Gradients of fish distribution in reservoirs

Marie Prchalová

UNIVERSITY OF SOUTH BOHEMIA
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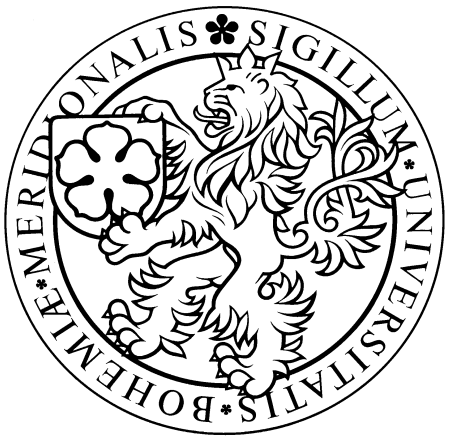

Gradients of fish distribution in reservoirs

Marie Prchalová

Ph.D. dissertation

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Annotation

Patterns of fish spatial distribution were studied in two Czech canyon-shaped reservoirs and in three Dutch basin-shaped reservoirs. Effects of environmental variables like habitat depth, slope, distance from the shore and distance from the dam were evaluated using multivariate statistics. Gillnet selectivity was also studied as fish were sampled using gillnets.

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Declaration

I declare that this dissertation was fully worked out by myself using the cited literature only.
I declare that in accordance with the Czech legal code § 47b law No. 111/1998 in valid version I consent to the publication of my dissertation in an edition made by removing marked parts archived by Faculty of Science in an electronic way in the public access section of the STAG database run by the University of South Bohemia in České Budějovice on its webpages.

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In České Budějovice, 9 April 2008

Marie Prchalová

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"…freedom of a will is only for people, who are able of it…"
Matyáš Tanner, head of the Czech division of Society of Jesus, 1675. In: Šotola, J., 1990. Society of Jesus. Praha: Československý spisovatel, p. 171.

Curriculum vitae

Marie Prchalová was born on 24 May 1979 in Kolín, Czech Republic. After her final graduation exams at the Secondary Agricultural School in Poděbrady, she started to study at the Faculty of Science, University of South Bohemia in České Budějovice, Department of Ecosystem Biology. In 2003, she successfully defended her Master's and RNDr. theses[*] and passed final exams for the degrees of M.Sc. in Ecology and RNDr. In the same year, under the leadership of the same supervisor, Dr. Jan Kubečka, and in the same department, Marie began her Ph.D. study in Hydrobiology. She focused on patterns of fish distribution in reservoirs in her dissertation. During her studies, fish were sampled using gillnets and it became quite important to improve the quality of assessment and analysis of gillnet catches. Motivated by this, she focused her attention also on gillnet selectivity. Marie has been a proud member of the FishEcU team since her first year at university. (www.hbu.cas.cz/fishecu/).

From 2002 – 2004, she worked at the Water Research Institute of T.G. Masaryk in Prague. The topic of her work was evaluating fish passage through the Střekov fish pass on the Elbe River[†] under the supervision of M.Sc. Ondřej Slavík, Ph.D.

Photo by Steve Miranda, Jiří Peterka and many others

[*] Prchalová, M., Draštík, V., Kubečka, J., Sricharoendham, B., Schiemer, F. & Vijverberg, J. (2003). Acoustic study of fish and invertebrate behaviour in a tropical reservoir. Aquatic Living Resources 16, 325-331.

[†] Prchalová, M., Vetešník, L. & Slavík, O. (2006). Migrations of juvenile and subadult fish through a fishpass during late summer and fall. Folia Zoologica 55(2), 162-166; Prchalová, M., Slavík, O. & Bartoš, L. (2006). Patterns of cyprinid migration through a fishway in relation to light, water temperature and fish circling behaviour. Journal of River Basin Management 4 (3), 213-218.

List of papers

The dissertation is based on the following papers (paper I – V in the text):

Paper I Prchalová, M., Kubečka, J., Vašek, M., Peterka, J., Seďa, J., Jůza, T., Říha, M., Jarolím, O., Tušer, M., Kratochvíl, M., Čech, M., Draštík, V., Frouzová, J., Hohausová, E. Patterns of fish distribution in a canyon-shaped reservoir. Journal of Fish Biology, accepted.

Paper II Prchalová, M., Kubečka, J., Čech, M., Frouzová, J., Draštík, V., Hohausová, E., Jůza, T., Kratochvíl, M., Matěna, J., Peterka, J., Říha, M., Vašek, M. The effect of depth, distance from dam and habitat choice on the spatial distribution of fish in a canyon-shaped reservoir. Ecology of Freshwater Fish, submitted.

Paper III Prchalová, M., Kubečka, J., Hladík, M., Hohausová, E., Čech, M., Frouzová, J., 2006. Fish habitat preferences in an artificial reservoir system. Verhandlungen der Internationalen Vereinigung für Limnologie 29, 1890-1894.

Paper IV Prchalová, M., Kubečka, J., Říha, M., Litvín, R., Čech, M., Frouzová, J., Hladík., M., Hohausová, E., Peterka, J., Vašek, M. Overestimation of percid fishes (Percidae) in gillnet sampling. Fisheries Research, accepted. doi:10.1016/j.fishres.2007.11.009.

Paper V Prchalová, M., Kubečka, J., Říha, M., Mrkvička, T., Vašek, M., Jůza, T., Kratochvíl, M., Peterka, J., Draštík, V., Křížek, J. Size selectivity of standardized multimesh gillnets in sampling coarse European species. Fisheries Research, submitted.

Author's contribution

Marie Prchalová (author of this dissertation) is the first author of all papers and wrote all of them. Most of the statistical analyses as well as processing of most of the raw results were performed by Marie Prchalová. All coauthors participated during all sampling, processed certain results (Milan Říha in the paper IV and V, Josef Křížek in in the paper V) and performed certain statistical analyses (Radek Litvín in in the paper IV, Tomáš Mrkvička in in the paper V).
All coauthors hereby consent to the publication of the papers in dissertation of Marie Prchalová and support it by their signatures:

Doc. RNDr. Jan Kubečka, CSc.

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Paper I – statement of acceptance and impact factor

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I am pleased to tell you that your work has now been accepted for publication in Fisheries Research. The manuscript will now enter the production process. Proofs will be sent to you in due course.

Thank you for submitting your work to this journal.

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Contents

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Introduction

Reservoirs have become an integral part of our cultural landscape. They have unquantifiable importance in drinking water supply. As such, water quality management is of prime interest. Fish have an indisputable function in water quality processes (Hrbáček et al., 1961; Williams and Moss, 2003) and reducing certain fish species in a system is a method of water body restoration (see Olin, 2005). However, if one wants to understand the effect of fish, the knowledge of fish spatial distribution is crucial.

The hunger for such knowledge is relatively recent and questions without answers are still found on this topic (see Vašek, 2004). The general consensus that originally riverine fish concentrate in the reservoir environment that is most similar to a river, i.e. the tributary and littoral areas (Fernando and Holčík, 1991), is now partially buried when fish biologists started to sample also the pelagic zone of the reservoirs (e.g. Vašek et al., 2004; Järvalt et al., 2005; Kahl and Radke, 2006).

The basic aim of my dissertation was to describe patterns of fish spatial distribution in five reservoirs that differed in morphology and certain limnological features. The Římov and Želivka water supply reservoirs in the Czech Republic have only one principal tributary and are located in relatively narrow valleys. Due to this morphology they are called canyon-shaped reservoirs. Both reservoirs are characterized by a pronounced longitudinal gradient of nutrients, phytoplankton and zooplankton (Straškrabová et al., 1994; Hejzlar and Vyhnálek, 1998; Desortová, 1998; Seďa and Devetter, 2000) and by well developed thermal and oxygen stratifications during summer.

Three Dutch basin-shaped reservoirs form large concrete bowls in the Meuse River in the polder district of Biesbosch. Environmental heterogeneity is very limited together with shelter possibilities and the growth of submerged marcophytes. The three reservoirs create a cascade – water from the river is pumped into the first one, then to the second one and water from the third one goes to the final treatment for drinking water. All three reservoirs are artificially destratified by strong aerations (Ketelaars et al., 1998).

In order to sample the fish vertical distribution in detail, up to eight depth layers in benthic habitats and up to three depth layers in pelagic habitats were fished. The benthic habitat was defined as the 1.5 m deep layer above the bottom. The pelagic habitat was defined as the volume of the open water with no contact with the bottom or shore. In order to describe the fish horizontal distribution, several localities along the longitudinal reservoir axis were sampled and catches from benthic and pelagic habitats were treated separately. As habitat preferences may change during ontogeny (e.g. Fischer and Eckmann, 1997; Čech et al., 2005; Jeppesen et al., 2006), samples of 0+ year old and older fish were analysed individually.

Fish were sampled using multimesh gillnets (EU Standard Document EN 14 757). Gillnets are widespread and highly respected gear. Gillnets are able to catch fish in a locality where other reliable gear are not applicable. In the temperate region, gillnets catch fish “simply always” (J. Kubečka).

Gillnets are a passive gear and as such they inclined to produce a biased picture that may not be fully representative of the fish community. Differences in activity and body morphological features between various fish species or size groups caused species and size selectivity of gillnets (see Kurkilahti, 1999). However, all important

aspects of gillnet selectivity has not been fully figured out yet. Thus the second aim of my dissertation was to describe the species and size selectivity of gillnets using comparable catches of gillnets and catches of an active sampling gear, beach seines.

Results

This dissertation is composed of five papers – one paper already published (paper III), two papers accepted (papers I and IV) and two papers submitted (paper II and V) to scientific journals.

Paper I – Patterns of fish distribution in a canyon-shaped reservoir

In August 2004 and 2005, an extensive study of the fish community was carried out in the largest water supply reservoir in the Czech Republic and Central Europe, the canyon-shaped Želivka Reservoir, using a fleet of Nordic multimesh gillnets. Fish were sampled at eight locations along the longitudinal profile of the reservoir and at five benthic depth layers covering depths from the surface down to 18 m (benthic gillnet 1.5 m high), and at three pelagic depth layers down to the depth of 5 m above the bottom (pelagic gillnets 4.5 m high). Catches of both juvenile (0+ year old) and adult (fish older than one year) fish were highest in the upper layers of the water column (i.e. in the epilimnion down to 5 m, and down to 10 m in the benthic habitats). Along the tributary-dam axis in the pelagic habitats, both juvenile and adult fish preferred the upper part of the reservoir, where the maximum number of species and also the highest amount of zooplankton were found. In the benthic habitats, fish selected location according to factors other than trophic status. More juvenile fish were recorded in the benthic habitats than in the pelagic habitats. Depth had the largest explanatory power for predicting fish community composition, followed by the affiliation with benthic/pelagic habitats and location on the longitudinal axis of the reservoir. The fish community was represented mainly by cyprinids and consisted of two distinct groups of species, with bleak *Alburnus alburnus* (L.), rudd *Scardinius erythrophthalmus* (L.) and asp *Aspius aspius* (L.) dominating the offshore group while perch *Perca fluviatilis* L. and ruffe *Gymnocephalus cernuus* (L.) were affiliated with the inshore group of the adult fish community. Roach *Rutilus rutilus* (L.), bream *Abramis brama* (L.) and pikeperch *Sander lucioperca* (L.) occurred in important proportions in both the inshore and offshore zones. All species, with the exceptions of adult perch (1+ and older), 0+ perch and 0+ roach, preferred the most eutrophic tributary part of the reservoir. The fish community was relatively stable between the two years sampled.

Paper II – The effect of depth, distance from dam and habitat choice on the spatial distribution of fish in a canyon-shaped reservoir

In 1999 – 2007, spatial distribution of the fish community in the Římov Reservoir, Czech Republic, was sampled using multimesh gillnets. Effects of depth, distance from the dam to the tributary as well as habitat choice on fish community structure, abundance, biomass and average weight were tested using redundancy analysis. Fish were recorded in all sampled depths and parts of the reservoir. Effects of three environmental variables were significant and most variability was explained by depth,

then by distance and habitat. Abundance and biomass of all species decreased with depth and responses of individual species were similar in juvenile as well as adult fish. Number of species, abundance and biomass of all species except perch increased heading towards the tributary and peaked close to or at the tributary. Responses of juvenile fish to distance differed from adult fish. The fish community were found to have different structures in benthic and pelagic habitats; species preferred to occupy epipelagic (bleak, asp, rudd and juvenile bleak, roach and bream) or littoral waters (perch, pikeperch, ruffe, roach, bream and juvenile percids). Larger fish of all species except pikeperch and ruffe were caught in pelagic habitats. This nine-year study showed that fish distribution in the reservoir followed distinct patterns, which were shaped by a combination of physiological constraints plus a trade-off between food resources and competition.

Paper III – Fish habitat preferences in an artificial reservoir system

Three Dutch artificially mixed reservoirs – De Gijster (320 ha), Honderd en Dertig (219 ha) and Petrusplaat (105 ha) – were sampled in 1998, 2000 and 2002 during late August an early September in order to describe fish habitat preferences. Eight benthic and three pelagic habitats covering all depth layers and bottom types were fished using multimesh gillnets. Fish were found in all habitats – the highest abundances were recorded in the benthic habitat 6 – 7 m deep with the flat bottom and in the benthic habitat with rugged bottom with numerous deep holes in the depth of 15 m. Pelagic habitats were occupied by less fish and most of them were recorded in the depth layer 9.5 – 5 m above the bottom. Multivariate analysis showed that most of the variability in community structure could be explained significantly simply by an affiliation to the individual habitat. We also tested following characteristics of the habitats – volume, depth, bottom type and slope, and found out that these variables had significant but lower effect on the fish community structure indicating that habitat was not only a set of abiotic characteristics. From habitat characteristics, volume had the strongest effect on the community of both 0+ year old and adult fish. 0+ year old fish were also significantly influenced by the depth – most 0+ year old fish occurred in depths down to 15 m. Only 0+ year old pikeperch and ruffe had positive correlation with the depth. 0+ smelt *Osmerus eperlanus* (L.) and 0+ bream inhabited preferably the pelagic habitats, whereas 0+ roach and 0+ ide *Leuciscus idus* (L.) were found in both pelagic and benthic habitats in abundances above the average. 0+ year old percids, perch, pikeperch and ruffe were found mainly in the benthic habitats. In case of adult fish, only smelt and bleak showed positive correlation with the volume – smelt preferred the pelagic habitats and bleak had the highest abundances in both pelagic and shallow benthic habitats. Adult pikeperch, bream and ruffe had positive correlation with the depth. Abundances of roach, perch and white bream *Blicca bjoerkna* (L.) were highest in the benthic habitats down to the depth of 15 m. This study showed that in absence of thermal and oxygen stratification, fish utilized all depths and volumes of the reservoir.

Paper IV – Overestimation of percid fishes (Percidae) in gillnet sampling

Overestimation of the number of percid fishes taken by gillnets was studied in eight reservoirs in the Netherlands and the Czech Republic during 1998 – 2006.

Overestimation was defined as a higher proportion of percids (percids/(percids + cyprinids)) in gillnets than in the reference community (catches by seines on the same beach and night as the gillnet catches). In total, 97 pairs of catches were compared and overestimation was found in more than 80% of cases. The overestimation ranged from a few percent to more than 1 000%, being dependent on the proportion of percids in the fish community. Overestimation was highest in reservoirs with the lowest proportions of percids. Overestimation was proved for perch, but not for pikeperch and ruffe. A correction factor was developed, for the proportion of perch in the gillnet catches, using an empirical cubic function. Analysis of the direct mechanisms by which fish were enmeshed in the gillnets showed that most fish were wedged, one quarter were gilled and only 1.5% were tangled. Percid species were relatively more frequently tangled and gilled than cyprinids but not to an extent that can completely explain the total overestimation. Furthermore, the overestimation was not caused by a higher probability of perch being retained in the gillnet, as was evident from an experiment with retaining perch and roach in the gillnet. Overestimation of perch is most likely caused by a higher probability of them encountering the gillnet, in comparison with cyprinids, which is related to their greater activity during dusk and dawn.

Paper V – Size selectivity of standardized multimesh gillnets in sampling coarse European species

We studied gillnet selectivity using a direct method of comparing fish size distributions from gillnet catches (Nordic type, mesh size range 5 – 135 mm, factor between adjacent mesh sizes 1.25) with reference distribution obtained by fry and adult beach seining (net length 10, 40 and 50 m, mesh size 1, 6 and 10 mm, respectively) in five Czech reservoirs. Target species were roach, perch and rudd. The most common pattern of differences in fish size distributions between the two gear was that more 0+ and 1+ year old fishes were caught by beach seine nets and slightly higher proportion of larger fishes was observed in gillnet catches. For three given species, gillnets were not able to enmesh fishes smaller than approximately 40 mm in standard length. We developed average species-specific corrections that increased proportions of 0+ and 1+ year old fish and deceased proportions of larger fishes. However, the average correction produced biased corrected size distribution in app. 20 % of cases. We also applied Kurkilahti's correction given in an European Standard EN 14 757, but it had a negligible effect on reducing bias in size distribution. Future research is needed to develop more accurate corrections, because without corrections for size distribution, interpreting results from gillnet sampling, especially these including data on 0+ and 1+ year old fishes, is very misleading.

General discussion, conclusions and perspectives

The following patterns of fish spatial distribution were studied and described in this dissertation:

A definite vertical pattern of the fish distribution was found in reservoirs with developed thermal and oxygen stratification and the trophic status ranging between meso- and eutrophy. The highest abundances of both juvenile and adult fish were recorded in the depth layer of epilimnion, directly below the surface to the depth of thermocline. In the epilimnion, fish utilized the highest water temperatures, oxygen

concentrations and food resources. This pattern of vertical distribution was described also in other reservoirs and lakes e.g. in Poland (Swierzowski et al., 2000), Estonia (Järvalt et al., 2005), Germany (Bohl, 1980), Sweden (Degerman et al., 1988), France (Brosse and Lek, 1999) and the Netherlands (Mous et al., 2004). However, as oxygen concentration directly below thermocline did not reach limiting values for fish occurrence (Straškraba, 1974), part of the population of roach, perch, bream and ruffe also occupied deeper layers in both pelagic and benthic habitats. This spatial segregation of perch was ascribed to avoidance of competition with roach (Persson, 1986; Kahl and Radke, 2006).

In reservoirs with no thermal and oxygen stratification, fish occupied all depth layers with preferences for a relatively shallow habitat (6 – 7 m) with the bottom without slope and for a deep habitat with the highest level of heterogeneity. Pelagic habitats were inhabited by less fish and most of them were recorded in the deepest part of it. Fish did not preferred the shallowest habitats probably due to a risk of predation by numerous piscivorous birds (Eckmann and Imbrock, 1996) present in the reservoirs.

A clear pattern of the fish horizontal distribution was found in reservoirs with a distinct longitudinal pattern of nutrients. Various ontogenetic stages (ecospecies) of roach, bream, bleak, asp, white bream, pikeperch and ruffe preferred parts of the reservoirs with a high trophy i.e. the upper and the tributary parts of the reservoirs. Contrary, juvenile and adult perch seemed to avoid parts of the reservoirs with the highest fish abundances and explored local maxima of zooplankton. In benthic habitats, the longitudinal pattern of the fish distribution was influenced not only by the gradient of nutrients but also by local characteristics of certain localities (e.g. the gentle bottom slope, dense vegetation of marcophytes etc.), where high abundances of especially juvenile fish were found.

Benthic and pelagic habitats were inhabited by different fish communities. All important species occurred in both types of habitats. However, the structure of the community changed significantly. Fish ecospecies could be divided into two groups. A group of epipelagic species – smelt, bleak, asp, rudd with their juveniles and juvenile bream and roach, preferred the upper depth layer of the pelagic habitats. A second group of inshore (littoral) species – adult roach and bream, and perch, pikeperch and ruffe with juveniles, occupied the benthic habitats down to a depth of approximately 15 m. In every sampled reservoir, pelagic habitats were not empty as expected by Fernando and Holčík (1991) indicating that originally riverine fish can utilize the resources of pelagic habitats in reservoirs. High abundances of juvenile cyprinids found in the pelagic habitats confirmed their diel horizontal migration between day littoral and night pelagic habitats (Bohl, 1980; Gliwicz and Jachner, 1992).

As a next step in studies of fish spatial distribution, Czech reservoirs with lower trophy, higher water transparency (e.g. the Nýrsko Reservoir) or without pronounced longitudinal pattern of nutrients (e.g. the Chabařovice mining pit) will be studied using gillnets. Further, time series of gillnet catches in the Římov Reservoir will be analysed and compared with time series of trawl catches of pelagic juveniles (Jůza et al., submitted) and littoral beach seine catches of adult fish (Říha et al., submitted). Based on gillnet catches and with knowledge of volumes of individual habitats, it will be possible to provide weighed estimate of the fish community of the whole reservoir (Prchalová et al. 2006, Kubečka et al. submitted).

As fish for my studies were sampled using gillnets, a part of this dissertation was dedicated to the gillnet selectivity. Studies on gillnet selectivity showed that gillnet catches have to be interpreted with caution due to biased species as well as size

composition. Based on comparison with the active sampling gear (beach seine nets), numbers of perch were found to be overrepresented in gillnet samples. Two experiments showed that the overrepresentation of perch was not caused by its thorny appearance (projections of opercula and ctenoid scales), which could increase the probability of capture and retention in the net. It was concluded that the higher proportion of perch was probably caused by its higher activity in comparison with other species and accordingly by its higher probability of encountering the gillnet.

Comparing fish size distributions from gillnets and beach seine nets indicated that gillnets provided a different size composition of the fish community. Juvenile roach, perch and rudd (0+ and 1+ year old) were underrepresented in gillnet catches. On the other hand, larger fish were slightly overrepresented in gillnets. Potential reasons for these biased proportions were not examined carefully though. However, it was hypothesized that both mechanical characteristics of gillnets as well as physiological abilities of fish of different sizes (swimming speed, manoeuvring capabilities) would play a role in the size selectivity of gillnets.

Corrections were developed for the species composition reducing proportion of perch, for the size distribution increasing proportion of small fish and the decreasing proportion of larger fish. However, these topics were answered in a way that gave rise to new questions, as usual, so better corrections should be found. Regarding these new questions, species and size compositions of gillnet catches as well as gillnet catch-per-unit-of effort will be compared with trawl and beach seine net catches and also with results derived from hydroacoustics in order to understand the relevance of the gillnet picture.

The fish spatial distribution in reservoirs was found to be clearly inhomogeneous and multimesh gillnets proved to be a reliable gear for outlining the gradients of distribution. Directions for future research emerged promisingly and I believe that I will not get lost.

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Patterns of fish distribution in a canyon-shaped reservoir

I

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Paper I – Abstract

In August 2004 and 2005, an extensive study of the fish community was carried out in the largest water supply reservoir in the Czech Republic and Central Europe, the canyon-shaped Želivka Reservoir, using a fleet of Nordic multimesh gillnets. Fish were sampled at eight locations along the longitudinal profile of the reservoir and at five benthic depth layers covering depths from the surface down to 18 m (benthic gillnet 1.5 m high), and at three pelagic depth layers down to the depth of 5 m above the bottom (pelagic gillnets 4.5 m high). Catches of both juvenile (0+ year old) and adult (fish older than one year) fish were highest in the upper layers of the water column (i.e. in the epilimnion down to 5 m, and down to 10 m in the benthic habitats). Along the tributary-dam axis in the pelagic habitats, both juvenile and adult fish preferred the upper part of the reservoir, where the maximum number of species and also the highest amount of zooplankton were found. In the benthic habitats, fish selected location according to factors other than trophic status. More juvenile fish were recorded in the benthic habitats than in the pelagic habitats. Depth had the largest explanatory power for predicting fish community composition, followed by the affiliation with benthic/pelagic habitats and location on the longitudinal axis of the reservoir. The fish community was represented mainly by cyprinids and consisted of two distinct groups of species, with bleak *Alburnus alburnus* (L.), rudd *Scardinius erythrophthalmus* (L.) and asp *Aspius aspius* (L.) dominating the offshore group while perch *Perca fluviatilis* L. and ruffe *Gymnocephalus cernuus* (L.) were affiliated with the inshore group of the adult fish community. Roach *Rutilus rutilus* (L.), bream *Abramis brama* (L.) and pikeperch *Sander lucioperca* (L.) occurred in important proportions in both the inshore and offshore zones. All species, with the exceptions of adult perch (1+ and older), 0+ perch and 0+ roach, preferred the most eutrophic tributary part of the reservoir. The fish community was relatively stable between the two years sampled.

Článek I – Abstrakt

V srpnu roku 2004 a 2005 proběhlo na nádrži Želivka – největší údolní nádrži na pitnou vodu v České republice a Střední Evropě, intenzivní sledování rybí obsádky pomocí mnohoočkových Nordických tenat. Ryby byly loveny na osmi místech podél podélné osy nádrže, v pěti bentických habitatech od hladiny až do hloubky 18 m (bentická tenata byla 1,5 m vysoká) a ve třech pelagických habitatech od hladiny do hloubky 5 m nade dnem (pelagická tenata byla 4,5 vysoká). Úlovky juvenilních (stáří 0+) i dospělých ryb (stáří 1+ a více) byly nejvyšší v horních vrstvách vodního sloupce tzn. v epilimniu do cca 5 m hloubky v pelagických habitatech a do hloubky 10 m v bentických habitatech. Juvenilní i dospělé ryby preferovaly v pelagických habitatech části nádrže nejblíž přítoku, kde byl také zaznamenán nejvyšší počet druhů ryb, nejvyšší hustota zooplanktonu a nejvyšší trofie. Distribuce ryb v bentických habitatech se však řídila pravděpodobně jinými faktory než trofií. Více juvenilních ryb bylo uloveno v habitatech bentických než pelagických. Při předpovídání složení rybí obsádky měl největší vysvětlující sílu faktor hloubky. Menší vliv byl zaznamenám u faktorů příslušnost habitatu do bentické či pelagické skupiny a umístění lovného místa na podélné ose nádrže. Kaprovité druhy ryb představovaly většinu rybích druhů společenstva. Ve společenstvu se daly dále odlišit dvě skupiny druhů dospělých ryb, a to druhy ouklej obecná *Alburnus alburnus* (L.), perlín ostrobřichý *Scardinius erythrophthalmus* (L.) a bolem dravý *Aspius aspius* (L.), které dominovaly pelagické skupině, a druhy okoun říční *Perca fluviatilis* L. a ježdík obecný *Gymnocephalus cernuus* (L.), které představovaly hlavní druhy skupiny příbřežních druhů. Plotice obecná *Rutilus rutilus* (L.), cejn velký *Abramis brama* (L.) a candát obecný *Sander lucioperca* (L.) se

vyskytovaly v obou dvou skupinách ve významných podílech. Všechny druhy s výjimkou juvenilních a dospělých okounů a juvenilní plotice vyhledávaly nejvíce úživnou přítokovou část nádrže. Rybí společenstvo se mezi dvěma sledovanými roky lišilo jen minimálně.

Author's contribution:

Marie Prchalová is the first author of this paper. The share of her work is approximately 90%.

The effect of depth, distance from dam and habitat choice on the spatial distribution of fish in a canyon-shaped reservoir

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II

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Paper II – Abstract

In 1999 – 2007, spatial distribution of the fish community in the Římov Reservoir, Czech Republic, was sampled using multimesh gillnets. Effects of depth, distance from the dam to the tributary as well as habitat choice on fish community structure, abundance, biomass and average weight were tested using redundancy analysis. Fish were recorded in all sampled depths and parts of the reservoir. Effects of three environmental variables were significant and most variability was explained by depth, then by distance and habitat. Abundance and biomass of all species decreased with depth and responses of individual species were similar in juvenile as well as adult fish. Number of species, abundance and biomass of all species except perch increased heading towards the tributary and peaked close to or at the tributary. Responses of juvenile fish to distance differed from adult fish. The fish community were found to have different structures in benthic and pelagic habitats; species preferred to occupy epipelagic (bleak, asp, rudd and juvenile bleak, roach and bream) or littoral waters (perch, pikeperch, ruffe, roach, bream and juvenile percids). Larger fish of all species except pikeperch and ruffe were caught in pelagic habitats. This nine-year study showed that fish distribution in the reservoir followed distinct patterns, which were shaped by a combination of physiological constraints plus a trade-off between food resources and competition.

Článek II – Abstrakt

Rybí společenstvo údolní nádrže Římov bylo vzorkováno mnohoočkovými tenaty v rozmezí let 1999 až 2007. Pomocí redundanční analýzy byl testován vliv hloubky, vzdálenosti od hráze a výběr habitatů na složení rybí obsádky, její početnost, biomasu a průměrnou váhu. Ryby byly zaznamenány ve všech hloubkách a částech nádrže. Vliv všech tří charakteristik prostředí byl průkazný a nejvíce variability bylo vysvětleno hloubkou, pak vzdáleností od hráze a habitatem. Početnost i biomasa všech druhů klesaly spolu s hloubkou a odpovědi jednotlivých druhů byly podobné u juvenilních i dospělých jedinců. Počet druhů, početnost a biomasa všech druhů vyjma okouna vzrůstaly ve směru od hráze k přítoku nádrže; maximálních hodnot dosáhly tyto ukazatele blízko přítoku. Odpovědi juvenilních ryb na charakteristiku vzdálenost od hráze se lišily od odpovědí ryb dospělých. Složení společenstva ryb se lišilo mezi bentickými a pelagickými habitaty – druhy jako ouklej obecná, bolen dravý, perlín ostrobřichý a juvenilní ouklej, plotice obecná a cejn velký preferovaly hladinové vrstvy volné vody a druhy jako okoun říční, candát obecný, ježdík obecný, plotice, cejn a juvenilní okounovité druhy obývaly zejména příbřežní mělké habitaty. Větší jedinci všech druhů ryb byli uloveni v pelagických habitatech. Tato devítiletá studie ukázala, že prostorové rozmístění ryb podléhá jasným předlohám, které byly tvarovány kombinací fyziologických omezení a trade-off mezi zdroji potravy a konkurencí.

Author's contribution:

Marie Prchalová is the first author of this paper. The share of her work is approximately 90%.

Fish habitat preferences in an artificial reservoir system

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III

Paper III – Abstract

Three Dutch artificially mixed reservoirs – De Gijster (320 ha), Honderd en Dertig (219 ha) and Petrusplaat (105 ha) – were sampled in 1998, 2000 and 2002 during late August an early September in order to describe fish habitat preferences. Eight benthic and three pelagic habitats covering all depth layers and bottom types were fished using multimesh gillnets. Fish were found in all habitats – the highest abundances were recorded in the benthic habitat 6 – 7 m deep with the flat bottom and in the benthic habitat with rugged bottom with numerous deep holes in the depth of 15 m. Pelagic habitats were occupied by less fish and most of them were recorded in the depth layer 9.5 – 5 m above the bottom. Multivariate analysis showed that most of the variability in community structure could be explained significantly simply by affiliation to individual habitat. We also tested following characteristics of the habitats – volume, depth, bottom type and slope, and found out that these variables had significant but lower effect on fish community structure indicating that habitat was not only a set of abiotic characteristics. From habitat characteristics, volume had the strongest effect on community of both 0+ year old and adult fish. 0+ year old fish were also significantly influenced by the depth – most 0+ year old fish occurred in depths down to 15 m. Only 0+ year old pikeperch *Sander lucioperca* (L.) and ruffe *Gymnocephalus cernuus* (L.) had positive correlation with the depth. 0+ smelt *Osmerus eperlanus* (L.) and 0+ bream *Abramis brama* (L.) preferably inhabited the pelagic habitats, whereas 0+ roach *Rutilus rutilus* (L.) and 0+ ide *Leuciscus idus* (L.) were found in both pelagic and benthic habitats in abundances above the average. 0+ year old percids, perch *Perca fluviatilis* L., pikeperch and ruffe were found mainly in the benthic habitats. In case of adult fish, only smelt and bleak showed positive correlation with the volume – smelt was found preferably in the pelagic habitats and bleak *Alburnus alburnus* (L.) had the highest abundances in both pelagic and shallow benthic habitats. Adult pikeperch, bream and ruffe had positive correlation with the depth. Abundances of roach, perch and white bream *Blicca bjoerkna* (L.) were highest in the benthic habitats down to depth of 15 m. This study showed that in absence of thermal and oxygen stratification, fish utilized all depths and volumes of the reservoir.

Článek III – Abstrakt

Preference ryb pro výběr habitatů byly sledovány v letech 1998, 2000 a 2002 na třech holandských, uměle míchaných nádržích – De Gijster (320 ha), Honderd en Dertig (219 ha) a Petrusplaat (105 ha). Ryby byly loveny pomocí sady mnohoočkových tenat v osmi bentických a třech pelagických habitatech. Ryby byly uloveny ve všech habitatech – nejvyšší početnosti byly zaznamenány v bentickém habitatu s plochým dnem a hloubkou 6 – 7 m a v bentickém habitatu se zvrásněným dnem v hloubce 15 m. Méně ryb obývalo pelagické habitaty s nejvyšší početností v hloubce 9,5 – 5 m nade dnem. Mnohonásobná statistická analýza ukázala, že největší vliv na složení rybího společenstva měla jednoduše příslušnost vzorků k jednotlivým habitatům. Dále jsme však testovali vliv následujících charakteristik habitatů – objem, hloubka, typ a sklon dna. Ukázalo se, že tyto charakteristiky mají průkazný, avšak nižší vliv na složení rybího společenstva než příslušnost vzorků k jednotlivým habitatům. To indikuje, že habitat není pouze souhrn abiotických charakteristik. Z testovaných charakteristik měl na složení společenstva jak juvenilních tak dospělých ryb největší vliv objem. Na juvenilní ryby měla dále velký vliv hloubka – nejvíce juvenilních ryb se vyskytovalo v hloubce do 15 m. Pouze u juvenilního candáta obecného *Sander lucioperca* (L.) a ježdíka obecného *Gymnocephalus cernuus* (L.) byla nalezena pozitivní korelace s hloubkou. Juvenilní koruška evropská *Osmerus eperlanus* (L.) a cejn velký *Abramis*

brama (L.) dávali přednost pelagickým před bentickými habitaty, zatímco juvenilní plotice obecná *Rutilus rutilus* (L.) a jelec jesen *Leuciscus idus* (L.) byli nalezeni v obou habitatech ve významných počtech. Juvenilní okounovité druhy okoun říční *Perca fluviatilis* L., ježdík a candát byly zaznamenávány zejména v bentických habitatech. Z dospělých ryb měly pozitivní korelaci s objemem habitatu pouze ouklej obecná *Alburnus alburnus* (L.) a koruška – nejvyšší početnosti korušky byly nalezeny v pelagických habitatech a nejvíce oukleje bylo loveno v pelagických a mělkých bentických habitatech. Pozitivní korelace s hloubkou byla popsána u dospělých candátů, cejnů a ježdíků. Početnosti plotice, okouna a cejnka malého *Blicca bjoerkna* (L.) byly nejvyšší v bentických habitatech do hloubky 15 m. Tato studie ukázala, že v nádržích s chybějící teplotní a kyslíkovou stratifikací dokáží ryby využívat všechny dostupné hloubky i objemy nádrže.

Author's contribution:

Marie Prchalová is the first author of this paper. The share of her work is approximately 90%.

Overestimation of percid fishes (Percidae) in gillnet sampling

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IV

Paper IV – Abstract

Overestimation of the number of percid fishes taken by gillnets was studied in eight reservoirs in the Netherlands and the Czech Republic during 1998 – 2006. Overestimation was defined as a higher proportion of percids (percids/(percids + cyprinids)) in gillnets than in the reference community (catches by seines on the same beach and night as the gillnet catches). A total of 97 pairs of catches were compared and overestimation was found in more than 80% of cases. The overestimation ranged from a few percent to more than 1 000%, being dependent on the proportion of percids in the fish community. Overestimation was highest in reservoirs with the lowest proportions of percids. Overestimation was proved for perch, but not for pikeperch and ruffe. A correction factor was developed, for the proportion of perch in the gillnet catches, using an empirical cubic function. Analysis of the direct mechanisms by which fish were enmeshed in the gillnets showed that most fish were wedged, one quarter were gilled and only 1.5% were tangled. Percid species were relatively more frequently tangled and gilled than cyprinids but not to an extent that can completely explain the total overestimation. Furthermore, the overestimation was not caused by a higher probability of perch being retained in the gillnet, as was evident from an experiment with retaining perch and roach in the gillnet. Overestimation of perch is most likely caused by a higher probability of them encountering the gillnet, in comparison with cyprinids, which is related to their greater activity during dusk and dawn.

Článek IV – Abstrakt

Nadhodnocení okounovitých druhů ryb bylo hodnoceno na osmi nádržích v Holandsku a České republice v rozpětí let 1998 až 2006. Nadhodnocení bylo stanoveno jako vyšší podíl okounovitých ryb (okounovité/(okounovité+kaprovité ryby)) v tenatech v porovnání s referenčním společenstvem, které bylo získáno z úlovků zátahovou sítí na stejných místech a během stejné noci jako úlovky tenaty. Celkem bylo porovnáno 97 párů úlovků a nadhodnocení okounovitých ryb bylo objeveno v 80% případů. Nadhodnocení kolísalo od několika procent do více jak 1000% a bylo závislé na podílu okounovitých v referenčním společenstvu. Nadhodnocení bylo nejvyšší na nádržích s nejnižším podílem okounovitých druhů ve společenstvu. Z okounovitých druhů bylo nadhodnocení prokázáno u okouna říčního, avšak ne u candáta obecného a ježdíka obecného. Za použití empirické kubické funkce jsme vyvinuli korekční faktor, který upravuje podíl okouna v úlovcích tenat. Analýza mechanismu, jakým jsou ryby zachytávány v tenatech, ukázala, že většina ryb byla do oček tenat vklíněna celým tělem, čtvrtina ryb byla zachycena za žábra a pouze 1,5% ryb bylo zachyceno za zuby a jiné hlavové výběžky. Okounovité druhy ryb byly relativně častěji uloveny zachycením za zuby a jiné hlavové výběžky a za žábra než ryby kaprovité, avšak ne v takovém rozsahu, který by vysvětlil jejich nadhodnocení. Další experiment odhalil, že nadhodnocení okouna není způsobeno ani jeho vyšší pravděpodobností udržení v síti. Uzavřeli jsme, že nadhodnocení okouna je pravděpodobně způsobeno zvýšenou pravděpodobností potkání sítě, která odpovídá vyšší aktivitě okounů během stmívání a rozbřesku v porovnání s kaprovitými rybami.

Author's contribution:

Marie Prchalová is the first author of this paper. The share of her work is approximately 90%.

Size selectivity of standardized multimesh gillnets in sampling coarse European species

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V

Paper V – Abstract

We studied gillnet selectivity using a direct method of comparing fish size distributions from gillnet catches (Nordic type, mesh size range 5 – 135 mm, factor between adjacent mesh sizes 1.25) with reference distribution obtained by fry and adult beach seining (net length 10, 40 and 50 m, mesh size 1, 6 and 10 mm, respectively) in five Czech reservoirs. Target species were roach, perch and rudd. The most common pattern of differences in fish size distributions between the two types of gear was that more 0+ and 1+ year old fishes were caught by beach seine nets and slightly higher proportion of larger fishes was observed in gillnet catches. For three given species, gillnets were not able to enmesh fishes smaller than approximately 40 mm in standard length. We developed average species-specific corrections that increased proportions of 0+ and 1+ year old fish and deceased proportions of larger fishes. However, the average correction produced biased corrected size distribution in app. 20 % of cases. We also applied Kurkilahti's correction given in an European Standard EN 14 757, but it had a negligible effect on reducing bias in size distribution. Future research is needed to develop more accurate corrections, because without corrections for size distribution, interpreting results from gillnet sampling, especially these including data on 0+ and 1+ year old fishes, is very misleading.

Článek V – Abstrakt

Na pěti českých nádržích jsme studovali selektivitu tenat pomocí přímé metody porovnání velikostních rozdělení ryb z tenat (Nordický typ, rozpětí velikosti oček 5 – 135 mm, faktor mezi přilehlými očky 1,25) s referenčními velikostními rozděleními získanými z úlovků zátahových sítí pro juvenilní a dospělé ryby (délka sítí 10, 40 a 50 m, velikost oček 1, 6 respektive 10 mm). Cílovými druhy byly plotice obecná, okoun říční a perlín ostrobřichý. Nejčastější rozdíl mezi velikostními rozděleními ryb ze dvou typů lovných prostředků byl následující: více juvenilních ryb (stáří 0+ a 1+ roku) bylo uloveno zátahovými sítěmi, zatímco více větších ryb uvázlo v tenatech. U všech cílových druhů nebyla tenata schopna ulovit jedince menší než přibližně 40 mm standardní délky. Pro jednotlivé cílové druhy jsme vyvinuli korekci, která v úlovcích tenat zvyšuje podíl juvenilních ryb a snižuje podíl starších ryb. Avšak naše korekce zkresluje podíly těchto skupin v ca 20% případů. Dále jsme použili Kurkilahtiho korekci uvedenou v Evropské normě pro lovení mnohoočkovými tenaty, ale tato korekce měla pouze zanedbatelný vliv při odstraňování velikostní selektivity tenat. Je zřejmé, že další výzkum na téma velikostní selektivity tenat je nezbytný. Bez korekcí velikostních rozdělení je totiž interpretace výsledků lovení tenaty velmi zavádějící, a to zejména pokud výsledky zahrnují také juvenilní ryby.

Author's contribution:

Marie Prchalová is the first author of this paper. The share of her work is approximately 90%.