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**Wpływ podgrzanych wód zrzutowych z elektrowni „Skawina”,
na ichtiofaunę rzek Skawinki i Wisły**

**Influence of heated discharge waters from the „Skawina” Electric
Power Station on the ichthyofauna of the rivers
Skawinka and Vistula**

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Abstract. — Investigations on the influence of heated waste waters discharged into the rivers Skawinka and Vistula showed that except in the hottest seasons of the year fish gather in the area of heated waters. In high temperatures of the water (20 °C and 28 °C for not heated and heated waters respectively) the total amount of fish caught decreased. It was found that such species as *Leuciscus cephalus* (L.), *Alburnus alburnus* (L.), *Barbus barbus* (L.), and *Leuciscus leuciscus* (L.), are highly eurythermic.

Investigations on the influence of the inflow of discharged heated waste waters on the ichthyofauna of the receptor were undertaken in 1964, on the order of the Institute for Water Control and Exploitation, by the Department of Fishery of the Agricultural College in Cracow, directed by the late Prof. dr. S. Ż a r n e c k i.

Observations were carried out in vicinity of the Electric Power Station in Skawina. This plant uses polluted water from the River Vistula for cooling the condensers, which after being heated, is discharged into the River Skawinka, whence they are returned to the River Vistula. Investigations were carried from 1964 to 1967.

The aim of these investigations was to determine the qualitative and quantitative composition of the ichthyofauna in heated and unheated waters in the rivers Skawinka and Vistula in the region of mouth of the River Skawinka in dependence on the seasonal changes in temperature.

Method

Investigations territory: Water for cooling the condensers in the Electric Power Station in Skawina is taken from the River Vistula above the dam Łączany and carried by the Łaczański canal for 22 km. Having passed through the condensers, the water is warmed by about 10 °C and subsequently let out from a height of 9 m into the small River Skawinka from which it flows into the River Vistula (fig. 1). The amount of water in the River Skawinka (0.5 m³/sec.) is very small in comparison with the amount of heated water discharged into it (24 m³/sec.); in fact, the water flowing along the bed of the Skawinka for 3 km is heated, polluted Vistula water.

Investigations were carried out in 6 sampling sectors (fig. 1). All those situated on the River Vistula were 1 km long, while that on the River Skawinka was 3 km long.

Technique of fishing.

Fishing was performed by means of an electric aggregate placed on a boat floating downstream over 1 or 3 km. The fish caught were sorted according to species, counted, weighed and measured; subsequently they were released into the water at the place where they were caught.

Efficiency of catches.

The individual sampling sectors on the River Vistula were very similar to each other with respect to the speed of the current, depth of the water, kind of the bottom and banks, hence it may be assumed that they should be characterized by a similar efficiency of catch. It was assumed that the efficiency of catch in the River Skawinka was in comparison with the River Vistula about three times lower, due to a three times higher speed of the water current. Therefore, the sampling sectors on the River Skawinka was three times longer than any other and the result of the catch were considered as comparable with those obtained elsewhere. Every year during the period of investigations 5 catches were made in individual sampling sectors, one catch being regarded as one passage of the boat along the whole length of the sector while constantly fishing. In every sector, during the 4 year investigation, fishing was carried out 20 times, 4 times between December and February, 4 in the months March—April, 4 in May and June, 4 in July — September, and 4 in October and November.

Manner of presenting results.

In order to make interpretation of the results easier a conventional differentiation of 3 seasons in the year was made:

1) Cold season — characterized by the range of temperatures 0.5 °C— —5.0 °C measured in unheated waters (sectors I and IV) and in heated waters from 1.0 °C (sector VI) to 15 °C (sector II), in dependence on the distance of the sector from the place of discharging the water.

2) Warm season — characterized by the range of temperatures 6.0 °C—20 °C measured in unheated waters and 7.0 °C to 28.0 °C in heated waters, in dependence on the position of the sector.

3) Hot season — characterized by temperatures measured in unheated waters above 20.0 °C and in heated waters above 21.0 °C (sector VI) and over 28.0 °C (sector II).

The results were plotted separately for each of these stipulated seasons of the year and the following was calculated:

1) the average number of fish caught in individual stipulated seasons of the year in all sectors during the 4 years of investigation,

2) the participation of particular species of fish caught in each sector in the 3 stipulated seasons expressed as percentage,

3) the average number of fish of particular species caught during one fishing in individual sectors in successive years of the investigations.

Results

Sampling sector I — the River Vistula above the inflow of heated waters.

The greatest number of fish were caught during the warm season of the year, 27 specimens on the average, and the smallest number of fish in the cold season, 4 specimens on the average. More than half of the fish caught in all the ranges of temperature were: *Leuciscus cephalus* (L.), the second dominant being *Alburnus alburnus* (L.). Besides, in small quantities were caught: *Barbus barbus* (L.), *Leuciscus leuciscus* (L.), *Carassius carassius* (L.), *Cyprinus carpio* (L.), *Blicca bjoerkna* (L.), *Abramis brama* (L.), *Perca fluviatilis* (L.), *Rutilus rutilus* (L.) and *Chondrostoma nasus* (L.) (fig. 1).

Sampling sector II — the Skawinka.

The greatest numbers of fish were caught in the cold and warm seasons of the year — 283 and 243 specimens on the average. The smallest numbers were recorded in the hot season — 109,6 specimens on the average. In all the 3 seasons of the year *Leuciscus leuciscus* (L.) dominated, always constituting over 50 per cent of the catch. In amounts from some scores to a few per cent there occurred: *Alburnus alburnus* (L.), *Abramis brama* (L.), and *Barbus barbus* (L.), (fig. 1). Besides these, other species were caught in small numbers: *Barbus petenyi* (L.), *Vimba vimba* (L.), *Leuciscus idus* (L.), *L. leuciscus* (L.), *Carassius carassius* (L.), *C. auratus gibelio* Bloch, *Cyprinus carpio* (L.), *Gobio gobio* (L.), *Scardinius erythrophthalmus* (L.), *Blicca bjoerkna* (L.), *Tinca tinca* (L.), *Perca fluviatilis* (L.), *Alburnus bipunctatus* Bloch, *Rutilus rutilus* (L.), *Rhodeus sericeus amarus* Bloch, *Phoxinus phoxinus* (L.), *Esox lucius* (L.) and *Chondrostoma nasus* (L.).

Sampling sector III — the River Vistula below the mouth of the River Skawinka, right side current.

The greatest numbers of fish — 287 specimens on the average — were caught in the cold season of the year. In the warm season 174 specimens were caught on the average. The smallest numbers of fish were caught during the hot season — 42 specimens. In all the seasons *Leuciscus cephalus* (L.) constituted over 50 per cent of the catch. During the warm and cold seasons *Alburnus alburnus* (L.) and *Abramis brama* (L.), were in the second and third position respectively and in the hot season *Alburnus alburnus* (L.) and *Rutilus rutilus* (L.). Moreover, small numbers of *Vimba vimba* (L.), *Leuciscus idus* (L.), *L. leuciscus* (L.), *Carassius carassius* (L.), *C. auratus gibelio* Bloch, *Cyprinus carpio* (L.), *Gobio gobio* (L.), *Scardinius erythrophthalmus* (L.), *Blicca bjoerkna* (L.), *Tinca tinca* (L.), *Lota lota* (L.), *Perca fluviatilis* (L.), *Rhodeus sericeus amarus* Bloch, *Lucioperca lucioperca* (L.), *Esox lucius* (L.), *Chondrostoma nasus* (L.), and *Saimo trutta m. trutta* (L.) occurred (fig. 1).

During the 4 years of investigation no changes, apart from the decline of *Chondrostoma nasus* (L.), were observed either in the quantitative or qualitative composition of the ichthyofauna of this sector.

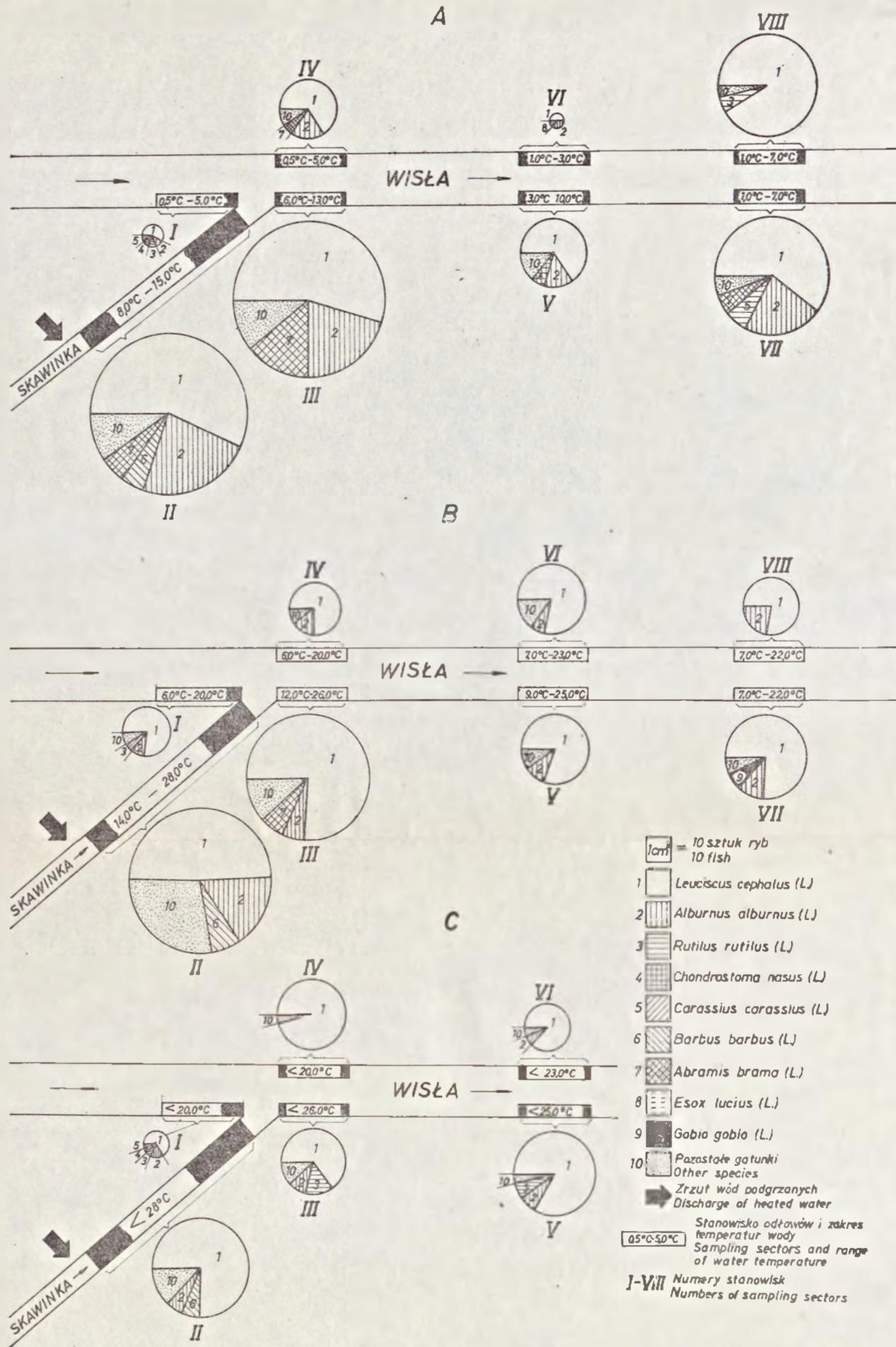
Sampling sector IV — the River Vistula below the mouth of the River Skawinka, left side current.

The richest catches in this sector were recorded in the hot season — 58 specimens on the average. In the cold and warm seasons on the average 40 and 30 specimens of fish were caught respectively (fig. 1).

Leuciscus cephalus (L.) constituted more than half the catch. In the second place was *Alburnus alburnus* (L.) which occurred, however, in a much lower percentage. Besides, *Barbus barbus* (L.), *B. petenyi* (H.), *Leuciscus leuciscus* (L.), *Carassius carassius* (L.), *C. auratus gibelio* Bloch, *Gobio gobio* (L.), *Abramis brama* (L.), *Perca fluviatilis* (L.), *Rutilus rutilus* (L.), *Esox lucius* (L.), and *Chondrostoma nasus* (L.) were caught in small quantities (fig. 1).

Sampling sector V — the River Vistula in the vicinity of Tynieć, 3.5 km below the mouth of the River Skawinka, right side current.

The greatest numbers of fish were caught in the hot season — 82 specimens on the average. In the other seasons similar amounts were caught — on the average 53 and 56 specimens in the cold and warm season respectively. Here too *Leuciscus cephalus* (L.) constituted more than half the catch. *Alburnus alburnus* (L.) followed in the second place but its participation was only 6 to 15.6 per cent of the fish caught. In the cold season the third place was occupied by *Chondrostoma nasus* (L.), constituting almost 7 per cent of the catch. Besides, *Rutilus rutilus* (L.), *Barbus barbus* (L.), *Abramis brama* (L.), *Perca fluviatilis* (L.), *Leuciscus leuciscus* (L.), *Esox lucius* (L.), *Carassius carassius* (L.), *Gobio gobio* (L.), *Cyprinus carpio* (L.), *Lucioperca lucioperca* (L.), *Rhodeus sericeus amarus*



Ryc. 1. — Ilość ryb i procentowy stosunek gatunków na poszczególnych stanowiskach. A — zimna pora roku, B — ciepła pora roku, C — gorąca pora roku; I — Wisła powyżej ujścia Skawinki, II — Skawinka poniżej zrzutu wód podgrzanych, III — Wisła poniżej ujścia Skawinki 0,0 km, nurt prawy, IV — Wisła poniżej ujścia Skawinki 0,0 km nurt lewy, V — Wisła—Tyniec, 3,5 km poniżej ujścia Skawinki — nurt prawy, VI — Wisła—Tyniec, 3,5 km poniżej ujścia Skawinki — nurt lewy, VII — Wisła—Bielany, 8 km poniżej ujścia Skawinki — nurt prawy, VIII — Wisła—Bielany, 8 km poniżej ujścia Skawinki — nurt lewy

Fig. 1. Number of fish and the percentage relation between species in individual sectors. A — cold season of the year, B — warm season of the year, C — hot season of the year; I — the Vistula above the mouth of the River Skawinka, II — Skawinka below the discharge point of heated waters, III — the Vistula below the mouth of the River Skawinka 0.0 km — right side current, IV — the Vistula below the mouth of the Skawinka 0.0 km — left side current, V — the Vistula—Tyniec, 3.5 km below the mouth of the Skawinka — right side current, VI — the Vistula—Tyniec, 3.5 km below the mouth of the Skawinka — left side current, VII — the Vistula—Bielany, 8 km below the mouth of the Skawinka — right side current, VIII — the Vistula—Bielany, 8 km below the mouth of the Skawinka — left side current

Bloch and *Scardinius erythrophthalmus* (L.) were caught in small numbers (fig. 1). During the 4 years of investigation no quantitative changes in the qualitative composition of the fish caught, besides a decline of *Chondrostoma nasus* (L.), were recorded.

Sampling sector VI — the River Vistula in the vicinity of Tynec, 3.5 km below the mouth of the River Skawinka, left side current.

The greatest numbers of fish were caught in the warm season of the year — 57 specimens on the average. In the hot season 25 specimens were caught on the average and in the cold season only 3 specimens.

In all the seasons of the year *Leuciscus cephalus* (L.) constituted over half the fish caught. *Alburnus alburnus* (L.) was in the second place amounting from 7 to 37 per cent of the caught fish. Besides, the following species were caught in small quantities: *Chondrostoma nasus* (L.), *Rutilus rutilus* (L.), *Barbus barbus* (L.), *Abramis brama* (L.), *Esox lucius* (L.), *Carassius carassius* (L.), *Perca fluviatilis* (L.).

Sampling sector VII — the River Vistula in the vicinity of Bielany 8.0 km from the mouth of the River Skawinka, right side current.

The greatest numbers of fish were caught in the cold season of the year — 156 specimens on the average. In the warm season 84 specimens were caught on the average. In temperatures above 20.0 °C no fish were caught in this sector. In all ranges of temperature *Leuciscus cephalus* (L.) formed more than 50 per cent of the catch. The second dominant was *Alburnus alburnus* (L.), constituting 10.7 to 22.4 per cent. Besides, small numbers of the following species were caught: *Abramis brama* (L.), *Rutilus rutilus* (L.), *Leuciscus leuciscus* (L.), *Perca fluviatilis* (L.), *Carassius carassius* (L.), *Esox lucius* (L.), and *Scardinius erythrophthalmus* (L.).

Sampling sector VIII — the River Vistula in the vicinity of Bielany 8.0 km from the mouth of the River Skawinka, left side current.

The greatest numbers of fish — 117 specimens on the average were caught in the cold season of the year. In the warm season 38 specimens of fish and in the hot season no fish at all were caught (fig. 1). Quantitatively, *Leuciscus cephalus* (L.) dominated in this sector, constituting more than half the catch. The second place in the cold season was occupied by *Rutilus rutilus* (L.) — 5.1 per cent of all fish and *Alburnus alburnus* (L.) — 21.0 per cent in the warm season. Besides, small quantities of *Abramis brama* (L.), *Carassius carassius* (L.), *Perca fluviatilis* (L.), *Chondrostoma nasus* (L.), and *Esox lucius* (L.), were caught.

During the course of the 4 years of investigation, besides a decline of *Chondrostoma nasus* (L.) in sectors III and V no changes either in the quantitative or qualitative composition of the fish caught were observed in other sectors.

Discussion

The greatest amounts of fish were recorded in sampling sectors II and III (lying within the range of heated waters) but only during the cold and warm stipulated seasons of the year, the number of fish caught decreasing considerably with the increase in water temperature. When the temperature of the heated water was over 28°C during the hot season of the year the numbers of fish caught in the mentioned sectors decreased to about the same amounts as were obtained in other sectors in this season. At the same time, a slight increase in the number of fish caught was recorded at high temperatures of the water in sector IV (the River Vistula just below the mouth of the Skawinka, left side current) and in sector V (the River Vistula in the vicinity of Tyniec, right side current).

It may thus be assumed that heated water is a factor attracting fish, the more effective the lower the temperature of the unheated water. This is confirmed by Trembley's (1960) data. He examined the Delaware River. According to the author's own investigations, a certain purification of the heated water due to its falling from a height of 9 m when discharged from the heat and power generating plant into the River Skawinka was probably an additional factor attracting fish. This is corroborated by the fact that in the unheated waters of the River Vistula much smaller numbers of fish were always caught in sector I in comparison with other sectors.

In all sectors *Leuciscus cephalus* (L.) was distinctly predominant, constituting always and everywhere over half the fish caught. The second dominant, though much less numerous, was *Alburnus alburnus* (L.).

The greatest variety of species was encountered also in sectors II and III. In sectors II and III 19 and 15 species of fish were found respectively.

Among the species encountered in the area of heated waters the following species should be mentioned:

The chub (*Leuciscus cephalus* L.) is a rheophylic species with a very wide range of occurrence. In submontane waters, i. e. in comparatively cold ones, the chub finds favourable living and development conditions. It occurs, too, in the lower courses of large rivers. Its domination in warmed waters also was shown by our investigations. It thus results that the chub is one of the most eurythermic of all rheophylic species, adapted to a wide range of temperature. The fact of domination of the chub in polluted heated and unheated waters demonstrates the great resistance of this species to pollution.

The ablet (*Alburnus alburnus* L.) held the second place after the chub with regard to number. Its range is also very wide (cool submontane waters, rivers, and lakes). The great numbers of ablet present in

polluted and heated waters of the rivers Skawinka and Vistula prove that this species is characterized by a great tolerance for high temperatures. It was noted that the ablet gather in the region of heated waters, whereas in the unheated part of the River Vistula only small numbers were caught.

The barbel (*Barbus barbus* L.) — the results of the investigations seem to throw new light on the thermal adaptation of the species as well as on its resistance to pollution. This species was the third dominant in the heated part of the River Skawinka and in the heated waters of the River Vistula it also appeared in relatively great numbers. The barbel thus proved to be a more eurythermic species than used to be considered, it having been thought to be an indicator species (the barbel region) for the region situated just below that of the trout. Doubts as to the value of this species as an indicator for a fish region lying below the trout region are corroborated by investigations carried out in the Silesian Vistula by Żarnęcki and Kolder (1956); they established that below the trout region there are territories which could, perhaps, be called the region of the chub rather than of the ablet. Nevertheless taking into consideration the above remarks, the chub cannot be regarded as a proper indicator species either.

The bream (*Abramis brama* L.) appeared as the third dominant in the heated part of the River Vistula and in the heated Skawinka it was also caught in great numbers. The bream gathers in heated waters in the cold and warm seasons of the year and its different distribution (rather in the heated waters of the River Vistula and less in the heated waters of the River Skawinka), could be explained by its better adaptation to life in the slower current of the Vistula. The investigations corroborated the stenothermal character of the bream which was to be expected considering its distribution in Polish waters.

The roach (*Rutilus rutilus* L.) is a fairly considerable component of the ichthyofauna of the heated region of the rivers Vistula and Skawinka. The fact that it gathers in heated waters is visible especially in the comparison of the results in heated and unheated waters.

The dace (*Leuciscus leuciscus* L.) was caught in quite considerable numbers especially in the heated part of the River Skawinka whereas in the unheated regions of the Vistula it was represented by single specimens. It thus results that it gathers in heated waters, which, with respect to the biology of this species is rather surprising.

The above-mentioned species (chub, ablet, barbel, bream, roach and dace) show a decisive preference for warm water, especially in the cold season of the year. Representatives of other species, on the other hand, were caught in too small numbers to permit determination of what waters they prefer to stay in.

The state of the ichthyofauna in the heated area established during

the period preceding the beginning of discharge of heated waters (Kolder 1955) showed a change; after heating *Acerina cernua* (L.) disappeared entirely and *Chondrostoma nasus* (L.) almost entirely, while 10 new species appeared, among which were: *Silurus glanis* (L.), *Barbus barbatus* (L.), *Carassius carassius* (L.) and *Cyprinus carpio* (L.).

During the period before the waters were heated *Leuciscus leuciscus* (L.) and *Chondrostoma nasus* (L.) dominated in the investigated area; *Vimba vimba* (L.), *Blicca bjoerkna* (L.), and *Esox lucius* (L.) were found in great numbers. These changes in the ichthyofauna were most probably caused not only by the influence of the discharged heated water but also by a considerable increase in pollution of the water in the River Vistula.

Conclusions

1. During the four years of investigation no lethal effect on the fish from the heating of the water was observed.
2. The gathering of fish in the area of heated water was established specially in seasons when the water temperature was lower.
3. With the increase in temperature of the water the number of fish caught in heated water decreased.
4. In all sampling sectors *Leuciscus cephalus* (L.) constituted more than half the fish caught, independently of temperature.
5. The occurrence of *Leuciscus cephalus* (L.), *Alburnus alburnus* (L.), *Barbus barbatus* (L.), and *Leuciscus leuciscus* (L.) demonstrates the fact that adult specimens of these species are eurythermic.

STRESZCZENIE

Badania nad wpływem podgrzanych wód zrzutowych z elektrowni Skawina na ichtiofaunę rzek Skawinki i Wisły prowadzone były w latach 1964—1967. Elektrownia Skawina pobiera wodę z Wisły, kilkanaście kilometrów powyżej ujścia rzeki Skawinki do Wisły i po użyciu jej i podgrzaniu zrzuca wodę do rzeki Skawinki w odległości 3 km od jej ujścia do Wisły. Ryby łowiono przy pomocy agregatu elektrycznego na 7 stanowiskach o długości 1 km każdy i na jednym o długości 3 km (na rzece Skawinka).

Uzyskane wyniki przedstawiono w odniesieniu do trzech umownych ciepłych pór roku. Stwierdzono zmiany w rybostanie spowodowane podgrzaniem wód. Wykazano, że zrzut wód podgrzanych powoduje zmiany w rozmieszczeniu ichtiofauny polegające na „przyciąganiu” ryb na obszar podgrzany poza okresami najwyższych temperatur wody. Na obszarze tym najwięcej ryb łowiono w zimnej

i cieplej porze roku. W gorącej porze roku. ogólna liczba ryb na tym obszarze malała. Stwierdzono eurytermiczny charakter niektórych gatunków ryb (kleń, ukleja, brzana, jelec).

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Table II				
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