Spatial distribution of gill parasites of *Lepomis gibbosus* (L.) and *Ambloplites rupestris* (Raf.)[1]

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Precise positions with regard to gill arches, sides of gill hemibranchs (anterior or posterior), and their sections (dorsal, medial, ventral) were recorded on 25 specimens monthly to determine spatial distribution of gill parasites of *Lepomis gibbosus* (L.) and *Ambloplites rupestris* (Raf.). Data were collected on three groups of parasites, Monogenea, Copepoda, and glochidia. The data, treated synecologically, were analysed for spatial distribution using a two-factor ANOVA and Duncan's multiple range test.

A significant preference for anterior sides of hemibranchs was noted for Monogenea and glochidia of *L. gibbosus* ($P < 0.001$). A definite affinity for anterior medial and posterior medial sections of hemibranchs was noted for Monogenea and glochidia of *L. gibbosus* ($P < 0.001$), while Copepoda of the same host were found most often on either anterior or posterior sections of hemibranchs ($P < 0.001$).

A well-defined preference for gill arches, in descending order, two, three, one, and four was noted for Monogenea and glochidia of *L. gibbosus* ($P < 0.001$), while no such preference was found for Copepoda of the same host ($P < 0.001$). The spatial distribution patterns exhibited by the three groups of parasites of *Ambloplites rupestris* followed generally the same patterns as those exhibited by the gill parasites of *L. gibbosus*, the only exception being the preference for anterior sides of hemibranchs exhibited by Copepoda ($P < 0.001$).

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La répartition spatiale des parasites branchiaux a été étudiée chez *Lepomis gibbosus* (L.) et *Ambloplites rupestris* (Raf.) par l'examen mensuel de 25 spécimens; la position précise des parasites a été déterminée: position de la branchie affectée, côté (antérieur ou postérieur) et section (dorsale, médiane ou ventrale) des hémibranchies. Trois groupes de parasites ont été considérés, les monogènes, les copépodes et les glochidies. Les données, considérées de façon synécologique, ont été analysées pour déterminer la répartition spatiale des parasites en se servant d'une analyse de variance à deux caractères et du Test de Duncan.

Les monogènes et les glochidies de *L. gibbosus* ont une préférence significative ($P < 0.001$) pour les côtés antérieurs et une affinité marquée ($P < 0.001$) pour les sections antérieure médiane et postérieure médiane des hémibranchies, alors que, chez le même hôte, les copépodes parasitent indifféremment les sections antérieures ou postérieures des hémibranchies ($P < 0.001$).

Les monogènes et les glochidies de *L. gibbosus* parasitent par ordre décroissant de préférence ($P < 0.001$) les arcs branchiaux deux, trois, un et quatre: les copépodes parasites du même hôte ne semblent pas avoir de préférence ($P < 0.001$). Chez *Ambloplites rupestris*, les trois groupes de parasites suivent à peu près la même répartition spatiale que chez *L. gibbosus* à une exception près puisque les copépodes semblent cette fois avoir une préférence ($P < 0.001$) pour les côtés antérieurs des hémibranchies.

[Traduit par le journal]

Introduction

Early workers noticed that some parasites have a [illegible] affinity or specificity for certain sites of [illegible] or regions of the host. Cerfontaine (1896, [illegible] was the first to record this phenomenon for [illegible]dophora *denticulata*, a gill parasite of *Pol*[illegible] *virens*. Suydam (1971) has reviewed sub[illegible] accounts (Akazaki 1965); Euzet and Ktari [illegible] Frankland 1955; Ktari 1969; Llewellyn 1956; [illegible]n and Owen 1960; Owen 1963; Slinn 1963; Wiles 1968) on spatial distribution of various Monogenea. All these workers defined specific areas of attachment by dividing each gill arch arbitrarily into several regions, and the parasite's position was then indicated with respect to these. However, almost all these studies considered a single species of parasite, in most cases of polypisthocotylid monogenean. Fernando and Hanek (1976) have reviewed the ecology of gill parasites in fishes.

[illegible] complexity of spatial

hosts under two limnologically different trophic regimes.

Materials and Methods

Fish were collected monthly between November 1971 and October 1972 from two localities: (*a*) a proximate portion of the Bay of Quinte ('Glenora') (44°03′ N, 76°48′ W and 44°06′ N, 76°51′ W) exhibiting typical oligotrophic features, and (*b*) West Lake (43°54′ N, 77°40′ W and 43°57′ N, 77°46′ W) exhibiting typical eutrophic features.

At each locality, 25 *L. gibbosus* and 25 *A. rupestris* were selected monthly from commercial catches for a total of 300 fish of each host. These were immediately examined at the Glenora Fisheries Research Station, Picton, Ontario.

Fish were killed instantly without bloodshed using a preparation needle inserted into the brain in the upper part of the eye. They were then weighed, fork length was recorded, and 8–10 scales were taken for age determination. Gill arches were separated and placed individually in small Petri dishes in water from their locality of origin. They were numbered I–IV anterioposteriorly, sides of hemibranchs were designated as anterior and posterior, and each was divided into 3 subequal sections (dorsal, medial, ventral), thus giving 6 subequal sections per gill arch for a total of 48 per fish (Fig. 1). Monogenea were removed from gill arches and all those from a section were placed in a drop of water on microscopic slides. They were fixed in ammonium picrate – glycerin under cover slips and the slide was labelled and stored for later identification. Number of specimens obtained from each section was recorded. Numbers of Copepoda and glochidia on each section of the gill arches were recorded; infested gill arches were separately preserved in 6% formalin, labelled, and stored for later identification. In this way precise location of every parasite was recorded.

A two-factor ANOVA was run to test the various aspects of spatial distribution with respect to the three groups of parasites under consideration (synecological approach). Significance was noted on 0.05, 0.025, and 0.001 levels to indicate degree of the role. An F value significant at the 0.10 level was noted only as an indicator that some sort of relationship might exist.

When effects were noted, Duncan's multiple range test was employed ($P < 0.05$ and $P < 0.01$) to determine more specifically where the significance lay.

Results

Spatial Distribution of Gill Parasites of Lepomis gibbosus

Gill Parasite Spectrum

The gill parasite spectrum consisted of the following: (*a*) seven species of Monogenea, viz. *Actinocleidus gibbosus* Mizelle and Donahue 1944, *Actinocleidus recurvatus* Mizelle and Donahue 1944, *Cleidodiscus robustus* Mueller 1934, *Urocleidus acer* (Mueller 1936) Mizelle and Hughes 1938, *Urocleidus attennatus* Mizelle 1941, *Urocleidus dispar* (Mueller 1936) Mizelle and Hughes 1938, and *Urocleidus ferox* Mueller 1934; (*b*) three species of Copepoda, viz. *Achtheres ambloplitis* Kellicott 1880, *Ergasilus caeruleus* Wilson 1911, and *Ergasilus centrarchidarum* Wright 1882; and *Lampsilis radiata* (Gmelin 1792).

A total of 23 470 parasites was recovered from the gills of *L. gibbosus* from November to October 1972 in Glenora, while 36 432 specimens parasites were recovered in West Lake. species composition and their incidence were most identical in both localities. *Urocleidus* was clearly the dominant species, reaching in Glenora and 76.9% in West Lake. Lower ranging from 1.6 to 11% of the parasite load observed for *A. gibbosus*, *A. recurvatus*, *caeraleus*, and *U. acer*. The percentage of the site load of *A. ambloplites*, *C. robustus*, *E. chidarum*, glochidia of *L. radiata*, *U. attenn* and *U. dispar* remained at extremely low levels (0.03 to 0.7%).

Overall, the Monogenea accounted for approximately 96% of the parasite load, Copepoda some 4%, and glochidia of *L. radiata* for a of 1% of the parasite load in both localities.

A synecological approach, treating communities and their constituent species in general terms comparing differences in spatial distribution terns exhibited by groups of parasites, viz. Monogenea, Copepoda, and glochidia, was adopted is used throughout the presentation.

Spatial distribution patterns with regard to arches, sides of gill hemibranchs (anterior or posterior), and their sections (dorsal, medial, ventral) as exhibited by Monogenea, Copepoda, and glochidia of *L. radiata* are given below.

Sides of Hemibranchs

A marked effect regarding sides of hemibranchs was noted for Monogenea ($F = 62.452$; $P < 0.0$ and glochidia of *L. radiata* ($F = 58.451$; $P < 0.0$ with Duncan's test ($P < 0.01$) indicating anterior side significantly different from the posterior side.

No effect was noted for Copepoda.

Sections of Hemibranchs

A definite effect, regarding sections of hemibranchs, was noted for the following: Monogenea ($F = 84.561$; $P < 0.001$); Duncan's test ($P < 0.01$) indicates (i) anterior medial section significantly different from the other sections; and (ii) posterior medial section significantly different from the other sections; (*b*) Copepoda ($F = 30.732$; $P < 0.001$); Duncan's test ($P < 0.01$) indicates (i) anterior medial and posterior medial sections significantly different from the other sections; (ii) anterior ventral and posterior dorsal sections significantly different from the other sections; and (iii) anterior dorsal, anterior ventral, and posterior ver-

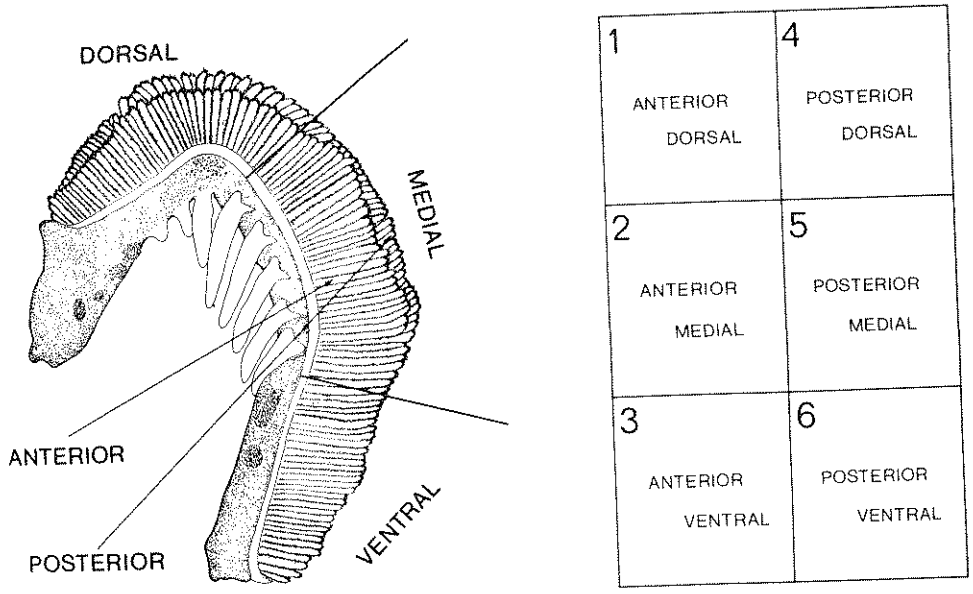

FIG. 1. Illustration of gill arch I showing arbitrary divisions into areas.

sections significantly different from the other ions; (c) glochidia of *L. radiata* ($F = 41.311$; 0.001); Duncan's test ($P < 0.01$) indicates (i) ior dorsal, anterior ventral, posterior dorsal, posterior ventral sections significantly differ- from the other sections; and (ii) anterior medial ons significantly different from the other sec-

ches

well-pronounced 'arch' effect was noted for genea ($F = 39.414$; $P < 0.001$) and glochidia *radiata* ($F = 25.691$; $P < 0.001$) with Dun- $P = 0.01$) indicating (i) arches one and four cantly different from arches two and three; h two significantly different from the other es and (iii) arch three significantly different the other gill arches.

eresting results were obtained for Copepoda 33.416; $P < 0.001$); Duncan's test ($P < 0.05$) ates arches one and four significantly different the other two arches, while Duncan's test (P indicates no significant differences among four gill arches.

Distribution of Gill Parasites of Amblop- es rupestris

Parasite Spectrum

Cleidodiscus glenorensis Hanek and Fernando 1972, *Cleidodiscus stentor* Mueller 1937, and *Urocleidus chautauquensis* (Mueller 1938) Mizelle and Hughes 1938; (*b*) three species of Copepoda, viz. *A. ambloplitis* Kellicott 1880, *E. caeruleus* Wilson 1911, and *E. centrarchidarum* Wright 1882; and (*c*) one species of glochidia, viz. glochidia of *L. radiata* (Gmelin 1792).

A total of 15 342 parasites was recovered from the gills of *A. rupestris* between November 1971 and October 1972 in Glenora, while 17 113 specimens of parasites were recovered during the same sampling period in West Lake. Although the parasite species composition was identical in both localities, the intensity of infestation of these parasites varied considerably. *Ergasilus centrarchidarum* was the dominant species in Glenora accounting for 77.9% of the parasite load; *C. stentor* reached 17.4% and *C. alatus* 2.7% of the parasite load. The remaining species exhibited extremely low to rare levels (0.13 to 0.8%).

In West Lake, *C. stentor* appeared to be the dominant species, accounting for 53.3%, while *E. centrarchidarum* reached 37.6% and *C. alatus* 6.5% of the parasite load. The remaining species, like in Glenora, were rare, exhibiting 0.2 to 1.1% of the parasite load.

Overall Copepoda accounted for 78.8%, Mono-

Lake, the parasite load was composed as follows: Monogenea (61%), Copepoda (38.5%), and glochidia of *L. radiata* (0.5%).

Spatial distribution patterns, as exhibited by the groups of parasites, Monogenea, Copepoda, and glochidia of *L. radiata* with regard to gill arches, sides, and sections of hemibranchs are presented below.

Sides of Hemibranchs

A marked effect regarding sides of hemibranchs was noted for all three groups of parasites: Monogenea ($F = 96.131$; $P < 0.001$), Copepoda ($F = 21.314$; $P < 0.001$), and glochidia of *L. radiata* ($F = 49.154$; $P < 0.001$). Duncan's test ($P < 0.01$) indicates the anterior side of hemibranchs to be significantly different from the posterior side.

Sections of Hemibranchs

A definite effect, regarding sections of hemibranchs, was recorded for the following: (*a*) Monogenea ($F = 101.34$; $P < 0.001$); Duncan's test ($P < 0.05$) indicates (i) anterior medial section significantly different from the other sections; and (ii) posterior medial section significantly different from the other sections; further, Duncan's test ($P < 0.01$) indicates anterior medial section significantly different from the other sections; (*b*) Copepoda ($F = 71.681$; $P < 0.001$); Duncan's test ($P < 0.01$) indicates (i) anterior medial and posterior medial sections significantly different from the other sections; (ii) anterior ventral, posterior dorsal, and posterior ventral sections significantly different from the other sections; and (iii) anterior dorsal section significantly different from the other sections; (*c*) glochidia of *L. radiata* ($F = 34.671$; $P < 0.001$); Duncan's test ($P < 0.01$) indicates (i) anterior medial section significantly different from the other sections; and (ii) anterior medial, anterior ventral, and posterior medial sections significantly different from the other sections of hemibranchs.

Arches

A well-pronounced 'arch' effect was noted for all three groups of parasites: (*a*) Monogenea ($F = 98.351$; $P < 0.001$); Duncan's test indicates each arch significantly different from each other; (*b*) Copepoda ($F = 94.116$; $P < 0.001$); Duncan's test (both at $P < 0.05$ and $P < 0.01$) indicates no significant differences among the four gill arches; and (*c*) glochidia of *L. radiata* ($F = 76.221$; $P < 0.001$); Duncan's test (both at $P < 0.05$ and $P < 0.01$) indicating; (i) arches I and IV significantly different from the other two arches; and consequently (ii) arches II and III significantly different from the other two arches.

Discussion

The original observation that some parasite have a higher affinity for certain organ sites o regions of the body first noted by Cerfontain (1896, 1898) has been greatly extended and refine Several studies have indicated that some parasite of fishes exhibited a site specificity for particula gill arches. Llewellyn (1956) found that *Diclid- phora merlangi* occur most often on gill arch of *Gadus merlangus* and *Gadus luscae* was mos prevalent on gill arches II and III of *G. lusca* Frankland (1955) indicated that *Dactylocot denticulata* was more prevalent on gill arch I *Gadus virens*. Wiles (1968) found that *Diplozoo paradoxum* occurred most often on gill arches I an II of *Abramis brama*. Suydam (1971) indicated th adhesive attitudes and site specificity of *Di dophora maccullumi* were similar to those de scribed for *D. denticulata* by Frankland (1955) *D. merlangi* by Llewellyn (1956), and for *D paradoxum* by Wiles (1968). Suydam (1971) als suggested that the direction of the ventilating cu rent may influence the position of Monogenea o the gills. Woskoboinikoff and Balabai (1936, 193 introduced the concept of a continuous gill curta separating buccal and opercular cavities. They als suggested that water flow over the gills was esse tially a continuous process. Hughes and Shelto (1958), working with three cyprinid species applied modern manometric methods and recorde that the gills offered appreciable resistance to wate flow. Differential pressure was consequently a ways found, usually with the gradient from bucca to opercular cavity. This concept of a dual pum relates primarily to water flow through the gills an has no straightforward anatomical basis since there is mechanical interaction through the system (Shel ton 1970). The geometry of the gills changes con stantly during a single breathing cycle (Shelto 1970); therefore, parts of the gill sieve are alte nately exposed to and protected from the wate flow. A number of workers have suggested that the gill filaments do separate during some stage in the opercular cycle. Saunders (1961) reported separa tion as the operculum was maximally abducted Hughes (1961) during opercular abduction, and Pasztor and Kleerekoper (1962) during all phases but principally during abduction. Most of this re search was concerned with the varying pressures occurring in the buccal and opercular cavities and the consequent respiratory current of the gills as a whole. Very little has been done previously to de termine whether all of the gill arches play an equal part in gaseous exchange or whether more of the

respiratory current than others. Consid suspect that at least most posterior gill a water flow than the described a single me volumes of water fl arches of *Salmo trutt* of *Anodonta cygnea* mouth of fish passivel hence to attach them the water flows acro considered to be distr proportions equal to passing over the dif marized his findings a in brown trout from V piratory current flows pair of gills, less flows all across the most po absence of more sophi more accurate result serve useful functions different volumes of v pairs of gill arches. H adopted, particularly i Kan's (1973) work indic section of the gills is di tion volume and the pat gills.

Considering our resul the three groups of paras *gibbosus* exhibited the significant preference hemibranchs was noted chidia of *L. radiata*; (*b*) the Copepoda, which we evenly on both sides of h affinity for anterior mec sections of hemibranchs and glochidia of *L. radia* found most often on eit sections of hemibranchs; place for arches, in desce one, and four was recor glochidia of *L. radiata*; ar for any gill arch for Copep

The results obtained for mites infesting the gills of agreement with those obta of *L. gibbosus*, the only n the preference for anteri exhibited by Copepoda. I here that synecological ap

espiratory current passes over some gill arches than others. Considering the size alone, one might suspect that at least in most freshwater fishes the most posterior gill arch, number IV, receives less water flow than the anterior ones. Paling (1968) described a single method of estimating the relative volumes of water flowing over the different gill arches of *Salmo trutta*. Marker parasites, glochidia of *Anodonta cygnea*, were allowed to enter the mouth of fish passively with respiratory current and hence to attach themselves to the gill filaments as the water flows across them. The glochidia were considered to be distributed over the gill arches in proportions equal to the actual volumes of water passing over the different gill arches. He summarized his findings as follows: "It was found that in brown trout from Windermere, most of the respiratory current flows over the second and third pair of gills, less flows over the first pair and least of all across the most posterior pair of gills." In the absence of more sophisticated methods producing more accurate results, Paling's (1968) findings serve useful functions in providing estimates of the different volumes of water flowing over the four pairs of gill arches. His findings, therefore, were adopted, particularly in view of Hughes and Morgan's (1973) work indicating that the degree of inflation of the gills is directly related to the ventilatory volume and the pattern of current flow over the gills.

Considering our results, it can be concluded that the three groups of parasites infesting the gills of *L. gibbosus* exhibited the following patterns: (*a*) a significant preference for the anterior side of hemibranchs was noted for Monogenea and glochidia of *L. radiata*; (*b*) no such effect was noted for Copepoda, which were found to be distributed evenly on both sides of hemibranchs; (*c*) a definite tendency for anterior medial and posterior medial sections of hemibranchs was noted for Monogenea and glochidia of *L. radiata*, while Copepoda were found most often on either anterior or posterior sections of hemibranchs; (*d*) a well-defined preference for arches, in descending order, two, three, one, and four was recorded for Monogenea and glochidia of *L. radiata*; and (*e*) no clear preference for any gill arch for Copepoda.

The results obtained for the three groups of parasites infesting the gills of *A. rupestris* are in full agreement with those obtained for the gill parasites of *L. gibbosus*, the only notable exceptions being the preference for anterior sides of hemibranch exhibited by Copepoda. It should be emphasized here that synecological approach was used in data analysis. Consequently, the various affinities for various parts or sections of gills as exhibited by 'groups' of parasites reflect actually the spatial preferences of the dominant species of parasite groups under consideration.

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AKAZAKI, M. 1965. Ecology and external form of the gill trematode *Heteraxine heterocerca* of the yellow-tail *Seriola guigueradiata*. Jpn. J. Ecol. **15**: 155–159.

CERFONTAINE, P. 1896. Contribution a l'étude des Octocotylides. Arch Biol. **14**: 497–560.

——— 1898. Contribution a l'étude des Octocotylides. IV. Nouvelles observations sur le genre *Dactylocotyle* et description de *Dactylocotyle luscae*. Arch. Biol. **15**: 301–328.

EUZET, L., and M. H. KTARI. 1970. *Heteraxinoides hannibali* n. sp. (Monogenea, Polyopisthocotylea), parasite branchial de *Pomadasys incisus* (Bowdich) 1825) (Teleostei) dans le Golfe de Tunis. Bull. Mus. Natl. Hist. Nat. Zool. **41**: 269–279.

FERNANDO, C. H., and G. HANEK. 1976. Gills. *In* Ecological aspects of parasitology. *Edited by* C. R. Kennedy. North-Holland Publ., Amsterdam. pp. 209–226.

FRANKLAND, H. M. T. 1955. The life history and bionomics of *Diclidophora denticulata* (Trematoda: Monogenea). Parasitology, **45**: 313–351.

HUGHES, G. M. 1961. Gill ventilation in fishes. Rep. Challenger Soc. **3**(13).

HUGHES, G. M., and M. MORGAN. 1973. The structure of fish gills in relation to their respiratory function. Biol. Rev. Cambridge Philos. Soc. **48**: 419–475.

HUGHES, G. M., and G. SHELTON. 1958. The mechanism of gill ventilation in three freshwater teleosts. J. Exp. Biol. **35**: 807–823.

KTARI, M. H. 1969. Recherches sur l'anatomie et la biologie de *Microcotyle salpae* Parona et Perugia, 1890 parasite de *Box salpa* (Teleosteen). Ann. Parasitol. Hum. Comp. **44**: 425–440.

LLEWELLYN, J. 1956. The host-specificity, microecology and comparative morphology of some trematode gill parasites. J. Mar. Biol. Assoc. U.K. **35**: 113–127.

LLEWELLYN, J., and I. L. OWEN. 1960. The attachment of the monogenean *Discocotyle sagittata* Leuckart to the gills of *Salmo trutta* L. Parasitology, **50**: 51–59.

OWEN, I. L. 1963. The attachment of the monogenean *Diplozoon paradoxum* to the gills of *Rutilus rutilus* L. I. Microhabitat and adhesive attitudes. Parasitology, **53**: 455–461.

PALING, J. E. 1968. A method of estimating the relative volumes of water flowing over the different gills of freshwater fish. J. Exp. Biol. **48**: 785–802.

PASZTOR, V. M., and H. KLEEREKOPER. 1962. The role of the

gill filament musculature in teleosts. Can. J. Zool. **40**: 785–802.

SAUNDERS, R. L. 1961. The irrigation of the gills in fishes. I. Studies of the mechanism of branchial irrigation. Can. J. Zool. **39**: 637–653.

SHELTON, G. 1970. The regulation of breathing. *In* Fish physiology. *Edited by* W. S. Hoar, and D. J. Randall. Vol. IV. pp. 293–359.

SLINN, D. J. 1963. Occurrence of *Discocotyle sagittata* on sea trout. Nature (London), **197**: 306.

SUYDAM, E. L. 1971. The micro-ecology of three species of monogenetic trematodes of fishes from the Beaufort – Cape Hatteras area. Proc. Helminthol. Soc. Wash. **38**: 240–246.

WILES, M. 1968. The occurrence of *Diplozoon paradoxum* Nordmann 1832 (Trematoda: Monogenea) in certain northern England and its distribution on the gills of Cyprinidae. Parasitology, **58**: 61–70.

WOSKOBOINIKOFF, M. M., and P. P. BALABAI. 1934. Vergleichende experimentelle Untersuchung des Atmungsapparates bei Knochenfischen. Vorläufige Mitteilung. Ergebnisse der Beobachtungen in den Sommern 1933 und 1934. (In Ukrainian with German summary.) Trav. Mus. Zool. Acad. Sci. Ukr. **10**: 145–155.

——— 1937. Vergleichende experimentelle Untersuchungen des Atmungsapparates bei Knochenfischen. Beobachtungsergebnisse vom Jahre 1935. (In Ukrainian with German summary.) Trav. Mus. Zool. Acad. Sci. Ukr. **16**: 77–125.