COMPARISON OF DIFFERENTIAL LEUKOCYTE COUNTS IN FISH OF ECONOMIC AND INDICATOR IMPORTANCE

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Abstract

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The aim of this study was to determine the percentage of individual types of leukocytes in fish of economic (carp - *Cyprinus carpio* L., tench - *Tinca tinca* L., European catfish - *Silurus glanis* L., rainbow trout - *Oncorhynchus mykiss* Walb.,) and indicator importance (bream - *Abramis brama* L., perch - *Perca fluviatilis* L., chub - *Leuciscus cephalus* L., brown trout - *Salmo trutta* m. *fario* L.). In all, we examined 191 fish specimens caught in non-contaminated or insignificantly contaminated localities in good state of health during the vegetation season and not within the season of their reproduction. Leukocytes stained according to Giemsa were classified as: lymphocytes, monocytes, myelocytes, metamyelocytes, neutrophilic granulocytes with band and segmented nuclei, eosinophils and basophils. Blood of all the fish species examined was of lymphocytic character. The mean percentage of individual lymphocytes varied from 84.2 ± 5.08 to 99.1 ± 0.99%. The lowest percentage of lymphocytes was found in the rainbow and brown trout (84.2 ± 5.08 and 87.3 ± 7.21%, respectively), while the highest values were in the perch (99.1 ± 0.99 and 97.5 ± 3.19%). Monocytes were sporadic in all the fish species; with the highest mean value found in the female spawner European catfish (1.42 ± 1.74%. The highest percentage of granulocytic series cells was found in rainbow (15.4 ± 7.80%) and brown trout (11.6 ± 7.23%); whereas the lowest values in the perch (0.8 ± 1.01 and 2.4 ± 3.15%). As far as the granulocytic series cells are concerned, metamyelocytes were most common with regards to their percentage in all the fish species excepting salmonids. There were prevailing band and segmented neutrophils in the rainbow and brown trout. Granulocytes were mostly represented by neutrophils in all the fish species studied. Eosinophilic granulocytes were found sporadically in the tench (0.17 ± 0.59%) and in 3-year old carp (0.10 ± 0.19%). Basophilic granulocytes were not found in any of the fish species examined. We found practically equal percentage of individual types of leukocytes in the carp, bream and perch of various age categories caught under the same conditions and in the same season of the year. There were no significant differences in the percentage of individual leukocytes in male and female spawners of 3-year-old carp, 3-year-old tench, and 2- to 3-year-old brown trout. Our results contribute to the use and help in introducing the examination of differential leukocyte counts as a biological monitoring method to evaluate surface water contamination.

Differential leukocyte count, lymphocytes, monocytes, granulocytes, species differences, age differences, sex differences

Differential leukocyte counts belong to important characteristics of the health state of fish and in many cases they are also helpful in evaluating the immune system. The differential leukocyte count, like other hematological characteristics, is dependent on the fish species (Rowley et al. 1988), physiological age (Hutton 1967; Kashiwagi et al. 1968; Radzinskaya 1966; Thomas et al. 1969), sex (Colgrove 1966; Pravda et al. 1993), season of the year (Pravda et al. 1985; Yokoyama 1960) and different methods of rearing and nutrition (Smith 1968; Golovina 1995; Svobodová et al. 1998). It is also considerably influenced by the health state of fish (Blaxhall 1972; Golovina 1993; Golovin et Golovina 1995; Řehulka 1996).

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Examination of white blood cells including their differential counts is used to evaluate the effect of drugs and anaestetics on fish. The percentage distribution of individual types of leukocytes were studied by Kouřil et al. (1989) in the brood tench after application of γ-globulines, by Svobodová et al. (1987) in carp following application of the anaesthetic agent Menocain, and by Svobodová et al. (1997) after use of malachite green in carp.

Marked changes in the percentage and absolute numbers of individual types of leukocytes are caused by stress factors (Peters 1986; Pulsford et al. 1994), and in particular various kinds of pollution including low levels of pH (Dheer et al. 1987; Jeziorska 1993). Not only experimental but also field studies on the effect of pollution on the white blood cell values mention decreased counts of leukocytes, decreased percentage and absolute counts of lymphocytes, and, contrary to this, increased percentage and absolute counts of neutrophils. Such changes were caused both by metals and organic pollutants (Dixon and Dick 1985; Vosyliene 1996; Rougier et al. 1994; Schwaiger et al. 1996; Nath and Banerjee 1996) under experimental conditions.

On the other hand, there are papers which mention opposite effects of some pollutants on blood values of fish, i.e. a rise in absolute and relative counts of lymphocytes (Thakur and Sahai 1993; Kumari and Banerjee 1993; Thakur and Pandey 1990; Gill et al. 1991).

Interesting results were obtained evaluating the white blood cell values after acute and long-term action of standard substances used in the aquatic toxicology to control the toxicity tests ($K_2Cr_2O_7$, $ZnSO_4 . 7H_2O$, p-nitrophenol). After 48 hours of action of these substances in concentrations of around 48 hour LC50 values in the carp it was found that the relative and absolute counts of lymphocytes were significantly decreasing and the counts of granulocytic series cells were increasing. Contrary to this, after 96 days of action of these substances in concentrations of 48 hour LC50 reduced to one third to one hundredth, no marked changes in the white blood cell values were found as compared to control fish (Svobodová et al. 1993ab). Witeska et al. (1995) and Slominska et al. (1995) found similar effects of lead after acute and chronic administration to the carp. The same results caused by ammonia in the carp were obtained by Wlasow and Dabrowska (1990) a Wlasow et al. (1990).

Fish white blood cell examination plays an important role in biological monitoring of surface water contamination. Results of such examinations are given by Trombickij and Gorbunenko (1993) in the bleak *(Alburnus alburnus* L.*)* from the Dnestr river above and below the city of Bendery; Backer et al. (1994) in the plaice *(Pleuronectes americanus)* from under the effluent discharge from paper mills compared with a reference locality; Jeney et al. (1996) in the roach from under effluent discharges from paper mills; Khan et al. (1996) in the plaice *(Pleuronectes americanus)* also from under effluent discharges from paper mills. Dubanský et al. (1995) examined the percentage of individual types of leukocytes in various fish species from several localities of the Skalice river contaminated by polychlorinated biphenyls. They introduced the so called "haematological index of fish stress loading", i.e. the ratio of lymphocyte and granulocyte counts expressed in %. The common gudgeon (*Gobio gobio* L.) was found to be an important indicator fish in this case because the hematological index of fish stress loading achieved very low values (0 to 5) below the source of contamination.

The physiological values of the differential leukocyte count are necessary to compare and evaluate the changes in fish exposed to stress load. This stress load may be artificial as in model experiments or natural due to various reasons. The differences in the blood values may be objectively evaluated in model experiments employing control fish groups. It is, however, different in biological monitoring when fish are caught in natural localities. It is necessary in these cases to compare the white blood values obtained with similar results originating from the same fish category, season of the year and non-contaminated localities.

It is the biological monitoring method that the so-called indicator fish species are used to assess contamination of rivers and dams. For example, there are following fish species used as indicators in the Czech Republic and Germany for the Elbe river- the bream and perch;

for the Morava river - the chub and perch; for small mountain and submountain rivers - the brown trout; and for water dams - the bream and perch.

In the paper presented we give a survey of percentage of individual types of leukocytes in fish of economic (carp -*Cyprinus carpio* L., tench - *Tinca tinca* L., European catfish - *Silurus glanis* L., rainbow trout - *Oncorhynchus mykiss* Walb.), and indicator importance (bream - *Abramis brama* L., perch - *Perca fluviatilis* L., chub - *Leuciscus cephalus* L., brown trout - *Salmo trutta* m. *fario* L.). Fish specimens were caught in non-contaminated or insignificantly contaminated localities in good state of health during the vegetation season and not within the season of their reproduction.

Materials and Methods

Table 1 surveys the characteristics, dates of examination and origin of the fish species examined. In all, 191 fish specimens of 8 different species were examined. We examined juvenile and adult fish specimens of both sexes

Table 1
Characteristics and origin of the fish examined

Fish species	n	Age (years)	Body weight in g mean ± SD	Dates of catching	Locality of catching
Carp *(Cyprinus carpio* L.)	10	1	80.5 ± 3.5	03. 06. 1996	pond – Vodňany
Carp *(Cyprinus carpio* L.)	10	2	1 023.0 ± 71.9	03. 06. 1996	pond – Vodňany
Carp *(Cyprinus carpio* L.)	20	3	1 618.0 ± 392.6	01. 11. 1994	pond – Vodňany
Tench *(Tinca tinca* L.)	18	3	165.4 ± 30.7	26. 06. 1996	pond – Vodňany
European catfish (females) *(Silurus glanis* L.)	6	4–6	8 330.0 ± 3 093.0	19. 06. 1997	pond – Vodňany
Rainbow trout *Oncorhynchus mykiss*- (Walbaum)	30	1/2	37.5 ± 4.4	20. 06. 1996	trout farm Annín
Bream *(Abramis brama* L.)	10	2–3	94.9 ± 3.5	24. 06. 1996	water dam Římov
Bream *(Abramis brama* L.)	9	4–7	306.0±78.2	24. 06. 1996	water dam Římov
Perch *(Perca fluviatilis* L.)	20	2–4	56.6 ± 25.6	27. 08. 1996 28. 08. 1996	the Elbe river – upstream Pardubice city and in Lysá nad Labem city
Perch *(Perca fluviatilis* L.)	10	7–9	378.0 ± 73.0	27. 08. 1996 28. 08. 1996	the Elbe river – upstream Pardubice city and in Lysá nad Labem city
Chub *(Leuciscus cephalus* L.)	10	2–4	102.6 ± 40.8	18. 07. 1996	the Otava river – Kestřany
Chub *(Leuciscus cephalus* L.)	10	4–7	452.2 ± 162.1	21. 08. 1997	the Morava river – upstream Uh. Hradiště
Brown trout *(Salmo trutta* L.)	23	2–3	151.1 ± 38.3	03. 07. 1997	the Tichá Orlice river – Červená Voda and Lichkov

with the exception of the generation European catfish of which only females were examined. They were in good health state, without clinical and pathological changes. Immediately after catching the fish, blood samples were taken by cardiac puncture using a heparinized needle and then blood smears were prepared. Blood smears were dried and then fixed by methanol. They were stained according to Giemsa (Humason 1979) and examined using a 1 000 × magnification.

We evaluated 200 leukocytic series cells and classified them on account of their morphology and staining as follows: lymphocytes, monocytes, myelocytes, metamyelocytes, band neutrophils, segmented neutrophils, eosinophils and basophils. Individual techniques of fish blood examination were employed (Svobodová et al. 1991).

We compared differential leukocyte counts of various age categories in the carp, bream and perch. Sex variations in the percentage distribution of individual leukocyte types were evaluated in 3-year old carp from the Dřemliny pond (9 male and 11 female spawners), 3-year old tench from a pond for experiments (7 male and 9 female spawners, 2 juvenile specimens) and 2- to 3-year old brown trout from the Tichá Orlice river (11 male and 12 female spawners). The influence of age and sex variation was statistically evaluated using the t-test (STAT PLUS 1.01 VÚVeL Brno).

Results

There are the results of determinations of the percentage distribution of individual types of leukocytes in fish species of economic and main indicator importance in Figs 1 to 13. All the fish species had the blood of lymphocytic character, i.e. lymphocytes prevailed in the white blood cell count. The lowest percentage values of were found in the rainbow and brown trout (84.20 ± 5.08% and 87.30 ± 7.21%, respectively), while the highest values in the perch (99.10 ± 0.99% and 97.50 ± 3.19%). In all the other fish species examined the mean values of lymphocytes varied from 89 to 97%.

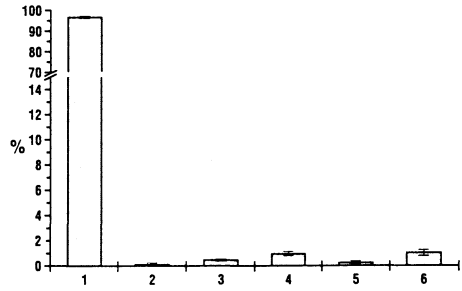

Fig. 1.
Leukocyte differential count in one-year-old carp. Legend: 1 - lymphocytes, 2 – monocytes, 3 – myelocytes, 4 – metamyelocytes, 5 - neutrophilic granulocytes, 6 - neutrophilic granulocytes with higher degree of lobation of the nuclei.

Monocytes represented 1.42 ± 1.74% of leukocytes in the brood European catfish and 0.32 ± 0.74% in the 3-year old market carp. Approximately 1% of monocytes out of the total leukocyte count was found in the tench, chub and brown trout. In the rainbow trout and bream of younger age categories the monocytes amounted to 0.40 ± 0.35% and 0.40 ± 0.94%, respectively. Sporadic monocytes were found in 1-year and 2-year-old carp (0.10 ± 0.07%

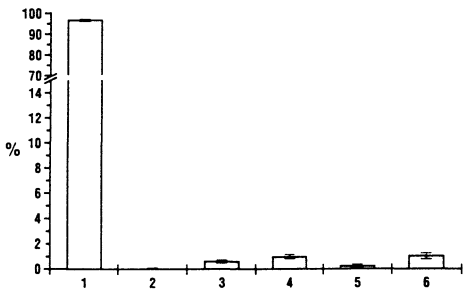

Fig. 2.
Leukocyte differential count in two-year-old carp. For legend see Fig. 1.

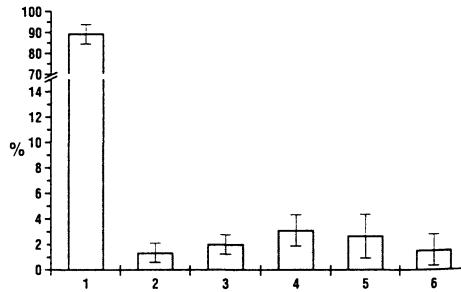

Fig. 3.
Leukocyte differential count in three-year-old carp. For legend see Fig. 1.

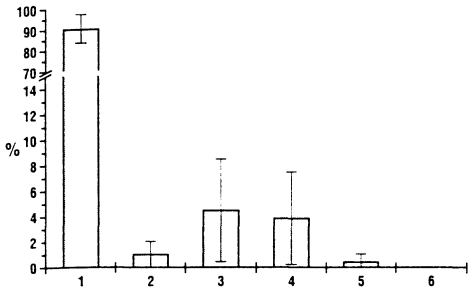

Fig. 4.
Leukocyte differential count in three-year-old tench. For legend see Fig. 1.

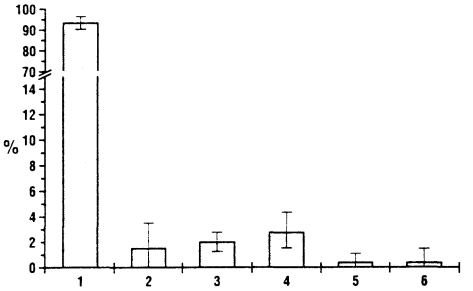

Fig. 5.
Leukocyte differential count in three to six-year-old catfish. For legend see Fig. 1.

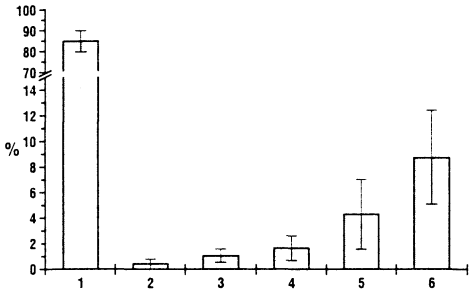

Fig. 6.
Leukocyte differential count in half-year-old rainbow trout. For legend see Fig. 1.

and 0.05 ± 0.05%, respectively), in the older age category of the bream (0.06 ± 0.17%) and in the perch (0.10 ± 0.21% and 0.08 ± 0.24%).

As far as granulocytes and their developmental stages are concerned, the percentage values were in inverse relation to the percentage of lymphocytes. It means that the highest percentage of granulocytes was found in rainbow and brown trout (15.4 ± 7.8% and 11.6 ± 7.2%, respectively) and the lowest values in the perch (0.8 ± 1.0% a 2.4 ± 3.2%). From the granulocytic series cells there were most numerous the metamyelocytes in all the fish species examined with the exception of salmonids (1-year-old carp 0.95 ± 0.19%; 2-year-old carp 1.13 ± 0.15%; 3-year-old carp 3.08 ± 1.23%; 3-year-old tench 3.83 ± 3.64%; female spawners of the European catfish 5.89 ± 4.18%; 2- to 3-year-old bream 3.75 ± 2.70%; 4- to 7-year-old bream 3.44 ± 1.59%; 2- to 3-year-old perch 0.88 ± 1.52%; 7- to 9-year-old perch 0.35 ± 0.47%). Higher percentage of myelocytes was also found in the tench and European catfish (4.44 ± 4.03 a 2.00 ± 0.76%). In 1-year and 2-year-old carps we found higher percentage of segmented neutrophils (1.00 ± 0.25 and 1.09 ± 0.27%, respectively), and higher percentage of band neutrophils in 3-year-old carp (2.64 ± 1.72%). The band and segmented neutrophils were only sporadic in female spawners of the European catfish (0.33 ± 0.55% and 0.33 ± 0.74%). On the other hand, in the rainbow and brown trout band and segmented neutrophils were considerably prevailing (the rainbow trout 4.20 ± 2.70% and 8.60 ± 3.64%; the brown trout 2.74 ± 1.48% and 5.84 ± 3.71%). The majority of granulocytes in all the fish species examined were represented by neutrophils. Eosinophils were only sporadically found in the tench (0.17 ± 0.59%) and the 3-year-old market carp (0.10 ± 0.19%). No basophils were found in any of the fish species examined.

Age differences in the percentage distribution of individual types of leukocytes were evaluated in the carp, bream and perch. In 1- and 2-year-old carp kept under the same pond conditions and examined during the same season of the year (June 1996) the percentage distribution of individual types of leukocytes was equal (Figures 1 and 2). We compared differential leukocyte counts of two age categories of the bream, i.e. 2- to 3-year-old and 4-

Table 2
Comparison of the percentage distribution of individual types of leukocytes in female and male spawners of the 3-year-old carp

Leukocytes	Females n = 11 mean ± SD (%)	Males n = 9 mean ± SD (%)
Lymphocytes	90.38 ± 4.36	88.19 ± 4.60
Monocytes	1.13 ± 0.78	1.56 ± 0.67
Myelocytes	1.75 ± 0.66	2.22 ± 0.86
Metamyelocytes	2.82 ± 1.40	3.39 ± 0.99
Band neutrophils	2.40 ± 1.38	2.93 ± 2.11
Segmented neutrophils	1.50 ± 1.17	1.57 ± 1.34
Eosinophils	0.05 ± 0.09	0.16 ± 0.26

Table 3
Comparison of the percentage distribution of individual types of leukocytes in female and male spawners of the 3-year-old carp

Leukocytes	Females n = 11 mean ± SD (%)	Males n = 9 mean ± SD (%)
Lymphocytes	90.38 ± 4.36	88.19 ± 4.60
Monocytes	1.13 ± 0.78	1.56 ± 0.67
Myelocytes	1.75 ± 0.66	2.22 ± 0.86
Metamyelocytes	2.82 ± 1.40	3.39 ± 0.99
Band neutrophils	2.40 ± 1.38	2.93 ± 2.11
Segmented neutrophils	1.50 ± 1.17	1.57 ± 1.34
Eosinophils	0.05 ± 0.09	0.16 ± 0.26

Table 4
Comparison of the percentage distribution of individual types of leukocytes in female and male spawners of the 2- to 3-year-old brown trout

Leukocytes	Females n = 12 mean ± SD (%)	Males n = 11 mean ± SD (%)
Lymphocytes	88.38 ± 6.07	86.09 ± 8.41
Monocytes	0.81 ± 0.80	1.55 ± 0.82*
Myelocytes	0.31 ± 0.46	0.05 ± 0.15
Metamyelocytes	2.18 ± 2.02	2.64 ± 3.80
Band neutrophils	2.55 ± 1.11	3.55 ± 3.45
Segmented neutrophils	5.78 ± 4.06	6.14 ± 3.32

to 7-year-old ones. Both groups were caught in the water dam Římov in the same season of the year (June 1996). The percentage distribution of lymphocytes was practically equal in both the groups (95.1 ± 3.4% and 94.9 ± 3.5%). From granulocytic series cells metamyelocytes prevailed in both groups and there were no significant differences in values of their percentage distribution (3.44 ± 1.59% and 3.75 ± 2.70%). Likewise, there were

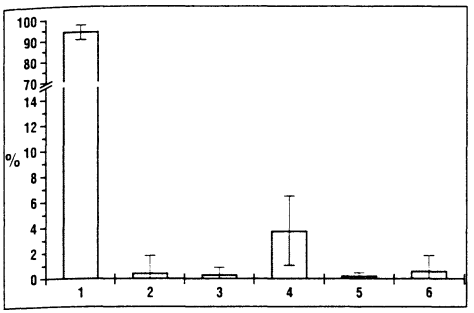

Fig. 7.
Leukocyte differential count in two to three-year--old bream. For legend see Fig. 1.

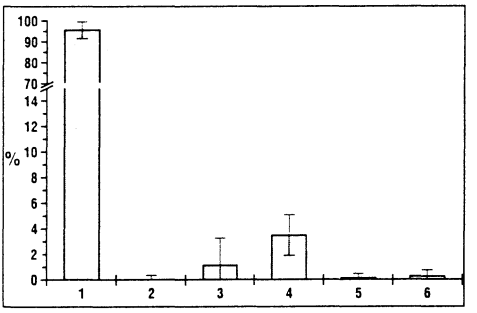

Fig. 8.
Leukocyte differential count in four to seven-year--old bream. For legend see Fig. 1.

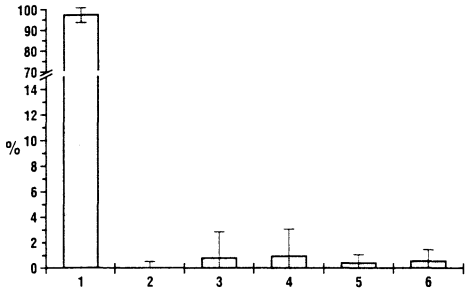

Fig. 9.
Leukocyte differential count in two to four-year-old perch. For legend see Fig. 1.

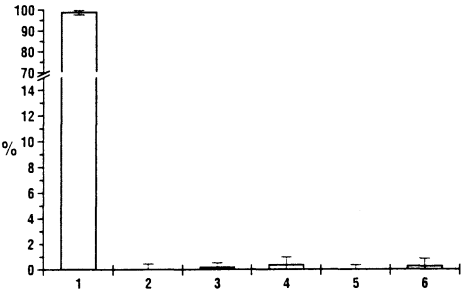

Fig. 10.
Leukocyte differential count in seven to nine-year--old perch. For legend see Fig. 1.

found no significant differences in the percentage distribution of individual types of leukocytes in the two age categories of the perch examined. Both groups of the perch were caught in the Elbe river in the locality upstream Pardubice city and in Lysá nad Labem city in the same season of the year (August 1996). In the younger age category (2- to 4-year-old perch) there were 97.5 ± 3.2% of lymphocytes and in the category of older fish (7- to 9-year-old perch) 99.1 ± 1.0% of lymphocytes. There prevailed metamyelocytes (0.88 ± 1.52% and 0.35 ± 0.47%) in both groups compared.

Tables 2 to 4 show the percentage distribution of individual types of leukocytes in female and male spawners of the carp, tench and brown trout. There were found no significant differences in values of the percentage distribution of individual types of leukocytes in female and male spawners of the fish species studied. Only male spawners of the brown trout had significantly higher percentage of monocytes as compared with values found in females ($P < 0.05$).

Discussion

The prevailing lymphocytic character of the white blood cell series was proven in 8 important economic and indicator fish species and was in accordance with published data (Rowley et al. 1988; Ellis 1977). The highest percentage of lymphocytes was found in

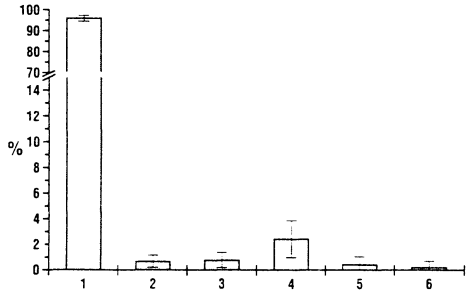

Fig. 11.
Leukocyte differential count in two to three-year--old chub. For legend see Fig. 1.

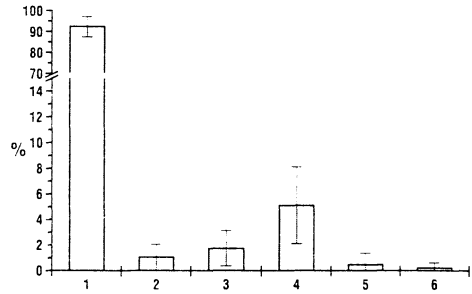

Fig. 12.
Leukocyte differential count in four to seven-year--old chub. For legend see Fig. 1.

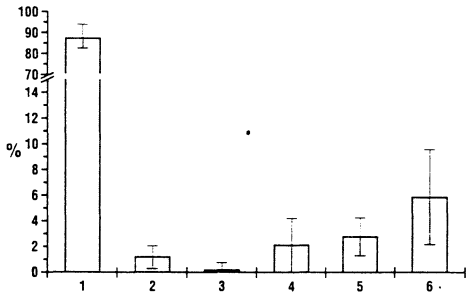

Fig. 13.
Leukocyte differential count in two-year-old brown trout. For legend see Fig. 1.

the perch and the lowest in salmonids. Variability of lymphocyte counts in individual fish species was very low and the standard deviation was under 10% of the mean in all cases. Contrary to this, variability of counts of other white blood cells (monocytes, individual granulocytes and their developmental stages) was very high in individual fish species. The standard deviation was equal to or even higher than the mean value in many cases. It was caused by the fact that in some specimens of the fish species studied there were found no monocytes or granulocytes and the cells of their developmental stages. We cannot, for example, generalize the fact that, unlike in other fish species, there are eosinophils present in the tench and 3-year-old carp. Eosinophils were present in blood samples of only 7 specimens out of 20 examined 3-year-old carp and in 2 specimens from 18 examined 3-year-old tench. Because of these reasons, we do not evaluate and find explanation to the statistical significance ($P < 0.05$) of the percentage of monocytes in female and male spawners of the brown trout.

In spite of this considerable variability of values of monocytes and granulocytic series cells, some specifics in the fish species examined may be outlined. Monocytes were sporadic in all the fish species (below 1.5% of the total leukocyte count). The highest percentage of the granulocytic series cells was found in salmonids and the lowest in the perch. Metamyelocytes presented the highest percentage counts in all the fish species examined with the exception of salmonids. Band and segmented neutrophils prevailed in salmonids.

As far as the use of values of the differential leukocyte count is considered, the ratio between the percentage of lymphocytes and granulocytic series cells (myelocytes, metamyelocytes, band and segmented neutrophils, or eosinophils) is crucial. In fish that were subjected to toxic substance influences the ratio becomes narrow (Peters 1986; Wlasow 1985; Svobodová and Pečená 1988; Rougier et al. 1994; Schwaiger et al. 1996; Nath and Banerjee 1996). From our results it is clear that, in using this parameter to evaluate toxic substance influences, it is always necessary to take the fish species into consideration. The ratio of lymphocytes to granulocytes differed significantly

in individual fish species examined. The lowest ratio number (below 8) was found in salmonids and the highest in the perch (40 to 120). The ratio varied from 10 to 35 in the other fish species.

Greater account of the health or immune state of fish is provided by the number of leukocytes and absolute numbers of individual types of leukocytes compared with values of their percentage distribution. Absolute and relative counts of individual types of leukocytes of control and test fish are compared in model tests. It is, however, not always possible to determine the numbers of leukocytes in cases of surface water contamination because of technical reasons. Therefore, we use the results of percentage distribution of individual types of leukocytes in these cases. In addition to it, there is another problem such as the possibility or impossibility of comparing the results obtained from the examined and reference localities. It happens very often, especially on rivers, that it is not possible to catch the same fish species from upstream and downstream of the source of contamination. Long-term contamination in a river often causes negative changes to fish communities (Vostradovský and Svobodová 1983). From this point of view the significance of this study lies in the area of providing physiological relative distribution of individual types of leukocytes in important fish species. Because of these reasons the analyses of fish were done during the vegetation season and not within the reproductive period. These are the conditions that the monitoring of contamination of rivers and water dams is mostly performed.

Many authors mention changes in the differential leukocyte counts in relation to the species, age, season, reproduction, etc. Our results prove the influence of species, age and sex characteristics. Differences in the relative distribution of individual types of leukocytes were well documented. We did not, however, find age and sex differences in individual fish species examined in the same season of the year and kept under the same conditions in the same localities. We did not compare values of the percentage distribution of leukocytes of 1- and 2-year-old carp caught in June with 3-year-old carp caught in November. We also did not evaluate the age difference in individual fish species originating from different localities (e.g., the chub).

Porovnání poměrného zastoupení jednotlivých typů leukocytů u hospodářsky významných a indikátorových druhů ryb

Cílem práce bylo stanovit procentuální zastoupení jednotlivých typů leukocytů u hospodářsky významných (kapr obecný - *Cyprinus carpio* L., lín obecný - *Tinca tinca* L., sumec velký - *Silurus glanis* L., pstruh duhový - *Oncorhynchus mykiss Walbaum*) a u indikátorových druhů ryb (cejn velký - *Abramis brama* L., okoun říční - *Perca fluviatilis* L., jelec tloušť - *Leuciscus cephalus* L., pstruh obecný - *Salmo trutta* L.). Celkem bylo vyšetřeno 191 kusů ryb odlovených z nekontaminovaných nebo z nevýznamně kontaminovaných lokalit. Ryby dobrého zdravotního stavu byly vyšetřovány ve vegetační sezóně, mimo reprodukční období. Leukocyty obarvené dle Giemsy byly řazeny do následujících kategorií: lymfocyt, monocyt, myelocyt, metamyelocyt, neutrofilní granulocyt s tyčkovitým a se segmentovaným jádrem, eosinofilní a basofilní granulocyt. Krev všech vyšetřovaných druhů ryb měla lymfocytární charakter. Průměrné hodnoty zastoupení lymfocytů se pohybovaly v rozmezí 84,2 ± 5,08 až 99,1 ± 0,99 %. Nejnižší procento lymfocytů bylo zaznamenáno u pstruhů duhových a u pstruhů obecných (84,2 ± 5,08 a 87,3 ± 7,21 %), nejvyšší hodnoty byly zjištěny u okounů říčních (99,1 ± 0,99

a 97,5 ± 3,19 %). Monocyty byly u všech druhů ryb zastoupeny ojediněle, nejvyšší průměrná hodnota byla zjištěna u jikernaček sumce velkého 1,42 ± 1,74 %. Nejvyšší procento buněk granulocytární řady bylo nalezeno u pstruhů duhových 15,4 ± 7.80 % a u pstruhů obecných 11,6 7,23%; nejnižší hodnoty byly zjištěny u okounů říčních (0,8 ± 1,01 a 2,4 ± 3,15 %). Z buněk granulocytární řady měly u všech druhů ryb s výjimkou lososovitých nejvyšší procentické zastoupení metamyelocyty. U pstruhů duhových a u pstruhů obecných převažovaly neutrofilní granulocyty s tyčkovitým a se segmentovaným jádrem. Převážnou většinu granulocytů u všech sledovaných druhů ryb tvořily neutrofilní granulocyty. Eosinofilní granulocyty byly nalezeny ojediněle u lína (0,17 ± 0,59 %) a u 3letého kapra (0,10 ± 0,19 %). Bazofilní granulocyty nebyly nalezeny u žádného z vyšetřovaných druhů ryb. U kaprů, cejnů velkých a u okounů říčních různých věkových kategorií, odebraných ve stejných podmínkách a vyšetřovaných ve stejném ročním období byly hodnoty procentického zastoupení jednotlivých typů leukocytů prakticky shodné. U mlíčáků a jikernaček 3letých kaprů, 3letých línů a 2-3letých pstruhů obecných nebyly zjištěny signifikantní rozdíly mezi hodnotami procentuálního zastoupení jednotlivých typů leukocytů. Výsledky práce jsou přínosem pro zavedení vyšetřování leukogramů ryb jako jedné z metod biologického monitoringu kontaminace povrchových vod.

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