# Life History Traits of Ylikiensis Roach *(Rutilus ylikiensis)* in Two Greek Lakes of Different Trophic State

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## ABSTRACT

The possible influence of trophic state on the life traits of a Greek endemic cyprinid fish *(Rutilus ylikiensis)* was investigated in two contrasting lakes. Lysimachia Lake is a eutrophic and very polluted shallow lake, while Trichonis Lake is an oligotrophic to mesotrophic, clearer, and deeper lake. Significant differences between the lakes were found in relation to the life history traits of the fish. In the eutrophic lake, fish achieved higher age and spawned more but smaller eggs than in the oligotrophic lake. In the eutrophic lake, females achieved higher age than males and the overall sex ratio of males: females was 1:3.42. The extrapolated mortality rate for females was significantly lower than that for males. Females were significantly heavier than males of the same length. In contrast to the above, no such differences between sexes were found in the oligotrophic lake.

## INTRODUCTION

*Rutilus ylikiensis* (Economidis 1991; ylikiensis roach) is an endemic cyprinid of Greece that occurs commonly in Lake Yliki and Lake Paralimni of central Greece and in the lower Acheloos River system of western Greece, which includes Trichonis Lake, Lysimachia Lake, Ozeros Lake, and Amvrakia Lake (Daoulas 1981, Economidis 1991, Economou et al. 1994). The life history of this species in the lower Acheloos River system is largely unknown. Most of the available information concerns its distribution (Economidis 1991, feeding (Daoulas and Economidis 1984), reproduction (Daoulas and Kattoulas 1985), larval stages (Economou et al. 1994), and contamination by heavy metals (Papagiannis et al. 2004). Knowledge of some biological parameters of this fish, such as growth rate, age structure, fecundity, and sex ratio in relation to the influence of anthropogenic factors is essential to understanding how the environment influences the life traits of this fish.

In freshwater ecosystems, increased nutrient concentrations can significantly increase production of algae and zooplankton, the main food sources for many young fish (Stockner and Shortreed 1985) and especially for planktivorous fish such as the ylikiensis roach. The abundance of food resources results in the increase offish growth, survival, and production rate (Stockner and Maclsaac 1996, Sandstrom and Karas 2002). Since a number of anthropogenic factors such as sewage waste and agricultural runoff can increase nutrient concentrations in aquatic ecosystems, it is important to examine the effects of those increases on some biological parameters.

The aim of the present study was to provide information on the age, growth, and reproduction of *R. ylikiensis* in two nearby lakes of western Greece - Trichonis Lake and Lysimachia Lake - in relation to their trophic states.

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## MATERIALS AND METHODS

Trichonis Lake (38°15' N, 21°30'E) is the largest (96.9 $km^2$) and deepest (maximum 58 m and average depth 30.5 m) natural lake in Greece. It is an oligolrophic warm monomictic lake with a mean Secchi disk depth of about 9 m. Lysimachia Lake (38°33' N, 21°30'E) has a surface area of 13.6 $km^2$, maximum depth of 9 m and a mean depth of 3 m. It is an eutrophic, warm, monomictic lake (Petridis 1993) with a mean Secchi disk depth <1 m. Moderate oxygen depletion is observed as a consequence of the eutrophic conditions due to nutrient enrichment mainly from agricultural runoff (Skoulikidis et al. 1998). Although there exists a water flow from Trichonis Lake to Lysimachia Lake, a permanent dam prevents fish movement between the two lakes.

Sampling was carried out monthly from December 1991 to November 1992. A 100 x 3 m trammel net (mesh 28 mm) was used to capture fish; the same net was used in each lake and was placed from dusk until dawn. During spring and summer, the net was placed near the shore of the lakes, while during the winter the net was placed interiorly. Totally, 314 individuals from Lysimachia Lake and 155 individuals from Trichonis Lake were collected. After collection, fish were frozen until further examined. Fork length (FL) was measured to the nearest 1 mm. Total weight (TW) and somatic (eviscerated) weight (NW) were measured to the nearest 0.1 g. The sex of all specimens was determined by microscopic examination of the gonads. The length-weight relationship was described by the equation $NW = c\ FL^b$, where $b$ is the growth exponent or length-weight factor and $c$ is constant. NW-FL regressions were tested for differences in slopes and intercepts between sexes and between lakes using analysis of covariance (ANCOVA); (Zar 1999).

Fish were aged by examination of scales, and the use of scales was validated by analysis of marginal growth. Along an axis from focus to middle of the anterior field, distance to annuli and overall scale size were measured on one representative scale for each fish. Marks were recognized by standard criteria (Bagenal and Tesch 1978; Everhard and Youngs 1975). These distances were used to estimate the relationship between fish length and scale radius, and this relationship was used to back-calculate lengths at age and to determine annual growth (Horppila and Nyberg 1999). Back-calculated lengths at ages were fitted to the von Bertalanffy model (Ricker 1975) by using non-linear regressions (Marquardt method) calculated with Fishparm computer software (Saila et al. 1988). The overall growth performance index $\Phi'$ (phi prime test) was employed to compare growth rates (Munro and Pauly 1983).

The instantaneous mortality rates (Z) were calculated for the total sampling period for males and females and/or lake separately using the length-converted catch curves (Pauly 1983). The slopes of the regressions were tested for differences between sexes and between lakes (ANCOVA).

Gonads were sexed macroscopically and weighed. The macroscopic and microscopic examination of gonads revealed that *R. ylikiensis* is a single spawner and the onset of spawning is in March. The reproductive period was validated by applying slight pressure to the abdomen to expel sperm or ova.

In order to study the reproductive strategies of the species in the two different habitats, fish from the lakes belonging to the same length group (FL: 16-19 cm) were compared. Fifteen ovaries from Trichonis Lake and 23 ovaries from Lysimachia Lake, collected in March, were examined. Eggs were counted using a variation of the volumetric methods described by Snyder (1983). The relationship between egg number (fecundity, F) and fork length was expressed by the equation $F = a\ FL^b$, (Bagenal and Braum 1978, Elliott 1995). The F-FL regressions were calculated for each lake separately, and the slopes were compared with ANCOVA.

Diameters of eggs were measured microscopically with an ocular micrometer. Two subsamples from different parts of each gonad were taken, and the diameters of 100 eggs were measured. The relationship between the mean egg diameter (D) and fork length was examined.

## RESULTS

The lengths of individuals ranged from 11.2 to 25.5 cm in Lysimachia Lake and 13.1 to 21.7 cm in Trichonis Lake. Fish smaller that 11.2 cm were not retained by the gear. Scale readings showed ten age classes in Lysimachia Lake and seven age classes in Trichonis Lake. The maximum lengths observed in both lakes were for 7 y old females - 25.5 cm in Lysimachia Lake and 21.7 cm in Trichonis Lake. A single scale annulus was formed from late March to May. By June all the scales had a new annual ring.

Fish growth was of a positive allometric nature (b > 3) in most cases (Table 1). The slopes of the NW-FL regressions differed significantly between sexes in Lysimachia Lake (Fi.3ii$^{=}$5.60, P=0.02), with females having a higher growth exponent *(b)*. There were no significant differences between the sexes in Trichonis Lake ($Fu_{52}$=0.14, P=0.71) or between the lakes when the sexes were combined ($Fi._{466}$=2.62, P=0.10).

Scale radius (R) was linearly related to fork length (FL). The slopes of FL-R regressions did not differ significantly between sexes or between lakes, indicating that both sexes grew at similar rates in the two lakes. Consequently, further estimations were made for both sexes combined. The relationship for Lysimachia Lake was FL = 7.30 + 26.93 R (N=94, $R^2$=0.90); for Trichonis Lake, it was FL = 7.29 + 27.49 R (N=27, $R^2$=0.74).

Mean back-calculated lengths of each age group were smaller than the observed lengths of the same age group at the time of catching and greater than the observed fork lengths at the time of catching of the previous age group. The predicted lengths at age offish from Lysimachia Lake were greater than those from Trichonis Lake (Fig. 1). Mean back-calculated fork lengths at age indicated rapid growth for the first year of life. Fish of Lysimachia Lake attained almost 52% of their maximum adult size during this period, and there was a steady decline in mean annual growth increments thereafter. The fish of Trichonis Lake attained nearly 54% of their maximum adult size during the first year and similarly showed gradual decline in annual growth increments thereafter. Values of the asymptotic fork lengths (Loo) and growth coefficients (k) from the von Bertalanffy growth model did not differ between the two lakes. Moreover, the values of the overall growth performance index Φ' were similar (1.94 and 1.97 for Lysimachia Lake and Trichonis Lake, respectively).

The instantaneous total mortality rate for sexes combined in Trichonis Lake was significantly greater than in Lysimachia Lake (0.85 versus 0.58; $F_{1\text{-}2}6$=4.51, P=0.043; Table 2). The slopes of the regressions differed significantly between sexes in Lysimachia Lake (Fig. 1); males showed higher mortality rates than females (1.22 versus 0.56; Fij23=10.68, P=0.003). In Trichonis Lake, there were no significant differences between sexes ($F_U$i=0.83, P=0.37).

Sexual maturation occurred after the first year of life, and *R. ylikiensis* is a single spawner. The most intensive period of gonad development began in February and reached its maximum at the end of March. The relationships between fecundity and fork length were F = 0.0002 ' $FL^{1,59}$(N=23, $R^2$=0.96) for Lysimachia Lake and F = 0.002 • $FL^{052}$ (N=15, $R^2$=0.97) for Trichonis Lake. The slope of the F-FL regression for Lysimachia

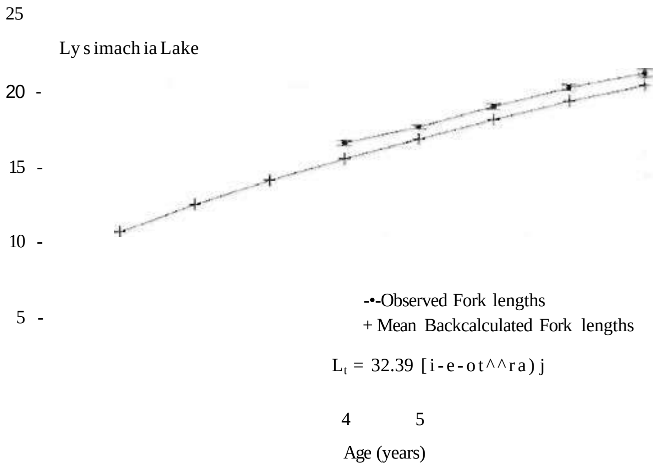
Table 1. Parameters of the relationship between somatic weight (NW) and fork length (FL) of *Rutilus ylikiensis* from Lysimachia Lake and Trichonis Lake.

| Lake | Sex | NW = c.$FL^b$ | 95%c.i. ofb | N | R2 | P |
|---|---|---|---|---|---|---|
| Lysimachia | Male | NW = 0.0012-FL3-07 | 2.93-3.22 | 71 | 0.96 | O.001 |
| | Female | NW = 0.0064-FL3.26 | 3.19-3.33 | 243 | 0.97 | <0.001 |
| Trichonis | Male | NW = 0.0071 -FL322 | 3.09-3.36 | 66 | 0.97 | O.001 |
| | Female | NW = 0.0063 • $FL^{3}$-$^{26}$ | 3.13-3.39 | 89 | 0.97 | <().()() 1 |

Lake was greater than that for Trichonis Lake (1.59 versus 0.52; $F_{U5}$= 10.89, P=0.002). The maximum potential fecundity for Lysimachia Lake was 14,500 eggs, and for Trichonis Lake it was 10,070 eggs.

The mean egg diameter (D) was positively related to fork length (i.e., larger females spawned bigger eggs). The D-FL regressions were linear, and the equations were $D = -0.897 + 0.12 \cdot FL$ (N=23, $R^2$=0.66) for Lysimachia Lake and $D = -0.299 + 0.07\ FL$ (N=15, $R^2$=0.58) for Trichonis Lake. The relationship between egg diameter and fish size also differed, with the slope of the D-FL regression being greater for Trichonis Lake (0.12 versus 0.07; $F_{L35}$=4.70, P=0.037).

In Lysimachia Lake, the overall male:female ratio (1:3.42) departed marked from unity ($X^2$=94.22, PO.001). In Trichonis Lake, the ratio was 1:1.35, which did not differ from unity ($X^2$=3.41, P=0.06). In both lakes the percentage of females increased according to age class, except age class 6 in Trichonis Lake where among eight specimens six males and two females were found. For most age classes, sex ratio appeared to depend on age class.



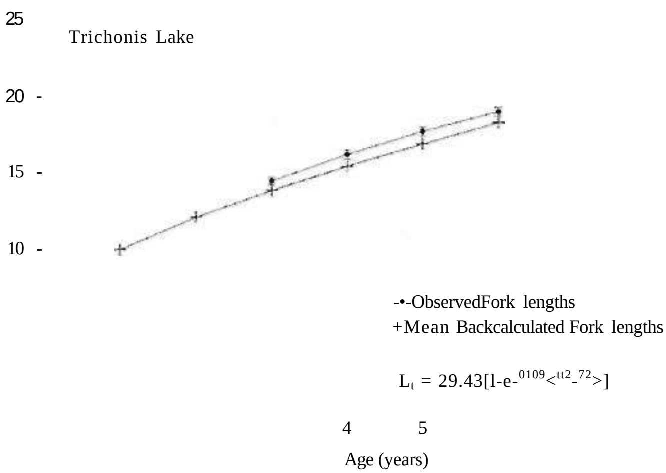




Figure 1. Observed and mean backcalculated fork lengths of *Rutilus ylikiensis* from Lysimachia Lake and Trichonis Lake.

Table 2. Total mortality rates estimated from the catch curves of *R. ylikiensis* from Lysimachia Lake and Trichonis Lake.

| Lake | Sex | Ln(N/dt)=a-Zt | Z | S.D. | N | $R^2$ | P |
|---|---|---|---|---|---|---|---|
| Lysimachia | Male | Ln(N/dt)=9.42-1.22t | 1.22 | 0.31 | 10 | 0.96 | <0.001 |
| | Female | Ln(N/dt)=7.22-0.561 | 0.56 | 0.11 | 16 | 0.95 | O.001 |
| Trichonis | Male | Ln(N/dt)=5.85-0.721 | 0.72 | 0.24 | 11 | 0.94 | <0.001 |
| | Female | Ln(N/dt)=7.19-0.891 | 0.89 | 0.21 | 13 | 0.94 | <0.001 |

## DISCUSSION

The exponent of fork length-somatic weight relationship showed that growth of *R. ylikiensis* is mainly positively allometric, which indicates a proportionally better weight gain in relation to growth in length. A similar growth pattern was reported in Trichonis Lake by Daoulas (1981; b was 3.20 for males and 3.32 for females). In Lysimachia Lake, females were significantly heavier than males having the same length. Bagenal and Tesch (1978) reported that differences in values of the growth exponent for individuals of the same species are observed when significant differences in environmental conditions exist. It appears that males are more affected than female by the extreme environmental conditions that occurred in Lysimachia Lake. Fish from Lysimachia Lake grew larger than those from Trichonis Lake.

The gonadosomatic index evaluation showed that the reproduction *ofR. ylikiensis* occurred mainly in March, which concurs with Daoulas and Kattoulas (1985) who found that the highest values of the index in Trichonis Lake were during February and March. In addition, Economou et al (1994) found that egg deposition of it!, *ylikiensis* in nearby Amvrakia Lake occurred in March. Similarly to Daoulas (1981), we observed that *R. ylikiensis* started reproducing after the first year of life. Penczak et al. (1977a) found that age 3+ *Rutilus rutilns* were sexually mature, while Mann (1973) studied the same species in rivers of southern England and recorded full maturity at age 5+.

Fecundity of *R. ylikiensis* was less than that reported by Daoulas and Kattoulas (1985; 19,570 eggs) and greater in Lysimachia Lake than Trichonis Lake. Differences in fecundity in relation to different biotopes have also been observed for populations of *Aphanins fasciatus* (Leonardos and Sinis 1998). Elliott (1995) reported that variations between populations may be caused directly by variations in energy intake that reflect the abundance of food and indirectly by variations in selection effects between habitats. It seems that the more eutrophic pattern of Lysimachia Lake is responsible for the higher fecundity. Females living in Lysimachia Lake invested more intensely in reproduction than fish form the other lake. Despite the high investment in reproduction, the coefficient of the length-weight relationship *(b)* was very similar to that offish from Trichonis Lake. Thus, the most likely explanation for the investment in reproduction at Lysimachia Lake is the higher food availability with greater energetic resources put into reproduction without having to sacrifice condition (Jobling 1994). At Lysimachia Lake, egg size was smaller compared with the other lake. Reduction in egg size may be caused by an elevated fecundity, since egg size is negatively correlated with fecundity (Kartas and Quignard 1984) or by exposure to contaminants (Munkittrick and Dixon 1988, Sandstrom et al. 1988, McMaster et al. 1991). At Lysimachia Lake, eutrophication may be responsible for the associated nutrient enrichment. It is also possible that habitat deterioration of environmental conditions could have reduced the density offish at this site. This situation may have enable ylikiensis roach to feed in a habitat where nutrients were more available as a result of reduced competition for food. Alternatively, the same conditions could have selected for fish with the highest fitness to survive and to reproduce in an altered environment (Moriarty 1988, Leblanc et al. 1997).

During this study, females predominated in both lakes. In Trichonis Lake, Daoulas (1981) found an overall sex ratio skewed toward females (1.28:1). Females were dominant in all age groups, and the magnitude of that dominance varied with increasing age. The dominance of females in overall sex ratio, such as the older age classes in Lysimachia Lake may reflect a high mortality rate in males. The strategy of *R. ylikiensis* in Lysimachia Lake in terms of sex ratio is the investment in females, and this strategy is characteristic of species from unstable and variable environments. Consequently, the differences between the sexes in Lysimachia Lake can be explained on the basis of the way that eutrophication and pollution affect fish. It seems that males are more vulnerable than females. Comparing the life history parameters of the fish between the lakes, it would be expected that longevity, growth rate, mortality rate, fecundity, and egg diameters are influenced by the eutrophic and unstable profile of Lysimachia Lake. However, it seems that the population of *R. ylikiensis* is not affected by the eutrophic and polluted status of the lake. Contrarily, the fish survive, grow well, and show a high degree of adaptability. Related traits found by Baranyi et al. (1997) who studied the genetic and morphological variability of/?, *rutilus* in Austria, suggest that this species is ecologically flexible. Moreover, Penczak et al. (1976,1977a, 1977b, and 1979) studying the ecology *oiR. rutilus* in two sites of the Pilica River in Poland, which differed in the degree of water pollution, found that there were no significant differences in biological parameters in relation to the water pollution.

As there is no absolute segregation between the two lakes, it is expected that juveniles born in Trichonis Lake drift into Lysimachia Lake. In that way, some fish born in Trichonis Lake live and grow in Lysimachia Lake. *R. ylikiensis* is an extremely eury trophic species (Daoulas and Economidis 1984) and, like other species of the *Rutilus* genus, survives quite well in eutrophic lakes (Griffiths and Kirkwood 1995, Kamjunke et al. 2002). According to Penczak et al. (1976, 1979), differences in the growth of *R. rutilus* were conditioned by the increase of sewage concentration and were statistically of little importance. Thus, the differences we observed in the life history parameters *ofR. ylikiensis* are due to phenotypic plasticity of the population in response to the different environmental conditions.

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LITERATURE CITED

Bagenal, T. B. and E. Braum. 1978. Eggs and early life history, pp. 165-210. *In* T.B. Bagenal (ed.). Methods for assessment of Fish production in fresh waters -IBP Handbook Vol 3. Oxford.

Bagenal, T.B. and F.W. Tesch. 1978. Age and growth, pp. 101-136. *In* Methods for Assessment of Fish production in fresh waters (T.Bagenal,eds -IBP Handbook, Vol. 3. Oxford.

Baranyi, C, G. Gollmann, and M. Bobin. 1997. Genetic and morphological variability in roach *Rutilus rutilus,* from Austria. Hydrobiologia 350: 13-23.

Daoulas, Ch. 1981. Contribution to the biology *of Rutilus rubilio* (Bonaparte, 1837) (Pisces, Cyprinidae) in lake Trichonis. Ph.D. Thesis, Univ. Salonica, Greece, 144 pp. (in Greek).

Daoulas, Ch. and P. Economidis. 1984. The feeding *of Rutilus rubilio* (Bp.) (Pisces: Cyprinidae) in Lake Trichonis, Greece. Cybium 8: 29-38.
Daoulas, Ch. and M. Kaltoulas. 1985. Reproductive biology *of Rutilus rubilio* (Bonaparte, 1837) in Lake Trichonis. Hydrobiologia 124: 49-55.
Economidis. P.S. 1991. Check List of freshwater fishes of Greece. Recent status of Threats and Protection. Hellenic Society for the Protection of Nature. Athens.
Economou, A.N., Ch. Daoulas, Th. Psarras, and R. Barbieri-Tseliki. 1994. Freshwater larval fish from Lake Trichonis (Greece). J. Fish Biol. 45: 17-35.
Elliott, J.M. 1995. Fecundity and egg density in the redd for sea trout. J. Fish Biol. 47: 893-901.
Everhart, W.H. and W.D. Youngs. 1975. Principles of Fishery Science. New York.
Horppila, J. and K. Nyberg. 1999. The validity of different methods in the backcalculation of the lengths of roach - a comparison between scales and cleithra. J. Fish Biol. 54: 489-498.
Griffiths, D. and R. C. Kirkwood. 1995. Seasonal variation in growth, mortality and fat stores of roach and perch in Lough Neagh, Nothern Ireland. J. Fish Biol. 47: 537-554.
Jobling, M. 1994. Fish bioenergetics. London, U.K.
Kamjunke, N. K., Schmidt, S., Pflugmacher, and T. Mehner. 2002. Consumption of cyanobacteria by roach *{Rutilus rutilns):* useful or harmful to the fish. Freshwater Biol 47: 243-250.
Kartas, F. and J.-P Quignard. 1984. La fecondite des poissons teleosteens. Masson, Paris.
Leblanc, J. C, Couillard,M. and J.-C. F. Brethes. 1997. Modifications of the reproductive period in mummichog *{Fundulus heteroclitus)* living downstream from a bleached kraft pulp mill in the Miramichi Estuary, New Brunswick, Canada. Can. J. Fish. Aquat. Sci. 54: 2564-2573
Leonardos, I. and A. Sinis. 1998. Reproductive strategy of *Aphanius fasciatus* Nardo, 1827 (Pisces: Cyprinodontidae) in the Mesolongi and Etolikon lagoons (W. Greece). Fish. Res. 35: 171-181.
Mann, R. K. H. 1973. Observations on the age, growth, reproduction and food of the roach *Rutilus rutilus* L. in two rivers in southern England. J. Fish Biol. 5: 707-736.
McMaster, M.E. G.J. Van der Kraak C.B. Portt K.R. Munkittrick P.K. Sibley I.R. Smith and D.G. Dixon. 1991. Changes in hepatic mixed-function oxygenase (MFO) activity, plasma steroid levels and age at maturity of a white sucker *{Catostomus commersoni)* population exposed to bleached kraft pulp mill effluent. Aquat. Toxicol. 21: 199-218.
Moriarty, F. 1988. Ecotoxicology. The study of pollutants in ecosystems. San Diego CA.
Munkittrick, K.R. and D.G. Dixon. 1988. Growth, fecundity, and energy stores of white sucker *{Catostomus commersoni)* from lakes containing elevated levels of copper and zinc. Can. J. Fish. Aquat. Sci. 45: 1355-1365.
Munro, J. L. and D. Pauly. 1983. A simple method for comparing growth of fishes and invertebrates. ICLARM Fishbyte 1: 5-6.
Papagiannis, I., I. Kagalou, J. Leonardos, D. Petridis, and V. Kalfakakou. 2004. Copper and zinc in four freshwater fish species from Lake Pamvotis (Greece) Environ. Int. 30: 3. 357-362
Pauly, D. 1983. Length-converted catch curves, a powerful tool for fisheries research in tropics (Part I). Fishbyte 1: 9-13.
Penczak, T., M. Molinski, E. Kusto, K. Palusiak, H. Panusz, and M. Zaiewski. 1976. The ecology of roach *Rutilus rutilus* (L.), in the Barbel region of the polluted Pilica River. II. Dry weight, ash and contents of some elements. Ekologia Polska 24:4, 623-638.
Penczak, T., M. Molinski, E. Kusto, K. Palusiak, H. Panusz, and M. Zaiewski. 1977a.

The ecology of roach *Rutilns rutilus* (L.), in the Barbel region of the polluted Pilica River. III. Lipids, Protein, total nitrogen and caloricity. Ekologia Polska 25: 1, 75-88.
Penczak, T., M. Zalewski, M. Molinski, and M. Gajos. 1977b. The ecology of roach *Rutilns rutilus* (L.), in the barbell region of the polluted Pilica River. IV. Elements of production and food consumption. Ekologia Polska 25:2, 241-255.
Penczak, T., E. Lorenc, J. Lorenc, and M. Zdziennicka. 1979. The ecology of roach *Rutilus rutilus* (L.), in the barbell region of the polluted Pilica River. V. Estimation of the age and growth according to opercular bones. Ekologia Polska 27:1, 135-154.
Petridis, D. 1993. Macroinvertebrate distribution along an organic pollution gradient in Lake Lysimachia (Western Greece). Arch. Hydrobiol. 128: 367-384.
Ricker, W.E. 1975. Computation and interpretation of biological statistics offish populations. Bulletin 191 Journal of the Fisheries Research Board of Canada.
Saila, S. B., C. W. Recksiek, and M. H. Prager. 1988. Basic fishery science programs: A compendium of microcomputer programs and manual of operation. Developments in Aquaculture and Fisheries Science, 18. Oxford.
Sandstrom, A. and P. Karas. 2002. Effects of eutrophication on young-of-the-year freshwater fish communities in coastal areas of the Baltic. Environ. Biol. Fish. 63: 89-101.
Sandstrom, O., E. Neuman, and P. Karas. 1988. Effects of a bleached kraft pulp mill effluent on growth and gonad function in Baltic coastal fish. Water Sci. Technol. 20: 107-118.
Skoulikidis, N.T., I. Bertahas and T. Koussouris. 1998. The environmental state of freshwater resources in Greece (rivers and lakes). Environ. Geol. 36 (1-2) 1-17.
Snyder, D.E. 1983. Fish eggs and larvae. Pp 165-198. *In* Nielsen, L.A. and Johnson, D.L., (eds). Fisheries Techniques, Bethesda, Maryland.
Stockner, J.G. and K.S. Shortreed. 1985. Whole-lake fertilization experiments in coastal British Columbia lakes: empirical relationships between nutrient inputs and phytoplankton biomass and production. Can. J. Fish. Aquat. Sci. 42: 649-658.
Stockner, J.G. and E.A. Maclsaac. 1996. British Columbia lake enrichment programme: two decades of habitat enhancement for sockeye salmon. Regul. River. 12: 547—561.
Zar, J.H. 1999. Biostatistical Analysis, 4nd edn. New Jersey.



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