TABLE 5. Frequency of occurrence (%) and mean number of the cestode, *Bothriocephalus acheilognathi*, (Order: Pseudophyllidea) from the foreguts of fishes collected from the Virgin River near Beaver Dam Wash, Arizona, 1979. Abbreviations are as follows: R = *Rhinichtnys osculus;* G = *Gila robusta;* L = *Lepidomeda;* P = *Plagopterus;* N = *Notropis lutrensis.*

Month		R	G	L	P	N	F. Ratio
	N	28	20	24	22		
February	%	3.7	35.0	4.1	0.0	ND	
	Mean	0.3	0.6	0.04	0.0		8.18*
	SE	0.1	0.2	0.1			
	N	27	4		26		
June	%	0.0	25.0	ND	0.0	ND	
	Mean	0.0	0.8		0.0		
	SE	0.0	0.8				
	N	29	31	31	28	26	
September	%	18.2	66.6	12.0	10.7	84.6	
	Mean	0.5	2.0	0.2	0.1	3.9	28.04*
	SE	0.2	0.5	0.2	0.1	0.6	
	N	23	9	27	27	27	
December	%	52.0	88.8	7.4	33.0	88.8	
	Mean	2.2	16.8	1.7	0.6	9.3	23.14*
	SE	1.2	6.0	1.7	0.3	2.0	

Note: Asterisks denote a significant difference among species at $p < 0.01$.
ND = No data.
SE is the standard error of the mean.

TABLE 6. Frequency of occurrence (%) and mean number of cestode parasites (Order: Pseudophyllidea) from the foreguts of fishes from the Virgin River in Nevada, 1979. An asterisk denotes a significant difference between species at $p < 0.01$.

Month		*Plagopterus argentissimus*	*Notropis lutrensis*	t
	N	24	48	
February	%	33	69	
	Mean	0.54	2.94	3.94*
	N	23	25	
June	%	13	36	
	Mean	0.13	3.76	2.01
	N	34	29	
September	%	53	86	
	Mean	1.76	6.03	3.45*
	N	27	27	
December	%	37	81	
	Mean	0.63	6.59	5.07*

observers have implicated them as being histopathogenic. The pathogenicity of the larval stage is usually due to compression or occlusion of a vital organ.

Early literature concerning the classification of *Posthodiplostomum minimum* is invested with synonymy and misinformation, partly because of inadequate description and erroneous identification and partly because some larval stages were described before their life histories, especially the adult, were known. Nomenclatural history has been reviewed by Miller (1954), Hoffman (1958), and Bedinger and Meade (1967).

Studies by Hunter (1937) on the transformation of *Cercaria multicellulata* to *Neascus van cleavei* and by Ferguson (1938) on transformation of metacercariae of *N. van cleavei* to adult *Neodiplostomum* culminated in the first description of the life cycle of *Posthodiplostomum minimum*.

Metacercariae have been found in all visceral organs but occur in abundance in the liver, spleen, kidneys, mesenteries, sinus venosus, heart, and ovaries (Figs. 2a, 2b, and 3a, 3b). Some strigeid larvae show positive histotropic effects toward specific fish tissue in vitro (Davis 1936). Avault and Allison (1965) found that the heart, liver, and kidneys contained approximately 79% of the total metacercariae in bluegill (*Lepomis machrochirus*). Metacercariae have not been reported in fish testis, apparently the only visceral organ alien to this parasite.

The occurrence of numerous metacercariae in visceral organs suggests deleterious effects on the well-being of the host and implicates *P. minimum* as a cause of mortality or morbidity. Hunter (1937, 1940) stated that death resulted if sufficient liver or other visceral tissue were destroyed by the metacercariae. Hughes (1928) observed bluegill, which had a heavy

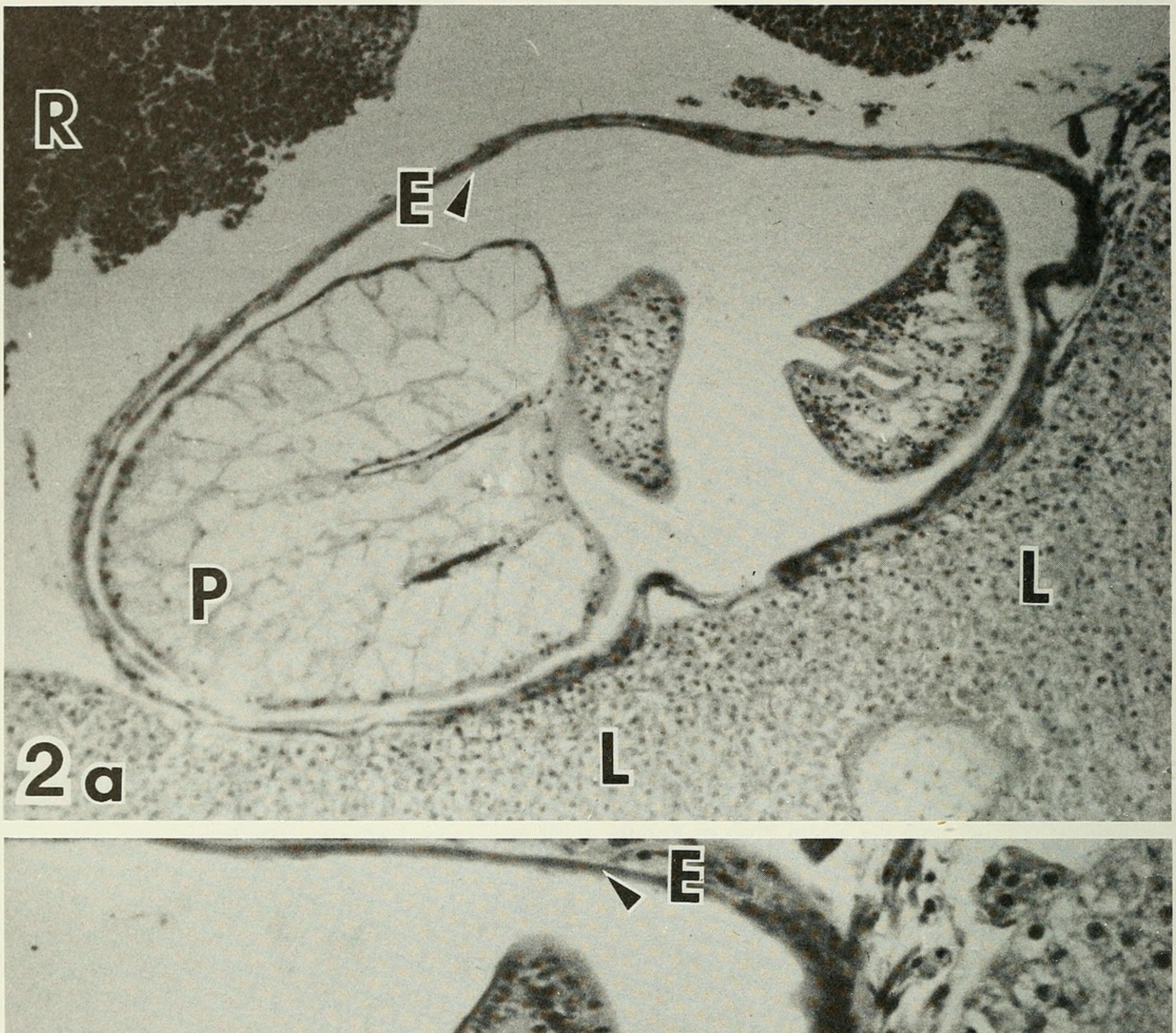

Fig. 2a, b. The metacercarial stage of *Posthodiplostomum minimum* (P) from the internal viscera of *Plagopterus argentissmus*. Note encapsulation (E) of the larval trematode and organ compression of the liver (L). Hemorrhaging (R) has occurred near the site of metacercarial encapsulation. Magnification, 2a—100X, 2b—430X.

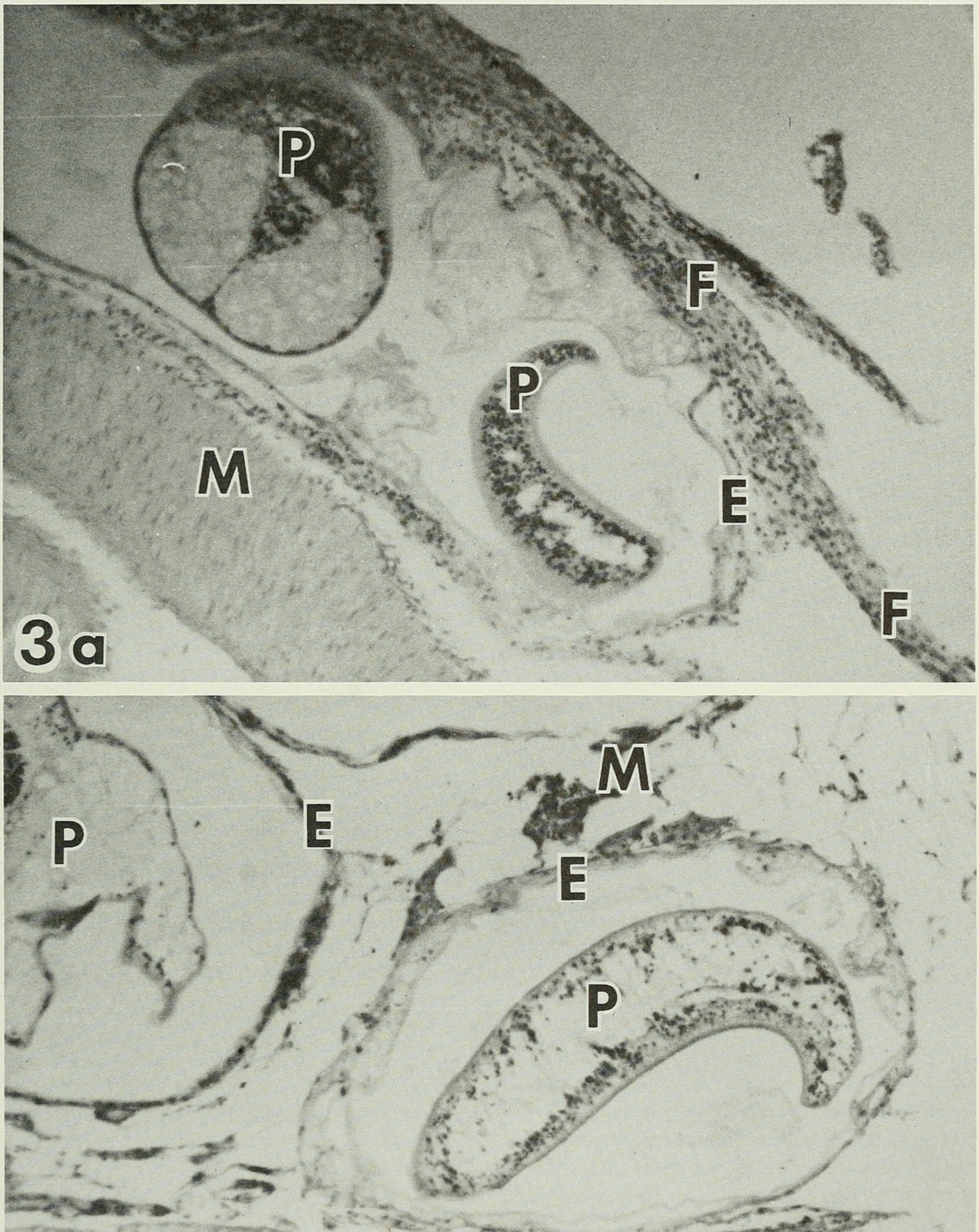

Fig. 3a, b. The larval stage of *Posthodiplostomum minimum* (P) from the internal viscera of *Plagopterus argentissmus*. 3a represents metacercariae encapsulated (E) in outer layer (F) (fibro serosa) of the intestinal tract. Note muscularis externa (M) (100X). 3b represents metacercariae encapsulated (E) in the mesentaries (M) of the viscera exhibiting compression on the intestine (N) (100X).

infection of *P. minimum* metacercariae, in Fife Lake, Michigan, dying in large numbers. This represents an example of a questionable cause-and-effect relationship because the parasite is ubiquitous and usually numerically abundant. More than circumstantial evidence is required to substantiate an allegation of *P. minimum* being a cause for fish mortality. Wild fish, with several hundreds of encysted metacercariae in the liver, sinus venosus, heart, and kidneys, are often observed to suffer no obvious debilitating effects. Colley and Olsen (1963) found as many as 991 metacercariae per bluegil, with metacercariae so dense as to be clumped en masse. Spall and Summerfelt (1969a) have observed 2,041 metacercariae in a bluegill from an Oklahoma reservoir.

Mortality due to stress and trauma from penetration of the cercariae has been observed in the laboratory following exposure of suitable host fish to high numbers of cercariae (Hunter 1937, Bedinger and Meade 1967). Host reactions following cercarial penetration include petechial hemorrhage at the site of invasion followed by congestion of surrounding venules and local edema, and an aggregation of leucocytes at the point of entry, particularly the phagocytic elements. Pathological effects include increased rate of excretion, increased plasma globulin and albumin, increased liver respiration, and decreased hematocrits (Smitherman 1964). Hemorrhage or a decrease in erythropoiesis would reduce hematocrits. The increase in the plasma proteins may represent a homeostatic response to the nutritional demands of the parasite, altered liver function, or effects on capillary permeability.

After encystment (19 days), mortality infrequently occurs. There is no experimental evidence to indicate mortality or other detrimental effects from the occurrence of encysted metacercariae.

Bothriocephalus acheilognathi = (*B. gowkongenesis* = *B. opsalichthydes*)

The Asian fish tapeworm, *Bothriocephalus acheilognathi*, represents a new introduction in North America, brought in through imports of grass carp to this country from China. Because of the new introduction and size of the adult worm, this parasite has become of major concern to fish and game officials throughout the country. Excellent reviews of the histopathology, biology, life history, control, and management of *Bothriocephalus* are found in a series of papers by Nakajima and Egusa (1947a, b, c, 1976a, b).

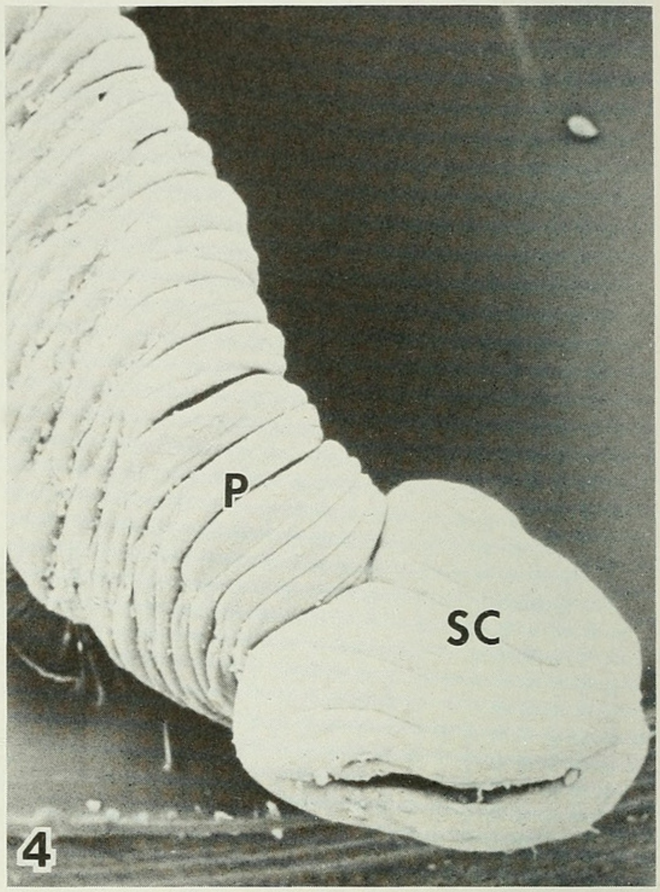

Fig. 4. A scanning electron micrograph of the Asian fish tapeworm, *Bothriocephalus acheilognathi*, from the intestine of the Virgin River roundtail chub, *Gila robusta seminuda*. Note the pit-viper shaped scolex (SC) and numerous proglottids (P). Photographed at 100X magnification.

The Asian fish tapeworm, characterized by its arrow or heart-shaped scolex (Fig. 4), has been a dangerous parasite for cultured grass carp and German carp fingerlings in Europe (Bauer et al. 1981). In Europe it has also been found in European catfish, guppies, mosquito fish, and other species (Hoffman 1983, Hoffman and Shubert 1984). In the United States it has been found in golden shiners and fathead minnows (Hoffman 1976), as well as in grass carp, Colorado squawfish, and mosquito fish. We add speckled dace, roundtail chub, Virgin spinedace, woundfin, and red shiner to that list.

The best known carp parasite transported to the fish ponds of many countries with the

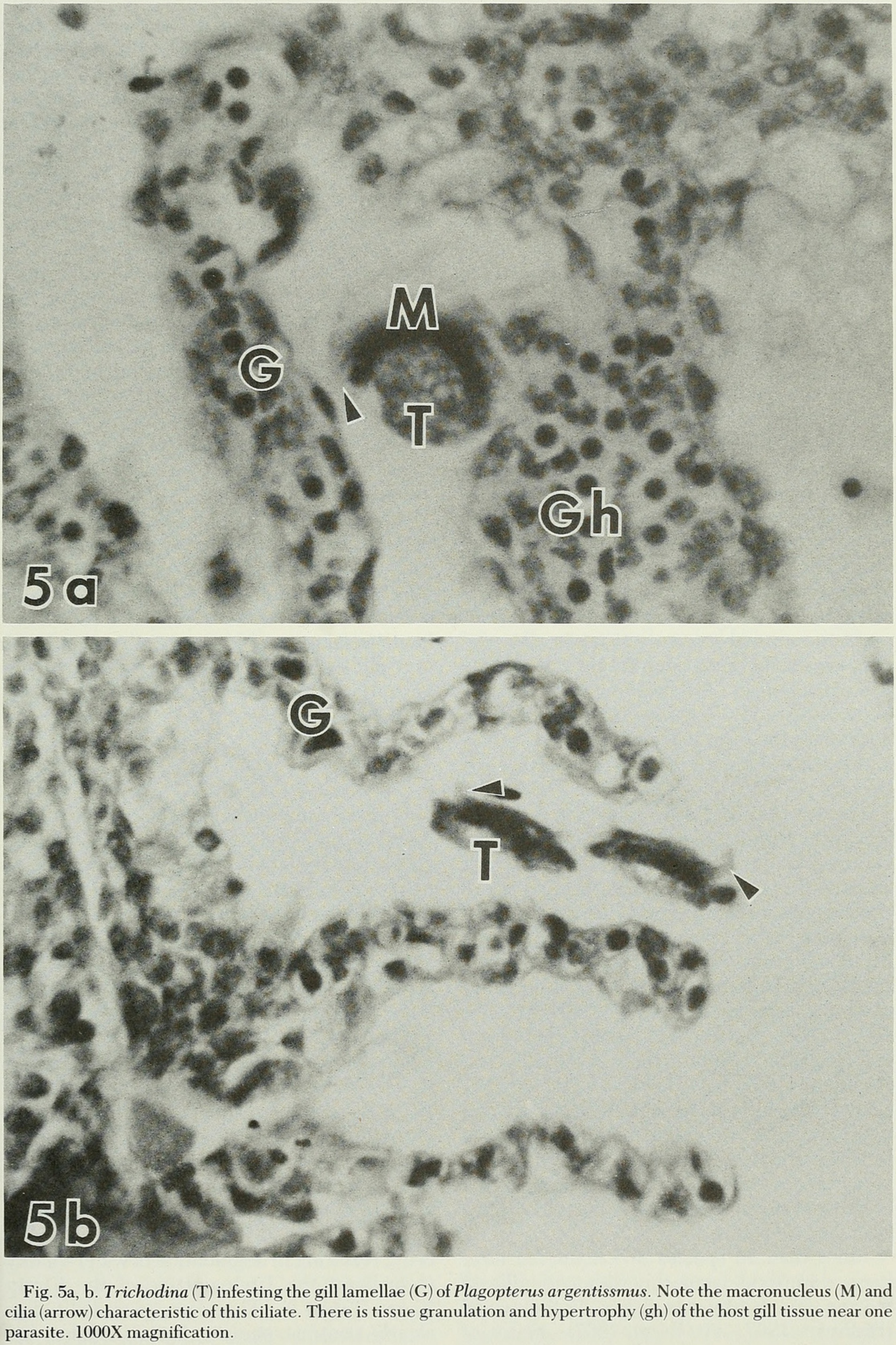

Fig. 5a, b. *Trichodina* (T) infesting the gill lamellae (G) of *Plagopterus argentissmus*. Note the macronucleus (M) and cilia (arrow) characteristic of this ciliate. There is tissue granulation and hypertrophy (gh) of the host gill tissue near one parasite. 1000X magnification.

Chinese carp is *Bothriocephalus acheilognathi* (= *B. gowkongensis*, = *B. opsalichthydis*) (Bauer et al. 1981). All European countries that culture carp in large quantities now have this pathogen. The spread of this parasite to new localities usually results in heavy infection of young fishes during the first years after it appears. *Bothriocephalus acheilognathi*, a thermophyllic parasite, can infect many fish species. Presumably it traveled to the United States by airplane in grass carp shipped from Asia.

Trichodina: Trichodinosis

This is a ciliated protozoan that was commonly observed on the gills of the woundfin minnow in August (Table 2).

This ciliate is ubiquitous among fish parasites throughout the world and usually is of minor concern for fish health. Members of the genus *Trichodina* Ehrenbert (Family; Urceolariidae Stein) are commonly seen on all kinds of aquatic animals. In fish they may settle on the skin in such numbers as to obscure the normal structure (Fig. 5a, 5b), and they are easily recognized by their similarity to a suction disk. Classification methods have been reviewed by Tripathi (1954). *Trichodina* parasitizes the skin, gills, and urinary bladder of the fish and is found both in freshwater and the sea.

The species of *Trichodina* that occur on North American freshwater fishes have not received the attention that they have in other areas of the world even though they are one of the most important groups of ectoparasites of freshwater fishes. Frequent references to trichodinids parasitizing fish occur in fish culture literature but the species are not named, as in the case for our study. Only Mueller (1937, 1938), David (1947), Lom (1963), Lom and Hoffman (1964), Hoffman (1967), and Wellborn (1967) have made major contributions to the knowledge of the taxonomy and distribution of *Trichodina* of North American freshwater fishes. Because of their small size, supposed lack of specific characters, and difficulty of removal from their hosts, they have been largely ignored.

More than 90 species of *Trichodina* have been described from the skin and gills of marine and freshwater fishes of the world (Hoffman 1967, Wellborn 1967). Many of these were described as new only because they were found on a different host or in another geographic location. In many cases the descriptions were inadequate since the uniform body structure of these ciliates yields few characters for differentiation of the species (Lom 1961, 1970, Mueller 1937). The inexact and insufficient descriptions of most early authors make the identification of many species doubtful. But the recently employed silver-impregnation technique of Klein and Chatton-Lwoff (Corliss 1953) reveals details of the adhesive disk that are important features of trichodinid taxonomy. Padnos and Nigrelli (1942) used the silver-impregnation technique to determine the ciliar patterns of trichodinids. But, according to Lom (1958), Raabe (1950) was the first to employ this technique in the study of the structure of the adhesive disk.

Trichodina rarely give rise to pathological manifestations of disease. It may be sporadically found in living fish, but it will only multiply in moribund and weakened ones. A macronucleus, mironucleus, and numerous food vacuoles are to be seen in the cytoplasm.

In our study we observed *Trichodina* on the gill surface (Fig 5a, 5b) of woundfin minnows in August.

DISCUSSION

Deacon and Hardy (1984) referred to segments of the Virgin River above Washington Diversion and above Mesquite Diversion as relatively undisturbed. Segments of the river below these two diversions were referred to as disturbed largely by irrigation withdrawals. Table 7 demonstrates that mean and minimum flows in May-November were substantially reduced at Bloomington below the Washington Diversion in 1985. Table 8 demonstrates a similar reduction in flow at Riverside, below the Mesquite Diversion in 1979. In addition, water quality in disturbed segments of Virgin River is also reduced, largely as a consequence of its use for agricultural irrigation (Sandberg and Sultz 1985). In June 1985 discharge from a salt spring (Pah Tempe Spring) suddenly increased dramatically, resulting in degradation of water quality throughout the Utah portion of the Virgin River (Table 9). Therefore, our 1979 data clearly contrast parasite loads in fishes ex-

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