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BULLETIN OF THE SEA FISHERIES INSTITUTE
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Carotenoids in fillets of spiny dogfish shark – *Squalus acanthias* L. (Chondrichthyes: Squalidae)

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Abstract. Using column and thin-layer chromatography, carotenoid content was examined in the skin and muscles of spiny dogfish (*Squalus acanthias*) individuals. Twelve carotenoids were found, with a predominance of canthaxanthin and astaxanthin. The total carotenoid content in the fillets examined ranged from 0.42 (muscles) to 5.72 $\mu g \cdot g^{-1}$ wet mass (skin).

Key words: shark, *Squalus acanthias*, spiny dogfish, carotenoids

INTRODUCTION

Apart from the many teleostean fish species which inhabit the seas and oceans, elasmosbranches, including sharks, also occur in substantial numbers. The meat of most sharks cannot be used for human consumption as it contains urea accumulated in the tissues as ammonia metabolite. Therefore, very few species are caught for consumption. One such species is spiny dogfish (*Squalus acanthias*) (Nikolski 1970) which, generally, is one of the most common sharks (Załachowski 1997, Barnes and Hughes 1999) and its meat is tasty. Moreover, its tissues provide oil, meal for feed and its skin is used in haberdashery – all of which make this species economically valuable. Catches of this shark mainly in Norway, Great Britain, Denmark, China, Japan and the USA total several thousand tons annually. It is found in both hemispheres and in all seas except those in polar and tropical regions. It usually lives in larger pods mostly near the sea bottom and feeds on demersal fish, squid or larger crustaceans (Rutkowicz 1982).

For many years the authors have studied the carotenoid content in different economically valuable sea fish species (see Czeczuga *et al.* 1999); this paper focuses on spiny dogfish (*Squalus acanthias*), a shark representative which is caught for human consumption.

MATERIALS AND METHODS

The fillets of three specimens of *Squalus acanthias* L. (syn.: *Spinax acanthias, Acanthias acanthias*) used for analysis came from Mediterranean Sea catches made in August 1996. The skin and the muscles were studied separately. On the day the specimens were caught, weighed

portions of the skin and the muscles were placed in dark containers, immersed in acetone, and then sent via air to the department's laboratory and were analysed the following week.

The carotenoid pigments were isolated using column and thin-layer chromatography. Prior to chromatography, the material was homogenized and then subjected to hydrolysis in a 10% KOH solution in a nitrogen atmosphere and at room temperature for 24 hours. The extract was then placed on the column of Quickfit Co. filled with Al_2O_3. The particular fractions were eluted using various solvent systems (Czeczuga 1980a). The eluent was evaporated and the remainder was dissolved in a suitable solvent to draw the maximum of absorption, which was necessary, among other things, to identify a particular carotenoid.

Irrespective of column chromatography, the carotenoids of the acetone extract were fractionated using thin-layer chromatography. Silicon gel-covered glass plates (Merck Co.) and various solvent systems (Czeczuga 1980a) were used. The R_f values were established according to commonly accepted criteria (Czeczuga and Czerpak 1976).

Carotenoids were identified based on the absorption maximum in different solvents, R_f values were identified according to the standards of F. Hoffman-La Roche Co., Basle and Sigma Chemical Co., USA and the ratios which were obtained for epiphase to hypophase. In order to distinguish tunaxanthin from lutein, spectral analysis was used to determine the presence of hydroxyl and epoxide groups at the iononic rings (end group) of these carotenoids (Wetter *et al.* 1971). The absorption maxima were determined with a Spektromom-203 spectrophotometer and Specol.

Quantitative ratios of the respective carotenoids were estimated according to the Davies method (Czeczuga 1988b), and the structure of carotenoids according to Straub (1987).

RESULTS

Twelve carotenoids were found in the material examined (Table 1 and Figure 1). The presence of deepoxyneoxanthin, idoxanthin and a relatively large number of ketocarotenoids in the skin

Table 1. List of carotenoids from *Squalus acanthias* L.

Carotenoids	Summary formula	Structure (see Fig. 1)	Semisystematic name
β-Carotene	$C_{40}H_{56}$	A - R - A	β,β-Carotene
β-Cryptoxanthin	$C_{40}H_{56}O$	A - R - C	β,β-Caroten-3-ol
Neothxanthin	$C_{40}H_{56}O$	B - R - D	ε,ε-Caroten-3-ol
Tunaxanthin	$C_{40}H_{56}O_2$	D - R - D	ε,ε-Carotene-3,3'-diol
Lutein epoxide	$C_{40}H_{56}O_3$	D - R - E	5,6-Epoxy-5,6-dihydroxy-ε,β-carotene-3,3'-diol
Deepoxyneoxanthin	$C_{40}H_{56}O_3$	C - R_1 - F	6,7-Didehydro-5,6-dihydro-β,β-carotene-3,5,3'-triol
Adonixanthin	$C_{40}H_{54}O_3$	C - R - G	3,3'-Dihydroxy-β,β-caroten-4-one
Papilioerythrin	$C_{40}H_{54}O_3$	D - R - G	3,3'-Dihydroxy-β,ε-caroten-4-one
Idoxanthin	$C_{40}H_{54}O_4$	G - R - H	3,3',4'-Trihydroxy-β,β-caroten-4-one
Canthaxanthin	$C_{40}H_{52}O_2$	I - R - I	β,β-Carotene-4,4'-dione
Phoenicoxanthin	$C_{40}H_{52}O_3$	G - R - I	3-Hydroxy-β,β-caroten-4,4'-dione
Astaxanthin	$C_{40}H_{52}O_4$	G - R - G	3,3'-Dihydroxy-β,β-carotene-4,4'-dione

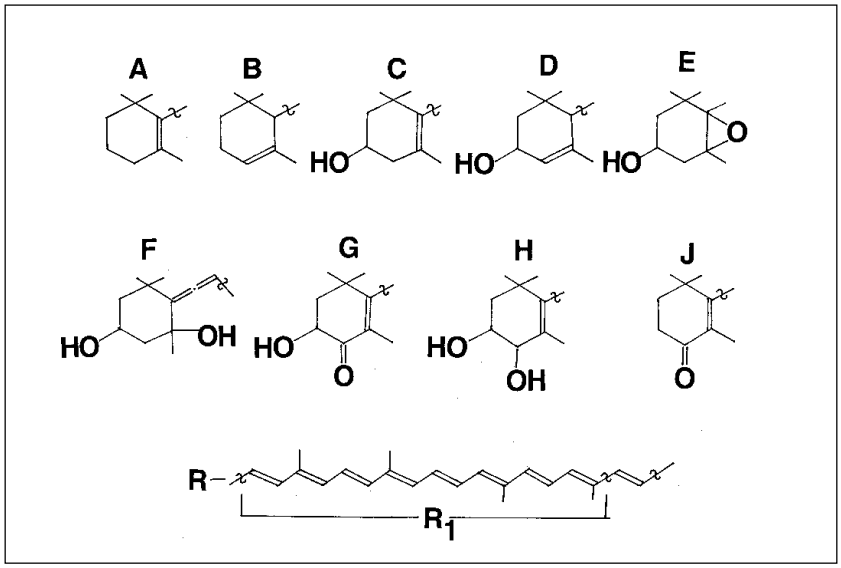

Fig. 1. Structural features of carotenoids from investigated materials

and muscles was noteworthy. Ketocarotenoids included adonixanthin, papilioerythrin, idoxanthin, canthaxanthin and astaxanthin, all of which, with the exception of papilioerythrin, lay on the β-carotene-into-astaxanthin transformation path. In comparison to the muscles, the skin showed a ten-fold higher carotenoid content. In the skin and muscles vitamin A provitamin carotenoids constituted approximately 10% and 15% of the total carotenoid content (Table 2).

Table 2. Carotenoid content in *Squalus acanthias* L. (n = 9)

Carotenoid	Skin (%)	Muscles (%)
β-Carotene	5.8(4.6 - 7.0)	9.6(5.3 - 10.4)
β-Cryptoxanthin	9.0(3.9 - 21.6)	14.6(12.6 - 14.9)
Neothxanthin	10.8(10.5 -11.2)	6.8(4.1 - 18.0)
Tunaxanthin	13.8(7.7 - 27.5)	3.4(2.9 - 15.6)
Lutein epoxide		3.5(2.5 - 13.2)
Deepoxyneoxanthin	7.4(5.4 - 8.2)	5.5(5.1 - 14.0)
Adonixanthin	2.1(0.8 - 4.2)	0.8(0.5 - 1.7)
Papilioerythrin	3.8(2.2 - 4.8)	1.7(1.2 - 4.5)
Idoxanthin	3.1(3.0 - 3.5)	2.8(2.4 - 3.0)
Canthaxanthin	17.2(9.6 - 28.9)	30.5(27.4 - 45.2)
Phoenicoxanthin	5.2(2.4 - 8.6)	2.3(1.8 - 3.4)
Astaxanthin	21.8(19.5 - 29.2)	18.5(14.8 - 25.9)
Total content in $\mu g \cdot g^{-1}$ wet weigh	5.485(4.884 - 5.720)	0.496(0.424 - 0.548)
Ketocarotenoids in %	53.2(42.3 - 57.8)	58.6(44.5 - 67.8)
Provitamin of vitamin A in $\mu g \cdot g^{-1}$ wet weight	0.568(0.442 - 0.628	0.084(0.064 - 0.092)
Provitamin of vitamin A in %	10.3(9.0 - 10.8)	16.9(14.2 - 18.8)

DISCUSSION

According to Hirao (1967), zeaxanthin (anchovyxanthin) is the predominant caroteid among representatives of Chondrichthyes. Astaxanthin occurs in smaller amounts. Carotenoids found in spiny dogfish skin and muscles are derivatives of α-carotene, β-carotene and ε-carotene. Lutein epoxide and papilioerythrin are α-carotene derivatives and neothxanthin and tunaxanthin are ε-carotene derivatives. The remaining xanthophills are produced via β-carotene transformations. Most β-carotene derivatives, α-carotene (Czeczuga 1981b) and ε-carotene (Bingham *et al.* 1979), are common fish carotenoids except for deepoxyneoxanthin and idoxanthin. Deepoxyneoxanthin is known as (Straub 1987) a derivative of neoxanthin, a carotenoid commonly encountered in the green parts of plants (Goodwin 1980). Deepoxyneoxanthin is derived from neoxanthin through the loss of one oxygen atom. It was first isolated from green mastigophoran *Euglena gracilis* cells by Nitsche (1974). Its presence was established only in a few fish species, e.g. in *Oncorhynchus mykiss* trout (Schiedt *et al.* 1985, Torrissen *et al*. 1989, Czeczuga and Czeczuga-Semeniuk 1998) and in the fillets of blue shark *Prionace glauca* from the fishing grounds of New Zealand (Czeczuga *et al.* 1999). It is also noteworthy that deepoxyneoxanthin was found in river lamprey (*Lampetra fluviatilis*) individuals caught during the autumn spawning migration in the Łupawa River in Pomerania and in the spring migration in the Vistula Lagoon (Czeczuga and Bartel 1998b).

Idoxanthin originates from adonixanthin by the attachment of a hydroxy group at the 4' iononic ring. It was first isolated by Herring (1969) in sea crustaceans (*Idothea metallica*), which lead a benthic mode of life. In fresh-water and sea fishes it has been encountered sporadically. In fresh-water fishes, it was first found in the muscles of carp (*Cyprinus carpio*) (Nagata and Matsuno 1979). Then, Czeczuga (1981a) detected it in the muscles of *Micropterus salmoides,* later in Danube salmo (*Hucho hucho*) (Czeczuga *et al.* 1986) and in rapfen (*Aspius aspius*) specimens (Czeczuga 1988a). Moreover, idoxanthin was found in the muscles of white bream (*Blica bjoerkna*) individuals collected in the Szczecin Lagoon (Czeczuga and Kłyszejko 1996). In sea fish, this carotenoid was encountered in the gonads of red sea bream (*Pagrus major*) and in three other sea fishes by Miki *et al*. (1982, 1984); Czeczuga and Chełkowski (1984) found it in the eggs of *Salmo trutta* m. *trutta* during its reproductive period. Additionally, idoxanthin was isolated from lamprey. Matsuno and Nagata (1979) found it in Arctic lamprey (*Lampetra japonica*), while Czeczuga and Bartel (1998b) did so in river lamprey (*Lampetra fluviatilis*) during their spawning migration from the Baltic Sea to rivers.

The main group of carotenoids found both in spiny dogfish skin and muscles contains ketocarotenoids which are β-carotene derivatives. The biosynthesis of carotenoids occurs exclusively in plant organisms; animals ingest them only with food. Carotenoids can be deposited in respective parts of the animal's body and some are transformed into other xanthophills. Not all of them can be evenly retained in fish bodies (Choubert 1979, Kamata *et al.* 1990) and this depends on carotenoid type (Hata and Hata 1976). In salmonids, the largest amounts of canthaxanthin and astaxanthin are retained in the muscles and skin (Torrissen *et al.* 1989) depending on age (Arai *et al.* 1987, Vershinin and Lukyanova 1993) and physiological condition (Hata and Hata 1975). Moreover, different carotenoids are retained in different organs, e.g. in *Salmo gairdneri irideus* β-carotene is found mainly in the walls of the alimentary canal, while zeaxanthin is located in the skin (Hata and Hata 1973). In red carp (*Cyprinus carpio*) and sea bream (*Chrysophrys major*), β-carotene absorbed from food is not converted into astaxanthin (Katayama *et al.* 1972a, 1972b) and accumulates mainly in the intestines.

The food of spiny dogfish includes benthic organisms, with a predominance of crustaceans, molluscs and fish (Nikolski 1970, Rutkowicz 1982, Barnes and Hughes 1999). In studies of carotenoids, different sea crustacean species from various latitudes (Czeczuga 1973b, 1974a,b, 1975, 1978, Czeczuga and Czerpak 1969, 1970, Czeczuga and Kłyszejko 1976), molluscs, including cephalopods, (Czeczuga 1976, 1980b, 1984) and fishes (Czeczuga *et al*. 1999) contained the largest amounts of the β-carotene derivatives canthaxanthin and astaxanthin. Thus, it can be assumed that spiny dogfish ketocarotenoids are of a food origin. Also, the ketocarotenoids in blue shark (*Prionace glauca*) fillets constituted over half of all the carotenoids found (Czeczuga *et al.* 1999). Ketocarotenoids appeared predominantly in two species of Chondrichthyes representatives of the genus *Raja.* Astaxanthin was most abundant in *Raja georgiana* individuals (Czeczuga and Kłyszejko 1978) while phoenicoxanthin predominated in *Raja nasuta* (Czeczuga *et al.* 1999).

The total carotenoid content found in spiny dogfish fillets should be considered to fall in the mean range, compared to the data for other Chondrichthyes representatives. The lowest values were found in ray (*Raja georgiana*) from the Antarctic – 0.122 (Czeczuga and Kłyszejko 1978), the highest was in blue shark (*Prionace glauca*) fillets from the fishing grounds of New Zealand – 0.862 $\mu g \cdot g^{-1}$ of wet mass (Czeczuga *et al.* 1999). The total carotenoid content in respective body parts changes within the year, particularly before the reproduction period. This refers not only to salmonid fish species (Crozier 1970, Czeczuga and Chełkowski 1984) but also to cyprinids (Czeczuga and Bartel 1998a) and river lamprey (*Lampetra fluviatilis*) (Czeczuga and Bartel 1998b). Carotenoids in fish combine with lipoproteins and in this form are transported by blood plasma (Ando and Hatano 1986).

Not all carotenoids are vitamin A precursors. Only those which have at least one free iononic ring are subject to transformation (Bauerbfeind 1972, Simpson *et al*. 1981). Among the carotenoids found in spiny dogfish fillets only β-carotene and β-cryptoxanthin are vitamin A provitamins. Two vitamin A molecules originate from β-carotene, one from β-cryptoxanthin. β-Carotene has two free iononic rings, while β-cryptoxanthin has only one. In the present study, the muscles of spiny dogfish appeared to be much less abundant in provitamin A than the skin was. In fresh-water fishes, the major transformations of precursors into vitamin A occur in the liver (Barua and Singh 1972, Hata *et al.* 1973). Thus, it should be assumed that the spiny dogfish liver, as a source of oil, has a substantially higher content of vitamin A precursors. As revealed in many studies, both phytophagous and predacious fresh-water and sea fish species contain variable amounts of carotenoids – vitamin A precursors (Czeczuga 1972, 1973a), depending on the food absorbed (Steffens and Karst 1972, Czeczuga and Czerpak 1976). Moreover, in fresh-water fish species such as *Lebistus reticulatus* and *Xiphophorus variatus*, canthaxanthin and astaxanthin can also be converted into vitamin A (Gross and Budowski 1966); this also takes place in adult individuals of rainbow trout (Guillou *et al.* 1989). This is likely to occur, as shown in certain salmonid species, when canthaxanthin and astaxanthin which have been ingested with food are reduced to the less oxygenated xanthophills, such as adonixanthin or zeaxanthin, and even to β-carotene (Kitahara 1983, Schiedt *et al.* 1985, Ando 1986), which is then converted into vitamin A.

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The comparison of Baltic herring and sprat age-length keys derived from Polish commercial and research data

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Abstract. In this paper, the age-length keys (ALK) of herring and sprat sampled from Polish commercial and research catches in 1995 and 1996 are compared with respect to time (quarters 1-4), catch location (Subdivision 24, 25, and 26) and fishing gear type (trawl, gillnet, research). Two methods have been applied to determine similar ALKs: cluster analysis and the χ^2 test.

The herring ALKs from Subdivision 25 and 26 do not differ significantly. They differ, however, from the ALKs collected in Subdivision 24. The ALKs from the first half of the year differ significantly from the ALKs from the third quarter. The comparison of herring ALKs with respect to gear is inconclusive: two out of four comparisons of trawl and gillnet ALKs show significant differences. There is no significant difference in the sprat ALKs from the first three quarters. On the other hand, the ALKs from the third and fourth quarters differ significantly. The comparison of ALKs with respect to subdivision is inconclusive: two out of four comparisons of ALKs from Subdivision 25 with ALKs from Subdivision 26 show significant differences.

The results of analyses show which ALKs can be used interchangeably, which may be helpful in both filling in the gaps in sampling for age and planning the sampling method.

Conclusions based on cluster analysis were confirmed by statistical tests; the distance between ALKs compared with cluster analysis and the probability from statistical tests showed a negative correlation.

Key words: age-length key, comparison, Baltic, herring, sprat

INTRODUCTION

The age structure of catches is one of the basic units of information used to describe the dynamics of fish populations. It constitutes the input of so-called age-structured stock assessment models, widely used to assess the present state of stocks and their past dynamics. Examples of such models include virtual population analysis (VPA), (Gulland, 1965), cohort analysis (Pope, 1972), separable VPA (Pope and Shepherd, 1982), catch at age analysis (Deriso *et al*., 1985) or multispecies virtual population analysis (Helgason and Gislason, 1979).

The age structure of catches is estimated using fish samples from which otoliths or scales are collected in order to determine fish age. Otolith or scale sampling and determining age from them are time consuming activities. In order to achieve a relatively accurate estimation of the age composition of the catches based only on age a rather high sample size would be required. To lower sample numbers, calculations are carried out using the so-called age-length

key (ALK) which was first introduced by Fridrikson (1934, after Kimura, 1977). This approach, which investigates both age and length composition, is thought to be less time consuming and length distribution can be determined even by inexperienced personnel. Once the length distribution of the catches is established, the numbers in each length class can be divided into particular age group numbers using the age-length key derived from the samples used for age determination. The contributions of each age to particular length classes are then summarized which yields the contribution of particular age groups to the catches. Although the utility of the ALKs has been questioned to some extent and it depends on the purpose for which the data are collected (e.g. Kimura, 1977; Gudmundsdottir *et al*., 1988), they are still widely used to assess the age structure of catches.

The intensity of sampling for age differs between areas, time periods, and fisheries and usually results in gaps which must be filled in. Therefore, it is tempting to investigate whether some ALKs could be used interchangeably (e.g. ALKs sampled in the first quarter and those sampled in the second quarter or ALKs sampled in neighboring subdivisions). Similar ALKs could also be pooled to produce a more precise overall ALK. Haynes (1993) used Fisher's exact test to compare the ALKs of Georges Bank haddock. Next, Horbowy (1998) used cluster analysis, the χ^2 test and Fisher's exact test to analyze the ALKs of Baltic cod. The author compared the results of the χ^2 test and Fisher's exact test to determine if both tests can produce similar results when sample size is large. This is important, as the χ^2 test is much simpler to perform than Fisher's exact test.

DATA AND METHODS

The ALKs sampled from Polish herring and sprat catches in 1995 and 1996 were analysed. The ALKs were presented in 1 cm length-classes comprising ages 0-9, and stratified by subdivision (24, 25, 26), quarter (1-4), year (1995, 1996), and gear (trawl, gillnet, research). In total, 24 ALKs were available for herring and 15 for sprat.

First, cluster analysis was used to select similar ALKs. The settings for cluster analysis were as follows:

– Euclidean distance,
– furthest neighbor method,
– untransformed data.

The furthest neighbor method was used because in this method groups are merged into clusters, so that the most distant members of the group are close enough together. Then, when using ALKs within the analysed cluster interchangeably, the highest error may be easily determined from the distance between groups forming the cluster. Before clusterization, ALKs were presented as age distribution at lengths in promilles. In many ALKs the ranges of length sampled only partly overlapped. Such ALKs could not be directly compared. Thus, in order to agglomerate the set of ALKs from 1995 or 1996 into clusters, such a range of length was selected for which age samples were present in all ALKs in a set. In addition, it was arbitrarily assumed that at least four observations in a length-class should be present so as to include the length in the analysis. In this way five length-classes (comprising fish from 21 cm to 25 cm) were common in herring ALKs from 1995, and five length-classes (fish from 22 cm to 26 cm) in herring ALKs from 1996. For sprat, the common length-classes comprised fish from 7 cm to

15 cm in the 1995 ALKs, and fish from 9 cm to 14 cm in ALKs from 1996. Finally, each selected ALK, confined to length-classes within a common range, was reshaped into a vector and clusterization was performed.

The ALKs are referred to by indicating the subdivision (24, 25, 26), quarter (1, 2, 3, 4), year (95, 96) and gear (T – trawl, G – gillnet, R – research); e.g., P 26 2 95 T denotes an ALK sampled from the catch performed with a trawl in Subdivision 26 in the second quarter of 1995 (P stands for Poland).

Next, certain specific hypotheses were formulated and tested using the χ^2 test. The hypotheses were as follows:

1. The ALKs obtained in the same quarter and subdivision but with different gear are not significantly different.

2. The ALKs obtained in the same subdivision and with the same fishing gear but in different quarters are not significantly different.

3. The ALKs obtained in the same quarter and with the same fishing gear but in different subdivisions are not significantly different.

In order to statistically compare two ALKs, length-classes which occurred in both ALKs and consisted of at least six age records were selected first. This is in accordance with Bennet and Hsu (1960) who found that at least six observations are needed to have reasonable power of the test. The length-classes were compared separately. It can occur that some lengths show statistically significant differences while others do not. The final evaluation of the significance of the differences between ALKs was based on the proportion of significant lengths in ALKs and the test statistic values for non-significant lengths. Generally, it was accepted that ALKs in which about 40% of the lengths-classes differed significantly were considered to be significantly different. The ALKs with a smaller number of length-classes with significant differences can also be evaluated as significantly different if the test statistic values for other lengths have a small probability of occurrence (say about 0.1).

For the statistical comparison of age distributions at a given length, the χ^2 test was used:

$$\chi^2 = \sum_j (E_{ij}^{obs.} - E_{ij}^{exp.})^2 / E_{ij}^{exp.}, \qquad [1]$$

$$E_{ij}^{exp.} = n_{i.}\, n_{.j}/n,$$

where:

$E_{ij}^{obs.}$ – observed number of fish at age j at given length of ALK i,
$E_{ij}^{exp.}$ – expected number of fish at age j at given length of ALK i,
$n_{i.}$ – number of fish at given length in ALK i,
$n_{.j}$ – number of fish at age j at given length in both ALKs compared,
n – total number of fish sampled at given length in both ALKs compared.

RESULTS

Cluster analysis

The dendrograms of herring and sprat ALKs obtained from the 1995 and 1996 data are presented in Figures 1 and 2.

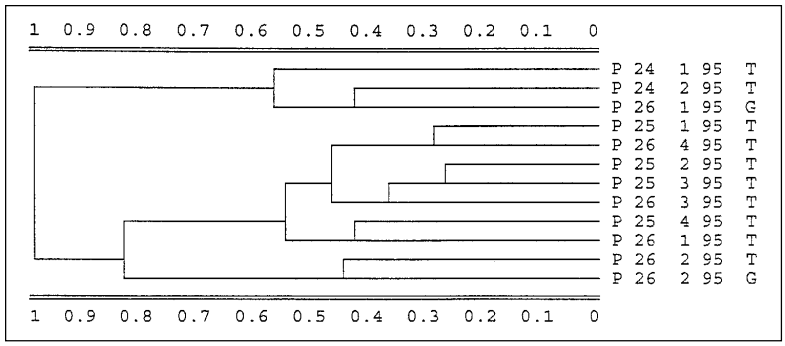

Fig. 1a. Dendrogram obtained from cluster analysis of herring age-length keys sampled in 1995

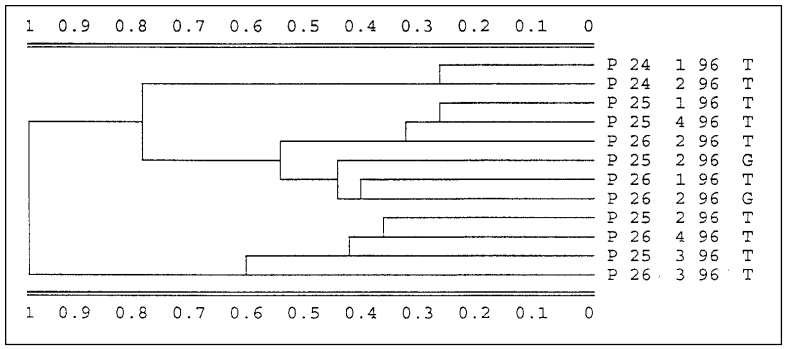

Fig. 1b. Dendrogram obtained from cluster analysis of herring age-length keys sampled in 1996

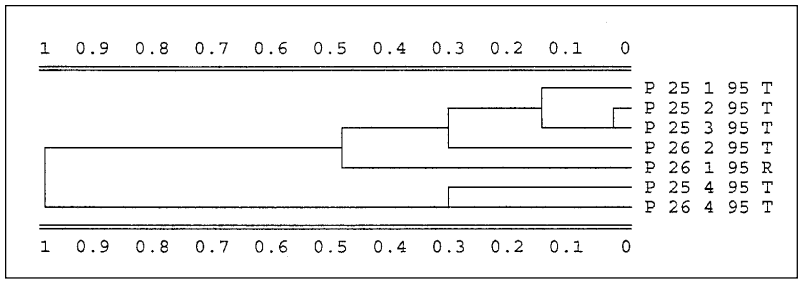

Fig. 2a. Dendrogram obtained from cluster analysis of sprat age-length keys sampled in 1995

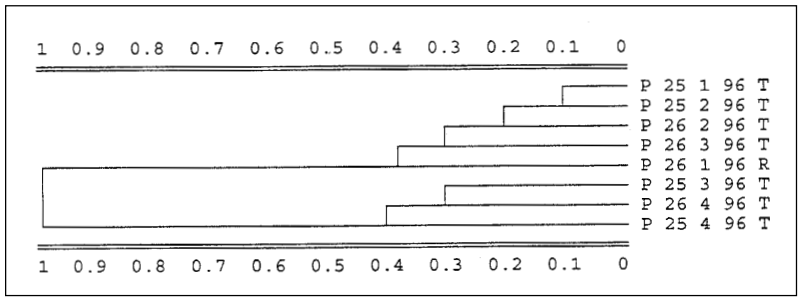

Fig. 2b. Dendrogram obtained from cluster analysis of sprat age-length keys sampled in 1996

Table 1. The maximum and the minimum distance between ALKs (in ‰) in cluster analysis (CA) and maximum and minimum distance per non-zero cell for herring and sprat

Cluster	Maximum distance	Minimum distance	Length classes used in CA	Maximum distance per non-zero cell	Minimum distance per non-zero cell
Herring 1995	1,514	440	21-25	347.3	100.9
Herring 1996	1,688	487	22-26	387.3	111.7
Sprat 1995	3,025	142	7-15	582.2	27.3
Sprat 1996	1,548	199	9-14	364.9	46.9

In both years herring ALKs from Subdivision 25 and 26 are mixed, suggesting no subdivision effect within these subdivisions. The ALKs from Subdivision 24, however, are similar and they differ significantly from all ALKs from Subdivisions 25 and 26 with the exception of the ALK P 26 1 95 G.

The time effect is relatively well demonstrated in the herring ALKs. Generally, the ALKs from the first and second half of the year belong to different clusters. The comparison of ALKs with respect to gear is inconclusive: some trawl and gillnet ALKs are similar (e.g. P 26 2 95 T and P 26 2 95 G, P 26 2 96 G and P 26 2 96 T) and some are not.

In the case of sprat, the subdivision effect is not clearly seen, but the data comprise only Subdivisions 25 and 26. In the 1995 dendrogram the ALKs P 25 1 95 T, P 25 2 95 T, and P 25 3 95 T form separate clusters, but the ALKs from the fourth quarter of the year from Subdivision 25 and 26 also form a cluster. The ALKs from Subdivision 25 and 26 are rather mixed in the 1996 dendrogram.

As with herring, the time effect is relatively wel -demonstrated in the sprat ALKs. The ALKs are approximately separated into data from the first three quarters and that from the fourth quarter. The exception is one ALK from the third quarter (P 25 3 96 T), which belongs to the cluster formed by the ALKs from the fourth quarter.

There are too few data to draw any conclusions regarding the effect of fishing gear, because in each year only one ALK refers to a research vessel while the others were collected by trawl fishery.

Table 1 presents the minimum and maximum distances from cluster analysis and minimum and maximum distances per non-zero cell. The maximum (minimum) distances per non-zero cell are calculated as maximum (minimum) distances divided by the square root of the mean number of non-zero elements in the ALKs. The mean number of non-zero elements in the ALKs equals about 38% of the total cell numbers for herring and 30% of the total cell numbers for sprat. The values in the table may be helpful in estimating the absolute difference between selected ALKs. This information is missing from the dendrograms (Figures 1 and 2) in which distances are presented as relative magnitudes. The minimum mean difference between percentages of the ages at length in two ALKs are at a level of 10% for herring and from 3% to 5% for sprat. The values for herring are relatively high while the sprat values are low. The maximum distances per non-zero cell are very large ranging from 35% to 39% for herring and from 36% to 58% for sprat. The analysis shows that some ALKs are very different.

Statistical tests

The results of the statistical tests are presented in Tables 2 and 3. The herring ALKs from the first and the second quarters do not show significant differences. However, the ALKs from the second and the third quarters differ very significantly. In two out of four comparisons the trawl

Table 2. Herring. Comparison of ALKs with respect to sampling time (quarters), sampling place (subdivisions) and sampling gear (NS – not significant, S – significant)

Gear

Comparison	Number of length classes compared	significantly different at 5%	significantly different at 1%	Final evaluation
P 26 1 95 T P 26 1 95 G	7	1	3	S
P 25 2 96 T P 25 2 96 G	9	4	4	S
P 26 2 95 T P 26 2 95 G	5	0	0	NS
P 26 2 96 T P 26 2 96 G	6	0	0	NS

Subdivision

Comparison	Number of length classes compared	significantly different at 5%	significantly different at 1%	Final evaluation
P 24 1 95 T P 25 1 95 T	7	2	0	S
P 24 1 96 T P 25 1 96 T	8	3	5	S
P 25 4 95 T P 26 4 95 T	13	2	0	NS
P 25 2 96 T P 26 2 96 T	15	3	0	NS
P 25 3 96 T P 26 3 96 T	12	2	2	?

Quarters

Comparison	Number of length classes compared	significantly different at 5%	significantly different at 1%	Final evaluation
P 24 1 95 T P 24 2 95 T	10	0	1	NS
P 26 1 95 T P 26 2 95 T	12	1	0	NS
P 24 1 96 T P 24 2 96 T	6	0	0	NS
P 26 2 95 T P 26 3 95 T	12	0	8	S

and gillnet ALKs are significantly different. The ALKs from Subdivisions 25 and 26 do not show significant differences. On the other hand, the ALKs from Subdivision 24 and 25 are significantly different. This result is in agreement with the stock differentiation of Baltic herring used for assessment purposes. The herring from Subdivisions 22-24 are assumed to belong to one stock, while the herring from Subdivisions 25-29S belong to another stock (Anon., 1997).

No significant differences between the sprat ALKs from the first and the second quarters or between ALKs from the second and the third quarters were discovered. The ALKs differ significantly between the third and the fourth quarters. It is difficult to make a judgement regarding the subdivision effect: two comparisons of Subdivision 25 and 26 show significant differences while another two do not.

Upon examining Table 2, one could ask why ALKs P 24 1 95 T and P 25 1 95 T, showing significantly different age distributions at a 5% level in two length-classes for seven analysed lengths, have been evaluated as significantly different. The reason is that the age distributions in the two other length-classes were statistically different at a significance level of about 10%. Finally, the values of test statistics for four out of seven length-classes which were compared had a relatively small probability of occurrence.

The differences, or lack thereof, between the ALKs which were statistically compared are also illustrated graphically. For this purpose, the mean age at length was calculated for each ALK. Next, the differences between the mean age at length for each of the two ALKs being statistically compared were determined. These differences are presented in Figures 3 and 4, and represent the results for herring and sprat, respectively. The differences shown in these figures illustrate well, in general, the findings obtained from statistical tests. The mean of the absolute differences between mean age at length varies for herring from 0.1 to 0.6 for ALKs evaluated as not significantly different, and it varies from 1.2 to 2.1 for ALKs for which significant differences were discovered. The averages of these means are 0.4 and 1.4, respectively. The means of the absolute differences vary for sprat from 0.08 to 0.28 with an average value of 0.14 for ALKs evaluated as not significantly different, while for significantly different ALKs this figure varied from 0.23 to 0.82 with an average value of 0.38.

Table 3. Sprat. Comparison of ALKs with respect to sampling time (quarters), sampling place (subdivisions) and sampling gear
(NS – not significant, S – significant)

Subdivision

Comparison	Number of length classes			Final evaluation
	compared	significantly different at		
		5%	1%	
P 25 2 95 T P 26 2 95 T	6	1	1	NS
P 25 4 95 T P 26 4 95 T	7	0	3	S
P 25 2 96 T P 26 2 96 T	7	0	0	NS
P 25 4 96 T P 26 4 96 T	5	1	3	S

Quarters

Comparison	Number of length classes			Final evaluation
	compared	significantly different at		
		5%	1%	
P 25 1 95 T P 25 2 95 T	6	0	0	NS
P 25 1 96 T P 25 2 96 T	7	0	0	NS
P 26 2 96 T P 26 3 96 T	6	0	0	NS
P 25 2 95 T P 25 3 95 T	7	0	0	NS
P 25 3 96 T P 25 4 96 T	6	2	2	S
P 25 3 95 T P 25 4 95 T	9	1	7	S
P 26 3 96 T P 26 4 96 T	5	2	1	S

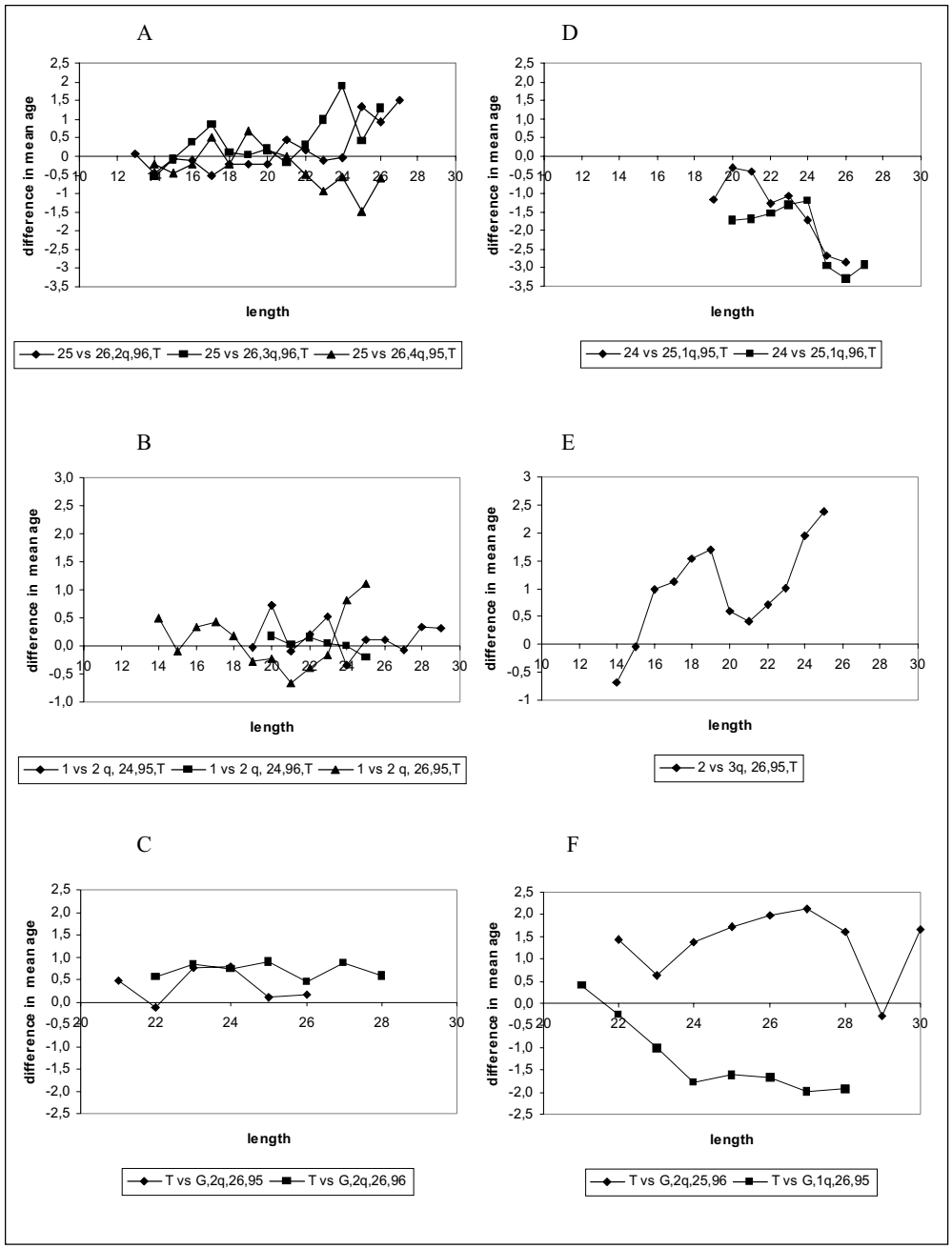

Fig. 3. Difference between mean age at length for age-length keys of herring sampled in 1995 and 1996. Figures A, B and C refer to ALKs for which significant differences were not demonstrated while Figures D, E and F refer to significantly different ALKs. In the legend e.g. 25 vs. 26, 2q, 96,T refers to differences for ALKs from Subdivision 25 and 26 sampled by trawl in the second quarter of 1996

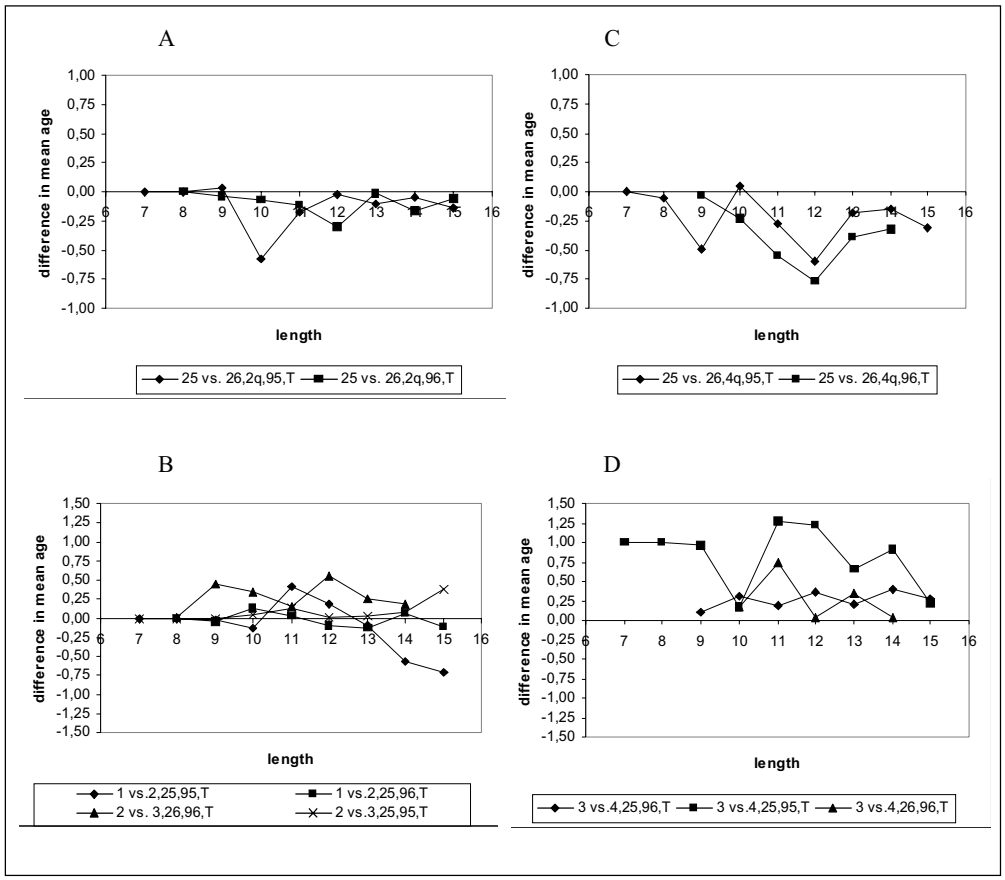

Fig. 4. Difference between mean age at length for age-length keys of sprat sampled in 1995 and 1996. Figures A, B and C refer to ALKs for which significant differences were not demonstrated while Figures D, E and F refer to significantly different ALKs. In the legend e.g. 25 vs. 26, 2q, 96,T refers to differences for ALKs from Subdivision 25 and 26 sampled by trawl in the second quarter of 1996

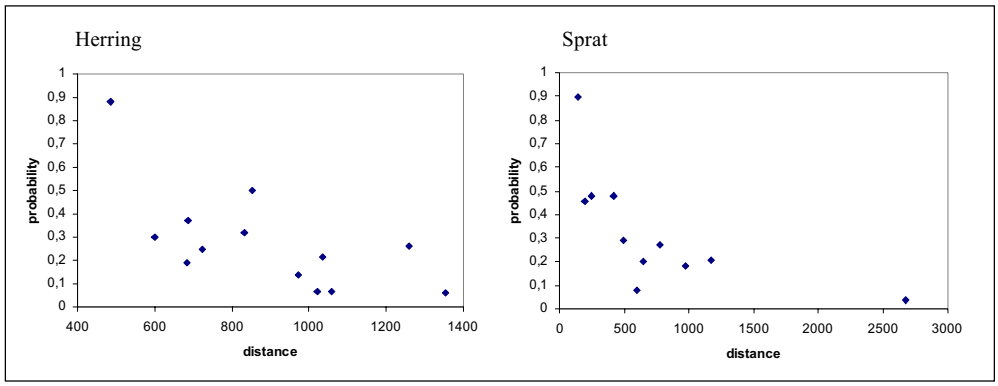

Fig. 5. The mean probability from χ^2 test plotted against distance (in ‰) between ALKs obtained by cluster analysis

Figure 3 is helpful in supporting the evaluation of the differences between herring ALKs P 24 1 95 T and P 25 1 95 T as statistically significant. This is due to the fact that five out of seven differences between mean age at length are higher than 1.0, while with insignificantly different ALKs most of the differences in mean age at length are lower than 0.5.

Finally, the mean probability of differences between ALKs occurring by random chance from the χ^2 test was plotted against distance between compared ALKs obtained from cluster analysis (Fig. 5). The presented relationship confirms good agreement between the results of cluster analysis and the results of statistical tests. The distance and probability are correlated (R = –0.7 for herring and –0.84 for sprat when exponential regression is fitted).

DISCUSSION

The test statistic [1] has approximately χ^2 distribution when sample size is large and the E_{ij}s are large. So, the approach presented is less precise than Fisher's exact test which is more appropriate for the comparison of ALKs. Fisher's exact test was used by Haynes (1993) for comparing the ALKs of Georges Bank haddock. Horbowy (1998) used both Fisher's exact test and the χ^2 test to analyze the ALKs of Baltic cod. The advantage of the χ^2 test is its simplicity. Many statistical packages can perform the test and the calculations may also be done using a spreadsheet. On the other hand, Fisher's exact test is less widely available and some standard statistical packages can perform the test only for contingency Table 2 x 2. The statistical textbooks warn that if the expected value of the variable in a cell is smaller than five, then the χ^2 test may not be a valid test. Analysis which has been performed for cod (Horbowy, 1998) suggests, however, that for the validity of the χ^2 test in the presented calculations the sample size is more important. When sample size was bigger than 20 both tests produced similar probability even if about 50% of the expected numbers in the cells was smaller than five. On the other hand, when sample size is smaller than 20, the tests may produce different results. This result is consistent with Conover (1980) who suggests that the χ^2 test produces good approximations for expected values in cells higher than one, provided the sample size is relatively big. In most of the compared age distribution at length for herring the sample size was in the range of 40 to 60, while for sprat it exceeded 100; thus, approximation by the χ^2 test is probably satisfactory.

It is worth mentioning that the examination of dendrograms obtained from cluster analysis led to similar conclusions as that of the results of statistical tests. The higher the Euclidean distance between the compared ALKs, the lower the mean probability from the χ^2 test is (Fig. 5). Thus, cluster analysis can be recommended as a tool for preliminary data analysis. Its results can be helpful in the formulation of hypotheses which are to be statistically tested. The disadvantage of cluster analysis is that it is not a method for testing hypotheses. The method, however, is useful not only for preliminary data analysis. The statistical test may not show significant differences when sample size is small. In such cases, clusters visualized in dendrograms may suggest for which ALKs an increase in sample size could possibly help in finding significant differences.

The findings of this paper can be applied in two ways. Firstly, one can use ALKs sampled from a catch performed in a given subdivision, quarter and by given fishing gear to determine the age distribution of catches in another subdivision, quarter or performed by different fishing gear, provided that the length distribution of the latter catch is known. Obviously, it may be

difficult to use ALKs sampled from catches performed with trawls and gillnets interchangeably, because the length selection of these two gear types may be very different.

Another application of the results presented here is to pool statistically similar ALKs to obtain ALKs of higher precision. This may be applicable when the sample size is small.

It should be noted that the results of the analyses conducted here will not remain applicable indefinitely. A possible change in fish growth rate may lead to different results in the future. So, these types of analyses should be repeated from time to time if ALKs are to be used interchangeably. In addition, if the results are to be used to determine the age structure of catches (and subsequently used for stock assessment), the user should take into account that not all length classes are of the same importance in such cases. Generally, small and very large fish comprise only a small part of the catches and do not influence assessment results markedly. Thus, the comparison of ALKs should be based not only on the percentage of statistically different length classes but also on the significance of differences at important (more frequent) lengths.

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The distribution, abundance and biomass of *Mysis mixta* and *Neomysis integer* (Crustacea: Mysidacea) in the open waters of the southern Baltic Sea

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Abstract. The distribution, abundance and biomass of two Mysidacea species (*Mysis mixta* and *Neomysis integer*) is described. *M. mixta* was the most abundant in the Słupsk Furrow and at the shallow water stations along the Polish coastline. It was almost absent in the deep waters of the Bornholm Basin. Occasionally, *M. mixta* was observed in the Gdańsk Deep. *Neomysis integer* was less abundant than *M. mixta*. It was found mainly in shallow waters south of Bornholm Island, on the northern edge of the Słupsk Bank and farther to the east, very close to the coastline. The values calculated from MIK net samples were lower than those from Bongo nets at the same stations. This was probably caused by a filtered water volume about 15 times greater in the case of the MIK nets. The greater volume of water decreased the influence of the patchy distribution of mysids and increased the probability of their successful catch.

A significant increase was observed, in comparison to the 1993-1994 data, in the abundance and biomass of both species of Mysidacea during June 1995 in the Słupsk Furrow, and during the August 1996 cruise at the stations in the Gdańsk Basin. This might be explained by the movement of large water masses and the improvement of oxygen conditions in the Słupsk Furrow and the Gdańsk Basin.

Key words: *Mysis mixta*, *Neomysis integer*, southern Baltic Sea, distribution, abundance, biomass

INTRODUCTION

Mysidacea is an important element of the food chain in the Baltic Sea. They feed upon zooplankton, so they compete with the early life stages of herring (Rudstam and Hansson 1990). On the other hand, they are a significant food component of older stages of herring and cod (Rudstam and Hansson 1990, Shvetsova *et al.* 1992, Szypuła *et al.* 1997). As stated by Salemaa *et al.* (1990), the first information regarding the presence and distribution of Mysidacea in the Baltic Sea is from the beginning of the twentieth century (Apstein 1906, Ekman 1914), but data on their abundance and distribution are still scarce.

Salemaa *et al.* (1990) presented general information on the abundance and distribution of *Mysis mixta* and *Mysis relicta* in the Baltic Sea area. Rudstam and Hansson (1990) and Salemaa *et al.* (1986) presented data on the distribution of Mysidacea in the northern part of the Baltic Sea. Razinkovas (1996) described the spatial distribution and migration patterns of mysids

in the Curonian Lagoon. Witek *et al.* (1993) presented changes of mysid biomass at selected stations in the Gulf of Gdańsk.

The main aim of this paper is to analyse the distribution, abundance and biomass of two Mysidacea species: *Mysis mixta* Lilljeborg and *Neomysis integer* Leach in the open waters of the southern Baltic Sea.

MATERIAL AND METHODS

Samples were collected during six R/V BALTICA cruises to the Gdańsk and Bornholm Basins and the Słupsk Furrow (Fig. 1) which were carried out in the period of 1993-1996. The main aim of these cruises was to assess cod larvae distribution and abundance. Samples were taken with Bongo net oblique hauls (333 µm mesh size) and MIK net hauls (opening of 2 m^2, 2 mm mesh size and 500 µm mesh size in the cod-end). In each case the volume of filtered water was measured by a flowmeter attached to the mouth of the gear. The water volume in the Bongo net hauls ranged from 189.4 to 1,747.6 m^3 (usually from 500 to 800 cubic meters with an average of 679.5 m^3). In MIK net hauls the volume of filtered water was about 15 times greater (average

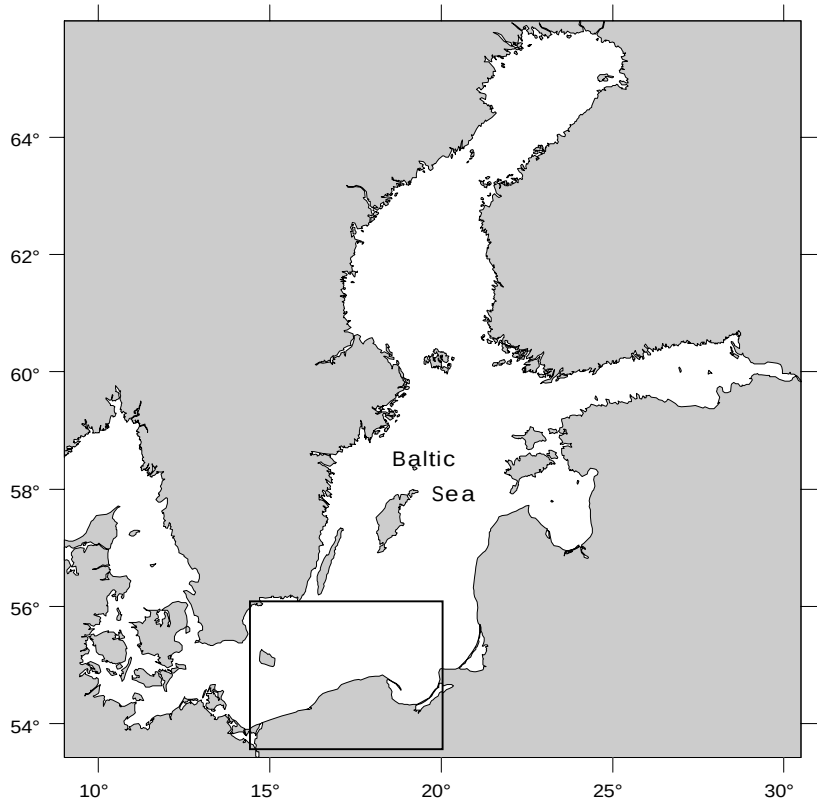

Fig. 1. Location of study area

9,985 m^3, range 2463-24328, usually 8-11 thousand cubic meters). The data presented in this paper are derived from samples taken during night hours only; this is due to Mysidacea day and night migration patterns (Rudstam *et al.* 1989, Rudstam and Hansson 1990, Shvetsova *et al.* 1992). Stations at which night samples were taken during particular cruises and their geographical positions are presented in Tables 1 and 2. Samples were preserved in 4% buffered formaldehyde and were sorted after the cruise. At each station salinity, temperature and oxygen concentration were recorded.

In total, 172 night samples were analysed (102 Bongo net and 70 MIK net). All specimens of *Mysis mixta* and *Neomysis integer* were counted and the total biomass of each taxon per sample was calculated by the displacement method. The values obtained were recalculated per 1,000 cubic meters of filtered water.

RESULTS

Distribution and abundance

Mysis mixta was found mainly in the area of the Słupsk Furrow and at shallow water stations along the Polish coastline (stations 57, RS1, B3, B4, D7). It was observed there during cruises in 1994, 1995 and 1996 (Table 1). Despite a similarity in the distribution pattern, abundance differed between particular cruises. The highest concentration was observed during the cruise in August 1996 at station D7 (depth 31 m) – 2,946 ind. · 1,000 m^{-3} (biomass 119.77 ml · 1,000 m^{-3}) (Table 1, Fig. 2). During the same cruise, *M. mixta* was also found in the area of the Gdańsk Deep (station G2) with an abundance of 124 ind. · 1,000 m^{-3} and a biomass of 3.21 ml · 1,000 m^{-3}. *M. mixta* was usually not observed at the deep stations of the Bornholm Basin. During the August 1996 cruise, the most extended station grid was covered; thus, these data were plotted in Fig. 2AB to demonstrate spatial distribution.

Neomysis integer was less abundant than *M. mixta* (Table 2). Concentrations higher than 200 ind. · 1000 m^{-3} were observed only during the August 1996 cruise (Fig. 3). The depth of the stations, which had an abundance of *N. integer* higher than 100 ind. · 1,000 m^{-3}, ranged from 15 to 41 meters. The depth of the hauls at these stations did not exceed 35 meters. *N. integer* was found mainly in the shallow waters south of Bornholm Island (stations 13, D0 and D1), on the northern edge of the Słupsk Bank (stations D6, D7 and D8) and farther to the east (stations 58 and 60) (Table 2, Fig. 3). The highest recorded concentration exceeded 1,200 ind. · 1,000 m^{-3} with a biomass of 23.95 ml · 1,000 m^{-3} (station D7 – August 1996).

Interannual changes in abundance and biomass

The analysis of the data from the same stations covered during different cruises suggested that the abundance and biomass of *M. mixta* increased in the area of the Słupsk Furrow (stations B3) and the Gdańsk Basin (stations 77 and G2) in the period 1993-1996 (Fig. 4). On the other hand, the changes in abundance observed at the Bornholm Basin stations (15, 17 and 226) were irregular and the values were much lower (Table 1). The abundance of *N. integer* increased at the Gdańsk Basin stations as well (Fig. 5). At the Bornholm Basin stations (15 and 17 *N. integer* was observed in rather low numbers and the differences between cruises were irregular (Table 2).

Table 1. Station numbers and geographical position with abundance (n*1,000 m^{-3}) and biomass (ml*1,000 m^{-3}) ("abundance"/"biomass") of *Mysis mixta* from 1993-1996 period.
B - Bongo net, MIK - MIK net. Night hauls only.

Station	Geographical		Depth	Sampling period (year/month)					
number	Position		(m)	Jul 93	Aug 94	Sep 94	Jun 95	Sep 95	Aug 96
10Gt	19° 06'	55° 07'	95	-	2/0.05 B	-	-	-	0 B, MIK
13	15° 20'	54° 30'	41	0 B, MIK	-	-	-	-	-
14	15° 20'	54° 40'	61	-	-	-	2/0.10 B	0 B	-
15	15° 20'	54° 50'	69	18/0.24 B 5/0.09 MIK	-	-	0 B	0 B	17/0.10 B 1/0.03 MIK
16	15° 40'	55° 10'	92	15/0.23 B	-	-	-	-	-
17	15° 40'	55° 00'	85	3/0.05 B	15/0.39 B 10/0.30 MIK	-	-	0 B	8/0.10 B 0 MIK
18	15° 40'	54° 50'	78	3/0.04 B 0 MIK	0 B	-	0 B	0 B	0 B
19	15° 40'	54° 40'	62	-	-	-	-	0 B	-
20	15° 40'	54° 30'	54	0 B, MIK	-	-	-	-	-
215	14° 40'	55° 40'	55	-	-	3/0.17 MIK	-	-	-
216	15° 00'	55° 40'	66	-	-	0 MIK	-	-	0 B
217	15° 00'	55° 30'	72	-	-	-	-	0 B	-
218	15° 00'	55° 20'	68	-	-	-	-	0 B	3/0.18 B 0 MIK
219	15° 00'	55° 30'	46	0 B 8/0.17 MIK	-	-	-	-	-
220	15° 20'	55° 00'	58	-	14/061 B 4/0.31 MIK	-	-	0 B	-
221	15° 20'	55° 10'	48	-	-	-	-	10/0.68 B	-
222	15° 20'	55° 20'	92	-	0 B, MIK	-	0 B	0 B	0 B, MIK
223	15° 20'	55° 30'	81	-	0 B, MIK	-	-	0 B	-
224	15° 20'	55° 40'	70	-	-	-	-	2/0.10 B	0 B, MIK
225	15° 40'	55° 40'	67	-	-	-	-	-	0 B, MIK
226	15° 40'	55° 30'	77	1/0.05 B 6/0.16 MIK	2/0.08 B	-	0 B	3/0.08 B	-
227	15° 40'	55° 20'	94	6/0.17 B 2/0.09 MIK	0 MIK	-	0 B	0 B	0 B, MIK
228	16° 00'	55° 20'	86	13/0.18 B 2/0.05 MIK	-	-	-	-	0 B, MIK
229	16° 00'	55° 30'	82	-	-	-	-	-	0 B, MIK
231	16° 00'	55° 50'	62	0 B, MIK	-	-	-	-	-
232	16° 20'	55° 50'	61	0 B 20/1.21 MIK	-	-	-	-	-
233	16° 20'	55° 40'	73	5/0.17 MIK	-	-	-	-	-
24	16° 00'	54° 30'	40	40/2.66 B 44/1.28 MIK	-	-	-	-	-
26	16° 00'	54° 50'	54	-	-	-	0 B	-	-
26A	16° 00'	54° 54'	68	-	1/0.01 MIK	-	-	-	-
27	16° 00'	55° 00'	77	0 B	7/0.36 B 5/0.22 MIK	-	-	-	0 B, MIK
29	16° 20'	55° 20'	66	-	-	-	-	-	0 B
33A	16° 15'	54° 40'	37	0 B	-	-	-	-	-
40	16° 40'	55° 10'	77	-	1/0.07 MIK	-	-	-	-
43	17° 00'	55° 20'	70	-	-	-	-	-	160/5.20 B
44	17° 00'	55° 10'	73	-	0 MIK	-	-	-	48/2.06 B
57	17° 40'	55° 10'	46	-	468/28.67 B 47/2.06 MIK	0 MIK	-	-	-
58	17° 40'	55° 00'	33	-	0 B 1/0.05 MIK	1/0.05 MIK	-	-	-
59	17° 40'	54° 50'	15	-	0 MIK	1/0.01 MIK	-	-	-
59A	17° 50'	54° 50'	15	-	-	0 MIK	-	-	-
60	18° 00'	54° 50'	15	-	0 B	11/3.92 MIK	-	-	-
63	18° 00'	55° 30'	70	-	0 B 36/0.76 MIK	-	-	-	-

continued

Station number	Geographical Position		Depth (m)	Sampling period (year/month)					
				Jul 93	Aug 94	Sep 94	Jun 95	Sep 95	Aug 96
72	18° 40'	55° 20'	15	-	0 MIK	-	-	-	-
77	18° 40'	55° 20'	84	-	37/1.41 B	-	-	-	177/3.80 B 1/0.01 MIK
79	18° 40'	55° 50'	95	-	0 B, MIK	-	-	-	-
80	18° 40'	55° 50'	109	-	0 B, MIK	-	-	-	-
97	19° 14'	55° 00'	60	-	-	-	531/7.60 B	-	-
B3	18° 00'	55° 20'	77	2/0.05 B	-	-	221/3.09 B	-	-
B4	16° 30'	55° 17'	62	-	-	-	-	-	2386/64.25 B 0 MIK
D0	15° 00'	54° 30'	31	-	-	-	-	-	136/3.23 B 64/0.27 MIK
D1	15° 16'	54° 28'	30	-	-	-	-	-	140/4.30 B 9/0.38 MIK
D2	15° 40'	54° 23'	30	-	-	-	-	-	0 B, MIK
D6	16° 43'	55° 04'	31	-	-	-	-	-	69/1.74 B 32/0.68 MIK
D7	17° 04'	55° 02'	31	-	-	-	-	-	2946/119.8 B 4877/131.4 MIK
D9	18° 04'	55° 02'	32	-	-	-	-	-	0 B 337/10.12 MIK
D8=50	17° 20'	55° 00'	30	-	-	-	-	-	72/0.85 B
G2	19° 19'	54° 50'	109	-	3/0.05 B	-	-	-	124/3.21 B 134/4.42 MIK
GD2	19° 06'	54° 36'	84	0 B	-	-	-	-	-
Gt1	18° 26'	55° 36'	95	-	0 B 2/0.06 MIK	-	-	-	-
IBY5	16° 00'	55° 14'	93	0 B 2/0.07 MIK	-	-	-	-	-
P115	19° 02'	54° 26'	50	0 B	-	-	-	-	-
RS1	17° 40'	55° 15'	60	0 B	153/7.92 B 200/9.04	-	-	-	-
RS2	17° 20'	55° 14'	93	0 B	0 B 42/1.98 MIK	-	-	-	-
T10	18° 40'	54° 47'	30	-	-	0 MIK	-	-	-
T12	18° 09'	54° 53'	19	-	-	0 MIK	-	-	-
T17	13° 31'	55° 35'	51	-	-	0 B	-	-	-
T18	14° 35'	55° 40'	51	-	-	0 B	-	-	-
T20	14° 40'	55° 48'	41	-	-	428/21.23 B	-	-	-
T21	14° 50'	55° 48'	51	-	-	8/0.38 B	-	-	-
T30	14° 40'	55° 35'	71	-	-	0 MIK	-	-	-
T31	14° 50'	55° 35'	74	-	-	0 MIK	-	-	-
T32	15° 00'	55° 35'	77	-	-	0 MIK	-	-	-
T33	15° 10'	55° 35'	75	-	-	0 MIK	-	-	-
T34	15° 20'	55° 35'	68	-	-	0 MIK	-	-	-
T5B	18° 35'	54° 57'	58	-	-	133/8.12 MIK	-	-	-
T6B	18° 33'	54° 55'	30	-	-	29/1.70 MIK	-	-	-
T7B	18° 30'	54° 50'	19	-	-	0 MIK	-	-	-
T8B	18° 28'	54° 50'	11	-	-	0 MIK	-	-	-
X1	15° 40'	55° 12'	92	2/0.08 B	-	-	-	-	-
X2	15° 40'	55° 07'	84	1/0.06 B	-	-	-	-	-
X3	15° 45'	55° 03'	79	2/0.06 B	-	-	-	-	-
X4	15° 50'	55° 00'	80	6/0.14 B	-	-	-	-	-
X5	16° 00'	55° 05'	84	11/0.22 B	-	-	-	-	-

"-" no night samples "0" no *Mysis mixta* in samples

Table 2. Station numbers and geographical position with abundance (n*1,000 m^{-3}) and biomass (ml*1,000 m^{-3}) ("abundance"/"biomass") of *Neomysis integer* from 1993-1996 period.
B - Bongo net, MIK - MIK net. Night hauls only.

Station	Geographical		Depth	Sampling period (year/month)					
number	Position		(m)	Jul 93	Aug 94	Sep 94	Jun 95	Sep 95	Aug 96
10Gt	19° 06'	55° 07'	95	-	5/0.05 B	-	-	-	0 B, MIK
13	15° 20'	54° 30'	41	123/3.55 B 8/0.14 MIK	-	-	-	-	-
14	15° 20'	54° 40'	61	-	-	-	0 B	0 B	-
15	15° 20'	54° 50'	69	13/0.12 B 0 MIK	-	-	0 B	5/0.09B	0 B, MIK
16	15° 40'	55° 10'	92	0 B	-	-	-	-	-
17	15° 40'	55° 00'	85	0 B	1/0.06 B 0 MIK	-	-	3/0.04 B	4/0.10 B 0 MIK
18	15° 40'	54° 50'	78	0 B, MIK	0 B	-	0 B	7/0.11 B	0 B
19	15° 40'	54° 40'	62	-	-	-	-	5/0.09 B	-
20	15° 40'	54° 30'	54	0 B 1/0.08 MIK	-	-	-	-	-
215	14° 40'	55° 40'	55	-	-	0 MIK	-	-	-
216	15° 00'	55° 40'	66	-	-	0 MIK	-	-	0 B
217	15° 00'	55° 30'	72	-	-	-	-	3/0.14 B	-
218	15° 00'	55° 20'	68	-	-	-	-	0 B	5/0.09 B 0 MIK
219	15° 00'	55° 30'	46	0 B 3/0.07 MIK	-	-	-	-	-
220	15° 20'	55° 00'	58	-	0 B, MIK	-	-	0 B	-
221	15° 20'	55° 10'	48	-	-	-	-	3/0.17 B	-
222	15° 20'	55° 20'	92	-	0 B, MIK	-	0 B	0 B	0 B, MIK
223	15° 20'	55° 30'	81	-	0 B, MIK	-	-	0 B	-
224	15° 20'	55° 40'	70	-	-	-	-	12/0.10 B	0 B, MIK
225	15° 40'	55° 40'	67	-	-	-	-	-	0 B, MIK
226	15° 40'	55° 30'	77	0 B, MIK	0 B	-	0 B	0 B	-
227	15° 40'	55° 20'	94	0 B, MIK	0 MIK	-	0 B	1/0.06 B	0 B, MIK
228	16° 00'	55° 20'	86	0 B, MIK	-	-	-		0 B, MIK
229	16° 00'	55° 30'	82	-	-	-	-	-	0 B, MIK
231	16° 00'	55° 50'	62	0 B, MIK	-	-	-	-	-
232	16° 20'	55° 50'	61	0 B, MIK	-	-	-	-	-
233	16° 20'	55° 40'	73	0 MIK	-	-	-	-	-
24	16° 00'	54° 30'	40	66/2.13 B 40/1.50 MIK	-	-	-	-	-
26	16° 00'	54° 50'	54	-	-	-	0 B	-	-
26A	16° 00'	54° 54'	68	-	0 MIK	-	-	-	-
27	16° 00'	55° 00'	77	0 B	0 B, MIK	-	-	-	0 B, MIK
29	16° 20'	55° 20'	66	-	-	-	-	-	0 B
33A	16° 15'	54° 40'	37	0 B	-	-	-	-	-
40	16° 40'	55° 10'	77	-	0 MIK	-	-	-	-
43	17° 00'	55° 20'	70	-	-	-	-	-	0 B
44	17° 00'	55° 10'	73	-	0 MIK	-	-	-	82/0.69 B
57	17° 40'	55° 10'	46	-	29/0.24 B 6/0.09 MIK	5/0.11 MIK	-	-	-
58	17° 40'	55° 00'	33	-	146/0.27 B 0 MIK	70/1.53 MIK	-	-	-
59	17° 40'	54° 50'	15	-	0 MIK	699/23.5 MIK	-	-	-
59A	17° 50'	54° 50'	15	-	-	605/16.6 MIK	-	-	-
60	18° 00'	54° 50'	15	-	117/0.23B	127/4.39 MIK	-	-	-
63	18° 00'	55° 30'	70	-	0 B, MIK	-	-	-	-
72	18° 40'	55° 20'	15	-	45/0.94 MIK	-	-	-	-
77	18° 40'	55° 20'	84	-	7/0.07 B	-	-	-	59/0.61 B
79	18° 40'	55° 50'	95	-	0 B, MIK	-	-	-	-

continued

Station number	Geographical Position		Depth (m)	Sampling period (year/month)					
				Jul 93	Aug 94	Sep 94	Jun 95	Sep 95	Aug 96
80	18° 40'	55° 50'	109	-	0 B 1/0.02 MIK	-	-	-	-
97	19° 14'	55° 00'	60	-	-	-	0 B	-	-
B3	18° 00'	55° 20'	77	0 B	-	-	0 B	-	-
B4	16° 30'	55° 17'	62	-	-	-	-	-	0 B, MIK
D0	15° 00'	54° 30'	31	-	-	-	-	-	972/9.69 B 732/12.84 MIK
D1	15° 16'	54° 28'	30	-	-	-	-	-	190/0.72 B 87/1.51 MIK
D2	15° 40'	54° 23'	30	-	-	-	-	-	19/0.16 B 0 MIK
D6	16° 43'	55° 04'	31	-	-	-	-	-	469/10.85 B 691/17.10 MIK
D7	17° 04'	55° 02'	31	-	-	-	-	-	1222/23.95 B 402/8.21 MIK
D9	18° 04'	55° 02'	32	-	-	-	-	-	0 B 25/0.30 MIK
D8=50	17° 20'	55° 02'	30	-	-	-	-	-	378/0.85 B
G2	19° 19'	54° 50'	109	-	1/0.05 B	-	-	-	17/0.13 B 7/0.07 MIK
GD2	19° 06'	54° 36'	84	0 B	-	-	-	-	-
Gtl	18° 26'	55° 36'	95	-	0 B, MIK	-	-	-	-
IBY5	16° 00'	55° 14'	93	0 B, MIK	-	-	-	-	-
P115	19° 02'	54° 26'	50	0 B	-	-	-	-	-
RS1	17° 40'	55° 15'	60	0 B	16/0.26 B 2/0.09 MIK	-	-	-	-
RS2	17° 20'	55° 14'	93	0 B	0 B, MIK	-	-	-	-
T10	18° 40'	54° 47'	30	-	-	5/0.08 MIK	-	-	-
T12	18° 09'	54° 53'	19	-	-	0 MIK	-	-	-
T17	13° 31'	55° 35'	51	-	-	18/0.11 B	-	-	-
T18	14° 35'	55° 40'	51	-	-	7/0.18 B	-	-	-
T20	14° 40'	55° 48'	41	-	-	18/0.18 B	-	-	-
T21	14° 50'	55° 48'	51	-	-	0 B	-	-	-
T30	14° 40'	55° 35'	71	-	-	0 MIK	-	-	-
T31	14° 50'	55° 35'	74	-	-	0 MIK	-	-	-
T32	15° 00'	55° 35'	77	-	-	0 MIK	-	-	-
T33	15° 10'	55° 35'	75	-	-	0 MIK	-	-	-
T34	15° 20'	55° 35'	68	-	-	0 MIK	-	-	-
T5B	18° 35'	54° 57'	58	-	-	2/0.06 MIK	-	-	-
T6B	18° 33'	54° 55'	30	-	-	28/1.14 MIK	-	-	-
T7B	18° 30'	54° 50'	19	-	-	296/8.48 MIK	-	-	-
T8B	18° 28'	54° 50'	11	-	-	476/10.6 MIK	-	-	-
X1	15° 40'	55° 12'	92	0 B	-	-	-	-	-
X2	15° 40'	55° 07'	84	1/0.06 B	-	-	-	-	-
X3	15° 45'	55° 03'	79	0 B	-	-	-	-	-
X4	15° 50'	55° 00'	80	0 B	-	-	-	-	-
X5	16° 00'	55° 05'	84	0 B	-	-	-	-	-

"-" no night samples "0" no *Neomysis integer* in samples

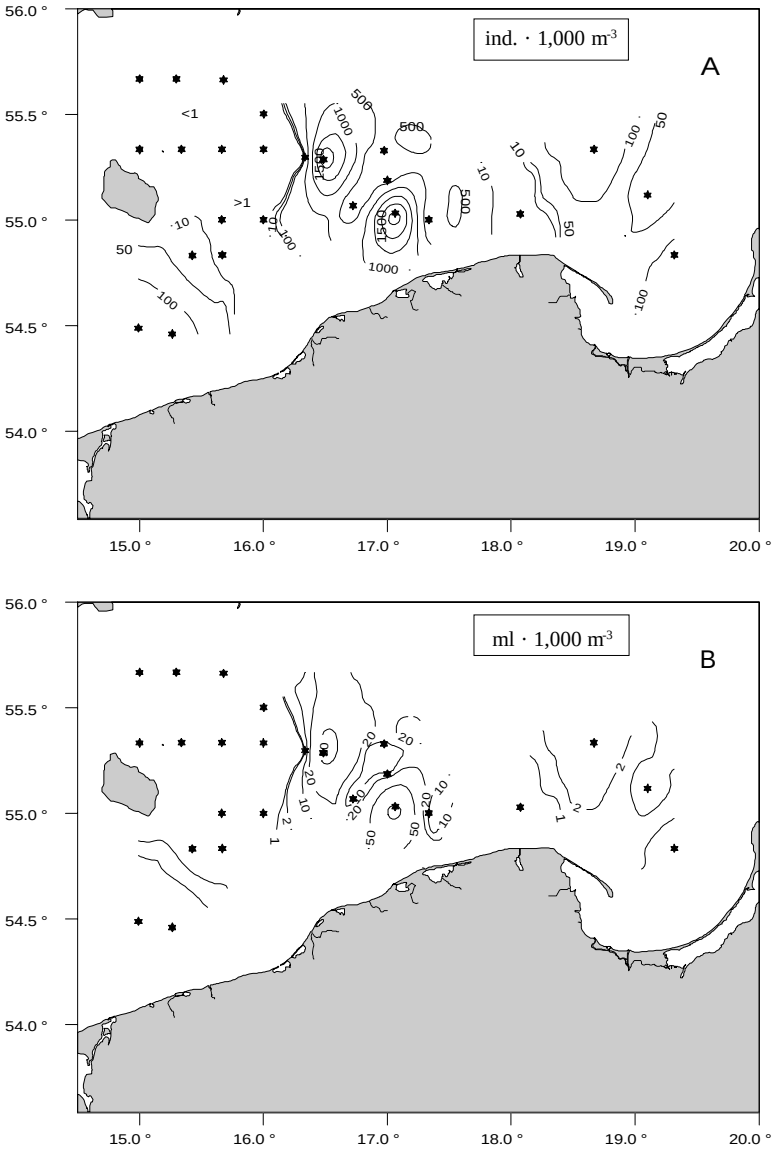

Fig. 2. Abundance (A) and biomass (B) of *Mysis mixta* in southern Baltic Sea (August 1996), Bongo net night hauls

Comparison of results obtained with two different types of gear (Bongo and MIK nets)

Samples collected with both types of gear gave similar information on the Mysidacea spatial distribution pattern; *Mysis mixta* was found at the Słupsk Furrow stations and in the shallow waters along the Polish coastline and *Neomysis integer* was observed mainly in shallow waters

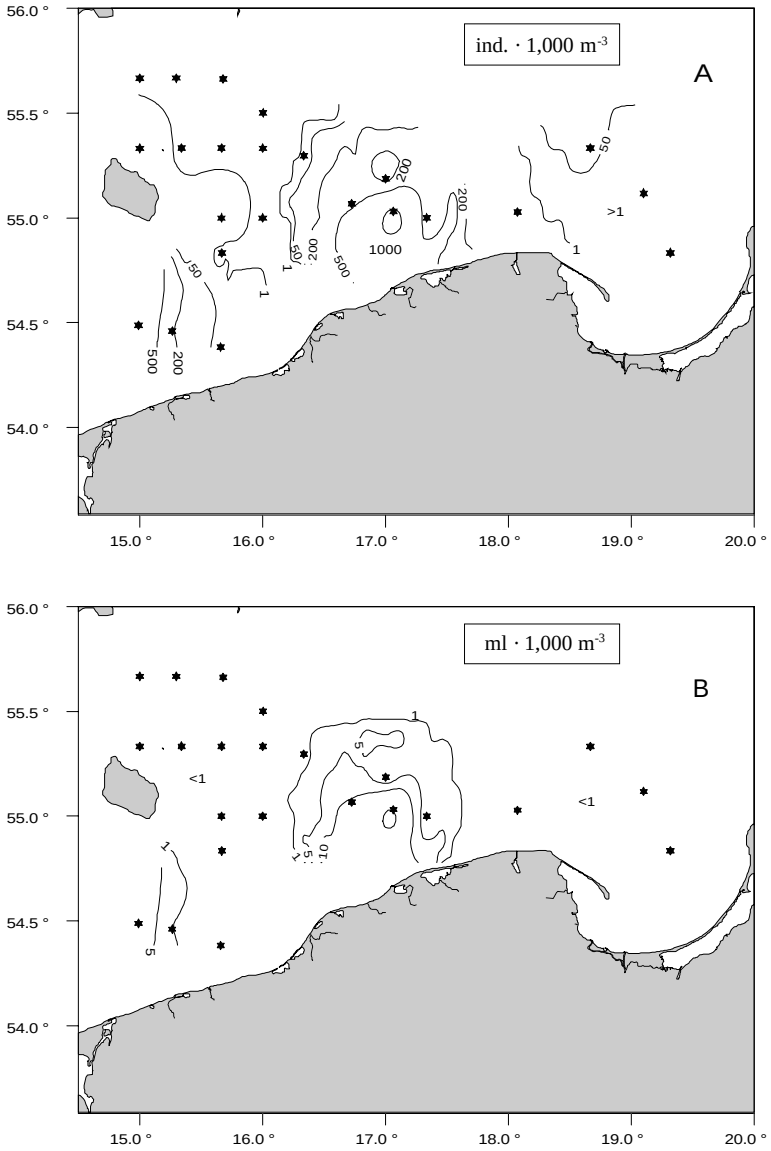

Fig. 3. Abundance (A) and biomass (B) of *Neomysis integer* in southern Baltic Sea (August 1996), Bongo net night hauls

at a depth of 30-40 meters (Tables 1 and 2). However, the abundance and biomass data were not comparable (Fig. 6). The *M. mixta* abundance from MIK net samples was usually lower in comparison to the results obtained from Bongo nets at the same stations. In the case of 6 stations, *M. mixta* was reported in the MIK net samples and absent in those from Bongo nets.

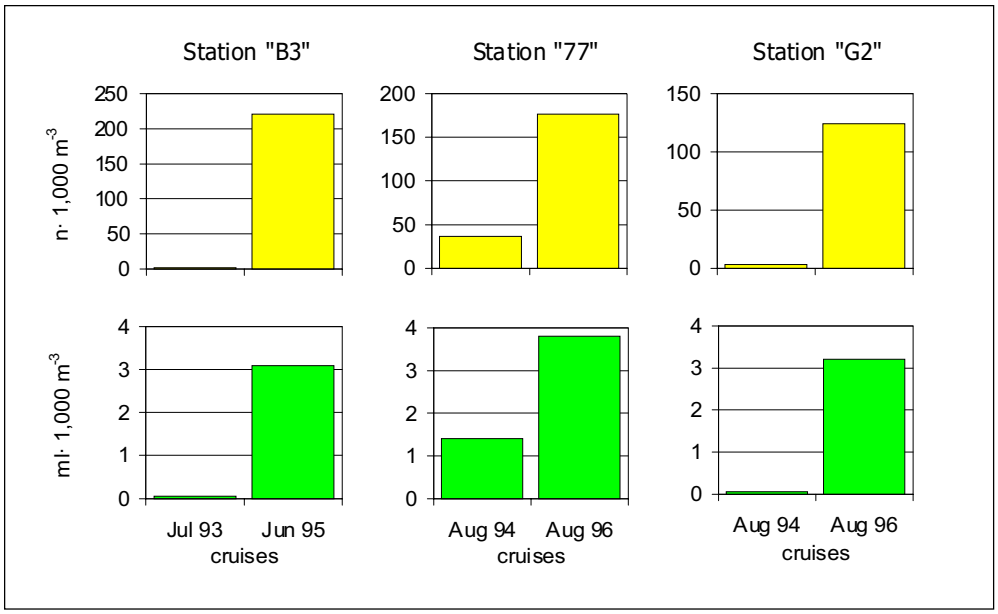

Fig. 4. Interannual changes in abundance (A) and biomass (B) of *Mysis mixta* in Słupsk Furrow (station "B3") and Gdańsk Basin (stations "77"and "G2"), Bongo net night hauls

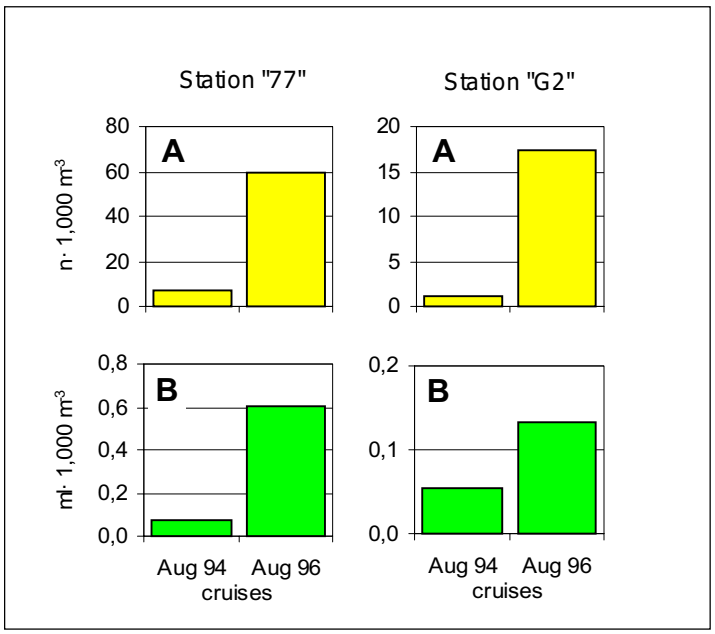

Fig. 5. Interannual changes in abundance (A) and biomass (B) of *Neomysis integer* in Gdańsk Deep (stations "77" and "G2"), Bongo net night hauls

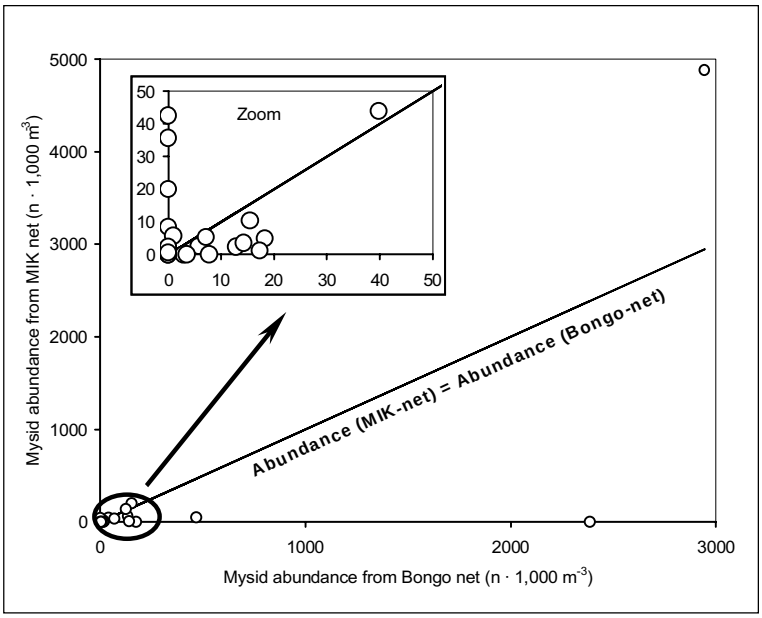

Fig. 6. Comparison of *Mysis mixta* abundance calculated on basis of Bongo and MIK nets, night hauls only

DISCUSSION

The data on the abundance and biomass obtained from Bongo and MIK nets were not comparable, but they allow for the following statement: *Mysis mixta* was the most abundant in the Słupsk Furrow and at the shallow water stations along the Polish coastline. It was almost absent in the deep waters of the Bornholm Basin. Occasionally, *M. mixta* was observed in the Gdańsk Deep. These results are basically convergent with those presented by Salemaa *et al.* (1990). They described *M. mixta* populations as weak or completely absent in the Gulf of Gdańsk and the Bornholm Basin. The abundance of mysid shrimps in the Gdańsk Basin may be reduced by a decrease in oxygen concentration (Kotta 1984, Rudstam *et al.* 1986). Specimens found in the Gdańsk Deep might be "washed off" from populations living in other areas (as suggested by Salemaa *et al.* 1990).

Despite this, *Neomysis integer* appear to be the most widespread species of mysids in the Baltic Sea (Köhn 1992) and they dominate in very shallow waters (Välipakka 1992, Simm and Kotta 1992). According to Węsławski (1981) their abundance decreases from a level of 100 ind. $\cdot$ m^{-3} at a depth of 0.5 meters to 10 ind. $\cdot$ m^{-3} at 2 meters and to 1 ind. $\cdot$ m^{-3} in waters 5 meters deep. This might explain why *N. integer* was less abundant than *M. mixta* in the samples presented in this paper. They were found mainly in the shallow waters south of Bornholm Island, on the northern edge of the Słupsk Bank and farther to the east, close to the coastline. At all the stations with an *N. integer* abundance higher than 100 ind. $\cdot$ 1,000 m^{-3}, the station depth ranged from 15 to 41 meters. Concentrations higher than 200 ind. $\cdot$ 1,000 m^{-3} were observed only during the August 1996 cruise.

The average mysid densities were an order of magnitude lower than those calculated by Salemaa *et al.* (1990) for the open waters of the Baltic Sea. The density of *M. mixta* ranged from 0 to 146 ind. · m^{-2} which was similar to values obtained by Rudstam and Hansson (1990) for the coastal waters of the northern Baltic proper. The highest recorded abundance (2.9 ind. · m^{-3} which meant 146 ind. · m^{-2}) was two times lower than that presented by Rudstam *et al.* (1986) and Rudstam *et al.* (1989) and much lower than that observed by Kotta and Simm (1979) in the Bay of Riga. For the majority of stations covered, the abundance of *M. mixta* did not exceed 20 ind. · 1,000 m^{-3}. The highest density of *N. integer* (14.5 ind. · m^{-2}) was also about two times lower than that observed in Swedish coastal waters (Rudstam *et al.* 1986) and several times lower than values reported for the Bay of Riga (Kotta and Simm 1979). Taking into consideration the fact that plankton sampling gear is not able to sample bottom water layers (3 to 5 meters from the bottom) and that a significant part of the mysid population stays close to the bottom during the night (Rudstam and Hansson 1990, Rudstam *et al.* 1989), the presented abundance and biomass calculations were underestimated.

The values calculated from MIK net samples were lower than those from the Bongo nets at the same stations. This was probably caused by a filtered water volume about 15 times greater in the case of the MIK nets. The greater volume of water decreased the influence of the patchy distribution of mysids and increased the probability of their successful catch. At six stations *M. mixta* was reported in the MIK net samples but absent in those from the Bongo nets.

A significant increase was observed, in comparison to the 1993-1994 samples, in the abundance and biomass of both species of Mysidacea during June 1995 in the Słupsk Furrow and during the August 1996 cruise at the stations in the Gdańsk Basin. Unfortunately, no information is available on mysid abundance from subsequent years, so it is impossible to answer the question of whether or not this was a short-term shift or a part of some long-term changes. A series of inflows of high salinity water from Kattegat to the Baltic Sea began in January 1993 (Wojewódzki 1996). The first of them renewed the deep layer of successive basins including the Gdańsk Deep. However, in the Gdańsk Deep the oxygen content had already dropped below 1 ml · l^{-1} in September 1993. Since March 1996 the oxygen concentration has increased in this area again to above 1 ml · l^{-1}, and to above 2 ml · l^{-1} since June 1996 (Wojewódzki 1996). An increase of Mysidacea abundance in the Słupsk Furrow has been noted since June 1995 and in the Gdańsk Basin since August 1996. This might suggest that mysids found these oxygen conditions sufficient or they were transported eastward to the Gdańsk Basin along with large water masses (as suggested by Salemaa *et al.* 1990).

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A comparative study of populations of southern blue whiting (*Micromesistius australis* Norman, 1937) from the Falkland and New Zealand fishing grounds using selected taxonomic characters

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Abstract. A comparative analysis of populations of southern blue whiting (*Micromesistius australis* Norman, 1937) based on the investigations of 17 taxonomic characters revealed that there was no subspecific differentiation between populations of southern blue whiting from the Falkland Islands and New Zealand fishing grounds. The differentiation which was noted did not vary in character from other commonly found differences between fish populations which are described in the literature.

Key words: southern blue whiting, Falkland Islands, New Zealand, taxonomic characters, comparative analysis

INTRODUCTION

The southern blue whiting (*Micromesistius australis* Norman, 1937) belongs to the *Micromesistius* Gill genus of the Gadidae family. The taxonomic position of this genus was first introduced by Norman [1937], thus separating it from the *Micromesistius poutassou* (Risso) which occurs in the north Atlantic and Mediterranean. The results of Norman's investigations were later confirmed by many researchers including Hart [1946], Szubnikow *et al.* [1969], Lopez and Belissio [1973], Szpak [1975] and Barrer-Oro and Tomo [1988]. In 1975 the Japanese researchers Inada and Nakamura [1975] separated the population which inhabits the waters of New Zealand from those which inhabit the waters of the Atlantic and Pacific near South America and Antarctica into two subspecies, *Micromesistius australis pallidus* and *Micromesistius australis australis*. Szust [1978], who compared both species of the genus *Micromesistius*, did not take this division into account and relied on the earlier established taxonomic unit.

In 1993 and 1994 Polish fishing vessels carried out simultaneous catches of blue whiting in the Atlantic fishing grounds near the Falkland Islands and in the New Zealand fishing grounds. The principal catches took place in September in both areas. By synchronizing the catches in these two distant regions during the period of the most intense spawning, simultaneous investigations of both commercial stocks of southern blue whiting were made possible.

The aim of this work is to characterize both populations using selected taxonomic characters and, through comparative analysis, to discover if the investigated populations differ.

MATERIALS AND METHODS

Material for the investigations was collected during four expeditions of two commercial fishing vessels; the m/t DALMOR II (1993-1994) in New Zealand and the m/t RYBAK MORSKI (1993-1994) in the Falkland Islands. Figure 1 illustrates the distribution of southern blue whiting and the location of sampling stations.

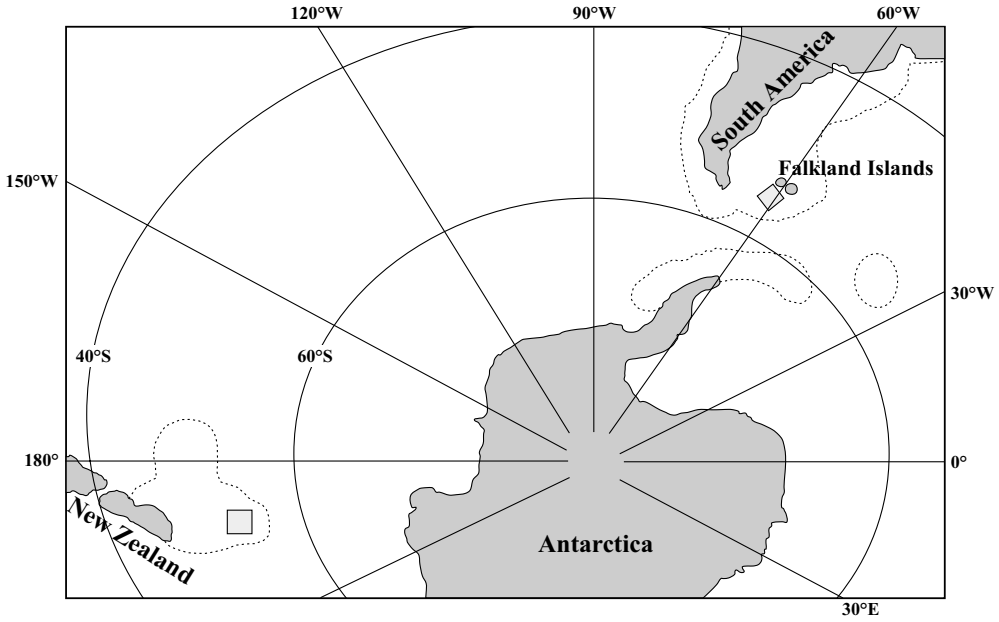

Fig. 1. Areas of southern blue whiting (*Micromesistius australis*) occurrence in the Atlantic and the Pacific (dotted line). Investigation areas are denoted with boxes

The selected taxonomic characters (meristic and biometric) of 940 specimens of southern blue whiting were analyzed (Table 1).

Table 1. Research material collected during expeditions of the m/t DALMOR and m/t RYBAK MORSKI

Region of investigation	Time of investigation	Number of fish collected
New Zealand	September 1993	110
	September 1994	210
	Total	320
Falkland Islands	Sept. - Dec. 1993	220
	Sept. - Dec. 1994	400
	Total	620

A smaller amount of material was collected from the New Zealand fishing grounds because the blue whiting catch period amounted to a total of 30 days over two years; while in the Falkland Islands the catch period was three months long each year.

A slide caliper was used to carry out measurements of biometric characters to the nearest mm. The following characters were recorded: total length (*longitudo totalis*), fork length (*l. forkalis*), body length (*l. corporis*), head length (*l. capitis*), from the tip of the snout to the origin of the first dorsal fin (*l. praedorsale*), from the tip of the snout to the anus (*l. praeanale*), body height (*altitudo corporis*), head width (*latitudo capitis*), eye spacing (forehead width – *latitudo frontis*) and eye diameter (*diameter oculi*).

The results of biometric character measurements are presented as a percentage index (the percentage of a particular character in relation to fork length, the selected basic feature). This method was introduced by Pravdin [1966] and it is commonly applied by many researchers.

The investigations of meristic characters included counting the number of radii in fins – dorsal (*pinnae dorsalis*: D I, D II, D III), anal (*pinnae analis*: A I, A II) and pectoral (*pinna pectoralis* P). Gill-rakers (*spinarum ad arcum branchiorum*) were calculated at the first arch and the total number of vertebrae (*vertebrae*) were counted.

In order to estimate the character variations of both populations and to describe their character the following comparative tests were applied:

1. t-Student
2. M_{diff},
3. Ginsburg
4. CD difference coefficient

One-parameter variance analysis was carried out, then the results obtained from the t-Student test were compared with the table value ($t._{tab}$) at a significance level of $\alpha = 0.05$. If the calculated value was greater than the table value, $t._{cal} > t._{tab}$, it was assumed that the investigated values varied significantly [Balicki and Bielecki, 1980]. The t-Student test was applied in two ways. Firstly, it was used to determine the differentiation between the taxonomic characters of males and females of one population with the goal of establishing sex dimorphism. Secondly, it was used to compare males, females and combined representations from the investigated populations.

The t-Student test only allowed for the determination of statistically significant differentiation among the investigated characters; it did not provide answers regarding their character. In order to draw the proper conclusions regarding taxonomic differentiation among specimens from both populations, three additional tests were applied, all of which include criteria for population or taxonomic division.

In test M_{diff} the following formula was applied:

$$M_{diff} = \frac{M_1 - M_2}{\sqrt{E_1^2 + E_2^2}}$$

where: M_1, M_2 – arithmetic averages

E_1, E_2 – standard errors.

Additionally, stricter criteria were applied [Sosiński 1981] where the significant value for differentiation occurs when $M_{diff} > 5$.

The Ginsburg test for meristic characters was carried out according to the author's [1938] criteria for race, subspecies and species division. These stipulate that if character compliance is lower than 10%, the division is made at the species level. If compliance ranges from 15% to 25%, the division is made at the subspecies level. Finally, if compliance is between 30% and 40%, the division is made at the race level.

The CD test, recommended by Mayr [1974], was calculated from the following formula:

$$CD = \frac{M_1 - M_2}{S_1 + S_2}$$

where: S_1, S_2 – standard deviation
M_1, M_2 – arithmetic averages

and accepting the 75% rule, the generally accepted level of subspecies division is CD = 1.28. If this condition is satisfied, the assumption that there are two separate subspecies is true.

During these commercial catches, the ships were required to use gear which complied with local regulations. In accordance with those of the Ministry of Agriculture and Fisheries (MAF), New Zealand, the protective mesh size in the codend was 100 mm, while the Falkland Interim Conservation Zone (FICZ) required it to be 90 mm. Therefore, only specimens under fishing pressure were investigated, and the protected fry in the catches were disregarded.

RESULTS

The characteristics of the taxonomic characters of southern blue whiting are presented in Table 2 for fish from the Falkland spawning grounds and in Table 3 for the fish from the New Zealand fishing grounds. The tables include data on the amount of research material, the range and average value of the investigated character, and the standard deviation for males, females and the two sexes combined. The biometric characters are presented as relative values (percentage of fork length), while the meristic characters are given in absolute values. Figure 2 presents curves which illustrate the frequency in percentages of meristic characters of the investigated populations of southern blue whiting.

In the blue whiting population from the Falkland spawning grounds, the males were characterized by higher average percent indices of the following biometric characters: total length, eye diameter, the length from the tip of the snout to the origin of the first dorsal fin and the length from the tip of the snout to the anus. The percent indices for head length and width were identical for both sexes, while those of the other characters were higher in females.

Analysis of meristic characters revealed that the average number of radii in the first and second dorsal fins (D I and D II) and the number of gill-rakers (sp. br.) were higher for males. Females were characterized by a greater average number of radii in the third dorsal fin (D III) and in the first anal fin (A I). Average values of other meristic characters were comparable. Among the meristic characters investigated, a two-peak frequency distribution of the number of gill-rakers was observed, which indicates the non-homogeneous character of the blue whiting population from the Falkland spawning grounds.

Comparative analysis of specimens of both sexes using the t-Student test revealed that both sexes varied only in body height. This is expressed in Table 4 as the percentage of the fork length.

Among the blue whiting population from New Zealand waters, it was the males who were characterized by greater average percentages of such biometric characters as total length, head length and eye diameter. Almost identical indices were obtained for head width and eye spacing in both sexes, while the indices of other characters were higher for females (Table 3).

Investigations of meristic characters revealed that males were characterized by a higher

Table 2. Characteristics of taxonomic characters of southern blue whiting from Falkland fishing grounds

Character	Males				Females				Males and females			
	n	range	*M*	δ^2	*n*	range	*M*	δ^2	*n*	range	*M*	δ^2
Biometric characters (in % of fork length)												
Total length (*longitudo totalis*)	308	101-15-107.16	104.13	0.70	312	101.45-107.35	104.12	0.66	620	101.15-107.35	104.12	0.68
Body length (*longitudo corporis*)	308	88.36-97.49	94.56	1.27	312	89.74-98.00	94.66	1.11	620	88.36-98.00	94.61	1.19
Body height (*latitudo corporis*)	308	12.27-20.88	16.62	1.91	312	11.94-24.17	17.33	2.31	620	9.89-24.17	16.96	2.16
Head length (*longitudo capitis*)	308	17.81-23.40	19.97	1.27	312	17.32-23.70	19.97	1.34	620	17.32-23.70	19.97	1.30
Head width (*latitudo capitis*)	308	6.02-10.08	7.66	0.72	312	5.88-10.04	7.66	0.78	620	5.88-10.08	7.66	0.75
Eye spacing (*latitudo frontis*)	108	2.41-4.21	3.32	0.38	112	2.48-4.25	3.37	0.37	220	2.41-4.25	3.35	0.38
Eye diameter (*diameter oculi*)	308	3.56-6.47	4.69	0.58	312	3.50-6.44	4.61	0.56	620	3.50-6.47	4.65	0.57
Length from the tip of the snout to the origin of the forst dorsal fin (*longitudo praedorsalis*)	108	28.64-35.75	33.09	1.54	112	26.90-36.82	33.07	1.73	220	26.90-36.82	22.08	1.63
Length from the tip of the snout to the anus (*longitudo praeanalis*)	108	28.13-35.69	32.32	1.26	112	27.89-36.19	32.25	1.54	220	27.89-36.19	32.29	1.41
Meristic characters												
D I	308	10-14	12.07	0.75	312	11-14	1215	0.72	620	10-14	12.11	0.74
D II	308	9-15	12.05	1.03	312	10-15	11.99	1.01	620	9-15	12.02	1.02
D III	308	20-27	23.74	1.11	312	20-28	23.89	1.26	620	20-28	23.82	1.19
A I	308	31-40	35.93	1.48	312	31-40	35.95	1.47	620	31-40	35.94	1.47
A II	308	22-29	25.54	1.30	312	22-29	25.66	1.21	620	22-29	25.60	1.25
P	308	19-23	20.58	0.89	312	18-23	20.57	1.02	620	18-23	20.58	0.96
sp. br	200	37-45	41.74	1.63	200	39-46	41.68	1.59	400	37-46	41.71	2.61
vertebrae (*vt*)	308	54-58	56.26	0.74	312	54-58	56.26	0.75	620	54-58	56.26	0.75

Table 3. Characteristics of taxonomic characters of southern blue whiting from New Zealand Falkland fishing grounds

Character	Males				Females				Males and females			
	n	range	*M*	δ^2	*n*	range	*M*	δ^2	*n*	range	*M*	δ^2
Biometric characters (in % of fork length)												
Total length (*longitudo totalis*)	150	103.06-106.22	104.75	0.53	170	102.71-106.48	104.63	0.54	320	102.71-106.48	104.69	0.54
Body length (*longitudo corporis*)	150	85.86-97.86	94.45	1.75	170	89.75-97.18	94.84	1.22	320	88.36-98.00	94.61	1.19
Body height (*latitudo corporis*)	150	12.30-23.33	17.52	1.91	170	11.63-24.41	19.34	2.48	320	11.63-24.41	18.49	2.40
Head length (*longitudo capitis*)	150	14.80-22.78	20.77	1.26	170	18.07-22.60	20.62	0.68	320	14.80-22.78	20.69	1.00
Head width (*latitudo capitis*)	150	7.27-10.00	8.46	0.46	170	7.31-10.29	8.46	0.53	320	7.27-10.29	8.46	0.50
Eye spacing (*latitudo frontis*)	150	4.24-5.97	4.97	0.32	170	4.00-5.73	4.98	0.31	320	4.00-5.97	4.98	0.31
Eye diameter (*diameter oculi*)	150	4.15-6.55	5.45	0.47	170	4.07-6.19	5.22	0.42	320	4.07-6.55	5.33	0.46
Length from the tip of the snout to the origin of the forst dorsal fin (*longitudo praedorsalis*)	150	29.75-33.48	31.67	0.84	170	28.93-34.35	31.69	0.89	320	28.93-34.35	31.68	0.87
Length from the tip of the snout to the anys (*longitudo praeanalis*)	150	30.17-34.74	32.13	0.89	170	28.93-35.51	32.50	0.96	320	28.93-35.51	32.33	0.94
Meristic characters												
D I	150	11-13	12.22	0.68	170	11-14	12.22	0.69	320	11-14	12.22	0.69
D II	150	11-15	12.28	0.82	170	11-14	12.09	0.78	320	11-15	12.18	0.81
D III	150	22-26	23.86	1.00	170	22-27	24.07	1.09	320	22-27	23.97	1.05
A I	150	33-40	36.40	1.40	170	33-40	36.34	1.36	320	33-40	36.37	1.38
A II	150	23-28	25.33	1.03	170	22-28	25.35	1.14	320	22-28	25.34	1.09
P	150	18-23	20.23	1.04	170	18-23	20.21	0.92	320	18-23	20.22	0.98
sp. br	150	38-47	42.00	1.72	170	38-46	42.35	1.63	320	38-47	42.18	1.68
vertebrae (*vt*)	150	56-58	56.17	0.40	170	55-58	56.21	0.46	320	55-58	56.19	0.44

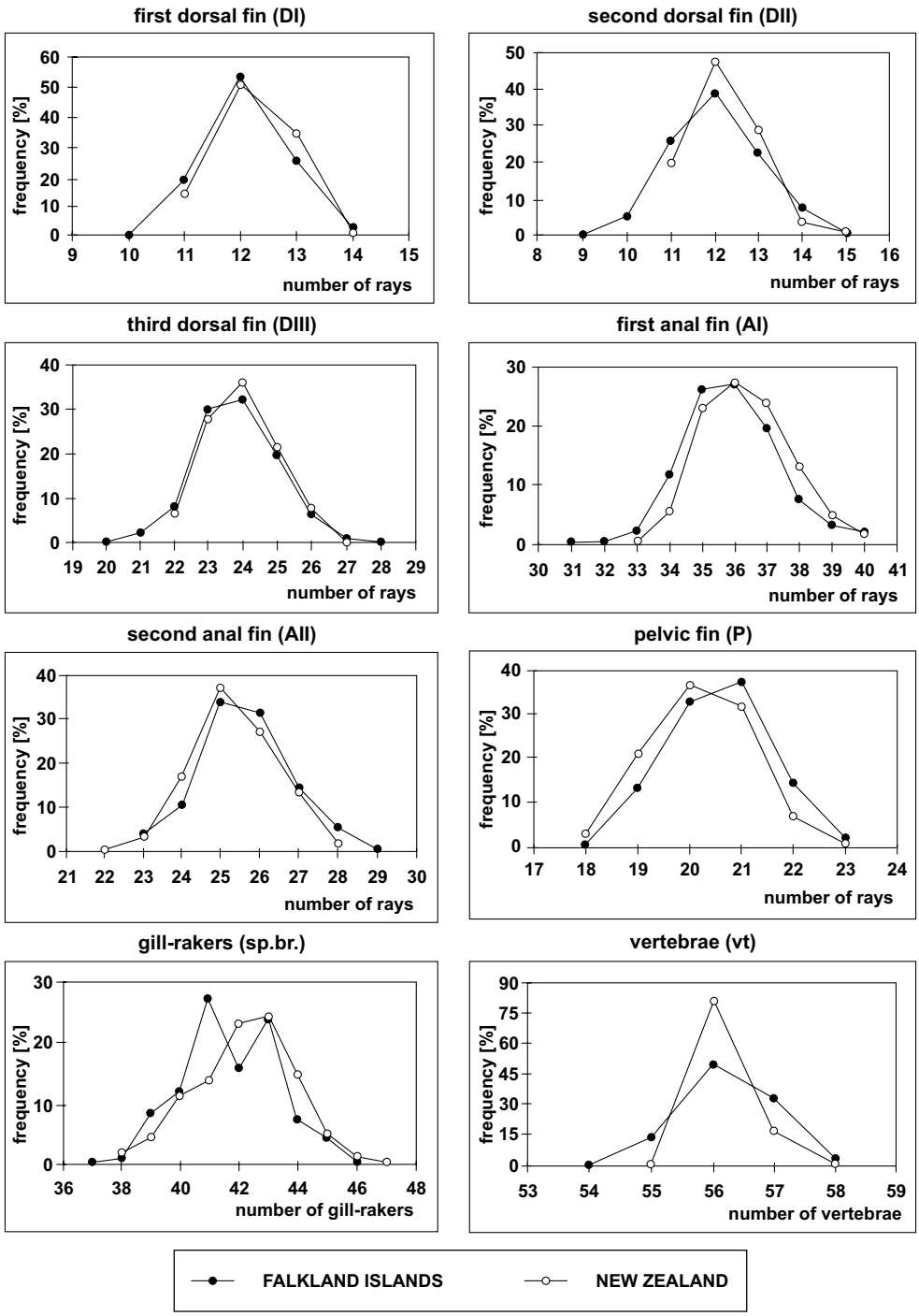

Fig. 2. Distribution of frequency of meristic characters in populations of southern blue whiting in both investigation areas

average number of radii in the second dorsal fin (D II) and in the first anal fin (A I). The average number of gill-rakers (sp. br.) and vertebrae (vt.) was greater for females, but the average values of other meristic characters were similar.

The comparative analysis of specimens of both sexes carried out using the t-Student test revealed that males and females differ in body length and height, eye diameter and length from the tip of the snout to the anus. These parameters are expressed in Table 4 as the percentage of fork length. The average number of radii in the first dorsal fin is also given.

The comparison of biometric characters of males from both populations revealed that those from New Zealand are characterized by higher average values of total length, body height, head length and width, eye spacing and diameter, while the Falkland males are characterized by higher average values of body length and the lengths from the tip of the snout to the origin of the first dorsal fin and from the tip of the snout to the anus.

The t-Student test revealed that males from both populations differ in seven of the nine biometric characters investigated. Only in the case of body length and the length from the tip of the snout to the anus were no differences confirmed (Table 4).

The results obtained from the M_{diff} test revealed that the indices of such characters as total length, head length and width, eye spacing and diameter and the length from the tip of the snout to the origin of the first dorsal fin, expressed as the percentage of fork length, differentiate the males of the two populations. The CD test results revealed that the differentiation of eye spacing is at the level of the subspecies. However, the results obtained from the CD test may not be correct, since the high test values might have resulted from differentiation in characters such as head length and width and eye diameter.

Comparative analyses of meristic characters revealed that in five cases, namely the first, second and third dorsal fins (D I, D II, D III), the second anal fin (A II) and the number of gill-rakers (sp. br.), the averages were higher among males from New Zealand, while the average number of radii in anal fin II, pectoral fin and the number of vertebrae were higher among Falkland males.

The t-Student test revealed that the males of both populations differ in the average number of radii in the first dorsal fin (D I), the second anal fin (A II) and the pectoral fin (P). Other tests (M_{diff},CD and Ginsburg test) did not reveal any differentiation.

The comparison of the average values of biometric characters of females from both populations revealed that only the length from the tip of the snout to the origin of the first dorsal fin was greater in the Falkland females. All other average values were higher for the females from New Zealand.

The t-Student test revealed that indices (expressed as the percentage of fork length) of seven of the nine characters investigated, including total length, the length from the tip of the snout to the origin of the first dorsal fin, body height, head length and width, eye spacing and diameter, differed among the females of both populations (Table 4).

The results of the M_{diff} test revealed differentiation of the same characters among the females of both populations as was obtained by the t-Student test. The CD test indicated only eye spacing as a character which could differentiate the two populations. As was the case with the males, the CD test results raise doubt as they probably resulted from the above mentioned differentiation of the other head parameters which were investigated.

The comparative analysis of the meristic characters revealed that the average values of characters of females from New Zealand and the Falkland Islands were higher than the average values obtained for the same characters in the males of both populations.

The t-Student test indicated that females of both populations differ in the average number

Table 4. Results obtained from statistical tests which determine southern blue whiting differentiation for both males and females within one population and both males and females and their combined representation for both populations

Characters	Males and females		Males from both populations				Females from both populations				Males and females from both populations			
	Falkland	New Zealand												
	t	*t*	*t*	M_{diff}	Ginsburg	CD	*t*	M_{diff}	Ginsburg	CD	*t*	M_{diff}	Ginsburg	CD
Biometric characters (in % of fork length)														
Total length (*longitudo totalis*)	0.22	1.92	*10.70*	*10.41*	·	0.50	*9.22*	*9.18*	·	0.43	*13.98*	*13.76*	·	0.46
Body length (*longitudo corporis*)	1.14	*2.30*	0.78	0.70	·	0.04	1.67	1.61	·	0.08	0.53	0.48	·	0.02
Body height (*latitudo corporis*)	*4.10*	*7.37*	*6.32*	4.75	·	0.24	*7.02*	*8.66*	·	0.42	*9.38*	*9.53*	·	0.33
Head length (*longitudo capitis*)	0.00	1.31	*4.75*	*6.32*	·	0.31	*8.73*	*7.06*	·	0.32	*9.48*	*9.40*	·	0.31
Head width (*latitudo capitis*)	0.02	0.15	*14.40*	*14.40*	·	0.68	*13.50*	*13.39*	·	0.61	*19.70*	*19.58*	·	0.64
Eye spacing (*latitudo frontis*)	0.98	0.18	*38.20*	*37.22*	·	*2.39*	*39.02*	*37.86*	·	*2.36*	*54.68*	*52.89*	·	*2.37*
Eye diameter (*diameter oculi*)	1.83	*4.60*	*14.98*	*14.98*	·	0.72	*13,54*	*13,42*	·	0.62	*19.73*	*19.65*	·	0.66
Length from the tip of the snout to the origin of the forst dorsal fin (*longitudo praedorsalis*)	0.09	0.20	*8.68*	*8.68*	·	0.60	*7.77*	*7.77*	·	0.53	*11.59*	*11.60*	·	0.56
Length from the tip of the snout to the anus (*longitudo praeanalis*)	0.40	*3.55*	1.45	1.37	·	0.09	1.67	1.53	·	0.10	0.39	0.37	·	0.02
Meristic characters														
D I	1.64	0.05	*2.04*	2.11	85.74	0.10	1.11	1.13	95.42	0.05	*2.31*	2.31	91.11	0.08
D II	0.63	*2.13*	*2.63*	2.64	81.67	0.12	1.06	1.14	87.05	0.05	*2.61*	2.61	89.90	0.09
D III	1.58	1.79	1.12	1.16	94.26	0.06	1.57	1.64	89.23	0.08	*1.98*	2.06	95.82	0.07
A I	0.17	0.42	*3.29*	3.30	83.82	0.16	*2.87*	2.87	86.24	0.14	*4.36*	4.37	89.16	0.15
A II	1.55	0.16	1.59	1.86	88.79	0.09	*2.74*	2.74	90.86	0.13	3.11	3.24	90.78	0.11
P	0.55	0.14	3.54	3.54	85.11	0.18	*3.96*	3.97	86.90	0.19	*5.34*	*5.34*	86.14	0.18
sp. br	0.34	1.85	1.46	1.46	80.17	0.08	3.97	3.97	80.74	0.21	3.86	3.86	82.19	0.15
vertebrae (*vt*)	0.06	0.66	1.38	1.68	65.37	0.08	0.84	0.96	71.50	0.04	1.56	1.82	68.90	0.06

Numbers which describe statistically significant differentiation are given in italics

of radii in anal fin I and II, the pectoral fin and the number of gill-rakers. Similarly to those of the males, the results of other tests (M_{diff}, Ginsburg and CD) did not indicate any taxonomic differentiation.

The analysis of representations of both sexes indicated that the blue whiting from New Zealand was characterized by higher average values of biometric characters (except for the length from the tip of the snout to the origin of the first dorsal fin) (Table 3).

Results of the t-Student test revealed that the indices of seven of the nine biometric characters of blue whiting from both populations vary. The exceptions are body length and the length from the tip of the snout to the origin of the first dorsal fin. The results obtained from the M_{diff} test were identical (Table 4).

Investigations of meristic characters revealed that the average number of radii in the three dorsal fins (D I, D II, D III), the first anal fin (A I) and the number of gill-rakers (sp. br.) was higher for blue whiting from the New Zealand spawning grounds. The Falkland blue whiting were characterized by a greater number of radii in anal fin II (A II), the pectoral fin (P) and a greater number of vertebrae (vt.). With the exception of the number of vertebrae, the t-Student test results indicated that these differences were statistically insignificant. The M_{diff} test determined that the two populations were differentiated by the number of radii in the pectoral fin (P). The CD and Ginsburg tests did not reveal any differentiation in any of the taxonomic characters (Table 4).

DISCUSSION

The results of investigations of the taxonomic characters of the southern blue whiting are rarely found in the literature. In the available literature, the results of investigations of selected taxonomic characters usually focus on the biological description of the species [Michiejew 1965, Szust 1969, Szubnikow *et al.* 1969, Szust and Silyanova 1971, Żukowski and Liwoch 1977, Więcaszek 1988]. Only three publications [Inada and Nakamura 1975, Szpak 1975, Szust 1978] include the comparative analysis of the southern blue whiting from the areas of the Patagonian Shelf and New Zealand. This work includes the analyses of many characters which was based on more abundant investigative material than was used by the above mentioned authors. Additionally, the current investigations were carried out over a period of two subsequent years, at the same time during the spawning period in the areas where both of the southern blue whiting populations occur.

The results of the investigations of biometric characters obtained by the author are comparable with those obtained by Inada and Nakamura [1975]. Both populations are differentiated with respect to such characters as body height, head length and width, eye spacing and diameter. These characters are expressed as the percentage of fork length. The females from New Zealand had higher values for most of the characters above which were investigated. Inada and Nakamura also state that for the Falkland blue whiting the length of the upper and lower jaw and the eye diameter decreased proportionally as head size decreased. The t-Student and M_{diff} test results for biometric characters indicated that the differentiation between the two populations allowed for their division. However, the CD test revealed that only eye spacing differentiation was on a level that warranted subspecies division. It must be remembered, that such high values obtained from the CD test might have been the result of the differentiation of characters such as head length and width and eye diameter. Therefore, the results obtained from the tests did not provide any

basis for the subspecific differentiation of the two populations.

The results of investigations of the number of rings in dorsal fins in both populations were comparable to those obtained by other authors [Szust 1971, Szubnikow *et al.* 1969, Szpak 1975, Żukowski and Liwoch 1977, Więcaszek 1988]. The average number of rings in each of the fins was slightly lower than that obtained by Inada and Nakamura [1975]. Also, the comparison of the two populations gave slightly different results. Unlike the author, Inada and Nakamura confirmed that the average number of rings in the first dorsal fin (D II) was higher for blue whiting from the Patagonian Shelf.

The results of the author's observations concerning the number of radii in both the anal fins (A I, A II) and the pectoral fin (P), like those of the dorsal fins (DI, D II, D III), varied from results obtained by Inada and Nakamura [1975], whose observations indicated a higher average number of radii in each kind of fin. Inada and Nakamura also confirmed, in contradiction to the present findings, that blue whiting from New Zealand were characterized by a greater number of radii in anal fin II (A II). The variance in results might have been caused by the quantitative difference of the research samples. The average values were very similar, though, while the modal values for two fins, the dorsal (D II) and the anal (A II), were identical.

The number of gill-rakers at the first arch (sp. br.) is a very important meristic feature. According to Szust [1978], this differentiation was the reason for the species division of the two both representatives of the *Micromesistius* genus. The results presented in this paper correspond to those obtained by Inada and Nakamura [1975], despite their slightly higher average values. The two peak frequency curve of the number of gill-rakers for blue whiting from the Falkland Islands area indicates the non-homogeneity of the Atlantic blue whiting population. The results obtained by Szust [1971] for the Scotia Sea, Żukowski and Liwoch [1977] and by Więcaszek [1988] from the area of the Patagonian Shelf confirm this thesis.

The author obtained different average numbers of vertebrae (vt.) from the specimens of both populations than did Inada and Nakamura [1975], who stated that blue whiting from New Zealand had, on average, 1.5 vertebrae more. However, Inada and Nakamura based their results on a total of 29 specimens from both regions.

The differentiation of all the meristic characters which were measured for various populations of the same species is widely documented in the literature. This variability is influenced by genetic background and environmental conditions, such as water temperature [Jordan 1891] and salinity [Schmidt 1917]. A greater range of character variety was characteristic of the blue whiting from around the Falkland Islands; this is probably due to the great geographical area which the blue whiting inhabits. Many researchers, including Norman 1937, Hart 1946, Szubnikow *et al.* 1969, Fisher and Hureau 1985, Marti 1969, Michiejew 1965, Basałajew and Pietuchow 1969, Szust and Silyanowa 1971, Skóra and Sosiński 1983 and Sosiński and Skóra 1985, have described this area as reaching from the latitude 40°S to the Antarctic Circle. According to the Jordan rule [1891] there is a dependence between the number of vertebrae and geographical latitude. This rule is confirmed by the distribution of vertebrae frequency which was more sustainable (greater variability) among blue whiting from the area around the Falkland Islands. Krzykawski [1988], while describing the variability of taxonomic features of Greenland halibut (*Reinhardtius hipoglossoides* Walbaum, 1792), found that the Jordan rule can be applied to the differentiation of other meristic features, except for the number of gill-rakers. Although this phenomenon was not clearly observed in the blue whiting, it was apparent in the number of radii in both dorsal and anal fins.

The results of the investigations did not indicate any character which could definitively differentiate the specimens of the two populations. The differences between the average values

of biometric features, expressed as the percentage of fork length, and the average meristic values did not exceed the limits accepted by other authors for the differentiation of ecological character. Inada and Nakamura [1975], while describing the environmental conditions in which both populations existed, observed that the New Zealand blue whiting preferred waters whose salinity range was narrower than the range in the water inhabited by blue whiting from the Patagonian Shelf. This differentiation is well explained by the results obtained by Schmidt [1917], who proved the impact of salinity on the variability of the number of vertebrae and by the conclusions drawn by Krzykawski [1988] regarding the impact of environmental parameters on other meristic features.

In summarizing their work, Inada and Nakamura [1975] confirmed that the differentiation of both populations was very small. Yet, they divided the populations into separate subspecies. According to them, the small degree of differentiation resulted from the short period which had passed from the time of migration in the interglacial period. Time is relative on the evolutionary scale; therefore, this parameter is difficult to verify and interpret. In accordance with the hypothesis concerning distribution directions of fish from the *Gadiformes* Svetovidov [1940] order, it was determined that migrations from the area of today's North Sea to the Pacific started in the Miocene period. Svetovidov indicated that the migration took place through the Bering Scharacters in the sub-polar area. According to Ekman [1953], Olsson [1972] and Pearson [1978] the migration took place along the east coast of North America. Akazaki [1962] suggested that the fish migrated to the Pacific through the so-called Panama land which was under water in periods between the early and late Pliocene period. Inhabitation of the southern Atlantic occurred due to migrations of fish from the Pacific around Cape Horn. The above theories concerned fish from the *Merlucciidae* family [Inada, 1981], but Angelescu *et al.* [1958] stated that these theories worked for fish of other representatives of the *Gadiformes* order (*Macruronus, Genypterus, Callorhynchus*). Schwartzhans [1978] was of another opinion concerning the migrations of fish from the *Micromesistius* genus. In his opinion these fish migrated to the southern Atlantic along the east coast of South America. Despite such a variety in interpretations concerning the directions of fish migrations, all scientists agreed with the hypothesis that the inhabitation of waters around New Zealand resulted from migrations of *Gadiformes* from waters surrounding the coasts of Southern America in the interglacial period. The time that has since passed (it is from this supposition that relativity is introduced) was sufficient to fully shape another species of the *Gadiformes* order, such as *Macruronus novaezealandiae*, and insufficient to differentiate others, like *Genypterus blacodes*. Therefore, reasoning that the lack of population differentiating characters is the result of insufficient time is not very convincing.

Mayr [1974] regarded the subspecies as "… a group of natural populations which inhabit a geographical sub-unit of the area in which the species occurs and which differ in taxonomy from other populations of this species". Commenting on this definition, Matile *et al.* [1993] added that, in practice, it allows for the type of differentiation which is not limited only to the verification of tags which indicate the place a fish was caught. Additionally, this definition should be supported by a statement regarding at least the partial separation of the genotype of a particular population. This separation should be revealed by partial noncompliance while interbreeding. This noncompliance is impossible to prove due to a lack of contact between populations.

CONCLUSIONS

- The comparative analysis of 17 taxonomic characters revealed that the degree of differentia-

tion of the characters did not exceed the standards of intra-species variability.

- The differentiation among the blue whiting of both populations did not vary in character much from the differences between populations of fish of the same species which are described in the literature. Therefore, the author concluded that there is no basis for the subspecific division of the populations of blue whiting from the New Zealand and Falkland spawning grounds.

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Larval stages of helminths in fish from the Vistula Lagoon and the Gulf of Gdańsk in relation to bird occurrence

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Abstract. A total of 5, 835 specimens of fish belonging to three families, Cyprinidae, Percidae and Gasterosteidae, were examined from January 1993 to March 1997. Sixteen species of parasites in the larval stage were observed and identified. The parasite species included: *Digenea* (*Diplostomum helveticum*, *Diplostomum spathaceum*, *Diplostomum paracaudum*, *Tylodelphys clavata*, *Ichthyocotylurus platycephalus*, *Ichthyocotylurus variegatus*, *Apatemon annuligerum*, *Posthodiplostomum cuticola*, *Posthodiplostomum brevicaudatum*); *Cestoda* (*Diphyllobothrium ditremum*, *Ligula intestinalis*, *Schistocephalus solidus*, *Paradilepis scolecina*); *Nematoda* (*Eustrongylides mergorum*) and *Acanthocephala* (*Corynosoma strumosum*, *Corynosoma semerme*). Based on the results which were obtained and on data regarding the occurrence of birds in the investigated areas, it can be stated that birds of the Laridae family play the greatest role in helminth circulation followed by those from the Podicipedidae, Phalacrocoracidae and Anatidae families.

Key words: helminths, fish, birds, the Vistula Lagoon, the Gulf of Gdańsk

INTRODUCTION

A comparatively large body of knowledge concerning the helminths of fish from the waters of the Vistula Lagoon and the Gulf of Gdańsk exists. However, there is not much data concerning the parasites of other vertebrates.

In the present work, it was decided to use data regarding larval stage helminths in fish to determine the potential bird species which are the most numerous final hosts of these parasites. Ichthyophagous birds are an indispensable link in the life cycle of many helminth species.

MATERIALS AND METHODS

A total of 5,835 fish, 3,431 from the Gulf of Gdańsk and 2,404 from the Vistula Lagoon, were examined from January 1993 to March 1997. The fish belonged to three families: Cyprinidae, Percidae and Gasterosteidae (Table 1). In the Vistula Lagoon, these families were represented

Table 1. Numbers fish species examined

Fish species	Gulf of Gdańsk	Vistula Lagoon
Gasterosteus aculeatus /stickleback	2880	8
Rutilus rutilus / roach	34	389
Pelecus cultratus / sichel	-	322
Abramis brama / common bream	47	376
Carassius auratus gibelio / german carp	-	101
Tinca tinca / tench	-	39
Alburnus alburnus /bleak	-	29
Blicca bjoercna / white bream	-	31
Vimba vimba / vimba bream	-	5
Aspius aspius /asp	-	7
Scardinus erythrophthalmus / rudd	-	4
Leuciscus idus / ide	-	1
Leuciscus leuciscus /dace	-	1
Stizostedion lucioperca / pikeperch	189	390
Perca fluviatilis / perch	281	371
Acerina cernua / ruffe	-	330
Total	3,431	2,404

by the common species of bream, roach, sichel, pike-perch, perch and ruffe and in the Gulf of Gdańsk by stickleback.

The fish originated from different regions of the Gulf of Gdańsk and the Vistula Lagoon (Fig. 1).

Both bodies of water are estuarine water reservoirs which are constantly influenced by the inputs of fresh and salty waters. According to data from the State Institute of Meteorology and Water Management in Gdynia, during the investigation period the average salinity in the Gulf of Gdańsk was 7‰ and in the Vistula Lagoon it was 2.7 ‰.

Cyprinid and percoidean fish were supplied by fishermen and Gasterosteidae were caught using minnow nets.

The parasites obtained were fixed in Berland fluid (acetic acid and formalin, 95:5) and then preserved in 70% alcohol. In order to determine the taxonomic classification of the parasites total preparations were made. Digenea, Cestoda and Acanthocephala were later colored in carmine alun acid and dehydrated successively in 50%, 70%, 85% alcohol, then twice in 96% alcohol, cleared in beechwood creosote and mounted in Canada balsam. The nematodes were exposed to lactophenol and placed in glycerin jelly.

RESULTS

Sixteen parasite species were identified. Digenea dominated over Cestoda, Nematoda and Acanthocephala.

The morphological and anatomical similarities of metacercariae of the genus Diplostomum can make identification and classification difficult (Graczyk 1992, Laskowski 1996, Niewiadomska 1996, Niewiadomska and Szymański 1991). The Diplostomum specimens were identified to the genus level, and some of the metacercariae were identified to the species level, including *Diplostomum helveticum*, *D. spathaceum* and *D. paracaudum*. These

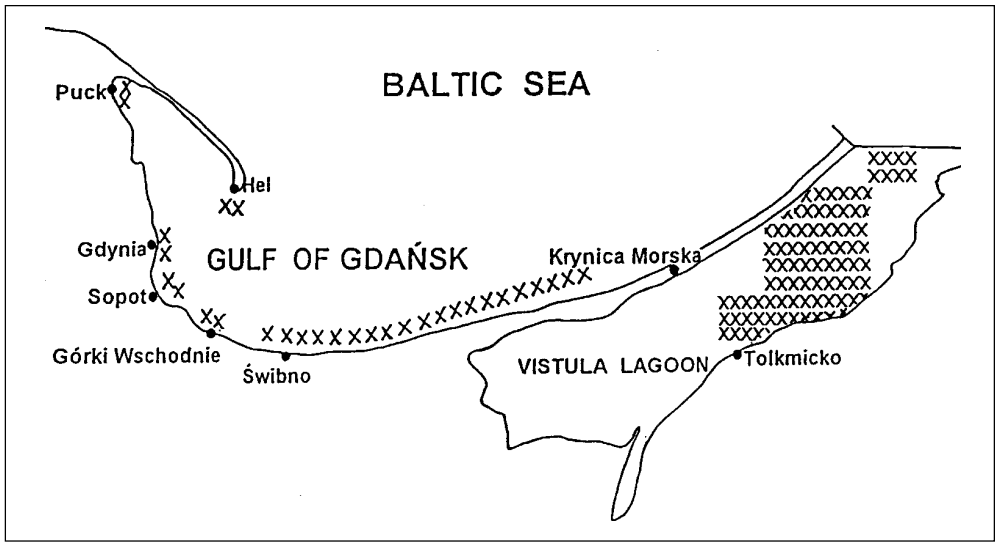

Fig. 1. Capture areas of fish for investigations (x)

Table 2. Prevalence [%] and mean intensity [ind.] of parasitic infestation of fish from Gulf of Gdańsk

Parasite/fish	Stickle-back	Common Bream	Roach	Pike perch	Perch
DIGENEA					
Diplostomum spp.	3.9/3.3	25.5/4.7	23.5/2.5	2.6/3.8	7.1/14.9
Tylodelphys clavata	-	12.8/2.2	52.9/1.7	2.1/3	32.4/45.2
Ichthyocotylurus platycephalus	-	-	-	1.6/3.7	1/3
Apatemon annuligerum	15.4/2.6	-	-	-	1.7/1.6
CESTODA					
Diphyllobothrium ditremum	0.7/2.9	-	-	-	-
Ligula intestinalis	-	17/1.1	-	-	-
Schisthocephalus solidus	6.3/1.2	-	-	-	-
NEMATODA					
Eustrongylides mergorum	0.07/1.5	-	-	-	-
ACANTHOCEPHALA					
Corynosoma strumosum	-	-	-	0.5/1	-
Corynosoma semerme	-	-	-	1/1	-

-: no infested fish

three species were from roach, bream, sichel and perch. The presence of other species of metacercariae cannot be ruled out. Due to the more than 20,000 parasite specimens which were collected, it was very difficult to identify all the species.

There were 12 helminth species from the Gulf of Gdańsk and 15 from the Vistula Lagoon (Tables 2, 3a and 3b). These were larvae which occur in the adult stage in the digestive tracts of ichthyophagous birds. The exceptions are *Corynosoma semerme* and *C. strumosum*, which usually live in the intestines of sea mammals. Birds act only as paratenic hosts for these acanthocephalans.

DISCUSSION

About 80 species of breeding birds, both migratory and non-migratory, live in the Gulf of Gdańsk and the Vistula Lagoon regions. Seventeen are birds of prey, of which fifteen are ichthyophagous and five are polyphagous species (Table 4). The other species are phytophagous, benthophagous and entomophagous, which occasionally feed on fish. A significant role in the circulation of helminths in the waters of the Gulf of Gdańsk and the Vistula Lagoon is played by ichthyophagous birds.

Until now, only a few parasite species which occur in the larval stage in fish have been identified in birds inhabiting the Gulf of Gdańsk. These include *Diplostomum commutatum* (Digenea) in common terns, *Diplostomum spathaceum* (Digenea) in common gulls (Markowski 1933a) and black-headed gulls (Cichowlas 1961), *Apatemon gracilis* (Digenea) in long-tailed ducks, *Cryptocotyle concavum* (Digenea) in long-tailed ducks (Sulgostowska and Grytner-Zięcina 1973 and 1974), velvet scoters and eiders (Grytner-Zięcina and Sulgostowska 1978) and *Diphyllobothrium dendriticum* (Cestoda) in common terns (Markowski 1933a). The helminths noted in the birds from the Vistula Lagoon were *Diplostomum baeri* (Digenea) in black-headed gulls, *Diplostomum spathaceum*, *Apophallus muhlingi* and *Mesorchis pseudoechinatus* (Digenea) in great black-backed gulls, lesser black-backed gulls, common gulls and black-headed gulls, and *Cryptocotyle concavum* (Digenea) in common gulls, great black-backed gulls and black-headed gulls (Malczewski 1964). Okulewicz and Rokicki (1998) found the nematod *Contracaecum micropapillatum* in cormorants from the Gulf of Gdańsk and the Vistula Lagoon. However, only metacerkariae *Cryptocotyle concavum* in deepsnouted pipefish (*Syngnathus typhle*) and sand goby (*Pomatoschistus minutus*) were confirmed in the Gulf of Gdańsk (Markowski 1933b and 1935). The presence of Digenea from the genus *Diplostomum spp.* was noted.

It was revealed that Digenea from the genus *Diplostomum* and *Tylodelphys clavata* most often appear in the cyprinid, percoidean and Gasterosteidae fish of the Gulf of Gdańsk and the Vistula Lagoon (Tables 2, 3a and 3b). *Diplostomum* were observed in all the examined species of fish, and the most infested were bream, roach and stickleback. According to the literature, *Diplostomum spp*. has a wide range of hosts which includes over 125 species of fish belonging to many families, including, among others, Cyprinidae, Percidae and Gasterosteidae (McKeown and Irwin 1995). Specimens of adult *Diplostomum* were noted in four bird orders and Charadriiformes, mainly from the suborder Larii, were most often infested (Niewiadomska 1996, Shigin 1996). The metacercariae *Tylodelphys clavata* settle in the corpus vitreum of percoidean fish, mostly perch (Kennedy and Burrough 1977, Pojmańska *et al*. 1980); many authors also report high infestation levels in some cyprinids (Kozicka 1959, Pojmańska *et al.* 1980). In the current work, the highest infestation values were noted in roach and perch in the Gulf of Gdańsk and in the Vistula Lagoon. Adult specimens of *T. clavata* were noted in birds from the genus *Podiceps* (Kozicka and Niewiadomska 1960). High infestation coefficients of these species in the fish in Gulf of Gdańsk and the Vistula Lagoon result from their wide occurrence in, among others, their final hosts. *Diplostomum spp*. infest birds of the genus *Larus* and *Phalacrocorax*, and *Tylodelphys clavata* infest birds of the genus *Podiceps podiceps*. From the observations of Kozakiewicz *et al.* (1997), Meissner and Goc (oral information, University of Gdańsk) it appears that the above mentioned genera of birds represent only several species of the great number which occur in the Gulf of Gdańsk and Vistula Lagoon regions. It should also be added, that the fish which are intermediate parasite hosts belong to species commonly occurring in the waters of the Gulf of Gdańsk and the Vistula Lagoon.

Table. 3a. Prevalence [%] and mean intensity [ind.] of parasitic infestation of cyprinids from Vistula Lagoon

Parasite/fish	Common bream	Roach	Sichel	German carp	Tench	Bleak	White bream	Vimba bream	Asp	Rudd	Ide	Dace
DIGENEA												
Diplostomum spp.	84.3/ 35.4	8.3/ 17.9	24.7/1.7	28.7/ 2.4	7.7/ 2	*/ 2	9.7/ 84	*/ 32	*/ 6.8	*/ 51.7	*/ 90	*/ 190
Tylodelphys clavata	14.9/7.8	69,9/ 27,6	-	1/ 2	2.6/ 1	-	3.2/ 7	-	*/ 5	-	*/ 41	-
Ichthyocotylurus platycephalus	6.1/ 3.7	0,5/ 2,5	-	-	-	-	-	*/ 1	-	-	*/ 3.0	-
Posthodiplostomum cuticola	17.8/ 8.6	26.5/ 6.7	0.6/ 1	3/ 1.7	-	-	9.7/ 4.0	-	-	-	-	*/ 6
CESTODA												
Ligula intestinalis	9.3/ 1.5	1/ 1	6/1.3	-	-	-	19.4/ 1.2	-	-	-	-	-
Paradilepis scolecina	0.3/ 1	0.8/ 5.7	-	-	5.1/ 2.5	-	-	-	-	-	-	-
NEMATODA												
Eustrongylides mergorum	-	-	-	-	-	-	-	-	*/ 1	-	-	-

Table 3b. Prevalence [%] and mean intensity [ind.] of parasitic infestation of stickleback and percoids from Vistula Lagoon

Parasite/fish	Stickleback	Pikeperch	Perch	Ruffle
DIGENEA				
Diplostomum spp.	*/ 7	5.4/ 4.3	11.6/ 5	8.8/ 3.6
Tylodelphys clavata	*/ 2	2.8/ 1.8	53/ 44	0.6/ 8.5
Ichthyocotylurus platycephalus	-	4.4/ 2.1	1.3/ 2	2.1/ 9.4
Ichthyocotylurus variegatus	-	-	3.8/ 2.4	0.3/ 1
Apatemon annuligerum	*/ 2	-	5.1/ 3.7	-
Posthodiplostomum brevicaudatum	-	-	3.8/ 5.7	-
CESTODA				
Ligula intestinalis	-	-	-	-
Schistocephalus solidus	*/ 1	-	-	-
NEMATODA				
Eustrongylides mergorum	*/ 2	-	-	22.1/ 1.1
ACANTHOCEPHALA				
Corynosoma strumosum	-	0.8/ 1	-	-
Corynosoma semerme	-	0.5/ 1	-	-

*: due to low specimen numbers (<30)prevalence disregarded, -: no infested fish

Of the six cyprinid species in the Vistula Lagoon in which *Posthodiplostomum cuticola* was found, the most infested were bream and roach (Table 3a). Similarly, Kozicka (1958 and 1963) and Kennedy (1974) observed these metacercariae mostly in cyprinids. The final hosts of this parasite are birds from the Ardeidae family, which occur in the Vistula Lagoon (Goc and Iliszko 1993, Tomiałojć 1990). The lack of parasites in the fish of the Gulf of Gdańsk may result from the sporadic occurrence of their final hosts and of the hosts of parthenogenetic generations of freshwater *Gastropoda* from the genus *Planorbis*. For the sake of comparison, Grabda-Kazubska and Batro-Warszawska (1987) obtained a prevalence of over 60% in bream, roach, rudd and white bream in the freshwater Lake Dgał.

Parasites from the genus *Ichthyocotylurus* were noted in perch and pike-perch in the Gulf of Gdańsk (Table 2) and in bream, roach, vimba bream, ide and in all the percoids in the Vistula Lagoon (Table 3a, 3b). They have a wide range of intermediate hosts among various species of freshwater fish (Bauer 1987). Attention should also be drawn to the fact that the host of the parthenogenetic generation of this parasite is the fresh-water snail *Valvata piscinalis*, a species which is rare in both the gulf and the lagoon in spite of the commonness of its final host, the gull. Thus, the infestation level of fish here is lower than is typical in freshwater reservoirs. For example, in the Vistula River near Warsaw, the infestation of bream was 83% (Reda 1987) and in the Konin lake complex it was over 50% (Pojmańska *et al.* 1980).

The next parasite, *Apatemon annuligerum*, occurred in perch, which is convergent with the observations of Kozicka (1972), and in stickleback (Table 2, 3b). This parasite is classified as a freshwater species since it inhabits mainly freshwater. This is why the level of infestation in the brackish waters of the Gulf of Gdańsk and Vistula Lagoon regions is clearly lower than that in freshwater reservoir, where infestation can even reach 100% (Lukyantseva 1976). It must be mentioned that *A. annuligerum's* final host is Anatidae, which occur widely in the area under investigation (Goc and Iliszko 1993, Meissner and Skakuj 1990, Tomiałojć 1990, Zyska *et al.* 1990).

Ligula intestinalis plerocerkoids were observed in the bream of the Gulf of Gdańsk (Table 2) and in the bream, roach, sichel and white bream of the Vistula Lagoon (Table 3a). This tapeworm is a common parasite in cyprinids (Kennedy and Burrough 1981, Sweeting 1976). In Poland it occurs most frequently in bream, roach and rudd (Kwiatkowski and Pokora 1995). In freshwater, the degree of fish infestation often reaches 100% (Bryliński 1970). The final hosts of this tapeworm include Laridae, Podicipedidae, Anatidae, all of which occur on a massive scale in the investigated region. This is also why a lowered infestation level is observed in the fish in the brackish waters of the Gulf of Gdańsk and the Vistula Lagoon; this may result from the rare occurence of this tapeworm's first intermediate host, namely, freshwater crustacean species.

The plerocerkoid *Schistocephalus solidus* occurred only in stickleback (Table 2, 3b), which, in the opinion of Solonchenko (1982), is its main host. The adult stages of this tapeworm were found, similarly to *Ligula intestinalis*, mostly in Podicipedidae, Laridae and Anatidae (Bezubik 1956), which, as has been mentioned previously, are common species in the Gulf of Gdańsk and Vistula Lagoon regions. As was the case with *L. intestinalis*, the *S. solidus* tapeworms achieved higher levels of infestation in freshwater, where these levels often reach several tens of percents (Haitlinger and Wolańska 1965).

Larvae of the nematod *Eustrongylides mergorum* were found in the Vistula Lagoon in ruffe (22.1%) and in one specimen each of stickleback and asp (Table 3a, 3b). In the Gulf of Gdańsk this nematode occurred only in stickleback and its infestation level was very low at just 0.07% (Table 2). In spite of the wide-spread occurrence of its final host (including Laridae,

Table 4. Bird species occurrence in Gulf of Gdańsk and Vistula Lagoon (Goc and Iliszko 1993; Goc – pers. comm., University of Gdańsk; Meissner - pers. comm., University of Gdańsk; Tomiałojć 1990; Zyska *et al*. 1990)

Predators/Ichthyophags	Poliphags	Others
Gavia arctica / black-throated diver	*Larus ridibundus* / black-headed gull	*Cygnus olor* / mute swan
Gavia stellata / red- throated diver	*Larus canus* / common gull	*Cygnus cygnus* / whooper swan
Tachybaptus ruficollis / little grebe	*Larus argentatus* / herring-gull	*Anser albifrons* / white-fronted goose
Podiceps cristatus / great crested grebe	*Larus fuscus* / lesser black-backed gull	*Tadorna tadorna* / sheldrake
Podiceps griseigena / red-necked grebe	*Larus marinus* / great black-backed gull	*Anas platyrhynchos* / wild duck
Podiceps nigricollis / black-necked grebe		*Anas penelope* / wigeon
Podiceps auritus / slavonian grebe		*Anas crecca* / teal
Ardea cinerea / common heron		*Anas acuta* / pintail
Mergus merganser / goosander		*Aythya ferina* / pochard
Mergus albellus / smew		*Aythya fuligula* / tufted duck
Mergus serrator / red-breasted		*Bucephala clangula* / goldeneye
Chlidonias niger / black tern		*Clangula hyemalis* / long-tailed duck
Sterna albifrons / little tern		*Melanitta fusca* / velvet scoter
Sterna hirundo / common tern		*Melanitta nigra* / common scoter
Phalacrocorax carbo / cormorant		*Somateria mollissima* / eider
Alcedo atthis / kingfisher		*Fulica atra* / coot
Haliae'tus albicilla / white-tailed eagle		and others

Podicipedidae, Anatidae) and intermediate hosts (*Oligochaeta*), the level of infestation of this parasite in the fish of the gulf and the lagoon is considerably lower than that in the fish of freshwater reservoirs. This is concurrent with the observations of Fagerholm (1982), who observed that 45% of the ruffe in freshwater Finnish lakes were infested.

The remaining helminth larval species (*Diphyllobothrium ditremum*, *Posthodiplostomum brevicaudatum*, *Paradilepis scolecina*, *Corynosoma semerme* and *C. strumosum*) were noted less frequently. It must be added that their final hosts are the following birds: *Phalacrocorax* (for *P. scolecina*), Laridae, Anatidae (for *D. ditremum*) and Ardeidae (for *P. brevicaudatum*). All of these, with the exception of Ardeidae, commonly inhabit the Gulf of Gdańsk and Vistula Lagoon regions. With respect to acanthocephalans, it should be added that the birds act only as paratenic hosts (Petrochenko 1958); thus, these parasites do not reach reproductive maturity in this host. It is improbable that birds, in comparison with other paratenic hosts, are the source of infestation for this parasite's final host, the seal. Therefore, it must be acknowledged that these birds do not provide these acanthocephalans with a link for further development and, as a result, they die.

On the basis of the analysis of larval stages occurring in Cyprinidae, Percidae and Gasterosteidae fish and by relating to this the occurrence of birds in the investigated reservoirs, it was ascertained that in the waters of the Gulf of Gdańsk and the Vistula Lagoon the greatest role in the circulation of parasitic helminths was played by birds from the Laridae, Phalacrocoracidae, Podicipedidae and Anatidae families, of which gulls are one of the most important final hosts for water helminths.

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