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Metazoan parasites of whitefish *Coregonus clupeaformis* (Mitchill) and cisco *C. artedii* Lesueur from Southern Indian Lake, Manitoba

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Metazoan parasites of whitefish *Coregonus clupeaformis* and cisco *C. artedii* from Southern Indian Lake, Manitoba were studied to reveal: species composition, differences with host age, sex, and location and season of capture. Whitefish hosted 19 species, 18 of which were also in cisco with generally lower intensity levels. Parasites exhibited definite patterns of abundance with host age and season, the primary causes being dietary and behavioural. No differences in parasite abundance existed between host sexes. Ranking of cisco parasites was significantly different between two sampling sites while whitefish parasites did not differ. Whitefish and cisco from sites 40 miles (64 km) apart had significantly different abundances of *Tetracotyle intermedia* but not *Triaenophorus crassus.* An increase in the abundance of copepod-vectored cestodes with a concomitant decrease in abundance of amphipod-vectored parasites is predicted after flooding and diversion.

I. INTRODUCTION

The parasite fauna of fishes of the large shallow northern lakes of Canada have received little attention, although many of these are fished commercially. Plans exist to impound many of these lakes but the effects on the parasitofauna of indigenous fish species are largely unknown. Smirnova (1955) and others have studied the effects of Soviet lakes but extrapolation may be unwise except in the most general terms.

In an effort to document the effects of lake impoundment and current diversion on fish parasites, background data was collected on several fish hosts including whitefish *Coregonus clupeaformis* and cisco *C. artedii,* from a range of host ages, seasons and sampling sites at Southern Indian Lake. Based on our findings, the expected consequences of the ecological changes on the parasitofauna of whitefish and cisco were predicted.

II. MATERIALS AND METHODS

Southern Indian Lake (SIL) is a large (surface area, 2250 km), shallow (mean depth, 9·2 m) riverine lake located north-west of Thompson, Manitoba (Fig. 1). With a maximum length of 140 km and maximum width of 30 km, it is the largest lake on the Churchill River System (Hecky, Harper & Kling, 1974). During the ice free period, from late May (mid-June in the extreme north) to early October, the lake remains isothermal and well oxygenated. Hecky (1975) described the morphometry and chemistry of the Southern Indian Lake in detail.

Fish species included the lake whitefish, cisco, northern pike *Esox lucius,* yellow walleye *Stizostededion vitreum,* sauger *S. canadense,* yellow perch *Perca flavescens,* goldeye *Hiodon alosoides,* burbot *Lota lota,* two suckers and several cyprinids (Ayles & Koshinsky, 1974).

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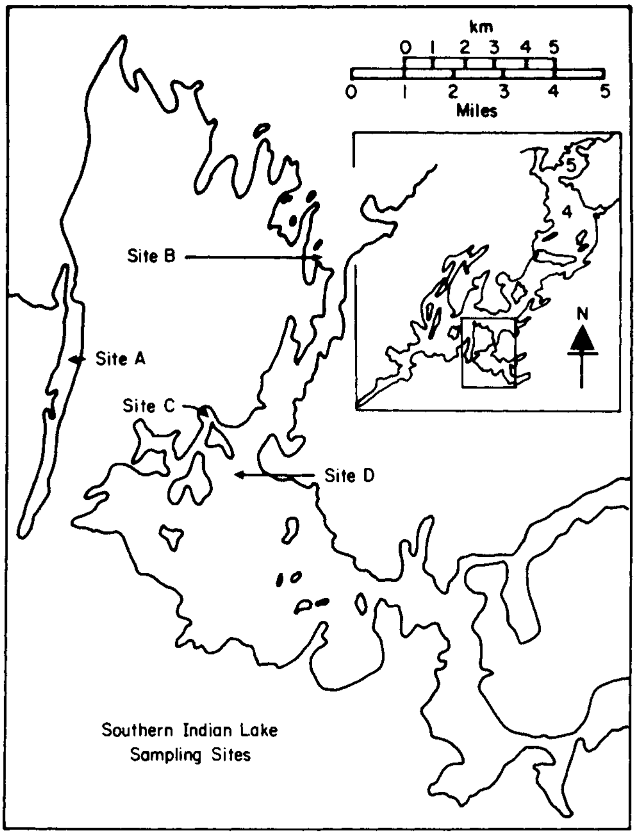

FIG. 1. Map of the southern portion of Southern Indian Lake showing sampling sites. Inset shows location of sites 4 and 5 at the north end of the lake.

Whitefish and cisco were collected from June 1975 through September 1976 using gill-nets (10–133 mm mesh). Fish were collected from each site (Fig. 1), once weekly from late May to mid-September 1976. Samples were also collected from areas 4 and 5 in June, July and August 1975 and from area 4, August 1976. Fish were necropsied within 4 h of collection except some winter samples which were frozen and autopsied later. Round weight, fork length, sex and maturity were determined. Scale and pelvic fin rays were taken for aging. All external and internal parasites were collected, counted, treated and identified according to standard parasitological techniques. Stomach contents were also collected and identified. Kendall's rank correlation coefficient (Siegel, 1956) was used to test sampling site differences in parasite abundance. Cox and Stuart test was used to test abundance trends with host age (Conover, 1971). The level of significance used in statistical testing was $P < 0{\cdot}05$.

TABLE I. Age distribution of samples

	Scale Age									
	0	1	2	3	4	5	6	7	8	9
No. of whitefish	27	47	12	25	52	53	64	78	65	93*
No. of cisco	33	69	24	60	65	63	49	40†		

* 9 years and older
† 7 years and older

TABLE II. Seasonal distribution of samples

	Winter	Spring	Summer	Autumn
No. of whitefish	11	189	340	30
No. of cisco	16	143	287	—

Throughout this text the term abundance of a parasite (population size) is calculated as the product of prevalence (percentage of fish infected) and intensity (mean number per infected fish). Dominance is the abundance of a parasite expressed as a percentage of the total abundance of all parasites. Those fish described as one-year old had survived one summer and so forth. Age distribution of samples appears in Table I. Seasonal distribution of samples appears in Table II. Seasons were defined as: winter (January–April), spring (May–June), summer (July–September), and autumn (October–December).

III. RESULTS

PARASITE FAUNA

In total, 570 whitefish and 446 cisco were autopsied to reveal all metazoan parasites, and an additional 985 and 756 respectively were examined for plerocercoids of *T. crassus.* These yielded 19 species of whitefish parasites and 18 from cisco, listed in order of prevalence in whitefish in Table III.

Based on abundance, the parasite fauna of cisco had a 39% index of similarity with that of whitefish. Generally, intensity of infection was less than in whitefish (Table III). *Cystidicola farionis* was absent from cisco, but present in 33·2% of whitefish.

HOST AGE

Study of parasite abundance in whitefish and cisco of different ages revealed four basic patterns (Table IV). Abundance of some parasites remained constant with host age once the parasite was established, whereas some increased or decreased. Others peaked at specific host age(s).

SEASON

As collection of data for comparative purposes cannot always be made at the same time of year, it is important to study how parasite abundance varies with season. Parasites of whitefish and cisco were grouped by their season of maximum abundance (Table V).

SEX

No differences were observed in the abundance of any parasite in whitefish or cisco of different sexes.

SAMPLING SITES

The ranking of parasite abundance at sampling sites was compared to test for differences and therefore the effectiveness of using sampling sites to represent large areas of the lake. Ranking of whitefish parasite abundance at each of the four sampling locations during 1976, revealed no significant differences but ranking of cisco parasites was significantly different between sites A and B ($\tau = 0{\cdot}43$).

TABLE III. Whitefish (W) and cisco (C) parasites

Parasite	Prevalence W	Prevalence C	Intensity W	Intensity C	Abundance W	Abundance C	Dominance W	Dominance C
*_Tetracotyle intermedia_ Hughes, 1928	75·5	29·1	37·74	5·53	28·50	1·61	38·96	4·11
Proteocephalus exiguus LaRue, 1911	75·2	34·2	22·63	— 36·65	17·02	12·53	23·27	32·00
Proteocephalus filicollis (Rudolphi, 1802)	—	51·2	—	—	—	18·76	—	47·91
*_Diplostomum spathaceum_ (Rudolphi, 1819)	56·7	26·1	13·29	8·14	7·53	2·13	10·29	5·44
*_Triaenophorus crassus_ Forel, 1768	49·7	63·5	2·27	2·19	1·12	1·39	1·53	3·55
Metechinorhynchus salmonis O. F. Muller, 1780	37·6	6·7	12·72	2·57	4·79	0·17	6·55	0·43
Cystidicola farionis Fischer, 1798	33·2	—	6·19	—	2·06	—	2·82	—
Discocotyle sagittata (Leuckart, 1842)	29·1	11·9	2·16	2·00	0·63	0·24	0·86	0·61
†_Raphidascaris_ sp.	23·0	14·3	3·63	2·58	0·84	0·37	1·15	0·94
Cyathocephalus truncatus (Pallas, 1781)	21·8	2·7	30·09	4·00	6·56	0·11	8·97	0·28
Crepidostomum farionis (O. F. Muller, 1784)	14·4	0·2	17·02	2·50	2·46	0·00	3·36	0·01
Ergasilus nerkae Roberts, 1963	14·2	20·9	5·58	4·98	0·79	1·04	1·08	2·66
Salmincola extumescens (Gadd, 1901)	14·0	—	1·18	—	0·16	—	0·22	—
Salmincola extensus (Kessler, 1869)	4·0	0·9	1·30	1·00	0·05	0·01	0·07	0·03
Argulus canadensis Wilson, 1916	3·5	3·1	1·60	2·36	0·06	0·07	0·08	0·18
*_Spinitectus gracilis_ Ward & Magath, 1916	3·0	6·8	19·00	10·22	0·57	0·69	0·78	1·76
Piscicola milneri (Verrill, 1874)	0·07	0·4	1·00	1·00	0·01	0·00	0·01	0·01
*_Diphyllobothrium_ sp.	0·2	0·7	1·00	1·00	0·00	0·01	—	0·03
Neoechinorhynchus cylindratum Van Cleave, 1913	0·0	—	2·25	—	0·00	—	—	—
Pomphorhynchus bulbocolli Van Cleave, 1919	0·0	0·0	1·00	1·00	—	0·00	—	—
Contracaecum brachyurum Ward & Magath, 1917	—	1·1	—	2·80	—	0·03	—	0·08
					73·15	39·16		

*Larval forms
†Larval forms in whitefish only

Abundance of *T. intermedia* and *T. crassus*, in whitefish and cisco, was measured for two areas (4 and 5), some forty miles north of the four sampling sites. Abundance of *T. crassus* in both species was comparable between the northern and southern sites. *T. intermedia* abundance, though comparable in cisco, was significantly higher in the northern sites in whitefish.

TABLE IV. Patterns of major parasite abundance with host age using the Cox and Stuart Test for Trend

Pattern	Whitefish	Cisco
Independent Once Established	**Triaenophorus crassus*	
	Discocotyle sagittata	
Increase	**Tetracotyle intermedia*	**Tetracotyle intermedia*
	**Diplostomum spathaceum*	**Diplostomum spathaceum*
	Metechinorhynchus salmonis	**Triaenophorus crassus*
	Cyathocephalus truncatus	*Raphidascaris* sp.
	Cystidicola farionis	*Proteocephalus filicollis/exiguus*
	**Raphidascaris* sp.	
	Crepidostomum farionis	
	Salmincola extumescens	
	Proteocephalus exiguus	
Decrease	*Ergasilus nerkae*	
Peaked		*Discocotyle sagittata* (@5 yr)
		Ergasilus nerkae (@3 yr)

*Larval forms

TABLE V. Patterns of major parasite abundance with season

Peak season	*Whitefish*	Cisco
Winter (Jan.–Apr.)	*Cystidicola farionis*	*Raphidascaris* sp.
	**Tetracotyle intermedia*	**Tetracotyle intermedia*
	Proteocephalus exiguus	*Proteocephalus filicollis/exiguus*
Spring (May–June)	*Crepidostomum farionis*	
	**Triaenophorus crassus*	
Summer (July–Sept.)	*Discocotyle sagittata*	*Discocotyle sagittata*
	**Diplostomum spathaceum*	**Diplostomum spathaceum*
		**Triaenophorus crassus*
Autumn (Oct.–Dec.)	**Raphidascaris* sp.	*Ergasilus nerkae*
	Metechinorhynchus salmonis	
	Cyathocephalus truncatus	

*Larval forms

IV. DISCUSSION

PARASITE FAUNA

The order of importance of the parasite groups based on abundance in Southern Indian Lake whitefish was: metacercariae (*T. intermedia* and *D. spathaceum*), copepod-vectored cestodes (*Proteocephalus* spp.) and finally amphipod-vectored parasites (*Cy. farionis, M. salmonis* and *C. truncatus*). In cisco the order was: copepod-vectored cestodes, metacercariae, and amphipod-vectored parasites. This order can be explained by host diet and density of intermediate hosts. In the areas sampled, amphipod populations were relatively low compared to gastropod and pelycopod (sphaerid) levels (Hamilton, 1974). As molluscs serve as intermediate hosts for metacercaria infections of whitefish, their density could be expected to be reflected by the prominance of these parasites. Although zooplankton were common in the study area (Patalas & Salki, 1974), they formed less than 15% of recognizable whitefish food while forming on average twice this amount in cisco. A heavy copepod diet is the major explanation for the importance of copepod-vectored cestodes in cisco. Amphipods formed less than 3% of cisco food and hence the low importance of amphipod-vectored parasites in cisco.

Only a few studies on whitefish and cisco parasites gave sufficient information to allow calculation of abundance values for a comparison of parasite importances. Dechtiar (1972), Leong (1975) and Bauer & Nikol'skaya (1957) using abundance values found amphipod-vectored parasites predominate. Hicks & Threlfall (1973) found the same order of importance in Labrador whitefish as the present study suggesting the more northerly lakes may be similar in this regard.

Dechtiar (1972) found copepod-vectored, amphipod-vectored, then metacercariae as the order of cisco parasite groups based on their abundance values. Dechtiar (1972) found *Cystidicola stigmatura* (*C. farionis*) in cisco, suggesting that different amphipod hosts were utilized for food compared to Southern Indian Lake, where whitefish, but not cisco were infected.

HOST AGE

Parasites of whitefish and cisco showed patterns of abundance with host age. These were related to changes in host diet, distribution and physical size with advancing host age. Cisco gill parasites, *D. sagittata* and *E. nerkae* increased in abundance with host age until gill size and ventilation current surpassed their adaptive abilities. *E. nerkae* has exhibited a peaked abundance pattern on spotted *Micropterus punctulatus* and largemouth bass *M. salmoides* (Cloutman & Becker, 1977). These authors suggested that as fish size increased, the probability of encounter increased until an as yet unproven physiological resistance develops. Leong (1975) found that while *Ergasilus auritus* peaked in abundance in cisco 3–4 years old, *E. nerkae* declined with host age.

The majority of Southern Indian Lake coregonid parasites increased in abundance with host age, either through the continued diet of infected intermediate hosts or continued exposure to motile larval stages. *M. salmonis* and *Cy. farionis* were examples of the former, while digeneans, *T. intermedia* and *D. spathaceum* were examples of the latter. Significantly more whitefish with benthic stomach contents (amphipods, gastropods etc.) were infected with *D. spathaceum* suggesting exposure may be greatest near the bottom. Bauer & Nikol'skaya (1957) found *T. intermedia* abundance increased with *Coregonus laveratus* age and attributed this to exposure time. Amphipod-vectored parasites, *Cy. farionis, C. truncatus* and *M. salmonis,* continued to increase in abundance as did the amphipod portion of the whitefish diet (0–18% during lifespan). The latter two parasites also benefited from increasing caecal size (Leong, 1975). Similarly, Southern Indian Lake cisco accumulate *T. crassus* plerocercoids and *Proteocephalus* as a result of their continued planktonic feeding. Petersson (1971) found coregonids which maintained a copepod diet accumulated *T. crassus* plerocercoids. Benthic feeding in adult whitefish explains the accumulation of *Raphidascaris* sp. larvae. Cisco diet became significantly more piscivorous with age and cisco accumulated the mature nematodes. The insect portion of whitefish diet did not change with age but the copepod portion was reduced. Thus diet may explain the continued accumulation of *Cr. farionis* vectored by mayfly nyaids but not the copepod-vectored *P. exiguus.*

Ergasilus nerkae declined in abundance with whitefish age as it did in whitefish and cisco in Cold Lake (Leong 1975). Increasing gill diameter and gill ventilation, changes of feeding mode (pelagic to benthic) (Leong, 1975) as well as increasing physiological resistance (Cloutman & Becker, 1977) have been suggested as causes.

Abundances of *T. crassus* and *D. sagittata* were independent of whitefish age once established. Constant levels of *T. crassus* could be related to an increase in gill-raker spacing in older whitefish (Petersson, 1971) coupled with persistance of plerocercoids for 3 to 4 years as suggested by Miller (1952). Constant abundance levels of *D. sagittata* may be attributed to a lifespan of several years as reported by Paling (1965) on brown trout.

SEASON

Amphipod-vectored parasites, *M. salmonis, C. truncatus* and *Cr. farionis* had similar patterns of seasonal abundance in Southern Indian Lake whitefish. The former two peaked in late autumn and the latter in early winter (Table V). Water temperature controlled their life cycles by affecting the development of amphipod intermediate hosts. Tedla & Fernando (1970) found amphipod abundances were temperature controlled and peaked in late summer and autumn. Parasites were infective by late autumn to early winter (Awachie, 1966). Amphipod *Pontoporeia affinis* was a prominant whitefish food item during these months and cooling temperatures may have lowered host resistance (Leong, 1975).

Digenean *Cr. farionis* peaked in abundance in the whitefish in spring. Large amounts of *Gammarus* sp. (intermediate host) were found in whitefish stomachs during this time suggesting diet controlled the seasonal abundance cycle.

D. sagittata peaked in summer on the whitefish and cisco. Winter mortality may have been a major factor. Paling (1965) observed high winter mortality of *D. sagittata.* This also explains the autumnal peak of *Ergasilus* observed on Southern Indian Lake cisco gills.

Proteocephalus spp. abundance peaked in the whitefish and cisco during spring. This was related to the cestode's life cycle. In early spring, mature gravid Proteocephalus were lost but were replaced in late spring by large numbers of immature Proteocephalus. A copepod dominated diet allowed reinfection. Bauer & Nikol'skaya (1957) suggested fluctuations in ingestion rates of copepods controlled abundance patterns.

SAMPLING SITES

Although much research has been done on the separation of marine fish stocks using parasite indicators, little work has been done with freshwater species. Our data showed differences in the ranking of the parasite fauna of cisco at sites A and B resulted from the greater abundance of *E. nerkae* at site A. Perhaps, lack of current at site A accounted for some of this difference. Cisco sampled at site A were younger than at site B, and as *E. nerkae* decreased in abundance with host age, this explains most of the difference. Though some parasites, such as *T. crassus* from whitefish and cisco, have similar abundance values in widely separated parts of Southern Indian Lake abundance of other parasites, like *T. intermedia* in whitefish, were more representative of a smaller area. Differences resulted from an unequal distribution of intermediate hosts for some parasites (such as gastropods and amphipods), and not others (copepods), and/or the relative abundance of host fish species. Although not a complete comparison of these two widely separated parts of Southern Indian Lake, it does draw attention to the danger of generalizing from sampling sites to an entire lake. In other systems Oakland (1949) and Sunde (1963) found differing levels of *T. crassus* infections in areas separated by less than 13 and 3 km respectively.

No differences were observed in abundance of *T. crassus* plerocercoids in Southern Indian Lake whitefish or cisco with depth, although these have been reported by Miller (1952). This may have resulted from homogeneity in the depth of catch samples (most made between 3 and 9 m).

FUTURE CHANGES

Based on the composition of the parasitofauna of whitefish and cisco in Southern Indian Lake the following predictions can be made of changes due to diversion and impoundment. If, as predicted by Hamilton (1974), benthic populations (amphipods) decrease, then whitefish and cisco will be forced to feed to a greater extent on cestode-vectoring copepods. Cestodes such as *T. crassus* and *Proteocephalus* spp. will increase in abundance while amphipod-vectored parasites (*M. salmonis, C. truncatus* and *Cy. farionis*) will decline. Petersson (1971) found these effects in impounded Swedish lakes.

Impoundment will cause dilution of fish and intermediate hosts causing an immediate though possibly temporary reduction in parasite numbers. Thereafter, the lasting effects on parasite numbers will depend on the effect of habitat changes on intermediate host numbers and the timing and degree of contact between infected and noninfected hosts.

Lubinsky (1973) reported that Smirnova (1955) and other Russian authors found that flooding and subsequent dilution of fish stocks caused a reduction in abundance of parasitic protozoa, monogenetic trematodes and parasitic copepods, as the chance of contact with their appropriate hosts declined. This was followed by a period of rapid increase when parasite numbers exceeded original levels. Smirnova (1955) and other authors have reported pathogenic effects on fish as a result. They found that parasites such as digenetic trematodes and cestodes increased or decreased in abundance with their invertebrate hosts, and were often slow to return to original levels.

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References

Awachie, J. B. E. (1966). Observations on *Cyathocephalus truncatus*. Pallas, 1781 (Cestoda: Spathebothriidea) in its intermediate and definitive hosts in a trout stream, North Wales. *J. Helminthol.* **40**, 1–10.

Ayles, H. & Koshinsky, G. D. (1974). The fisheries of Southern Indian Lake: present conditions and implications of hydroelectric development. Can.-Manitoba, Lake Winnipeg, Churchill and Nelson Rivers Study. *Envir. Can., Fish. Service, Wpg., Man.* 104 pp.

Bauer, O. H. & Nikol'skaya, N. P. (1957). Dynamics of the parasitofauna of the whitefish *Coregonus lavaretus* from Lake Ladoga and its epizootic importance. In parasites and diseases of fish. Edited by G. K. Petruchevski. *Bull. State Sci. Res. Inst. Lake, River Fish* **XLII**, 224–238.

Cloutman, D. G. & Becker, D. A. (1977). Some ecological aspects of *Ergasilus centarchidarum* Wright (Crustacea: copepoda) on largemouth and spotted bass in Lake Fort Smith, Arkansas. *J. Parasitol.* **63**, 372–376.

Conover, W. J. (1971). *Practical Nonparametric Statistics.* New York: John Wiley & Sons Ltd.

Dechtiar, A. O. (1972). Parasites of fish from Lake of the Woods, Ontario. *J. Fish. Res. Bd Can.* **29**, 275–283.

Hamilton, A. E. (1974). Zoobenthos survey of Southern Indian Lake. Can.-Manitoba, Lake Winnipeg, Churchill and Nelson Rivers Study. *Envir. Can., Fish. Service, Wpg., Man.* 30 pp.

Hecky, R. (1975). The phytoplankton and primary productivity of Southern Indian Lake (Manitoba) a high latitude, riverine lake. *Verh. Internat. Verein. Limnol.* **19**, 599–605.

Hecky, R., Harper, R., & Kling, H. (1974). Phytoplankton and primary production in Southern Indian Lake. Can.-Manitoba, Lake Winnipeg, Churchill and Nelson Rivers Study. *Envir. Can., Fish. Service, Wpg., Man. Append.* **4**, 11–51.

Hicks, F. J. & Threlfall, W. (1973). Metazoan parasites of salmonids and coregonids from coastal Labrador. *J. Fish Biol.* **5**, 399–415.

Leong, R. T. S. (1975). Macroparasites of fishes of Cold Lake, Alberta: a community analysis. Ph.D. Thesis, Univ. Alberta, Edmonton.

Lubinsky, G. (1973). Parasites of fishes and man-made lakes of the U.S.S.R. Unpub., Univ. Manitoba, 17 pp.

Miller, R. B. (1952). A review of the *Triaenophorus* problem in Canadian lakes. *Bull. Fish. Res. Bd Can.* **95**.

Oakland, G. B. (1949). Statistical studies of whitefish infestation. *Fish. Res. Bd Can., Rep. Centr. Fish. Res. Sta., Wpg., Man.* Append. 9.

Paling, J. E. (1965). The population dynamics of the monogenean gill parasite *Discocotyle sagittata* Leukart on Windermere trout, *Salmo trutta* L. *Parasitol.* **55**, 667–694.

Patalas, C. & Salki, A. (1974). Zooplankton study in Southern Indian Lake. Can.-Manitoba, Lake Winnipeg, Churchill and Nelson Rivers Study. Bd Rep., *Tech. Rep.*, Append. 5, I, 11 pp.

Petersson, Å. (1971). The effects of lake regulation on populations of cestodan parasites of Swedish whitefish Coregonus. *Orkos* **22**, 74–83.

Siegel, S. (1956). *Nonparametric Statistics for the Behavioural Sciences.* Toronto: McGraw Hill Book Co. Inc.

Smirnova, K. V. (1955). Fauna of parasites of fishes of the Tsimbansk and Manyck water reservoirs. Tezesy dokladov. 8 go soveshschani po parasitologischeskim prlblemam. *Izdat. Akad. Nauk. S.S.S.R.*

Sunde, L. A. (1963). South Indian whitefish infestation test (March 5–7, 1963). Dept. Mines Nat. Resources, Fish. Branch, Prov. Man.

Tedla, S. & Fernando, C. H. (1969). Observations on the seasonal changes of the parasite fauna of yellow perch (*Perca flavescens*) from the Bay of Quinte, Lake Ontario. *J. Fish. Res. Bd Can.* **26**, 833–843.