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The microbiological state of fish feed, water, and *Silurus glanis* L. skin of fry during intensive rearing

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Abstract. Water, fish feed and fish skin were studied during the pond rearing of European catfish (*Silurus glanis L.*) fry. The numbers of heterotrophic bacteria cultured on broth agar at a temperature of 22°C and 37°C (TVC 22°C and TVC 37°C), heterotrophic bacteria cultured on TGY medium at a temperature of 25°C (TGY 25°C), total coliforms (TC) at a temperature of 37°C, fecal coliforms (FC) at a temperature of 44.5°C, fecal streptococci (FS) at a temperature of 37°C in the studied water samples varied as follows: 2000-44000, 750-5500, 8600-88000 cfu in 1cm^3, 1-300, 1-65, 1-95 in 100 cm^3. *Pseudomonas fluorescens, Aeromonas hydrophila*, and *Pseudomonas aeruginosa* occurred in 100 cm^3 of water at 300-5,000, 10-609, 0-8 cfu, respectively. The numbers of TVC 22°C, TVC 37°C, TGY 25°C, yeast and mould fungi in 1 g of feed were 2200000-4500000 cfu, 290000-5000000 cfu, 1400000-4400000 cfu, 120-1500 cfu, and 70-1000 cfu, respectively. TC, FC, and FS varied as follows: 40-120 cfu/ 100g, 1-4 cfu/ 100g, 2000-35000 cfu/100 g. *Pseudomonas fluorescens* was noted at 2-70 cfu/ 100g feed; *Pseudomonas aeruginosa* and *Aeromonas hydrophila* were not observed. On 1 cm^2 of skin surface the numbers of TVC 22°C, TVC 37°C and TGY 25°C ranged from 10^3 to 10^4 cfu, while the amounts of TC, FC and FS ranged from 1-220 cfu, 1-3 cfu, and 1-80 cfu, respectively. Mould fungi occurred at 10 cfu/1cm^2 and yeast at 8-220 cfu/1 cm^2. Potentially pathogenic bacteria were observed in numbers ranging from several to several dozen cfu/ 1cm^2 of skin surface, depending on the bacteria type. Statistical analysis indicated significant differences ($p < 0.05$) in the occurrence of TVC 22°C, TVC 37°C, TGY 25°C, FC, *Pseudomonas fluorescens*, *Pseudomonas aeruginosa* and *Aeromonas hydrophila* in the water, fish feed and on the skin of European catfish fry.

Key words: microflora, water, fry, European catfish, feed

INTRODUCTION

The high nutritional values of fish proteins and an increasing demand for good quality freshwater fish has led to the intensification of fisheries production. Currently, production is based entirely on artificial fish feed (Ben-Gera 1994). Unfortunately, aside from their basic nutritional function, fish feeds pose the most serious threat to the aquatic environment and, consequently, to the fish reared in these waters. Feed that is rich in proteins,

carbohydrates and lipids (Guziur 1997) provides a perfect medium for the development of microbes that are present in basins or rearing ponds or those which are deposited into the water with fish excrement (Sugita *et al. 1*985, Zmysłowska *et al.* 2000b). Only about one quarter of the phosphorus and nitrogen contained in feed is utilized to build fish tissues. The remainder of the nutrients is either excreted in diluted forms or falls to the bottom. Additional factors that contribute to the contamination of the aquatic environment include the products of fish metabolism (ammonia nitrate, urea) and widely applied antibacterial agents such as antibiotics and formalin (Karpiński 1995). Due to the low body weight and resistance of fry, it is especially susceptible to adverse environmental conditions. The good condition of fry and the continued rearing of it with minimum losses both depend on the appropriate monitoring of the fish in rearing ponds. This is closely connected to ensuring a continuous flow of water with the appropriate physical, chemical, and biological parameters (of which microbiological quality is important). The amount and the bacteriological purity of the applied feed are also significant factors. Small amounts of organic substances in the water that come from, among other sources, the rationalization of the feeding factor are not responsible for the deterioration of the microbiological state of water that is characterized by small numbers of heterotrophic bacteria and fungi and indicators of contamination levels (TVC 22ºC and TVC 37ºC) and sanitary state (TC, FC, FS). Large numbers of bacterial macrofauna in rearing pond water are usually reflected in the quantitative and qualitative composition of the microflora on the surface of fish skin and in the digestive tract (Niewolak and Tucholski 2000a, Zaleski 1985, Zmysłowska 2001, Zmysłowska *et al.* 2001b).

The environmental requirements of the European catfish (*Silurus glanis* L.), especially with regard to oxygen, are easily met; this fact, combined with its quick growth and the high market value of its meat, have spurred increasing interest in rearing this fish species in Poland (Guziur 1997). The intensive rearing of this species based on feed can lead to the deterioration of microbiological conditions in the water by increasing the numbers of bacterial indicators of contamination (TVC 22ºC and TVC 37ºC) and sanitary state (TC, FC, FS). One consequence of poor environmental conditions is weakened fish condition and the spread of diseases due to the development of potentially pathogenic bacteria such as *Pseudomonas fluorescens*, *Pseudomonas aeruginosa*, *Aeromonas hydrophila*, and others (Strauss 1985, Buras *et al.* 1985).

The aim of this work was to determine the dependencies in the occurrence of bacterial indicators of contamination level (TVC 22ºC and TVC 37ºC) and sanitary state (TC, FC, FS), fungi and selected potentially pathogenic bacteria (*Pseudomonas fluorescens*, *Pseudomonas aeruginosa*, *Aeromonas hydrophila*) in the water and fish feed and on the skin of European catfish (*Silurus glanis* L.) during intensive rearing in a closed cycle.

MATERIALS AND METHODS

Subject of the studies and the description of the experiment

The experiment was conducted at the Fish Farm in Komorowo near Łukta. The European catfish (*Silurus glanis L.*) fry were released into a pond with a volume of 450 dm^3.

The diurnal water exchange in the pond was from 5-10%. During the experiment the water temperature varied from 16 to 21°C, and the oxygen concentration was from 3.0 to 5.5 mg × dm^{-3}. There were 1,000 specimens of catfish (*Silurus glanis* L.) fry in the pond. The initial individual fish weight was 4.0 g ± 1.3 g and body length was about 7 cm. The fry were fed with Nutra – T made by (Nutreco, France), which was supplied every eight hours in rations of 30-120 g depending on fish body weight and how long the experiment had been ongoing. By the conclusion of the experiment, the fry body weight had increased by 100-120% and losses were at 14%.

Microbiological studies

Microbiological studies of the water, fish feed and fish fry were conducted during intensive, experimental rearing of European catfish (*Silurus glanis L.*) in a closed cycle pond. The experiment lasted for eight weeks from 3 January 2001 to 13 February 2001. The study samples comprised of ten catfish fry specimens were collected at two-week intervals. The quantitative studies of the water and feed as well as the catfish fry skin were comprised of the following microbiological determinations:

– total number of heterotrophic bacteria cultured on broth agar after 72 hours of incubation at a temperature of 22° C (TVC 22°C);

– total number of heterotrophic bacteria cultured on broth agar after 24 hours of incubation at a temperature of 37° C (TVC 37°C);

– total number of heterotrophic bacteria cultured on TGY medium (Seppänen 1971) after 7 days of incubation at a temperature of 25° C (TGY 25°C);

– total number of coliforms (TC) cultured on Endo medium (Standard Methods – Anon. 1992) after 48 hours of incubation at a temperature of 37°C (TC);

– number of fecal coliforms (FC) cultivated on Endo medium (Standard Methods – Anon. 1992) after 24 hours of incubation at a temperature of 44.5°C (FC);

– number of the fecal streptococci (FS) cultured on Slanetz and Bartley (Merck) agar after 72 hours of incubation at a temperature of 37°C (FS);

– total number of yeast and mould fungi on Sabourand medium after five days of incubation at a temperature of 28°C;

– number of *Pseudomonas fluorescens* (fluorescent under a Wood's lamp) cultured on King B medium after 72 hours of incubation at a temperature of 25°C (Burbianka and Pliszka 1977);

– number of *Pseudomonas aeruginosa* (fluorescent under a Wood's lamp) cultured on King A medium (Burbianka and Pliszka 1977) after 24 hours of incubation at a temperature of 42°C;

– number of bacteria of the genus *Aeromonas hydrophila* cultured on mA medium (Rippey and Cabelli 1979) after 20 hours of incubation at a temperature of 37°C.

The quantitative studies of water, with a focus on TVC 22°C, TVC 37°C, TGY 25°C and the numbers of yeast and mould fungi were made using the flooded plate method. The results obtained were calculated into cfu per 1cm^3 of water. In order to determine the numbers of TC, FC, FS, *Pseudomonas fluorescens*, *Pseudomonas aeruginosa*, and *Aeromonas hydrophila*, the investigated water samples were condensed (100 cm^3) on No. 2 SYNPOR membrane filters (0.50 ㎜ pore diameter), which were then placed on the appropriate culture media. The cultured colonies were identified to the species level based

on data from Bergey's Manual of Systematic Bacteriology (Anon. 1994). The results obtained are presented as cfu per 100 cm^3 of water.

The quantitative studies of catfish fry skin required collecting a culture from a 1cm^2 area of skin under sterile conditions. These samples were transferred to plates that were then filled with the appropriate selective culture media. The results were recalculated and are presented in cfu per 1 cm^2 of skin area. Ten catfish specimens were used each time these investigations were conducted.

Feed samples (10g) were collected under sterile conditions and homogenized with 90 cm^3 of a sterile 0.85% NaCl solution. They were then cultured on the appropriate selective media, and the results were calculated and are presented in cfu per 1g or 100 g of feed.

After collection, the water, feed and fish samples were transported to the laboratory under refrigeration at a guaranteed temperature of 4-6°C. The time between sampling and determinations did not exceed six hours.

Statistical analysis

In order to determine the dependence between the occurrence of the determined indicatory and potentially pathogenic microbes in the water and feed and on the skin of European catfish, single parameter Anova variance analysis was applied with water, feed and fish skin as the parameters. The applied statistical method assumed that the variances in different groups were homogeneous (the same), and the best test to verify this assumption was the Leven test. When the test appeared significant, the variance homogeneity hypothesis was abandoned (when $p < 0.05$) and the Kruskal-Walis test (the non-parametric equivalent of single parameter variance analysis) was done. This verified the hypothesis that the compared samples were collected from populations with the same distribution or distributions with the same median (Stanisz 1998).

RESULTS

The results of the microbiological studies of the pond water during intensive catfish fry rearing in a closed cycle are presented in Figure 1. The total number of bacterial indicators of contamination level in the studied samples of pond water, TVC 22ºC and TVC 37ºC, varied from 2000 to 44000 cfu and from 750 to 5500 cfu in 1cm^3, respectively, depending on the time of sampling. The heterotrophic bacteria determined on TGY medium at a temperature of 25°C were observed in greater numbers – from 8600 to 88000 cfu in 1cm^3 of water. The smallest numbers of the above groups of microbes were observed at the beginning of the experiment, while the greatest numbers were noted after the four weeks of the experiment. The numbers of microbes indicatory of the sanitary state (TC, FC, FS) varied from 1 cfu to several dozen or several hundred cfu in 100 cm^3 of water, depending on the type of bacteria and sampling time. The numbers of TC, FC and FS in the studied water were in the ranges of 1-300, 1-65, 1- 95 cfu/100 cm^2, respectively. The lowest numbers were confirmed at the beginning of the study period, while the highest were noted two weeks into the study. The numbers of yeast and mould fungi varied from 4 to 180 cfu and

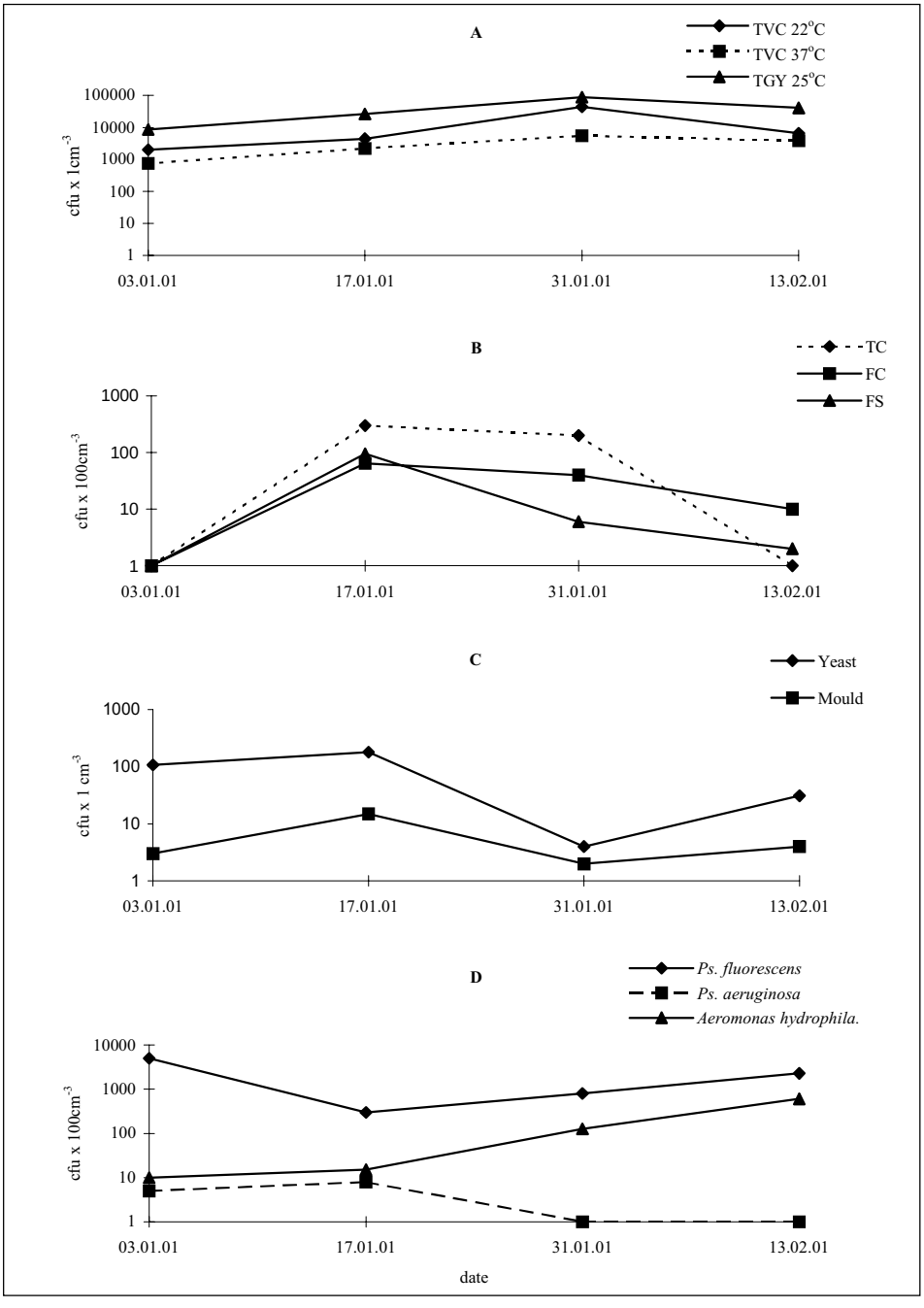

Fig. 1. Numbers of: A – bacterial indicators of contamination levels (TVC 22°C, TVC 37°C); heterotrophic bacteria on TGY medium (TGY 25°C); B – bacterial indicators of the sanitary state (TC, FC, FS); C – fungi (yeast and mould); D – potentially pathogenic bacteria (*Pseudomonas fluorescens*, *Pseudomonas aeruginosa*, *Aeromonas hydrophila*) in the pond water used for rearing European catfish fry in a closed cycle.

from 2 to 15 cfu in 1 cm^3 of water, respectively. Minimum numbers of them were observed after four weeks, while the maximum numbers were noted after two weeks into the experiment. The numbers of potentially pathogenic bacteria in 100 cm^3 of water varied from one to several thousand cfu, depending on the type and time of sampling. The most numerous were *Pseudomonas fluorescens* (300-5000 cfu/100 cm^3), while the least numerous were *Aeromonas hydrophila* (10-609 cfu/100 cm^{-3}). In the water samples *Pseudomonas aeruginosa* did not exceed 8 cfu in 100 cm^3.

The results of microbiological quality analyses of the feed supplied to the catfish fry during the experiment are presented in Table 1. The numbers of bacterial indicators of contamination levels, TVC 22ºC and TVC 37ºC, and heterotrophic bacteria determined on TGY medium at a temperature of 25ºC varied as follows: 2200000-4500000 cfu/ 1g, 290000-5000000 cfu/ 1 g and 1400000-4400000 cfu/ 1 g of feed. The smallest average numbers were observed for TVC 37ºC, while the greatest numbers were noted for TVC 22ºC. The numbers of yeast and mould fungi varied from 120 to 1500 cfu and from 70 to 1,000 cfu in 1g of feed. Of the bacteria indicatory of the sanitary state, no fecal coliforms (FC) were noted in 100 g of feed. The total number of TC bacteria varied from 40 to 120 cfu. The most numerous were fecal streptococcus (FS) at 2000 to 35000 cfu in 100 g of feed. Among potentially pathogenic bacteria, only *Pseudomonas fluorescens* was observed at numbers ranging from 2 to 70 cfu/100 g.

The studies of the skin of the catfish fry indicated the presence of bacterial indicators of contamination levels, *i.e.*, TVC 22ºC and TVC 37ºC, and heterotrophic bacteria deter-

Table 1. Numbers of: bacterial indicators of contamination levels (TVC 22ºC, TVC 37ºC) and sanitary state (TC, FC, FS), heterotrophic bacteria on TGY medium, fungi (yeast and mould) and potentially pathogenic bacteria: *Pseudomonas fluorescens, Pseudomonas aeruginosa* and *Aeromonas hydrophila* in the feed fish, eaten by european catchfish fry (*Silurus glanis L.*) during rearing in closed cycle

Group of microorganisms	Sample volume (g)	Numbers of microorganisms (cfu)
TVC 22ºC	1	3600000[a] 2200000 – 4500000[b]
TVC 37ºC	1	1000000 290000 – 5000000
TGY 25ºC	1	2200000 1400000 – 4400000
TC	100	90 40 – 120
FC	100	0
FS	100	19000 2000 – 35000
Yeast	1	210 120 – 1500
Mould	1	300 70 - 1000
Pseudomonas fluorscens	100	30 2 – 70
Pseudomonas aeruginosa	100	0
Aeromonas hydrophila	100	0

[a] mean, [b] range

mined on TGY medium at a temperature of 25°C. The numbers varied from 10^3 to 10^4 cfu/ cm^2, depending on the bacterial group determined and the experiment time. The numbers of bacteria on 1 cm^2 of fish skin varied as follows: TVC 37°C – from 7000 to 11000 cfu; TGY 25°C – from 9000 cfu to 13000; TVC 22°C – from 14000 to 25000. The bacteria indicatory of the sanitary state were innumerous in the range of one to several or several hundred cfu. The numbers of TC bacteria varied from 1 to 220 cfu/cm^2; fecal bacteria from the FC group – from 1 to 3 cfu/ 1cm^2, and fecal streptococcus (FS) – from 1 to 80 cfu/ 1cm^2 of skin of the studied fry. Mould fungi were sporadic, as their presence was observed only after six weeks of the experiment at numbers of 10 cfu/1 cm^2. The yeast fungi numbers per 1 cm^2 of catfish fry skin varied from 8 to 220 cfu. Potentially pathogenic bacteria occurred on the fry skin in numbers ranging from several to several hundred cfu, depending on the type. The lowest numbers of bacteria were observed for *Aeromonas hydrophila* (from 5 to 8 cfu/1 cm^2), while those of *Pseudomonas aeruginosa* varied from 10 to 30 cfu/1 cm^2, and the numbers of *Pseudomonas fluorescens* were from 150 to 220 cfu/1 cm^2 of skin of the investigated catfish fry (Fig. 2).

The statistical analysis applied, which included the Leven test and variance analysis, only confirmed the absence of statistically significant differences in fecal streptococcus – FS ($p = 0.293010$) in the water and feed and on the skin of the studied fish. In the other cases, the Leven test was statistically significant. The application of the Kruskal-Walis test showed statistically significant differences ($p < 0.05$) in the occurrence of the total number of bacteria determined on the broth agar at temperatures of 22 and 37°C; the total number of bacteria on TGY medium at a temperature of 25°C; the number of fecal coliforms (FC), *Pseudomonas fluorescens*, *Pseudomonas aeruginosa* and *Aeromonas hydrophila* in the water and fish feed and on the European catfish fry skin (Table 2).

DISCUSSION

The occurrence of the heterotrophic bacteria determined on agar media (TVC 22°C, TVC 37°, TGY 25°C) in numbers that were approximately 10-100 times lower in 1 cm^3 of water than in 1 g of the feed supplied to the European catfish fry (*Silurus glanis* L.) during the experiment indicates that the applied feed could have contributed to the microbiological pollution of the water. This phenomenon is reflected in the results of the statistical analysis that indicated there were statistical differences ($p < 0.05$) in the occurrence of the majority of microbes in the water and feed and on the skin of the studied fry. The numbers of these microorganisms on the skin surface indicate that there is a close relationship between the microflora of the water, feed and fish (Lewandowska *et al*. 2001, Zmysłowska *et al*. 2000a, Zmysłowska *et al.* 2000b, Zmysłowska *et al.* 2002). According to Lésel (1979), the occurrence of heterotrophic bacteria on the surface of fish skin could result from their concentration in the feed supplied and the dynamics of changes in the aquatic environment. When the bacteriological contamination of the water is low, bacteria indicatory of contamination are observed on fish skin or in the internal organs, but never in the muscles (Niewolak and Tucholski 2000b). It was confirmed during the intensive rearing of catfish

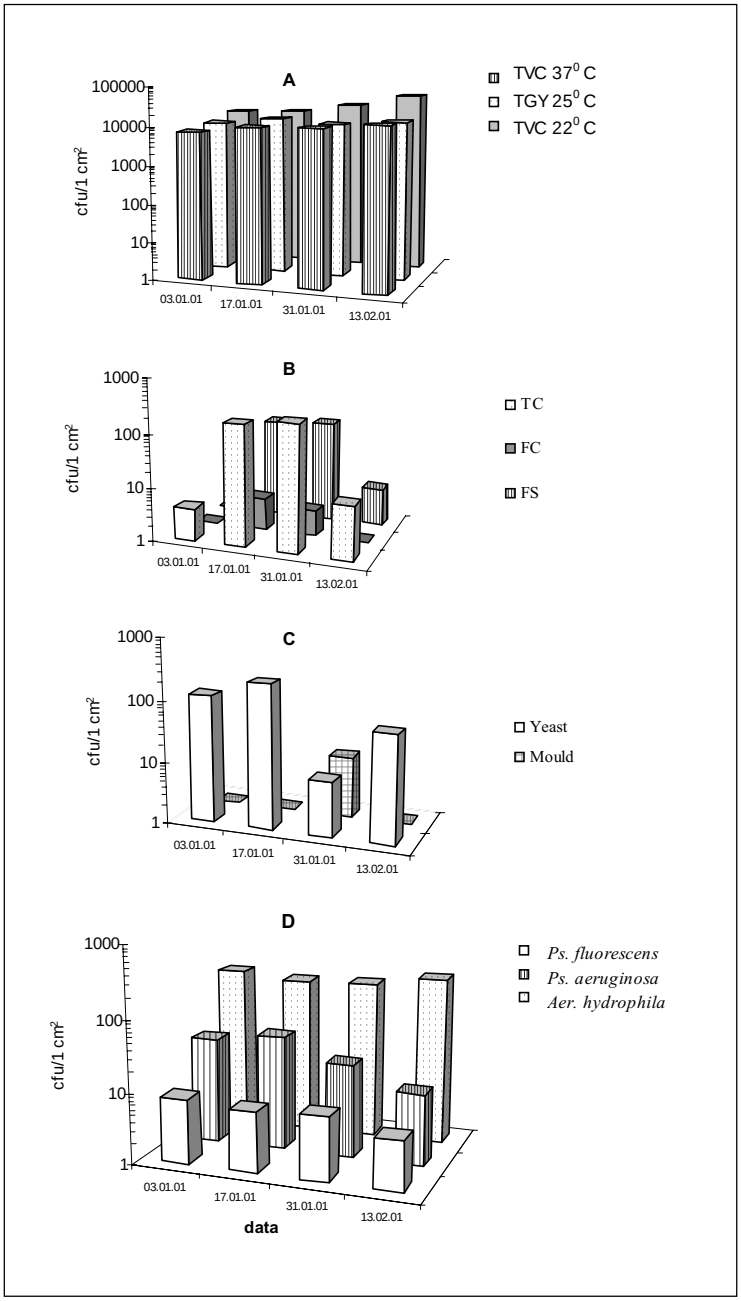

Fig. 2. Occurrence of: A – bacterial indicators of contamination levels (TVC 22°C, TVC 37°C); heterotrophic bacteria on TGY medium (TGY 25°C); B – bacterial indicators of the sanitary state (TC, FC, FS); C – fungi (yeast and mould); D – potentially pathogenic bacteria (*Pseudomonas fluorescens*, *Pseudomonas aeruginosa*, *Aeromonas hydrophila*) on the skin (1 cm^2) of European catfish fry reared in a closed cycle.

Table 2. The dependence between the occurrence of the bacterial indicators of contamination level and sanitary state (TVC 22°C, TVC 37°C, TGY 25°C, TC, FC, FS) and some pathogenic microbes verified by Leven test (significance at level $p < 0.5$) in the water, feed and on the skin of catfish fry (*Silurus glanis* L.) during intensive rearing in closed cycle

Fish feed	Water of pond									Skin of fry
	TVC 22°C	TVC 37°C	TGY 25°C	TC	FC	FS	*Ps. fluorescens*	*Ps. aeruginosa*	*Aer. hydrophila*	
TVC 22°C	0.0061*									TVC 22°C
TVC 37°C		0.0061*								TVC 37°C
TGY 25°C			0.0068*							TGY 25°C
TC				0.4809						TC
FC					0.0262*					FC
FS										FS
Ps. fluorescens							0.0137*			*Ps. fluorescens*
Ps. aeruginosa								0.0105*		*Ps. aeruginosa*
Aer. hydrophila									0.0215*	*Aer. hydrophila*

*statistically significant differences ($p < 0.05$)

fry in a closed cycle that the greater numbers of coliforms (TC) and fecal streptococci (FS) and the absence of fecal coliforms (FC) in the pond water are reflected in the increased numbers of them in the feed. The same tendencies in the occurrence of these microbes were observed in the studies of the fry skin surface. Similar results were obtained by other researchers investigating different fish species in varied aquatic environments (Harnisz 2002, Lewandowska *et al.* 2001, Świątecki 1994, Zmysłowska 2001, Zmysłowska *et al.* 2001a, Zmysłowska *et al.* 2002). The increased numbers of yeast and mould fungi and the corresponding greater numbers of indicatory bacteria, which were confirmed in the authors' own studies, are, from a sanitary-epidemiological point of view, confirmation that there is a relationship between bacterial and fungal microflora in the aquatic environment (Dynowska 1995). Similar tendencies were noted in the quantitative changes of the numbers of potentially pathogenic bacteria, such as *Pseudomonas fluorescens*, *Pseudomonas aeruginosa* and *Aeromonas hydrophila*, in the water and on the catfish fry skin surface. This indicates that they can possibly colonize the surface of fish depending on the presence of a given pathogenic microorganism in the aquatic environment (Crouse-Eisnor *et al*. 1985). On the other hand, some of them represent the natural microflora of the fish throughout their lives (Sugita *et al.* 1990, Zmysłowska *et al.* 2001b).

The results obtained from the present microbiological studies indicate that there are correlations between the quantitative occurrence of the studied microorganism groups in the water and feed and on the skin of the European catfish (*Silurus glanis* L.) during its rearing in a closed cycle. The fish feed pollutes and modifies the pond water microflora composition and, as a consequence, it can pose a threat to the health and condition of reared European catfish (*Silurus glanis* L.) fry. However, fish do require food, and the feed delivered to them should be of the highest hygienic quality. Adding organic matter to fresh water always increases the risk of microflora growth.

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Lipid oxidation and lysine availability in Atlantic mackerel hot smoked in mild conditions

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Abstract. The available literature data indicate that in different market samples of smoked fish notable changes in proteins and lipids occur due to smoking and during storage. Therefore, the objective of this work was to investigate the availability of lysine and the state of lipids in mackerel as affected by mild hot smoking in an industrial automatic smokehouse at a core temperature in the fish not higher than 60°C, and during refrigerated storage. The oxidation of lipids in the frozen stored raw material used for smoking was generally low. However, the variability of the peroxide value within the examined batches of fish was large, 5.1-12.3 mg O/100 g lipids. In hot smoked mackerel stored at 2°C no statistically significant effect of storage time on the contents of lipid oxidation products was noted, probably due to the antioxidant activity of smoke phenols. The lipid oxidation products in concentrations found in the samples had no effect on the sensory quality of the smoked fish during 14 days at 2°C. The lysine availability was similar in the smoked samples and in the raw material. The contents of phenols in the meat of mackerel hot smoked in mild conditions were considerably low at 4.8-7.6 mg/100 g and were only about 3.5 times higher than the small background level in the thawed fish. The skin contained 2.5 times more phenols than the inner parts of the fish. The low concentration of phenols corresponded well to the mild conditions of smoking.

Key words: hot smoked mackerel, lipid oxidation products, lysine availability

INTRODUCTION

Fatty fish are recommended as part of a healthy human diet since they are rich in high quality protein, polyenoic fatty acids (PEFA) from the n-3 family, vitamins, and mineral components. One of the traditional industrial processing methods of fatty fish is cold or hot smoking. In many European countries smoked fish, predominantly salmon, Bűckling, mackerel, halibut and other flat fishes, eel, and sprats, comprise about 10-15 % of the total consumption of fishery commodities. There is high market demand for smoked mackerel because of its attractive smoky flavor and color and the high content of nutritionally beneficial fat.

Consumers interested in healthy eating can easily find information on the contents of nutrients in fish of various species in food lexicons and cook books. However, these data

refer predominantly to fresh fish, while far fewer results are published on canned, marinated, grilled, fried, or smoked products. Furthermore, in many cases there is a great discrepancy between the contents of protein, PEFA, vitamins, and mineral components in the fresh material and in a commercial product or a ready-to-eat dish. It is generally known that industrial and culinary food processing, as well as storage even under refrigeration, can inevitably cause some losses of certain nutrients due to leaching, biochemical processes, or chemical reactions. These losses depend on the fish properties and processing conditions, mainly temperature, acidity, contents of salt and various reactive components, the character of the medium during heating, oxygen access, and treatment time. Furthermore, processing may even generate undesirable, nutritionally objectionable or toxic compounds (Sikorski 2004).

Generally, smoking involves dressing fresh or thawed fish, brining, pre-drying, treating with wood smoke or smoke preparations, heating the meat to the desired temperature, followed by chilling and packaging. Any of these unit operations can affect the labile nutrients contained in the raw material.

FACTORS AFFECTING CHANGES IN THE NUTRIENTS OF SMOKED FISH

Changes in proteins

The effect of heating

The smoking process can cause a decrease in the digestibility or biological value of fish proteins. The effect depends on the temperature and length of heating, which differ very much in the hot smoking applied by various processors. Prolonged heating at an elevated temperature can cause some loss of sulfur-containing amino acids and lysine residues in proteins. It can also generate harmful compounds, including a number of mutagens and carcinogenic heterocyclic amines (Sikorski 2004). The extent of the loss of nutritionally valuable food components, like vitamins and labile amino acids and the formation of antinutritional compounds should be small in mild heated products. It can, however, be significant in the outer layers of smoked fish exposed to high smoke temperatures in a traditional smoking kiln. Generally, the loss of sensitive amino acid residues caused by the heat processing conditions used in sterilizing foods may be no higher than a few percent (Sikorski 2001).

Changes in amino acid residues can be caused in part by the Maillard reaction, which involves a reducing saccharide or a secondary product of lipid oxidation, or, in smoked foods, a wood smoke aldehyde, and the ε-NH_2 group of lysine residue or a terminal α-NH_2. Further reactions lead to the generation of different reactive products including dicarbonyl and polycarbonyl unsaturated compounds that also interact with amines and amino acids. Many Maillard reaction products are mutagenic and/or carcinogenic (Lee and Shibamoto 2002). Reactions of the lysine residue with other food components, including dehydroascorbic acid, result in the crosslinking of the heated protein (Fayle *et al*. 2000). Excessive heating may also lead to the formation of cross-linking isopeptide bonds be-

tween the ε-NH_2 group of lysine and the β and γ-carboxyl groups of aspartic and glutamic acid residues or their amides. Crosslinking may decrease the digestibility of the protein.

Cooking food causes a partial loss of thiamine, particularly at alkaline pH. Thiamine and its decomposition products may also participate in the Maillard reaction. The early products of the reaction of lysine residue with aldehydes can be utilized in the human body, but further changes make the amino acid unavailable. A certain amount of nitrogenous compounds and lipids may be lost during hot smoking in the cooking drip. The extent of changes in the biological value of proteins can be investigated by determining the available lysine or the contents of products of reactions involving lysine.

Currently, many fish processing plants utilize only the highest quality raw material and all contemporary hygiene requirements are observed. In such smoking plants the applied heat treatment does not necessarily need to assure a temperature of 83°C for 30 minutes in the center of the thickest part of the product, which is required to inactivate *Clostridium botulinum* type E spores. Often the temperature of the center of the fish reaches only 60°C. In these conditions smoked fish of very high sensory quality can be produced, and the loss of the biological value of the proteins should be minimized.

The effect of smoke components

Several components of wood smoke, predominantly phenols, aldehydes, and nitric oxide can react with some amino acid residues in muscle proteins. In model experiments it was shown that smoking reduced the contents of SH groups in a 0.1% cysteine solution and in beef meat by about 97% and 60%, respectively. The respective loss in amino groups in a 0.1% solution of methionine and in beef meat due to smoking was 12.5% and 27%. The effect caused by the phenol fraction of smoke was three times higher than that of the smoke aldehydes (Krylova *et al.* 1962). Market samples of traditionally smoked bonga and sardinella in Nigeria contained about 3.2 and 3.2-3.8 g of available lysine /16 g N (Egwele *et al.* 1986). In minced tilapia, smoked in 0.5-cm sheets on a wire mesh, a significant loss in available lysine was detected by Obileye and Spinelli (1978). In mince smoked for two hours at 30°C plus three hours at 70°C to a final moisture content of 52% the loss of available lysine was 17.7%. After twelve hours of smoking at 70°C to a moisture content of 22.6% the loss was 18.9%, and after sixteen hours of heating at 70°C without smoke it was only 8.9%. In Atlantic mackerel which had been gutted, brined, and hot smoked in rather harsh conditions (one hour at 50°C in a kiln plus seven or fifteen hours at 80°C), packed in plastic bags and stored at 30°C the loss of available lysine just after smoking was about 17.5% and after twelve weeks it was 13.7% (Eyabi-Eyabi *et al.* 1988). The lower value in the stored samples is probably due to large variability of the raw material and process conditions. The loss of thiamine, at an average of about 50%, was more affected by fish to fish variation than by storage time. Bhuiyan *et al.* (1986) demonstrated that in Atlantic mackerel fillets that had been hot smoked for three hours in an AFOS Torry Mini Kiln the total loss of available lysine was 6.6% of the initial value in the unsmoked raw material. The highest loss was in the outermost layer, 8.8%, and the lowest was in the innermost layer, 4.4%. The loss of tryptophan in the whole fillet was 4.4 %, while in the outer layer it was 7.1%, and in the inner layer it was 1%. The changes caused by smoking decreased by about 9% the protein efficiency ratio of the mackerel muscle used in rat feeding experiments.

Changes in lipids in fresh and frozen raw material

The oxidation and hydrolysis of fish lipids cause significant deterioration of the sensory properties of products and the loss of nutritionally desirable n-3 PEFA – eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

Lipid hydrolysis in fish meat can be catalyzed by endogenous lipases and phospholipases, and, during the latter stages after capture, by bacterial enzymes. The endogenous enzymes also retain high activity in frozen tissues, and some can even be activated (Levskaya *et al.* 1984). Lipid oxidation can be caused by autoxidation and photosensitised oxidation; it can also be catalyzed by the lipoxygenase of the gills and skin, by the peroxidase of the blood, and the microsomal NADH peroxidase of the muscle. The lipid peroxides decompose to various short-chain fatty acids, alcohols, aldehydes, ketones, and hydrocarbons. Fish muscle also contains endogenous antioxidants. The relative concentrations of pro- and antioxidants in various tissues depend on the type of muscle as well as the species and condition of the fish (Hultin 1992). The susceptibility of lipids to oxidation depends on the biological state of the specimens and on post-mortem treatment. Due to the effect of so many factors, the degree of oxidation of lipids in different parts of one fish and in various batches of fish of the same species, even stored under identical conditions, may differ significantly. Therefore, there is high variability in the state of lipids in raw material used for smoking. Lipid changes in fish during processing and storage have been reviewed by Undeland (1995) and Sikorski and Kołakowska (2001) and addressed in-depth recently by Kołakowska *et al.* (2002).

Oxidation of lipids in smoked fish

Smoke phenols as antioxidants

Smoking can also influence lipid oxidation. Brining, drying, heating, and reactive smoke components can affect the tissue enzymes involved in oxidation reactions as well as generate and change the stability of radicals. Sodium chloride and some other cations present as impurities in the brine are pro-oxidative. Smoke components, on the other hand, are known for their antioxidant effect. Of the several hundred wood smoke components, phenols have the highest antioxidant activity (Kurko 1966). The phenol fraction of smoke is a mixture of about 240 compounds. Their antioxidant activity depends on their structure. According to Kurko (1966), the strongest phenolic antioxidants in wood smoke include pyrocatechol, hydroquinone, and α-naphthol, which are equal in antioxidant activity to butylhydroxyanisole, and especially 3-methylpyrocatechol, 4-ethylpyrocatechol, and pyrogallol. The activity of pyrogallol exceeds that of butylhydroxytoluene about fivefold.

The composition and contents of phenols depend primarily on the temperature of smoke generation, but also on the kind of wood and the access of air to the smoldering material. Thus, the effectiveness of the antioxidant action of smoking is related to the composition and the quantity of the phenol fraction of wood smoke absorbed by the smoked food. Phenolic antioxidants are known to exhibit prooxidative activity if applied in high concentrations. However, the content of smoke phenols deposited on fish during smoking or added to foods with smoke flavorings is usually low enough not to exert prooxidative

action (Chomiak and Goryń 1977). According to many literature data, the total content of phenols in smoked products ranges approximately from 5 to 60 mg/100 g of tissue (Miler and Sikorski 1990). Cardinal *et al.* (2002) found that it ranged from about 0.1 to about 3 mg phenols/100 g wet weight of cold smoked Atlantic salmon fillets, depending on the size and lipid content of the fish, as well as the smoking method. According to Ionas *et al.* (1977), in cold smoked mackerel the total content of phenols in the meat and skin of the fish was 4.6-45 mg and 96.4-354 mg/100 g, respectively, and was related to the smoking parameters. However, because of differences in procedures of isolation of the phenols from smoked fish, *i.e.*, extraction with organic solvents or steam distillation, as well as in methods of quantitative determination, not all literature data are directly comparable (Lustre and Issenberg 1970, Toth *et al.* 1982). According to Kurko and Luchak (1984) hot smoked mackerel and cold smoked common bream contained 5.6 and 11.7 mg phenols/ 100 g, respectively, when determined in extracts, but only 0.2 and 0.7 mg/100 g, respectively, in steam distillates. The total amount of phenolic compounds isolated from smoked pork belly by Lustre and Issenberg (1970) was 28 mg/100 g. Potthast (1978) reported, that the content of phenols in various smoked meat products was as high as 170 mg/100 g.

The extent of oxidation

The net result of the pro-oxidative action of salt and heating and the antioxidant effect of wood smoke components cannot be predicted for different assortments of smoked fish. There are several published data which indicate that the oxidation of lipids in smoked products proceeds at a lower rate than in unsmoked controls, while in other papers contradictory results are presented.

In the experiments of Eyabi-Eyabi *et al.* (1988) a twofold increase in the peroxide value was observed in Atlantic mackerel packed in plastic bags during the first four weeks of storage at 30ºC, while up to twelve weeks later no significant changes had occurred. The thiobarbituric acid value (TBA) decreased due to smoking by about 80% and during the subsequent storage of the product for up to twelve weeks it dropped to almost zero. No significant changes in the contents of EPA and DHA were found due to smoking and storage. According to Münkner and Meyer (1996), in vacuum packed hot smoked Atlantic mackerel stored at 5ºC TBA remained in the range of 0.31 to 0.39 for up to 33 days, and in hot smoked mackerel fillets it was 0.63 to 0.76. The TBA value in smoked gutted mackerel taken from the market was 0.82-1.20, but in the fillets it was lower (0.60 to 0.84). Cha *et al*. (2001) studied saury fillets containing 28.1-30% fat that were seasoned with a mixture of sugar, salt, monosodium glutamate, and sorbitol and then soaked for 10 seconds in 5% liquid smoke Scansmoke PB 2110, dried for 40 h at 40ºC, packed in polyethylene film, and stored at about 19ºC. After 15 and 60 days, the TBA and peroxide values were significantly lower than in the control seasoned samples that were not treated with the smoke solution. On the other hand, Beltran and Moral (1989) noted a statistically significant increase in the peroxide value, TBA, and concentration of free fatty acids in hot smoked sardine fillets. These had been iced 30-32 h after capture and contained 5.1% lipids; they were then brined, surface-dried in the air for 12 h and smoked 2 h at 30ºC plus 45 min at 75ºC in a kiln.

STUDY OBJECTIVES

Available literature data on the changes of proteins and lipids in fish due to smoking are very limited and refer predominantly to heavily smoked products or different commodities available on the market. The aim of this work was to investigate whether brief hot smoking at a core temperature not exceeding 60°C in controlled industrial conditions, that are known to yield a product of high sensory quality, significantly affects the lysine availability and the state of lipids in Atlantic mackerel just after treatment and during storage under refrigeration.

MATERIALS AND METHODS

Preparation and smoking of mackerel

Atlantic mackerel, frozen in 20-kg blocks, packed in polyethylene film and cardboard boxes was imported by a local processor and kept for 1-3.5 months in the plant at–-20ºC prior to smoking. The fish were prepared for smoking and smoked in industrial Begarat kilns at an automatically controlled temperature, humidity and density of smoke, which was supplied from an external generator, according to the flow chart in Figure 1. The product was stored in boxes, and the internal temperature of the fish was 2±1ºC.

For analysis the meat from three fish was separated, minced in a grinder using a plate with 2-mm orifices, and mixed thoroughly to prepare average samples that were used to determine the chemical indices in triplicate.

Chemical assays

NaCl was determined using the Mohr method according to PN-74/A-86739. Dry weight and total Kjeldahl nitrogen were determined with AOAC methods (1990). The lipids in the extracts were obtained according to Bligh and Dyer (1959) and dried at 80ºC to a constant weight. Peroxide number was determined by the thiocyanate method according to BN-74/8020-07. The anisidine value was determined according to Polish Standards PN-93/A-86926 in the lipid extracts. Available lysine was assayed according to the Carpenter method (Rao *et al*. 1963), phenols by bromometric titration according to PN-72/C- 04602.04, and pH with the use of a microcomputer CP-315M pH meter (Elmetron). The concentration of phenols is presented in mg of phenol/100 g.

Sensory analysis

A panel of ten trained panelists performed the product sensory assessment. The quality indices of smoked mackerel that were assessed were selected in preliminary experiments from the following set: skin color, skin gloss, smoky flavor, rancid off-odor, other off-odors, taste, juiciness, fibrousness, flavor acceptability, and total acceptability. The refrigerated samples were allowed to stand for 30 minutes at room temperature before analysis. Each attribute (Table 5 and 6) was determined by every panelist in one whole

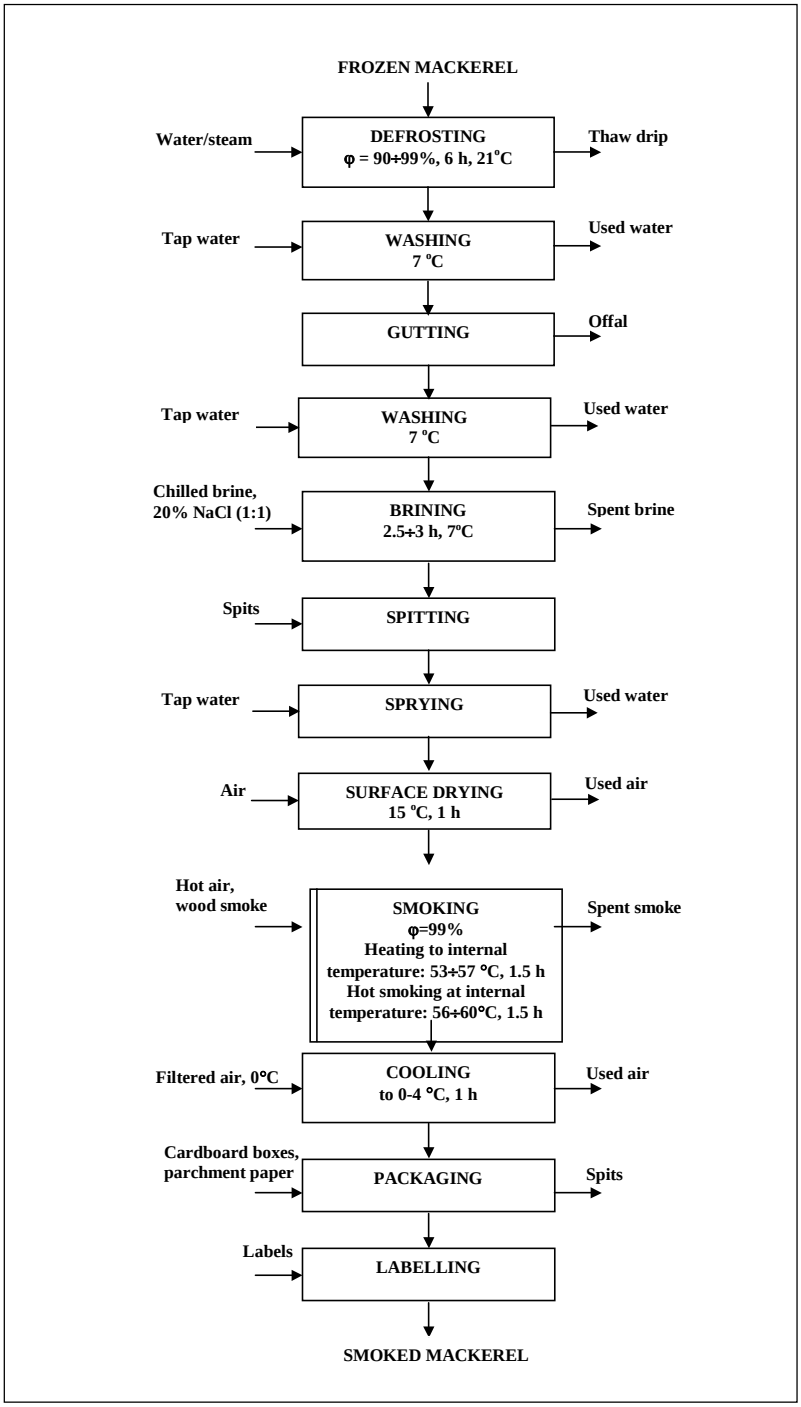

Fig. 1. Flow chart of hot smoking of mackerel in mild conditions.

fillet using a score sheet with the attributes graded on a 5-point intensity or preference scale. The results were evaluated statistically by analysis of variance (one-way procedure) or the Student's t-test.

RESULTS AND DISCUSSION

The results of analysis indicated variation in the chemical composition of thawed mackerel in the three investigated batches. The water content was 54.5- 59.1%, protein 16.8 - 19.6%, and lipids 18.9 - 27.2% . High variability, especially in the lipid content, was also noted in the smoked product (Table 1).

The oxidation of lipids in the stored frozen raw material used for smoking was generally comparatively low and was several times lower than the level Kołakowska *et al.* (1998) determined in mackerel. However, the variability of the peroxide value within the three examined batches of fish was large ranging from 5.1 to 12.3 (Table 2). No relation between the peroxide value and the pH of the meat, lipid content, or concentration of NaCl was detected. The peroxide value (12.3 and 11.2 mg O/100 g lipids) was similar in samples that were stored frozen during a similar period (1 and 1.5 months) but had significantly different lipid contents (27.2 and 22.1%). In the experiment by Kołakowska *et al.* (1998) the degree of lipid oxidation was higher in the frozen fish that contained less fat.

In three batches of smoked mackerel the content of peroxides was about 50% lower than in the thawed samples, and that of the anisidine value was about 2.5 times higher (Table 2). Undeland (1995) reported that in traditional hot smoked mackerel the peroxide number and TBA were six and two times higher than in the raw fish. Beltran and Moral (1989) also found that hot smoking caused a several-fold increase in the peroxide and TBA in sardine fillets. According to Kołakowska *et al*. (1998), hot smoking caused the decomposition of peroxides in mackerel that was lower in lipids but initially more oxidized, while it resulted in an increase in the peroxide number in mackerel that was richer in lipids and less oxidized.

Storage time was not noted to have a statistically significant effect on the contents of lipid oxidation products in hot smoked mackerel at 2°C. However, the results in Table 2 indicate that there was a slight tendency for the peroxide value to increase with storage time. This very slow rate of oxidation during storage might have been due to the effectiveness of the smoke antioxidants. Furthermore, the results of sensory analysis show that the lipid oxidation products in concentrations found in the samples had no effect on the sensory quality of the smoked fish during 14 days at 2°C (Table 3). The intensity of the rancid odor was very low and did not change during storage. A small, though statistically significant, decrease in juiciness was noted after seven days at 2°C. According to Kołakowska *et al*. (1998), the rate of accumulation of lipid oxidation products during storage was higher in hot smoked mackerel made from thawed fish with a higher initial degree of lipid oxidation than in smoked fish made of less oxidized raw material.

According to Braekkan and Boge (1962), the content of lysine in Atlantic mackerel fillets was 8.8 g/100 protein. The concentration of available lysine in the thawed mackerel used as raw material for smoking in the current experiment was about 10% lower than this

Table 1. The gross chemical composition of the meat of thawed and hot smoked Atlantic mackerel (g/100 g wet weight) [a]

Mackerel	Water	Lipids	Crude protein	Chlorides	pH
Raw	54.5 - 59.1 56.8 ± 2.3	18.9 –27.2 22.7 ± 3.4	16.8 - 19.6 18.2 ± 1.1	0.62 - 0.70 0.63 ± 0.05	5.93 - 6.17 6.05 ± 0.09
Smoked 1[b]	55.4 - 58.7 56.8 ± 1.4	19.3 – 22.9 21.0 ± 1.5	18.5 - 19.0 18.7 ± 0.2	1.71 - 2.03 1.9 ±0.14	5.77 - 6.11 5.95 ± 0.14
7[b]	53.8 - 57.4 55.1 ± 1.6	17.7 – 25.7 22.2 ± 3.3	17.1 - 19.6 18.2 ± 1.0	1.76 - 2.68 2.17 ± 0.41	5.61 - 5.95 5.77 ± 0.14
14[b]	54.3 - 55.8 54.9 ± 0.6	20.3 – 22.8 21.5 ± 1.0	18.8 - 20.1 19.4 ± 0.5	1.95 - 2.63 2.33 ± 0.25	5.65 -5.97 5.84 ± 0.14

[a] Range of results and mean value ± standard deviation characterizing samples from three batches of fish
[b] Days of storage at 2°C

Table 2. The effect of storage at 2°C on lipid oxidation and available lysine in hot smoked mackerel meat[a]

Mackerel	Time of storage [days]	Anisidine value	Peroxide number [mg O/100 g lipids]	Available lysine [g/100 g protein]
Thawed	0	2.8 - 3.6 3.1 ± 0.4	5.1 - 12.3 9.6 ± 3.2	7.5 - 8.0 7.8 ± 0.3
Smoked	1	6.8 - 10.1 8.3 ± 1.4	3.0 - 5.9 4.8 ± 1.3	7.5 - 8.0 7.7 ± 0.3
	7	6.2 - 10.1 8.1 ± 1.6	3.5 - 11.4 6.7 ± 3.4	6.9 - 8.2 7.6 ± 0.7
	14	6.1 - 8.8 7.1 ± 1.0	3.7 - 9.4 7.2 ± 2.5	7.5 - 8.1 7.8 ± 0.3

[a] Range of results and mean value ± standard deviation characterizing samples from three batches of fish

The results evaluated statistically by analysis of variance (one-way procedure) do not differ significantly ($p > 0.05$).

Table 3. Effect of storage at 2°C on the sensory attributes of mackerel hot smoked in mild conditions

Time of storage	Color	Gloss	Juiciness	Rancid off-odour	Flavor acceptability	Total acceptability
(days)	Intensity scores on a 5-point scale				Preference scores on a 5-point scale	
1	4.6[a]	4.1[a]	4.3[a]	1.2[a]	4.1[a]	4.1[a]
7	4.6[a]	4.2[a]	3.9[a]	1.1[a]	3.9[a]	3.8[a]
14	4.3[a]	3.9[a]	3.4[b]	1.2[a]	3.7[a]	3.7[a]

The values in a particular column followed by different letters differ significantly ($p < 0.05$)

(Table 2). The lysine availability in the smoked samples was similar to that in the raw material.

The contents of phenols in the meat of mackerel hot smoked in mild conditions were considerably low at 4.8-7.6 mg/100 g (Table 4). The mean value was only about 3.5 times higher than the low background level determined in the thawed fish. This low concentration of phenols corresponded well to the mild conditions of smoking. The content of phenols in fish skin was 2.5 times higher than it was in the meat (Table 4). This concurs with the fact that the majority of the smoke phenols is retained in the skin and subcutaneous lipid layer in smoked fatty fish, while in lean fish up to about 65% of the total mass of phenols can diffuse into the deeper tissue layers (Kurko and Mezenova 1985). During storage at 2°C the contents of phenols in the meat did not change significantly, while their concentrations in the skin decreased by about 30%. It can be assumed that the loss of the phenols from the skin without a corresponding significant increase in concentration in the meat was caused by the low proportion of the mass of the skin to that of the meat (about 6%) and possibly by interactions of some phenols with muscle proteins during storage.

Hot smoked mackerel taken directly from various producers different significantly in sensory quality; the highest quality notes were consistently given to the product manufactured by producer 1 according to the flow chart in Figure 1 (Table 5).

Table 4. The contents of phenols in the meat and skin of hot smoked Atlantic mackerel stored at 2°C

Fish	Time of storage [days]	Phenols	
		[mg/100 g meat]	[mg/100 g skin]
Thawed	0	0.9 - 3.0 1.9 ± 0.9	not determined not determined
Smoked	1	4.8 - 7.6 6.6 ± 1.2	16.2 - 19.3 17.8 ± 1.6
	7	4.5 - 9.7 6.7 ± 2.2	8.8 - 14.9 11.8 ± 3.1
	14	2.6 - 6.6 5.5 ± 2.1	11.2 - 13.2 12.2 ± 1.0

[a] Range of results and mean value ± standard deviation characterizing samples from three batches of fish

Table 5. The sensory quality of smoked mackerel[a] obtained from various producers

Producer	Color	Gloss	Juiciness	Rancid off-odour	Flavor acceptability	Total acceptability
	intensity scores on a 5-point scale				preference scores on a 5-point scale	
1	4.9 ± 0.3	4.6 ± 0.5	4.4 ± 0.3	1.1 ± 0.3	4.8 ± 0.1	4.7 ± 0.1
2	4.6 ± 0.3	4.0 ± 0.5	4.1 ± 0.3	1.0 ± 0.3	3.8 ± 0.1	3.8 ± 0.1
3	3.5 ± 0.2	2.9 ± 0.3	4.3 ± 0.1	1.1 ± 0.1	3.6 ± 0.3	3.6 ± 0.3
4	2.8 ± 0.3	2.1 ± 0.2	2.4 ± 0.3	1.8 ± 0.1	2.6 ± 0.3	2.6 ± 0.3

[a] Stored for one day at 2°C

CONCLUDING REMARKS

The results presented and discussed above as well as those of the authors' earlier investigations (Kołodziejska *et al.* 2002) indicate that hot smoking Atlantic mackerel in a plant that meets all current requirements regarding good manufacturing practice and HACCP, in an automatic smokehouse in mild heating conditions at a core temperature not exceeding 60°C, guarantees very good sensory quality, long shelf life of a high quality product, and only negligible loss in the nutritive value of the smoked fish.

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Estimates of the fishing power of bottom trawls applied in Baltic fish surveys

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Abstract. Since autumn 1999, inter-calibration experiments have been carried out to compare historical catch per unit effort values (CPUE) of national and new standard bottom trawls (types TV3#520 and TV3#930) applied in Baltic fish surveys. Estimates of the fishing power of the former Polish standard P20/25 and the Latvian LBT trawls differed significantly with regard to cod. In contrast, both independent estimates of the Granton (Denmark), GOV (Sweden), Hake 4M (Russia) and HG20/25 (Germany) trawls were comparable. The relationship between the two estimates of the fishing power of Polish gears is 1 to 2. The comparison of the Baltic cod CPUE-values of paired stations (in ICES Sub-division 25) between P20/25 and HG20/25 trawls show that the fishing power of the Polish gear characterize catchability well in relation to the former, standard GOV gear. The impact of the revised estimate of the fishing power of the Polish gear regarding stock abundance indices of Baltic cod are described and discussed.

Key words: bottom-fishing gear, inter-calibration experiments**,** fishing power, cod CPUE, southern Baltic.

INTRODUCTION

Demersal trawl surveys carried out in the first quarter of the year supply a tuning parameter that can be used in the assessment of the eastern Baltic cod stock. The Baltic cod CPUE-values from different national surveys are combined to produce recruitment indices of year classes (Anon. 2001a).

Poland carried out the first young fish trawl surveys in the Baltic Sea in 1962 (Netzel 1974). Most of the Baltic countries also developed national trawl surveys during subsequent years. However, it was difficult to combine the results of these national surveys because the fishing gears and the survey periods varied.

The first attempts to co-ordinate national surveys of young fish were made in 1985 (Anon. 1985), and they were continued with varying intensity in subsequent years. Several attempts were made to determine the conversion factors among different fishing gears. Schulz and Grygiel (1984, 1987) compared the results of inter-calibration experiments

between the EISBÄR and DOKTOR LUBECKI research vessels. The lengths and main engine power of these vessels differed and although they used similar herring bottom trawls, *i.e.* HG20/25 and P20/25, respectively, their catches produced different species compositions and length distributions. The experiments were conducted in the Kołobrzeg fishing ground. In March 1986 an inter-calibration experiment was carried out under the auspices of the ICES Study Group on Young Fish Surveys in the Baltic; however, comparisons could not made due to low catches (Anon. 1987). Further inter-calibration experiments in the Baltic Sea were done between the German bottom trawls Sønderburger and HG20/25 (Oeberst and Frieß 1994). The HG20/25 fishing gear construction was based on that of the Polish P20/25 trawl. Studies have shown that the mouth opening of the HG20/25 is larger than that of the Sønderburger, and that the catchability of cod from the 0 and 1 age groups is higher.

Sparholt and Tomkiewicz (1998, 2000) applied generalized linear models to calculate the "fishing power" of national bottom trawls and developed a robust method for compiling trawl survey data used in the assessment of central Baltic cod. The "fishing power" factors are used to transform the national catch per unit effort into CPUE-values of the former standard GOV trawl.

A more one attempt to establish internationally coordinated trawl surveys in the Baltic Sea was made in 1995 (Anon. 1995). The EU Study Project No. 98/099 (Anon. 2001b) provided funding for the development of new standard fishing gears (type TV3#520 and TV3#930). Since autumn 1999, a number of laboratories in Baltic countries have been conducting inter-calibration experiments between national and new standard gear (Anon. 2001d, 2003). Various methods have been used to estimate the conversion factors for transforming historical national CPUE-values into those of the new standard trawls (Anon. 2001d, 2002, 2003, Oeberst *et al.* 2000).

The comparisons of trawl catchability were then used to assess factors that are comparable with the "fishing power" values estimated by Sparholt and Tomkiewicz (1998, 2000). Corrections of the conversion factors, which are presented in Anon. (2001d) and Oeberst *et al.* (2000), were necessary since crosschecks and analyses conducted by Gasjukov (Anon. 2002) suggested that small errors are possible in the realization of the proposed model. The errors were corrected, and the reworked estimates were used in the current study.

The aim of the study was to identify which of the different methods for determining the "fishing power" is the most suitable for describing the catchability of the Polish P20/25 trawl in relation to the new, standard gear and to illustrate the consequences of different versions of "fishing power".

MATERIAL AND METHODS

The Polish R/V BALTICA carried out inter-calibration experiments between the former national P20/25 trawl and the new, large version of the TV3#930 trawl. The German R/V SOLEA conducted experiments between the HG20/25 and TV3#520 (smaller version of the standard trawl) trawls. Conversion factors (C_f; equation [1]) based on inter-

calibration experiments (Anon. 2001d, 2002, 2003) were used to estimate the values that are comparable to the values of "fishing power" (F_{p1}) estimated by Sparholt and Tomkiewicz (1998, 2000).

$$Cf\,(\text{TV3\#930}, \text{national gear}) = \left(\frac{\text{CPUE of TV3\#930}}{\text{CPUE of national gear}} \right) \quad [1]$$

Polish inter-calibration experiments were carried out in ICES Sub-divisions 25 and 26 as part of the international spring surveys in 1999 and 2000. Sixteen paired hauls were made in 1999 and twenty-two in 2000. Germany carried out inter-calibration experiments in spring 2000 and in November 1999 and 2000. Altogether, sixty-four paired hauls were conducted in ICES Sub-divisions 22 and 25.

The preliminary analyses of C_f (ICES 2001b, 2002, 2003) leads to the conclusion that these factors are constant for cod larger than 24 cm. This is supported by the fact that the different mesh sizes in the front of the belly and in the cod-end of the compared trawls do not significantly influence catchability.

The CPUE-values of the GOV type fishing gear, used by Sweden and partially by Denmark, was defined as the old standard unit of historical survey results. The CPUE-values of the large, standard gear TV3#930 were defined as the new standard of the current surveys. Inter-calibration experiments have shown that C_f(TV3#930,GOV) is equal to one in the cod length range defined above (Anon. 2001b, 2002, 2003). Therefore, it was only necessary to estimate the conversion factors C_f(TV3#930, national gear).

In many cases the results of inter-calibration experiments can be used directly since the national gears were calibrated with trawl type TV3#930. In some cases, however, inter-calibration experiments were conducted between national fishing gears and the new standard trawl TV3#520, and a direct calculation of the conversion factors C_f(TV3#930, national gear) was not possible. In these cases, the conversion factor C_f(TV3#930, TV3#520) was calculated with equation [2]:

$$C_f(\text{TV3\#930, national gear}) = C_f(\text{TV3\#930, TV3\#520}) \times C_f(\text{TV3\#520, national gear}) \quad [2]$$

The conversion factors were used to assess the parameter "fishing power II" (F_{p2}) with equation [3]:

$$F_{p2}(\text{national gear}) = 1 / C_f\,(\text{TV3\#930, national gear}) \quad [3]$$

The coefficient F_{p2} is comparable with F_{p1} estimated by Sparholt and Tomkiewicz (1998, 2000). The CPUE data of national surveys stored in the BITS database were used to decide which "fishing power" values are more suitable for describing the catchability of the national gear in relation to the new standard unit (Anon. 2001c).

The database mentioned above is the same one that Sparholt and Tomkiewicz (2000) used in their analyses. The CPUE-values of paired stations were compared. Hauls of different national fishing gears fulfilling the following conditions were defined as paired stations:

– both hauls were carried out within the same depth range of 10 m;
– the distance between both stations was less than 00°15' both north and east;
– both hauls were carried out within an arbitrarily set period of 15 days.

These criteria were set to ensure that conditions were highly similar and that the fish densities and length distributions of the paired hauls were comparable. In some cases, if two or more hauls were carried out in close proximity and with the same type of trawl, the mean values of the hauls were compared with the results of the other trawl.

Two different methods were used to compare the CPUE-values of paired stations. Firstly, the CPUE-values of each gear were added, and the length distributions of cod of the two gears were analyzed. Secondly, the quotient CPUE (trawl 1)/CPUE (trawl 2) of each paired station was calculated for different fish length ranges and the distribution of this parameter was analyzed.

The effects of different "fishing power" estimates concerning the stock abundance indices of the Baltic trawl surveys were analyzed by comparing the length distributions of cod stocks in ICES Sub-divisions 25 and 26. The CPUE-values of national hauls were multiplied by the same "fishing power" parameter to obtain CPUE-values that corresponded with the CPUE-values of the standard GOV trawl. The mean values of the transformed CPUE were estimated according to defined depth layers. Moreover, the stratified means of ICES sub-divisions were assessed using the areas of the depth layer as weighting factors. These algorithms were applied with parameters F_{p1} and F_{p2}.

RESULTS

The mean CPUE-values of the Polish P20/25 fishing gear were compared with those of the TV3#930 trawl, and the mean CPUE-values of the German HG20/25 trawl were compared with those of the TV3#520 trawl. The mean conversion factors C_f, based on 2-cm intervals, were estimated for cod in the length range from 10 to 48 cm. The mean C_f for cod larger than 24 cm was 1.80 and 1.13 for the Polish and German experiments, respectively (Table 1). The mean C_f of the Polish trawl varied widely between length intervals due to the low number of inter-calibration experiments. The range of mean C_f of the German trawl was nearly constant for cod larger than 24 cm.

The fishing power F_{p2} based on equation [3] was comparable with F_{p1} in many cases; however, F_{p1} and F_{p2} differed significantly with the P20/25 (Poland) and LBT (Latvia) fishing gears. The mean values of C_f, F_{p1}, and F_{p2} by gear are summarized in Table 2. Furthermore, the ranges of parameter F_{p2} are given since, in many cases, the amount of inter-calibration experiment data available is low. The number of the inter-calibration experiments alone cannot explain these differences. Parameter F_{p2} of the Polish P20/25 trawl corresponds with that calculated for the German HG20/25 trawl.

Catchability was compared between Polish and German trawls using the CPUE-values of paired stations to check whether F_{p1} or F_{p2} more suitably describes reality. The Polish and German institutes carried out spring trawl surveys in ICES Sub-division 25 from 1993 to 1999, but since the spatial and temporal distribution of hauls was not coordinated, the number of stations that could be used for the analyses is rather low.

Table 1. Mean conversion factors (C_f) of cod and the number of inter-calibration experiments (N) of national gear types P 20/25 (Poland) and HG 20/25 (Germany)

Length classes [cm]	TV3 #930 vs. P20/25		TV3 #520 vs. HG20/25	
	N	conversion factor C_f	N	conversion factor C_f
16	12	1.38	25	1.17
18	13	1.64	23	1.21
20	15	1.12	25	1.04
22	16	1.23	30	1.18
24	15	1.27	31	1.08
26	16	1.55	31	1.07
28	14	1.82	31	1.30
30	17	1.70	32	1.26
32	11	2.42	31	1.10
34	12	2.02	30	0.95
36	14	1.72	26	1.13
38	8	0.98	27	1.25
40	15	2.81	19	1.06
42	7	2.18	17	1.36
44	3	1.61	14	1.15
46	6	1.68	8	0.87
48	2	-	4	1.22

Table 2. Estimates of mean fishing power F_{p1} and F_{p2}, and mean conversion factors C_f by national gears

Country	Gear	F_{p1}	C_f (TV3#520, national gear)	C_f (TV3#930, national gear)	Range of F_{p2}	Mean F_{p2}
Denmark	Granton	0.57		3.76	0.18-0.81	0.34
Germany	HG20/25	0.87	1.13	1.80	0.59-0.93	0.71
Latvia	LBT	0.44	0.73	1.16	0.28-1.28	1.10
Poland	P20/25	0.34	-	1.80	0.46-1.31	0.71
Russia	Hake 4M	0.93	-	1.77	0.46-1.75	0.72
Sweden	GOV	1.00	-	1.28	0.84-1.20	1.00
Germany	TV3#520	-	-	1.59	0.58-1.25	0.81

Two depth layers were applied to compare catchability between Polish and German trawls since the fish density patterns of smaller (< 30 cm in total length) and larger (> 50 cm) cod are varied and probably influenced by the thermocline (Oeberst 2000). The thermocline was mostly observed at a depth of about 60 m in ICES Sub-divisions 25 and 26 (Anon. 1996, Nehring *et al.* 1996, Matthäus *et al.* 2000). Higher CPUE-values of large cod were observed with relatively low variance in water deeper than 60 m, while small cod were distributed heterogeneously in areas above the thermocline.

The mean CPUE-values of Polish and German fishing gears at stations with a mean water depth of more than 60 m (Table 3) are presented in Figure 1. The length distributions of cod are given at 2-cm length intervals. The results obtained suggest that the mean catchability of both gears is comparable, although the mean CPUE-values of the Polish gear were higher in the 19 to 31 cm cod length range and the German gear captured more cod in the 37-51 cm range.

Table 3. Data of paired stations in ICES Sub-division 25 at water depths of more than 60 m

Poland						Germany						Differences[a)]			
location		depth [m]	station no.	trawl type	date	location		depth [m]	station no.	trawl type	date	lat. 00'N	long. 00'E	depth [m]	days
55°16'	17°21'	90	47	P20/25	15.02.93	55°16'	17°21'	85	79	HG20/25	13.02.93	0	0	–5	2
55°20'	17°31'	80	46	P20/25	15.02.93	55°15'	17°33'	90	82	HG20/25	13.02.93	5	2	10	2
55°20'	17°31'	80	46	P20/25	15.02.93	55°16'	17°21'	85	79	HG20/25	13.02.93	4	10	5	–2
55°17'	17°10'	90	37	P20/25	14.02.95	55°18'	17°21'	85	79	HG20/25	16.02.95	1	11	–5	2
55°19'	17°23'	80	63	P20/25	19.03.98	55°18'	17°25'	89	79	HG20/25	5.03.98	1	2	9	14
55°14'	17°25'	90	52	P20/25	4.03.99	55°17'	16°10'	85	80	HG20/25	2.03.99	3	75	–5	2
55°19'	17°20'	80	53	P20/25	4.03.99	55°18'	17°21'	85	79	HG20/25	3.03.99	1	1	5	1
55°19'	17°20'	80	53	P20/25	4.03.99	55°15'	17°19'	90	82	HG20/25	3.03.99	4	1	10	1
55°14'	17°25'	90	52	P20/25	4.03.99	55°18'	17°21'	85	79	HG20/25	3.03.99	4	4	–5	1
54°45'	15°44'	70	44	P20/25	15.02.95	54°46'	15°39'	78	74	HG20/25	23.02.95	1	5	8	–8
54°47'	15°36'	70	51	P20/25	13.03.98	54°47'	15°40'	76	74	HG20/25	26.02.98	0	4	6	–15
54°49'	15°21'	70	28	P20/25	26.02.99	54°46'	15°39'	76	74	HG20/25	28.02.99	3	18	6	–2
54°53'	15°43'	80	16	P20/25	25.02.00	54°47'	15°39'	77	74	HG20/25	2.03.00	6	4	–3	–5
54°32'	15°39'	60	48	P20/25	16.02.95	54°38'	15°38'	67	68	HG20/25	23.02.95	6	1	7	–7
54°34'	15°39'	60	50	P20/25	13.03.98	54°38'	15°38'	65	68	HG20/25	1.03.98	4	1	5	12
54°47'	15°36'	70	51	P20/25	13.03.98	54°38'	15°38'	65	68	HG20/25	1.03.98	9	2	–5	12
54°49'	15°57'	60	39	P20/25	10.02.93	54°47'	15°57'	58	65	HG20/25	12.02.93	2	0	–2	–2
54°34'	15°39'	60	50	P20/25	13.03.98	54°31'	15°45'	53	65	HG20/25	1.03.98	3	6	–7	–12
54°43'	15°48'	60	54	P20/25	15.03.98	54°31'	15°45'	53	65	HG20/25	1.03.98	12	3	–7	–14
54°49'	15°57'	60	39	P20/25	10.02.93	54°47'	15°57'	58	65	HG20/25	12.02.93	2	0	–2	–2

[a)] between German and Polish data

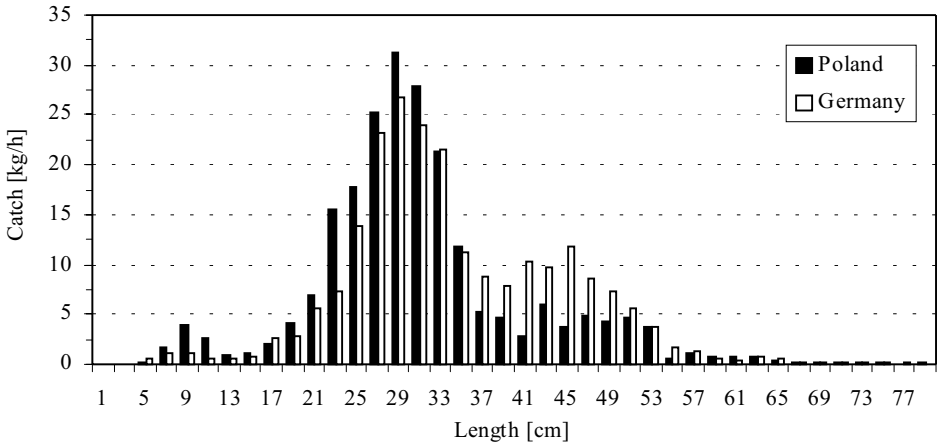

Fig. 1. Mean catches of cod (CPUE-values) at 2-cm length intervals,
based on 20 stations in water deeper than 60 m for Polish and German trawls.

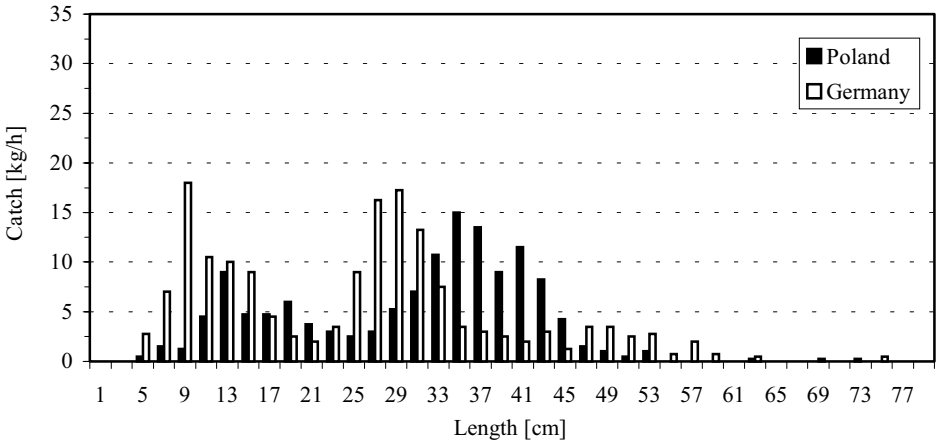

Fig. 2. Mean catches of cod (CPUE-values) at 2-cm length intervals,
based on 8 stations in water deeper than 60 m for Polish and German trawls.

The mean CPUE-values of paired stations with a mean water depth of less than 60 m (Table 4) are shown in Figure 2. The length distributions of cod given are also at 2-cm intervals. The German HG20/25 trawl retains specimens smaller than 33 cm more effectively and fewer of those in the 33 to 45 cm range than does the Polish P20/25 trawl. Pooling all the paired data led to the conclusion that the two fishing gears have a comparable mean catchability of cod, but some differences were recorded with regard to length range.

The quotient CPUE(P20/25)/CPUE(HG20/25) was analyzed using data at 2 cm length intervals to check whether the mean log transformed quotients were significantly different from zero. Log transformations were used because it was assumed that the quotient was

Table 4. Data of paired stations in ICES Sub-division 25 at water depths of less than 60 m

Poland						Germany						Differences [a]			
location		depth [m]	station no.	trawl type	date	location		depth [m]	station no.	trawl type	date	lat.	long.	depth [m]	days
54°28'	15°29'	50	47	P20/25	16.02.95	54°26'	15°42'	48	62	HG20/25	23.02.95	2	13	-2	7
54°26'	15°36'	50	40	P20/25	28.02.99	54°25'	15°41'	46	62	HG20/25	1.03.99	1	5	-4	1
54°40'	16°10'	40	48	P20/25	1.03.99	54°55'	16°13'	47	63	HG20/25	2.03.99	15	3	7	1
55°00'	17°27'	30	62	P20/25	6.03.99	55°00'	17°27'	37	60	HG20/25	3.03.99	0	0	7	-3
54°59'	17°20'	30	27	P20/25	28.02.00	55°00'	17°31'	39	60	HG20/25	1.03.00	41	11	9	1
54°46'	16°50'	30	51	P20/25	17.02.95	54°50'	16°35'	24	56	HG20/25	19.02.95	4	15	-6	2
54°38'	16°21'	30	40	P20/25	11.03.98	54°49'	16°25'	27	54	HG20/25	1.03.98	11	4	-3	-10
54°46'	16°53'	30	39	P20/25	11.03.98	54°51'	16°38'	23	56	HG20/25	5.03.98	5	15	-7	-6

[a] between German and Polish data

Table 5. Number of available data sets (no.), mean values (mean) and standard deviations (Sd) of the log-transformed quotient CPUE(P20/25)/CPUE(HG20/25) by paired stations presented in Tables 3 and 4

Length	Hauls of Table 3			Hauls of Table 4		
[cm]	no.	mean	Sd	no.	mean	Sd
19	7	0.36	0.22	1	0.39	–
21	10	0.05	0.31	1	0.74	–
23	14	0.19	0.52	2	0.18	0.67
25	17	–0.03	0.63	2	–0.12	1.02
27	17	0.11	0.36	4	–0.63	0.71
29	19	–0.04	0.46	3	–0.38	0.55
31	17	–0.03	0.61	5	–0.19	0.25
33	19	–0.11	0.43	3	0.07	0.38
35	16	–0.10	0.37	4	0.24	0.76
37	16	–0.30	0.42	4	0.41	0.54
39	10	–0.15	0.63	3	0.31	1.01
41	10	–0.38	0.56	3	0.79	0.42
43	9	–0.09	0.67	3	0.61	0.04
45	6	–0.17	0.74	1	–0.70	–
47	6	–0.05	0.54	2	–0.39	0.80
49	7	–0.31	0.55	1	–1.04	–
51	4	–0.16	1.01	1	–0.30	–
53	4	0.20	0.48	–	–	–

lognormal distributed. Table 5 summarizes the results segregated by paired stations. T-tests indicated that the mean values were never significantly different from zero.

All of the results combined lead to the conclusion that the Polish P20/25 trawl and the German HG20/25 trawl have the same "fishing power", and that F_{p2} is a suitable estimate to transform CPUE-values of the Polish gear into CPUE-values of the new standard gear.

The effects of coefficients F_{p1} and F_{p2} regarding the estimation of cod stock abundance indices were analyzed because the values of F_{p1} and F_{p2} of the Polish P20/25 gear were different. The abundance indices of ICES sub-divisions were calculated by stratified means using depth layers as the strata. The CPUE-values of all the participating countries are used to estimate the means within the strata. The fishing power of all the trawls combined is necessary since ICES sub-divisions normally include two or more countries.

The two cod length distribution versions from ICES Sub-division 25 in 1997 are presented in Figure 3, while Figure 4 shows the example of estimates from ICES Subdivision 26 in 1995. $Fp(1)$ marks the length distribution based on F_{p1}, and $Fp(2)$ is the alternative version. The differences in the two cod length distribution versions were recorded in the two ICES sub-divisions from 1993 to 1999. Graphs representing other years are not included, as they are similar to those in Figures 3 and 4. The estimates based on F_{p1} were always significantly higher. This is presented in Figure 5 for the cod length distribution obtained using F_{p2} in relation to F_{p1} (ICES Sub-division 25 in 1999) and implies that F_{p1} was used as 100%. Comparable estimates are also presented in Figure 6 for ICES Subdivision 26 in 1995. The relative difference between the compared length distributions

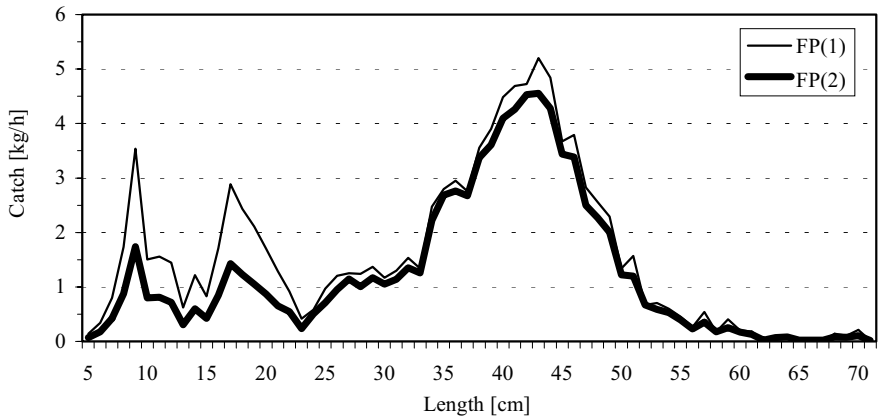

Fig. 3. Calculated cod stock length distribution based on coefficients F_{p1} and F_{p2} in ICES Sub-division 25 in 1997.

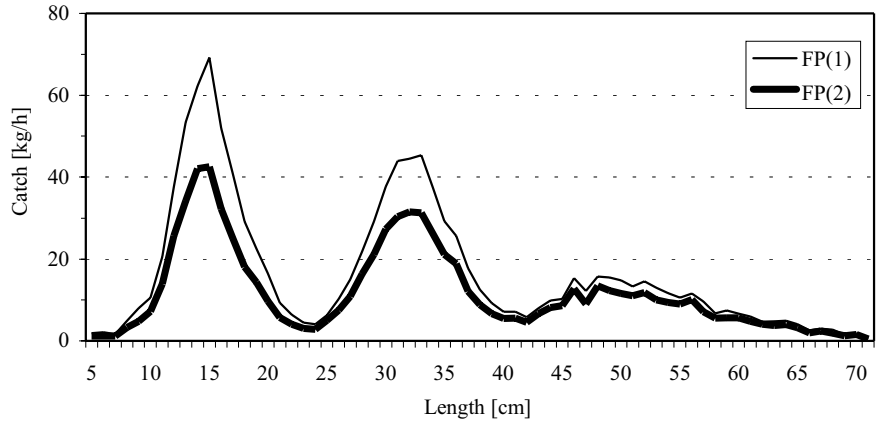

Fig. 4. Calculated cod stock length distribution based on coefficients F_{p1} and F_{p2} in ICES Sub-division 26 in 1995.

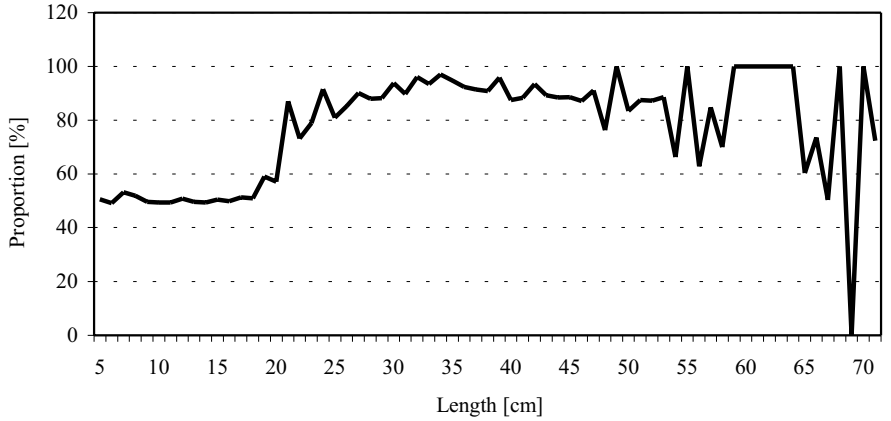

Fig. 5. Proportion of cod stock abundance indices based on the relation of F_{p2} to F_{p1} in ICES Sub-division 25 in 1997.

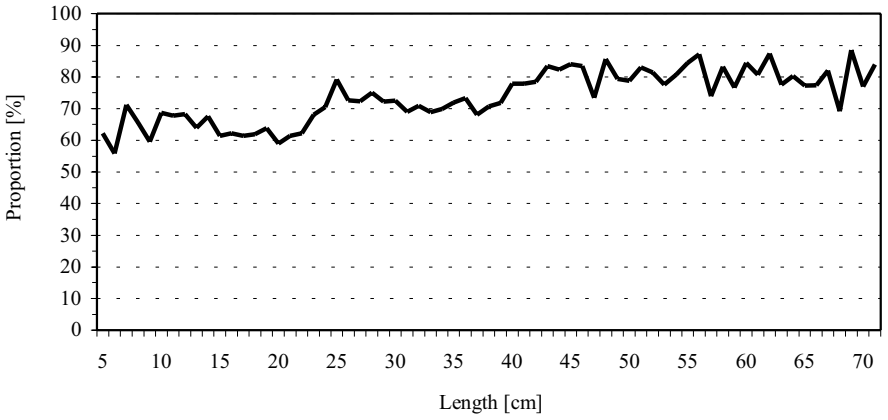

Fig. 6. Proportion of cod stock abundance indices based on the relation of F_{p2} to F_{p1} in ICES Sub-division 26 in 1995.

was higher in ICES Sub-division 26 and varied from year to year. The results of inter-calibration experiments and the comparisons of F_{p1} and F_{p2} values led to the conclusion that the small differences between F_{p1} and F_{p2} in the GOV and HG20/25 gear types do not significantly influence the stock abundance indices.

DISCUSSION

Inter-calibration experiments have shown that the F_{p2} values of the Granton, GOV, Hake 4M and HG20/25 gear types agree well with fishing power F_{p1} estimated by Sparholt and Tomkiewicz (2000). However, estimates concerning the Polish P20/25 trawl and the Latvian LBT and Danish Granton gears differed significantly. The relationship between the F_{p1} and F_{p2} of Polish gear is 1 to 2. The effects of varied estimates of the cod CPUE-values of the Polish trawl significantly influence the stock abundance indices calculated for ICES Sub-divisions 25 and 26 depending on the proportion of hauls conducted by the Polish vessel R/V BALTICA. This result is important since the number of annual Polish hauls and their spatial distribution is variable, and their influence on the stock indices varies accordingly.

Analyses of CPUE-values have shown that the inter-calibration experiments of the Polish gear produced realistic estimates of fishing power. This opinion is supported by the fact that the estimates of F_{p2} of the Polish P20/25 trawl and the German HG20/25 trawl are comparable, and that the two gears have a similar construction that varies only slightly (Schulz and Grygiel 1984, 1987).

There are various explanations as to why the estimates of fishing power for Polish gear differed. Different data sets and methods were applied in the analyses. Sparholt and Tomkiewicz (1998, 2000) used generalized linear models that calculate F_{p1} in one step in relation to all the other gears involved. This leads to the conclusion that interactions be-

tween the cod CPUE obtained with other gears can influence the CPUE-values of the Polish gear. In contrast, direct comparisons of national fishing gears and new standard gears were carried out, and paired stations using Polish and German gears were analyzed. These results are completely independent from the catches of other gears that were also used in the trawl surveys conducted by other laboratories.

A second reason that F_{p1} and F_{p2} differ in some cases is that Sparholt and Tomkiewicz (2000) used age-aggregated data, whereas length-based data was used in the current work. It is well known (Anon. 2001a) that cod otoliths are interpreted differently in eastern Baltic countries than they are in the west. Differing cod otolith interpretations can therefore lead to varied estimations of CPUE-value at age per countries. However, different interpretations of the otolith "annual rings" were probably insignificant to the current studies, as they were based on total length measurements. Both estimates of fishing power probably describe reality well and the use of age- and length-based CPUE-values trigger the differences.

Therefore, it appears to be useful to combine the CPUE-values of length intervals used for assessing the cod stock length distribution in order to reduce the influence of different age reading interpretations on the stock abundance indices that are based on international trawl surveys. Indices of age group abundance can be estimated in a subsequent step using various otolith interpretations to conduct sensitivity analyses and to check the consequence of different otolith interpretations on stock abundance indices. The possibility of analyzing the influence of the different age reading interpretations is very important since stock abundance indices based on trawl surveys are the only estimates of the eastern Baltic cod stock that are independent of fishery.

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Feeding habits of Pacific black halibut *Reinhardtius hippoglossoides matsuurae* Jordan et Snyder, 1901 and Kamchatka flounder *Atheresthes evermanni* Jordan et Starks, 1904 in the western North Pacific*

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Abstract. The diets of Pacific black halibut *Reinhardtius hippoglossoides matsuurae* and Kamchatka flounder *Atheresths evermanni* inhabiting the western Bering Sea and Pacific waters off the northern Kuril Islands and southeastern Kamchatka are examined. The diets of both predators consisted mostly of shrimps, cephalopods and fishes. The consumption of large amounts of fishery offal by Pacific black halibut and Kamchatka flounder in the western Bering Sea was noted. The diets of the species considered in both study areas are compared, and diet variations depending on fish size, capture depth, area and sex are analyzed.

Key words: diet; feeding habits; Pacific black halibut; *Reinchardtius hippoglossoides matsuurae*; Kamchatka flounder; *Atheresthes evermanni*; western Bering Sea; northern Kuril Islands; southeastern Kamchatka

INTRODUCTION

Pacific black halibut (Greenland halibut) *Reinhardtius hippoglossoides matsuurae* and Kamchatka flounder *Atheresthes evermanni* are very important targets of groundfish fishery in the North Pacific Ocean (Eschmeyer *et al.* 1983, Fadeev 1984, Kramer *et al.* 1995). The biology of these species in the western Bering Sea and in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka has been studied insufficiently. The feeding habits of these predatory pleuronectids in the western Bering Sea were investigated long ago (Vernidub, Panin 1937; Vernidub 1938, Gordeeva 1954, Shuntov 1966, Noviko 1974), though all these papers comprised limited data on diets based mostly on the frequency of occurrence of dietary components in stomachs. There are several publications dealing with

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the feeding habits of species considered in the Kuril-Kamchatka area (Novikov 1974; Orlov 1997, 1998, 1999, 2000). However, the diet descriptions in all of these papers are also based only on the frequency of occurrence of food items in stomachs. No studies have been conducted recently on the feeding habits of Pacific black halibut and Kamchatka flounder in the northwestern Pacific based on quantitative data on stomach contents.

MATERIAL AND METHODS

In this study, the stomach contents of Pacific black halibut and Kamchatka flounder sampled aboard the Japanese trawlers KAYO MARU No. 28 and TOMI MARU NO. 82 during the 1997 summer-autumn bottom trawl survey and commercial fishing operations were analyzed. Samples for analysis were taken from bottom trawl catches conducted in the western Bering Sea (WBS) between 168°E and 177°W and in Pacific waters off the northern Kuril Islands and southeastern Kamchatka (NK) between 47°50′N and 51°40′N (Fig. 1). The trawl had vertical and horizontal openings of about 5 and 25 m, respectively. Fishing was carried out around the clock. The content of each analyzed stomach was sorted, identified to the lowest possible taxonomic level, and weighed. The weight of each prey taxon was recorded to the nearest 0.1 g. Prey groups were described in terms of the percent of total stomach content weight (% *W*) and frequency of occurrence (% *FO*). The frequency of occurrence was calculated as the number of stomachs that contained that prey group divided by the number of stomachs that contained food. Fishes showing signs of regurgitation (digested food items in the mouth or gill cavity or a flaccid or water-filled stomach) or net-feeding (freshly consumed prey items in the mouth or throat) were omitted from analysis.

Fork lengths (*FL*; snout to the end of the middle rays of tail) were measured.

Specimens of both species considered were grouped into several length categories of 5 cm increments to analyze size-dependent dietary variations.

To analyze the geographic differences of halibut diets, the investigated areas were subdivided (Fig. 1). The western Bering Sea was divided into two sub-areas (168-174°E and 174°E-177°W), and Kuril-Kamchatka – into three sub-areas (47°50′-49°35′N, 49°35′-50°40′N, and 50°40′-51°40′N).

The stomachs examined and those with food were as follows: Pacific black halibut 589/411 and 203/93 in the WBS and NK, respectively; Kamchatka flounder 446/184 and 1443/300 in the WBS and NK, respectively.

RESULTS

General description of diets

The diet of both species consisted of a wide spectrum of prey (Table 1). The total number of food items in the stomach contents of Pacific black halibut during the study period was

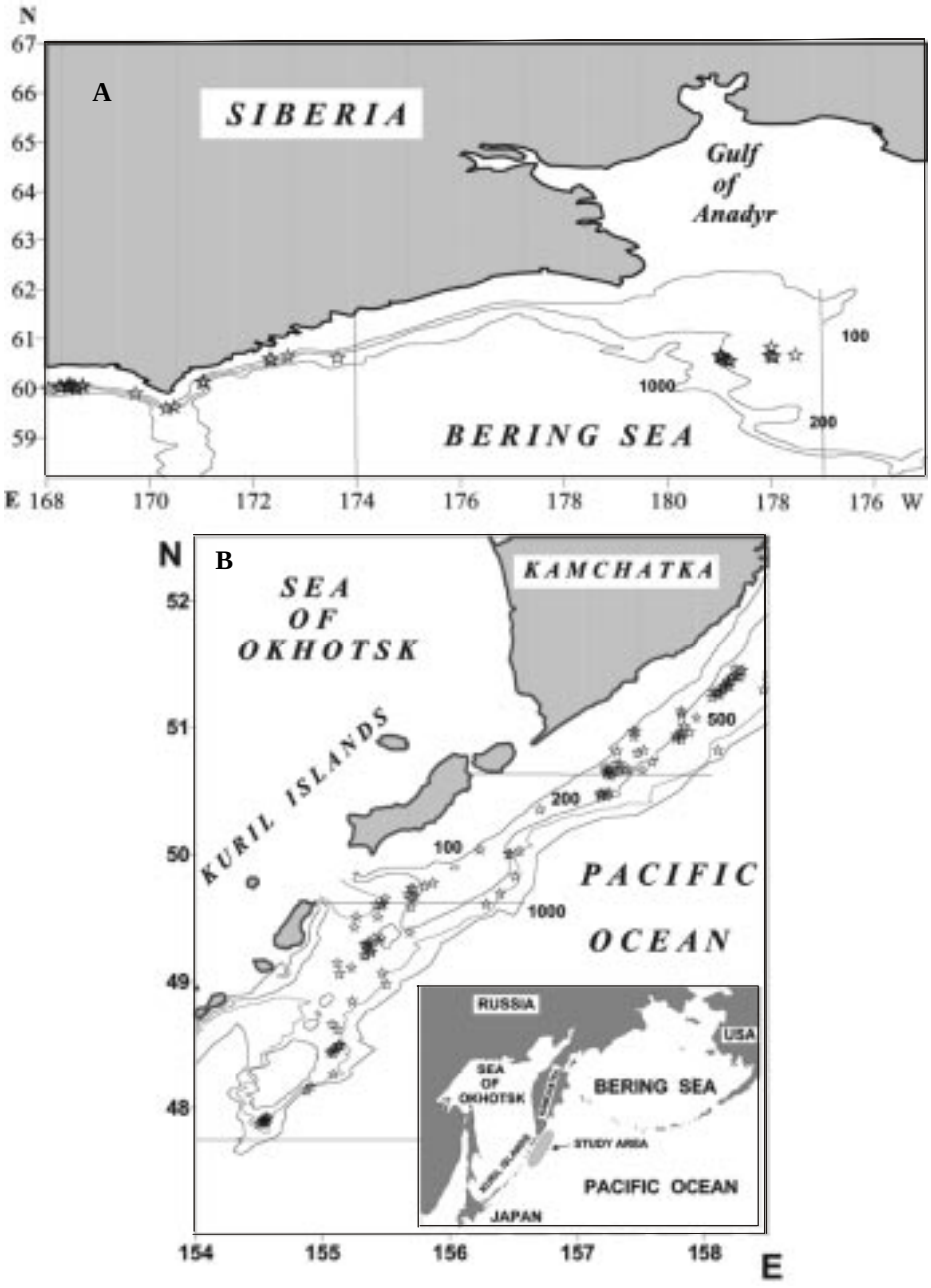

Fig. 1. Map of the study area showing bottom trawl stations (asterisks) where stomachs of Pacific black halibut and Kamchatka flounder were sampled.
A – western Bering Sea, B – northern Kuril Islands. Thin curves and numbers show isobaths (m), vertical and horizontal lines are the borders of distinguished areas.

Table 1. Prey items expressed as frequency of occurrence (%*FO*) and weight (%*W*) of Pacific black halibut and Kamchatka flounder collected in the western Bering Sea (WBS) and Pacific waters off the northern Kuril Islands and southeastern Kamchatka (NK) in summer–autumn 1997.

Prey item	Pacific black halibut				Kamchatka flounder			
	WBS		NK		WBS		NK	
	% *FO*	% *W*	% *FO*	% *W*	% *FO*	% *W*	% *FO*	% *W*
1	2	3	4	5	6	7	8	9
SPONGIA	–	–	–	–	–	–	0.3	< 0.1
COELENTERATA								
Actiniaria	0.2	< 0.1	–	–	–	–	–	–
ANNELIDA								
Polychaeta	–	–	–	–	–	–	0.7	0.1
CRUSTACEA								
Mysidacea								
Mysidacea gen sp.	0.5	< 0.1	–	–	0.5	0.1	1.0	0.4
Gnathophausia gigas	0.2	< 0.1	–	–	–	–	–	–
Euphausiacea								
Euphausiidae gen sp.	–	–	15.1	9.8	–	–	3.0	0.7
Amphipoda								
Amphipoda gen. sp.	–	–	2.2	0.6	–	–	0.7	0.1
Ampelisca sp.	–	–	2.2	0.1	–	–	–	–
Decapoda								
Pandalus goniurus	1.2	< 0.1	–	–	1.6	0.1	–	–
P. hypsinotus	0.2	< 0.1	–	–	1.1	< 0.1	–	–
Pandalus sp.	–	–	8.6	8.5	–	–	47.7	53.7
Pandalopsis dispar	0.2	< 0.1	–	–	–	–	–	–
Sclerocrangon sp.	–	–	–	–	–	–	0.7	< 0.1
Pagurus sp.	–	–	–	–	–	–	0.3	< 0.1
MOLLUSCA								
Gastropoda								
Buccinidae gen. sp.	0.2	< 0.1	–	–	0.5	< 0.1	–	–
Cephalopoda								
Teuthidae gen. sp.	1.2	< 0.1	–	–	0.5	< 0.1	–	–
Berryteuthis magister	18.0	11.2	62.4	69.4	10.3	11.9	19.1	17.2
Galyteuthis phyllura	–	–	1.1	1.3	–	–	–	–
Gonatopsis borealis	–	–	–	–	–	–	0.3	< 0.1
Octopoda gen sp.	0.7	1.9	1.1	3.0	1.1	0.8	1.0	1.4
OSTEICHTHYES								
Clupea pallasii	12.4	8.9	–	–	8.7	10.4	–	–
Mallotus villosus	–	–	–	–	–	–	0.3	0.9
Leuroglossus schmidti	0.2	< 0.1	6.5	3.3	–	–	0.3	0.1
Myctophidae gen sp.	3.2	0.1	3.2	0.3	–	–	3.0	2.3
Stenobrachius leucopsarus	0.5	< 0.1	–	–	0.5	0.1	0.3	< 0.1
S. nannochir	3.4	0.3	–	–	–	–	–	–
Theragra chalcogramma	19.2	30.8	1.1	1.9	13.0	15.5	2.3	5.1
Albatrossia pectoralis	0.5	0.9	–	–	–	–	–	–
Coryphaenoides cinereus	0.2	0.1	–	–	–	–	–	–

Table 1. continued

1	2	3	4	5	6	7	8	9
Leptoclinus maculatus	–	–	–	–	–	–	1.0	0.9
Lumpenella longirostris	–	–	–	–	1.1	0.7	–	–
Zoarcidae gen. sp.	–	–	–	–	–	–	0.3	1.2
Lycodes brevipes	0.2	< 0.1	–	–	1.1	1.1	–	–
L. brunneofasciatus	–	–	–	–	–	–	0.3	0.2
Lycodes concolor	–	–	–	–	1.1	1.3	–	–
L. diapterus	0.7	0.2	–	–	–	–	–	–
Lycodes sp.	0.5	< 0.1	–	–	–	–	0.3	0.4
Cottidae gen. sp.	–	–	–	–	–	–	0.7	0.6
Artediellus sp.	–	–	–	–	–	–	0.3	< 0.1
Icelus sp.	–	–	–	–	–	–	0.3	0.2
Triglops scepticus	–	–	–	–	–	–	1.6	2.2
Dasycottus setiger	0.2	< 0.1	–	–	–	–	–	–
Malacocottus zonurus	–	–	–	–	1.1	0.7	0.3	0.3
Sarritor frenatus	–	–	–	–	–	–	0.7	0.1
Liparidae gen. sp.	0.2	< 0.1	1.1	0.7	–	–	0.7	1.2
Careproctus furcellus	0.2	< 0.1	–	–	–	–	–	–
Hippogliossoides elassodon	0.2	0.2	–	–	–	–	–	–
Unidentified fish	5.4	0.8	4.3	1.0	14.7	3.6	16.8	10.7
Fish eggs	–	–	–	–	–	–	0.3	< 0.1
Fishery offal	43.3	44.4	–	–	40.8	53.4	–	–
Unidentified organic material	1.2	< 0.1	–	–	5.4	0.2	–	–
Number of stomachs analyzed	589		203		446		1443	
Stomachs with food	411		93		184		300	
Length range, cm	43–102		28–91		37–84		23–78	
Mean length ± SE	69.30 ±0.43		58.62 ±0.99		54.83 ± 0.37		49.37 ± 0.25	
Weight range, g	730–14200		140–7700		450–6700		100–6600	
Mean weight ± SE	3537.0 ± 86.2		2385.2 ± 115.1		1828.0 ± 48.5		1452.7 ± 25.4	

no less than 29, and that of Kamchatka flounder no less than 31, excluding fish parts discarded from the fishing vessels processing the catch and unidentified organic materials.

The diet of Pacific black halibut (Fig. 2) in the WBS consisted mostly of fishery offal (44.4% *W*), fishes (42.5% *W*) and cephalopods (13.1% *W*). Walleye pollock *Theragra chalcogramma* was the primary fish species consumed (30.8% *W*), followed by Pacific herring *Clupea pallasii* (8.9% *W*). Red squid *Berryteuthis magister (*11.2% *W*) was the most common of the cephalopods. In the NK this species consumed mainly cephalopods (73.6% *W*), small crustaceans (10.6% *W*), shrimps (8.5% *W*), and fishes (7.3% *W*). Similarly to the WBS, red squid (69.4% *W*) was the most common prey item among the cephalopods, but the northern smoothtongue *Leuroglossus schmidti* was most numerous fish prey (3.3% *W*). Differences in diet composition between the areas considered might be explained by the decidedly larger size of the WBS fish (69.30 cm vs. 58.62 cm) and regional faunistic distinctions.

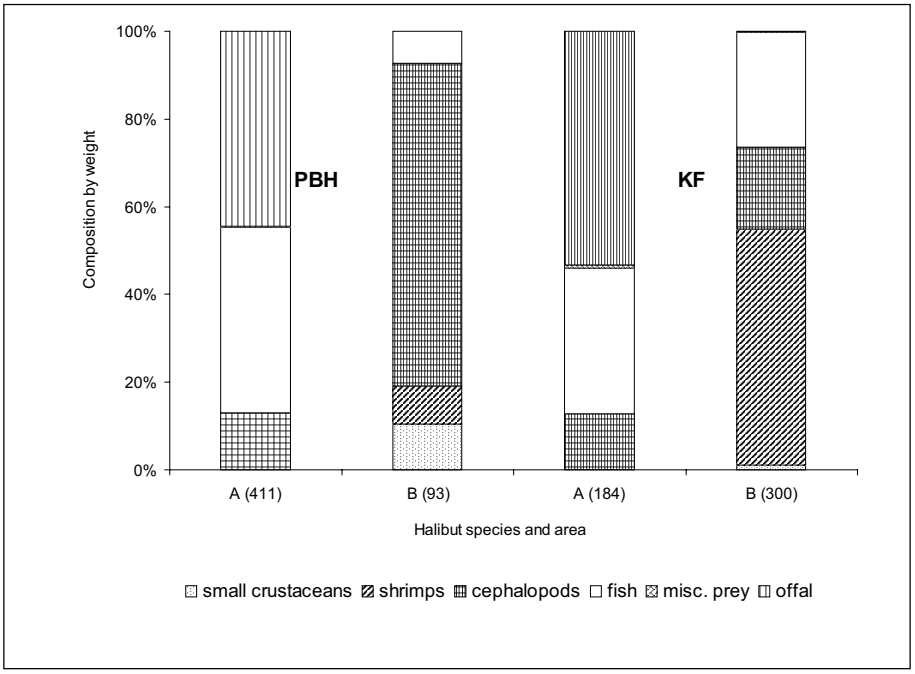

Fig. 2. Diets of Pacific black halibut (PBH) and Kamchatka flounder (KF) categorized by the percentage of the weight of the main food items, summer-autumn 1997.
A – western Bering Sea, B – northern Kuril Islands (sample size is shown in parentheses).

Similarly to the species from the area described above, the diet of Kamchatka flounder (Fig. 2) in the WBS consisted mostly of fishery offal (53.4% *W*), fishes (33.3% *W*) – mainly walleye pollock (15.5% *W*) and Pacific herring (10.4% *W*), and cephalopods (12.7% *W*), mainly red squid (11.9% W). In the NK this species consumed mainly shrimps (53.7% *W*), various fishes (26.3% *W*), and cephalopods (18.6% *W*). Walleye pollock (5.1% *W*) was the most important fish in the diet of Kamchatka flounder off the northern Kuril Islands and southeastern Kamchatka. Mesopelagic fishes were second in rank (approximately 2.4% *W*) followed by spectacled sculpin *Triglops scepticus* (2.2% *W*). Differences in diet composition between the areas considered might be explained by the same reasons as above, namely that the WBS Kamchatka flounder were considerably longer than the NK fishes (54.83 and 49.37 cm, respectively).

Feeding habits vs. size

Changes were noted in the diet compositions of both species as the size of the fishes increased. Increases in the size of Pacific black halibut from the WBS were accompanied by increasing consumption of fishes and fishery offal, and the declining importance of cephalopods in the diet (Fig. 3A). Large Pacific black halibut (size groups 46-80 cm) from the NK ate more cephalopods (mean 86.6% *W*) (Fig. 3B). The role of cephalopods in the diet of fish of the same size group from the WBS was considerably smaller (mean only

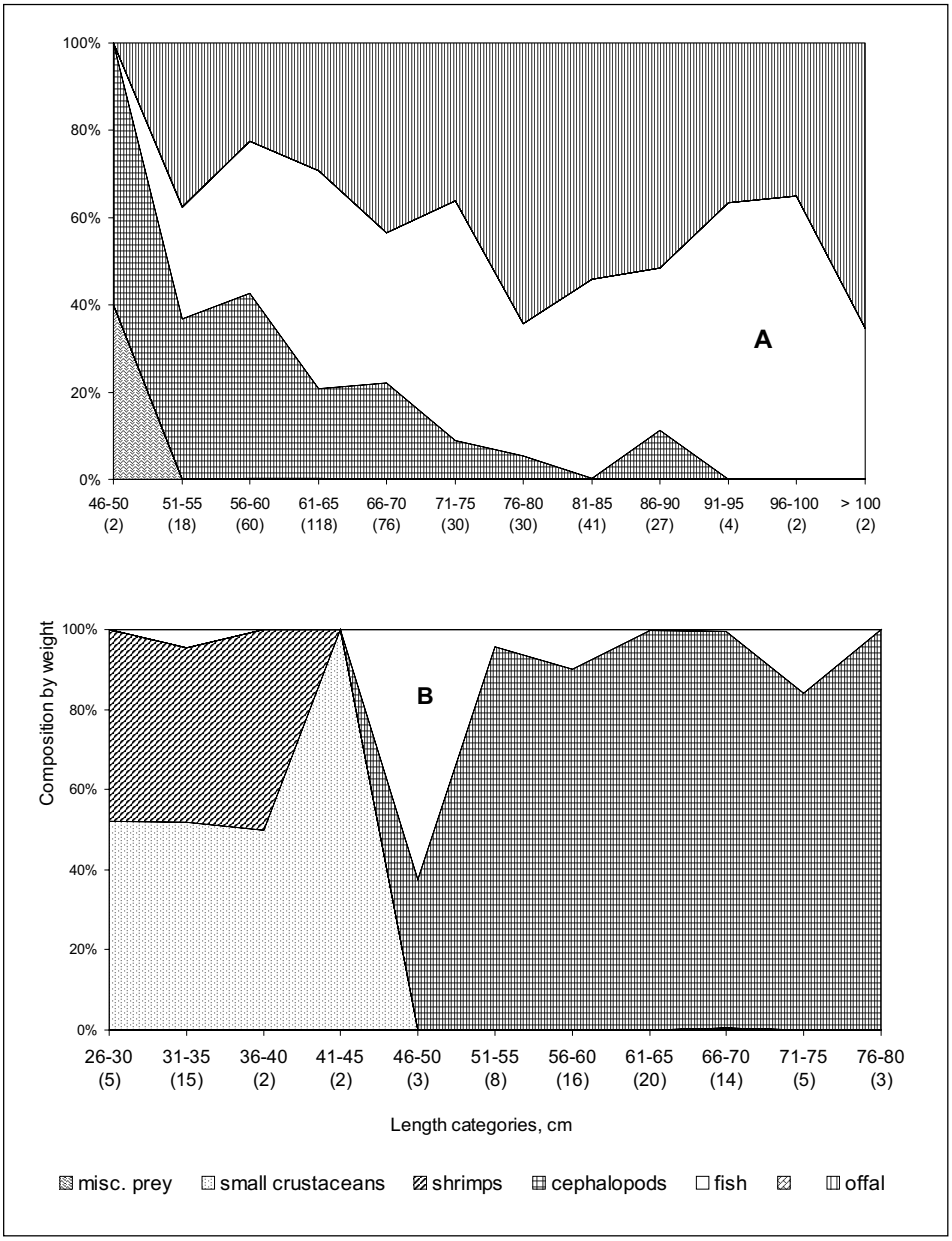

Fig. 3. Variations in the main food items of Pacific black halibut by predator size (sample size is shown in parentheses): A – western Bering Sea, B – northern Kuril Islands.

28.0% *W*). Small-sized NK individuals (*FL* less than 45 cm) consumed mostly euphausiids, shrimps and fishes (Fig. 3B).

The role of fishery offal in the diet of WBS Kamchatka flounder increased as their size increased. Fish prey were of considerable importance for all size groups. Cephalopods

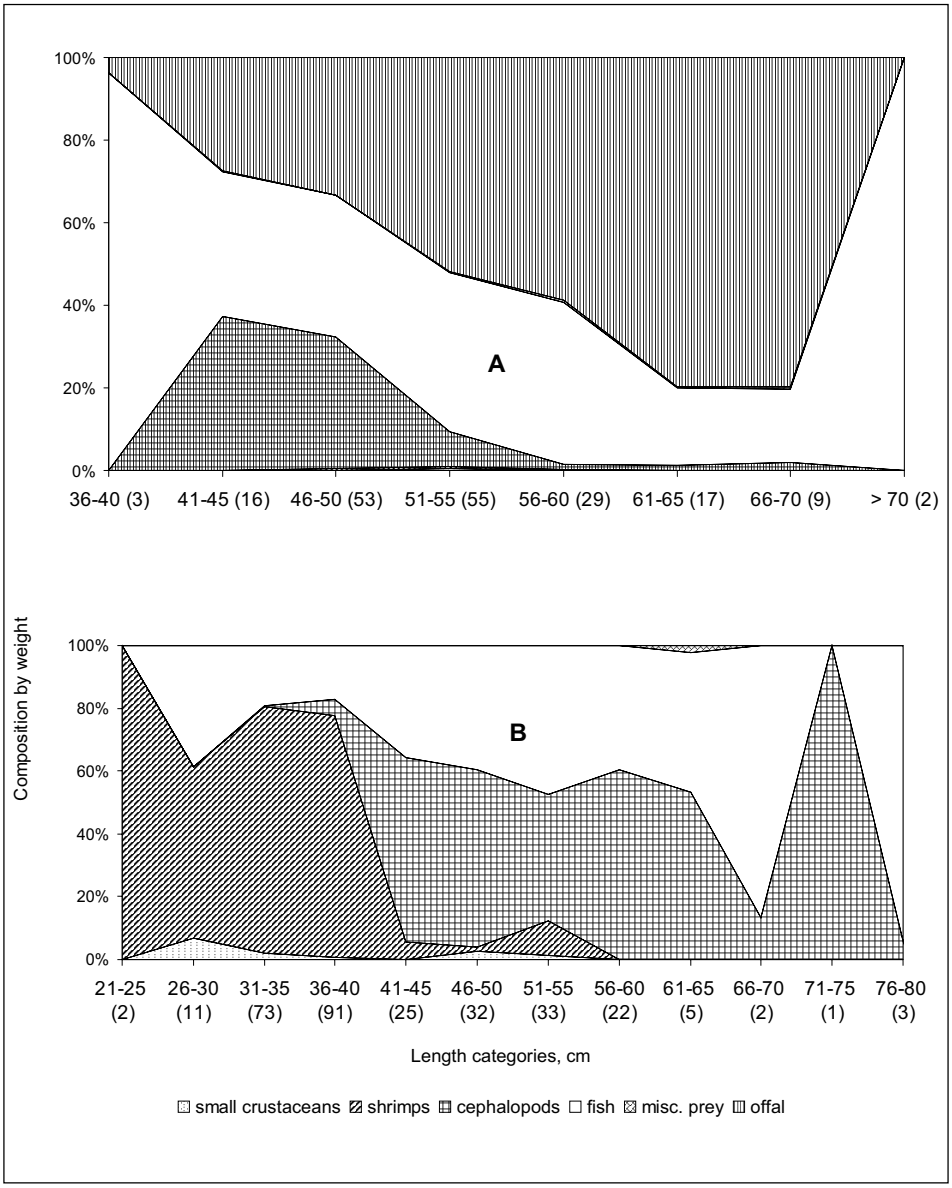

Fig. 4. Variations in the main food items of Kamchatka flounder by predator size (sample size is shown in parentheses): A – western Bering Sea, B – northern Kuril Islands.

played an essential role (mean 34.6% *W*) in the diet of specimens 41-50 cm long (Fig. 4A). Increases in the size of Kamchatka flounder from the NK were accompanied by decreasing shrimp consumption and the increasing importance of cephalopods and fish in the diet (Fig. 4B).

Feeding habits vs. capture depth

Considerable differences in diet composition were detected at various depths. The stomach contents of WBS Pacific black halibut at shallower depths (< 300 m) consisted mostly of fishery offal (63.1%) and fish (31.9%) – mostly walleye pollock. At depths of 300-400 m the diet of this species was comprised of 39.8% offal, 46.7% fish, and 13.4% cephalopods. At greater depths (> 400 m) the examined Pacific black halibut ate mostly fish (40.1%) and offal (33.1%), with cephalopods occupying third position in the diet (26.3%). Other food components did not play an important role.

At shallower depths (< 300 m) in the NK area this species ate mostly small crustaceans (euphausiids), cephalopods and shrimps, while at deeper depths Pacific black halibut fed mainly on cephalopods (red squid) and fish (predominantly mesopelagic species). At shallower depths the proportion of small crustaceans in its diet varied from 39.1 to 35.5%, cephalopods – 38.9 to 32.3%, and shrimps – 12.1 to 31.4%. At depths of 300-400 m the diet of Pacific black halibut was comprised only of cephalopods (78.1%) and fish (21.9%). At depths of 400-500 m this species fed mostly on cephalopods (96.2%), while at even greater depths (500-600 m) it ate cephalopods (85.3%) and fish (14.7%).

WBS Kamchatka flounder consumed mostly fishery offal (67.2%), fish (25.7%), and cephalopods (6.7%) at shallower depths (< 300 m). At depths of 300-400 m their diet was comprised mainly of offal (53.8%), fish (28.6%), and cephalopods (17.2%). At greater depths (> 400 m) Kamchatka flounder fed mostly on Pacific herring, walleye pollock, and other fish (63.2%), fishery offal (30.0%), and also cephalopods (4.7%).

In the NK area the diet of this species at shallower depths (< 300 m) consisted mostly of fish (86.6-13.5%) and shrimps (9.0-83.8%). Kamchatka flounder from deeper (300-400 m) waters consumed cephalopods (52.8%), fish (32.1%), and shrimps (15.1%), while at the greatest depths (400-600 m) only cephalopods (57.7-63.7%) and fish (38.9-36.0%) were the most important components of their diets.

Feeding habits vs. sex

Essential differences between male and female diets were detected. The female Pacific black halibut in the WBS ate more fishery offal (47.5% *W*) and walleye pollock (35.5% *W*), while males fed mostly on fishery offal (35.2% *W*), red squid (25.3% *W*) and Pacific herring (17.6% *W*). In the NK area Pacific black halibut females consumed more fish and red squid, while males ate shrimps in considerably larger quantities – 12.3% *W* vs. 3.5% *W* for males and females, respectively (Fig. 5).

Female Kamchatka flounder in the WBS fed mostly on fishery offal (64.4% *W*), while males consumed more fishes (50.6% *W*), especially Pacific herring (25.1% *W*) and red squid (22.2% *W*). In the NK females ate more shrimps (59.8% *W*) and large fish (27.4% *W*), while males fed mostly on red squid (26.6% *W*) and small fish species (25.0% *W*). Nevertheless, the most abundant prey items in the male diet were shrimps at 45.8% by weight (Fig. 5).

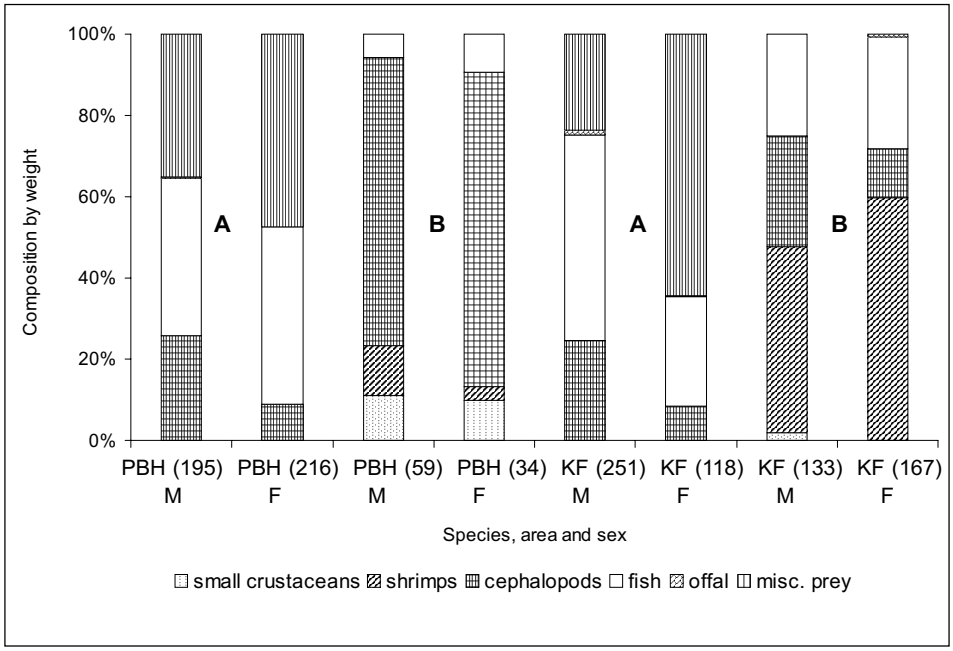

Fig. 5. Variations in the main food items of Pacific black halibut (PBH) and Kamchatka flounder (KF) by sex. A – western Bering Sea, B – northern Kuril Islands (sample size is shown in parentheses).

Feeding habits vs. area

Regional differences were observed in the diets of both species within the two study areas. Fishes (61.4% *W*) and cephalopods (37.2% *W*) were more important in the diet of Pacific black halibut caught in the western part of WBS, while fishery offal (59.9% *W*) and fishes (35.6%) were the most significant dietary components in the eastern part (Fig. 6A). The diet of Pacific black halibut in the NK area changed from the south to the north; the significance of small crustaceans and shrimps in the diet increased, while that of cephalopods and fishes decreased (Fig. 6B).

The diet of Kamchatka flounder in the western part of the WBS consisted mostly of fish (71.2% *W*) and cephalopods (22.% *W*), while in the eastern part it was comprised mainly of fishery offal (73.6%), while fish prey was second in rank (Fig. 7A). In the NK area the importance of cephalopods in the Kamchatka flounder diets decreased from south to north, while that of shrimps increased (Fig. 7B). Thus, in the southern part of the study area cephalopods were the most important dietary component (53.7% *W*) of this fish species, in the middle part they were second in rank (22.4% *W*), and in the north the role of cephalopods was negligible (1.6% *W*). Contrarily, the importance of shrimps increased from 8.6% *W* in the south to 82.9% W in the north.

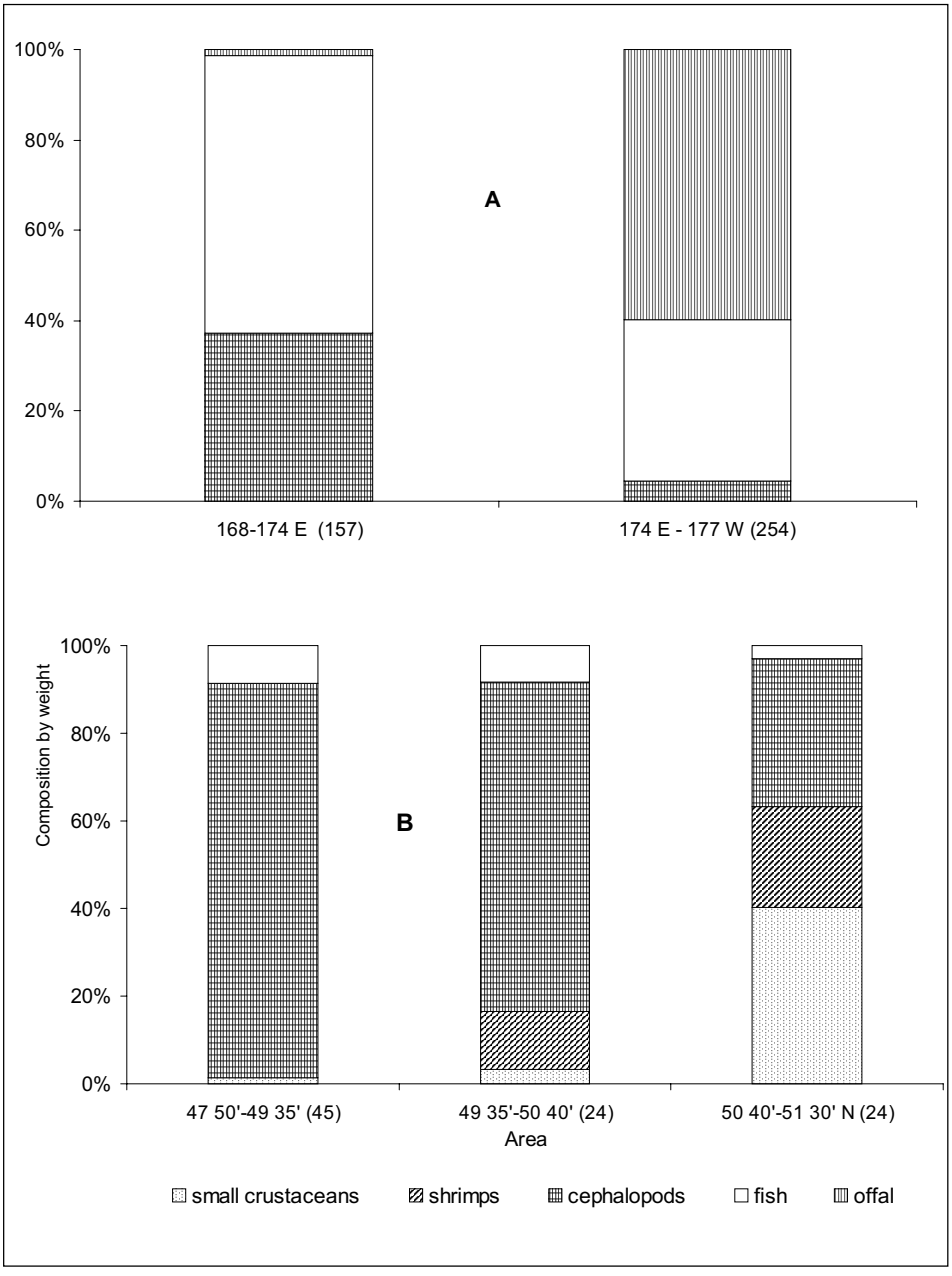

Fig. 6. Variations in the main food items of Pacific black halibut by sample area (sample size is shown in parentheses): A – western Bering Sea, B – northern Kuril Islands.

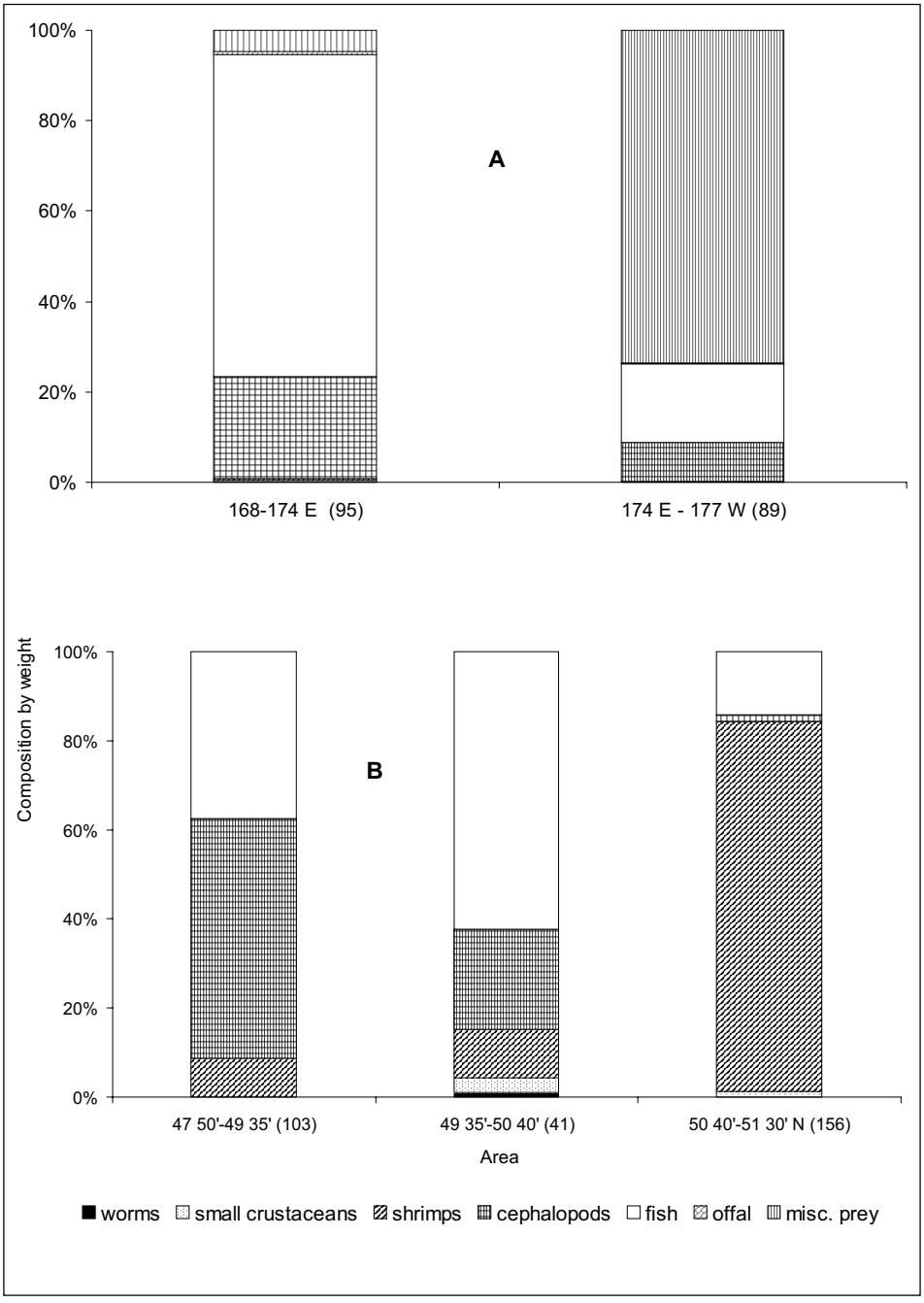

Fig. 7. Variations in the main food items of Kamchatka flounder by sample area (sample size is shown in parentheses): A – western Bering Sea, B – northern Kuril Islands.

DISCUSSION

Pacific black halibut and Kamchatka flounder are typical predatory species. In many areas of their range the adults prey mostly on fish, squids, and shrimps. The diet composition of the North Atlantic Greenland halibut *Reinhardtius hippoglossoides* consists of the same prey categories and is similar to that of the congeneric Pacific black halibut. Thus, in the waters of the Flemish Pass the diet of Greenland halibut consisted of fish (39%), cephalopods (32%), and decapod crustaceans (22%) (Rodriguez-Marin *et al.* 1995). On the deep slope of northeast Newfoundland this species consumes mostly squid *Gonatus* sp. (Dawe *et al*. 1998). According to the data of Pedersen and Riget (1992), in the waters of West Greenland its diet is composed mainly of redfish *Sebastes* sp. (17 to 48%) and northern shrimp *Pandalus borealis* (21 to 43%). The bulk of the diet of Greenland halibut in the Norwegian and Barents Seas consisted of capelin *Mallotus villosus*, polar cod *Boreogadus saida*, juvenile redfish and other small-sized fish species while northern shrimps and cephalopods were second and third in rank, respectively (Shvagzhidis 1990). Off of Iceland the main prey species of Greenland halibut were capelin, eelpout (Zoarcidae), and the shrimps *Hymenodora glacialis* and *Pandalus borealis* (Solmundsson 1993). According to data of Michalsen and Nedreaas (1998), the main food components of the species in the current study in the western Barents Sea are the boreoatlantic armhook squid *Gonatus fabricii* and herring *Clupea harengus*.

In the eastern Bering Sea Pacific black halibut consumed mostly walleye pollock (55.8-58.3%), squids (8.1-17.8%), and fishery discards (2.2-11.9%) (Lang *et al*. 1991; Lang, Livingston 1996). This composition differs very much from that off the Aleutian Islands (Yang 1996), where Pacific black halibut fed mostly on squids (46.2%) and mesopelagic fishes (41.8%). The comparison of the present data with that from other areas showed that the diet compositions of Pacific black halibut are rather similar in the western and eastern Bering Sea, and in the area off the Aleutians and the Kuril-Kamchatka area. There are two likely reasons for this similarity. On the one hand, the western and eastern Bering Sea and waters off the Aleutian and Kuril Islands and southeastern Kamchatka are geographically close. On the other hand, the bottom morphology in both pairs of areas is similar. Thus, the eastern and western Bering Sea are characterized by a wide shelf and smooth continental slope. Contrarily, the areas around the Aleutian and Kuril Islands have a narrow shelf and steep slope. Both of these might contribute to the similarity of the diet compositions of Pacific black halibut in various areas of the North Pacific Ocean.

There are limited data on the diet composition of Kamchatka flounder in the northeastern Pacific. Only the paper by Yang and Livingston (1986) showed that in the eastern Bering Sea this species fed mostly on walleye pollock (55.8-85.9%) and that other fishes are second in rank. Other important food components are shrimps (for fish smaller than 30 cm) and euphausiids (for fish larger than 30 cm). A comparison showed that the diet compositions of Kamchatka flounder in the western (according to the present study) and eastern Bering Sea (Yang and Livingston 1986) differed somewhat due to the lack of fishery discards in the diet of eastern Bering Sea fishes. This was probably associated with the absence of fishery activity in the study area during the summer of 1983.

Research indicates that from the 1930s to the 1960s walleye pollock composed the base of the Pacific black halibut diet in the western Bering Sea (Vernidub and Panin 1937, Gordeeva 1954, Novikov 1974). There was no fishery offal found in the diet because Russian walleye pollock fishery was not developed here in this period (Shuntov *et al*. 1993). In the NK area, according to previous studies based on frequency of occurrence (Novikov 1974; Orlov 1997, 1998, 1999, 2000), red squid was also the most important dietary component of this predator.

From the 1930s to the 1960s walleye pollock was the most important dietary component of Kamchatka flounder in the western Bering Sea (Vernidub 1938, Gordeeva 1954, Novikov 1974). There was no fishery offal detected in stomach contents during previous studies for the same reason as it was lacking in Pacific black halibut. According to previous studies based on frequency of occurrence (Novikov 1974, Orlov 1997, 1998, 1999, 2000), the most important dietary components of Kamchatka flounder in the NK area were also shrimps, fish, and cephalopods.

Size-dependent differences in the diets of both species considered in the western Bering Sea have never been described in detail. Shuntov (1966) showed that frequencies of occurrence of squids, fishes, and other invertebrates in the stomachs of four halibut size groups (< 20, 20-40, 40-60, and > 60 cm) differed significantly. Size-dependent dietary distinctions of the species considered in the current study from the Pacific waters off the northern Kuril Islands and southeastern Kamchatka were reported only in the paper by Orlov (1997). Although it was based on the frequency of occurrence of food components in stomachs, its results were similar to those of the present study.

No studies of depth-dependent changes in the diet of western Bering Sea halibut have been conducted previously. This type of research in the NK area has only been reported in a single paper (Orlov 1997) that was based on frequency of occurrence analysis, thus, the results differed from those of the present study.

Differences in diet composition between males and females in both study areas were related to distinct variations in their sizes. The males of both species in both areas considered were shorter than females: 63.53 vs. 74.14 cm and 53.80 vs. 55.73 cm for Pacific black halibut in WBS and NK, respectively; 52.30 vs. 56.59 cm and 40.87 vs. 42.88 cm for Kamchatka flounder, respectively. Sex-dependent distinctions between the male and female diets in the WBS area have never been reported previously. The prevalence of fishery offal in the diet of female Kamchatka flounder from WBS is related mostly to different sex ratio of species considered within various parts of study area. Thus, in the western part (168-174°E) bottom trawl catches were comprised mostly of females (77.5%), while in the eastern part of the area (174°E-177°W) males were caught more frequently (57.4%). Since a large number of processing vessels were located in the eastern part of WBS during the study period, females, which were most frequent in this area, fed mainly on fishery discards. Sex-dependent differences for both of the halibut species that inhabit the Pacific waters off the northern Kuril Islands and southeastern Kamchatka have been described in only one paper (Orlov 1997). As in this paper frequency of occurrence was used for stomach content analysis, the results of the previous and present studies are different.

Studies of area-dependent differences in western Bering Sea halibut diets were conducted only once (Gordeeva 1954). However, they were based on the examination of

a small number of stomachs. This type of investigation for the species from NK considered in the present work have never before been undertaken. The domination of fishery offal in both halibut diets in the eastern part of the WBS area is related to intensive, specialized walleye pollock fishery in this area by numerous Russian and foreign fishing vessels, which process the catch into filleted fish and discard the offal. Other predators, such as Pacific halibut *Hippoglossus stenolepis* (Moukhametov and Orlov 2004) and rougheye rockfish *Sebastes aleutianus* (Orlov 2002), have been observed feeding on fishery offal in the area considered in the present study. Differences in diet composition between the various parts of the NK study areas might be explained by essential distinctions in predator sizes (62.17, 55.24, and 39.42 cm for Pacific black halibut and 51.92, 40.32, and 35.87 cm for Kamchatka flounder in the southern, middle, and northern parts, respectively), by different sampling depths (301-500, 301-500, and 201-300 m for Pacific black halibut and 301-500, 101-400, and 201-300 m for Kamchatka flounder in the southern, middle and northern parts, respectively), and also by local faunistic distinctions.

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The "revival" of the twaite shad (*Alosa fallax,* Lacepede 1803) population in the Curonian Lagoon

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Abstract. Twaite shad became increasingly common in the Curonian Lagoon in the late 1990s. The lack of access to traditional spawning grounds meant that this species began reproducing in the estuary of the Nemen River and the shallow waters of the Curonian Lagoon. Due to the ban on twaite shad catches and landings, fishermen discard catches and they decompose contributing to an increase in pollution in the fishing grounds.

Key words: Curonian Lagoon, twaite shad

These days, it is rare for the declining trend of a fish population due to strong anthropogenic pressure to be arrested and for such populations to exhibit signs of renewal. A population of twaite shad (*Alosa fallax,* Lacepéde 1803), one of the clupeid species inhabiting the Curonian Lagoon, has found itself in just this situation.

Of the four species representing *Alosa sp.* genus that occur in the northwestern Atlantic, the Mediterranean, Black Sea, and the Caspian Sea, twaite shad is the most widely dispersed geographically. With the exception of the Caspian Sea, this species inhabits coastal waters; in the north it has been observed near Iceland and the southern coasts of Norway. These migratory fish are euryhaline and spend most of their lives in salty or brackish waters. They migrate to fresh waters only for spawning (Svetovidov 1952). These fish are very sensitive to water pollution. The main spawning grounds of the twaite shad population in the Baltic Sea were located in the Nemen River (Lithuania), which flows into the Curonian Lagoon (Švagždys 2000)

In the first half of the twentieth century, twaite shad was a commercially important species. Catches of it the Baltic Sea between 1910 and 1919 exceeded 2,000 tons (Svetovidov 1952). In 1935 and 1936 great concentrations of twaite shad comprised mostly of fish measuring up to 50 cm in length gathered at the inlet to the Curonian Lagoon. The lagoon inlet was too narrow for the huge numbers of entering fish and some of them died or were stranded on the sandy beaches of the lagoon. The fish that entered the lagoon swam to the Nemen River where they undertook a 400-kilometer migration upstream to spawn. In 1959 a dam was erected on the river to provide water to a hydroelectric power plant. This obstacle prevented fish from reaching their spawning grounds. At the same time, wastewa-

ter from industrial facilities began to pollute the river waters. In the 1950s and 1960s, all fish species inhabiting in the Curonian Lagoon were subjected to intensive fishing. All three of these factors contributed to the rapidly decreasing twaite shad population and catches, and by 1957 this species had disappeared from fisheries statistics. Single specimens of twaite shad were only registered in experimental catches (Gaigalas 2001).

In 1995 twaite shad was listed as an endangered species in the Lithuanian Red Book (Anon. 1995).

Following a nearly forty-year break in catches with gill-nets and eel fyke-net sets along the Lithuanian coast and in the Curonian Lagoon, twaite shad has once again been observed. The results of recent studies indicated that pollution has decreased substantially in the waters of both the Nemen and the Curonian Lagoon (Olenin 2002).

These fish have proven to be a very flexible species that reacts swiftly to changes in environmental conditions. Evidence of this is the fact that the fish found new spawning grounds situated near the mouth of the Nemen and in the shallow waters (1.5- 2 m) of the Curionian Lagoon (Švagždys 2000).

In 1992, twaite shad were first observed in catches made in the Curonian Lagoon. In recent years the largest catches were registered in 2000 and 2002 at 440 kg and 516 kg, respectively. Gaigalas (2001), who is involved in studies of the protection of twaite shad resources, estimated that over the 1997-1998 period fishermen caught several tons of twaite shad a year in the Curonian Lagoon. However, since this species is still under full legal protection (Anon. 1995), fishermen do not register landings, so there is a lack of sound information regarding the actual twaite shad abundance in Lithuanian waters.

The increase of twaite shad resources is accompanied by a variety of issues that must be studied in order to make the appropriate decisions regarding the legal status of this fish species. This includes the availability of this species to the fisheries in the Curonian Lagoon.

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FORMA MASZYNOPISU

Prace należy składać w 2 egzemplarzach maszynopisu pisanego jednostronnie, formatu A4, z podwójnym odstepem (konieczna jest dyskietka z całością materiału). Słowa, które powinny być złożone drukiem pochyłym (kursywą), tzn. łacińskie nazwy gatunków i rodzajów oraz symbole wielkości zmiennych należy podkreślić wężykiem (~~~~~). Innych podkreśleń nie należy stosować.

W pracach kategorii 1 i 2 obowiązuje następująca kolejność:

1. Tytuł: krótki (do 100 znaków).

2. Imię i nazwisko autora oraz **nazwa i adres instytucji macierzystej.**

3. Abstrakt musi poprzedzać każdy artykuł naukowy i notę; objętość – najwyżej 1 strona maszynopisu.

4. Słowa kluczowe: kilka pojęć pozwalających na odszukanie danej pracy w systemach komputerowych.

5. Tekst. Objętość maszynopisu prac kategorii 1 nie powinna przekraczać 40 stron, a kategorii 2 – 15 stron. W pracach kategorii 1 i 2 stosuje się tradycyjny podział: 1) wstęp, 2) materiał i metoda badań, 3) wyniki badań, 4) dyskusja, 5) bibliografia. Wyniki pomiarów należy podawać w jednostkach miar przyjętych w systemie metrycznym, a ich skróty – zgodnie z Międzynarodowym Układem Jednostek Miar (SI).

6. Podziękowania należy ograniczyć do niezbędnego minimum (inicjały imienia i nazwisko osoby, do której są adresowane, bez wymieniania tytułów naukowych i nazw instytucji).

7. Bibliografię należy zestawiać w porządku alfabetycznym, podając bezpośrednio po nazwiskach autorów rok wydania i wymieniając tylko prace cytowane w tekście (np. Kowalski 1990). Tytuły czasopism – w pełnym brzmieniu. Tytuły prac – w językach oryginału (z wyjątkiem tytułów w języku rosyjskim wydrukowanych alfabetem niełacińskim, np. cyrylicą, które należy przetłumaczyć na język polski lub angielski).

8. Przypisy oznacza się cyfrą arabską we frakcji górnej (...[1]) i numeruje kolejno w całym tekście, z wyjątkiem tabel; treść przypisów – na osobnych stronach.

9. Tabele są dodatkowym źródłem informacji; nie należy powtarzać w nich danych występujących w tekście lub na rysunkach. Tabele numerowane, każda na osobnej stronie, muszą mieć tytuł; powołanie na nie należy umieścić w tekście. Każdą kolumnę w tabeli opatruje się tzw. „główką" wyjaśniającą zawartość kolumny. Przypisy w tabelach należy oznaczyć literami, kursywą, we frakcji górnej (np. Lata[a]), a ich objaśnienie umieścić pod tabelą.

10. Ilustracje. Obowiązuje kolejna numeracja z przywołaniem każdego numeru w tekście. Podpisy pod ilustracjami – na osobnej kartce. Stosowane na rysunkach skróty, terminy i symbole muszą odpowiadać użytym w tekście. Każdy rysunek, umieszczony na osobnej kartce oraz opisany kolejnym numerem i nazwiskiem autora, po wyskalowaniu musi zmieścić sie w kolumnie; trzeba to uwzględnić stosując odpowiednią grubość linii i wielkość opisów na rysunkach. Redakcja przyjmuje wyłącznie rysunki wykonane techniką komputerową (konieczny wydruk i dyskietka). Prace można ilustrować fotografiami (mogą być kolorowe). Łączna objętość rysunków i zdjęć nie może przekraczać 30% objętości pracy.

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Plik powinien być zachowany na dyskietce w takim formacie, aby umożliwić odczytanie go w programach przez nas stosowanych. Preferowanym formatem jest Word for Windows. Rysunki wykonane techniką komputerową prosimy zapisywać na dyskietce w formacie wykonania.

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Na wykonanie i odesłanie korekty autorskiej przewiduje się termin 10-dniowy. Na tym etapie nie należy dokonywać zmian autorskich w tekście, a jedynie poprawić usterki techniczne.

EGZEMPLARZE AUTORSKIE

Każdy autor opublikowanego artykułu otrzymuje 1 egzemplarz czasopisma, autorzy prac kategorii 1 otrzymują ponadto 10 nadbitek swej pracy; kategorii 2 – 5 nadbitek.

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