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Parasitology

A PRELIMINARY EVALUATION OF HEALTH CONDITION OF EEL (*ANGUILLA ANGUILLA* L.)) FROM THE SZCZECIN LAGOON IN 1971–1973 AND 1982–1983

WSTĘPNA OCENA STANU ZDROWOTNEGO WĘGORZY (*ANGUILLA ANGUILLA* (L.)) W WODACH ZALEWU SZCZECIŃSKIEGO W LATACH 1971–1973 I 1982–1983

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The health condition of eel [*Anguilla anguilla* (L.)] caught in the Szczecin Lagoon off Trzebież in 1971–1973 and in 6 fishing grounds in 1982–1983 is evaluated. The clinical analysis, anatomo–pathological examinations, and hematologic parameters demonstrated a considerable increase in the incidence of circulatory disorders involving acute or chronic damaging inflammations, dominated by necropoietic lesions in viscera. The extent of pathologic changes is conditioned by, i.a., toxic effects of cyanobacteria (including *Microcystis aeruginosa*) blooms occuring in the Lagoon's eutrophic waters.

INTRODUCTION

Instances of eel mortality (*necrosis ulcerosa cutis, morbus anguillarum*) were frequently recorded in the Szczecin Lagoon within 1970–1973, along with multiple cases of toxicosis–like chronic condition Grabda et al., 1973; Einszporn–Orecka, 1976; Orecka–Grabda, 1986).

A permanent supply, mainly with the River Odra discharge, of anthropogenic pollution (industrial, urban, and agricultural effluent) to the Lagon results in adverse changes in the biological equilibrium of the Lagoon's ecosystem. Long–term hydro-

chemical surveys carried out by the Environmental Control Centre in Szczecin (Mutko, 1977, 1979, 1986) and by Poleszczuk and Sitek (1993) demonstrate a steadily increasing eutrophication of the Lagoon. Since 1970, mean annual phosphate and nitrogen contents have been increasing considerably, the latter by as much as 100%. In 1983, the mean annual content of nitrogen compounds in the Lagoon was 1.45–2.93 mg/l, with peak values of 3.36–5.0 mg/l; the highest values were recorded in the spring (April–May) close to the River Odra mouth.

A comparison between contents of phosphorus compounds in 1968–1969 vs. 1954–1956 shows a 5 to 20–fold increase (Drzycimski, 1986), the maximum values exceeding 1.0 mg PO/dm, i.e. that of water quality class III (Mutko, 1986). A significant increase in the Lagoon's phosphate content occurred after "Police" Chemical Works, situated near the Odra mouth, became operative. Consequently, mean phosphate contents in 1983 ranged from 0.28 (November) to 1.08 mg/l (April), with a maximum of 3.72 mg/l recorded in April in the northern part of the Lagoon.

Excessive nutrient supply in the Lagoon creates conditions favouring growth of eutrophication–exploiting organisms, including mass development of phytoplankton, its biomass exceeding that found in 1954–1956 by a factor of 3–4 (Drzycimski, 1986). Phytoplankton biomass, as measured with chlorophyll a concentrations in water, was similar in 1982 and 1983 (unpublished data of Environmental Control Centre). Since April, in both the Great and Small Lagoon, the phytoplankton was dominated by diatoms (*Melosira varians, M. granulata, Sceletonema subsalsum, Asterionella formosa, Diatoma elongatum* and other species). The spring diatom bloom was followed by a mass development of cyanobacteria all over the Lagoon in summer, the cyanobacteria assemblage consisting of *Microcystis aeruginosa, Aphanizomenon flos–aquae, Anabaena spiroides,* and *Oscillatoria rubences. M. aeruginosa* dominating from June through September. Świerczyński et al. (1986) recorded *M. aeruginosa* density in 1983 to exceed 6 million colonies/dm^3. Concurrently, chlorophyll a concentrations amounted to 125, 277, and 314 mg/dm^3 in the surface water (48–111 mg/dm^3 in the near–bottom layer) from the northern to southern areas of the Lagoon as measured along the ship lane. The lowest values (to 59 mg/dm^3) were recorded near the Odra mouth.

Increasing eutrophication and long–lasting phytoplankton blooms are accompanied by considerable fluctuations in other water parameters (pH, oxygen saturation, BOD_5, etc.). Within 1971–1973 and in 1983, water pH was found to increase, as shown by data collected at a station located near Gate 2 in the central part of the Lagoon. The mean annual and maximum pH values increased from 8.0–8.3 to 8.85 and from 8.6–8.9 to 10.0, respectively (Mutko, 1977, 1986). The annual mean and maximum in 1983, determined from data for 5 stations located in different areas of the Lagoon were 8.7 and 10.0, respectively (except for a station at the Odra mouth with pH 8.2). The pattern of yearly fluctuations overlaps that of annual cycles of

phytoplankton development, with pH maxima coinciding with intensive blooms. At 4 out of 6 stations visited in August 1983, the strongly alkaline water had pH around 10.0.

The Szczecin Lagoon with its shallow (mean and maximum depths of 4 and 7 m, respectively, discounting the dredged ship lane), wind and wave mixed water has good oxygen conditions. In 1983, the mean annual dissolved oxygen content ranged within 9.0–14.3 mg/l (maximum up to 22.6 mg/l), oxygen saturation reaching 256.0%. High saturation values were recorded also in 1971 (up to 190.0%) and in 1975 (over 200%) (Mutko, 1977, 1986). Hypersaturation was evident in the near–bottom water as well, e.g. 57.1 to 170.5% in August 1983 (Poleszczuk and Sitek, 1993). Hyperoxygenation in summer (July – August) is accompanied by high surface and bottom water temperatures (19.6–22.0°C and 18.4–20.8°C, respectively).

According to Mutko (1986), long–term data on BOD_5 values in the Lagoon demonstrate a characteristic spatial pattern: higher values occur in the northern areas and lower in the southern regions, close to the pollutants discharging mouth of the Odra. BOD_5 values peak during phytoplankton blooms; in August 1983, the mean value was 7.2 mg O_2/l (maximum 9.0 mg O_2/l).

Progressing degradation of the Lagoon's biocoenoses is evident, i.a., as changes in composition of the fish fauna and in reduced catches of certain species, including the eel (Drzycimski, 1986; Kompowski, Pieńkowski 1992).

Adversely changed environmental conditions and increasing eutrophication create conditions which are conducive to fish infections and intoxications.

MATERIALS AND METHODS

The eels examined were caught in several fishing grounds in the Lagoon in 1983 and off Trzebież in 1971–1973 and 1982. The fish were examined in January, July and September 1971, July and August 1972, and in August 1973, August 1982, and August 1983. In 1983, the eel were caught near the Piastowski Canal, off Lubin, Stepnica, Nowe Warpno (there the fish were kept for 3 days in cages), Trzebież, and in Stara Odra Canal (Fig. 1).

About 400 eel individuals measuring 31–89 cm (total length) and weighing 40–1250 g were examined. The fish age, as determined from the number of rings on scales and polished otoliths, ranged from 1+ to 11+ (not counting the larval period).

After capture, the fish were brought to the laboratory and kept in aerated aquaria for 1 to 3 days. The fish underwent autopsy after at least 20 hours; clinical, anatomopathological, and parasitological examinations were performed (the latter will be a subject of a speparate paper).

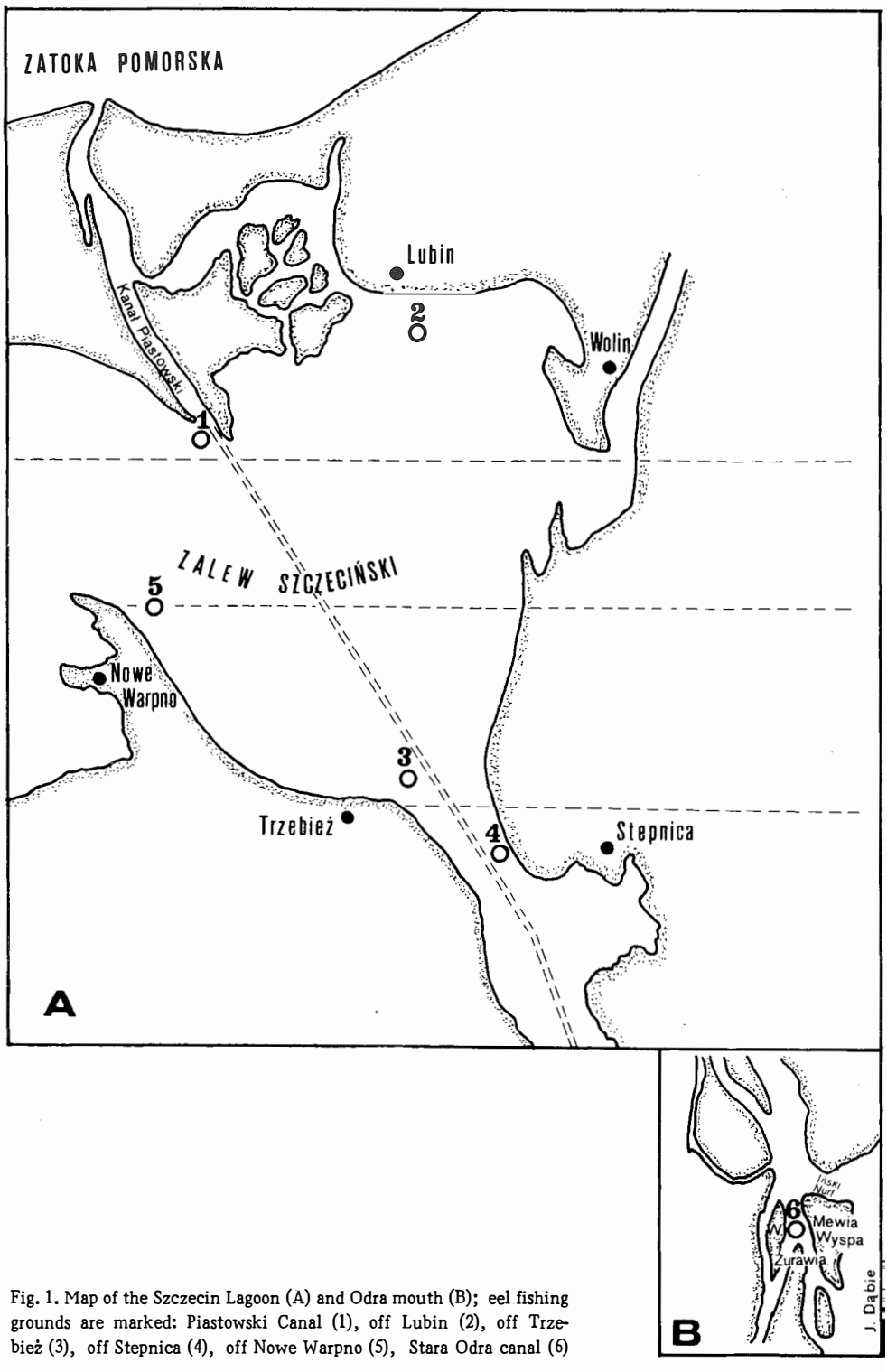


Fig. 1. Map of the Szczecin Lagoon (A) and Odra mouth (B); eel fishing grounds are marked: Piastowski Canal (1), off Lubin (2), off Trzebież (3), off Stepnica (4), off Nowe Warpno (5), Stara Odra canal (6)

Hematologic parameters such as counts of morphotic elements of the blood, hemoglobin content, and cell volume (PCV) were determined. The blood was collected from the caudal vein with a hepar in–treated Pasteur pipette.

Quantitative analyses of morphotic elements, always made on the first drop of blood, included:

– erythrocyte, leukocyte, and thrombocyte counts per mm^3 of peripheral blood; according to the generally accepted procedures, in a Burker chamber;
– hemoglobin content; photocolorimetrically (at 540 nm wavelength), with Drabkin reagent (cyanmethemoglobin technique);
– relative cell volume (PCV); in microcentrifuge, using Wiltrobe micropipettes and heparin–treated capillaries;
– erythrocyte indices: mean cell hemoglobin content (MCH), mean cell hemoglobin concentration (MCHC), mean cell volume (MCV), blood cell index, and leukocyte index.

The data collected will be used in cyto– and histopathological analyses to be published at a later date.

RESULTS

Pathological changes of various intensity were found in an average of up to 50% of the eels; in different fishing grounds, from single individuals to 80% of the catch were affected. Lesions and hyperemia, frequently associated with swelling and ecchymoses, particularly at the fin bases, were recorded in an average of 30% of the eel, both in 1982–1983 (in various areas of th Lagoon), and in 1971–1973 off Trzebież. Skin lesions in the form of single or extensive ecchymoses, especially on the ventral side, were observed in 13% (exceptionally in 46%) of the fish (particularly off Nowe Warpno and Stara Odra Canal). In fish from some areas (notably off Stepnica), the pathologically changed skin produced less mucus; scale contours were very sharp. In other areas, skin depigmentation – particularly on the head and dorsal side – was more frequent than in the earlier period and was accompanied by necrotic patches and small tissue lesions. Noteworthy were milky–grey, extensive patches of different shape on the skin, their incidence increasing under certain conditions (e.g. when the fish were kept in cages).

Moreover, 100% of the fish caught in the Stara Odra Canal showed strongly reddened mouth mucosa, with spotty ecchymoses. Phacoscotasmus was frequent. Another frequently occurring symtom was congestion of gill lamellae accompanied by dilatation of gill capillaries. More seldom, but in 46% of cage–kept fish caught off Nowe Warpno, anemia–like symptoms with extravasations and gill lamella necrosis were observed.

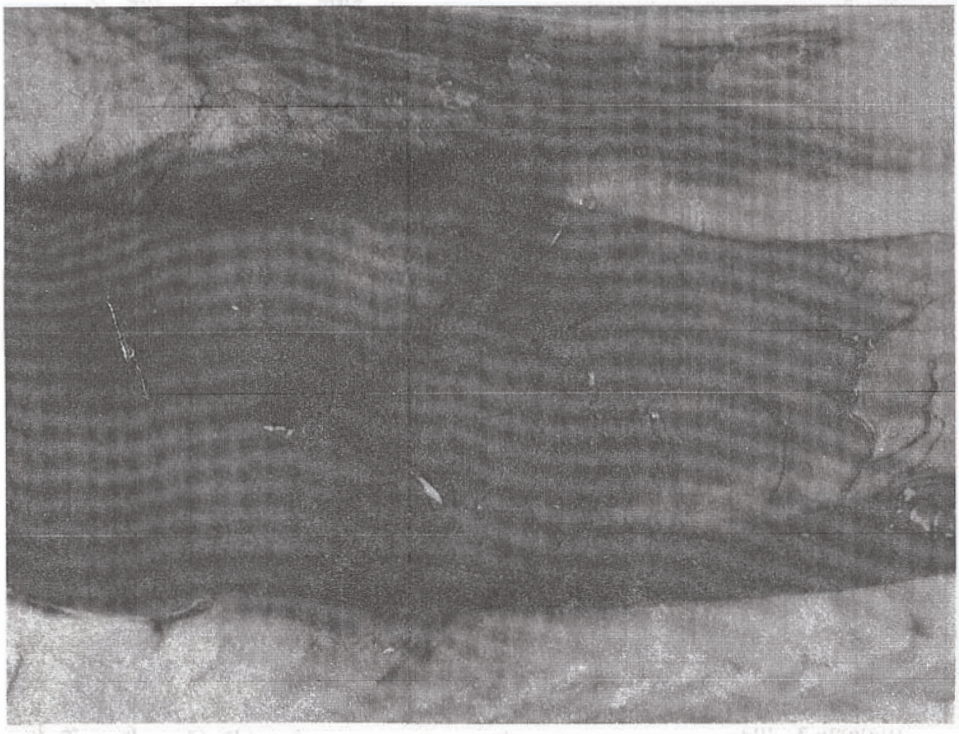


Fig. 2. General congestion of hepatic parenchyma with visible ecchymoses, particularly within hepatic lohes; nearby visible dilated blood vessels of stomach walls

Long–term data obtained from biopses showed preponderance of circulatory disorders, evident as excessively dilated and bloodcell filled vessels (primarily the supra– and subintestinal veins and arteries) of the internal and external peritoneal laminae. Such changes were recorded in, on the average, 71% of the fish caught in 1983 in different areas of the Lagoon Fig. 2, 3. The changes were particularly intense in the eel caught off Stepnica (up to 86% of the catch were affected), Stara Odra Canal (88%), and Nowe Warpno cages (92%). Off Trzebież in 1982–1983, the symptoms concerned about 50% of the fish, compared to 10% in 1971–1973. In few cases only (about 6%), the body cavity contained extracellular fluid.

Similarly characteristic changes were associated with congestion spots ecchymoses in the swim bladder wall. An opaque, blood–containing extracellular fluid collected in the bladder lumen and, in larger amounts, in the duct connecting the bladder with the gut. Non–specific changes in the appearance of the swim bladder chamber and the pneumatic duct were observed in, on the average, 65% of the eel (23–92% in 1983 and 9.1–70% in 1971–1973).

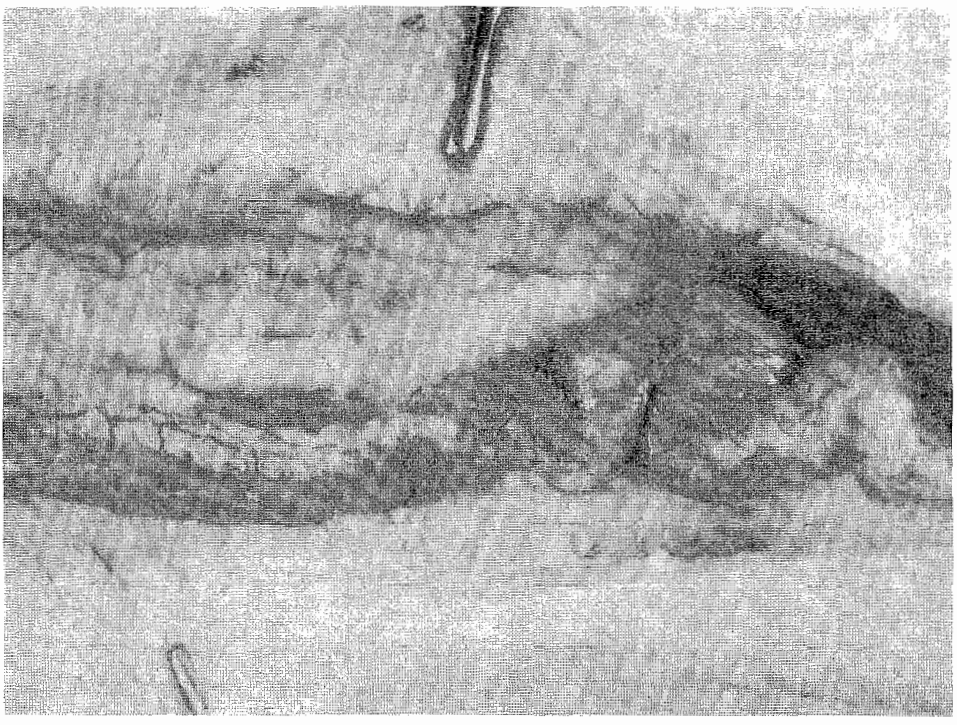


Fig. 3. Network of blood vessels in posterior part of peritoneum and intestine wall

Macroscopic examination of the internal organs demonstrated chronic or acute changes affecting most individuals. Liver lesions were found in 95% of the eels. The nature of changes and frequency of their occurrence were at as high a level as that recorded in 1971. An average of 67% of the eel showed general or local liver congestion and swelling with simultaneous parenchymal infiltration, hemorrhage centres, and even blood clots. The hepatic tissue in some individuals (18% on the average) showed altered coloration (from red–brown to sand–coloured to light milky) with differently coloured spots, resulting from preogressing degenerative and necrotic processes. Liver deformations, usually in differently colored lobes (from cherryred to black) were frequent.

Considerable pathologic changes had been occurring, as in the liver, in the kidney tissue since 1971, an average of 45% of the fish being affected in that year. In 1983, however, in some fishing grounds (particularly off Stepnica, Nowe Warpno, and Stara Odra) even 82% of the catch showed pathologic symptoms. Macroscopic examinations revealed the changes to occur along the entire kidney, the mesonephros trunk section being highly damaged. The tissue there was strongly functionally impaired

and degenerated. The poorly blood–supplied tissue was swollen, had reduced cohesiveness to the point of colliquative form of watery parenchyma texture. Acute changes in the mesonephros were recorded in 46% of the fish examined, caught in Stara Odra, and off Stepnica and Lubin. Fewer fish were affected by changes in the caudal section of mesonephros; 18% of the eel (in 1983) showed considerable parenchymal tissue hypertrophy related to the hemopoietic function.

Changes in the appearance of the spleen involved hypertrophy and deformations, and – less frequently – atrophy of the organ. The enlarged, lobate spleens with nodular surface were usually swollen, had loose texture, the tissue being infiltrated with blood containing fluid. Such changes were recorded in an average of 16% of the fish in 1971–1973, while up to 46% were affected in 1983.

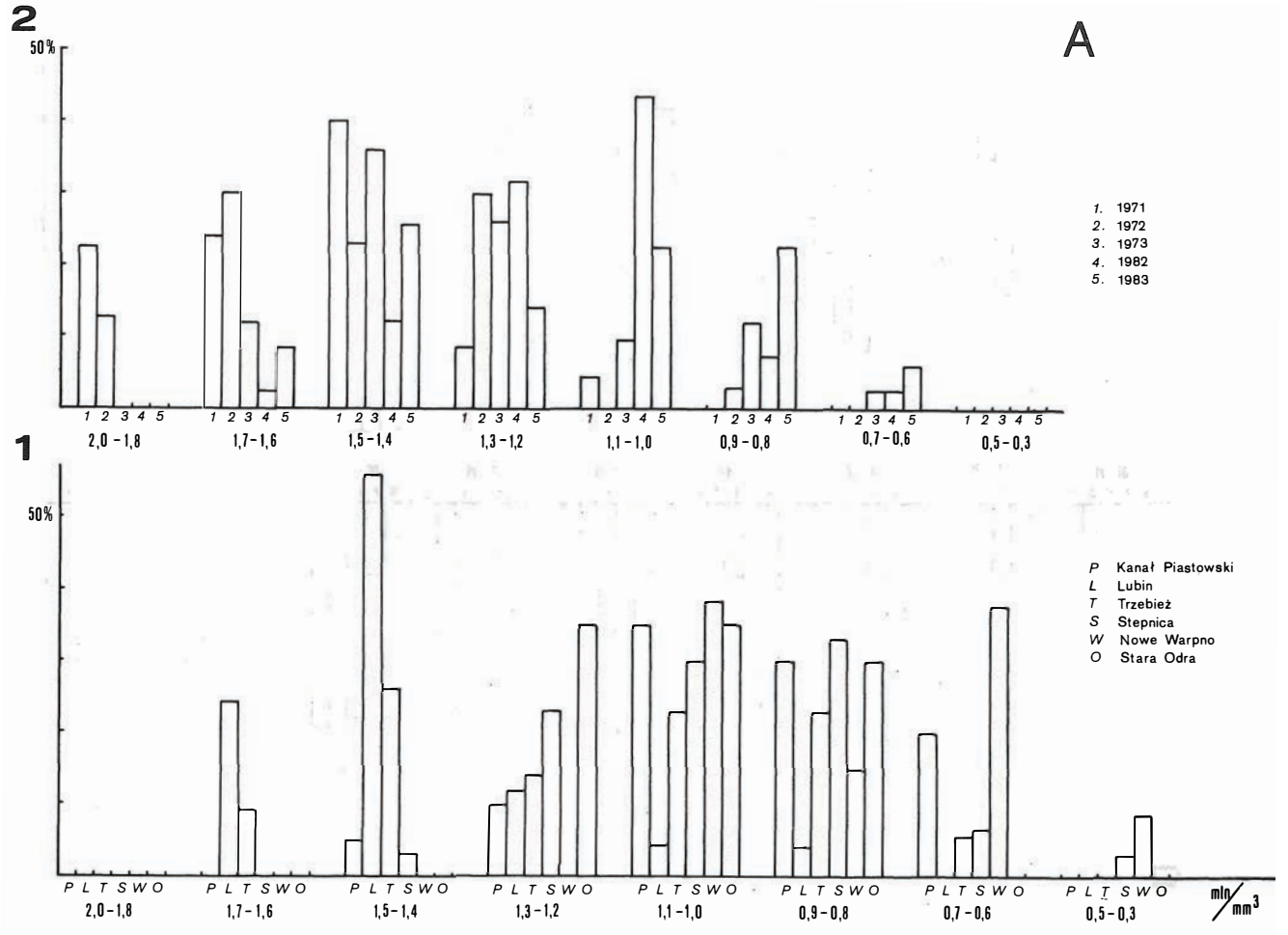
Hemorrhagic inflammations of the intestinal mucosa were observed in 33% of the fish (or 48% in 1983). Strongly congested mucosa, particularly in the terminal part of the intestine (occasionally associated with anal inflammation) was recorded in 92% and 72% of the Stara Odra Canal and Nowe Warpno catches. The affected intestines had poorly developed, peeling off muscles with symptoms of catarrhal inflammation.

Hematologic parameters

Hematologic data for 1982–1983 were compared with those for 1971–1973 off Trzebież (Orecka–Grabda, 1986). The values were similar to those reported by Kreutzmann (1973), Schliecher (1927), and Zajceva (1967).

The mean physiologic erythrocyte count, determined with the clinical evaluation on mind, was 1.538 million/mm^3 ± 47 – ± 148. The 1983 data show the erythrocyte counts ranging within 1.4–1.7 million/mm^3 to occur in 17% of the eel examined, caught mostly in the northern part of the Lagoon (Fig. 4.1A). Most fish, however, showed values lower than the control. In 1983, as many as 76% of individuals from the 5 fishing grounds showed a lowered erythrogram (Fig. 4.1A). Low erythrocyte counts, reduced by about 600 million/mm^3 and 850 million/mm^3, were recorded in 66% and 10% of individuals, respectively. Extremely low counts (about 340 million/mm^3, were found in the eel caught off Stepnica and in those kept in Nowe Warpno cages (Fig. 4.1A). Comparative erythrogram analysis for one fishing ground (off Trzebież), performed on data for 1971–1973 and 1982–1983 demonstrates an increase in the incidence of moderate and substantial anemia from 13 to 85% (Fig. 4.2A).

Other hematological parameters, particularly the relative cell volume (PCV), are clearly correlated with erythrocyte counts (Figs. 4.1B and 2B). Compared to the average physiological hematocrit, determined from 1971–1973 data and amounting to 36.7 + 2.85%, the 1983 hematocrit shows a decreasing trend, the difference being 11–12% (20% at the highest). Thus 86% of individuals failed to develop a control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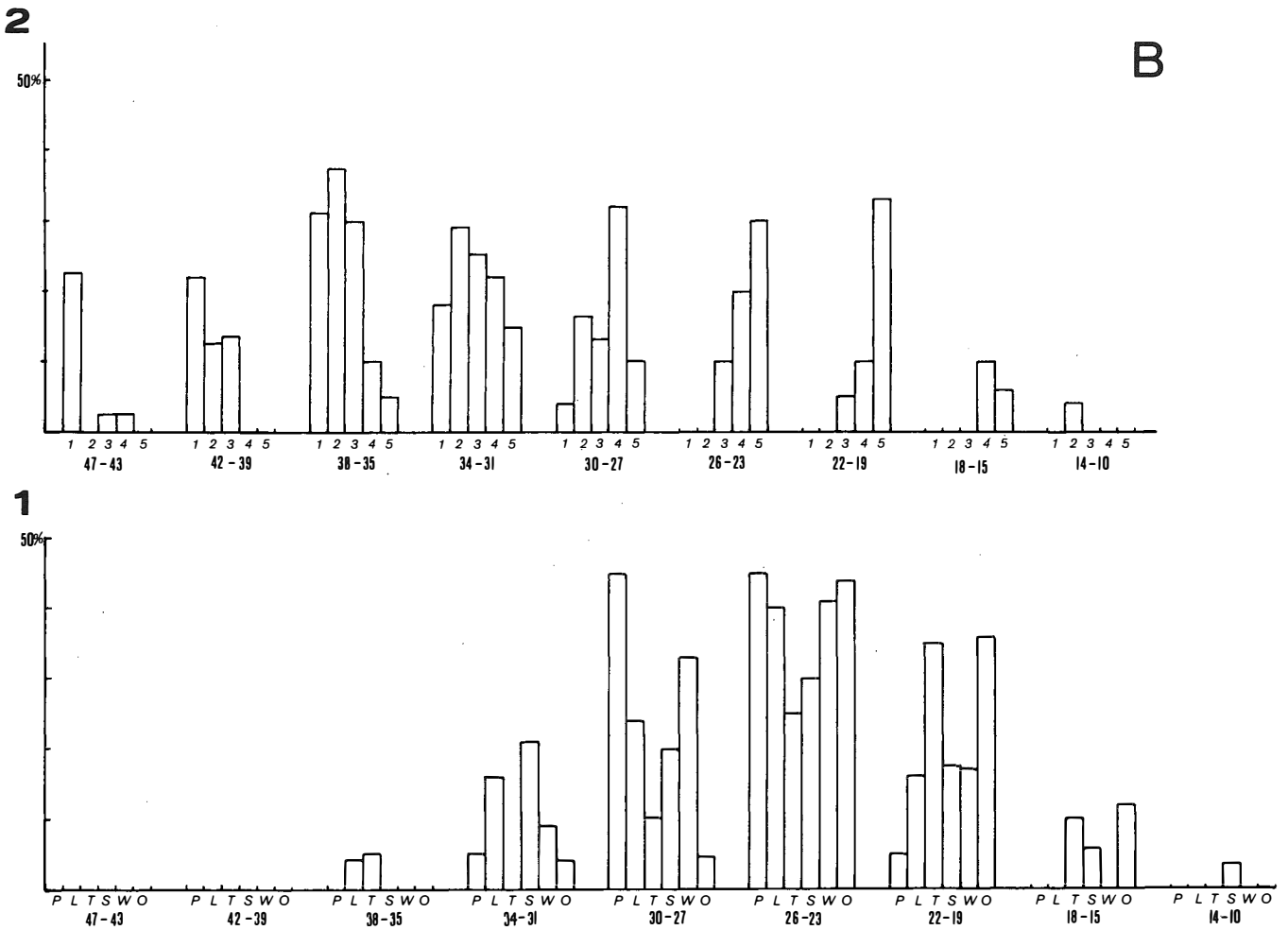
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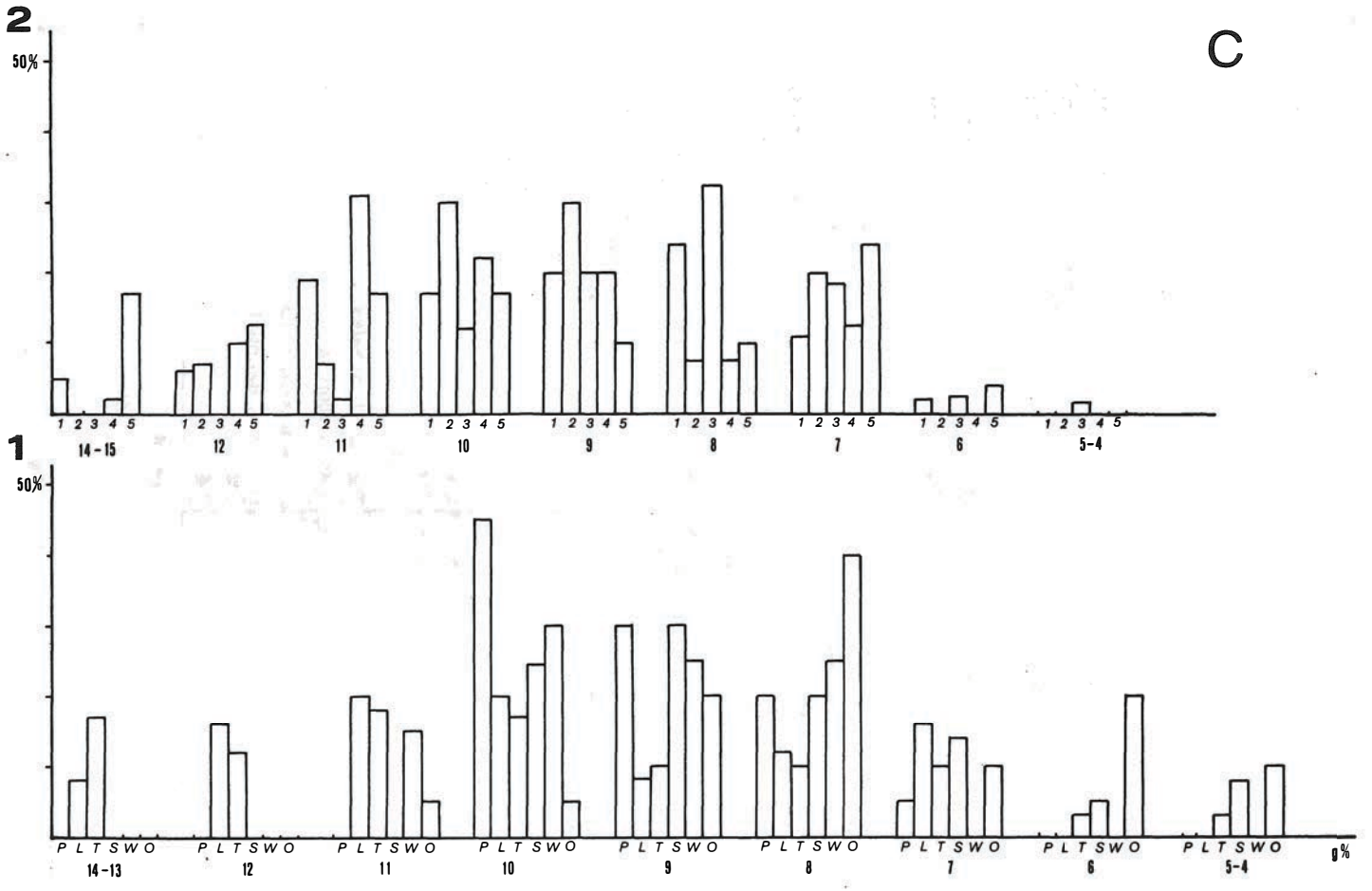
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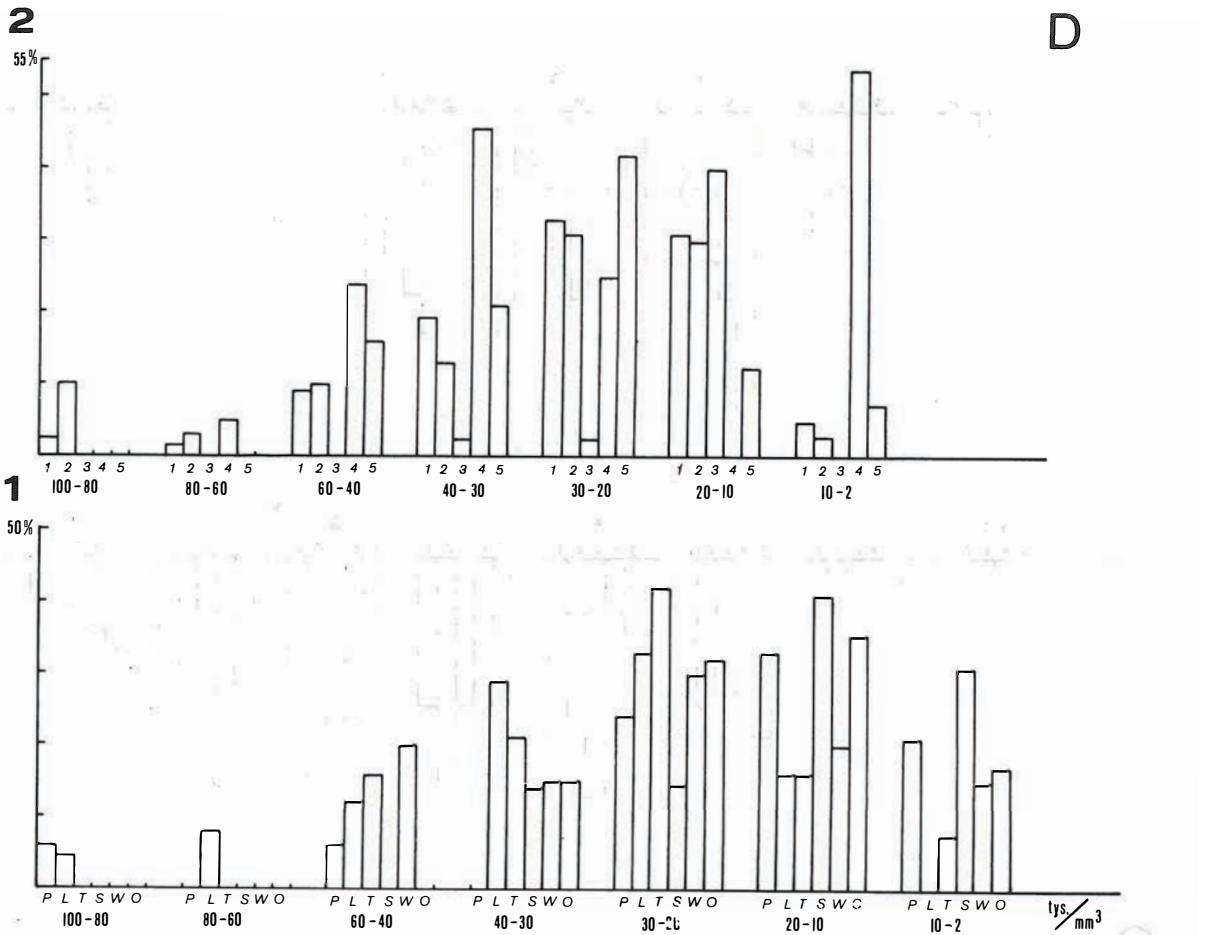

Fig. 4. Percentages of the eel caught in different areas of the Szczecin Lagoon in 1983 (1) and off Trzebież in 1971–1973 and 1982–1983 (2) by peripheral blood hematologic parameters: erythrocyte count (A), hematocrit (B), hemoglobin content (C), leukocyte count (D)

hematocrit. With respect to PCV, differences between the 1971–1973 and 1982–1983 data are seen in the eel caught off Trzebież. The PCV level of 47–39% was in 1971, 1972–1973, and 1982 recorded in 47, about 14, and 3% of individuals, while in 1983 no individual had PCV in that range (Fig. 4.2B).

Of other parameters, hemoglobin content below the control value occurred in 1983 in about 35% of individuals overall; 45 and 70% of individuals from off Stepnica and Stara Odra, respectively, showed lower–than–control hemoglobin contents (Fig. 4.1C). The physiological average hemoglobin content, calculated from the 1972–1973 data,was 9.76 ± 0.86 g% (9.34 to 10.06 g%); 60% of individuals examined at that period reached the control level (Fig. 4.2C). In 1983, the control value was recorded in 40% of individuals; 25% of the eel (mostly those caught in northern fishing grounds) had higher values. The lowest level (7 or 5 g%) was found in 15% of individuals caught off Stepnica and Nowe Warpno.

As seen from the pattern presented above, erythrocyte parameters must have undergone marked changes within 1971–1983. Specifically, the range of mean cell hemoglobin content increased from 59–80 µg to 46–170 µg. The mean hemoglobin content in 1971–1973 was 65 µg in 66% of the control eel population. Similar value in 1983 was recorded in 11% of individuals; dominant were higher values (80–170 µg), found in 80% of the population. Moreover, different ranges were revealed in some groups of fish examined: 40–80 µg in the eel caught in the northern part of the Lagoon (off Lubin) vs. 80–170 µg off Nowe Warpno.

Erythrocyte size (MCV) was subject to considerable changes. In 1983, MCV values ranged widely (147–464 μ^3), compared to the 1971–1973 range of 173–314 μ^3. The mean value in that time was 232 μ^3 and was characteristic of 82% of individuals. while in 1983 larger erythrocytes were encountered: 40% of the eel had their MCV ranging within 260–464 μ^3.

In 1971–1973, the peripheral blood leukogram and physiological standard was 16.000 ± 5.380/mm^3. The leukocyte count ranging within 20.000–30.000/mm^3 was typical of 30 and 25% of the fish in 1971–1973 and 1983, respectively; low leukocytosis (30.000–40.000/mm^3), was revealed in 15 and 20% of the population in the respective periods, while high leukocytosis (40.000–80.000/mm^3) was revealed in 20 and 12% of the eel in the respective periods. Moderate and low leukopenia (10.000/mm^3 and less) was found in 32 and 44% of individuals in 1971–1973 and 1983, respectively (Figs. 4.1D and 2D).

DISCUSSION

Clinical and anatomopathological changes in the eel examined demonstrated a complex nature of etiopathogenesis and multifaceted effects of factors related to

eutrophication and pollution of the Lagoon. The excessive input of nutrients (phosphorus and nitrogen compounds) results in physico-chemical and biotic changes related to periodic phytoplankton blooms. Algal photosynthesis (including that of cyanobacteria) alters the oxygen regime (considerable diurnal fluctuations in dissolved oxygen content, including a complete lack of oxygen) and water pH. Life processes of the algae disturb the carbonate balance, whereby strongly alkalic, toxic calcium hydroxidae, capable of increasing pH to as much as 11.0 is produced (Turoboyski, 1979).

At pH 10 occurring periodically in different parts of the Lagoon, typical alkalosis symptoms were obesrved in the eel: skin changes (depigmentation, pigment patches, jelly–like mucous efflorescences), phacoscotasmus, and congestion of excessively mucus–covered gills. Data obtained from eel cultured in the presence of *Microcystis aeruginosa* furnish a partial confirmation of observations made in the alkaline open waters: at algal concentrations of 64 million colonies/dm^3, skin pigmentation intensity changed within 72 h as a result of migration and deformation of melanocytes (Świerczyński, Czerniewska 1992).

Diurnal variations in pH and oxygen saturation (under a given set of pressure and high temperature conditions) are conducive to bubble disease. The periodically occurring oxygen hypersaturation (occasionally up to 256%) coupled with rapid drops in oxygen concentrations (to deficit levels) at night lead to increased blood oxygenation followed by a fast release of oxygen from the tissue fluid and the blood. The eel examined did show gas bubbles, particularly in gill vessels.

Symptoms of irregular blood flow are visible as congestions, extravasations, and embolisms, mainly in blood vessels of the internal peritoneum, supra- and subintestinal and hepatic veins. The frequency of circulatory disorders was found to increase, from 10% of the eel affected in 1971–1973 to 71% (or even 92%) in 1983. Toxic effects were manifest in the internal organs as acute and chronic damaging inflammations, dominated by degenerative and necrotic changes (the liver was affected in 95% of the eel, while the kidney in 82%).

The pathologic changes observed are related to, i.a., activity of cyanobacterial endotoxins; the endotoxin produced by *M. aeruginosa* is classified with strong parenchymal toxins along with hydroxylamine (Szerow, 1974; Prost, 1989). Raaberg et al. (1991) injected microcystin IR (cyclic peptide hepatotoxin) isolated from *M. aeruginosa* to *Cyprinus carpio.* Histological examination revealed damaged hepatocytes and degeneration of the Bowmann capsule and kidney canaliculi. Similar changes, indicative of acute toxemia, have been observed in the eel since 1971, for example kidney lesions resembling colliquative necrosis are related to endoparenchymal tissue reduction and atrophy of nephron elements, particularly in the mesonephros (found in 46% of the eel) (Orecka–Grabda, in prep.).

Responses to irregular gas exchange (fluctuating oxygen concentrations and pH) and exogenous toxins in fish involve alterations in peripheral blood parameters relative to the physiological standards. Anisopoikilocytosis–type anemia with reduced erythrocyte count (76% of the population) and low hematocrit (PCV) (at least 86%) are recorded. Regular hemoglobin contents recorded in 65% of the eel, indicative of increased cell saturation and capacity to hold oxygen in the system is an adaptive mechanism allowing to bind the excess of oxygen. Erythrocytes vary markedly in size, their volume being increased to as much as 464 μ^3. Hematologic data evidence intensified lysis of blood cells, accompanied by low (20% of the fish) and high (12%) leukocytosis or, more often, leukopenia (44% of the eel).

The *Microcystis cyanobacteria* at densities of few to several million cells/dm^3 are toxic to fish. In their bioassay study on 2000 fish individuals, Świerczyński et al. (1992) identified the range of lethal concentrations (LC) from 4.3 million/dm^3 (lethal for *Gasterosteus aculeatus*) to 23.3 million/dm^3 (lethal for *Carassius carassius*). The *M. aeruginosa* density lethal for *Anguilla anguilla* was 13.3 million/dm^3. The values are comparable to naturally occurring densities in the Szczecin Lagoon (4–6 million colonies/dm^3) (Świerczyński et al., 1987). Additionally, Piesik (1992) found water pH above 10 in the Lagoon (in July O August 1986) to affect about 20% of the area. In the southern part of the Lagoon, at a pH range of 9.2–9.7, mortality of *Gymnocephalus cernua* and *Gasterosteus aculeatus* was recorded. Both the data referred to above and observations on eel kept for a short time in cages placed close to shore demonstrate that the eel in the Lagoon is threatened by potential mortality, particularly when progressing environmental degradation is factored in. Fish mortality resulting from adverse effects of cyanobacteria (including *Microcystis aeruginosa*) were recorded by, i.a. Kabata (1985), Roberts (1985), and Parra et al. (1986).

CONCLUSIONS

1. The *Anguilla anguilla* individuals occurring in alkaline and eutrophic Szczecin Lagoon show symptoms of alkalosis and bubble disease.
2. The progressing eutrophication (in 1971–1983) and toxic effects, including those produced by cyanobacteria, brings about circulatory disorders of the eel and damaging inflammation in the fish internal organs.
3. As shown by the 1983 data, hematogic parameters of the peripheral blood of the eel showed values reduced with respect to those recorded in 1972–1973.

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WSTĘPNA OCENA STANU ZDROWOTNEGO WĘGORZY (*ANGUILLA ANGUILLA* (L.)) W WODACH ZALEWU SZCZECIŃSKIEGO W LATACH 1971–1973 I 1982–1983

STRESZCZENIE

W oparciu o analizę zmian klinicznych, anatomopatologicznych i wskaźników hematologicznych oceniono zdrowotność węgorzy (*Anguilla anguilla* (L.)) odłowionych z wód Zalewu Szczecińskiego w latach 1982–1983 i 1971–1973. W obrazie sekcyjnym dominowały zaburzenia w krążeniu w postaci przekrwienia, wyborczyn, ognisk krwotocznych w narządach wewnętrznych oraz otrzewnej. W związku z tym, w wątrobie przewlekłe stany zapalne typu uszkadzającego występowały u około 90% węgorzy (na zbliżonym poziomie od roku 1971). Ponadto zmiany w nerkach o charakterze martwicy rozpływnej, zwłaszcza w odcinku śródnercza tułowiowego (mesonephros), stwierdzono u około 45% ryb (maksymalnie do 80%). Jednocześnie krew obwodowa węgorzy charakteryzuje się zaniżonymi parametrami w stosunku do wartości uzyskanych w latach 1971–1973. Występuje niedokrwistość typu anizopoikilocytozy z obniżoną liczbą erytrocytów (u 76%), z niskimi wartościami hematokrytu (u 86%) i hemoglobiny (średnio u 35%, maksymalnie do 70%). Zaznacza się przy tym wyraźne zróżnicowanie wielkości erytrocytów w kierunku zwiększenia wymiarów nawet do 464 μ^3. Wzmożonym procesom hemolitycznym towarzyszy częściej leukopenia (u 44%) rzadko wysoka leukocytoza (u 12% ryb).

Sumując, zmiany chorobowe wskazują na złożony charakter etiopatogenezy, wynikający przede wszystkim z oddziaływania na ryby zalkalizowanych i zeutrofizowanych wód Zalewu. Zakres zmian patologicznych warunkuje m.in. toksyczne działanie *Cyanophyta* (w tym *Microcystis aeruginosa*) zwłaszcza w okresie silnych zakwitów (LC_{50} dla *Anguilla anguilla* w granicach 13,3 mln/dcm^3, w wodach Zalewu przeciętnie 6,5 mln/dcm^3 wody). Bezpośrednim następstwem tych zjawisk są objawy chorobowe alkalozy (alcalosis) i choroby gazowej.

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