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Studies on aquatic fungi. XXI. The Lake Mamry complex

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Forty seven species of fungi were found in the Lake Mamry complex. The following fungi unknown from Poland were recorded: *Rhizophydium amoebae*, *R. apiculatum*, *R. nodulosum*, *Chytriomyces annulatus*, *Hyphochytrium catenoides*, *Aphanodictyon papillatum* and *Achlya orion.*

INTRODUCTION

Lake Mamry, one of the largest lakes in Poland, belongs to the system of Great Masurian Lakes through which a water divide runs so that the water of these lakes is drained in two directions. Beginning with the water of Lake Niegocin it flows into the Vistula basin whereas the waters of the Lake Mamry complex flow from Lake Kisajno to the north and are drained by the River Węgorapa to Pregoła. Within the Lake Mamry complex various trophic types of lakes can be distinguished, from the eutrophic type (among others Lake Niegocin) to that, nearest to the oligotrophic type, i.e. Północne Lake (Czeczuga, 1964). They take also differ in their morphometry.

Continuing our studies on aquatic fungi in the north-eastern region of Poland (Czeczuga, Próba, 1987; Czeczuga, 1991), we decided to investigate the species composition of aquatic fungi in this group of lakes with reference to the chemistry of the water. The results obtained not only increase our knowledge of the hydromycoflora in Poland but also serve to widen our knowledge in general of the biology and ecology of certain species.

THE FIELD OF STUDY

Eight lakes were included in these studies (Fig. 1, Table 1). Their morphometric data are presented.

— Lake Dargin (Site V) is located in the centre of the Lake Mamry complex. It is a lake with a tachymitic circulation and is characterised by a quite high temperature of the hypolimnion (P a s c h a l s k i, 1959). The samples were collected from the eastern shore near the rocks of Fulędzki Róg. It has a sandy bed and a depth of 0.30 m.

— Lake Dobskie (Site IV) constitutes the western part of the Mamry complex. It is abundant in vascular plants (B e r n a t o w i c z, R a d z i e j, 1960). The samples were collected near Doba. The bed is silty. Depth – 0.25 m.

— Lake Gołdopiwo (Site VIII) lies to the east of Lake Dargin. It resembles Północne Lake Mamry in its limnological type. The samples were taken from the south–eastern shore to the south of Jeziorowskie Lake. The bed is sandy. Depth – 0.25 m.

— Lake Jagodne (Site I). The samples were collected from a site situated to the north east of Jagodne. Its bed is silty, the shore is overgrown with reeds. Depth – 0.5 m.

— Lake Kisajno (Site III) constitutes the southern part of the whole Mamry complex. The site is situated on the eastern shore of the lake at Pierkunowo is a bed sandy. Depth 0.45 m.

— Północne Lake Mamry (Site VI). This lake is situated farthest to the north of all the lakes of the complex. The samples were collected from the western shore opposite the island of Dębowa. The bed is muddy, overgrown with reeds. Depth – 0.5 m.

— Lake Niegocin (Site II), one of the largest lakes in the locality of Giżycko. The site from which the samples were collected was on the eastern shore, approximately 500 m to the south of Giżycko town. The shore is overgrown with reeds, the bed is muddy. Depth – 0.50 m.

— Lake Święcajty (Site VII) is joined to Północne Mamry by a comparatively broad inlet. The site was situated on the eastern shore at Ogonki. The bed was sandy, depth – 0.35 m.

Fig. 1. Sampling sites in lakes

Table 1

Characteristics of the investigated lakes

Lake	Lenght	Width	Area	Depth
	in km (max.)		ha	in m (max.)
Dargin	8.8	4.9	3030.0	37.6
Dobskie	7.7	4.6	1719.5	22.5
Gołdopiwo	5.4	2.7	1070.0	36.5
Jagodne	6.1	1.5	736.0	37.4
Kisajno	8.5	3.1	1896.0	25.0
Mamry Północne	9.2	4.6	2504.0	43.8
Niegocin	8.4	4.5	2598.8	39.7
Święcajty	5.5	2.4	829.0	28.0

METHODS

Samples of water were collected once a month over the years 1988-1989 for hydrochemical analysis and for studies on the various species of aquatic fungi. The water was collected in a 5-litre Ruttner bucket from the depth at which the bucket was immersed. In the water, the temperature was measured and the following was determined: the pH, CO_2, dissolved oxygen, BOD_5, the oxydability of the water and its alkalinity, the hartdness of the water calculated in Ca and Mg, ammonium, organic nitrogen, nitrates, phosphates, chlorides, iron, manganese, sulphates, dry residue, substances dissolved in the water and the suspension in the water. For determinations of the different chemical elements in the water the methods recommended by Standard Methods (Golterman, Clymo, 1971) were employed; the detailes of these methods were described in a previous paper (Czeczuga, Próba, 1980).

The zoosporic fungi in the water were studied by a method based on direct microscopic examination of the water and of materials collected from the water as well as by the bait method (onion skin, hemp-seeds, clover-seeds, snake skin, hairs and filings of horn) applied in environmental studies and in the laboratory. The methods were described in detail in a paper by Fuller, Jaworski (1986). In addition (for *Hyphomycetes*), the foam collected from the surface of eddies in running water or at the edges of stagnant water was examined directly under a microscope (Casper, 1965; Arnold, 1968). The samples were fixed in formalin-acetic-alcohol immediately after collection and brought to the laboratory.

For determination of the fungi the following keys were used: for zoosporic fungi – Skirgiełło (1954), Batko (1975) and Sparrow (1960); for *Hyphomycetes* – Dudka (1974) and Ingold (1975); for yeasts – Błagodatskaja et al. (1980) and Kreger van Rij (1984).

RESULTS

The mean and the ranges of variation values of the basic boigens most frequently limiting primary production and other hydrochemical parameters are presented in Table 2.

As regards ammonia nitrogen it was not found during the investigation in Lake Gołdopiwo, Północne Mamry and Święcajty but the highest mean value of this form of nitrogen was determined in Lake Jagodne. The lowest content of nitrates on the other hand was noted in the Lake Gołdopiwo and the highest in Lake Jagodne and Niegocin. Nitrate nitrogen was not found in Lake Kisajno, Północne Mamry and Święcajty.

The lowest content of phosphorus was found in Lake Północne Mamry and the highest in the Lake Niegocin and Jagodne.

In the Lake Mamry complex and in some of the adjacent lakes, 47 species of aquatic fungi were noted, namely, species of the *Chytridiomyces* (10), *Hyphochytriomycetes* (1), *Oomycetes* (19), *Endomycetes* (5), *Ascomycetes* (1) and of the *Hyphomycetes* (11 species) (Table 3). Seven species were found as new for the hydromycoflora of Poland. These were *Rhizophydium amoebae* from Lake Jagodne, *Rhizophydium apiculatum, Rhizophydium nodulosum, Chytriomyces annulatus* and *Hyphochytrium catenoides* from the waters of Lake Niegocin, *Aphanodictyon papillatum* from Lake Kisajno, and *Achlya orion* observed in the water collected from Lake Dobskie (Fig. 2). *Dactylella submersa*, a fungus belonging to a group of rare fungi, representatives of the *Hyphomycetes*, was also noted in the water of Lake Święcajny.

Several species of yeasts were olso recorded: *Candida aquatica* was found in the foam of Lake Kisajno, and other species such as *Candida albidus, Candida tropicalis* and *Rhodotorula glutinis* were found in Lake Niegocin. The smallest number of species was noted in Północne Lake Mamry (No. 7) wheras the greatest number in Lake Niegocin (No. 14).

During the two years of studies, only 2 species occurred during the summer: *Saprolegnia ferax* was noted at the site on Lake Niegocin and *Anguillospora longissima* was found at the site on Północne Lake Mamry.

DISCUSSION

The three fungi of the *Rhizophydium* genus new to Polish hydromycoflora belong to the keratinophilous group (B a t k o, 1975), *Rhizophydium amoebae* is usually found as a saprophyte on the exuviae of insects in water, through it is also known to be a parasite of *Amoeba terricola*. The *Rhizophydium apiculatum* is similar; it is a saprophyte of substrata containing keratin and is also a parasite of protozoa. On the other hand, the *Rhizophydium nodulosum* is a saprophyte of hair and other materials containing kreatin found in the loam and water of bodies of fresh water.

Table 2

Chemical composition of the water in particular lakes (mg l^{-1})

Specification	Lake			
	Dargin	Dobskie	Gołdopiwo	Jagodne
Temperature °C	6.8 (4.2-9.5)	9.9 (7.4-12.0)	9.8 (7.2-10.5)	8.4 (4.1-11.0)
pH	7.7 (7.6-7.9)	8.4 (8.15-8.8)	8.1 (8.0-8.3)	8.1 (7.9-8.3)
O_2	19.5 (18.4-20.6)	21.2 (20.0-24.0)	19.8 (8.2-21.4)	18.0 (16.2-20.0)
BOD_5	8.0 (7.0-10.4)	8.8 (6.8-9.6)	6.2 (6.0-7.2)	6.4 (5.8-6.8)
Oxydability	8.0 (7.0-10.4)	6.6 (4.6-8.5)	6.8 (5.6-7.0)	8.3 (6.4-9.8)
CO_2	8.3 (4.4-12.1)	4.4 (2.2-11.6)	6.6 (5.8-6.8)	8.4 (6.6-9.9)
Alkalinity in $CaCO_3$*	2.4 (2.3-2.5)	2.5 (2.4-2.6)	3.0 (2.8-4.2)	3.1 (2.9-3.3)
$N(NH_3)$	0.005 (0.0-0.01)	0.02 (0.0-0.08)	0.0 (0.0-0.0)	0.15 (0.03-0.42)
$N(NO_2)$	0.002 (0.0-0.004)	0.005 (0.002-0.007)	0.001 (0.0-0.002)	0.004 (0.001-0.006)
$N(NO_3)$	0.025 (0.0-0.05)	0.04 (0.0-0.085)	0.001 (0.0-0.003)	0.07 (0.0-0.17)
PO_4	0.37 (0.35-0.39)	0.22 (0.04-0.42)	0.42 (0.38-0.72)	1.04 (0.42-1.62)
Cl	32.5 (24.0-42.5)	31.0 (23.0-46-4)	20.0 (18.2-24.2)	35.3 (27.0-48-6)
Total hardness in Ca	34.9 (34.6-36.3)	41.3 (34.6-51.1)	39.6 (32.4-46.6)	49.7 (43.9-54.7)
Total hardness in Mg	15.5 (13.8-17.2)	13.6 (12.1-14.6)	15.1 (12.2-18.4)	14.3 912.5-17.2)
SO_4	25.7 (21.8-29.6)	27.0 (19.8-32.5)	23.9 (18.8-24.2)	33.0 (30.4-37.9)
Fe	0.05 (0.0-0.15)	0.07 (0.0-0.10)	0.0 (0.0-0.0)	0.13 (0.05-0.20)
Mn	0.0 (0.0-0.0)	0.01 (0.0-0.03)	0.01 (0.0-0.05)	0.0 (0.0-0.0)
Dry residue	225 (226-284)	258 (238-277)	253 (230-268)	280 (271-295)
Dissolved solids	207 (201-214)	213 (199-225)	234 (210-248)	238 (200-258)
Suspended solids	48 (12-83)	45.5 (13-83)	19 (10-42)	42 (15-95)

cont. Tab. 2

Specification	Lake			
	Kisajno	Mamry Północne	Niegocin	Święcajty
Temperature °C	8.6 (4.8-11.0)	7.2 (3.8-10.5)	8.7 (4.8-11.0)	7.2 (3.8-10.5)
pH	8.2 (8.1-8.32)	8.0 (7.9-8.1)	8.3 (8.1-8.6)	7.9 (7.8-8.1)
O_2	18.4 (16.3 -20.2)	21.4 (20.2-24.5)	16.2 (14.0-18.4)	18.6 916.2-20.2)
BOD_5	4.4 (3.8-4.9)	6.8 (5.4-7.0)	7.6 (6.8-10.2)	5.8 (4.2-6.4)
Oxydability	6.5 (5.3-7.8)	6.2 (6.0-6.8)	8.3 (7.6-9.5)	6.9 (6.5-7.3)
CO_2	0.7 (0.0-2.3)	4.2 (3.8-4.8)	6.2 (4.4-8.2)	6.6 94.4-8.8)
Alkalinity in $CaCO_3$*	2.6 (2.4-2.9)	2.5 (2.4-2.6)	3.0 (2.9-3.2)	2.8 (2.6-2.9)
$N(NH_3)$	0.008 (0.0-0.25)	0.0 (0.0-0.0)	0.10 (0.05-0.18)	0.0 (0.0-0.0)
$N(NO_2)$	0.002 (0.0-0.003)	0.001 (0.0-0.003)	0.004 (0.001-0.006)	0.002 (0.001-0.003)
$N(NO_3)$	0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.06 (0.0-0.18)	0.0 (0.0-0.0)
PO_4	0.26 (0.0-0.47)	0.12 (0.10-0.32)	1.79 (0.66-4.00)	0.23 (0.11-0.35)
Cl	27.6 (23.0-36.0)	23.0 (18.4-32.3)	33.0 (28.0-43.0)	30.0 (22.0-36.8)
Total hardness in Ca	37.7 (31.7-44.6)	38.5 (33.8-43.2)	50.2 (46.8-54.7)	32.8 (28.1-39.6)
Total hardness in Mg	13.3 910.3-15.5)	13.5 (10.8-16.3)	13.3 (12.9-13.8)	14.4 (11.6-17.2)
SO_4	22.9 921.4-23.9)	20.3 (16.9-23.8)	25.0 (16.9-30.4)	27.1 (26.3-28.0)
Fe	0.08 (0.0-0.15)	0.05 (0.0-0.10)	0.13 (0.05-0.20)	0.07 (0.0-0.18)
Mn	0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.01 (0.0-0.03)	0.0 (0.0-0.0)
Dry residue	218 (208-238)	293 (268-318)	325 (291-391)	261 (248-272)
Dissolved solids	206 (200-214)	228 (221-235)	277 (245-288)	232 (226-239)
Suspended solids	12.3 (4-24)	171 (947-295)	52 (3-104)	28.5 (22-35)

Table 3
Aquatic fungi found in particular lakes

Family and species	Lake							
	1*	2	3	4	5	6	7	8
Chytridiomycetes								
Rhizophydium amoebae Karling	–	–	–	s	–	–	–	–
Rhizophydium apiculatum Karling	–	–	–	–	–	–	s	–
Rhizophydium nodulosum Karling	–	–	–	–	–	–	s	–
Polyphagus euglenae Nowakowski	–	–	–	–	–	–	–	s
Chytridium xylophilum Cornu	sa	sa	s	–	sa	sa	sa	sa
Chytriomyces annulatus Dogma	–	–	–	–	–	–	s	–
Polychytrium aggregatum Ajello	–	–	a	sa	–	–	s	–
Nowakowskiella elegans (Nowak.) Schroet.	–	s	–	sa	–	s	–	–
Nowakowskiella macrospora Karling	–	–	a	–	a	–	a	a
Blastocladiopsis parva (Whiffen) Sparrow	s	–	–	–	–	s	–	s
Hyphochytriomycetes								
Hyphochytrium catenoides Karling	–	–	–	–	–	–	s	–
Oomycetes								
Rozellopsis inflata (Butler) Karling	–	–	–	–	s	a	s	s
Myzocytium proliferum Schenk	–	–	sa	–	–	–	–	–
Aphanomyces irregularis Scot	s	s	–	–	–	–	–	–
Aphanodictyon papillatum Huneycutt	–	–	–	–	s	–	–	–
Achlya oligacantha de Bary	–	s	–	–	–	–	–	–
Achlya orion Coker et Couch	–	sa	–	–	–	–	–	–
Achlya polyandra Hildebrandt	–	–	–	s	–	–	–	–
Achlya racemosa Hildebrandt	–	–	–	–	–	–	–	s
Isoachlya anisospora (de Bary) Coker	sa	s	–	–	sa	–	–	–
Saprolegnia ferax (Gruit) Thurnet	sa	–	–	sa	s	sa	sa	–
Dictyuchus monosporus Leitgeb	sa	a	a	sa	a	s	a	–
Leptomitus lacteus (Roth) Agardt	–	s	–	–	–	–	–	–
Pythium artotrogus de Bary	–	s	–	–	–	–	–	–
Pythium debaryanum Hesse	–	a	–	–	–	–	–	sa
Pythium monospermum Pringsheim	–	–	–	–	a	–	s	–
Pythium rostratum Butler	–	–	a	–	–	–	–	–
Pythium ultimum Trow	–	–	–	s	–	–	–	–
Pythium undulatum Petersen	–	–	–	–	–	–	sa	–
Zoophagus insidians Sommerst.	–	–	–	s	–	–	–	–
Endomycetes								
Candida aquatica Jones et Sloof	–	–	–	–	a	–	–	–
Candida tropicalis (Castell.) Berkhout	–	–	–	–	–	–	sa	–
Cryptoccocus albidus Fell et Phaff	–	–	–	–	–	–	a	–
Rhodotorula glutinis (Fres.) Harrison	–	–	–	–	–	–	a	–
Trichosporon cutaneum (de Beur. et al.) Ota	sa	–	s	–	–	–	–	–
Ascomycetes								
Apostemidium guernisaci (Crouan) Boud	–	sa	–	–	–	–	–	–
Hyphomycetes								
Anguillospora longissima (Saccordo et Sydow) Ingold	s	–	–	sa	a	sa	a	a
Arthrobotrys oligospora Fres	sa	sa	–	–	–	–	–	–
Bacillispora aquatica Nilsson	–	s	–	–	–	–	–	–
Clavariopsis aquatica Wildeman	–	–	a	–	–	–	–	a
Dactylaria brochopaga Drechsler	–	–	–	s	–	–	–	–
Dactylella submersa (Ingold) Nilsson	–	–	–	–	–	–	–	s
Fusarium aquaeductum (Radlk. et Rabenh.) Lagerh.	–	–	–	s	–	–	–	–
Lemonniera aquatica Wildeman	–	–	s	sa	s	–	–	–
Robillarda phragmitis Cunnel	–	–	–	sa	–	–	–	–
Tetracladium marchalianum Wildeman	–	–	–	–	–	–	a	–
Triscelophorus monosporus Ingold	–	s	–	–	–	–	–	–
Number of species	9	14	9	13	11	7	17	10

* Lakes: 1 – Dargin, 2 – Dobskie, 3 – Gołdopiwo, 4 – Jagodne, 5 – Kisajno 6 – Mamry Północne, 7 – Niegocin and 8 – Święcajty
s – spring, a – autumn

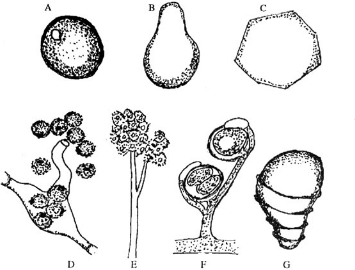

Fig. 2. Aquatic fungi

A – *Rhizophydium amoebae* – sporangium (brown, 10–22 μ); B – *Rhizophydium apiculatum* – sporangium (7–10 x 13–19 μ); C – *Rhizophydium nodulosum* – sporangium (62 μ; D – *Hyphochytrium catenoides* – sporangium and zoospores; E – *Aphanodictyon papillatum* – sporangium; F – *Achlya orion* – oogonium and antheridium; G – *Chytriomyces annulatus* – sporangium (8–40 x 6–28 μ) from folds

The next species new to the Polish hydromycoflora, *Hyphochytrium catenoides,* belongs to the *Hyphochytriomycetes*, and is the first species of this class to be found in Polish waters in the present investigations. Species of the genus *Hyphochytrium* are usually parasites of algae or other species of fungi. *Hyphochytrium catenoides* has been found as a saprophyte on the remains of higher plants and as a parasite of algae of the genera *Nitella* and *Chara*. In the present investigations, this fungus was found in the littoral part of Lake Niegocin in May 1988. It is more widely discribed in soils rather than in water (B a r r, 1970). In addition, it should be noted that *Hyphochytrium catenoides* has been found several times in the waters of the Antarctic which are still comparatively pure (H a r d e r, P e r s i e l, 1962; W i l l o u g h b y, 1971; E l l i s – – E v a n s, 1985). In our case, Lake Niegocin is the most polluted of all the lakes in the group studied. In the littoral part of Lake Kisajno another keratinolytic fungus also occurred, whose habitat is both water and soil. On the other hand, *Achlya orion* belongs above all to aquatic saprophytes being rarely in soil (M i l k o, 1985) through under certain conditions it can lead a parasitic life (P r a b h u j i et. al., 1984). It grows better in periods when the water is shallower, i.e. in autumn – spring (R a o, M a n o h a r a c h a r y, 1983). Its growth was observed in the water taken from the littoral part of Lake Dobskie in May and October 1985.

As was mentioned above, in the littoral water of Lake Święcajty the growth of the spores of a comparatively rare representative of the *Hyphomycetes*, *Dactylella submersa*, was observed in May 1988. This fungus was found on the leaves decaying in the water of some streams in Great Britain by I n g o l d in 1944. The growth of this fungus was next observed in the same biotopes by N i l s s o n .(1962) in Sweden, B a n h e g y i (1962) in Hungary, S l a d e č k o v a (1963) in Czechoslovakia, M a r v a n o v á, M a r v a n (1969) in Cuba, and D u d k a (1974) in Ukraine. In lakes, the growth of *Dactylella submersa* was observed in the Germany by C a s p e r (1965, 1966) and in Poland. The present authors have found this fungus in a pool in the park of Branicki's Palace (C z e c z u g a, M u s z y ń s k a, 1990) and in the water of Lake Jagodne. P e a c h (1950) noted a predatory fungus, *Dactylaria brochopaga* which catches nematodes. We found this fungus in the littoral zone of this lake in May 1988.

Another interesting finding was that of the saprophyte *Blastocladiopsis parva* growing on a snake skin and leaves of grasses in the water of three lakes (Dargin, Północne Mamry, Święcajty). This is the third report of the occurrence of this fungus in Poland. It was first found in the water of a limnocrenik spring in Zwierzyniecki woods (C z e c z u g a et. al., 1989), and then in the water of the lowland river Marycha (C z e c z u g a et. al., 1990).

The studies on aquatic fungi in the Mamry complex revealed the progressive popullation of these lakes by municipal wastes. While in 1988, the sewage fungus *Leptomitus lacteus* was observed only in Lake Dobskie, in 1989 this nitrophilic fungus was found in several other lakes of this complex. Lake Niegocin is particularly highly polluted; this has been confirmed not only by hydrochemical data of the water but also by the presence of 3 out of 5 keratinophilic species and 3 yeast species. The studies on yeasts in different types of lakes in Estonia showed (S o l n t z e v a, V i n o g r a d o v a, 1989) that species such as *Candida tropicalis* and *Cryptoccocus albidus* are most abundant in lakes of greater trophicity, rich in organic compound dissolved in water.

The presence of *Leptomitus lacteus,* keratinophilic fungi and yeasts manifests the effect of municipal wastes drained from the town of Giżycko into Lake Niegocin.

As was mentioned above, the lowest number of species of aquatic fungi was noted in Północne Lake Mamry, whereas Lake Niegocin had the greatest number. It should be noted that both hydrochemical (G i e y s z t o r, O d e c h o w s k a, 1958; O l s z e w s k i, P a s c h a l s k i, 1959; P a s c h a l s k i, 1959) and biological investigations (B e r n a t o w i c z, R a d z i e j, 1960; C z e c z u g a, 1964) which have been carried out for over twenty years have now shown that Północne Lake Mamry was and is most approximate to oligotrophic groups of lakes.

The mean chlorophyll content over a period of two years amounted to 4.4 $\mu g\ l^{-1}$. Some lakes were found to contain chlorophyll in increasing amounts, i.e.: Dargin

(8,4), Jagodne (9.0), Kisajno (12.4), Dobskie (13.3), Święcajty (15.4), and Niegocin (18.1 $\mu g\ l^{-1}$).

Through over twenty years have elapsed since studies on chlorophyll content as an index of the trophicity of the lakes were carried out and despite the fact that their degree of eutrophication has risen (Gliwicz et al., 1980), the order to these lakes according to increasing eutrophication remains the same; Północne Lake Mamry is the least eutrophic whereas Lake Niegocin is the most eutrophic as a result of the inflow of large amounts of municipal wastes. This indicates that such a state of the lake favours the development of different species of aquatic fungi.

In the summer only two species of aquatic fungi were found. Similar observations have been made by other authors in studies on various types of lakes (Suzuki, 1960 a, b; Casper, 1965; Czeczuga, 1990).

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