

A simple proof of gillnet saturation

Marie Prchalová*, Jiří Peterka, Martin Čech and Jan Kubečka

*Biology Centre of the AS CR, v.v.i., Institute of Hydrobiology, Na Sádkách 7, CZ-370 05 České Budějovice, Czech Republic (*corresponding author's e-mail: marie.prchalova@hbu.cas.cz)*

Received 24 July 2012, final version received 22 oct. 2012, accepted 7 nov. 2012

Prchalová, M., Peterka, J., Čech, M. & Kubečka, J. 2013: A simple proof of gillnet saturation. *Boreal Env. Res.* 18: 303–308.

Gillnet saturation was assessed between standard (overnight, uninterrupted exposure) and consecutive (half or one hour exposures) sampling in two Czech reservoirs. The consecutive sampling yielded a greater number and biomass of fish as compared with those of the standard sampling. Species compositions were comparable between sampling types. Shannon's diversity indices did not differ significantly between the two sampling approaches.

Introduction

Gillnets are widely used to assess relative abundances and biomass of fish. Although gillnets have indisputable advantages, their catches can be biased for certain species or sizes of fish or towards catching actively swimming fish. Moreover, when gillnets become saturated, their catchability potential is reduced, and this can lead to the lower representativeness during surveys with gillnets.

Gillnet saturation is a result of several processes leading to a non-linear relationship between the gillnet catch and the duration of exposure (soak time). In particular, these factors include space limitations, gillnet shape deformation when fish are caught, and fish avoidance of occupied nets (for a review on gillnet saturation, see the Introduction in Prchalová *et al.* 2011).

Because gillnet saturation has not been studied extensively, its effects are generally underestimated. The European standard on gillnet fishing (EN 14 757) states that with the use of standard benthic gillnets, saturation can affect catches that are ≥ 6 kg (CEN 2005). In the study estimating this weight threshold, only single mesh size

of 19 mm was used, and the size distribution of fish was assumed to be random across all mesh sizes (Hamley 1980). However, a recent study showed that even lower catch volumes reduce gillnet catchability (Olin *et al.* 2004). The effects of gillnet saturation on catchability are of particular concern in continental Europe, where water tends to have higher trophic status with higher fish densities — e.g., 81–1000 kg ha⁻¹ in Spanish reservoirs (Lara *et al.* 2009); 89–181 kg ha⁻¹ in Lake Balaton, Hungary (Tátrai *et al.* 2008); 41–291 kg ha⁻¹ in the Neusiedler See, Austria (Herzig and Kubečka 2001); 260–1000 kg ha⁻¹ in shallow Dutch lakes (van Donk *et al.* 1990, Vlught *et al.* 1992); 42–805 kg ha⁻¹ in Czech reservoirs (Prchalová *et al.* 2009a); and approximately 670 kg ha⁻¹ in shallow Danish lakes (Jeppesen *et al.* 1998). The inaccuracies caused by gillnet saturation can have severe effects on sampling projects, especially in waterbodies such as those.

In 2008, we performed a simple yet demanding experiment to elucidate the principles of gillnet fishing (Prchalová *et al.* 2010 and 2011). We made the assumption that gillnet catch (CPUE, Catch Per Unit of Effort) is a function of fish

activity, saturation, fish escapement and catchable biomass rate. The aim was to describe and determine fish activity and saturation to get fish density rate (termed catchable biomass rate). Fish density rate was then supposed to be linearly related to the real fish density.

We defined two periods, with peak times at sunset and sunrise, of fish gillnet activity followed by a plateau of low night activity. This activity pattern coincides with general notions for the expected activity of most European freshwater fish species (Vašek *et al.* 2009, Prchalová *et al.* 2010). To describe saturation, we used cameras to record gillnets as fish were caught (Prchalová *et al.* 2011). In the model we developed for saturation, we found that fish escaping after a short time of being caught was a significant phenomenon. For this reason, we included fish escape in our gillnet-catch model. The fish density rate was determined and recommended to be used instead of CPUEs in reporting gillnet results because the former is free of saturation, fish activity and fish escapement biases.

However, previous reports on fish activity and saturation did not demonstrate the direct effects of saturation during field experiments. Thus, in this short communication we aimed to report on the comparison of gillnets that were repeatedly cleared and gillnets that were continuously exposed.

Materials and methods

Study areas

Experiments were carried out in two reservoirs in the Czech Republic: the canyon-shaped Římov and the pond-like Nové Mlýny I. The Římov and Nové Mlýny I reservoirs have surface areas of 210 and 528 ha, maximum depths of 45 and 4.3 m, and average depths of 16 and 1.8 m, respectively. The fish assemblages in these reservoirs are dominated by cyprinids, with *Rutilus rutilus*, *Abramis brama*, *Alburnus alburnus* and *Blicca bjoerkna* being most common. Detailed descriptions of these reservoirs and their fish communities can be found in Prchalová *et al.* (2009b, 2010, 2011).

Gillnetting and data analysis

Benthic gillnets, mounted in the bottoms of the reservoirs, were used as these nets are easier to operate and can achieve larger catches than pelagic gillnets, as assessed by reservoir studies. Gillnets were manufactured following the European standard EN 14 757 guidelines (CEN 2005). We used 12 different mesh sizes that ranged from 5 to 55 mm knot to knot. Each mesh size was distributed in panels that totaled 2.5 m in length and 1.5 m in height (Pokorný site, Brloh, Czech Republic). Location details for each experiment can be found in Prchalová *et al.* (2010 and 2011).

We set up two groups of gillnets. The first group (1 h) was cleared or set repeatedly at half or one hour intervals throughout the night; three replicates were conducted in each reservoir. In both reservoirs, gillnets were cleared every hour. The exception was high-catch periods (16:30–20:30 and 06:30–09:30) in the Nové Mlýny I, where gillnets were reset every half an hour because of its dense fish assemblages (Prchalová *et al.* 2010). We replaced gillnets as quickly and silently as possible to minimize disturbing the fish.

The second group of gillnets (standard) was set and left overnight with no interruptions. The standard and 1-h gillnets were set within the same habitat types and localities, with a distance of approximately 100 m from each other. Total gillnet exposure times were 12 h in the Římov and 18 h in the Nové Mlýny I. From our experience with sampling fish in targeted reservoirs, we did not expect fish to gather within a given sampled habitat due to water current, waves or any structural complexity of the habitat. Therefore, we assumed the homogeneous access of fish to both groups of gillnets set.

We recorded data on fish species and numbers, body length (± 5 mm) and weight (± 1 g). We compared absolute numbers (fish per gillnet) and biomass (kg per gillnet) of fish between the standard and 1-h groups. For the 1-h group, we calculated these values from the data collected throughout the entire catching period. We performed comparisons with a *t*-test for dependent samples in STATISTICA (StatSoft, Tulsa, OK). Shannon's diversity index (H') for number and biomass of fish was calculated as follows: $-\sum p_i \times \ln p_i$, where p_i is the proportion of species *i*.

Results and discussion

In both reservoirs, the number of fish caught was significantly higher in the 1-h exposure group than in the standard-exposure group (Table 1 and Fig. 1). Fish biomass was also higher in the 1-h group for both reservoirs, but only the Nové Mlýny I results were significant (Table 1 and Fig. 2). In the Římov, even though the number of fish was higher in the 1-h group, because the catch consisted mainly of small-bodied species, such as ruffe and bleak, the biomass difference did not reach statistical significance. There were no differences in the distribution of catch sizes between the 1-h and standard groups (Fig. 3).

The species compositions of the catches from the standard and 1-h exposures were similar in terms of relative abundances and biomass (Table 1 and Fig. 4). From the standard and 1-h exposures, eight species were recorded in the Římov, with seven of these being fairly common. In the Nové Mlýny I, 1-h exposures recorded nine species, while standard gillnetting collected only seven common species. Shannon's diversity indices did not differ significantly between exposure types, but the 1-h group had slightly higher values overall due to its larger sample sizes (Table 1). Considering all species combined, the number of fish increased from the standard to 1-h exposure conditions with a range increment of 1.3-fold to 3.4-fold (mean = 2.3) and 1.3-fold to 3.9-fold (mean = 2.7) in the Římov and Nové Mlýny I, respectively. Exceptions to this included bleak in the Římov, which had a 35-fold increase, and roach and bream in the Nové Mlýny I, which had 5.7-fold and 5.6-fold increases, respectively.

To the best of our knowledge, our experiment was the first to examine consecutive gillnetting

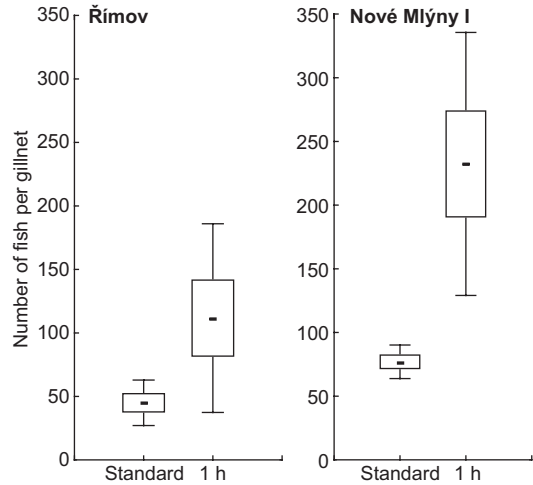


Fig. 1. Number of fish caught during standard and 1-h exposures in the Římov and Nové Mlýny I reservoirs. Means, SDs and 95%CLs are indicated by black squares, boxes and whiskers, respectively.

conditions with a fine temporal resolution (one hour and half hour). These results support previous findings on gillnet saturation that indicate a non-linear relationship between gillnet catch and exposure time (Hickford and Schiel 1996, Kennedy 1951, Koike and Takeuchi 1982, Minns and Hurley 1988). To date, the most detailed study of this nature was carried out by Olin *et al.* (2004), who used continuous and consecutive gillnetting on a relatively fine temporal scale (12 h *vs.* 3 × 4 h and 4 h *vs.* 4 × 1 h) and found that continuous gillnetting yielded significantly lower catches than consecutive gillnetting.

In this study, we compared gillnet saturation in repeated short-time exposures and continuous overnight exposures under the assumption that the short-time exposures are affected less by gillnet saturation than the overnight ones. In

Table 1. *t*-test results comparing number of fish, total biomass and diversity indices between standard and 1-h exposures. *p* values indicating significant differences are set in boldface.

Test category	<i>n</i>	df	Total catches				Shannon diversity index (<i>H'</i>)			
			Standard	1 h	<i>t</i>	<i>p</i>	Standard	1 h	<i>t</i>	<i>p</i>
Římov (no. of fish)	3	2	135	335	-4.713	0.042	1.278	1.494	-1.965	0.188
N. Mlýny I (no. of fish)	3	2	231	697	-7.333	0.018	1.186	1.437	-1.896	0.198
Římov (kg)	3	2	10.581	12.021	-0.423	0.714	1.321	1.595	-2.500	0.130
N. Mlýny I (kg)	3	2	27.989	99.362	-4.304	0.049	0.820	1.293	-3.766	0.064

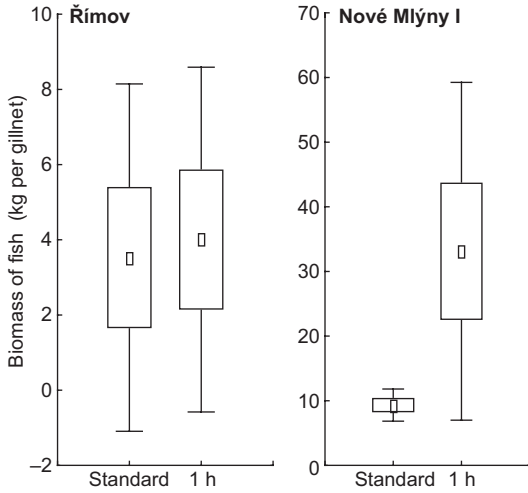


Fig. 2. Biomass of fish caught during the standard and 1-h exposures in the Římov and Nové Mlýny I reservoirs. Means, SDs and 95%CLs are indicated by black squares, boxes and whiskers, respectively.

conditions of dense fish assemblages in the Nové Mlýny I, we cleared the gillnets every half an hour during periods of high fish activity. However, it is possible that fish may have reacted differently to partially full gillnets because even small catches have been shown to reduce gillnet catchability (Olin *et al.* 2004). The design of the current experiment did not allow for the comparison of standard exposures with catches of absolutely non-saturated nets as it is practically impossible to obtain such data.

It is likely that differences between consecutive and continuous gillnet sampling and gillnet saturation were influenced by abiotic and biotic factors. The study sites differed between res-

ervoirs mainly in water temperature (23 °C in Římov vs. 13 °C in Nové Mlýny I), fish density (Figs. 1 and 2), transparency (100 vs. 35 cm of the Secchi depth) and slightly in oxygen concentration (11.3 vs. 8.8 mg l⁻¹). It has been shown that a gillnet catch is significantly influenced by water temperature and fish density with catches increasing with temperature and density to a certain point, decreasing thereafter (Hansson and Rudstam 1995, Linlökken and Haugen 2006). Furthermore, gillnet catch size can also decrease with greater visibility (Hansson and Rudstam 1995). Therefore, it can be expected that the rate of saturation is controlled by fish activity and is thus indirectly related to water temperature, transparency and fish density. However, the design of the current study consisted of only two observations under different conditions, which does not allow us to assess the effects of environmental factors on saturation.

Although species compositions were similar between the two types of sampling, the most evident differences deserve further comment. In the Římov, the increased proportion of *Alburnus alburnus* in the 1-h exposure group was due to the morning catch of *A. alburnus* shoal by a single gillnet (Fig. 4). It is possible, and certainly likely, that species-specific reactions to partially full gillnets were present, even though we have not discussed these reactions thus far because they are beyond the scope of the current report. A design using an underwater camera under conditions of relatively clear water has to be implemented to reveal species-specific reactions in detail. A large number of cameras would be needed to further gather a representative dataset,

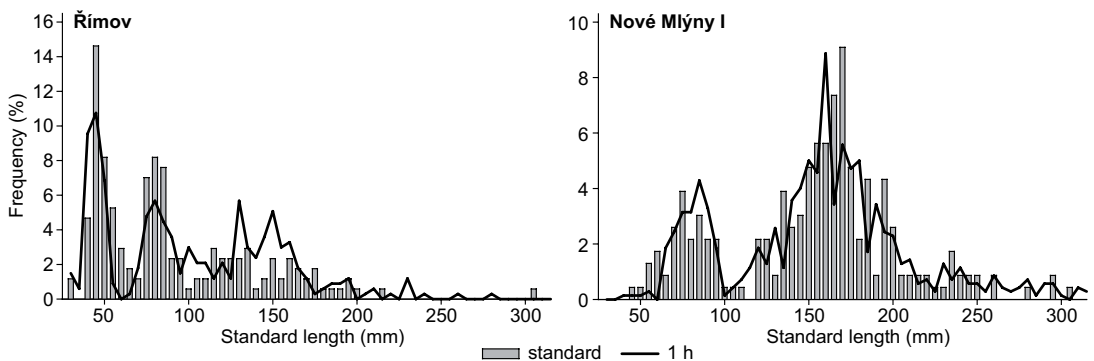


Fig. 3. Distribution of body lengths for all species recorded during catches in the Římov and Nové Mlýny I reservoirs.

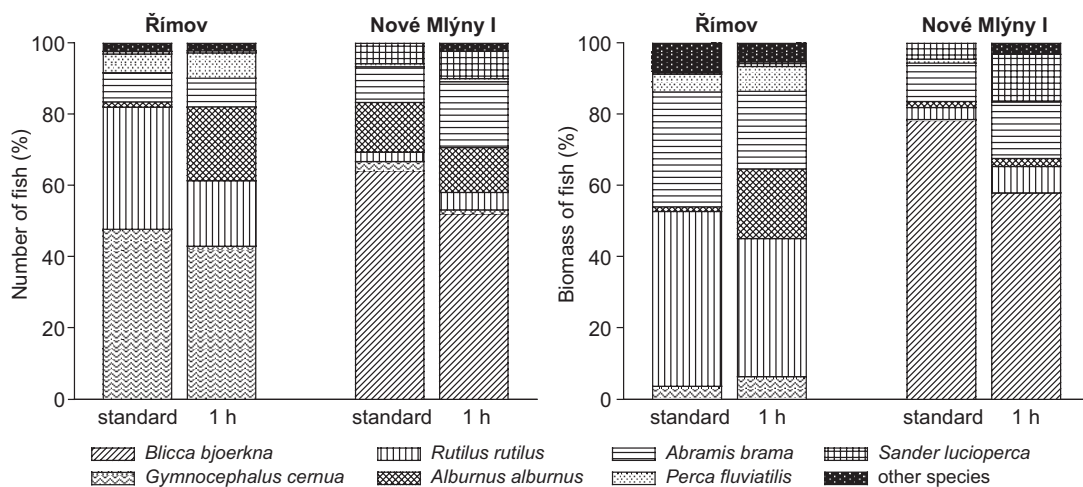


Fig. 4. Species compositions in standard and 1-h catches from the Římov and Nové Mlýny I reservoirs. The contribution of each species is expressed as a percentage of the total number of fish (left) and total biomass of fish (right). Data for the 1-h exposures represents the sum of all catches.

while repetitions could be burdened by inter-day differences in abiotic conditions.

We demonstrated that saturation is an important phenomenon in gillnet sampling, and therefore, saturation now stands along other well-documented gillnet biases for certain fish species (Prchalová *et al.* 2008) or fish sizes (Olin and Malinen 2003, Olin *et al.* 2009, Prchalová *et al.* 2009c). Proper procedures to address saturation are recommended in Prchalová *et al.* (2011).

Acknowledgements: The authors would like to thank E. Hohausová, J. Svobodová, M. Kratochvíl, M. Muška, J. Beneš, E. Bouše, J. Černý, J. Jan, O. Jarolím, M. Jankovský, L. Kočvara, T. Mrkvička, Z. Prachař, M. Tušer, L. Vejřík and J. Zima for their help with field work and data processing, and M. Šimonovská, the grandmother, for baby-sitting while this paper was being revised. We would also like to thank two anonymous referees for their helpful comments. The funding for this study was provided by the Project IAA600960901 from the Grant Agency of the Academy of Sciences of the Czech Republic and by the Projects 206/09/P266 and GPP505/12/P647 from the Grant Agency of the Czech Republic, with institutional support RVO:60077344.

References

- CEN 2005. *Water quality – Sampling of fish with multimesh gillnets*. CEN TC 230, European Standard EN 14 757 2005.
- Hamley J.M. 1980. Sampling with gillnets. *EIFAC Tech. Paper* 33: 37–53.
- Hansson S. & Rudstam L.G. 1995. Gillnet catches as an estimate of fish abundance: a comparison between vertical gillnet catches and hydroacoustic abundances of Baltic Sea herring (*Clupea harengus*) and sprat (*Sprattus sprattus*). *Can. J. Fish. Aquat. Sci.* 52: 75–83.
- Herzig A. & Kubečka J. 2001. Fish biomass distribution in Neusiedler See (Austria): a hydroacoustic assessment of fish stock. *Verh. Internat. Verein. Limnol.* 27: 3660–3665.
- Hickford M.J.H. & Schiel D.R. 1996. Gillnetting in southern New Zealand: duration effects of sets and entanglement modes of fish. *Fish. Biol.* 66: 669–677.
- Jeppesen E., Jensen J.P., Sondergaard M., Lauridsen T., Moller F.P. & Sandby K. 1998. Changes in nitrogen retention in shallow eutrophic lakes following a decline in density of cyprinids. *Archiv für Hydrobiologie* 142: 129–151.
- Kennedy W.A. 1951. The relationship of fishing effort by gill nets to the interval between lifts. *J. Fish. Res. Bd. Can.* 8: 264–274.
- Koike A. & Takeuchi S. 1982. Saturation of gillnet for pondsmelt *Hypomesus transpacificus nipponensis*. *Bull. Jpn. Soc. Sci. Fish.* 48: 1711–1716. [In Japanese with English summary].
- Lara G., Encina L. & Rodríguez-Ruiz A. 2009. Trophometric index: a predictor for fish density, biomass and production in Mediterranean reservoirs in Spain. *Fish. Manage. Ecol.* 16: 341–351.
- Linløkken A. & Haugen T.O. 2006. Density and temperature dependence of gill net catch per unit effort for perch, *Perca fluviatilis*, and roach, *Rutilus rutilus*. *Fish. Manage. Ecol.* 13: 261–269.
- Minns C.K. & Hurley D.A. 1988. Effect of net length and set time on fish catches in gill nets. *N. Am. J. Fish. Manage.* 8: 216–223.
- Olin M. & Malinen T. 2003. Comparison of gillnet and trawl in diurnal fish community sampling. *Hydrobiologia*

- 506–509: 443–449.
- Olin M., Kurkilahti M., Peitola P. & Ruuhijärvi J. 2004. The effects of fish accumulation on the catchability of multi-mesh gillnet. *Fish. Res.* 68: 135–147.
- Olin M., Malinen T. & Ruuhijärvi J. 2009. Gillnet catch in estimating the density and structure of fish community — comparison of gillnet and trawl samples in a eutrophic lake. *Fish. Res.* 96: 88–94.
- Prchalová M., Kubečka J., Říha M., Litvín R., Čech M., Frouzová J., Hladík M., Hohausová E., Peterka J. & Vašek M. 2008. Overestimation of percid fish (Percidae) in gillnet sampling. *Fish. Res.* 91: 79–87.
- Prchalová M., Kubečka J., Muška M., Frouzová J. & Jančůvský M. 2009a. *Průzkum rybí obsádky nádrže Nové Mlýny I v roce 2008*. Report of the Institute of Hydrobiology, BC AV CR, v.v.i.
- Prchalová M., Kubečka J., Čech M., Frouzová J., Draštík V., Hohausová E., Jůza T., Kratochvíl M., Matěna J., Peterka J., Říha M., Tušer M. & Vašek M. 2009b. The effect of depth, distance from dam and habitat on spatial distribution of fish in an artificial reservoir. *Ecol. Freshw. Fish* 18: 247–260.
- Prchalová M., Kubečka J., Říha M., Mrkvička T., Vašek M., Jůza T., Kratochvíl M., Peterka J., Draštík V. & Křížek, J. 2009c. Size selectivity of standardized multimesh gillnets in sampling coarse European species. *Fish. Res.* 96: 51–57.
- Prchalová M., Mrkvička T., Kubečka J., Peterka J., Čech M., Muška M., Kratochvíl M. & Vašek M. 2010. Fish activity as determined by gillnet catch: a comparison of two reservoirs of different turbidity. *Fish. Res.* 102: 291–296.
- Prchalová M., Mrkvička T., Peterka J., Čech M., Berec L. & Kubečka J. 2011. A model of gillnet catch in relation to the catchable biomass, saturation, soak time and sampling period. *Fish. Res.* 107: 201–209.
- Tátrai I., Specziár A., György A.I. & Bíró P. 2008. Comparison of fish size distribution and fish abundance estimates obtained with hydroacoustics and gill netting in the open water of a large shallow lake. *Annales de Limnologie — International Journal of Limnology* 44: 231–240.
- van Donk E., Grimm M.P., Gulati R.D. & Klein Breteler J.P.G. 1990. Whole-lake food-web manipulation as a means to study community interactions in a small ecosystem. *Hydrobiologia* 200–201: 275–289.
- Vašek M., Kubečka J., Čech M., Draštík V., Matěna J., Mrkvička T., Peterka J. & Prchalová M. 2009. Diel variation in gillnet catches and vertical distribution of pelagic fish in a stratified European reservoir. *Fish. Res.* 96: 64–69.
- Vlught J.C., Walker P.A., Does J. & Raat A.J.P. 1992. Fisheries management as an additional lake restoration measure: biomanipulation scaling-up problems. *Hydrobiologia* 233: 213–224.