Verhandlungen der Gesellschaft für Ichthyologie Band 4, 2004, 91-105

Distribution, density and habitat of *Cottus poecilopus* (Heckel, 1836) in Lake Hancza (North East Poland) as compared with the situation in the Luzin lakes (North East Germany)

Verteilung, Dichte und Habitat von *Cottus poecilopus* (Heckel, 1836) im Hanczasee (Nordostpolen) und ein Vergleich mit der Situation in den Luzinseen (Nordostdeutschland)

Jan Kotusz[1], Martin Krappe[2], Jan Kusznierz , Marcin Propiolek[4], Philip Riel[2], Arno Waterstraat[2] & Andrzej Witkowski[1]
[1]University of Wroclaw, Museum of Natural History, ul. Sienkiewicza 21, PL-50–335 Wroclaw
[2]Society of Nature Conservation and Landscape Ecology, Dorfstraße 31, D-17237 Kratzeburg (corresponding author A. Waterstraat; Waterstraat@gnl-kratzeburg.de)
[3]University of Wroclaw, Zoological Institute, ul. Sienkiewicza 21, PL-50–335 Wroclaw
[4]Agricultural University of Wroclaw, Department of Zoology & Ecology, ul. Kozuchowska 5b, PL-51–631 Wroclaw

Summary: The distribution of the Siberian sculpin, *Cottus poecilopus*, in the lakes of the South Baltic basin is currently restricted to Hancza (NE Poland) and the Luzin (NE Germany) lakes. Other populations are extinct due to pollution. The Luzin lake population is highly endangered. In Lake Hancza the littoral habitats were used by sculpins for spawning in spring. The density of sculpins in this time was significantly and positively correlated with the occurrence of cobbles of a diameter between 10 and 20 cm. Sandy bottom was not used by sculpins. Between April and May 2002 the maximum sculpin density in the littoral zone increased from 7.5 to 16.5 ind./100 m shoreline. Most of the year *C. poecilopus* live in the profundal or sublittoral areas. Diurnal vertical movements of sculpins could be observed in August 2002. During the day most of the fish were absent above a depth of 28 m, whereas at dusk and night they migrated up to 16 m. The sediment particle size structure in the Luzin lakes and Lake Hancza did not differ significantly. All these lakes were characterized by dominance of stony bottom in the littoral and by sandy and muddy bottom in the sublittoral and profundal zones. That's why possible changes of the sediments of the Luzin lakes are not responsible for the population decline of the Siberian sculpin.

Key words: Siberian sculpin, *Cottus poecilopus*, glacial relict, habitat use, lake population, seasonal occurrence, spawning migrations, diurnal movements, eutrophication, conservation.

Zusammenfassung: Die Verbreitung der Ostgroppe (*Cottus poecilopus*) im südlichen Ostseeraum ist gegenwärtig auf den Hanczasee (Nordostpolen) und die Feldberger Seen (Luzinseen, Nordostdeutschland) beschränkt. Infolge der Eutrophierung ihrer Wohngewässer sind alle anderen Seepopulationen ausgestorben. Die Luzinpopulation ist ebenfalls gefährdet. Im Hancza-See erhöhte sich im Litoral die Groppendichte von April bis Mai 2002 von 7,5 auf 16,5 Ind./100 m Uferlänge. Die Flachwasserbereiche werden nur im Frühjahr zur Laichzeit genutzt. Die Dichte der Groppen im

Litoral korreliert positiv mit dem Angebot an Steinen der Korngröße 10-20 cm. Sandige Abschnitte werden gemieden. Die übrige Zeit im Jahr leben die Groppen im Sublitoral oder Profundal. Im August 2002 konnten diurnale Wanderungen beobachtet werden. Tagsüber hielten sich die Groppen vorwiegend unterhalb 28 m auf, in der Abenddämmerung und nachts stiegen sie bis auf 16 m auf. Zwischen den Luzinseen und dem Hanczasee konnten keine wesentlichen Unterschiede in den Sedimenten festgestellt werden. Hartsubstrate dominieren in allen Seen im Uferbereich, gefolgt von sandigen Sedimenten und Muddeflächen in der Tiefe. Somit ist davon auszugehen, dass Veränderungen der Sedimentqualität der Luzinseen nicht für den Rückgang der Ostgroppe verantwortlich sind.

Key words: Ostgroppe, *Cottus poecilopus*, Eiszeitrelikt, Habitatnutzung, Seenpopulation, saisonales Auftreten, Laichwanderungen, Nahrungswanderungen, Eutrophierung, Arterhaltung.

1. Introduction

The Siberian sculpin, *Cottus poecilopus*, has a wide holarctic distributionand is ranked among the European "northern species" (Banarescu 1991). It occurs in two centres in the Carpathian-Sudetic and Scandinavian area. The latter is divided into the northern part, which comprises Finland, NE Sweden and a fragment of Norway and the southern part, including S Sweden, SW Norway and the Jütland Peninsula. Besides, isolated localities are known from NW Russia and a few lowland lakes in the south of the Baltic Sea (Witkowski in press). In the South Baltic catchment area *C. poecilopus* is restricted to some lakes in the districts of Holstein, Jütland, Mecklenburg, Pomerania and Suwalki (Tab. 1). In this area the Siberian sculpin is a glacial relict.
Glacial relict fishes and malacostraca colonized the area during the late stages of the Vistulian glaciation about 10.000 years ago. In more then 20 deeper lakes of Germany and Poland such glacial relicts as *Mysis relicta* (Mysidacea), *Pontoporeia affinis* (Haustoriidae), *Pallasiola quadrispinosa* (Gammaridae) and *Cottus poecilopus* (Cottidae) were recorded (Fig. 1, after Segerstrale 1957). These investigations started already at the beginning of the 20th century (Samter 1905, Thienemann 1925, 1928,

Tab. 1: Collections of Siberian Sculpins from the South Baltic populations (MNHUW – Museum of Natural History Wroclaw; MZH – Museum of Zoology Hamburg, BON – Collection Bonito e.V. Feldberg).
Tab. 1: Zusammenstellung von Belegexemparen der Ostgroppe von südbaltischen Populationen (MNHUW – Museum für Naturgeschichte Breslau; MZH – Zoologisches Museum Hamburg, BON – Sammlung Bonito e.V. Feldberg).

locality	date	collector	collection	n
Lake Insko (Pomeranian district)	24.8.1926	Thienemann, A.	MZH	1
Lake Großer Plöner See (Holstein)	1.7.1924	Thienemann, A.	MZH	1
Lake Großer Plöner See (Holstein)	17.8.1926	Hasselley	MZH	2
Lake Großer Plöner See (Holstein)	1885 – 1898	Duncker, G.	MZH	4
Lake Großer Plöner See (Holstein)	-	Duncker, G.	MZH	10
Holtem Aa (Jütland)	21.5.1929	Mohr, E.	MZH	10
Lake Schmaler Luzin (Meckl.)	15.6.1926	Duncker, G.	MZH	1
Lake Zansen (Meckl.)	20.8.1924	Thienemann, A.	MZH	2
Lake Zansen (Meckl.)	1966	Haase, B.	BON	1
Lake Hańcza (Suwałki district)	22.5.1974	Witkowski, A.	MNHUW	73

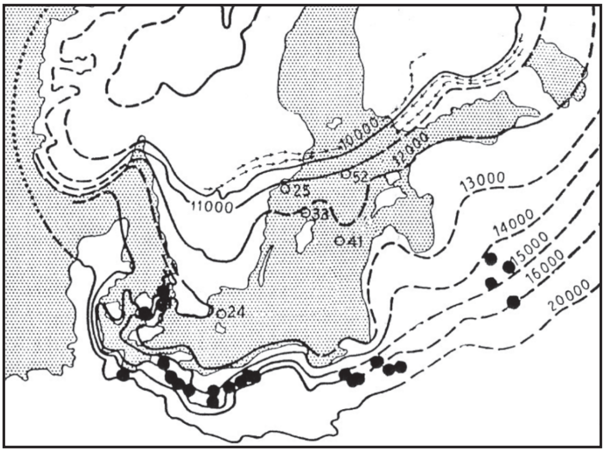

Fig. 1: Ice cap limits during the late stages of the Vistulian glaciation and locations of glacial relicts (from Segerstrale 1957).
Abb. 1: Eisgrenzen im Spätglazial und Lage der Vorkommen von Reliktarten entlang des Eisrandes (aus Segerstrale 1957).

1950, Duncker and Ladiges 1960). In most of the mentioned lakes the glacial relicts are extinct now (Waterstraat 1988, Köhn and Waterstraat 1990). In Germany and Poland the last populations of the Siberian sculpin have survived in the lakes of the Feldberg lake district (Winkler et al. 2002, Knaack 2003) and Lake Hancza (Witkowski 1975, 1984).

Since all the lakes inhabited by *C. poecilopus* are oligo- or mesotrophic, their natural status is endangered by pollution with nutrients. Increased man-produced waste and the intensification of agriculture give rise to problems with nitrate and phosphorus enrichment. The effects of eutrophication in lakes are numerous and well known. Usual symptoms include increased growth of phytoplankton. This production may lead to deoxygenation of the deeper waters, undesirable changes in the fish community and, sometimes, death of fish. In fact, these negative effects of pollution occur in most of the lakes inhabited by *C. poecilopus*.

Another negative human impact is connected with fisheries. One of the most harmful effects can be caused by introduction of predators like the eel, wels or lake trout.

Currently the last not endangered population of the Siberian sculpin in the South Baltic lakes is restricted to Lake Hancza (Witkowski 1975, 1984). In the Luzin lakes the extinction of the species was supposed (Winkler et al. 1991), but a very small and highly endangered population was recently discovered by Knaack (2003). In Germany and Poland programmes to protect these lakes have been adopted in accordance with the Water Directive of the European Union, that now will be implemented. In order to restore the habitat conditions suitable for the Siberian sculpin, the ecological demands of this species largely unknown as yet have to be known. Our investigations in Lake Hancza and the Luzin lakes try to fill some of these gaps.

2. Investigation area, material and methods

Lake Hancza is situated in NE Poland in the Suwalki district (Fig. 2). It is the deepest lake of the whole Central European lowland (Cydzik et al. 1995). Beside *C. poecilopus*, another glacial relict, the amphipod *Pallasiola quadispinosa*, inhabits the lake (Niedomagala 2002).

The Luzin lakes are part of the Feldberg lake area in the Mecklenburg-Strelitz district, a part of the federal state Mecklenburg-Vorpommern in NE Germany (Fig. 2). In the past all these lakes were oligotrophic.

The genesis of Lake Hancza is quite similar to that of the Luzin lakes, especially of Lake Schmaler Luzin. Both areas were influenced by the Saale glaciation and formed by the glaciers of the Vistulian glaciation (Bajkiewicz-

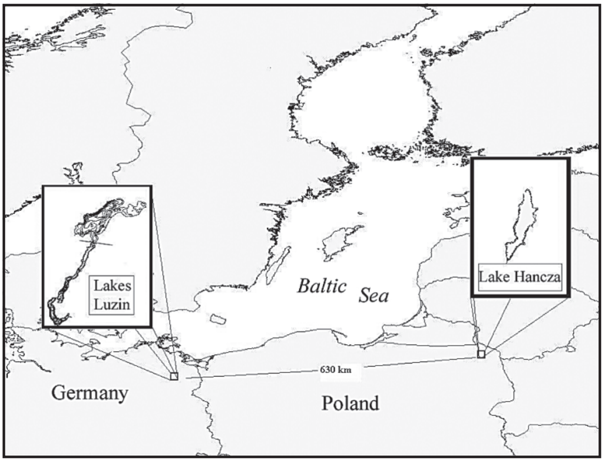

Fig. 2: Map of the localization of Lake Hancza and the Luzin lakes.
Abb. 2: Lage der Untersuchungsgebiete Hanczasee und Luzinseen.

Tab. 2: Lake characteristics.
Tab 2: Seencharakteristik.

		Lake Breiter Luzin	Lake Schmaler Luzin	Lake Hańcza
Altidude (m)		84.2	84.2	229
area (ha)		268	134	311
volume (mio m.ł)		67.5	20.6	120.4
max. depth (m.)		58.5	34	113.5
mean depth (m.)		25.2	14.7	38.7
shoreline (km.)		13.2	14	11
watershed (km˛)		14	?	39.7
flushing rate (a)		15 – 20	?	4.4
trophic situation	1950	oligotrophic	oligotrophic	oligotrophic
	1990	meso-eutrophic	eutrophic	oligo-mesotrophic
	2002	meso-eutrophic	mesotrophic	mesotrophic

Grabowska 1994 cit. in Dobek 2002, Schmidt 1997). Glaciation resulted in a large litho-littoral zone, which is unusual for lowland lakes of Central Europe. Different geographic areas, the higher latitude and bigger depth of Lake Hancza as well as the significant pollution of the Luzin lakes are responsible for the ecological differences (Tab. 2).
To confirm the occurrence of Siberian sculpins, a preliminary electrofishing of the lake took place in May 2001. In the littoral zone of the shore of Lake Hancza we chose three sites of visibly different types of lake bottom. Those sites were selected after thorough inspection of the whole shoreline of the lake. Shore sites with completely sandy bottom were excluded, because no animals could be caught. During the whole study period the sampling sites, with a total of 850 m in length, were electrofished nine times with an AC-impulse electrofishing backpack-gear. Each fish caught was anaesthetised with MS 222, then measured (Tl with an accuracy of 1 mm; weight with an accuracy of 0.5 g) and individually marked by injection of colour elastomeres. A coloured stone (white in April and yellow in May) was used to mark the precise position of each fish previously caught.
To study environmental requirements of the Siberian sculpin in the littoral zone, all chosen sites were divided into sections of 10 m in length with white vertical lines painted on shore trees or boulders. In each section a belt of 3 m in width (from the bank) was checked

by electrofishing. For all 83 sections the following parameters were estimated visually:

- percentage of bottom substrate of different particle diameter
- percentage of area covered by dead branches and sticks
- percentage of area covered by detritus
- percentage of area covered by living tree roots
- available interstices (estimated by category 1-3).

We used this investigation design, because it is sufficent for observations of habitat preferences as well as for mark-recapture and migration studies. The microhabitat of each fish – a circle of 1 m in radius around the fish position – was described by using the same methods as for 10 m sections (see above).

From August 20th to 23rd, 2002, the summer vertical distribution was investigated by scuba diving. At different daytimes and sites, standardized line transects were controlled by divers. A standard transect was defined as a line orthogonal to the shore, which started at the surface and ended up at 30 m. Each sculpin found within the visual range (3-4 m) was registered with regard to the depth and the substrate type of the site. Altogether 61 transects were controlled.

Scuba diving was also used to investigate the sublittoral and profundal sediment structure in the lakes. The sediment composition of the Luzin lakes was estimated visually every 10 m on standardized line transects (rectangualar to the shore) of 100 m; gravel and sand concentrations were analyzed separately. In Lake Hancza only a survey of the sublittoral and profundal sediment structure was made. Water temperature and oxygen concentration was measured *in situ* (WTW Oxi 197 S) in 1 m intervals.For statistical analysis, the programme Statistica 5.01 (© StatSoft Inc.) was used. To test the effect of habitat use at different sites, an analysis of variance (one-way ANOVA) was applied. Spearman's correlation analyses were employed to compare the density of fishes with the resource quality at different sections.

3. Results

3.1. Seasonal occurrence and density of *Cottus poecilopus* in the shore zone of Lake Hancza

We observed *C. poecilopus* specimens in the littoral zone only in springtime (Fig. 3). The first two individuals in our sections were caught after icebreak at the end of March 2002. During the next two months the total number of fishes caught in this sections increased to 137. At the beginning of June only one individual was found. From Juli until the end of November no individuals were caught in the area investigated. From the 57 fishes individually marked in April, only one was recaptured during the electrofishing conducted 27 days later, whereas from the 137 sculpins marked in May we did not receive any recapture information until the end of June. The recaptured specimens moved a short distance (25 m) horizontally. These results suggest that the temporary residence of a given individual in the littoral zone of Lake Hancza does not last more than 30 days.

In all studied sites we observed an increase of fish density between April and May from 7.5 to 16.5 ind./100 m of shoreline. Differences in fish density between the three examined sites resulted from the diversity of habitat resources available to the sculpins.

Among the 199 fishes caught in spring all size classes were present (means: 65.4 mm; 4.7 g). The biggest specimen reached 120 mm (20 g) and the smallest 30 mm (0.5 g). There were no statistically significant differences between samples from the three sites in the total length distributions ($p>0.05$, one-way ANOVA). We observed that in April the specimens appearing at the shore were slightly larger than those caught in May (for variables Tl and w: $p<0.01$, Whitney-Mann-U-test). On May 12th, 2004 one nest with an egg clutch has been found in the shallow water (depth of 20 cm) of Lake Hancza. The clutch in the eyed egg

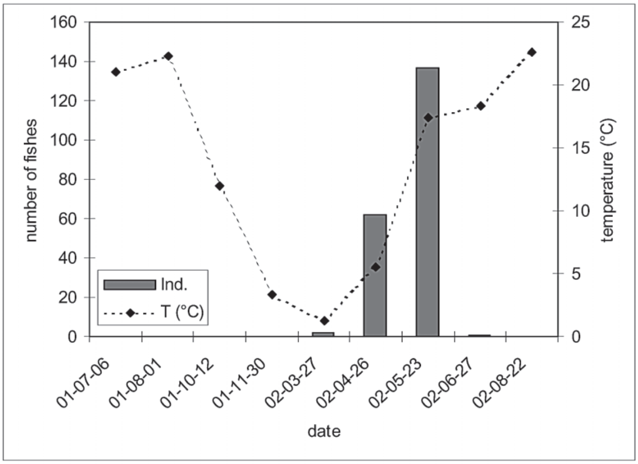

Fig. 3: Total number of fishes caught in 83 sections with a total length of 830 m in the littoral zone and the temperature of coastal water (0.3 m in depth) at nine times in Lake Hancza.
Abb. 3: Gesamtfang innerhalb der 83 Fangstrecken von insgesamt 830 m im Litoral des Hancza-See im Vergleich mit dem Temperaturverlauf (in 0,3 m Wassertiefe) zu neun Terminen.

Tab. 3: Mean percentage of available and used habitat recources (significance level of ANOVA one-way for 83 sections of shoreline and localities (n = 199) where sculpins were caught). *Estimated visually by categories: 1 – low, 2 – medium, 3 – high.
Tab. 3: Mittelwerte der verfügbaren und genutzten Habitatressourcen mit Signifikanzlevel der einseitigen ANOVA für 83 Sektionen des Ufers und der 199 Fangstellen von Groppen. *Durch Sichtkontakt nach Kategorien geschätzt: 1 – niedrig, 2 – mittel, 3 – hoch.

	particle diameter (mm)	habitat recources available (n=83)	habitat used (n=199)	F	p
detritus		2.71	4.57	4.34	0.038
sand	<2	11.33	5.19	11.12	0.001
small gravel	2–20	8.37	2.85	19.83	0.000
large gravel	20–50	9.82	8.39	0.97	0.325
small cobbles	50–100	11.81	15.43	3.68	0.056
large cobbles	100–200	22.71	34.80	18.34	0.000
stones	200–300	17.10	14.76	1.02	0.313
bolders	>300	16.08	13.89	1.03	0.311
dead branches		7.86	4.82	4.63	0.032
vegetation		2.53	0.10	7.25	0.008
tree roots		4.22	2.50	3.00	0.084
interstices availability*		1.71	1.69	0.05	0.825

stage stuck at the inside wall of a large stone with 20 cm in diameter. A nest guarding male was not observed.
We failed to find the Siberian sculpin in the Luzin lakes, but a few specimens have been observed by Knaack (2003) in the littoral and profundal zone of Lake Breiter Luzin.

3.2. Habitat use by *Cottus poecilopus*

A comparison of available and used habitats of the Siberian sculpin in the Lake Hancza littoral zone shows that the species clearly prefers large cobbles (particle size of 10-20 cm) and avoids places with a large share of

sand and small gravel in the bottom substrate (ANOVA one-way, p<0.01) (Tab. 3). The fishes avoid places with macrophyte vegetation (p<0.01), dead branches and/or detritus (p<0.05). The other habitat parameters seem to be less important (Tab. 3).
Similar results were obtained by a correlation analysis using the number of fish caught in different lake sections and the available habitat resources of these sections. To minimize systematic bias, only one catch period (May 2002) was taken into account in this analysis. The positive correlation (Tab. 4) between fish density and percentage of large cobbles was highly significant (p<0.001)
The regression line (Fig. 4) shows the abundance of sculpins increasing with a rising share of large cobbles in the bottom substrate of Lake Hancza.

3.3. Vertical distribution and circadian movements of *Cottus poecilopus* in summer

The littoral catches, which were carried out in summer, autumn, and winter, until the appearance of the first ice cover (beginning of December), revealed that *C. poecilopus* stayed in deeper zones of Lake Hancza during these seasons. This was confirmed by an underwater observation of sport-divers in August 2001. One specimen was caught in the east side of the lake bed at a depth of 29 m. Therefore, we suggest that the occurrence of sculpins in summer starts in depths below 20 m.
By subsequent regular studies with scuba equipment it was possible to describe the *C. poecilopus* distribution in Lake Hancza during the summer stagnation period (August 2002). Altogether, 18 individuals were caught in 61 transects (Fig. 5).
The minimum depth where sculpins occurred was 9 m, but most individuals were noticed below 20 m, i.e. below the thermocline (Fig. 6). The scattered occurrence found in the studied transects also may reflect a pattern of distribution typical for deeper (not examined) zones. All observed individuals stayed on soft bottom (organic lake sediment, mussel shells, clay or fine silt), except for one individual found on a wreck. The deepwater microhabitats utilized by *C. poecilopus* significantly differed from the spring microhabitat, which was full of shelters (stones, roots, dead branches etc.). Most of the individuals were recorded during night observations (Fig. 5). The probability of finding one individual in one transect equalled p = 0.47 and p = 0.05 at dusk or night and at daytime, respectively. We suppose, that this reflects the diurnal distribution of the individuals, because no shelter or other hiding places were present between 9 and 28 m. During the day most of the individuals obviously went into deeper zones of the lake.

Tab. 4: Spearman correlation coefficient (Spearman r) between available habitat resources (sections: n=83) and density of *Cottus poecilopus* (n=137) of Lake Hancza in May 2002
Tab. 4: Spearmans Korrelations Koefizient (Spearman r) zwischen dem verfügbaren Habitatangebot (n = 83 Sektionen) und der Dichte von *Cottus poecilopus* (n = 137) im Mai 2002 im Hanczasee.

	Spearman r	p
detritus	-0.074	0.508
sand	-0.141	0.202
small gravel	-0.230	0.036
large gravel	-0.216	0.050
small cobbles	0.117	0.293
large cobbles	0.555	0.000
stones	-0.058	0.600
bolders	0.229	0.037
dead branches	-0.038	0.735
vegetation	0.211	0.055
tree roots	-0.008	0.946
interstices	0.144	0.195

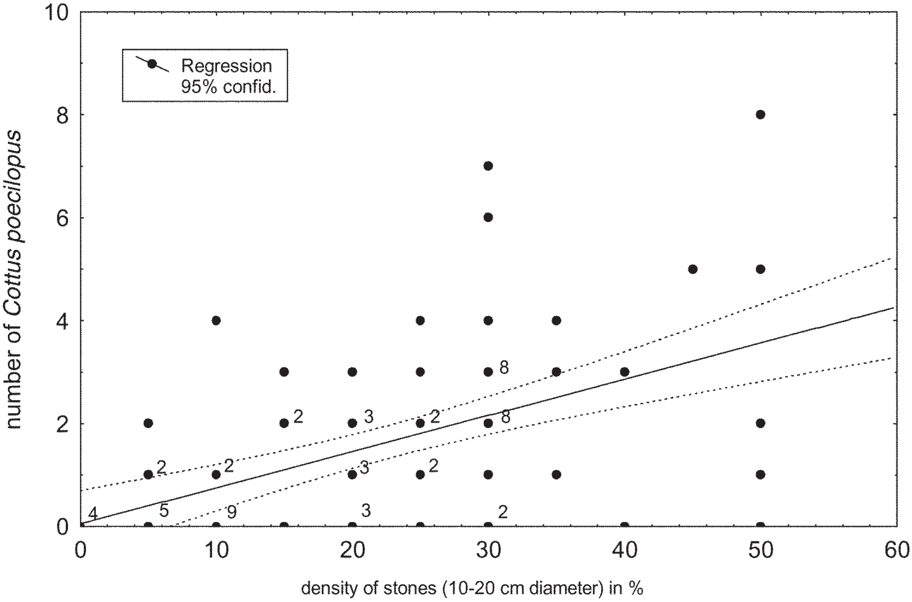

Fig. 4: Regression line of *Cottus poecilopus* abundance in May 2002 in relation to the portion of large cobbles (particle size 10-20 cm, r = 0.52977; number of sections = 83; number of individuals caught = 137; numerical indices mean the number of cases for each point).
Abb. 4: Regression der Abundanz von *Cottus poecilopus* im Mai 2002 in Abhängigkeit von Vorkommen großer Steine (Korngröße 10-20 cm, r = 0,52977, 83 Sektionen, 137 gefangenen Tiere, Ziffern entsprechen der Anzahl Fälle je Punkt).

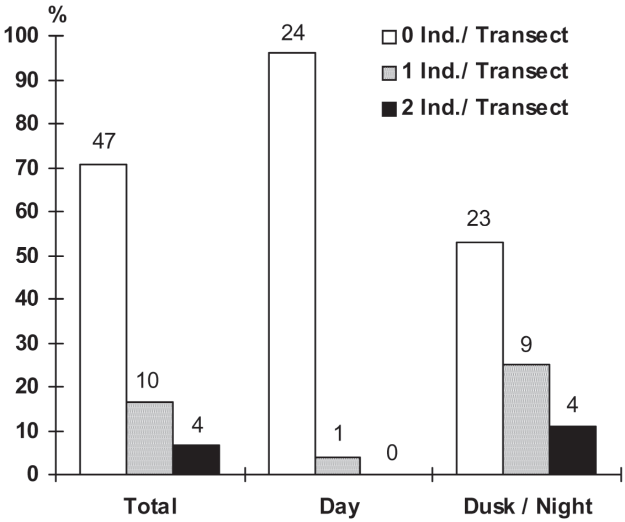

Fig. 5: Percentage distribution of *Cottus poecilopus* in Lake Hancza in relation to the time of the day (numbers above the bars indicate the total number of transects).
Abb. 5: Prozentuale Verteilung der Anwesenheit von *Cottus poecilopus* zu den verschiedenen Tageszeiten im Hanczasee (die Zahlen über den Säulen entsprechen der Anzahl der jeweils betauchten Transekte).

3.4. Comparison of habitat quality in Lake Hancza and Lakes Luzin

The highest summer epilimnetic temperature observed in Lake Hancza did not exceed 23 °C, while in the Luzin lakes temperatures up to 25 °C are possible. During the summer stagnation the metalimnion (temperature shifts > 1 °C m^{-1}) in both lakes is situated between 6 and 13 m depth. The beginning

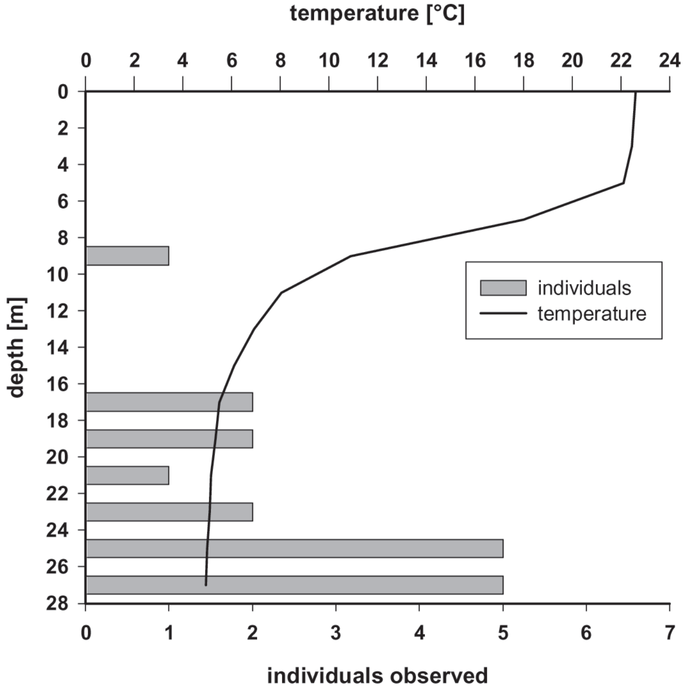

Fig. 6: Vertical distribution of *Cottus poecilopus* in Lake Hancza during the summer stagnation in August 2002 (total number of observed individuals: 18, approximately constant effort for each depth in the range from 0 to 28 m).
Abb. 6: Vertikalverteilung von *Cottus poecilopus* im Hanczasee im August 2002 während der Sommerstagnation (Gesamtzahl der beobachteten Tiere: 18, annähernd konstanter Untersuchungsaufwand für jede Tiefe im Bereich von 0-28 m).

of water circulation is observed from mid-October. Homothermy in the whole water column falls on the turn of November in Lake Hancza, whereas in Lake Breiter Luzin it does not occur before January. Usually, from mid-December up to the end of March the surface of Lake Hancza is covered by ice. In the Luzin lakes years without permanent ice cover alternate with those of ice cover present in two or three winter months. In the first half of April in the Luzin lakes and in the second half of this month in Lake Hancza the temperature of the surface water increases slightly. The oxygen concentration in the Lake Hancza waters during the summer stagnation is very high. Even at a depth of 60 m it does not drop below 8 mg/l (Fig. 7). The eutrophication of Luzin lakes is expressed in a characteristic metalimnetic and hypolimnetic depletion of oxygen concentration during the period of summer stagnation. At the end of summer the oxygen concentration in the whole water column below 10 m does not reach more than 6 mg/l.

The littoral of Lake Hancza and Lakes Schmaler and Breiter Luzin is dominated (60-70% of the shore) by cobbles, stones and bolders (Tab. 5). In Lake Hancza the share of this particle sizes in the 83 investigated sections, representing 89% of the shore line, totals 69.7 % (Tab. 3). Sand and gravel are the dominating sediments of the other third of the lake littoral.

The sublittoral and profundal areas in all lakes are dominated by sandy and muddy substrates. Twenty transects in the Luzin lakes were analyzed by scuba diving. Stones were regularly found in the upper 5 m layer, in one transect also down to 20 m. The mean maximum depth of stony bottom was 8.6 m. The highest concentration of sand was found in the sublittoral zone. The maximum depth of sandy bottom recorded was 27.0 m, the mean maximum depth was 17.0 m. In the deepest areas organic matter occurred. Muddy bottom was observed at a minimum depth of 7.0 m and 15.8 m on average. The only specific character of Lake Hancza was

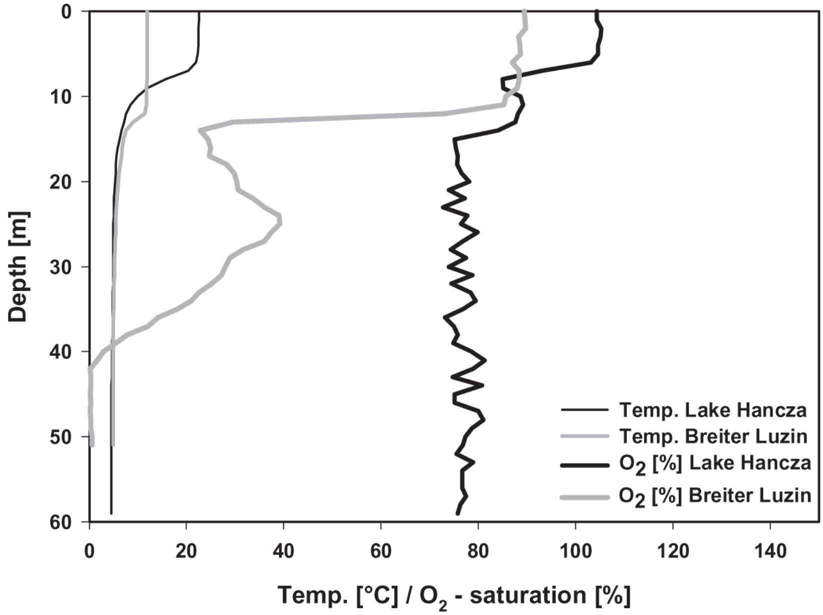

Fig. 7: Profiles of temperature and oxygen saturation during the summer thermocline in Lake Hancza (Aug. 22, 2002) and Lake Breiter Luzin (Oct. 8, 2003).
Abb. 7: Temperatur- und Sauerstoffsättigungsprofil im Hanczasee am 22. August 2002 und im Breiten Luzin am 8. Oktober 2003 während der Sommerstagnation.

that the transitional section between sand and mud began at 20-25 m deep, in a single transect 10-20 m.

4. Discussion

Cottus poecilopus has not been recorded to migrate vertically in the annual cycle yet. However, available data on its biological traits concern mainly stream populations, studied both in natural and laboratory conditions (Andreasson 1973, Cichar 1969, Orsag and Zelinka 1974, Starmach 1962, 1962a, 1965, 1971, Jurajda 1992). Ecological data of lake populations are scanty (Witkowski in press).
In Lake Hancza, the spring vertical migrations are not directly induced by thermal conditions. At the beginning of the upward

Tab. 5: Precentage of different sediments on the shore line of the investigated lakes (for Lake Hancza after Dobek 2002).
Tab. 5: Prozentualer Anteil der verschiedenen Sedimentklassen imFlachwasserbereich der untersuchten Seen (im Hanczasee nach Dobek 2002).

<table>
<tr><th>Sediment class dominance</th><th>Breiter Luzin</th><th>Schmaler Luzin</th><th>Lake Hańcza</th></tr>
<tr><td>> 200mm</td><td>14%</td><td>48%</td><td rowspan="2">64%</td></tr>
<tr><td>200 mm - 63mm</td><td>45%</td><td>24%</td></tr>
<tr><td>63 mm - 2 mm</td><td>4%</td><td>2%</td><td rowspan="2">36%</td></tr>
<tr><td>(<2 mm)</td><td>22%</td><td>22%</td></tr>
<tr><td>rhizomes</td><td>15%</td><td>4%</td><td>-</td></tr>
</table>

migration the temperature of the surface is very low (1.1-1.3°C). Individuals that come later to the shoreline area enter much warmer water (up to 17 °C) (Fig. 3). The appearance of sculpins in the littoral zone during spring, observed in this population, is probably caused by the spawning migration to the areas where the fishes find more favourable conditions for reproduction and offspring development. The sublittoral and profundal zones of the lake are dominated by sandy and muddy bottom, whereas stony substrate is the obligatory bottom type in spawning habitats of stream populations (Starmach 1962a, b), since *C. poecilopus* adopts shelters between stones as nests (speleophilous reproductive guild; Balon 1981). Moreover, in the places chosen for nests, the males remove all the mud and fine gravel before spawning and during the whole incubation period of the eggs. They also clean the underside of the stone that has been selected for the attachment of eggs (Starmach 1962a, b). Thus the suitable spawning conditions can only be provided by the littoral zones of the investigated lakes. For instance, nests with egg clutches were observed in the littoral of Lake Hancza in May 1984 by one of the authors (Witkowski in press). In Mai 2004 we could confirm this observation. This is also the month with the highest density of *C. poecilopus* in the littoral zone. Our data suggest that stones of 10-20 cm in diameter are the most preferred by the Hancza population.

Migrations into the littoral zone have not been reported from Scandinavia where *C. poecilopus* is fairly abundant in lakes and reservoirs (Nybelin 1969, Andreasson 1972, Kullander 2002). Probably this behaviour does not occur there. Scandinavian lakes are colder and less eutrophic than Lake Hancza. Therefore the whole bottom, and not only the littoral, may supply sculpins with suitable habitats during the entire year. The spawning migration in the life-cycle is not a typical trait of the freshwater *Cottus* species, although it has been documented for some Far-Eastern Asiatic and American species *C. kazika*, *C. hangiongensis* (Lucas and Baras 2001), *C. rhotheus* (Thomas 1973) and *C. asper* (Krejsa 1967).

The summer migration of Siberian sculpins into the deeper, hypolimnetic zone of Lake Hancza is probably caused by high temperature of the surface water. In July and August it reaches more than 22 °C (Fig. 3), whereas the lethal temperature for this stenothermophilic species tested on a stream population is 24 °C (Starmach 1965).

The distribution pattern of sculpins in the lake-bed sublittoral and profundal sections of Hancza is hardly known, but it should, at least partly, be correlated with food distribution. As *C. poecilopus* feeds on various crustaceans (Orsag and Zelinka 1974), we expected that it also feeds on the amphipod *Pallasiola quadrispinosa*, which is abundant in Lake Hancza profundal zone; the summer densities of this amphipod range from to 120-150 ind./m^2, as estimated in 2000 and 2002 by Niedomagala (2002) and Riel (2003). Moreover, a seasonal habitat shift has been recorded for *P. quadrispinosa*. During summer this invertebrate concentrates below the thermocline, but in spring and autumn it is noted in the littoral, too (Niedomagala 2002). This phenomenon may be the reason for the sculpin distribution and migrations, but our hitherto obtained data on its diet composition during the spawning period do not support this assumption. During the spawning season *P. quadrispinosa* occurs at a depth below 1 m (Niedomagala 2002), whereas *C. poecilopus* is observed in shallower places, feeding on other invertebrates.

Further research is also necessary to interprete the observed circadian profundal summer movements of *C. poecilopus* in Lake Hancza. During the day most individuals remain below a depth of 28 m, whereas at night they migrate up to 16 m. Andreasson (1969, 1972), Müller (1970) and Starmach (1962b, 1965) describe *C. poecilopus* as night-active in summer. Thus, the sculpin's occurrence in shallower zones at dusk and night-time could be simply an effect of increased locomotory activity. However, this type of migration could also be caused by other reasons, e.g. the preference for deeper and darker profundal habitats during the daylight, which serve as shelters, and for shallower sites at twilight and during night foraging. However, it cannot be excluded that sculpins follow their prey. Vertical diurnal migrations of crustaceans are described for different species (Pothoven et al. 2000). Niedomagala (2002) supposed that *P. quadrispinosa* can reduce the feeding pressure of predators in this way. As *C. poecilopus* prefers relatively constant temperature within a range of 2 °C (Fig. 7), the hypolimnetic temperature gradient can also be an important factor which influences circadian migrations in summer. The oxygen concentration in the whole water body of Lake Hancza is very high, at high and low temperatures (Fig. 7), and therefore this factor does not seem to be decisive in migration behaviour.

Comparing the abundance of the Siberian sculpin in Lake Hancza and in the Luzin lakes some possible reasons of its decline in German localities became evident. The lakes examined are fairly similar in thermal conditions and bottom structure. These two factors together with oxygen concentration and flow intensity (in rivers) are regarded as critical for the survical of *C. poecilopus* (Andreasson 1969, Starmach 1962b, 1971). Another ecological factor of vital importance is the availability of food, which also is comparable in the investigated lakes. Riel (2003) has not found significant differences between Lake Hancza and Luzin Lakes with respect to the abundance and species diversity of macroinvertebrates. However, the macroinvertebrate communities of the two lakes are distinguished by occurrence of different relic crustaceans. In the Luzin lakes, the mysid *Mysis relicta* occurs in the profundal zone instead of *P. quadrispinosa* (Waterstraat 1988). Like *P. quadrispinosa* in Lake Hancza, the mysid is known to migrate vertically in a diurnal cycle (Waterstraat and Krappe 2003, Scharf and Koschel 2004). Although the importance of the two crustaceans in the diet of the Siberian sculpin is not entirely known, they may replace each other as food component.

The main dissimilarities in ecological conditions between the Polish and German lakes investigated originate in the different intensity of human impact. The Suwalki region in Poland is sparsely populated, only one small village is settled next to Lake Hancza. The oxygen concentration is high in the whole water body of this lake, whereas in the Luzin Lakes, which are under more intensive anthropogenic pressure (densely populated area), a large part of the hypolymnion is poor of oxygen. Before the restoration of Lake Schmaler Luzin at the end of the 1990s, the majority of the hypolimnion totally lacked oxygen during summer (Koschel et al. 2001). In this lake the Siberian sculpin and *Mysis relicta* have been extincted. The same process of oxygen loss has been observed in Lake Breiter Luzin. Simultaneously, H_2S-formation at the bottom has been reported since 1976 (Richter 1982). Currently, the maximum O_2-concentration in the hypolimnion falls below 6 mg/l and no oxygen can be detected below 40 m at the end of the summer stratification period. Eutrophication effects have destroyed the profundal habitats of *C. poecilopus* and this factor seems to be one of the most crucial reasons for the decline of sculpins.

Another reason for the endangering of sculpin in the Luzin lakes may be eels, opportunistic feeders that could easily adapt to feeding on sculpins. The first introduction into these isolated lakes was probably made in the beginning of the 20th century. In the Feldberg region lakes were intensively stocked with eels, especially in the last fifty years. For example, in the 1980s annual stocking of Lake Breiter Luzin with 50 kg of elvers or 20 kg of older juveniles was a common procedure. At this time, the fisherman catches yielded 2-3 kg/ha. Today the percentage of eels in the littoral fish fauna of the Luzin lakes reaches 5.8-14.6%, as revealed by our investigations. High numbers of this predators may have caused a rapid increase of mortality in the sculpins and a strong decrease in its population size.

In order to reduce the harmful influence of human activity in the Feldberg region, a restoration programme for Lake Schmaler Luzin has been started recently. Thanks to this programme, the oxygen concentration in the hypolimnion recorded during the summer stagnation season has rapidly increased (Koschel and Dietrich 2000, Koschel et al. 2001). The first species recovered in the lake was *Mysis relicta* (Waterstraat and Krappe 2003, Scharf and Koschel 2004), which has immigrated from the neighbouring Lake Breiter Luzin. Here the conditions have improved and especially the total phosphorus loading has dropped (Scharf and Koschel 2004). Nevertheless, further endeavour is necessary to impede the eutrophication of this lake. To rescue the highly endangered last German population of the Siberian sculpin, the input of nutrients should be reduced and an effective fishery management is needed.

Acknowledgements

We are grateful to Rüdiger Bless, Klaus Peter Zsivanovits (Federal Nature Conservation Agency), Anika Börst, Dirk Lämmel, Franziska Neubert, Marion Rumpf, Ralf Schachler (Society of Nature Conservation), Wolfgang Jansen, Roland Lemcke, Klaus Ubl (Institute of Fishery Rostock) for their assistance in field investigations. We also appreciate the help of fishermen U. Frankiv (Fishery Lakes Luzin), Henryk Kuprewicz (Fishery Lake Hancza) and Robert Stabinski (Polish Angling Association, Suwalki).

We would like to express our thanks to Renata Brasinska for linguistic improvement of the manuscript.

The study was funded by the Federal Nature Conservation Agency and the Ministry of Environment in Mecklenburg-Vorpommern. The research in Lake Hancza was conducted in agreement with the permission of Ministry of Environment of the Polish Government no. DOPog.-4201-01-1/02.

Literature

Andreasson, S. 1969. Locomotory activity patterns of *Cottus poecilopus* Heckel and *C. gobio* L. (Pisces). Oikos 20, 78-94.

Andreasson, S. 1972. Distribution of *Cottus poecilopus* Heckel and *Cottus gobio* L. (Pisces) in Scandinavia. Zool. Scripta 1, 69-78.

Andreasson, S. 1973. Seasonal changes in dial activity of *Cottus poecilopus* and *C. gobio* (Pisces) at the Arctic Circle. Oikos 24, 16-23.

Balon E.K. 1981. Additions and amendments to the classification of reproductive styles in fishes. Env. Biol. Fish. 6, 377-389.

Bajkiewicz-Grabowska, E. 1994. Charakterystyka fizycznogeograficzna hydrograficzna Suwalskiego Krajobrazowego-zwiazki z krajobrazem, stan eutrofizacji, kirunki ochrony. Zesz. nauk. PAN 7, 15-31.

Banarescu, P. 1991. Zoogeography of Fresh Waters, Vol 2: Distribution and Dispersal of Freshwater Animals in North America and Eurasia. Aula Verlag, Wiesbaden.

Cichar J. 1969. Taxonomical and ecological notes on *Cottus gobio* Linneaus, 1758, and *Cottus poecilopus* Heckel, 1836 (Osteichthyes: Cottidae). Acta Soci. Zool. Bohem. 33, 102-110.

Cydzik, D., Kudelska, D., Soszka, H. 1995. Atlas stanu czystosci jezior badanych w Polsce w latach 1989-1993. Panstwowa Inspekcja Ochrony Srodowiska, Biblioteka Monitoringu Srodowiska. Warszawa.

Dobek, I. 2002. Mikrofauna bezkregowa litolitoralu jeziora Hancza. Katedra Ekologii i Ochrony Srodowiska. Akademia Podlaska w Siedlcach, Siedlce.

Duncker, G., Ladiges, W. 1960. Die Fische der Nordmark. Abh. Verh. Naturwiss. Ver. Hamburg; N.F. Bd. 3 (Suppl.). Cram, De Gruyter & Co. in Komm., Hamburg.

Jurajda, P. 1992. Fecundity of the Siberian sculpin (*Cottus poecilopus*). Folia Zool. 41, 63-68.

Knaack, J. 2003. Neunachweis und Beobachtungen an der Ostgroppe, *Cottus poecilopus* (Heckel, 1836) in Feldberger Seen (Mecklenburg/Vorpommern). Z. Fischkunde 6, 19-27.

Köhn, J., Waterstraat, A. 1990. Recent distribution of glacial relict Malacostraca in the lakes of Mecklenburg. Ann. Zool. Fenn. 27, 231-235.

Koschel, R.H., Dittrich, M. 2000. Induzierte hypolimnische Calcitfällung: Die Anwendung einer neuen Ökotechnologie zur Restaurierung des Schmalen Luzins, pp. 28-47. In: Uckermark-Report (Landesanstalt für Großschutzgebiete des Landes Brandenburg, Hrsg.).

Koschel, R., Dittrich, M., Kasprzak, P., Mehner, T., Roßberg, R, Scheffler, W. 2001. Restaurierung Schmaler Luzin (Mecklenburg-Vorpommern): Vier Jahre Kombination von künstlicher Calcitfällung und Belüftung im Hypolimnion eines eutrophen Sees, pp. 543-548. Eigenverlag der DGL, Tutzing, Dt. Ges. Limn. Jahrestagung 2000 Magdeburg. Erweiterte Zusammenfassungen.

Krejsa R.J. 1967. The systematics of the Prickly Sculpin, *Cottus asper* Richardson, a polytypic species. Patr II. Studies on the life history, with especial reference to migration. Pacific Science 21, 414-422.

Kullander, S.O. 2002. Swedish Fishes: Check List of Swedish Fishes. World Wide Web electronic publication. Swedish Museum of Natural History. http://www.nrm.se/ve/pisces/allfish.shtml.en

Lucas M.C., Baras E. 2001. Migration of Freshwater Fishes. Blackwell Science, Boston.

Müller K. 1970. Die Tages- und Jahresperiodik der Buntflossenkoppe *Cottus poecilopus* Heckel am Polarkreis. Oikos (Suppl.). 13, 108-121.

Niedomagala**,** W. 2002. Populacja reliktowego skorupiaka *Pallasiola quadrispinosa* (Sars, 1876) w jeziorze Hancza. Instytut Zoologii. Warszawa, Uniwersytet Warszawski.

Nybelin, O. 1969. Om stensimpans, *Cottus gobio* L., och bergsimpans, *C. poecilopus* Heckel, utbredningshistoria i södra och mellersta Sverige. Acta Zool. Reg. soc. scient. litt. Gothoburg 4, 1-56.

Orsag, L., Zelinka, M. 1974. Zur Nahrung der Arten *Cottus poecilopus* Heck. und *Cottus gobio* L. Zool. Listy 23, 185 - 196.

Pothoven, S.A., Fahnenstiel, G.L., Vanderploeg, H.A., Luttenton, M. 2000. Population dynamics of *Mysis relicta* in southeastern Lake Michigan, 1995-1998. J. Great Lakes Res. 26, 357-365.

Richter, W. M. 1982. Zum Sauerstoffhaushalt der Gewässer der Feldberger Seenplatte an Hand ausgewählter sommerlicher Tiefenprofile seit 1924 und 1962, Teil I. Acta hydrochim. hydrobiol. 10, 611-622.

Riel, P. 2003. Untersuchung zur Eignung der Oberen Feldberger Seen als Lebensraum für die Ostgroppe (*Cottus poecilopus* Heckel, 1836). Diplomarbeit, Zoologisches Institut. Greifswald, Universität Greifswald.

Samter, M. 1905. Die geographische Verteilung von *Mysis relicta, Pallasiella quadrispinosa, Pontoporeia affinis* in Deutschland als Erklärungsversuch ihrer Abstammung. Anhang zu den Abhandlungen d. kgl.-preuß. Akademie der Wiss. vom Jahre 1905, Berlin.

Scharf, J., Koschel, R. 2004. Distribution, abundance and life history of *Mysis relicta* (Loven) in the Feldberg Lake District, Germany. Limnologica, in press.

Schmidt, W. 1997. Das Feldberger Seengebiet. - Werte der Deutschen Heimat. H. Böhlaus Nachf., Weimar.

Segerstrale, S. G. 1957. On the immigration of the glacial relicts of northern europe, with remarks on their prehistory. Comment. Biol. Soc. Scient. Fenn. 16, 1-117.

Starmach, J. 1962a. Tarlo glowacza pregopletwego *Cottus poecilopus* Heckel obserwowane w akwarium. Wszechswiat 4, 100-103.

Starmach, J. 1962b. Koppen in den Karpathenflüssen. I Vermehrung, embryonale und larvale Entwicklung bei *Cottus poecilopus* Heckel. Acta Hydrobiol. 4, 321-343.

Starmach, J. 1965. Koppen in den Karpathenflüssen. II Antreten und Charakteristik der Buntflossenkoppe (*Cottus poecilopus* Heckel) und weissflossigen Koppe (*Cottus gobio* L.) im Raba-Flußgebiet. Acta Hydrobiol. 7, 109-140.

Starmach, J. 1971. Oxygen consumption and respiratory surface of gills in *Cottus poecilopus* Heckel and *Cottus gobio* L. Acta Biol. Cracov. Zool. 14, 9-15.

Thienemann, A. 1925. *Mysis relicta*. Z. Morphol. Ökol. Tiere 3, 389-440.

Thienemann, A. 1928. Die Reliktkrebse *Mysis relicta, Pontoporeia affinis, Pallasea quadrispinosa*, und die von ihnen bewohnten norddeutschen Seen. Arch. Hydrobiol. 19: 521-582.

Thienemann, A. 1950. Verbreitungsgeschichte der Süßwasserfischwelt Europas. Die Binnengewässer Bd. XVIII. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Thomas A.E. 1973. Spawning migration and intragravel movement of the torrent sculpin, *Cottus rhotheus*. Trans. Amer. Fish. Soc. 3, 620-622.

Waterstraat, A. 1988. Zur Verbreitung und Ökologie der Reliktkrebse *Mysis relicta* (Loven), *Pallasea quadrispinosa* (Sars) und *Pontoporeia affinis* (Lindstrom). Arch. Naturschutz Landsch. forsch. 28, 121-137.

Waterstraat, A., Krappe, M. 2003. Forschungsergebnisse zum Schutz der glazialen Reliktarten der Feldberger Seen im Kontext langjähriger Bemühungen zum Gewässer- und Artenschutz. Nat. Naturschutz Meckl.-Vorpomm. 38, 75-84.

Winkler, H.M., Hamann, N., Waterstraat, A. 1991. Rote Liste des Landes M/V - Rundmäuler, Süßwasserfische und Wanderfischarten. Umweltministerium M/V.

Winkler, H.M., Waterstraat, A., Hamann, N. 2002. Rote Liste der Rundmäuler, Süßwasser- und Wanderfische. Schwerin, Umweltministerium Mecklenburg-Vorpommern.

Witkowski, A. 1975. Glowacz pregopletwy, *Cottus poecilopus* Heckel, 1836 w jeziorze Hancza. Przegl. Zool. 19, 224-227.

Witkowski, A. 1984. Morphological variability in lake and river populations of *Cottus poecilopus* Heckel, 1836 (Pisces: Cottidae). Acta Ichthyol. Pisc. 14, 43-57.

Witkowski, A. in press. *Cottus poecilopus* Heckel, 1840. In: The Freshwater Fishes of Europe (A. Lelek, ed.). Vol. 7. Aula Verl. Wiesbaden.