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ON CORRELATIONS BETWEEN THE GROWTH OF CERTAIN LAKE FISH SPECIES

UWAGI O KORELACJACH POMIĘDZY WZROSTEM KILKU GATUNKÓW RYB JEZIOROWYCH

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The author determined the correlations in the growth of bream, pike perch, roach, whitefish and small whitefish – Coregonus albula coexisting in lakes. Negative correlations of growth are noted for species of various thermal requirements. The pairs of species playing a similar role in ichthyofauna assemblages of overlapping feeding niches, living in various types of lakes as well as the fish of various sizes demonstrated separate types of growth correlation. The pairs of species forming the relation of "predator – prey" demonstrated special correlations of growth.

INTRODUCTION

Each species reacts individually to the influence of physical environment and biocenotic factors. The ecological problems of determining the dominant factors and the circumstances of their action, have already been widely discussed. Kryžanowski (1949) and Disler, Razničenko, Soin (1965) stressed that an adaptation of fish to reproduction conditions Kryžanowski's selection of the of so called "ecological groups of fish") reflected not only the moments of life in embryonic and larval stages but also influenced the remaining periods. This determines the adaptation to temperature – oxygen conditions and the extent of development of particular senses. **Nikolski** (1947) found that the ichthyofauna of the Russian rivers represented a heterogenic group of species derived in extremal cases from 12 ichthyofaunistic complexes of a different historical age and distribution. Such complexes are characterized not only by the species pecularities but also by the ecological ones. They permit to conclude on the origin of "ecological fish groups". The heterogenity of cyprinid fish, according to the author, results from their phylogenetic development in various complexes of fauna. The species playing the same ecological role (occupying similiar niches) in various complexes exhibit the keenest competition when met in the same biocenosis. **Nilson** (1960) in relation to various salmonid species co-existing in the Swedish lakes and **Želtenkova** (1965) in experiments with larvae of various cyprinid species ascertained the division of feeding niches between the particular species in case of their direct contacts. This illustrates the general ecological rule formulated by **Gause**: one niche for one species. According to **Swärdson** (1953), in case when several forms of whitefish meet in one lake, one of these forms will be discriminated in its growth. In particular lakes, such a discrimination affected various forms of whitefish. **Geyer** (1939) recorded positive correlations between the growth of bream, white bream, roach and rudd (the species of partly overlapping feeding niches) living in the East-Holstein lakes. **Zawisza** (1961) when searching for a similiar dependence of the same species living in lakes near **Węgorzewo**, reported a rather sporadic occurrence of such relationships, i.e., in mesotrophic lakes only. According to **Puchu** (1968), in the south-eastern Estonian lakes the growth of tench, crucian carp and rudd is correlated with the same features of lakes, while the growth of the remaining species discussed by him is correlated with a different group of factors. Several authors: **Šorygin** (1952), **Pliszka** (1953), **Nilson** (1960) among the others point to the fact that the food convergence of fish results frequently from abundance of a defined food in the environment. The fresh-water fishes of moderate latitudes, according to **Larkin** (1956) and **Nikolski** (1967) are characterized by their high degree of euryphagy. **Larkin** assignes this to the instability of fresh water environment (from the geological point of view) while **Nikolski** to the seasonal succession of organisms forming the feeding objects for this fish group.

Even such a fragmentary review of literature proves that the problem of the physical and biocenotic environment influence on the species, when considered in various aspects, gives ambigous results.

The aim of this work was to determine the possibility of deducting, from the growth data of one species about the perspectives for the other ones, in particular: 1) those possessing similar physiological requirements (i.e. of common origin); 2) those living in overlapping feeding niches (i.e. originating from various complexes). The studies are concerned with the correlations of growth between bream, pike perch*, roach*, small whitefish and whitefish. The bream and pike perch represent the Pontocaspian complex, the roach the Boreal one, whitefish and small whitefish the Arctic one. Pike perch is

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***) The materials related to growth of roach and pike perch, worked out by H. Wilkońska, were used in this work.**

a predatorr; small whitefish a specialized plankton feeder; whitefish, bream and roach are the species belonging to the same feeding niches of various complexes.

MATERIAL AND METHOD

An interdependence between the growth of particular fish species during their coexistence in lakes was investigated by the linear correlation method. Various periods of the fish life were considered in relation to various stages of development and to alterations of a habitat to which the fish is subjected during its life cycle. According to Vasnecov (1953), the transition from one stage to another and the subsequent changes of feeding niches are primarily connected rather with attaining the defined sizes than the calendar age. The denotations of growth index of small fish (S), medium size (M) and large ones (L) used in this work in relation to the particular species are explained in Table 1. The probability of occurrence of various interrelations between the growth of the species discussed in different types of environment is considered calculating the correlations between their growth separately in sets of different limnologic types of lakes (according to Stangenberg (1936) and in the entire material. The results were interpreted according to Guilford's (1960) treatment of the correlation coefficients:

r of values < 0.200 – relation of negligible importance;
r of range between 0.200 and 0.400 – relation small, but distinct;
r of range between 0.400 and 0.700 – significant relation;
r of range between 0.700 and 0.900 – considerable relation;
r of range between 0.900 and 1.000 – relation very certain.

According to the author, when evaluating the applicability of correlation coefficinet "r". in tests, the value of coefficient plays a greater role than its significance level. The author considers the generally used levels of significance (0.05 and 0,01) to be too high for the case and suggests to apply of the lower ones. In the present investigation only the relations expressed by their coefficients > 0.200 (±), if their significance level is > 0.1, are interpreted. Lower values of coefficients and particularly their signs were interpreted only when the results obtained from the abundant material had reached the significance level 0.05.

RESULTS

Tables 2 to 9 present the results of calculations of correlation coefficient "r" between the growth of bream, pike perch, roarch, whitefish and small whitefish of various stages of life in lakes of each limnological type and in all the types of lakes combined. The number of sets (n), out of which the results were obtained, was noted and the coefficients with significance levels 0,1 and 0.01 were underlined (the latter with a thick line).

1. Correlations between the growth of species belonging to the same complex.

1.1. Bream – pike perch. In the whole material (Tab. 2) the negative relations between the growth of small pike perch and bream of all sizes are noted. The relations are "distinct" according to the assumed principles of evaluation in case of small and medium

Table 1

Indexes of growth assumed for various periods of fish life

Species	Small (S)	Medium (M)	Large (L)
bream	average length of 3-year fish (before reaching 15 cm l.c. during a period of potential posibilities of plankton feeding)*)	maxim. annual increase of weight before reaching 700 g (when feeding on bottom fauna; before attaining potential possibilities of utilizing the molluscs)*)	individual weight when breaking the weight increases (index of reaching the potential limit sizes in an environment.)*)
pike perch	average length of 1-year old fish	average length of 4-year old fish	–
roach	average length of 3-year old fish	average length of 6-year old fish	annual increase of weight after reaching the length of 16 cm l.c. (after reaching the potential possibilities of feeding on molluscs) **)
whitefish	–	average length of 5-year old fish	individual weight at breaking the weight increases
small whitefish	–	average length of 3-year old fish	

*) acc. to Marciak 1974

**) acc. to Karpińska-Waluś 1961.

Table 2

Growth correlations of bream and pike perch in each limnological type of lakes and for all the types combined

	All types			Eutrophic			Pond type		
	Bream			Bream			Bream		
	S	M	L	S	M	L	S	M	L
	n = 64	61	47	31	29	19	31	30	26
S									
Pike	−0.270	−0.234	−0.123	−0.418	−0.230	−0.100	0.085	−0.280	−0.320
perch	57	57	44	28	27	18	29	29	25
M.	0.178	0.059	−0.009	−0.350	−0.062	−0.132	0.259	0.208	−0.038

size bream. From ecological point of view there is no reason to interprete the above relations on the basis of a direct interaction of species (e.g., displacement of a species into an unfavourable niche). No physiological grounds can either be used for interpretation of an antagonism that could exist between two species of different thermal requirements. The above statement permits an interpretation of the relations discusssed on the basis of relations depending upon the density of predator and prey. The higher the prey density, the lower is its growth and the better conditions occur for its predator. The interrelation may result not only from the density of bream alone, but also from the whole assemblage of the fishes with the feeding niche partly overlapping that of bream (in this case also the roach constituting the main food of pike perch). When dividing the material according to the types of lakes, the separate correlations of bream and pike perch growth in eutrophic and pond type lakes appear. Within the eutrophic lakes, which on account of their depth are characterized, according to Mikulski (1964), by a smaller abundance of pike perch, decidedly more negative correlations between the growth of bream juveniles and pike perch occur. The relations become less distinct with the age of bream. This proves that the higher the density of bream juveniles the lower is their growth, but at the same time the better is the food availability for pike perch, and (or) the lower the growth of bream juveniles, the longer can they constitute the food available for pike perch feeding on relatively small organisms. In the pond type lakes with the higher density of pike perch population, no relation between the growth of small bream and small pike perch occurs. Probably the growth of small bream in this type of lakes is not correlated with the population density, owing to its feeding on plankton. Negative correlations between the growth of pike perch juveniles and the older groups of bream may point to an influence of a decreased density of bream population during its earlier developmental period caused by numerous pike perch population (of limited growth). The "distinct" positive growth correlations of small and medium size bream with the growth of medium size pike perch in the pond type lakes may result from a similar effect of temperature on the growth of both species.

1.2. Whitefish – small whitefish. Owing to the low number of material (n=22) the growth correlation of these species was examined with respect to the entire material without considering the type of lakes (Table 3). In spite of similar thermal – oxygen requirements ans partly overlapping feeding niches, the values of "r" coefficients obtained show no correlation between the growth of whitefish and small whitefish.

Table 3

Growth correlations of whitefish and Small whitefish in lakes of various types combined

		Small whitefish
Whitefish	M	n = 22
		0.156
	L	22
		–0.086

2. Correlations between the growth of species belonging to different complexes occupying similar feeding niches.

2.1. Bream – roach. Only "distinct" positive growth correlations of these species were noted (Table 4). In the whole material the "distinct", statistically significant correlations on the level 0.01 occur between the growth of small bream and small and medium size roach. The relations differ according to various types of lakes. In α and β mesotrophic lakes distinct relations between the growth of medium and large size bream and large roach (above 16 cm) are recorded. In the eutrophic lakes, the correlations are similiar to those determined in the whole material, the growth relation of young fish of both species being more marked. A different nature of relations occurs in the pond type lakes. It is expressed as "distinct" correlations between the growth of small and medium size fish and those of medium size ones. A definite lack of correlation between the growth of young and large fish, without spatial isolation of species in the pond type lakes, may indicate the feeding niche division between the bream and roach. This is probably connected with the periphytic algae and fauna occurring abundantly in the pond type lakes and being accessible for roach, but of minor use for bream.

2.2. Bream – whitefish. Only positive "distinct" and "significant" correlations are stated also for the growth of bream and whitefish (Table 5). The correlations concern mainly the large and medium size fish of both species. The correlation between the growth of medium size bream and large whitefish, as expressed by the "r" coefficient = 0.449 at the significance level 0.01, is the strongest relationship ascertained for the whole material considered in this work. Owing to the different thermal requirements of both species, the correlations of growth mentioned above should be assigned to a similiar role played by the bottom fauna available to bream and whitefish.

Table 4

Growth correlations of bream and roach in particular limnologic lake types and for all together

		All types			α-mesotrophic			β-mesotrophic			Eutrophic			Pond type		
		Roach			Roach			Roach			Roach			Roach		
		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Bream	S	n=440	434	371	26	26	25	87	87	74	225	225	196	98	92	74
		0.247	0.217	−0.044	−0.052	−0.019	−0.143	0.101	−0.056	−0.166	0.346	0.243	−0.076	0.077	0.261	0.079
	M	440	434	371	26	26	25	87	87	74	225	225	196	98	92	74
		0.054	0.081	0.176	−0.162	0.029	0.215	0.073	0.040	0.261	0.020	0.086	0.207	0.221	0.204	0.096
	L	440	434	371	26	26	25	87	87	74	225	225	196	98	92	74
		0.049	0.088	0.143	−0.190	−0.125	0.271	0.125	0.116	0.172	0.077	0.123	0.174	0.181	0.157	0.096

Table 5

Growth correlations of bream and whitefish in various types of lakes combined

		Whitefish	
		M	L
Bream	S	n = 31 0.107	31 –0.005
	M	31 0.321	31 0.449
	L	31 0.141	31 0.270

2.3. Roach – whitefish. Only negative, "significant" and "distinct" correlations between the growth of small and medium size roach, and medium size whitefish were found (Table 6). This is surprising when the positive relations of whitefish and

Table 6

Growth correlations of roach and whitefish in various types of lakes combined

		Whitefish	
		M	L
Roach	S	n = 30 –0.406	30 –0.129
	M	30 –0.277	30 0.004
	L	25 0.027	25 –0.170

bream growth are taken into account. In this case, the "significant" correlation (r = –0.406) between the growth of roach juveniles and medium size whitefish may result from: 1) different thermal requirements of both species (according to **Nikolajev** – 1968 and **Wilkońska** (in preparation) the growth of roach juveniles exhibits a strong positive correlation to temperature); 2) a divergence of feeding niches in case of small and medium size fish feeding on plankton. Under such circumstances, the roach according to **Stangenberg** (1958) is able to utilize effectively the phyoplankton, the abundance of which may limit the availability of zooplankton which in turn is the suitable food for whitefish.

3. The correlation between the growth of species belonging to separate complexes, occupying different feeding niches.

3.1. Roach – pike perch. Only positive, statistically significant and "distinct" correlations of roach and pike perch growth are apparent (Table 7). The correlations concern

Table 7

Growth correlations of roach and pike perch in particular limnologic lake types and for all together

		All types			Eutrophic			Pond type		
		Roach			Roach			Roach		
		S	M	L	S	M	L	S	M	L
Pike perch	S	n=51	50	44	24	24	24	25	24	18
		0.055	0.048	0.037	0.017	0.188	0.126	0.208	−0.123	−0.199
	M	48	47	41	21	21	21	25	24	18
		0.026	0.177	0.283	−0.011	0.137	0.237	0.100	0.286	0.360

primarily the large fish of both species in the whole material as well as in sets from the particular lake types. In the pond type lakes correlations between the growth of both species juveniles are more clearly marked. This may be interpreted as the result of a positive influence of the water transparency on the large roach growth and of its adverse influence on the number of pike perch acting as a predator in muddy waters. All this finally contributes to better growth of the latter.

3.2. Bream – small whitefish. These two species exhibited only negative "distinct" and statiscically significant correlations of growth (Table 8). This related to all materials as well

Table 8

Growth correlations of bream and small whitefish in each limnological type of lakes and for all the types combined

		Small whitefish			
		All types	α-mesotrophic	β-mesotrophic	Eutrophic
Bream	S	n = 121	24	66	31
		−0.080	−0.332	−0.047	−0.104
	M	121	24	66	31
		−0.162	−0.361	−0.050	−0.255
	L	121	24	66	31
		−0.048	−0.014	−0.134	0.099

as to α – mesotrophic and eutrophic lakes. Particularly negative growth correlations of small whitefish and of small and medium size bream in the α – mesotrophic lakes may be assigned to an adverse influence of low temperatures on the bream growth in this type of lakes in which the limiting influence of this temperature range on the small whitefish growth is missing.

Table 9

Growth correlations of roach and small whitefish in each limnological type of lakes and for all the types combined

		Small whitefish			
		All types	α-mesotrophic	β-mesotrophic	Eutrophic
Roach	S	n = 110	23	58	29
		0.042	−0.017	0.067	−0.341
	M	110	23	58	29
		−0.056	−0.195	0.008	−0.321
	L	95	22	49	24
		−0.077	0.143	0.037	0.003

3.3. Roach – small whitefish. Between the growth of roach and small whitefish (Table 9), "distinct", statistically significant, negative correlations were noted only in the eutrophic lakes. As in the cases of negative correlations of roach and whitefish as well as that of bream with small whitefish, the correlations concerned small and medium size fish. All these interrelations may be assigned to the same factors: separate temperature effects on the bream and roach growth on one side, and the whitefish and small whitefish growth on the other, as also to an unfavourable influence of the water bloom on the growth of small whitefish and whitefish feeding on zooplankton.

CONCLUSIONS

The obtained results of the significant negative correlations between the growth of bream and pike perch and the lack of correlation between the growth of whitefish and small whitefish, do not support the initial thesis suggesting a possibility of positive correlations between the growth of species possesing similar physiological thermal requirements. The significant negative correlations between the growth of roach and whitefish, bream and small whitefish, and roach and small whitefish indicate to a separate temperature influence on the warm – water and cold – water species, or prove the infavourable influence of the water blooms on the zooplankton – eating *Coregonidae* species.

The similar ecological requirements of the species (the partial overlapping of feeding niches resulting from their analogical role in various ichthyofauna assemblages) in case of bream and roach, as well as bream and whitefish, determine the similarity of these species growth as expressed by the positive correlations. In each lake type, a different division of feeding niches occured among the various sizes of this fish species; such a conclusion could be drawn from the fact that distinct, statistically significant correlations occured between the growth of various size groups of bream and roach in different lake types.

The correlations between growth of fish species referred to as "predator – prey" (bream and pike perch) seem to be influenced by the density of both species, resulting in negative indexes of growth correlations. The positive correlations in the pike perch and roach growth may be an effect of the missing influence of the roach population density (the species known for its euryphagy), or may result from the indirect influence of transparency: a positive one on the roach growth and a negative one on the number of pike perch, consequently contributing to its better growth.

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UWAGI O KORELACJACH POMIĘDZY WZROSTEM KILKU GATUNKÓW RYB JEZIOROWYCH

Streszczenie

Celem pracy było ustalenie czy istnieje możliwość wnioskowania na podstawie danych wzrostowych jednego gatunku o perspektywach dla innych – szczególnie zaś: 1) posiadających podobne wymagania fizjologiczne (o wspólnym pochodzeniu), 2) zajmujących zbieżne nisze pokarmowe (wywodzących się z różnych kompleksów). Rozważania dotyczą korelacji pomiędzy wzrostem leszcza, sandacza, płoci, siei i sielawy różnych wielkości w jeziorach różnych typów limnologicznych.

Stwierdzone współczynniki korelacji prostoliniowej – r mieszczą się w zakresie ±0,000 do 0.450 przy liczebnościach zbiorów n = 22 do 440.

Na przykładzie obliczonych korelacji wzrostu leszcza i sandacza oraz siei i sielawy – par gatunków wywodzących się z tych samych kompleksów ichtiofauny – nie znaleziono potwierdzenia postawionej na wstępie tezy o możliwości dodatnich korelacji pomiędzy wzrostem gatunków o zbliżonych wymaganiach fizjologicznych.

Podobne wymagania ekologiczne gatunków (częściowe pokrywanie się nisz pokarmowych, wynikłe ze spełniania analogicznej roli w różnych zespołach ichtiofauny) tylko w niektórych sytuacjach decydowały o podobieństwach wzrostu, które wyrażały dodatnie jego korelacje u leszcza i płoci oraz leszcza i siei. W poszczególnych typach limmologicznych zbiorników następował różny podział nisz pokarmowych pomiędzy ryby różnych wielkości tych gatunków, co można wnioskować z wystąpienia „wyraźnych" statystycznie istotnych korelacji pomiędzy wzrostem odrębnych grup wielkości leszcza i płoci w różnych typach jezior.

Istotne, ujemne korelacje pomiędzy wzrostem płoci i siei, płoci i sielawy oraz leszcza i sielawy wskazują na odrębny wpływ temperatury na gatunki ciepłolubne i zimnolubne, względnie dowodzą niekorzystnego wpływu zakwitów na wzrost wyspecjalizowanych zooplanktonofagów (sielawy i siei).

Na korelacje wzrostu ryb stanowiących układ drapieżca ofiara w przypadku leszcza i sandacza wyraźny wpływ wydają się mieć stosunki zagęszczenio-zależne tych gatunków, dające w wyniku ujemne korelacje ich wzrostu. Dodatnie korelacje wzrostu sandacza i płoci wynikać mogą z braku wpływu zagęszczenia populacji płoci na jej wzrost, względnie z pośredniego odrębnego oddziaływania przezroczystości na wzrost płoci i liczebność sandacza.

О ВЗАИМОСВЯЗИ МЕЖДУ РОСТОМ НЕКОТОРЫХ ВИДОВ ОЗЁРНЫХ РЫБ

Резюме

Целью настоящей работы было установление возможности обобщения на основе возрастных данных одного вида перспектив для других видов, а особенно для: 1) имеющих сходные физиологические требования (общее происхождение), 2) занимающих конвергентные кормовые ниши (происходящих из разных комплексов). Содержание работы касается корреляции между ростом ле-

ща, судака, плотвы, сига и ряпушки разных размеров в озёрах разного лимнологического типа.

Установленные коэффициенты прямолинейной корреляции располагаются в пределах от ± 0,000 до ± 0,450 при n = 22 до 440.

На примере подсчитанной корреляции роста леща и судака, а также сига и ряпушки - видовых пар, происходящих из одних и тех же комплексов ихтиофауны - не подтвердилось выдвинутое в начале работы предположение о том, что существует возможность положительных корреляций между ростом видов со сходным физиологическими требованиями.

Сходные экологические требования видов (частичная конвергенция кормовых ниш, вытекающая из аналогичной роли в разных комплексах ихтиофауны) только в отдельных случаях влияли на сходство роста, которое выражалось его положительными корреляциями у леща и плотвы, а также у леща и сига. В отдельных лимнологических типах водоёмов отмечалось различное разделение кормовых ниш между рыбами разных размеров одних и тех же видов, о чём можно судить на основе „отчётливых" статистически существенных корреляций между ростом отдельных размерных групп леща и плотвы в озёрах разного типа.

Существенные отрицательные корреляции между ростом плотвы и сига, плотвы и ряпушки, а также леща и ряпушки указывают на особое влияние температуры на теплолюбивые и холодолюбивые вида или же свидетельствуют о неблагоприятном влиянии зацветания озёр на рост типичных зоопланктонофагов (ряпушки и сига).

На корреляцию роста рыб, входящих в систему хищник - жертва (в данном случае леща и судака), ощутимое влияние могут иметь соотношения плотности этих видов, дающие в итоге отрицательные корреляции их роста. Положительные корреляции роста судака и плотвы могут вытекать из отсутствия влияния плотности популяции плотвы на её рост или же из непосредственного специфического воздействия прозрачности на рост плотвы и численность судака.

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