonids.

Camallanus corderoi, described in *Percichthys trucha* (Cuvier & Valenciennes) (Torres et al., 1990), develops secondarily in the *Salmo* spp. that showed lower prevalences and mean intensities than those of the autochthonous host in the same biotopes of the Valdivia river basin.

As in *S. gairdneri* and *S. trutta*, in *P. trucha* it was also observed that the length of the hosts, but not the sex, has an influence on the prevalence and mean intensity of infection by *C. corderoi* (Torres et al., 1990). This situation has also been confirmed for *C. oxycephalus* Ward & Magath (Spall & Summerfelt, 1969; Stromberg & Crites, 1975; Amin, 1984) in the northern hemisphere.

Although the genus *Camallanus* includes about 56 species (Petter, 1979), only two, *C. tridentatus* (Drasche) and *C. corderoi*, have been described in South America (Travassos et al., 1928; Torres et al., 1990), and on their life cycles there is only information about *C. oxycephalus, C. lacustris* (Zoega) and *C. sweety* Moorthy (Chubb, 1982). There are also antecedents about the responsibility of some *Camallanus* species for severe harm and death to the fishes (Petter et al., 1974).

The prevalence and mean intensity of the infections by *Contracaecum* sp. in the examined salmonids was lower than that observed in *P. trucha* (Torres et al., 1990). The sex variable did not have an influence on the prevalence of the infections by *Contracaecum* sp. in *S. gairdneri* and *S. trutta* but the length of the host had an influence in *S. trutta* infection. Previously, a similar situation to *S. gairdneri* had been found in *P. trucha* for the infections by *Contracaecum* sp. (Torres et al., 1990).

The larvae of *Contracaecum* sp. have also been observed in *Galaxias platei* by Torres (1983). Furthermore, there are records of adults of *Contracaecum rudolphii* Hartwich and *Contracaecum* sp. in fish-eating birds of the same region (Torres et al., 1982, 1983) which probably correspond to the definitive hosts for the larval stages found in the fishes. Preliminary observations in natural infections of *S. trutta* suggest that the larvae of *Contracaecum* may be responsible for the harm in their hosts (Torres & Cubillos, 1987) especially in massive infections.

The variance/abundance ratio indicated overdispersion or aggregation of the *C. corderoi* infrapopulations, that is to say, most of the fishes were not infected or were infected with a small number of parasites, and only a few hosts showed a large number of them, a situation which derives from differences of age, behaviour, genetic susceptibility to infection and other factors (Scott, 1987). In the infections by *Contracaecum* sp., in some sectors, overdispersion was observed, and in others, the degree of aggregation was low.

According to the diet of the examined salmonids, it can be concluded that their infection apparently does not occur habitually through the consumption of copepods. Although copepods were not present in most of the fishes, they constitute the habitual intermediary hosts of *Camallanus* spp. (Chubb, 1982) and of *Contracaecum* spp. (Barus et al., 1978) with known life cycles.

Moravec (1971) observed that the fourth-stage larvae and the adults of *C. lacustris* may be transferred by predation among different fish species. Since introduced salmonids often consume other planktophagous fishes of their surroundings (especially *Galaxias* spp.), which are also hosts of *C. corderoi* and *Contracaecum* sp. (Covarrubias, 1989), this infection mechanism can be suggested for salmonids. This would also explain the higher prevalences and intensities of infection by *C. corderoi* and *Contracaecum* sp. in the salmonids of greater length, which presented a larger number of fish prey in their diet.

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