



**BIOLOGICKÉ
CENTRUM**
AV ČR, v. v. i.



METHODOLOGY OF MONITORING FISH COMMUNITIES IN RESERVOIRS AND LAKES

Kubečka, J., Balk H., Blabolil, P., Frouzová, J., Kolařík, T., Kratochvíl, M., Muška, M., Prchalová, M., Říha, M., Sajdlová, Z., Soukalová, K., Souza, A., Tušer, M., Vejřík, L., Vejříková I.,



Biology Centre CAS v.v.i.
Institute of Hydrobiology

Methodology of monitoring fish communities in reservoirs and lakes

*Kubečka, J., Balk H., Blabolil, P., Frouzová, J., Kolařík, T., Kratochvíl,
M., Muška, M., Prchalová, M., Říha, M., Sajdlová, Z., Soukalová,
Souza A. T., A., Tušer, M., Vejřík, L., Vejříková I.,*

Edited by :

J. Kubečka and K. Soukalová

České Budějovice, 2022



EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education



SUMMARY

The book contains the overview and the description of the methods for the monitoring of qualitative and quantitative composition of the fish stock of lakes and reservoirs. It gives thorough description of the fieldwork and primary processing of information collected. Template field protocols to accompany every sample are attached. Use of multi-mesh gillnets, hydroacoustics, beach seining, long lines and electrofishing boat is described for the basic monitoring within the scope of the EU Water Framework Directive (2000/60/EC) monitoring of ecological quality or potential of lakes and reservoirs.

Reviewers:

Doc. Mikko Olin, PhD., Senior Researcher at Natural Resources Institute Finland (Luke), **Helsinki, Finland**

David Ritterbusch PhD., Researcher at Institute of Inland Fisheries **Potsdam Sacrow, Germany.**

Ing. Pavel Jurajda, PhD., Head of Fish ecology, Institute of Vertebrate Zoology CAS, **Brno, Czech Republic.**

RNDr. Jiří Peterka, PhD., Director of the Institute of Hydrobiology, Biology Centre CAS, **České Budějovice, Czech Republic**

The publication was supported by ESIF in frame of the project „Biomaniplulation“, reg. no. CZ.02.1.01/0.0/0.0/16_025/0007417 and by the Strategy AV21 of the Czech Academy of Sciences, VP20 - Water for life.

The authors would like to thank colleagues from the FISHECU.Cz working group for their many years of dedicated cooperation in sampling water bodies and the colleagues of the Vltava, Elbe, Moravia, Odra and Ohře River Catchment Authorities, the Czech and Moravian Fishery Association, colleagues from EVIDES water company, dr. Arco Wagenvoort (AqWa), prof. Josef Wanzenbock, University of Innsbruck, prof. Alois Herzig, Biological Station Neusiedler See and many other research and water management colleagues for many years of stimulating cooperation. We would also like to thank to our reviewers for their comments on the text of the methodology.

1s	Introduction: aims, strategies, and method selection for fish monitoring	06
1.1	Fully drainable waters (fishponds)	09
1.2	Sampling strategies: locality-based, continuous and area surveys	09
1.3	Sampling period and method selection	12
1.4	General guidelines for catch and data processing	13
1.4.1	Sampling for age analysis	14
1.4.2	Sampling for determination of length-weight relationships and biomass	15
1.5	Health and safety	15
1.6	References	16
2	Sampling by gillnets	20
	Sampling with gillnets has many advantages, such as:	
	However, there are some drawbacks that researchers should be aware of, namely:	
2.1	Basic equipment	22
2.2	Other equipment	26
2.3	Sampling	27
2.3.1	Selection of sampling sites	27
2.3.2	Sampling	30
2.4	Catch evaluation	32
2.5	Corrections of gillnet catches	32
2.5.1	Mesh size selectivity	33
2.5.2	Correction for overestimation of perch	33
2.5.3	Rough eel-abundance assessment using eel attacks	34
2.5.4	Correction for gillnet saturation and avoidance	35
2.5.5	Correction for shortened exposure time	37
2.6	References	38
3	Hydroacoustic surveys	44
	Advantages of hydroacoustic survey:	46
	Limitations of hydroacoustic survey:	46
3.1	Basic equipment	47
3.2	Other equipment required	47
3.3	Sampling	48
3.4	Processing and interpretation of results	50
	Acknowledgment	53
3.5	References	53
4	Electrofishing	59
	Advantages of electrofishing:	59
	Limitations of electrofishing:	60
	Principle of electric fishing	60
4.1	Use, time and suitable conditions for electric fishing	61

4.2	Equipment	61
4.2.1	Electrofishing boat	61
4.2.2	Generator unit	62
4.2.3	Electrodes	63
4.3	Additional equipment	65
4.4	Sampling	66
4.4.1	Selection of locality and environment	66
4.4.2	Before sampling	66
4.4.3	Sampling	67
4.5	The efficiency of electrofishing	68
4.5.1	Biological factors	68
4.5.2	Environmental factors	69
4.5.3	Technical factors	70
	Current type	70
	Electrodes size and shape	70
4.6	Catch processing	71
4.7	Data processing	71
4.8	Importance of correct settings	72
4.9	Work safety	72
4.10	References	73
5	Sampling by beach seine nets	76
	Advantages of beach seine nets:	76
	Disadvantages of beach seining:	77
5.1	Equipment	77
5.1.1	Beach seine net	77
5.1.2	Other equipment	78
5.2	Sampling	79
5.2.1	Selectivity of beach seine nets	79
5.2.2	Sampling period	79
5.2.3	Selection of suitable sites and sampling effort	80
5.3	Realization of a haul	81
5.3.1	Net preparation	81
5.3.2	Net deployment	81
5.3.2.1	Block net	81
5.3.2.2	Pull-by-rope	82
5.4	Pulling net to the shore	83
5.5	Measurement and calculation of swept area extension and catch per area unit parameters	84
5.5.1	Block net	84
5.5.2	Pull-by-rope method	84

5.6	Evaluation of results	85
5.7	References	86
6	Hook-lines used for sampling of european catfish (silurus glanis)	90
	The advantages of using hook-lines:	90
	The disadvantages of using hook-lines:	91
6.1	Scheme of hook-lines and the equipment	91
6.1.1	Basic equipment	91
6.1.2	Additional equipment	92
6.2	Sampling	93
6.2.1	Selective sampling of catfish using hook-lines	93
6.2.2	Sampling time	94
6.2.3	Selection of suitable location, sampling effort and time schedule	94
6.2.4	Assembly of the hook-line, its servicing and coping with the catch	95
6.2.4.1	Preparation of hook-line	95
6.2.4.2	Assembly of the hook-line in the field	95
6.2.4.3	Mounting of the snoods	96
6.2.4.4	Checking of the snoods and taking out of the caught catfish	97
6.3	Evaluation of the results	99
6.4	Reference	100
7	Managing data in ecology and fishery science: importance, challenges and tools	102
7.1	Increased generation and use of data in science	102
7.2	Data management workflow in science	103
7.3	Database basics	104
7.4	Example on a relational database in fish ecology	106
7.5	Data accessibility	108
7.6	Data legacy	108
7.7	Final remarks	109
7.8	References	109

1 Introduction: aims, strategies, and method selection for fish monitoring

Jan Kubečka¹, kubecka@hbu.cas.cz Kateřina Soukalová¹, katerina.soukalova@hbu.cas.cz

¹ Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, Na Sádkách 7, 370 05, České Budějovice, Czech Republic

Monitoring usually means continuous assessment, analysis and evaluation of a given situation or phenomenon. The main requirement of monitoring programmes is the comparability of the results in time and space. For fish monitoring, the results should be comparable for different waterbodies and different survey years. To achieve comparability, monitoring surveys must be carried out in a standardized manner (Bonar et al., 2009). This aim was greatly supported by the activity of the EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN), who facilitated the creation of European standards applicable to fish sampling in all waterbodies. Also, for some important methodical approaches, European standards were not developed yet and the standardization requires thorough guidelines. The original impetus for this publication was the current project Biomanipulation as a tool for improving water quality of dam reservoirs of the Operational programme Research, Development and Education (in Czech OP VVV, <https://opvvv.msmt.cz/download/file1530.pdf>) where a new edition of the methodology for monitoring fish stocks in lakes and reservoirs is one of the deliverables. This book is a follow-up of earlier Czech guidelines for fish sampling provided by Kubečka and Prchalová (2006) and Kubečka et al. (2010). Earlier editions were written in Czech what significantly reduced the impact of the information. Therefore, it was decided to publish a new edition in English so our long-term experience and extracts from extensive literature can benefit the scientific communities of more countries.

Monitoring fish in reservoirs and lakes can have several levels, depending on the purpose of monitoring:

1. Monitoring of fish communities for the application of Water Framework Directive 2000/60 / EC of the European Parliament and of the Council EC of 23 October 2000 establishing a framework for Community action

in the field of water policy (hereafter WFD). For this purpose, knowledge of abundance, biomass composition and population structure of size and age is needed to assess ecological status or potential of the water body.

2. More specific purposes like explaining the dynamics of fishery catches, scientific studies, or background data management of fish stocks and their commercial exploitation require more detailed information obtained on a more representative material with a controlled error due to the selectivity of fishing gear and space heterogeneity of fish occurrence (known probabilities of estimation errors, confidence intervals, etc.).
3. Monitoring of fry (age-0 or young-of-the-year) communities is methodologically different. Fish fry is the smallest component of the community and consequently requires specific modification of sampling strategies. Studies of fish fry quantity provide important information on year class strength of particular species at particular age, which can be important for the explanation of population dynamics and success of individual year classes. Because fry community surveys include only one year class and year class strength often varies from year to year (Jůza et al., 2014) fry surveys are usually not the part of routine monitoring programmes (one survey of "older fish" includes several year classes in one run). One exception is WFD monitoring of Czech running waters which is based solely on fry monitoring as advocated by Jurajda et al. (2010). Fry samples may be a bycatch of monitoring samples of the whole community (e.g., Prchalová et al., 2009b) but in general, sampling of fish fry is not considered as the core part of fish monitoring programs when the whole community (several year classes) has to be assessed. Therefore, the monitoring of fry communities is not the primary aim of this book.

Of the European standards, EN 14962 Water quality - Guidance on the scope and selection of fish sampling methods (CEN 2005) gives the framework for selecting the right methodologies. The following text often refers to three European standards for monitoring fish communities under the Framework Directive: Water quality - Sampling of fish with multi-mesh gillnets (EN 14 757, Update CEN, 2015), Water quality - Guidance on the estimation of fish abundance with mobile hydroacoustic methods (EN 15910, CEN, 2014) and Sampling of fish with electricity (EN 14 011, CEN, 2003). Of the foreign implementations of the Framework Directive for the monitoring of stagnant

water, the Scandinavian system (Appelberg et al., 1995), the Austrian system (Gassner et al., 2006) and the German system (Mehner et al., 2005; Garcia et al., 2006) were used. This text is not meant as replacement but rather as complement of the above mentioned European sources and standards.

Sound monitoring programmes should provide information on quantity, biomass, species and size (and age) composition at whole waterbody or its main parts. If the waterbody or the fish community is not homogeneous, the monitoring program should consider the spatial distribution of the above parameters. Inhomogeneities in fish distributions can usually be described in terms of spatial gradients:

1. Vertical gradient, depth dependent differences, e.g. caused by light, temperature and oxygen
2. Horizontal, longitudinal gradients, especially for valley reservoirs and prolonged lakes
3. Transversal gradient between benthic (near bottom) and pelagic (open water) habitat

The gradients predetermine the sampling habitats which should be parts of waterbody with a relatively homogeneous fish community where sample variation is caused mainly by random effects. Definition of appropriate sample habitats is an important task for preparation of every survey. In our opinion, only gillnets are suitable for sampling of all habitats. All other methods are somehow habitat-selective, a fact that should be kept in mind when extending the results to the whole waterbody. When all habitats of a waterbody can be sampled, but their share on the whole area is not equal, there are three possible strategies for analyses:

1. Use relative indices for selected habitats (like benthic/pelagic habitats). With this approach, fish measures characterizing the whole waterbody are not available. Data usage can be thus similar to approaches which cannot sample all habitats (hydroacoustics, seining, electrofishing).
2. Stratify the sampling effort the way that the number of samples in individual habitats correspond to their importance (volume) in the waterbody. In this case whole lake values of composition, abundance and biomass can be obtained by averaging individual catches. European gillnet norm (CEN, 2015) gives good description of depth-stratified

sampling of benthic habitats, while proportional sampling of pelagic habitats may be a challenge when pelagic volumes are significantly larger than benthic.

3. In a volume weighted approach fish parameters from individual habitats are weighted by the habitat volumes (Lauridsen et al., 2008; Kubečka et al., 2013; Alexander et al., 2015; Tesfaye et al., 2022). This is the only approach for obtaining lake wide population parameters for bigger water bodies (area > 1 km², depth > 10 m).

The following parts of the introduction chapter summarize general guidelines common to most of specific chapters dealing with individual sampling approaches.

1.1 Fully drainable waters (fishponds)

For water bodies that can be completely drained, it is possible to estimate the fish stock either by the methodology described in this book or by an estimation of the complete fish inventory obtained from the complete fishing when the reservoir or fish pond is emptied. These catches can provide information on total abundance and biomass and on the species composition of the stock. Drainable fishponds often contain both commercial and weedy, undesirable fish species. For a correct estimate of the fish stock, it is necessary to pay attention to non-commercial fish species, i.e. to determine their share in the stock both from the results of the commercial catch itself and by surveying the fish that pass through the screens during water release and further inspection of the bottom of the fishpond after the fishing.

1.2 Sampling strategies: locality-based, continuous and area surveys

Individual fish species and size categories do not occur evenly in lakes and reservoirs, but show density gradients, which should be at least partially known in order to obtain meaningful data (Prchalová et al., 2008b). At the same time, different sampling approaches have different spatial coverage and it is usually not practical to sample the entire waterbody area or

volume, especially for larger waters. Figure 1.1 shows three basic schemes of sampling strategies. For the sampling in a spatially limited catch area (e.g., gillnets, beach seines, or shore catches with an electroshocker) a **locality-based strategy** can be feasible for simple inventory surveys (Fig. 1.1a). Characteristic localities for sampling should be selected in the waterbody so they characterize the main gradients of the spatial distribution of fish and include all the depths in a proportional matter (depth-stratified sampling design, see chapter 2.1 in more details). Minimum number of sampled localities can be determined from Table 2.2. The guidelines are written for the installation of gillnets, but catches by all other means with a locality-based strategy can be made in the same locations.

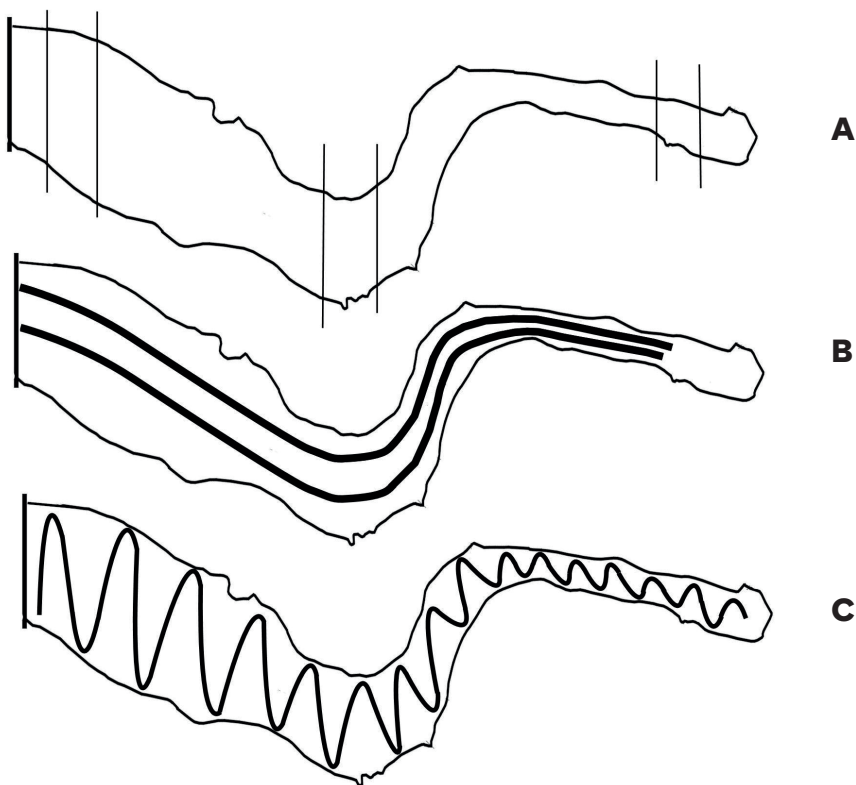


Figure 1.1. Schematic representation of sampling areas/trajectories at locality-based (A), continuous (B) and area (C) survey strategies in elongated water.

The number and types of localities should be selected according to the volume, area and morphology of the water body. Several benthic or pelagic gillnets are then installed at each locality (in all habitats present in depth stratified design; Table 2.1). In water bodies with prolonged morphology like reservoirs with clearly defined tributary and dam areas, again at least two

localities should be selected just in tributary and dam parts (Table 2.2). The fish abundance, biomass same as the number of species peak usually in the tributary parts of these water bodies (Prchalová et al., 2008b, 2009a; Vašek et al., 2016). In water bodies larger than 150 ha at least three localities in the tributary, dam and middle parts should be sampled (Fig. 1.2). When the surface area is more than 500 ha, another locality located between the tributary and the middle parts should be added. In case the water body has a bay reaching over 10 % of the total surface area, such bay should be sampled as well (Fig. 1.2).

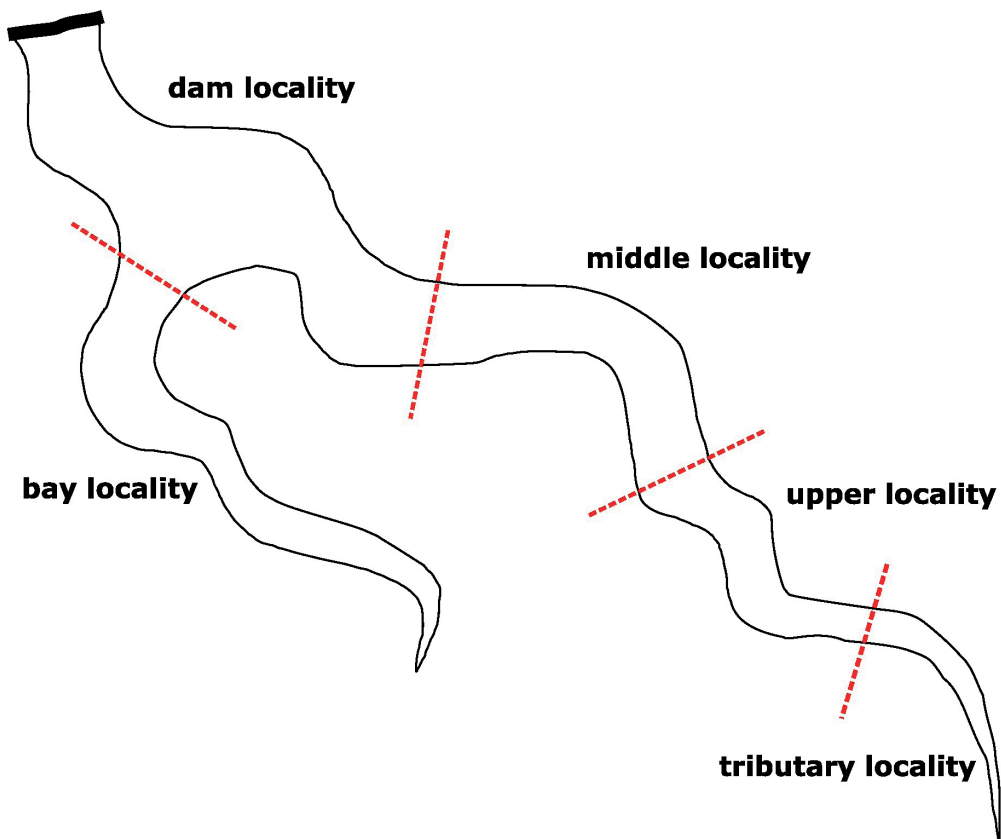


Figure 1.2. Example of locality based sampling strategy on a canyon-shaped reservoir with an area over 500 ha and a bay representing > 10 % of the area of the entire reservoir.

Continuous sampling strategy means the same effort applied on linear transects along the lake (Fig. 1.1b). This strategy is feasible for the methods where setting of sampling gear is quite complicated and time demanding (like with twin trawling, Říha et al., 2012) and it is not feasible to dismantle and reassemble this set-up several times during sampling of a waterbody. Examples are pelagic twin trawling (Říha et al., 2012; Rakowitz et al., 2012)

or fry trawling (Jůza and Kubečka, 2007; Jůza et al., 2015). Bottom gear of pelagic trawls is not designed for the contact with the rough bottom what is another reason for roughly linear trajectories along deep areas of the waterbody. Unlike fry trawls, larger trawls are not being used for standard regular monitoring of the fish communities in most of countries so we do not include standardized description of this approach.

A whole area survey strategy covers the whole waterbody (Fig. 1.1c) and is obviously the most accurate sampling approach, which can fully cover all gradients. Zig-zag hydroacoustic survey (Fig. 1.1c) or depth-stratified gillnet survey (Fig. 2.3) can serve as typical examples of area survey strategy.

1.3 Sampling period and method selection

The catch of fish depends on their activity, which in exothermic organisms is controlled by the ambient temperature. It is useful to plan the sampling for a period in which all or most of the target species are active and make full use of water body production (the so-called growing season). In the conditions of stagnant waters in Central Europe, it is optimal to sample fish communities from mid-July to the end of September. In more northern localities, the optimal period can be shorter. It is recommended to avoid spring periods when the distribution and activity of many species is heavily affected by reproductive behaviour (high activity, spawning migrations) and later autumn sampling, when fish may migrate to deeper parts for overwintering.

The selection of suitable fishing method is described on a general level by European standard Water quality - Guidance on the scope and selection of fish sampling methods (EN 14 962, CEN 2005). Selection of the methods depends on waterbody type, monitoring aim, need for comparability with other data and other circumstances. Good monitoring program strives to estimate true composition of fish community with the least selective approaches (Kubečka et al., 2009). In the other words, the main players of the fish community should not be seriously under- or over estimated. Absolute quantity per unit of area or volume is another challenge. Generally, the largest volumes of lakes and reservoirs can be surveyed by hydroacoustics and multimesh gillnets. Hydroacoustics can potentially estimate fish quantity but two main weaknesses need to be kept in mind:

There is no direct information on the species composition in acoustic results and quality and representativeness of data is often violated at surface and nearbottom blind zones. Gillnets can sample with comparable effectivity practically all habitats of standing waters, but the catch is dependent on fish swimming activity and it provides relative rather than absolute abundance and biomass estimates. Passive character of gillnet operation causes significant underestimation or overestimation of some species. Active sampling with electrofishing and seining is relatively quantitative and robust but restricted to shallow or very shallow habitats. Trawling and purse seining are relatively efficient in the open waters (Říha et al., 2012) but application of these methods is technically demanding and they are not widely used for fish monitoring. None of the methods listed is robust to estimate status of emerging important player European catfish (*Silurus glanis*) in lakes and reservoirs so we introduce new efficient monitoring approach to sample it by baited long lines. It is clear that for most sampling situation we lack a "supermethod" which would provide true picture of the fish community. In this respect the combination of several approaches is so far the only option to obtain sound information about fish in lakes and reservoirs. Awareness of the limitations of individual methods and using their complementarity is a way forward to quantitative information. If we are forced to compromise and use semi-quantitative or selective approaches, we should keep in mind that the real composition of the fish community may be different than our data. However, this kind of approach still may be useful to monitor the changes in some size classes of certain species if the selected method enables robust sampling.

1.4 General guidelines for catch and data processing

From all the catching techniques described in this methodology, with the exception of hydroacoustic survey, we obtain a sample from the aquatic environment in the form of a fish catch. Whole catch has to go through processing to determine the data for ichthyological analyses like species composition, relative or absolute abundance and biomass, size or age structure. After getting the catch, it is important to process the fish as quickly as possible. The catch is sorted by species and measured to the nearest

5 mm in fish older than one year (in Czech conditions usually standard length). Young of the year bycatch in gillnet catch is measured with an accuracy of 1 mm. Data on the species and body length of each individual are recorded in field protocols (see individual chapters), which also contain information on the given catch - waterbody, date, location, habitat, type of net and other data related to habitat. If the fish are killed during surveys, it is essential to ensure that this biomass is properly utilised for good. According to our experience, the most advantageous is the provision of killed fish to zoos as animal feed.

1.4.1 Sampling for age analysis

In a representative part of individuals (about 100 fish from each abundant species across the size spectrum) we take otoliths and scales for age estimation. Other bony structures are also possible to use (see detailed manual by VanderKooy 2009).

For the fish which are killed during the survey preferred age estimation structures are **otoliths**. For the species with big sagitta (e.g., percids, salmonids, pike) it is recommended to use sagitta and for the species with small sagitta (e.g., cyprinids, catfish) it is recommended to use lapillus (Stevenson and Campana, 1992).

If the fish (with scales) are to be released alive or have scales with good readability (e.g., young cyprinid fish as bream, rudd, roach...) we use **scales** from the left side of the fish from a place above the lateral line approximately above the base of the abdominal fins (Jůza, 2003) as the scales are easy and nonlethal to fish to take and quick to process (no need to sectioning or polishing as in otoliths).

We recommend to store scales and otoliths in paper bags and make sure that the samples are always properly dried (risk of deterioration of mold samples). We record the date, waterbody, locality, habitat, species, length (optimally body standard length and total length), weight and possibly sex of the fish on the sample bag. Samples for age analysis can also serve as samples for determining length weight relationships, see the following chapter.

1.4.2 Sampling for determination of length-weight relationships and biomass

Representative number of the individuals for each important species (100 fish minimum) should be weighted with an accuracy of one gram for later determination of the length-weight relationship. The individuals for weighing should be selected across the size spectrum so that the subsequent length-weight relationship is representative for all sizes present.

The following simple formula is usually sufficient for description of L/W relationship:

$$W = a * L^b,$$

where W is the weight of the fish, L is the length of the fish and a and b are the estimated parameters for the power function. The weight and length of a fish can enter into a relationship in different units - grams, kilograms, millimetres, centimetres, etc. However, for each unit the parameter "a" has a different value (parameter b does not change), and therefore it is always necessary to show the units of W and L.

Using the parameters of the length-weight relationship, we can estimate the weight of all caught individuals, without having to weigh all of them individually in the field. From the weight of all individuals, it is then possible to calculate the estimated biomass of the catch, both total and for individual species or size groups.

If the small number of samples collected or another limitation does not allow us to calculate the weight relationship for a given waterbody, it may be appropriate to use the weight relationships from other waters or take the relationships listed for each species in the FishBase internet database (<http://fishbase.org>). However, the origin of the length/weight relationships must always be stated in the results report.

1.5 Health and safety

Working in water can be dangerous. It is the responsibility of the survey leader to establish appropriate safety and health measures and to determine compliance with all conditions of national or, where applicable,

internal regulations. Special rules apply to electric catches (see chapter 4). Especially the night work can be demanding, and it is necessary to supply the operators with sufficient light, clothing and rain protection. It is always necessary to wear a life jacket on working boats.

1.6 References

ALEXANDER T.J., VONLANTHEN P., PERIAT G., DEGIORGI F., RAYMOND J.C., SEEHAUSEN O., 2015: Estimating whole-lake fish catch per unit effort. *Fisheries Research* 172, 287–302.

APPELBERG M., BERGER H.-M., HESTHAGEN T., KLEIVEN E., KURKILAHTI M., RAITANIEMI J., RASK M., 1995: Development and intercalibration of methods in Nordic freshwater fish monitoring. *Water, Air and Soil Pollution* 85, 401-406.

BONAR S.A., HUBERT W.A., WILLIS D.W., editors. 2009: Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

CEN, 2003. European standard Water quality. Sampling of fish with electricity (EN 14 011) Brussels, Belgium, 2003, 16 pp.

CEN, 2005. European standard Water quality - Guidance on the scope and selection of fish sampling methods (EN 14 962) Brussels, Belgium, 2005, 25 pp.

CEN, 2014. Water quality - Guidance on the estimation of fish abundance with mobile hydroacoustic methods (EN 15910) Brussels, Belgium, 2014, 45 pp.

CEN, 2015. Water quality: sampling of fish with multi-mesh gillnets (EN14757) Brussels, Belgium, 2015, 30 pp.

GARCIA X.F., DIEKMAN M., BRAMICK U., LEMCKE R., MEHNER T., 2006: Correlations between type-indicator species and lake productivity in German lowland lakes. *Journal of Fish Biology* 68, 1144-1157.

GASSNER H., ZICK D., BRUSCHEK G., MAYRHOFER K., FREY I., 2006: Metodik – Handbuch. Fischbestandsaufnahme und Bewertung des ökologischen Zustandes der natürlichen und künstlichen Seen Österreichs (>50 ha) gemäss EU-Wasserrahmenrichtlinie. Bundesamt für Wasserwirtschaft, Institut für Gewässerökologie, Fischereibiologie und Seenkunde, Mondsee, 27 pp.

JURAJDA P., SLAVIK O., WHITE S., ADAMEK Z., 2010: Young-of-the-year fish assemblages as an alternative to adult fish monitoring for ecological quality evaluation of running waters. *Hydrobiologia* 644 (1), 89-101.

JŮZA T., 2003: Růst vybraných druhů ryb v různých typech vod ČR. Bakalářská práce. Biologická fakulta Jihočeské Univerzity, České Budějovice, 75 pp.

JŮZA T., KUBEČKA J., 2007: The efficiency of three fry trawls for sampling the freshwater pelagic fry community. *Fisheries research* 85, 285-290.

JŮZA T., VAŠEK M., KRATOCHVÍL M., BLABOLIL P., ČECH M., DRAŠTÍK V., FROUZOVÁ J., MUŠKA M., PETERKA J., PRCHALOVÁ M., ŘÍHA M., TUŠER M., KUBEČKA J., 2014: Chaos and stability of age-0 fish assemblages in a temperate deep reservoir: unpredictable success and stable habitat use. *Hydrobiologia* 724 (1), 217-234. DOI 10.1007/s10750-013-1735-y

JŮZA T., RICARD D., BLABOLIL P., ČECH M., DRAŠTÍK V., FROUZOVÁ J., KOČVARA L., MUŠKA M., PETERKA J., PRCHALOVÁ M., ŘÍHA M., SAJDLOVÁ Z., ŠMEJKAL M., TUŠER M., VAŠEK M., VEJŘÍK L., KUBEČKA J., 2015: Species-specific gradients of juvenile fish density and size in pelagic areas of temperate reservoirs. *Hydrobiologia* 762, 169-181. DOI: 10.1007/s10750-015-2346-6

KUBEČKA J., PRCHALOVÁ M., 2006: Metodika odlovu a zpracování vzorků ryb stojatých vod. Methodology of capture and processing of stillwater fish samples. Metodiky VÚV, TGM, Praha, 22 pp.

KUBEČKA J., FROUZOVÁ J., BALK H., ČECH M., DRAŠTÍK V., PRCHALOVÁ M., 2009: Regressions for conversion between target strength and fish length in horizontal acoustic surveys. In: PAPADAKIS J.S., BJORNO L., (eds.), *Underwater acoustic measurements. Technologies & Results*. Foundation for Research & Technology, Heraklion, Greece, ISBN 978-960-98883-2-5: 1039-1044.

KUBEČKA J., FROUZOVÁ J., JŮZA T., KRATOCHVÍL M., ŘÍHA M., PRCHALOVÁ M., 2010: Metodika monitorování rybích společenstev nádrží a jezer. (Methods of monitoring of the fish communities of reservoirs and lakes, in Czech) Biology Centre AS CR, 64 pp. ISBN 978-80-86668-08-6

KUBEČKA J., PRCHALOVÁ M., ČECH M., DRAŠTÍK V., FROUZOVÁ J., HLADÍK M., HOHAUSOVÁ E., JUZA T., KETELAARS H.A.M., KRATOCHVIL M., PETERKA J., VAŠEK M., WAGENVOORT A.J., 2013: Fish (Osteichthyes) in Biesbosch storage reservoirs (the Netherlands): a method for assessing complex stocks of fish. *Acta Societatis Zoologicae Bohemicae* 77, 37-54.

LAURIDSEN T.L., LANDKILDEHUS F., JEPPESEN E., JØRGENSEN T.B., SØNDERGAARD M., 2008: A comparison of methods for calculating Catch Per Unit Effort (CPUE) of gill net catches in lakes. *Fisheries Research* 93, 204-211.

MEHNER T., DIEKMANN M., BRAMICK U., LEMCKE R., 2005: Composition of fish communities in German lakes as related to lake morphology, trophic state, shore structure and human-use intensity. *Freshwater Biology* 50, 70–85.

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., 2008b: Distribution patterns of fishes in a canyon-shaped reservoir. *Journal of Fish Biology* 73, 54-78.

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. *Ecology of Freshwater Fish* 18, 247-260.

RAKOWITZ G., TUŠER M., ŘÍHA M., JŮZA T., BALK H., KUBEČKA J., 2012: Use of high-frequency imaging sonar (DIDSON) to observe fish behaviour towards a surface trawl. *Fisheries Research* 123–124, 37–48. doi:10.1016/j.fishres.2011.11.018

ŘÍHA M., JŮZA T., PRCHALOVÁ M., MRKVIČKA T., ČECH M., DRAŠTÍK V., MUŠKA M., KRATOCHVÍL M., PETERKA J., TUŠER M., VAŠEK M., KUBEČKA J., 2012: The size selectivity of the main body of a sampling pelagic pair trawl in freshwater reservoirs during the night. *Fisheries Research* 127–128, 56–60. <http://dx.doi.org/10.1016/j.fishres.2012.04.012>

STEVENSON D.K., CAMPANA S.E., 1992: Otolith microstructure examination and analysis. *Canadian Special Publication of Fisheries and Aquatic Sciences* 117, 126 pp.

TESFAYE G.C., SOUZA A.T.S., BARTOŇ D., BLABOLIL P., ČECH M., DRAŠTÍK V., HOLUBOVÁ M., KOČVARA L., MARTINEZ VON DOSOW C., MORAES K., MUŠKA M., PRCHALOVÁ M., ŘÍHA M., SAJDLOVÁ Z., SEĎA J., SOUKALOVÁ K., ŠMEJKAL M., TUŠER M., VAŠEK M., VEJŘÍK L., VEJŘÍKOVÁ I., PETERKA J., JŮZA T., KUBEČKA J., 2022: Long-term monitoring of fish in a freshwater reservoir: different ways of weighting complex spatial sampling. Submitted to *Frontiers in Environmental Science*.

VANDERKOOY S. (editor), 2009: A Practical Handbook for Determining the Ages of Gulf of Mexico Fishes (second edition). Gulf States Marine Fisheries Commission, publication number 167.

VÁŠEK M., PRCHALOVÁ M., ŘÍHA M., BLABOLIL P., ČECH M., DRAŠTÍK V., FROUZOVÁ J., JÚZA T., KRATOCHVÍL M., MUŠKA M., PETERKA J., SAJDLOVÁ Z., ŠMEJKAL M., TUŠER M., VEJŘÍK L., ZNACHOR P., MRKVIČKA T., SEĎA J., KUBEČKA J., 2016: Fish community response to the longitudinal environmental gradient in Czech deep-valley reservoirs: implications for ecological monitoring and management. *Ecological Indicators* 63, 219–230.

2 Sampling by gillnets

Marie Prchalová¹, marie.prchalova@hbu.cas.cz Jan Kubečka¹, kubecka@hbu.cas.cz

¹ Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, Na Sádkách 7, 370 05, České Budějovice, Czech Republic

Gillnets are a passive gear, where whole catch depends entirely on fish activity. Fish are caught in the gillnet in various ways; they are gilled, wedged or entangled by teeth or body processes (Hamley, 1980; Prchalová et al., 2008a).

A gillnet consists of the net, the bottom lead line and the upper float line, and the lines on the sides of the gillnet. The lines with the net are balanced to ensure the vertical position and the opening of the meshes of the gillnet in the water. Gillnets are most commonly used as benthic and pelagic multimesh nets. Standard gillnet sampling with benthic and pelagic multimesh gillnets is governed by the European standard EN 14 757 Water quality - Sampling of fish with multimesh gillnets (CEN EN14757, 2015). The following guidelines for gillnet sampling are derived from and fully consistent with this standard, and also reflect the best practises of our research group.

Advantages of gillnets sampling:

- All depths of the water body can be sampled, representing all habitats of lakes or reservoirs.
- A wide spectrum of fish species can be caught.
- A wide spectrum of fish sizes can be caught - fish larger than 40 mm can be caught in standard multimesh gillnets (Prchalová et al., 2009b), geometric series of mesh sizes ensure that the proportion of size classes better matches the actual sizes of the sampled fish population (Kurkilahti, 1999), so gillnet samples can be used as a reliable basis for fish size composition and consequently age determination.
- Sampling with gillnets is consistent with the EU Water Framework Directive for fish sampling methods (Water Framework Directive 2000/60/ EC, 2000), and gillnets are now used as a standardised sampling method

in most EU countries. Data obtained with multimesh gillnets are highly comparable with international fishing results.

Drawbacks of gillnets sampling:

- Gillnets provide data on relative abundance and biomass of fish by catch per unit of sampling effort (CPUE). Currently, the relationship and conversions between CPUE and absolute abundance or biomass (number of individuals or their weight per hectare or volume) are relatively poorly understood.
- Gillnets can be severely damaged at sites with submerged obstacles such as fallen trees, snags, stumps, rocks, etc.
- Only actively moving fish can be caught in gillnets, some fish species, size classes, or even certain sexes may be underrepresented in gillnet samples (territorial pike, round goby *Neogobius melanostomus* females, or juveniles; Kurkilahti et al., 2002; Olin and Malinen, 2003; Prchalová et al., 2008a, 2009b; Žák et al., 2018). Accordingly, certain species or size classes may be overrepresented, which can be corrected by adjusting the proportions of certain species and/or size classes (see chapter on gillnet catch correction).
- Catchability of species depends on body morphology, body size, and manoeuvring abilities, e.g., eels are extremely rarely caught in gillnets (Vetemaa et al., 2006; Prchalová et al., 2013a), as is the European catfish *Silurus glanis*.
- Fish that have already been caught in gillnets reduce the likelihood that a new fish will be caught, in a process called saturation or avoidance (Olin et al., 2004; Prchalová et al., 2011a, 2013b); in dense fish communities, catch corrections for saturation may be required (see chapter on gillnet catch correction).
- Gillnets are usually lethal to fish when deployed overnight. In rare cases, some live fish can be disentangled and released back into the water after processing, but this is quite laborious and can usually only be done on larger individuals, such as predator species.

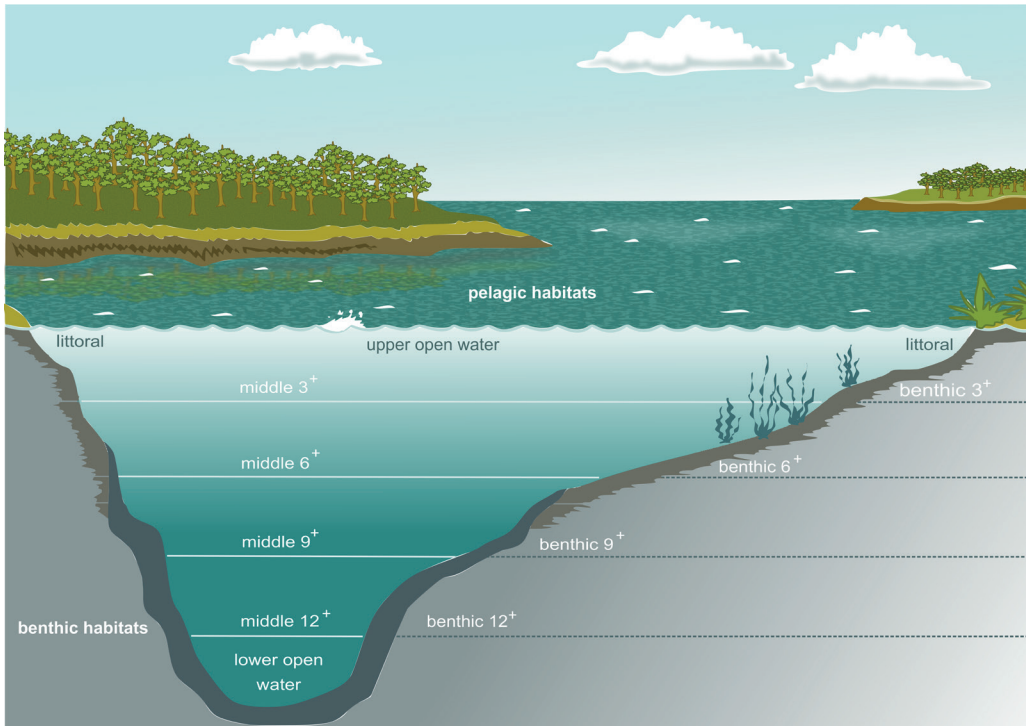


Figure 2.1. Overview of habitats to be sampled by benthic and pelagic gillnets (see Table 2.1 for depth ranges) in a model waterbody with maximum depth of 15 m.

2.1 Basic equipment

Standard gillnet types are constructed as follows: A gillnet consists of 2.5 m long net panels with a specific mesh size. The net panels are sewn together over their entire height. A standard multiple mesh gillnet has 12 different mesh openings: 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 29, 35, 43 and 55 mm knot-to-knot (see Table 2.3 for thread diameters). The order of mesh size panels was originally randomized within a gillnet, but was kept the same for all gillnets. Benthic gillnets have a height of 1.5 m and thus have an area of 45 m². Pelagic nets are usually higher; nets with a height of 3 m are the most common in the Czech sampling design. This gillnet design follows the European standard EN 14 757 Water quality - Sampling of fish with multimesh gillnets (CEN EN14757, 2015).

The use of gillnets can be differentiated according to the target habitat, i.e. benthic (bottom) or pelagic (open water; Fig. 2.1, Table 2.1).

Table 2.1. An overview of benthic and pelagic habitats together and the depth of installation of appropriate gillnets.

Habitats	Depth of Habitat (m)	Depth of bottom at installation (m)	Gillnets construction
Benthic habitats:			
Littoral	0 – 3	1.5 – 3	benthic
Benthic 3+	3 – 6	4.5 – 6	benthic
Benthic 6+	6 – 9	7.5 – 9	benthic
Benthic 9+	9 – 12	10.5 – 12	benthic
Benthic 12+	12 – 20	13.5 – 20	benthic
Benthic 20+	20 - 35	21.5 - 35	benthic
Benthic 35+	35 - 50	36.5 - 50	benthic
Benthic 50+	50 - 75	51.5 - 75	benthic
Benthic 75+	> 75	> 75	benthic
Open water habitats			
Upper open water	0 – 3	>5	epipelagic
Middle open water 3+	3 – 6	>8	mesopelagic
Middle open water 6+	6 – 9	>10	mesopelagic
Middle open water 9+	9 – 12	>13	mesopelagic
Middle open water 12+	12 – 20	>21	mesopelagic
Middle open water 20+	20 - 35	>36	mesopelagic
Middle open water 35+	35 - 50	>51	mesopelagic
Middle open water 50+	50 - 75	>75	mesopelagic
Middle open water 75+	> 75	Deeper than the net	mesopelagic
Lower open water	site dependent	3-6 m above bottom	bathypelagic

Table 2.2. Number of localities for benthic and pelagic sampling for water bodies with prolonged morphology in relation to their total area.

Surface area	Number of localities	
	benthic gillnets	pelagic gillnets
< 150 ha	2	2
≥ 150 ha	3	3
≥ 500 ha	4	4
bay ≥10% total area	1	1

Benthic gillnets - balanced so that the bottom lead line copies the bottom and the upper float line ensures the vertical position of the gillnets in the water column (Fig. 2.2); height 1.5 m; floats with strings at each end of the

float line to facilitate location of gillnets in the water; area of a benthic gillnet is 45 m²; benthic gillnets sample benthic habitats (Fig. 2.1); minimum depth for installation is 1.6 m.

Epipelagic gillnets - used in the upper part of the water column as the upper float line copies the surface (Fig. 2.2); height 3 m; in shallow places (tributaries, ponds) the height of epipelagic gillnets can be reduced to 1.5 m; the area of a standard epipelagic gillnet is 90 m² (45 m² in gillnets for shallow areas); epipelagic gillnets sample the upper (surface) open-water habitat (Fig. 2.1); the minimum depth for installation is 5 m (3 m in shallow areas).

Mesopelagic gillnets - deployed in the depth layers between the surface and bottom thanks to slowly sinking lead lines and floats on strings of desired length (Fig. 2.2); height 3 m; the area of a one mesopelagic gillnet is 90 m²; mesopelagic gillnets are used to sample middle open water habitats (Fig. 2.1); the minimum depth for installation is 8 m.

Bathypelagic gillnets - construction like epipelagic gillnets; installation above the bottom thanks to weights on strings of desired length (Fig. 2.2); the area of a bathypelagic gillnet is 90 m²; bathypelagic gillnets sample habitats in lower open water (Fig. 2.1); the minimum depth for installation is 10 m but depends on locality.

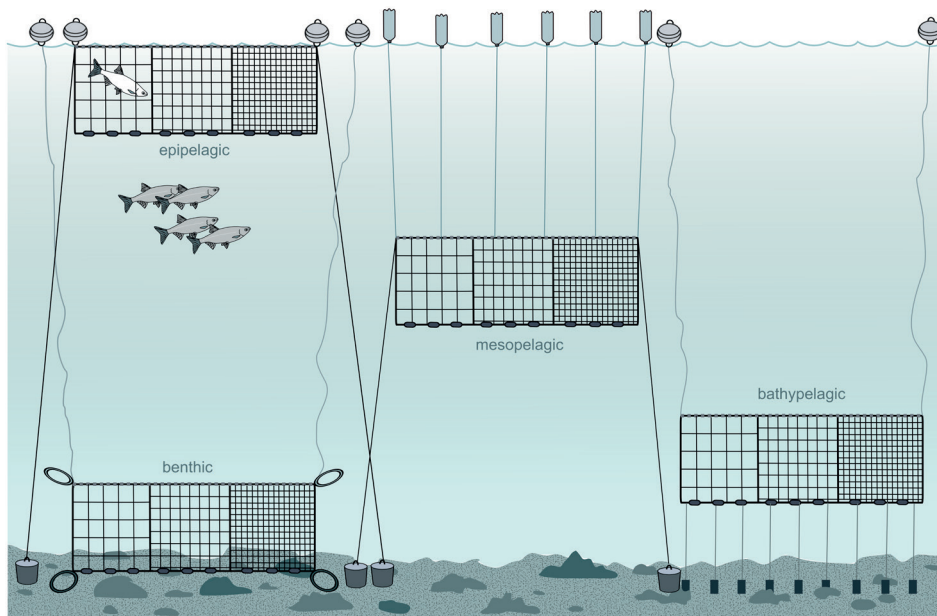


Figure 2.2. Installation design of various gillnet types – benthic, epipelagic, mesopelagic, and bathypelagic gillnets.

To catch also larger fish (> 30 cm standard length) usually occupying lentic water bodies, it is important to enlarge the series of mesh sizes in the standard gillnets by larger mesh sizes – 70, 90, 110 a 135 mm, knot-to-knot (Table 2.3; Prchalová et al., 2009b; Šmejkal et al., 2015). Species as bream *Abramis brama*, carp *Cyprinus carpio*, tench *Tinca tinca* and wels catfish *Silurus glanis* were found to be underrepresented if the community was sampled by standard gillnets only (Šmejkal et al., 2015). **Large mesh gillnets** are of similar construction types as the standardized gillnets, yet we recommend construct them as a separate gillnets. The length of each mesh size panel is 10 m. The thread materials in 70- and 90-mm mesh size can be monofilament. In the two largest mesh sizes, the multifilament or multithread materials seem to be better option for netting catchability but, in any case, the following bearing capacity should be hold: 8 – 14 kg for 110mm mesh size and 14 – 20 kg for 135mm mesh size. Installation follows above mentioned rules valid for standard gillnets. To ease the installation, large mesh gillnets can be set in connection with the standard gillnets by joining these two gillnets together. Large mesh gillnets can be equipped by plastic rings to prevent tangling of the netting corners (Fig. 2.2).

Table 2.3. Overview of mesh sizes (knot-to-knot) used in standard multimesh gillnets and in large mesh gillnets together with their thread diameters (CEN EN14757, 2015) and minimum recommended bearing capacity (breaking strength).

Mesh size (mm)	Thread diameter (mm)	Bearing capacity (kg)
Standard gillnets:		
5	0.10	0.40
6.25	0.10	0.50
8	0.10	0.55
10	0.12	1.10
12.5	0.12	1.30
15.5	0.15	1.30
19.5	0.15	1.30
24	0.17	1.50
29	0.17	1.50
35	0.20	1.70
43	0.20	1.80
55	0.25	3.20
Large mesh gillnets:		
70	0.25	4.00
90	0.30	5.00
110	6 x 0.2, 0.2/6	8.00
135	16 x 0.2, 0.2/9-12	14.00

Data obtained with large mesh gillnets needs to be treated **independently** of those obtained with standard gillnets. This is very important, because summarizing the catches would make the data incomparable to results obtained with standardized nets earlier or at other sites.

2.2 Other equipment

To perform gillnet sampling most effectively, following equipment is recommended alongside gillnets:

- a boat equipped with engine and oars
- depth meter (e.g., lower-class commercially available echosounder)
- ropes, floats and anchors for installation of pelagic gillnets
- boxes where gillnets both empty and with catch can be stored and transported
- container with anaesthetics or other means to put down the entangled fish in the gillnets during retrieving the catch out of the water
- tools to label the boxes with catches (e.g., sturdy paper with soft graphite)
- GPS instrument and locality map to point out the gillnet positions
- buckets and containers to store catches before and after processing
- scales and weights to record fish size and weight
- template sheets to record the catch (electronic or printed on sturdy papers)
- yellow buoys – necessary when the boat traffic is present on the locality, yellow buoys mean obstacles for shipping

2.3 Sampling

2.3.1 Selection of sampling sites

Gillnets can be used at almost any location within a water body. Exceptions include sites in proximity of the dam and extraction tower, sites close to harbours or other locations with higher boat traffic or recreation areas, and sites with submerged obstructions such as fallen trees, stumps or rocks.

Sampling with gillnets follows locality-based or whole area survey strategy of fish sampling (see chapter 1.2 Sampling strategies). Gillnets can be set at different depth layers and along the longitudinal axis of the water body to cover the vertical and longitudinal gradient of fish occurrence (Prchalová et al., 2008b, 2009a; Vašek et al., 2016).

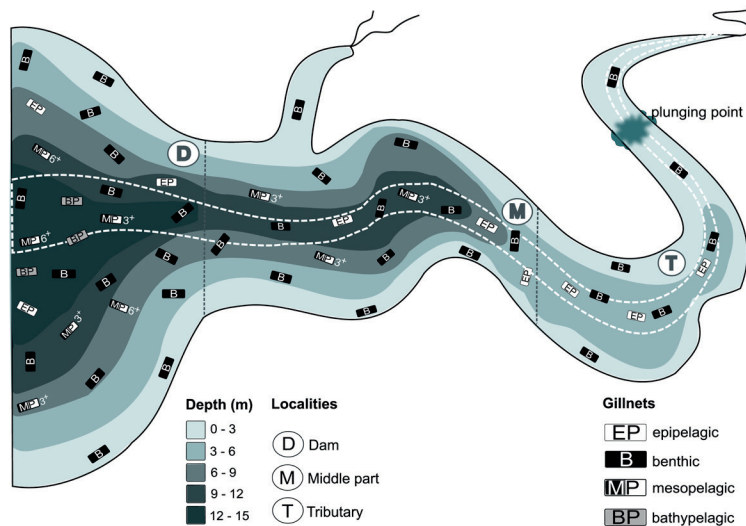


Figure 2.3. Example of the depth stratified random sampling design for gillnet deployment in a model water body with elongated morphology, maximum depth of 15 m, and surface area of 200 ha. The total number of gillnets to be deployed is 34 in the following depth stratification. Littoral (0-3 m) and benthic 3+ (3-6 m) habitats 9 gillnets each, benthic 6+ and benthic 9+ habitats 6 gillnets each, and benthic 12+ habitats 3 gillnets, upper open water 9 gill nets, middle open water 3+ 6 gill nets, middle open water 6+ and lower open water 3 gill nets each, one benthic gill net to slowed river area upstream of the plunging point of the reservoir (see Table 2.1 for depth ranges). The original riverbed is represented by a white dashed line. In reservoirs with this maximum depth, the lower open water can be sampled with both mesopelagic or bathypelagic gillnets, depending on possibilities of the research group.

There are two types of sampled habitats - benthic and pelagic (Fig. 2.1). It is recommended to use depth stratified random sampling design at every locality, i.e., set nets randomly within a depth stratum (Fig. 2.3). The number of depth strata is determined by the maximum depth at the locality (Table 2.1). The effort in each depth stratum is determined by the volume of water in that stratum, i.e., the morphology of a water body. The volume fractions of deeper habitats are lower compared to shallow habitats and the effort is adjusted accordingly (Fig. 2.3). The effort per depth strata can be found in Annex A of the European standard EN 14 757 Water quality - Sampling of fish with multimesh gillnets (CEN EN14757, 2015). Here is a summary table (Table 2.4) of gillnet effort derived from CEN EN14757 with effort extended to include pelagic gillnets.

Table 2.4. Minimum benthic gillnet effort (column BG) needed to attain such precision guaranteeing distinguishing 50% difference in the CPUE between the sampling, in relation to the size and depth of the water body (CEN EN14757, 2015). The minimum recommended effort of pelagic gillnets is also given (column PG). The effort is valid for standard multimesh gillnets. In case large mesh gillnets are installed as well, the number of nets must be doubled.

Max. depth (m)	Surface area (ha)											
	< 20		21 – 50		51 – 100		101 – 250		251 – 1 000		> 1000	
	BG	PG	BG	PG	BG	PG	BG	PG	BG	PG	BG	PG
0 – 5.9	8	3	8	3	16	6	16	6	24	9	24	9
6 – 11.9	8	6	16	6	24	12	24	12	32	12	32	12
12 – 19.9	16	9	16	9	24	12	32	15	40	15	40	15
20 – 34.9	16	12	24	12	32	15	40	18	48	18	56	21
35 – 49.9	16	15	32	15	32	15	40	21	48	18	56	21
50 – 74.9					40	18	40	21	56	21	64	24
> 75									56	21	64	24

The number of sites to be sampled with gillnets within a water body depends on the morphology and size of the water body sampled (Table 2.2). The total amount of gill nets depends on the surface area and maximum depth of the water body (Table 2.4). In water bodies with homogeneous shorelines (i.e., no distinct bays or tributaries/dam sections), no locations are specified, and random sampling is used for benthic gillnet sampling. Pelagic gillnets are best used over the deepest part of the water body (Figs. 1.2, 2.1, and 2.3). Ponds and mining lakes are typical examples of water bodies of this type.

For water bodies with elongated morphology and clearly defined tributary and impoundment areas, at least two localities should also be selected in tributary and impoundment areas only (Table 2.2). Fish abundance, biomass, and species number usually peak in the tributaries of these water bodies (Prchalová et al., 2008b, 2009a; Vašek et al., 2016). In water bodies larger than 150 ha, we sample three localities in the tributary, reservoir, and middle part (Fig. 2.3). If the area is larger than 500 ha, we add another locality located between the tributary and the middle part (Fig. 1.2). If the water body has a bay that is more than 10 % of the total area, it is also sampled (Fig. 1.2).

Special care should be given to sampling tributary parts of reservoirs or lakes with prolonged shaped and distinct area where the river water is plunged into the reservoir water. This ecotone consists of two different habitat types:

1) inflowing slowed river with slowed current, in summer with lower temperature and little or no phyto- and zooplankton. Only benthic gillnets can be installed in slowed river water as there is not enough depth for pelagic nets.

2) tributary part of lake/reservoir water with zooplankton and phytoplankton located downstream of the plunging point, where tributary plunges under warm lake/reservoir epilimnion. Both benthic and pelagic nets can be installed there according to the depths available.

Plunging point can usually be distinguished according to debris on the surface at the point of the river water plunging. It is recommended to consult the tributary sampling design with the depth profile of the water temperature. The most upstream gillnets in the true lake/reservoir water should not be placed directly downstream of the plunging point as it takes some distance for the river water to plunge down under the epilimnion (if the temperature and/or depth profile is not available, the most upstream gillnets should be placed at least 200 m downstream of the plunging point). In contrast to tributary catches, catches in the slowed river are usually much lower, so it is important to report this habitat type separately.

In fish abundance monitoring studies, the minimum effort for gillnet sampling has to ensure the precision guaranteeing distinguishing of 50% CPUE-difference between sampling occasions (CEN EN14757, 2015). The

effort depends on the surface area and the maximum depth of the water body (Table 2.4). The European standard defines effort only for benthic gillnets. Therefore, we added the minimum effort also for sampling with pelagic gillnets. It is true that sampling precision increases with sampling effort. However, to obtain a sufficiently accurate estimate of basic fish community indicators, sampling effort can be reduced, and unwanted fish mortality minimized. The three best reduced scenarios are to sample the entire longitudinal profile in the epilimnetic layer and/or in the near-surface layer, and to sample all depth layers at the farthest points along the longitudinal gradient, i.e., at the dam and tributary parts (Blabolil et al., 2017). In addition, the use of only one gill net per depth stratum and locality is generally not a problem for the accuracy of fish community indicators (Blabolil et al., 2021).

2.3.2 Sampling

Gillnets are set from the boat in a direct line to the specified depth or to the specified depth range for benthic gillnets. Depth is measured with a depth gage (simple echosounder with a beam angle up to 20 degrees). Epipelagic and mesopelagic gillnets must be anchored or tied to a stable object (navigation buoy, bridge abutment, tree on shore, etc.) to prevent the net from drifting. The exact position of the gillnets is recorded with the using GPS instrument and can be marked on the map by hand.

Installation is done 2 - 3 hours before sunset, and the nets are hauled in 2 - 3 hours after sunrise. In the Czech Republic, this means that gillnets are set no later than 7:00 p.m. and are set at least until 7:00 a.m. in the summer. This time period is given by fish activity, which peaks at dusk and dawn for most Central European coarse fish species (Fig. 2.4; Prchalová et al., 2010). Thus, exposure time ensures that both the peak of fish activity is captured, and bias is avoided. For detailed information on sunrises and sunsets, see www.timeanddate.com/worldclock/sunrise.html.

If overnight exposure of gillnets is not possible, a shortened exposure period may be used. Reasons for such a situation may include water management constraints, lack of time, an overly too dense fish populations and associated gillnet saturation of gillnets, need to catch live fish, etc. Catches from shortened exposition time need to be recalculated to overnight standard

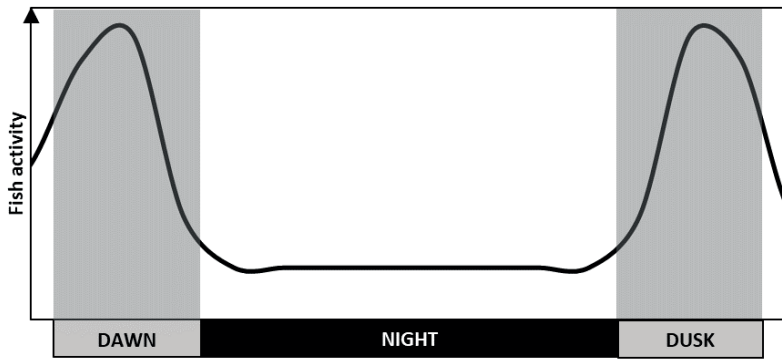


Figure 2.4. Fish overnight activity from the view of gillnet catches covering dusk and dawn peaks of activity and the night plateau of very low activity (Prchalová et al., 2010).

exposition (see chapter 2.5 Correction of gillnet catches). In any case, the shortened exposure must last at least 2 hours and must cover the evening or morning peak of fish activity (Fig. 2.4). Exposure exclusively during night-time hours will result in an extremely distorted picture of the sampled fish community, as most fish have minimal catchability due to reduced night-time activity, resulting in very low gillnet catches (Prchalová et al., 2010).

It is strongly recommended that gillnets be carefully placed in boxes to avoid entanglements during installation. Wind and weather conditions can be fierce during gillnet installation, and a struggle with a tangled gillnet is a situation one would rather not experience. After exposure is complete and the gillnet is returned to the box with the catch, the gillnet must be properly labelled (habitat, locality, depth, fish released if applicable, other gillnet specific information).

Benthic sampling can be done by two people, one handling the gillnets and the other steering the boat and checking the depth. For pelagic gillnets, which are higher than benthic, the optimal number of net handlers is two. For meso- and bathypelagic gillnets, a third person is beneficial to handle the ropes between the floats and the net, if possible.

2.4 Catch evaluation

The basic outputs of gill net sampling are species composition, relative abundance and biomass, and size and age structure of fish stocks. Species composition can be determined by synthesising all sampled habitats. In waters with elongated morphology, it is recommended that species composition is weighted according to the proportion of total reservoir volume represented by each locality and depth stratum (Fig. 1.3, Tesfaye et al., submitted). In waters of homogeneous shape, such a procedure is not necessary (Fig. 1.2).

Relative abundance is expressed in catch per unit effort (numerical CPUE), i.e., 1000 m² of gillnets per overnight exposure in each habitat and in total. The same is true for biomass per unit effort (BPUE). Reporting results “per net” is generally less accurate because nets vary in size, in which case gillnet dimensions must be reported. Results are usually given separately for juveniles and older fish.

2.5 Corrections of gillnet catches

The following subsections address corrections to the various types of gillnet selectivity. Gillnet monitoring is a passive sampling method, and as such, catches are biased by different types of catch selectivity (see section on gillnet disadvantages).

Fish caught with gillnets generally represent an unknown proportion of the size classes or communities that occur in the waterbody of interest. By gillnet selectivity we define the qualitative picture of this proportion that is usually represented by the catch probability of certain size classes or species to the gillnets. **In any case where a correction is used, it is necessary to detail this process in the presentation of methods.**

2.5.1 Mesh size selectivity

Great efforts were made to determine the proportion of fish caught in each mesh sizes of gillnets. Geometric series of mesh sizes with a coefficient of 1.25 ensure coverage of a wide range of sizes and relatively similar size selectivity within a given size range. However, studies from the 1990s have shown that each mesh size has its own selectivity curve. Therefore, the statistical model SELECT was developed to correct for the differences in selectivity between mesh sizes (Millar, 1992, 2000; Millar and Holst, 1997). To apply the model SELECT, catches must be sorted by mesh sizes. The procedure of mesh size correction is not trivial, and it is not recommended to do it manually, but to use special software for catch processing, in which the model SELECT is already included.

2.5.2 Correction for overestimation of perch

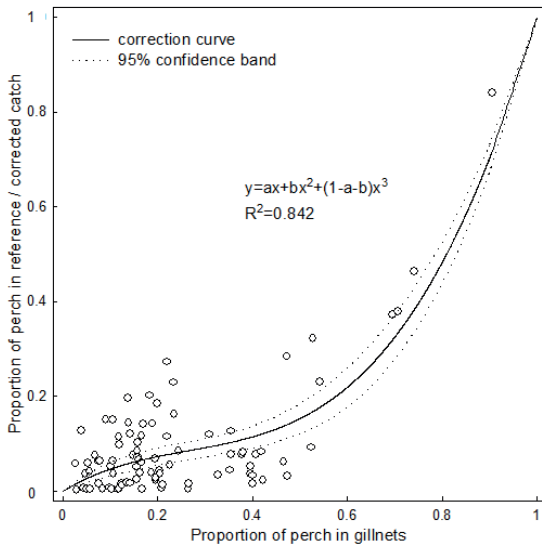
It has been shown that the European perch *Perca fluviatilis* is overrepresented in gillnet catches (Fig. 2.5; Prchalová et al., 2008a). The most likely reason for this is that, compared to other fish species, perch have a higher probability of encountering and retaining in the gillnet in comparison to other fish species. This probability is probably related to the higher activity of perch during dusk and dawn.

The proportion of perch can be corrected using the following empirical cubic function:

$$y = a*x + b*x^2 + (1 - a - b)*x^3; R^2 = 0.842,$$

where x is the proportion of perch in the gillnet catch, y is the corrected proportion of perch, and a and b are constants with values of 0.604 and -1.587, respectively. The data must be entered into the function as proportions between 0 and 1, not as percentages. First, the proportion of perch is corrected and then the proportion of all other species is adjusted so that the total again equals 1.

The share of the species is adjusted as follows:



$$p_c = (p \cdot 1 / (1 - ok)) \cdot (1 - ok_c),$$

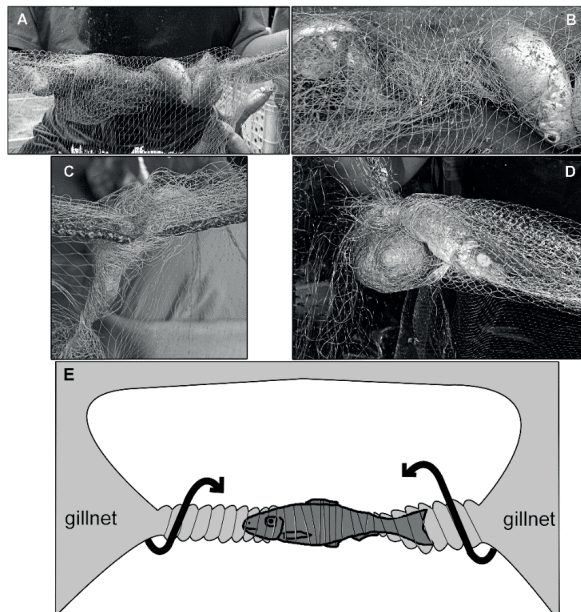
where p is the original proportion of corrected species, ok is the original proportion of perch, and p_c and ok_c are the adjusted proportions of both species. Based on the corrected proportions of the species, the total catch (CPUE) can be corrected accordingly. All of these corrections must be made manually.

Figure 2.5. Relationship of proportion of perch in the community and in the gillnet catch and corrected/reference community (Prchalová et al., 2008a).

2.5.3 Rough eel-abundance assessment using eel attacks

Because of its complex life cycle, cryptic behaviour, body shape, ability to excrete mucus and excellent manoeuvring (writhing and reverse movements), the European eel *Anguilla anguilla* is difficult to monitor especially using gillnet sampling.

Characteristic involutions of gillnet netting with a partially eaten fish inside have been registered during gillnet sampling (Fig. 2.6). These involutions are the result of eel attacks on fish caught in gillnets. When comparing the abundance of eel attacks in gillnets with the abundance of eels captured with active fishing gear



(beach seine and trawl), a positive and significant correlation was found (partial Spearman R 0.640, Prchalová et al. 2013; Fig. 2.6.). Therefore, it is recommended to record and report the number eel attacks to be used for rough monitoring of eel presence in a water body.

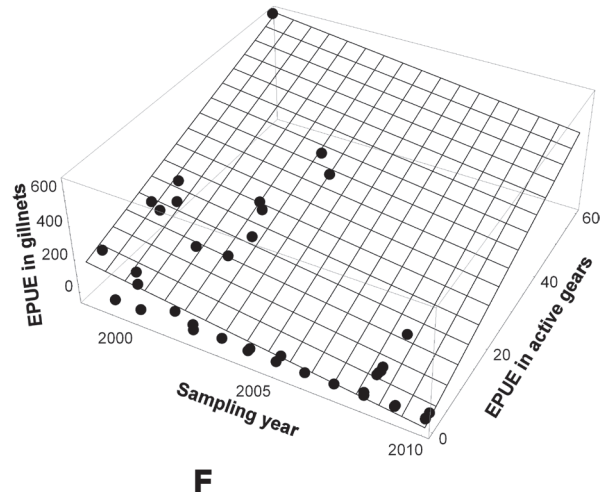


Figure 2.6. Examples of typical eel attacks in gillnets (A–D), a layout of a general eel attack (E), and the correlation between the abundance of eel attacks in gillnets, eels recorded during active sampling and sampling year (F).

2.5.4 Correction for gillnet saturation and avoidance

Fish that have already been caught in gillnets reduce the likelihood that new fish will be caught. This phenomenon is called saturation or avoidance (Olin et al., 2004; Prchalová et al., 2013b). Saturation depends on the density of fish in the sampled water body. Comparison of gillnet catches between water bodies with different fish densities is biased by saturation at high fish densities. To avoid this bias, a detailed model of gillnet catches was developed (Prchalová et al., 2011b). The philosophy of this model is to interpret gillnet catches not as CPUE, but as fish biomass that can be caught per one hour of sampling in an empty gillnet with fish having a unit activity (so called catchable biomass rate; Fig. 2.7). This frees the gillnet catch from the effects of saturation, fish activity, and fish falling out of the net during gillnet exposure.

The catchable biomass model is quite complex and difficult to run manually. Instead, a table is used to convert gillnet catches (Table 2.5). In this table, we can read the values of catchable biomass corresponding to absolute catches with standard benthic gillnets (i.e., with an effort of 45 m²). The conversion of absolute catches (per 45 m²) to catches per uniform gillnet effort (per 1000 m²) can be done as follows:

$$E_{1000} = E_{45} * 1000/45,$$

where E_{1000} is catch per 1000 m² of gillnets and E_{45} is the non-standardized catch regarding the effort. 1000 a 45 are gillnet efforts in areas of netting.

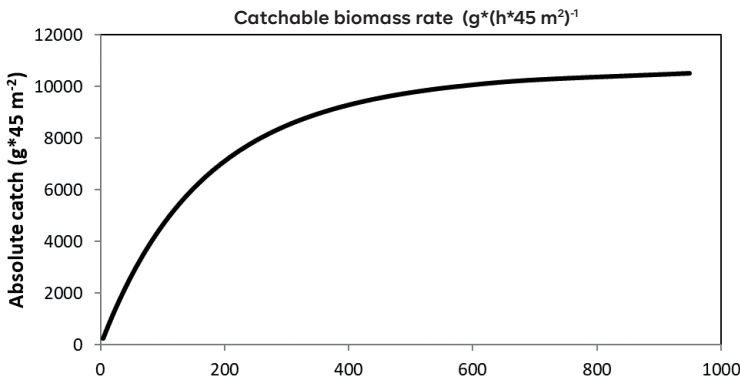


Figure 2.7. Relationship between the absolute standard benthic gillnet catch (effort 45 m²) and the catchable biomass rate (Prchalová et al., 2011b). The relationship is nonlinear due to the saturation.

Table 2.5. This table can be used to convert gillnet catches of different exposure times to the catchable biomass rates and to the whole night exposition. Column **Absolute catches (g)** represents absolute catches of standard benthic gillnet with an effort of 45 m². The catchable biomass rates are in next columns depending on the length of gillnet exposures: **Whole night** = standard overnight exposition covering both dusk and dawn peaks of fish activity and the whole night; **Peak** = 2h exposure just over dusk or dawn peak of fish activity; **Peak + 3 h** = exposition over the 2 h dusk or dawn peak of fish activity plus 3 extra h, 5 h in total; **Peak + 6 h** = exposition over the 2 h dusk or dawn peak of fish activity plus 6 extra h, 8 h in total; **Peak + 9 h** = exposition over the 2 h dusk or dawn peak of fish activity plus 9 extra h, 11 h in total.

Values of the catchable biomass rate can be read in the line related to actual absolute catch in the column **Absolute catches (g)**. Conversion of catches from shortened expositions to overnight ones is done as follows: First, the line with a given absolute catch is located, from the same line we read the rate of catchable biomass for a given shortened exposition (columns 3 – 6). Second, we look up the closest value to read catchable biomass rate in the column **Whole night**. Third, from the same line we read the absolute catch now converted to the standard overnight exposition. Deducted catch shows how much the gillnet would have caught if exposed over the whole night.

Absolute catches (g)	Catchable biomass rate (g*(h*45 m ²) ⁻¹)				
	Whole night	Peak	Peak + 3 h	Peak + 6 h	Peak + 9 h
250	4.0	8.0	9.4	11.0	12.5
500	8.1	16.2	19.2	22.3	25.5
750	12.4	24.6	29.3	34.2	39.2
1000	16.7	33.3	39.7	46.5	53.6
1250	21.2	42.2	50.5	59.4	68.7
1500	25.9	51.3	61.7	72.9	84.6
1750	30.6	60.7	73.3	87.1	101.4
2000	35.6	70.4	85.4	101.9	119.3
2250	40.6	80.4	97.9	117.5	138.3
2500	45.9	90.7	111.1	134.0	158.6
2750	51.4	101.3	124.8	151.5	180.3
3000	57.0	112.3	139.2	170.0	203.6

3250	62.9	123.7	154.2	189.8	228.8
3500	69.0	135.5	170.1	210.9	256.2
3750	75.3	147.7	186.8	233.6	286.1
4000	81.9	160.5	204.5	258.1	318.9
4250	88.8	173.7	223.2	284.6	355.3
4500	96.0	187.5	243.2	313.7	395.8
4750	103.5	202.0	264.5	345.6	441.4
5000	111.4	217.1	287.4	380.9	493.2
5250	119.8	232.9	312.1	420.5	552.6
5500	128.6	249.5	338.9	465.4	621.4
5750	137.8	267.1	368.2	516.8	701.8
6000	147.7	285.6	400.4	576.8	796.5
6250	158.1	305.3	436.3	648.1	908.5
6500	169.3	326.2	476.6	734.5	1040.8
6750	181.3	348.5	522.6	841.9	1196.0
7000	194.1	372.4	575.9	978.0	1376.3
7250	208.1	398.2	639.3	1152.8	1583.8
7500	223.2	426.3	716.7	1376.2	1821.0
7750	239.8	456.9	815.4	1654.7	2092.2
8000	258.2	490.6	948.3	1991.2	2403.6
8250	278.7	528.1	1141.9	2389.6	2764.7
8500	301.7	570.3	1451.2	2859.7	3189.3
8750	328.2	618.6	1959.8	3419.4	3697.9
9000	358.9	675.0	2709.1	4098.2	4321.8
9250	395.6	742.5	3703.3	4944.1	5110.6
9500	440.7	826.4	5000.4	6037.6	6148.2
9750	498.7	936.7	6738.0	7526.2	7586.9
10000	578.7	1095.8	9201.1	9710.1	9733.6
10250	702.8	1371.8	13063.8	13300.0	13304.4
10500	950.0	2141.0	20390.5	20443.4	20443.5
10750	1899.3	6879.6	41860.1	41860.5	41860.5

2.5.5 Correction for shortened exposure time

If we are forced to adjust the exposure time from overnight to a shorter period, this must be stated when presenting the results. In addition, the results must be converted to the total overnight exposure time to allow comparison between water bodies. The catchable biomass model described in the previous subsection allows for such a conversion. Using the same Table 2.5, we can convert catches from four different shortened exposure times - 2 hours of exposure just over the peak of fish activity at dusk or dawn, exposure over the 2-hour peak of fish activity at dusk or dawn plus 3 additional hours (total exposure time 5 hours), exposure over the 2-hour peak of fish activity at dusk or dawn plus 6 additional hours (total exposure time 8 hours), and exposure over the 2-hour peak of fish activity at dusk or dawn plus 9 additional hours (total exposure time 11 hours). The exact procedure for converting catch rates can be found in Table 2.5 caption.

2.6 References

BLABOLIL P., BOUKAL D.S., RICARD D., KUBEČKA J., ŘÍHA M., VAŠEK M., PRCHALOVÁ M., ČECH M., FROUZOVÁ J., JŮZA T., MUŠKA M., TUŠER M., DRAŠTÍK V., ŠMEJKAL M., VEJŘÍK L., PETERKA J., 2017: Optimal gillnet sampling design for the estimation of fish community indicators in heterogeneous freshwater ecosystems. *Ecological Indicators* 77, 368–376.

BLABOLIL P., ČECH M., DRAŠTÍK V., HOLUBOVÁ M., KOČVARA L., KUBEČKA J., MUŠKA M., PRCHALOVÁ M., ŘÍHA M., SAJDLOVÁ Z., ŠMEJKAL M., TUŠER M., VAŠEK M., VEJŘÍK L., VEJŘÍKOVÁ I., PETERKA J., JŮZA T., 2021: Less is more – Basic quantitative indices for fish can be achieved with reduced gillnet sampling. *Fisheries Research* 240, 105983.

CEN, 2015. Water quality: sampling of fish with multi-mesh gillnets (EN14757) Brussels, Belgium, 2015, 30 pp.

HAMLEY J. M., 1980: Sampling with gillnets. EIFAC Technical Paper 33, 37–53.

KURKILAHTI M., 1999: Nordic multimesh gillnet - robust gear for sampling fish populations. University of Turku.

KURKILAHTI M., APPELBERG M., HESTHAGEN T., RASK M., 2002: Effect of fish shape on gillnet selectivity: a study with Fulton's condition factor. *Fisheries Research* 54, 153–170.

MILLAR R.B., 1992: Estimating the size-selectivity of fishing gear by conditioning on the total catch. *Journal of the American Statistical Association* 87, 962–968.

MILLAR R.B., HOLST R., 1997: Estimation of gillnet and hook selectivity using log-linear models. *ICES Journal of Marine Science* 54, 471–477.

MILLAR R.B., 2000: Untangling the confusion surrounding the estimation of gillnet selectivity. *Canadian Journal of Fisheries and Aquatic Sciences* 57, 507–511.

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 multimesh gillnet. *Fisheries Research* 68, 135–147.

PRCHALOVÁ M., KUBEČKA J., ŘÍHA M., LITVÍN R., ČECH M., FROUZOVÁ J., HLADÍK M., HOHAUSOVÁ E., PETERKA J., VAŠEK M., 2008a: Overestimation of percid fishes (Percidae) in gillnet sampling. *Fisheries Research* 91, 79–87.

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., 2008b: Distribution patterns of fishes in a canyon-shaped reservoir. *Journal of Fish Biology* 73, 54–78.

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., 2009a: The effect of depth, distance from dam and habitat on spatial distribution of fish in an artificial reservoir. *Ecology of Freshwater Fish* 18, 247–260.

PRCHALOVÁ M., KUBEČKA J., ŘÍHA M., MRKVIČKA T., VAŠEK M., JŮZA T., KRATOCHVÍL M., PETERKA J., DRAŠTÍK V., KRÍŽEK J., 2009b: Size selectivity of standardized multimesh gillnets in sampling coarse European species. *Fisheries Research* 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. *Fisheries Research* 102, 291–296.

PRCHALOVÁ M., HORKÝ P., SLAVÍK O., VETEŠNÍK L., HALAČKA K., 2011a: Fish occurrence in the fishpass on the lowland section of the River Elbe, Czech Republic, with respect to water temperature, water flow and fish size. *Folia Zoologica* 60, 104–114.

PRCHALOVÁ M., MRKVIČKA T., PETERKA J., ČECH M., BEREC L., KUBEČKA J., 2011b: A model of gillnet catch in relation to the catchable biomass, saturation, soak time and sampling period. *Fisheries Research* 107, 201–209.

PRCHALOVÁ M., KUBEČKA J., ŘÍHA M., ČECH M., JŮZA T., KETELAARS H.A.M., KRATOCHVÍL M., MRKVIČKA T., PETERKA J., VAŠEK M., WAGENVOORT A.J., 2013a: Eel attacks—A new tool for assessing European eel (*Anguilla anguilla*) abundance and distribution patterns with gillnet sampling. *Limnologica* 43, 194–202.

PRCHALOVÁ M., PETERKA J., ČECH M., KUBEČKA J., 2013b: A simple proof of gillnet saturation. *Boreal Environment Research* 18, 303–308.

ŠMEJKAL M., RICARD D., PRCHALOVÁ M., ŘÍHA M., MUŠKA M., BLABOLIL P., ČECH M., VAŠEK M., JŮZA T., MONTEOLIVA A., ENCINA L., PETERKA J., KUBEČKA J., 2015: Biomass and Abundance Biases in European Standard Gillnet Sampling. *PLoS ONE* 10, 1–15.

TESFAYE G.C., SOUZA A.T.S., BARTOŇ D., BLABOLIL P., ČECH M., DRAŠTÍK V., HOLUBOVÁ M., KOČVARA L., MARTINEZ VON DOSOW C., MORAES K., MUŠKA M., PRCHALOVÁ M., ŘÍHA M., SAJDLOVÁ Z., SEĎA J., SOUKALOVÁ K., ŠMEJKAL M., TUŠER M., VAŠEK M., VEJŘÍK L., VEJŘÍKOVÁ I., PETERKA J., JŮZA T., KUBEČKA J., 2022: Long-term monitoring of fish in a freshwater reservoir: different ways of weighting complex spatial sampling. Submitted to *Frontiers in Environmental Science*

VAŠEK M., PRCHALOVÁ M., ŘÍHA M., BLABOLIL P., ČECH M., DRAŠTÍK V., FROUZOVÁ J., JŮZA T., KRATOCHVÍL M., MUŠKA M., PETERKA J., SAJDLOVÁ Z., ŠMEJKAL M., TUŠER M., VEJŘÍK L., ZNACHOR P., MRKVIČKA T., SEĎA J., KUBEČKA J., 2016: Fish community response to the longitudinal environmental gradient in Czech deep-valley reservoirs: Implications for ecological monitoring and management. *Ecological Indicators* 63, 219–230.

VETEMAA M., ESCHBAUM E., VERLIIN A., ALBERT A., EERO M., LILLEMÄGI R., PIHLAK M., SAAT T., 2006: Annual and seasonal dynamics of fish in the brackish-water Matsalu Bay, Estonia. *Ecology of Freshwater Fish* 15, 211–220.

Water Framework Directive 2000/60/EC, 2000. European Parliament and Council, https://ec.europa.eu/environment/water/water-framework/index_en.html.

ŽÁK J., JŮZA T., BLABOLIL P., BARAN R., BARTOŇ D., DRAŠTÍK V., FROUZOVÁ J., HOLUBOVÁ M., KETELAARS H.A.M., KOČVARA L., KUBEČKA J., MRKVIČKA T., MUŠKA M., ŘÍHA M., SAJDLOVÁ Z., ŠMEJKAL M., TUŠER M., VAŠEK M., VEJŘÍK L., VEJŘÍKOVÁ I., WAGENVOORT A.J., 2018: Invasive round goby *Neogobius melanostomus* has sex-dependent locomotor activity and is under-represented in catches from passive fishing gear compared with seine catches. *Journal of Fish Biology* 93, 147–152.

Attachment: Field protocols

1. For recording GPS time and setting gillnets from which exact position can be read
2. For recording the catch

Gillnets

Reservoir:

Locality:

GPS No.: _____

Date	Stratum Locality spot	Setting Start time	Setting End time	Removal Start time	Bottom Start time	Bottom slope / substrate
	0 - 3 A D	: :	: :	:		
	0 - 3 B E	: :	: :	:		
	0 - 3 C F	: :	: :	:		
	3 - 6 A D	: :	: :	:		
	3 - 6 B E	: :	: :	:		
	3 - 6 C F	: :	: :	:		
	6 - 9 A D	: :	: :	:		
	6 - 9 B E	: :	: :	:		
	6 - 9 C F	: :	: :	:		
	9 - 12 A D	: :	: :	:		
	9 - 12 B E	: :	: :	:		
	9 - 12 C F	: :	: :	:		
	12 - 20 A D	: :	: :	:		
	12 - 20 B E	: :	: :	:		
	12 - 20 C F	: :	: :	:		
	20 - 35 A D	: :	: :	:		
	20 - 35 B E	: :	: :	:		
	20 - 35 C F	: :	: :	:		
	35 - 50 A D	: :	: :	:		
	35 - 50 B E	: :	: :	:		
	35 - 50 C F	: :	: :	:		
	50 - 75 A D	: :	: :	:		
	50 - 75 B E	: :	: :	:		
	50 - 75 C F	: :	: :	:		

Bottom slope: riverbed / flat / slope

Bottom substrate: mud / sand / rubble / rocks / stumps

GPS device has to PE switched ON and GPS track logging has to Pe turned on:

Menu → Menu → Tracks → (Track log ON) → Setup → Data Card Setup → Log Track To Data Card (checked)

GPS device has to have proper timezone set - Czech with daylight saving:

Menu → Menu → Setup → Time

Format: 24 hour / TZ: Prague / UTC offset: +01 hrs 00 min

Daylight Saving Time: Auto

3 Hydroacoustic surveys

Jan Kubečka¹, kubecka@hbu.cas.cz, Helge Balk², helge.balk@fys.uio.no

Jaroslava Frouzová¹, jarkafrouzova@gmail.com, Milan Muška¹, milan.muska@hbu.cas.cz,

Michal Tušer¹, michal.tuser@hbu.cas.cz

¹ *Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, Na Sádkách 7, 370 05, České Budějovice, Czech Republic*

² *University of Oslo, Department of Physics, POB 1048, N-0317 Oslo, Norway*

During a hydroacoustic survey, the water body is examined with scientific echosounders in order to estimate fish abundance, biomass, size and spatial distribution. Mobile survey is the common strategy covering the water body with well-planned transect patterns. Most common sound frequencies range from 70 to 200 kHz while there are some use of lower and higher frequencies as well. The common frequencies have no problems with propagation under temperate freshwater conditions (up to a distance of 100 m from the research vessel) and are sensitive enough to detect individuals as small as fish larvae. Scientific echosounders have a well-defined sampling volume of the water under investigation and can record every fish in the sampled volume. The echosounder emit short bursts of sound pulses (pings) to the water forming small Pulse Volumes (PV) filled with sound. These PV's travels through the waterbody with a speed of ~1500 m/s. The software of modern echosounders include corrections of small changes of sound speed with temperature and salinity. When a traveling pulse hit fish or other targets, these targets reflects some of the sound back to the echosounder. The echosounder records this total reflection from the waterbody and presents the results in the Amp-Echogram as seen in Fig. 3.1a.

Single echo detector (SED) is an important part of the post processing system. If there are two or more fish embedded in the PV simultaneously, the echo from these fish will be summed and occur as one bigger fish not useful for sizing of individuals. The task for the SED is to suppress such multiple target echoes and detect only echoes from fish being alone in the pulse volume. The output from the detector is individuals described with acoustic size, observed time, range, and for split beam systems, also angular position

in the beam. The acoustic size can be presented either as the targets acoustic back scatter coefficient σ_{bs} measured in m^2 or by its Target Strength (TS) measured in dB re 2π . While TS is useful for presentation in SED-echograms and for plotting acoustic size distributions as seen in Fig. 3.1. The linear counterpart σ_{bs} is more useful for mathematical operations like averaging. The relationship between TS and σ_{bs} is:

$$(1) \quad TS = 10 \log(\sigma_{bs}) \quad \text{or} \quad \sigma_{bs} = 10^{\frac{TS}{10}}$$

For a fish size distribution as seen in Fig. 3.1c. we find the average acoustic fish size according to

$$\overline{\sigma_{bs}} = \frac{1}{N} \sum_{n=1}^N \sigma_{bs,n} \quad (2)$$

Where n is the index of the individual detections and N the total number of fish detections.

Volume back scattering strength (Sv) in dB or its linear counterpart, volume backscattering coefficient s_v in m^2/m^3 is another important parameter obtained from the echosounder data. It measures how much a proportion of the water reflect. The operator selects the amount of water by framing a region of water in the echogram. The occurring s_v represent the sum of reflection from all fish in the framed region divided by the framed volume of water. The relationship between Sv and s_v is:

$$(3) \quad Sv = 10 \log(s_v) \quad \text{or} \quad s_v = 10^{\frac{Sv}{10}}$$

The area backscattering strength S_A measured in m^2 per 1 ha of water area is similar to Sv except that it relates to area rather than to the $\overline{s_v}/\overline{ts}$ volume.

Fish abundance (f / m^3) can be found according to the scaling method (Balk and Lindem, 2014).

$$\text{Abundance} = f / m^3 = \frac{\overline{Sv}}{\overline{\sigma_{bs}}} \quad (4)$$

Where $\overline{\sigma_{bs}}$ according to the convention that capital letter is used to indicate logarithmic values while lower letters are applied for linear values. Volume abundance can be converted to area abundance and expressed as fish per hectare.

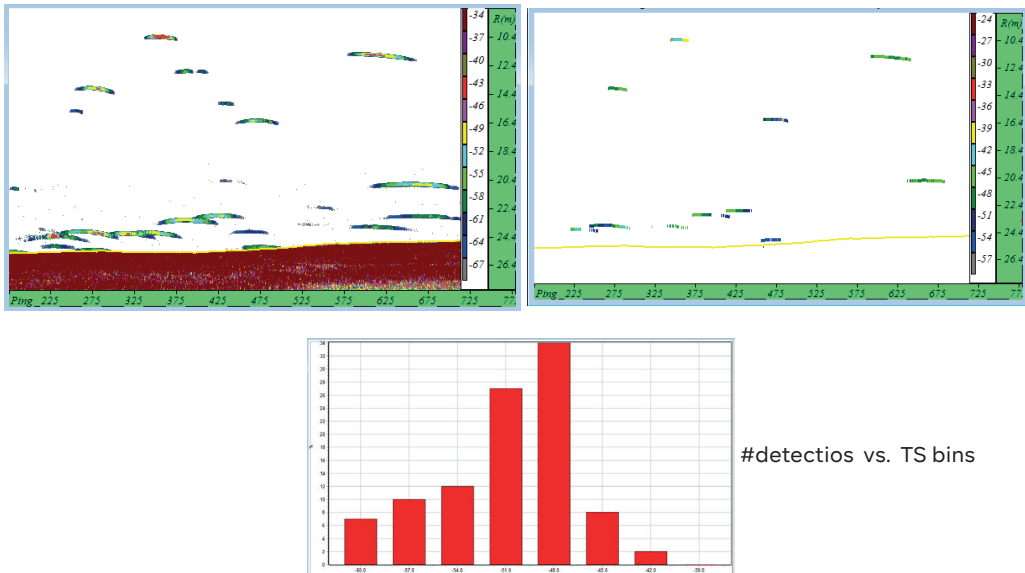


Figure 3.1. Left: a) Vertically recorded Amp-echogram showing the total reflection from fish and bottom. Right: b) SED-echogram showing only the output from the SED. Bottom: c) Size distribution from single echo detections from the fishes seen in the SED-echogram. Here TS from individual detections are grouped in size bins of 3 dB. X-axis show increasing TS while the y-axis show number of detections.

Advantages of hydroacoustic survey:

- Sampling of large areas and volumes of water in a short time, allowing monitoring of water body as a whole
- Minimal interference with fish life, no harm to fish
- No selectivity and high resolution: all individuals with > 2-3 cm length in open water are counted
- Multidimensional information with longitude, latitude, depth and time of sampling allows analysis of habitat preferences and migration

Limitations of hydroacoustic survey:

- It is not possible to directly identify the species of recorded fish
- Fish near the bottom, shore or shelters cannot be detected
- Size determination has greater variance than direct catches and

measurements of captured fish; in particular, it is difficult to interpret the size of fish observed by the horizontal mobile survey

- The method is highly demanding in terms of instrumentation, expertise and time required to process large amounts of recorded data.
- Interpretation and data collection can be complicated by factors such as gas bubbles, flood events and subsequent inorganic water turbidity, thermal stratification of the water column, aquatic vegetation, and aquatic invertebrates

3.1 Basic equipment

The most commonly used echosounder is the scientific split-beam echosounder set up to emit short constant wavelength (CW) sound pulses with frequencies as mentioned above. For horizontal surveys, it is desirable to use transducers that produce beams with weak side lobes (30 dB and less). For vertical surveys in shallower waters (up to 50 m depth), it is usually advantageous to use transducers with beams as wide as possible (for split-beam echo sounders the practical limit today is about 18 degrees). When fish density is very high or the fish stay deep, narrower beam openings may be practical for obtaining high proportion of single targets.

The newly developed EK80 broadband echosounder can emit both CW and frequency modulated pulses (FM), but the philosophy of data acquisition and processing of FM has not yet been fully developed and FM mode is therefore not applied in regular monitoring surveys.

3.2 Other equipment required

- A motorized vessel that is at least partially covered and capable of carrying electronic equipment on board
- A device for measuring the inclination of the transducer (known as a tilt-meter)
- A device for measuring the angle between the direction of the horizontal transducer and the direction of movement of the vessel (to measure pan of horizontal transducer)

- Equipment to keep the transducer in the appropriate position (a rotator controllable from the vessel's deck)
- Laptop with 12 V power supply and corresponding sufficient DC power supply (12 V)
- Calibration spheres (Simmonds and MacLennan, 2005; Table 3.1)
- GPS device with USB interface and cable and mapping software including recorded bathymetric maps of relevant water bodies
- Paper blind map for backup records of the field protocol
- Software for processing hydroacoustic data (Sonar5-Pro, Echoview)

3.3 Sampling

When planning the hydroacoustic survey at an unknown waterbody with no acoustic survey history, the survey should include day and night echosounding with both horizontally and vertically oriented transducers (see Fig. 3.2). The survey must not be conducted during extraordinary atmospheric events (storms, heavy rains, high winds, etc.) that endanger safety and increase an acoustic noise level in recordings. Also, windless weather seems to be inconvenient because the smooth water surface causes interference with acoustic targets in the upper water layer, hence uncertainty in target acoustical size and position (Balk et al., 2017).

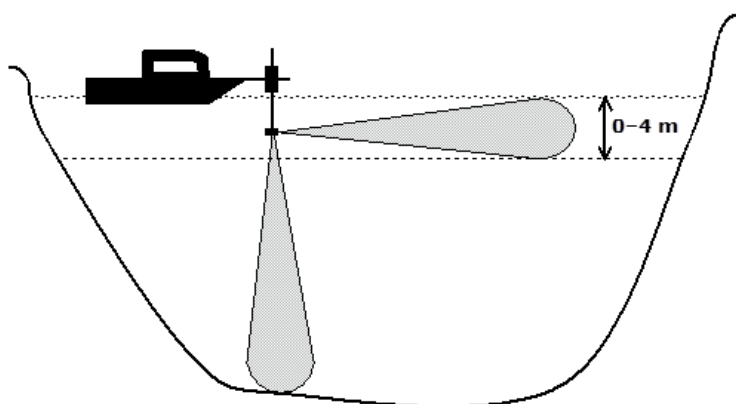


Figure 3.2. Hydroacoustic survey with horizontally and vertically oriented acoustic beams. For simplicity, the horizontally oriented beam is shown in front of the vessel - in practice, the axis of the cone is perpendicular to trajectory of the survey vessel.

Horizontal and vertical surveys can be performed either a) simultaneously (using two separate echosounders) or b) one echosounder with multiplexed transducers or c) sequentially starting with the horizontal followed by the vertical survey. The horizontally oriented transducer is placed at a depth of at least 0.5-1 m below the surface so that the echosounder's beam does not touch the surface (tilting 1-3 ° downwards with common 7 degree transducers). The transducer for the vertical survey is placed 20 cm below the surface and the beam must point vertically downwards.

The overall sensitivity of the echosounder system must be calibrated using a standard tungsten carbide sphere (diameter 33.2 mm for 120 kHz and 21.2 mm for 400 kHz; Simmonds and MacLennan, 2005; Table 3.1). Newer echosounders control programs (e.g., SIMRAD ER60 and ER80) have a calibration menu that automates the determination of system sensitivity and makes calibration relatively simple. If a complete calibration is not possible, it is recommended to record the calibration sphere directly in the middle of the acoustic beam ('on the axis') and to adjust the system gain so that the TS readings match the theoretical values in Table 3.1.

Table 3.1. Dimensions and target strengths (TS) of tungsten carbide (TC) and copper (Cu) calibration spheres at a sound speed of 1,450 m / s in fresh water (Simmonds and MacLennan, 2005; Simrad Kongsberg).

Frekvensy (kHz)	Diameter (mm)	Band width (kHz)	TS (dB)	type
38	38,1	4	-42	TC
38	60,0	4	-33,7	Cu
70	33,2	7	-41,3	TC
70	38,1	7	-40,6	TC
120	23,0	12	-40,8	Cu
120	33,2	12	-41,0	TC
120	38,1	12	-40,1	TC
200	36,4	20	-39,8	TC
200	38,1	20	-40,0	TC
400	21,2	40	-44,6	TC
420	21,2	40	-44,3	TC

Short pulses (0.1-0.5 ms) should be used for data acquisition (short pulses are recommended for dense fish populations and not too long ranges < 50 m; Longer pulses containing more energy may be used for longer ranges). Pulse repetition rate should be controlled by the range of the monitored

volumes (typically 5 - 20 emissions / s). At larger locations, the pulse repetition rate is limited by the return time of the reflection from the distant bottom or the opposite shore (horizontal beaming) or by the time required to attenuate the energy of a previous emission trapped between the surface and the bottom (vertical beaming). Unfiltered raw data from the entire relevant range of distance from the transducer (usually 50 m at locations where the depth does not exceed this value) should be always stored on a hard disk of the control computer. At the same time, the GPS coordinates of the ship's movement should be stored.

Regarding the survey coverage, the survey vessel should move along a winding zigzag trajectory if the width of the water body permits (Fig. 1.1c). In narrow and shallow localities, the vessel moves as much as possible to maximize sampling volume resembling thus continuous sampling strategy (Fig. 1.1b). The trajectory should be recorded in a mapping software using a GPS device and simultaneously sketched manually on a blind map with the times of passage of each individual location. The volume explored should be at least 10 % of the volume of the water body for bodies with area up to 150 ha and at least 5 % of the volume for larger bodies.

The range of processed data (distance from the transducer) of the horizontal survey may be limited if the sound beam bends due to sharp temperature stratification of the water column. For that reason, during the survey, the temperature stratification should be measured at least in three points of the longitudinal profile of the water body. The depth of the water column surveyed by horizontal survey is usually set at 4 m (depth of the epilimnion or its upper part) and this value must always be set in the corresponding menu of the processing program. Deeper layers should be surveyed by vertical beaming. Range of the vertical survey is limited by the moment when the sound beam touches the bottom.

3.4 Processing and interpretation of results

Sonar5-Pro post-processing software (CageEye AS, Oslo, Norway) is currently the main choice for processing freshwater hydroacoustic data because it handles both horizontal and vertical surveying. Raw acoustic data are converted to this program using the appropriate calibration parameters. The first step is to extract TS data properly by tuning the SED parame-

ters. Suggested initial conversion settings for this detector are analogically to the study of Parker-Steller et al. (2009): -75 dB for a lower threshold, 0.6 and 1.6 for minimum and maximum pulse duration relative to emitted pulse duration, determination of echo duration at -6 dB from the peak value, 6 dB for maximum beam compensation (2-way, 3 dB for 1-way), and a maximum phase deviation of 0.6 in both directions (mechanical degrees).

Analogically to other methods, refereed in this book, young of the year (YoY) fish are usually not estimated in routine hydroacoustic surveys. To suppress the YoY, invertebrates and other noises in the acoustic data, a standard length threshold (SL threshold) in mm that separates YoY from older fish is established from pelagic gillnets catches valid for the hydroacoustic survey in question. This SL threshold is converted to an acoustic TS threshold with the application of the equations from Frouzova et al. (2005). For vertical records, the relationship is:

$$TS = 21,44 * \text{Log SL} - 84,05 \quad (5)$$

For horizontal records, the relationship is:

$$TS = 24,26 * \text{Log SL} - 100,68 \quad (6)$$

Where SL is the standard body length in mm, and TS the resulting target strength threshold that will suppress YoY and other similarly weak noise in the acoustic data. The obtained TS threshold is applied to the SED echogram while the threshold for the Amp echogram is set 6 dB lower. (TS threshold – 6 dB) to allow including reflections in the outer part of the beam.

The analysed part of the echogram should be framed by the user and separated from the reflections from the bottom, opposite bank, macrophytes, and possibly other structures in an automatic or manual manner. The processed data usually start 4 m from the transducer. For the framed areas, S5 will calculate the average s_v and average σ_{bs} , and obtain the abundance according to (4).

For vertical data, the average acoustic size for the fish population can be determined directly from the measured TS values of individual fish using the equation 5 or the equation of Love (Draštík et al., 2017). For horizontal recordings, aspect is unknown and since aspect influence strongly on the observed TS, it is necessary either to apply a correction to the *in-situ* observations or to obtain \bar{L}_S from an alternative source. These two methods are described by (Godlewska et al., 2012):

1. Observed TS influenced by aspect can be corrected with a deconvolution process removing the aspect influence in a statistical way. The output from the deconvolution will be a corrected TS distribution, which can be converted to a length frequency distribution (Kubečka et al., 1994) The method is valid only under the assumption that fish are randomly distributed in the water body. This may, however, not always be the case (Tušer et al., 2009). The deconvolution method needs a double TS–TL regression equation to work. One equation for the side aspect and another for the tail/head aspect. We recommend applying the TS–SL relationship from Frouzova et al. (2005) for common European species:

$$TS = 24.15 * \text{Log SL} - 86.51 \text{ for side aspect} \quad (7)$$

and

$$TS = 19.29 * \text{Log SL} - 99.98 \text{ for head/tail aspect} \quad (8)$$

2. If *in-situ* TS distribution is not representative, length structure observed by the direct related fish catch can be applied as an alternative source of size distribution. The catch is then registered in Sonar5-Pro's "catch basket" together with a reference to the appropriate TS/Length/weight regression equations. Sonar5-Pro will convert the registered catch into TS values that can be applied in the acoustic analysis as if it was obtained *in-situ* from the acoustic data. This method can be used both for vertical and horizontally recorded data. For vertical records, fish in the catch basket should reference a dorsal aspect regression as (5) found in Frouzová et al. (2005). For horizontal records, fish in the "catch basket" should reference an all aspect SL-TS_{AS} regression (Kubečka et al., 2009). This regression has been obtained by monitoring fishes rotated 360 deg.

$$TS_{AS} = 23.153 * \text{Log SL} - 93,407 \quad (9)$$

S5 performs all necessary conversions and averaging. Abundance will be calculated for the framed regions and also Biomass if appropriate length-weight relationship is included in the referenced regressions. Sonar5-Pro's "catch basket" may in addition be used as a source of information on the size distribution of the monitored fish (size distribution source).

From the horizontal and vertical hydroacoustic surveys we obtain the following data:

- Volume of sampled water
- Acoustic and physical size distribution
- Abundance (individuals / ha or m³)
- Biomass (kg / ha)
- Volume backscattering strength (S_V)
- Area backscattering strength S_A

S_V and S_A can be used to compare fish biomass in different water bodies if we do not take in to account size and species composition.

Processing the records from the vertical survey will provide a size composition of fish at depths greater than 4 m, complementing samples from mesopelagic and bathypelagic gillnets.

Acknowledgment

This contribution was supported by the Project no.: EHP-BFNU-OVNKM-2-040-2019 of the Programme BFNU - NFP Bilateral Funds Size estimation and taxonomical identification of European freshwater fishes using a broadband echosounder

3.5 References

BALK H., LINDEM T., 2014: Sonar4 and Sonar5-Pro. Post Processing Systems. Operator Manual Version 6. 0. 2. Lindem Data Aquisitions A/S, Norway

BALK H., SØVEGJARTO B.S., TUŠER M., FROUZOVÁ J., MUŠKA M., DRAŠTÍK V., BARAN R., KUBEČKA J., 2017: Surface-induced errors in target strength and position estimates during horizontal acoustic surveys. Fisheries Research 188, 149-156. <http://dx.doi.org/10.1016/j.fishres.2016.12.017>

BARAN R., JŮZA T., TUŠER M., BALK H., BLABOLIL P., ČECH M., DRAŠTÍK V., FROUZOVÁ J., JAYASINGHE A.D., KOLIADA I., MRKVIČKA T., MUŠKA M., RICARD D., SAJDLOVÁ Z., VEJŘÍK L., KUBEČKA J., 2017: A novel upward-looking hydroacoustic method for improving pelagic fish surveys. Scientific Reports 7, 4823. DOI:10.1038/s41598-017-04953-61

DRAŠTÍK V., GODLEWSKA M., BALK H., CLABBURN P., KUBEČKA J., MORRISSEY E., HATELEY J., WINFIELD I.J., GUILLARD J., 2017: Hydroacoustic standardization: a new step forward based on comparisons of methods and systems from a large deep lake. *Limnology & Oceanography Methods* 15 (10), 836–846. DOI:10.1002/lom3.10202

FROUZOVÁ J., KUBEČKA J., BALK H., FROUZ J., 2005: Target strength of European freshwater fish and its dependence on fish body parameters. *Fisheries Research* 75, 86-96.

GODLEWSKA M., FROUZOVA J., KUBECKA J., WIŚNIEWOLSKI W., SZLAKOWSKI J., 2012: Comparison of hydroacoustic estimates with fish census in shallow Malta Reservoir – which TS/L regression to use in horizontal beam applications? *Fisheries Research* 123–124, 90–97. doi:10.1016/j.fishres.2011.11.023

KUBECKA J., DUNCAN A., DUNCAN W., SINCLAIR D., BUTTERWORTH A.J., 1994: Brown trout populations of three Scottish lochs estimated by horizontal sonar and multi-mesh gillnets. *Fisheries Research* 20, 29-48.

KUBEČKA J., FROUZOVÁ J., BALK H., ČECH M., DRAŠTÍK V., PRCHALOVÁ M., 2009: Regressions for conversion between target strength and fish length in horizontal acoustic surveys. In: PAPADAKIS J.S., BJORNO L., (eds.), *Underwater acoustic measurements, Technologies & Results*. Foundation for Research & Technology, Heraklion, Greece, ISBN 978-960-98883-2-5: 1039-1044.

PARKER-STETTER S.L., RUDSTAM L.G., SULLIVAN P. J., WARNER D.M., 2009: Standard operating procedures for fisheries acoustic surveys in the Great Lakes. *Great Lakes Fish. Comm. Spec. Pub.* 09-01. 180 pp.

SIMMONDS E.J., MACLENNAN D.N., 2005: *Fisheries Acoustics*. Chapman & Hall, London, 456 pp.

TUŠER M., KUBEČKA J., FROUZOVÁ J., JAROLÍM O., 2009: Fish orientation along the longitudinal profile of the Římov reservoir during daytime: Consequences for horizontal acoustic surveys. *Fisheries Research* 96 (1), 23-29.

Attachment: Recommended field protocols

1. For calibration of the echosounders
2. For logging the acoustic survey information

ACOUSTIC CALIBRATION PROTOCOL

Date _____

Computer _____

Locality _____

Participant _____

Water temperature [°C]

Reference target

Type / Size [mm]					
Target Strength [dB]					
Range [m]					

Transducer attributes

Name					
Frequency [kHz]					
Pulse duration [ms]					
Power [W]					

Beam model

Transducer Gain [dB]					
Sa Correction [dB]					
Athw Angle [deg]					
Athw Offset [deg]					
Along Angle [deg]					
Along Offset [deg]					

Specific notes

Please, append the capitalized label "APPLIED" to a filename of the final calibration file.

4 Electrofishing

Petr Blabolil^{1,2,*} petr.blabolil@hbu.cas.cz, Tomáš Kolařík¹, kolarik.tom1@seznam.cz

Michal Kratochvíl¹ kratochvil@cz-ryby.cz

¹ *Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, Na Sádkách 702/7, 370 05 České Budějovice, Czech Republic*

² *Faculty of Science, University of South Bohemia, Branišovská 1760, 370 05 České Budějovice, Czech Republic*

This chapter is a description of the fishing methodology with an electroshocker, the equipment and its use and the processing and evaluation of the catch. The chapter describes sampling of fish mainly older than young-of-the-year in stagnant waters and aims to extend and adequately supplement previous methods (EN 75 7706 CEN 2003; Kubečka and Prchalová; 2006, Bednář et al., 2013). In shallow areas, it is possible to carry out electrofishing by wading or from the shore, but such conditions are rather exceptional in reservoirs and lakes, which is why electrofishing from a boat is described in the following text.

Advantages of electrofishing:

- All types of shores inaccessible to other methods like seine or other types of nets can be sampled (stumps, roots, aquatic vegetation, flooded terrestrial vegetation, sunken trees, large stones, etc.)
- With the correct use and adjustment of the equipment, electric fishing is one of the gentlest fishing methods. Caught fish show rapid recovery and can be released alive after measurement in most cases. The aquatic environment is not damaged
- Electrofishing allows quick and easy sampling of large shore areas in a relatively short time, usually, the equipment can be moved and prepared quickly
- It has relatively low demands on the number of workers (usually 3-5 people), sampling is physically undemanding and clean

- A wide range of species and sizes can be caught. The presence of some species may exclusively be proven by this method (loaches or gobies)

Limitations of electrofishing:

- Limited use in deeper waters (> 1 m deep)
- Reduced efficiency at low water conductivity, and conversely high demands on the power at high water conductivity
- Limitation of stunned fish tracing in waters with high turbidity
- Depending on the settings, electrofishing is species and size selective
- There is a risk of electric shock if used incorrectly. Employees must pass a special training and obtain a licence.
- It is necessary to obtain a valid exemption for electric fishing
- It is necessary to carefully maintain the equipment (remove any coatings, pay attention to storage and operation in a dry place) and inspect the units once a year by an inspection technician with the necessary qualifications

Principle of electric fishing

Electrofishing uses an electric shocker to create an electric field in the water. The field is generated between two electrodes immersed in water (positive catching anode and negative cathode). The current carriers between the two electrodes are ions dissolved in the water. The electric field stimulates the nervous system of fish in the range of an electric field. If the fish is on the edge of the electric field, it tries to escape it (excitation). Within the field, the fish turns its head toward the anode (positive electrotopism) and swims uncontrollably toward the anode (galvanotaxis). Fish may be temporarily immobilized or stunned, with many fish beginning to sink (galvanonarcosis). A fish can be easily caught if it turns around in the electric field.

In reservoirs and lakes, there are two basic strategies of electrofishing from a boat, first, continuous sampling in transects and the second, point-sampling at individual sites. Continuous sampling is suitable on unstructured or poorly structured shores and can be used to a limited extent in the open water of shallow or temperature-stratified waters. Point sampling is applied at structured littoral, where continuous sampling would often be interrupted.

4.1 Use, time and suitable conditions for electric fishing

Electrofishing should not be conducted under extreme temperature conditions. The ideal water temperature is 10 – 20 °C for common fish species in temperate Europe. If salmonids are present, electrofishing should be conducted at water temperatures of 10 – 15 °C (Beaumont et al., 2002). The time of day sampling can have a major impact on results. In general, night time sampling is considered less convenient due to limited visibility and poses a lower safety. On the other hand, fish escape responses are lower at night, and some species migrate to shore from deeper waters or shelters (e.g., pikeperch, ruffe).

4.2 Equipment

4.2.1 Electrofishing boat

A stable sufficiently spacious boat for the transport of electrical equipment, storage/processing of catch, and crew should be used. The boat must be easily manageable to avoid obstacles in a rugged coastal area. In practise, a boat with a length of 5 – 6 m and a width of 1.5 – 2 m seems ideal. The size of the boat depends on the number of fishermen to ensure their safety while considering the ease of handling the boat. The boat can be made of conductive aluminium alloy or non-conductive material. It can also have two closed chambers, the first at the bow (to maintain buoyancy) and the second at the stern (it can be advantageous to fill the rear flowing chamber with water to balance the bow with operators and barrels). An alternative is the tilting bow, which brings the fishermen closer to the surface. In the front part of the boat there is always a removable safety railing with a height of at least 1 m, which serves as a support for the fishermen and as a protection against an accidental fall into the water. The boat also has mounts for the outboard motor in the back of the boat and paddle mounts (in front of and behind the bench seat). The outboard motor should have a power rating of at least 10 kW if the sampled water body is larger and there are long crossings between locations in the lake. For electrofishing, the length of the

motor leg must be optimally chosen so that the cooling water inlet of the motor does not rise above the water when the front of the boat is loaded with standing crew or a full tub of water. The "leg" should be relatively short or with the possibility of tilting, the so-called shallow drive. The location of the catchers and the objects used for this purpose should be precisely determined and adhered to onboard. In front of the boat are the operators and there is a tank with water and oxygen or aeration equipment. A water pump can be useful to change the water in the fish keeping tank. The electric unit is located in the back of the boat so that it can be operated by the boat driver while driving. In case of imminent danger of injury to the crew or other persons, the driver switches off the unit. One or two anodes should be attached depending on the intended fishing method. Two anodes are usually fixed stationary in the lower corners of the railing ("booms"), while one anode can be operated by hands. All equipment must be secured against falling off the boat into the water.

4.2.2 Generator unit

The generator unit is housed in a metal frame and consists of a gasoline engine, a power generator, and a control box. Battery-powered systems are usually not feasible due to insufficient power. The generator for an electric boat should have a minimum power of 5 kW, and for fishing in waters with increased water conductivity - at least 10 kW. The control box should be equipped with the possibility of regulating the output voltage for waters with different conductivity, so that the total power applied to the water is similar regardless of its conductivity. It should be possible to choose between direct current and pulsed direct current operation. With pulsed current, control of the pulse frequency is an essential component (usually 20 to 100 per second), and individual adjustment of the duty cycle can be provided. The control box should also include a built-in voltmeter and amperemeter for orientation control of voltage and current output values.

To activate the current, the electric boat has a system of two safety switches: 1. the main switch on the generator with the on/off position, 2. a foot or hand-held switch that activates the electrodes only when being held on (so called the dead man's system). The main switch is usually operated by the crew leader (usually the boat driver), while the dead man's system is operated by the leader of fishing operation. Both switches must always be on

simultaneously to activate the electric field. Information about the current operation of the unit should be indicated by a light.

4.2.3 Electrodes

For continuous fishing with electric boats, a system with two anodes and one cathode is used. The two anodes are attached to 3 m long nonconductive rods that point almost forward of the boat (Fig. 4.1). The rods are terminated with metal rings to which a pin is attached to connect the anode. The star-shaped anode, 0.8 m in diameter, is equipped with six steel cables that are immersed in the water during actual fishing. Each hanging cable should be 0.5 – 1 cm in diameter (thicker cables are more suitable) and at least 0.9 m long. The distance between the centres of the anodes (tips of the two rods supporting both anode systems) should be about 2 m (Miranda and Kratochvíl, 2008). Both rods supporting the anodes are kept at the correct height (the tilt level) independently by lengthening or shortening the chain (Fig. 4.1). If the boat is moved for long distances, it is advisable to raise both anodes completely above the water. The anode system can be disassembled and easily transported or stored.



Figure 4.1. Continuous boat electrofishing using two anodes in front of the boat, where the metal boat construction serves as the cathode (photo: Ivana Vejříková).

In point sampling, the anode is a one fishing rod of non-conductive material fitted with a metal plate (copper or aluminium alloys) or a conductive frame onto which the dip net can be sewn (Fig. 4.2).



Figure 4.2. Point abundance fishing for fry from a boat. The positive anode (circular shape) at the end of the fibreglass rod is placed in the water in front of the boat and at the same time, the electric field is activated by foot switch. All stunned fish are then collected by an operator with a landing net (photo: Petr Blabolil).

The entire body of an aluminium boat can serve as the cathode. Alternatively, a conductive metal strip (copper) with cables immersed in water or the hull of a metal boat can be used as the cathode. All conductive parts of the boat, including the outboard motor and the metal structure of the electrical system, must be at the same electrical potential as the hull of the boat to prevent accidental penetration of the circuit by stray current. Copper tape that runs loosely behind the boat or is attached to a float is not ideal because it can be caught by obstacles in the water (branches, submerged plants, larger rocks, etc.), change the shape of the electric field, or have the possibility of contact with the hull or propeller.

4.3 Additional equipment

- Safety equipment for the fishermen (non-conductive waterproof gloves and boots, life jacket, hearing protection)
- Devices for measuring water characteristics (conductometer, Secchi plate, thermometer)
- Landing nets (dipnets) with a handle made of non-conductive material (2 – 3 m long), preferably with knotless netting. Mesh size and depth of the netting are determined by the size of the target fish; we recommend landing nets with a double frame, wherein the case of friction against the substrate, the mesh sewn to the inner frame is not damaged
- Fish tubs made of non-conductive material with oxygenation or aeration equipment
- Polarizing glasses
- GPS device for measuring the length of the fished section and locating the transect
- A blind map of the waterbody for records of the occurrence of individual types of the coastal environment in different areas of the waterbody
- Measures, scales, protocols, stationery
- Voltmeter/oscilloscope for mapping and checking electric field parameters
- When fishing during the night, sufficient lighting for catching and processing fish need to be equipped
- A communication device (mobile phone or walkie-talkie) for security reasons
- First aid kit, powder fire extinguisher
- Tools for assembling electrical parts in a compact unit

4.4 Sampling

4.4.1 Selection of locality and environment

If sampling is taking place at a water body that is being sampled for the first time or where there have been visible changes since the last sampling (rise/fall in water level, flood event), it is necessary to select appropriate sites at each location in advance. Sites should be characteristic of the investigated locality and should represent a significant part of the riparian structure of the water body (e.g., boulders, rocks, beaches, submerged trees, submerged terrestrial or submerged aquatic vegetation, etc.). The number, type, and location of electrofishing sites correspond to specific sampling purposes and depend on the morphology and size of the waterbody. In most cases, the number and location of sites are consistent with the number and location of sites required for gillnet sampling (see Chapter 1.2 Sampling strategies, locality-based strategy).

For each environment, basic characteristics such as bank slope, bottom substrate, presence/absence of vegetation, etc. (see protocol appendix) should be recorded. The location of the sampled environment is recorded with a device from GPS and simultaneously in a blind map of the water body. Photographic documentation is strongly recommended to be able to reproduce habitat conditions later. Information on the location and time of sampling, as well as site conditions, must also be entered into the operating logbook.

4.4.2 Before sampling

Before beginning sampling, the instrument should be tested for proper operation and adjustment outside the assumed sampling area (e.g., at a sampling site that will not be sampled during the survey). It is advisable to know the conditions prevailing at the sampling site. These include water temperature, transparency, and conductivity. Based on this knowledge, the appropriate method of fishing should be applied and also the setting of the electrical unit (voltage, current type, and for pulse current, the frequency of pulses or duty cycle) should be selected. If conditions permit, the most fish-friendly direct current should be used. If conditions require the use of

pulsed DC current (e.g., high water conductivity and low power), set the lowest possible pulse frequency; if necessary (observing more than 20% escaping fish), gradually increase the frequency. If too high a value is set from the beginning, can cause stunning of the fish (galvanonarcosis), which are no longer able to move to the anode (galvanotaxis). Sinusoidal alternating current is dangerous to fish and its use is prohibited in most cases.

Before starting sampling, it is essential to secure the selected area. Unauthorized persons are not allowed to be at the fishing site or in its immediate vicinity. The protection zone consists of a minimum distance of 10 m from the electric boat. All equipment and electrode connections must also be checked prior to sampling. Electrodes must be placed in the water prior to starting the equipment. Prior to sampling, the crew shall agree on the sampling method, communication signals, and the duties of each operator. Special care must be taken when fishing at night.

4.4.3 Sampling

When fishing with an electric boat, the boat moves forward slowly and in a straight line parallel to the shore or in open water. The minimum distance from the shore depends on its slope. Electrofishing in systematic transects is possible only in large, shallow areas with water depths of < 1 m. Experience has shown that the minimum fishing effort is 100 m of shoreline and the minimum catch is 100 fish older than young-of-the-year. In waters or environments with low fish density, 1000 m of bank length is considered sufficient even if the 100 fish requirement is not met. Even when fish density is high, it is desirable to design the number of catches so that the sample is representative and variability among catches is minimal.

Boat movement is provided by a slow-speed motor so that the boat moves at the speed at which the crew succeeds in collecting stunned fish. Usually, the boat moves at a speed of 0.5 to 3 km/h, depending on the number of fish, rugged shores, obstacles in the water, etc. We usually fish only once at each sampling site.

During continuous sampling, the foot switch is usually activated by an operator standing at the bow. For safety reasons, the main switch is usually turned on by the driver at the stern of the boat, who has the entire crew on board in view and can turn off the power if there is any danger. The power

can be turned on continuously or, better, every 3 – 5 m of the boat's path, with pauses of about 1 - 3 seconds. By turning it off for short periods of time, fish at the edge of the electric field are less likely to be startled and more effectively captured in the field itself. Temporarily stunned fish are collected by two operators standing side by side at the bow of the boat. The fish must be removed from the electric field as soon as possible and placed in a tank with well-oxygenated water so they can recover as quickly as possible. If fish densities are high, another crew may be on board to collect fish that escape the view of the operators standing at the bow of the boat.

During point sampling, the boat travels along the shore and at certain intervals the anode is immersed in the water in front of the boat (0.2 – 1 m deep) and at the same time an electric current is activated for 5 - 10 seconds (Kraatochvíl et al., 2014). At this point, the boat is stopped. All stunned fish are collected and placed in a marked container. Then the boat moves to the next point at a distance of at least 5 m. Because of the short distances between points, the boat is usually moved by rowing or poling. By moving the anode away from the structured substrate (e.g., dense vegetation, boulders), the fisherman can use galvanotaxis to “pull” fish from this environment that might be neglected during continuous electrofishing (e.g., bitterling, sunfish, topmouth gudgeon). The number of points sampled is noted in the log.

4.5 The efficiency of electrofishing

Electrofishing efficiency indicates how much of the community was caught during sampling. Efficiency depends on several aspects, some of which may vary by site and sampling period. Factors affecting electrofishing efficiency also include biological factors, environmental conditions, technical equipment of the electrofishing gear, and crew experience.

4.5.1 Biological factors

Biological factors are determined by fish species (different anatomical, morphological, and physiological characteristics) or size (Dolan and Miranda, 2003). Larger fish are more likely to escape from the reach of the electric field due to their greater kinetic energy. On the other hand, they also have a higher potential difference between head and tail and are more conspicu-

ous in the water than smaller fish. Both of these factors cause size selectivity. A higher pulse frequency should be set to catch smaller fish. Cyprinids are more sensitive to electricity than salmonids, for example.

Fish behaviour is another important factor affecting electrofishing success. When spawning fish are targeted, they are less shy and respond with considerable delay to an approaching electrofishing boat. Males tend to stay longer at spawning sites, so they are more likely to be caught (Šmejkal et al., 2022). Fish seeking shelter may remain wedged in shelters after stunning, so they may be underestimated in catch and electrofishing is generally less efficient at capturing bottom associated species (Hupfeld et al., 2022).

4.5.2 Environmental factors

Factors affecting the success of electrofishing include the environmental conditions under which sampling takes place. First and foremost, this includes the conductivity of the water, which is given by the coefficient of ion concentration in the water and its temperature. Ion concentration is influenced by several factors (geology, precipitation, runoff in river basins, etc.). Under Central European conditions, 150-600 $\mu\text{S}/\text{cm}$ are the most common values. Conductivity decreases with decreasing temperature because ions are less mobile and resistance increases. A temperature drop of 1°C reduces conductivity by 2.5 %. With higher resistance, the power must be increased to increase the electrical voltage and current. If conductivity is low, it makes sense to use larger electrodes (especially the anode) and, conversely, if conductivity is high, to reduce the area of the electrodes and reduce the voltage.

The bottom and the shore substrate are crucial for the propagation of the electric field. If the substrate has high conductivity (clay, organic sediments, mud), the field may weaken as the current propagates through. If the substrate has low conductivity (gravel, stones), the electric field spreads much better in the water and it is easier to catch fish. The setting of the electrical equipment should also be adjusted to the type of bottom substrate and the structures on the bottom. If there are metal objects on the bottom, such places should be avoided.

The turbidity of the water plays an important role in electrofishing. The advantage of electrofishing in turbid waters is the limited ability of fish to detect approaching fishing vessels. The disadvantage, on the other hand, is the reduced visibility of stunned fish.

4.5.3 Technical factors

Current type

Direct current or pulsed direct current with different types of waves is preferred for fish sampling. If the power of the unit is insufficient in waters with high conductivity even when pulsed current is used, the requirements for the amount of current needed can be reduced by setting the pulse frequency appropriately. At the same time, such an adjustment is gentler on the fish without reducing the efficiency of electrofishing. On the contrary, the ideally selected pulse frequency can attract fish from a greater distance. When fishing, the frequency should be set so that it is not dangerous for the fish (20-30 Hz). If the efficiency of electrofishing is too low, the pulse frequency should be gradually increased in steps of about 10 Hz.

Electrodes size and shape

Different electrode sizes and shapes affect the range and intensity of the electric field (Martinez and Kolz, 2013). On the other hand, this field must not be too strong near the anodes themselves, as this may have a negative effect on the fish caught. It is recommended to avoid energy losses. This is achieved by making the cathode area as large as possible compared to the anode area. The electric field is not homogeneous, it is strongest at the electrodes and usually has no effect at a distance of about 10 metres. Electrodes with a larger surface area have less resistance when the current passes into the water, they produce a larger and less intense electric field near the electrode, and there is no risk of injury to the fish. In waters with low conductivity, a large electrode surface is required, otherwise not enough current will be delivered to the water.

4.6 Catch processing

After sampling in a given environment/locality, the unit must be switched off, the anodes picked up from the water and the boat safely anchored at the shore. Then the fish catch should be processed as quickly as possible. Fish that are sensitive to handling (especially predators) should be processed first. Also, larger fish should be processed first because they consume more oxygen and may be more susceptible to low oxygen concentrations. Fish older than young-of-the-year are identified by species, weighed, and standard length measured. Fish up to 100 mm are measured to the nearest 1 mm, and larger fish to the nearest 5 mm. Scales may be removed to determine age or back-determination of growth, and the fish are released back into the water. All data are recorded in a protocol that also contains information about the environment (localities, water bodies) from which the samples were taken. Fish should be released near the shore at the sampling site, at a sufficient distance from other sections where fishing is still to be done. Before the next sampling, the water in the tub should be replaced with fresh water.

4.7 Data processing

Data obtained from semiquantitative catches tell us about relative abundance and biomass, species composition, size and age structure, or year class strength. The number and biomass of fish caught by electrofishing are expressed per unit effort.

Three basic measures of effort are used to interpret continuous electrofishing catches. Abundance of fish caught refers to the length of shoreline fished (number of fish / 100 m of shoreline). Catch per 100 m of shoreline can be reported separately for each environment/locality separately as well as for the entire water body. Another option is to relate the catch to the time of sampling. Most often, the catch is converted to the number of fish caught per fishing hour. In any case, it is advisable to sample for at least 10-15 minutes, depending on the number of fish caught. It is also possible to convert the catch to the effective fishing area, i.e., the length of the coast multiplied by the width of the section fished. The latter statement is not commonly used because of the difficulty in quantifying the total area sampled.

For point sampling, the number of electrofishing points should be at least 10 points if fish are caught or, if there are more points with no catch, a total of 30 points per habitat/locality. Catches are reported as the average number of fish per point and the percentage of points with catches. Shoreline length is less representative for point-based sampling compared to continuous sampling because spacing between sample points is often greater at low fish densities. A standardization of catch per area can be derived from the area of anode circumference, but this expression is not commonly used as in continuous electrofishing.

4.8 Importance of correct settings

Observation of not convulsively and jerkily swimming fish indicates incorrect adjustment of the unit. When properly adjusted, fish are usually not stunned, and when this does occur, unconsciousness lasts only a relatively short time. It takes a few minutes to a maximum of a few minutes for the fish to fully recover. In extreme cases, such as improper use of electrical equipment and excessive exposure of fish to electric current, physiological exhaustion or complete stiffness (tetanus) of the fish may occur. This can lead to irreversible damage due to muscle tension, and in extreme cases the spine can fracture (Culver and Chick, 2015). Contact with the active electrode can burn the surface of the fish body.

4.9 Work safety

Maintaining safety is very important when working with electricity in water. Working with electrical equipment can be life-threatening and requires proper training of the people involved. The sampling team should consist of at least three fishermen who have completed professional training in a three-year cycle. During the training, they have demonstrated knowledge in the use of electrical equipment and in first aid and have received a certificate of this training. Every year, the electrical equipment must be professionally inspected by an electrician and any defects found must be repaired. All fishermen in the fishing group are required to wear a life jacket, non-conductive waterproof boots and gloves. Sampling in poor visibility (fog) or other unfavourable climatic conditions (rain, storm, frost, extreme

heat, etc.) is prohibited. A fire extinguisher must be available on the boat in case of fire. Other local health and safety regulations may apply in different countries.

4.10 References

BEAUMONT W.R.C, TAYLOR A.A.L., LEE M.J., WELTON J.S., 2002: Guidelines for electric fishing best practice. R & D Technical report W2-054/TR, Environment Agency, Bristol, 188 pp.

BEDNÁŘ R., DUBSKÝ K., DVOŘÁK K., KAŠE J., NUSL P., POUPĚ J., 2013: Lov ryb elektrickým agregátem. Český rybářský svaz, Praha. 136 pp.

DOLAN C.R., MIRANDA L.E., 2003: Immobilization Thresholds of Electrofishing Relative to Fish Size. Transactions of the American Fisheries Society 132 (5), 969-976.

CULVER E.F., CHICK J.H., 2015: Shocking Results: Assessing the Rates of Fish Injury from Pulsed-DC Electrofishing. North American Journal of Fisheries Management 35 (5), 1055-1063.

CEN, 2003. European standard Water quality. Sampling of fish with electricity (EN 14 011) Brussels, Belgium, 2003, 16 pp.

HUPFELD R.N., JONES G., HANSEN K., KIM H.H., PHELPS Q.E., 2022: An assessment of gears for sampling shovelnose sturgeon in tributaries. Journal of Applied Ichthyology 38 (2), 165-169.

KRATOCHVÍL M., VAŠEK M., PETERKA J., DRAŠTÍK V., ČECH M., JŮZA T., MUŠKA M., MATĚNA J., KUBEČKA J., 2014: Towards a better understanding of small scale distribution of littoral age-0 fish in a deep-valley reservoir: day or night surveys? Hydrobiologia 728, 125-139.

KUBEČKA J., PRCHALOVÁ M., 2006: Metodika odlovu a zpracování vzorků ryb stojatých vod. Metodiky VÚV, TGM, Praha, 22 pp.

MARTINEZ P.J., KOLZ K.L., 2013: Performance of Four Boat Electrofishers with Measured Electrode Resistances for Electrofishing Boats and Rafts. North American Journal of Fisheries Management 33 (1), 32-43.

MIRANDA L.E., KRATOCHVÍL M., 2008: Boat electrofishing relative to anode arrangement. Transactions of the American Fisheries Society 137, 1358-1362.

ŠMEJKAL M., BARTOŇ D., BRABEC M., SAJDLOVÁ Z., SOUZA A.T., MORAES K.R., BLABOLIL P., VEJŘÍK L., KUBEČKA J., 2022: Behaviour affects capture probability by active sampling gear in a cyprinid fish. Fisheries Research 249, 106267.

Attachment: Example of field protocol

1. For recording the catch and sampling conditions

5 Sampling by beach seine nets

Milan Říha¹, milan.riha@hbu.cas.cz , Jan Kubečka¹, kubecka@hbu.cas.cz

¹ *Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, Na Sádkách 7, 370 05, České Budějovice, Czech Republic*

Beach seining is an active fishing method used to catch fish in littoral shallow areas. This fishing technique is one of the oldest net fishing methods and was used thousands of years before our era (Gabriel et al., 2005). This is due to the simplicity of the gear and its application. Basically, it is a net fence with floats on the top and weights on the bottom line, which can be supplemented by hauling ropes on the sides. Over time, this method has evolved into a number of other fishing techniques, such as purse seine or trawls nets (Wardle, 1993).

Today, beach seining is used in all types of waters (reservoirs, lakes, rivers, and coastal marine areas) for both commercial fishing and fish community sampling. Depending on the type and size of the target fish species or the environment in which the technique is used, there are a large number of different beach seine designs and application methods (Hahn et al., 2007). In this methodology, we focus on the use of beach seining for qualitative and quantitative sampling of littoral species in lentic waters. This means that the recommended net and sampling design has a low size and species selectivity and provides a representative picture of the littoral fish community.

Advantages of beach seine nets:

- Sampling equipment is simple and inexpensive
- A large littoral area can be sampled in a relatively short period of time
- The sampled area can be precisely defined; therefore, its extent can be accurately calculated and environmental characteristics within the area described (e.g., bottom slope and substrate, presence of submerged macrophytes, etc.
- Sampling is active and can be performed at any time of day

- The range of species and sizes that can be caught is wide, selectivity by species and size is low
- Fish are caught alive and with minimal trauma

Disadvantages of beach seining:

- The application is limited to shallow littoral areas, usually to a depth of 4-5 m
- The bottom of the sampled area must have the following properties: a shallow slope of max. 25°, even terrain, no bigger obstacles like stones, stumps, or a dense cover of submerged macrophytes, no thick layer of soft sediment
- Sampled areas may not be representative for the shoreline of the water body

5.1 Equipment

5.1.1 Beach seine net

As mentioned earlier, a beach seine is a net fence that may also be equipped with a bag (Fig. 5.1). The bag is the enlarged centre section where fish concentrate during a tow and their escape is reduced (Hahn et al., 2007). The net is wrapped around its entire circumference with a rope (called the line). The lower line (lead line) is equipped with loads, while the upper line (float line) is equipped with floats. The recommended construction of the net depends on the deployment method. The most accurate method for sampling is to use the net as a block net (block net method) and encircle a sample area. It is also possible to spread a net parallel to the shore and pull it to the shore with ropes (pull-by-rope method) if the length of the net is sufficient to reduce sampling size selectivity. A detailed description of sampling methods is provided below.

Based on our experience, we recommend the following specifications for seine nets. The length of the net should be 150 to 200 m for the block net method or at least 40 m for pull-by-rope method. The height of the net

should be 4 to 5 m. Mesh size should be 10 mm to prevent smaller fish from escaping through the meshes (10-mm meshes are small enough to retain 1+ and older fish of most fish species found in Central Europe). Smaller meshes can significantly increase drag and the capture of debris and mud. However, if the desired target fish can pass through the recommended 10 mm meshes, the mesh size should be reduced. As a load, it is recommended that a load rope weighing 200 g/m be sewn along the entire length of the bottom rope. The floats should be made of styrofoam and placed on the top line at a maximum distance of 1 m from each other. When designing block nets, we recommend that the floats be colour-coded every five and ten metres (it is advantageous to use two easily distinguishable colours for marking). Colour differentiation of the floats makes it easier to determine the length of the deployed net when it is released into the water (see Chapter 5.4).

5.1.2 Other equipment

- As a sampling boat we recommend a rowboat with a minimum load of 500 – 800 kg and a minimum length of 4 – 5 m. This boat should be equipped with oars to move around while setting the net and have an outboard motor to allow for faster transport between sampling locations.
- Depth measure gauge (or small commercial echo sounder)
- A GPS device to record the exact location of sampling sites and swept area dimensions
- Equipment to measure and weigh fish, logs recording the catch, and other accessories necessary to collect the desired fish samples
- Equipment to repair the net if it breaks; a thicker thread and larger needle will suffice
- Sampling should be done by at least 4 people

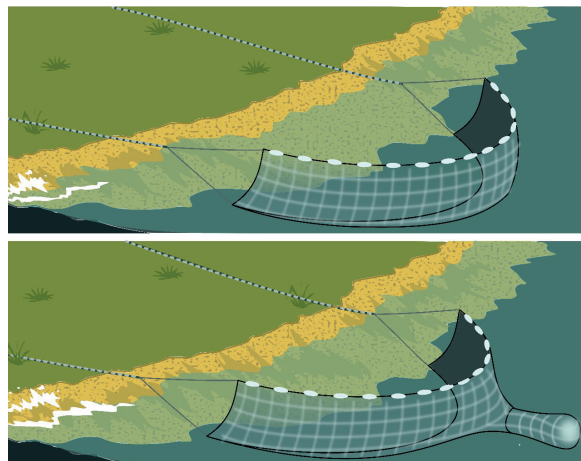


Figure 5.1. Beach seine nets, simple net fence (upper figure) or a net with a bag in the middle (lower figure).

5.2 Sampling

5.2.1 Selectivity of beach seine nets

The selectivity of beach seining depends mainly on the nature of the bottom at the sampled sites. At sites with a suitable bottom (i.e., gradual slope of the bottom, unstructured bottom substrate, and no obstacles or bumps), efficiency is nearly 100 % if beach seining is done correctly. However, efficiency decreases when ideal conditions are not maintained (Pierce et al., 1990). Benthic fish species are underestimated when the bottom substrate consists of larger rocks or smaller terrain irregularities (Lyons, 1986; Parsley et al., 1989). All species are underestimated when the net is caught behind submerged obstacles and subsequently released or rolled up because of the heavy presence of macrophytes (Pierce et al., 1990). When flow is present (near tributaries), higher flow velocity can also reduce net efficiency (Neufeld et al., 2016). In addition, the length of the net used has a significant effect on sampling efficiency. Size selectivity is inversely related to net length, as larger fish can escape when shorter nets are used (Říha et al., 2008). Therefore, we recommend changing sampling sites and increasing net length when large numbers of escaping fish are observed. In addition, we recommend discarding the results of hauls where major problems occurred, such as net snagging or bottom rope rolling. We also recommend the use of larger nets when sampling by the pull-by-rope method (net lengths greater than 40 m significantly reduce size selectivity; Říha et al., 2008).

5.2.2 Sampling period

Sampling can be performed at any time of a day, but numerous studies have shown that night-time sampling is better for the quantitative assessment of fish populations (Midwood et al., 2016; Říha et al., 2015; Wegscheider et al., 2020). At night, fish are less responsive to sampling gear (Wardle, 1993; Říha et al., 2008; Rakowitz et al., 2012), and the fine-scale distribution of fish is more uniform and less patchy as schools and aggregations of fish usually disperse at night (Říha et al., 2017), and fish densities and species abundance are generally higher due to night inshore migration (Kubečka, 1993; Říha et al., 2011, 2015). Night sampling should be conducted about one hour after

sunset and 1.5 hours before sunrise to avoid migration peaks during twilight (Prchalová et al., 2010). Sampling should not be conducted on cloudless full moon nights with strong moonlight and on nights with atmospheric disturbances (heavy rains, storms). The best period for an unbiased assessment of fish stocks in Central Europe is mid-July to late September. This period is outside the spawning season for most species, which could lead to aggregations that affect sampling results (unless specific questions are asked).

5.2.3 Selection of suitable sites and sampling effort

In general, the rules for locality-based sampling strategies (Chapter 1.2) apply to the selection of sampling sites. Suitable sites for seining often represent only a small portion of littoral areas, so selecting a sampling area is not straightforward. However, because the success of sampling is highly dependent on the selection of a suitable littoral site, we must pay close attention to it.

The sampling area should have the following characteristics: the gradual slope of the bottom (maximum 25°), no obstacles (stones larger than 20 cm, branches, tree stumps, etc.), no large irregularities in the terrain, and not too many submerged macrophytes (more than 3 kilograms per m²; Pierce et al., 1990). We recommend that unknown areas be surveyed prior to sampling. These areas can be swept with a simple thick rope (at least 6 hours before sampling), and if the rope does not become snagged, a seine sampling can be performed. An alternative is visual inspection of the bottom by divers.

We recommend that two to three samples be taken at each locality identified for gillnet use (Chapter 1.2). It allows to estimate the variability of sampling at each locality and increase the representativeness of the results obtained. We recommend that these hauls be conducted at different locations within localities. However, if two suitable locations for netting are not available at a given area, all hauls can be conducted on the adjacent beach.

5.3 Realization of a haul

5.3.1 Net preparation

Sampling begins with a net preparation. The net is folded at the front of the boat so that the top line is folded on one side of the boat and the bottom line is folded on the opposite side (Fig. 5.2). Crossing of these two lines should be avoided, as this would cause difficulties when deploying the net. Also, when the net is loaded, any objects caught in the net (twigs, wires, fish, etc.) should be removed as they can pin the net layers together and cause undesirable fish avoidance and distortion results.

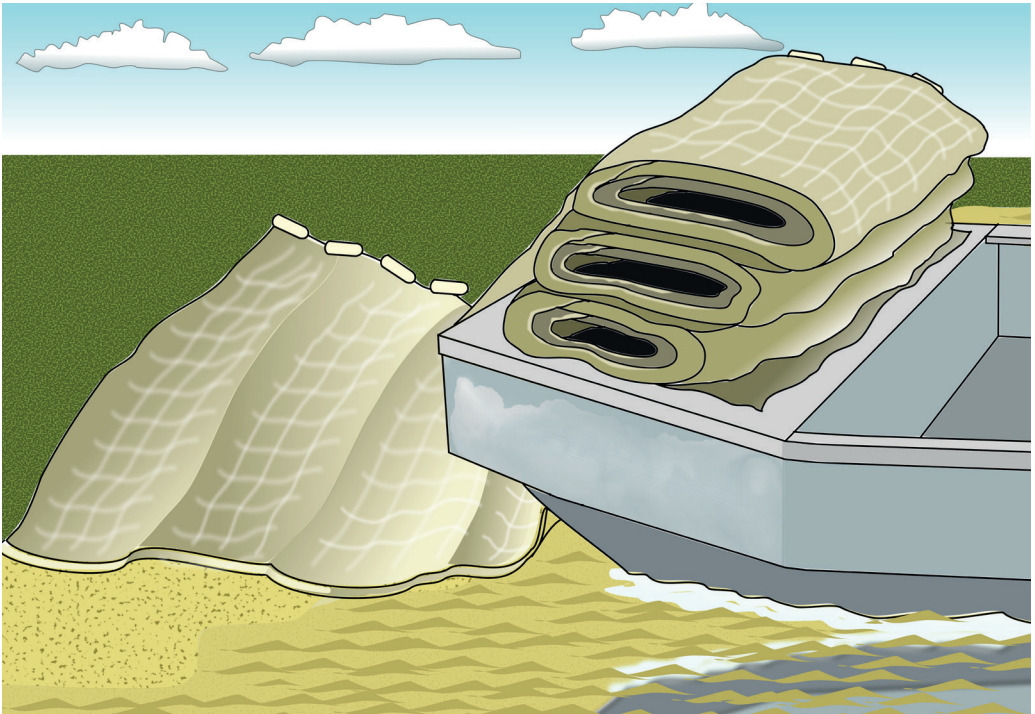


Figure 5.2. Beach seine block net ready for use. One end of the net is on the shore, the rest of the net is folded at the front of the boat so that the top line is on one side of the boat and the bottom line is folded on the opposite side.

5.3.2 Net deployment

5.3.2.1 *Block net*

The net is deployed so that the entire swept area is enclosed by the net (see Fig. 5.3). When deploying the net, the boat crew usually consists of three

workers, one of whom rows, steers the boat, and checks the depth with the depth sounder, while two workers deploy the net. A fourth worker remains ashore. At the beginning of the deployment, the boat is oriented so that the stern is perpendicular to the shore. The beginning of the net is deployed on shore, and the worker remaining on shore holds it to prevent it from being pulled into the water as the net is deployed. The boat moves (at a speed of about 1 - 2 km*h⁻¹) perpendicular to the shoreline and the workers begin to release the net into the water. With this, the boat begins to move around the side of the swept area. The length of this side should be at least 25 – 30 m. However, this length should be corrected according to the slope of the bottom of the swept area, as the net can be deployed to a maximum depth equal to the height of the net (we recommend a depth half a meter less than the net height, as the net tends to pinch when pulled). If the bottom depth is greater than the height of the net at a distance of less than 10 meters from the shore, it is recommended that you use a higher net or find a location with a lower bottom slope. After the boat reaches the lateral end, it turns 90 degrees toward the shore, and the net is deployed in this direction perpendicular to the shore. If the depth allows, we try to keep the rectangular or square shape of the enclosed area to make it easier to calculate the dimensions of the swept area (Fig. 5.3).

5.3.2.2 *Pull-by-rope*

In this method, the end of the side rope (the side at the top of the folded net) is held by a worker on the shore, and the boat moves into the open water, maintaining an angle of about 45-60° to the shoreline (Fig. 5.3). When the end of the rope is reached (or the maximum bottom depth for deployment,

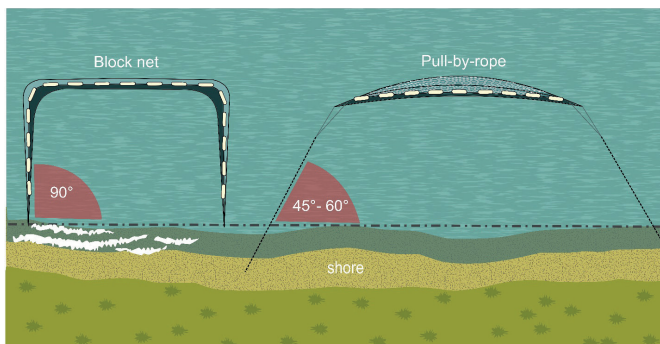


Figure 5.3. Schema of the net deployment, shown are the two presented types of net deployment - block net and pull-by-rope methods.

see above), the boat is turned parallel to the shoreline and the crew begins deploying the net. It is recommended to maintain a similar distance from the shore when deploying the net, but only if the bottom depth is no greater than

the net height. When the net is fully deployed, the boat turns towards the shore, keeping the same angle as when deploying the first rope, and deploys the other rope towards the shore (Fig. 5.3).

5.4 Pulling net to the shore

Block net

After the net is deployed, the workers begin to pull the net on both sides to the shore. The pulling is done in such a way that one worker on each side pulls the upper line and the other worker pulls the lower line (it is best to have two workers on each side pulling the bottom line because pulling of a bottom line, in particular, is physically demanding). The bottom line should be pulled about 0.5 to 1 m in front of the top line when pulling. However, the distance between the lines should not be too great so that the top line does not sag. It is important that the bottom line is in contact with the bottom at all times and that fish do not pass under it (e.g., by the worker bending down and pulling the bottom line as close to the bottom as possible with his hand or by stepping on the bottom line with his foot while pulling, thus keeping it as close to the bottom as possible). The top line should be held as high as possible while pulling it out and tightened by shaking and kinking it to keep the floats moving and prevent the fish from jumping away. As the net is pulled out, workers at both ends slowly move toward each other until the entire net is pulled out of the water. The catch is then shaken into the part of the net that contains the most fish and collected in the appropriate boxes for further processing.

Pull-by-rope method

The ropes are pulled symmetrically toward the shore on both sides, maintaining a 45-60 degree angle to the shoreline. Both ends of the net should reach the shoreline at the same time. If the team on one side of the net is faster, they should wait until the slower team on the other side has brought their end of the net ashore. When the net reaches the shoreline at both ends, the procedure is the same as for pulling the block net (see above).

5.5 Measurement and calculation of swept area extension and catch per area unit parameters

To obtain a reliable estimate of fish CPU parameters, the swept area should be measured accurately (Fig. 5.4). There are several options that can be considered for this procedure:

5.5.1 Block net

1. Using the portable device GPS during deployment and recording the boat trajectory (after deployment, a worker can also record using GPS the shape and dimensions of the shoreline in the swept area). This is the most accurate method of estimating the swept area dimensions.
2. Measure the side length of the swept area using a colour code on the net. Marked floats are counted and recorded on each side of the sweep area during the deployment and then used to calculate the side lengths. The extent of the shoreline of the swept area (if the regular shape of the swept area is not maintained) can be measured with a tape measure or other rangefinders.
3. Measure the side length of the swept area with a tape measure or other measuring device. These measuring devices can be used after the net is spread to measure and record each side length. This method is relatively time consuming compared to the previous two.

5.5.2 Pull-by-rope

The procedure is much simpler because the length of the net is constant and only two distances need to be measured: the distance between the shoreline and the net (using GPS, another measuring device, or the length of the deployed rope on each side) and the length of the swept shoreline (can be measured using GPS or a measuring device after a haul is completed).

All dimensions, as well as the approximate shape of the sampled area, should be carefully recorded (see Fig. 5.4). Ideally, the sampled area should

be in the shape of a rectangle or square if a block net is used, or in the shape of a trapezoid at pull-by-rope approach, but it is common for the area to be more in the shape of a trapezoid if the depth isobath is followed. Therefore, different formulas must be used to calculate the swept area depending on its shape. The formulas for the calculation are as follows:

Rectangle:

$$sa = \frac{a \cdot b}{10\ 000}$$

Square:

$$sa = \frac{a^2}{10\ 000}$$

Trapezoid:

$$sa = \frac{a+L}{20\ 000} * b$$

Where "sa" is the swept area (in hectares), "a" is the length of the shoreline seined, "b" is the distance of the net from the shore and "L" is the net length (all lengths are in meters; see Fig. 5.4).

Catch is based on area, i.e., catch parameters are divided by a swept area extent, and the resulting values yield abundance/biomass per hectare (the sampling unit can be changed as desired). An example of a seine catch protocol is provided below.

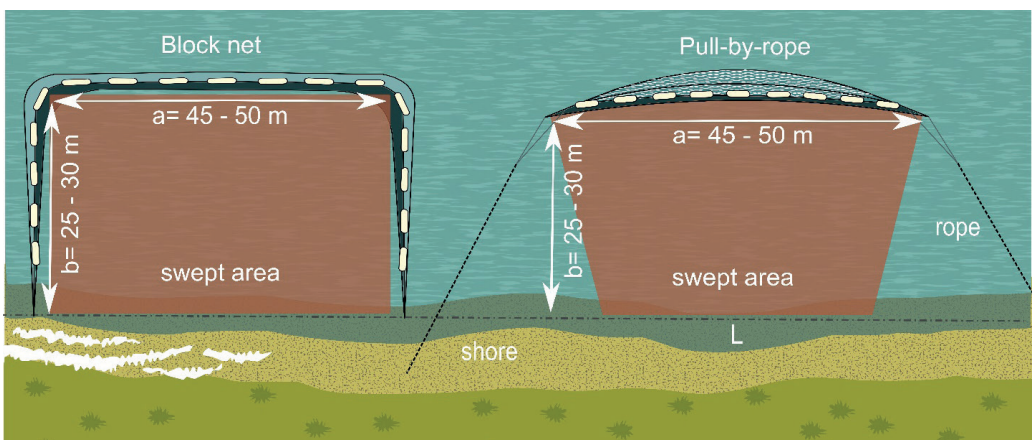


Figure 5.4. Calculation schema of the swept area by block net method (usually rectangular or square) and pull-by-rope method (usually in the shape of the isosceles trapezoid).

5.6 Evaluation of results

Beach seine sampling provides information on the abundance, biomass, and size composition of individual species present in the nearshore area of each site at the time of capture. When assessing the fish community of an entire water body, we must be aware that communities in open water and structured habitats have different species and size compositions (Říha et al., 2015). The assessment must consider the proportion of the coastline that

has a similar character to the area covered by the beach seines, and thus the representativeness of these data. This aspect should also be considered during sampling planning. If the shoreline suitable for seine sampling is less than 30%, then seine sampling should be combined with electrofishing or using gillnets in locations inaccessible to seine sampling.

5.7 References

GABRIEL O., LANGE K., DAHM E., WENDT T., 2005: Fish catching methods of the world. 4th edition. Blackwell Publishing, Oxford. 523 pp.

HAHN P.K.J., BAILEY R.E., RITCHIE A., 2007: Beach seining. In: JOHNSON D.H., SHRIER B.M., O`NEAL J.S., KNUTZEN J.A., AUGEROT X., O`NEAL T.A., PEARSONS T.N., (eds.) Salmonid field protocols handbook: Techniques for assessing status and trend of salmon and trout. American Fisheries Society, Bethesda 267–323.

KUBEČKA J., 1993: Night inshore migration and capture of adult fish by shore seining. *Aquaculture and Fisheries Management* 24, 685–689.

LYONS J., 1986: Capture efficiency of a beach seine net for seven freshwater fishes in a north-temperate lake. *North American Journal of Fisheries Management* 6, 288–289.

MIDWOOD J.D., CHAPMAN J.M., CVETKOVIC M., KING G.D., WARD T.D., SUSKI C.D., COOKE, S.J., 2016: Diel variability in fish assemblages in coastal wetlands and tributaries of the St. Lawrence River: a cautionary tale for fisheries monitoring. *Aquatic Sciences* 78.

NEUFELD K.R., POESCH M.S., WATKINSON D.A., 2016: The effect of hydrologic alteration on capture efficiency of freshwater fishes in a highly modified prairie stream. *River Research and Applications* 32 (5), 975-983.

PARSLEY M.J., PALMER D.E., BURKHARDT R.W., 1989: Variation in capture efficiency of a beach seine for small fishes. *North American Journal of Fisheries Management* 9, 239-244.

PIERCE C.L., RASMUSSEN J.B., LEGGETT W.C., 1990: Sampling littoral fish with a seine - corrections for variable capture efficiency. *Canadian Journal of Fisheries and Aquatic Sciences* 47, 1004-1010.

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. *Fisheries Research* 102, 291–296.

RAKOWITZ G., TUŠER M., ŘÍHA M., JŮZA T., BALK H., KUBEČKA J., 2012: Use of high-frequency imaging sonar (DIDSON) to observe fish behaviour towards a surface trawl. *Fisheries Research* 123–124, 37–48.

ŘÍHA M., KUBEČKA J., MRKVIČKA T., PRCHALOVÁ M., ČECH M., DRAŠTÍK V., FROUZOVÁ J., HLADÍK M., HOHAUSOVÁ E., JAROLÍM O., JŮZA T., KRATOCHVÍL M., PETERKA J., TUŠER M., VAŠEK M., 2008: Dependence of beach seine net efficiency on net length and diel period. *Aquatic Living Resources* 21, 411–418.

ŘÍHA M., KUBEČKA J., PRCHALOVÁ M., MRKVIČKA T., ČECH M., DRAŠTÍK V., FROUZOVÁ J., HOHAUSOVÁ E., JŮZA T., KRATOCHVÍL M., PETERKA J., TUŠER M., VAŠEK M., 2011: The influence of diel period on fish assemblage in the unstructured littoral of reservoirs. *Fisheries Management and Ecology* 18, 339–347.

ŘÍHA M., RICARD D., VAŠEK M., PRCHALOVÁ M., MRKVIČKA T., JŮZA T., ČECH M., DRAŠTÍK V., MUŠKA M., KRATOCHVÍL M., PETERKA J., TUŠER M., SEĎA J., BLABOLIL P., BLÁHA M., WANZENBÖCK J., KUBEČKA J., 2015: Patterns in diel habitat use of fish covering the littoral and pelagic zones in a reservoir. *Hydrobiologia* 747, 111–131.

ŘÍHA M., WALSH M.G., CONNERTON M.J., HOLDEN J., WEIDEL B.C., SULLIVAN P.J., HOLDA T.J., RUDSTAM L.G., 2017: Vertical distribution of alewife in the Lake Ontario offshore: Implications for resource use. *Journal of Great Lakes Research* 43, 823–837.

WARDLE C.S., 1993: Fish behaviour and fishing gear. In: PITCHER T.J., (Ed.) *Behaviour of teleost fishes*, 2nd edition, London, Chapman & Hall, pp. 463–495.

WEGSCHEIDER B., LINNANSAARI T., WALL C.C., GAUTREAU M.D., MONK W.A., DOLSON-EDGE R., SAMWAYS K.M., CURRY R.A., 2020: Diel patterns in spatial distribution of fish assemblages in lentic and lotic habitat in a regulated river. *River Research and Applications* 36, 1014–1023.

Attachment: Recommended field protocols

1. For recording seining catch

6 Hook-lines used for sampling of European catfish (*Silurus glanis*)

Lukáš Vejřík¹, lukas.vejrik@hbu.cas.cz, Ivana Vejříková¹, ivana.vejrikova@hbu.cas.cz

¹ *Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, Na Sádkách 7, 370 05, České Budějovice, Czech Republic*

Hook-lines originate in the marine environment, where they are widely used to catch large predatory fish and they currently appear to be the most effective means of monitoring European catfish, the largest freshwater predatory fish in Europe (Vejřík et al., 2019a). This important apex predator can live in many habitats and until recently there was no robust method for its monitoring. The method is based on recreational and commercial angling and was modified for this reason. The method can be used in any standing or gently flowing water greater than 2 m deep. The hook-lines can be installed both in shore areas and in open water. The hook-line installation is very flexible, both in its length and in the number of applied snoods. This text deals with the use of hook-lines, focusing on the efficiency and selectivity of the method.

The advantages of using hook-lines:

- The equipment is simple and inexpensive
- The method is most efficient on the European catfish
- Simple usage and handling of the gear
- Low mortality (< 5 %) relates to this method
- The method can be applied in a wide range of environments and can be flexibly adapted to the needs of specific aquatic bodies
- Can be combined with the capture-recapture method to estimate the population size
- Reduction of a catfish population to harmless levels may be efficiently achieved (in localities where European catfish is non-native, with invasive behaviour or overpopulated)

The disadvantages of using hook-lines:

- It is necessary to have fish baits (ideally alive, unless prohibited by the law of the country)
- The equipment is dependent on the feeding activity of the catfish; during periods when catfish do not eat (winter) or eat scarcely (light part of the day), the efficiency of the method is low
- The method is intended for catching adult catfish in size > 70 cm (total length, TL)

6.1 Scheme of hook-lines and the equipment

6.1.1 Basic equipment

Figure 6.1 shows a diagram of hook-lines. The hook-lines used to catch adult catfish may vary in length. However, for standardisation purposes, two basic lengths are used: 60 m and 235 m. The rope should have a diameter of 5 mm. The shorter version (60 m) and the longer version (235 m) of hook-line is always equipped with 10 and 15 snoods, respectively. Three main buoys are located at the ends and in the middle of the line. Anchoring ropes (\varnothing 10 mm) from 3.5 to X m long (depending on the depth) with weights (32 kg each) are attached to the buoys, which fix the main line in the right place. Auxiliary buoys (ideally five empty bottles of 1.5 to 2 L) are placed every five metres (for a line 60 m long) or 15 metres (for a line 235 m long) between the main buoys. These auxiliary buoys mark the place where the snoods are located. The hanging snoods should be 2.5 m long and consist of two parts: i) a 2 m long fishing line with a maximum load of 50 kg and ii) a more durable 0.5 m long fishing-line with a maximum load of 100 kg. A swivel is placed between these two parts to prevent twisting, and a 150 g fishing lead hangs on the snood to keep it at the appropriate depth. At the end of the snood, there is a multi-hooks system with one single hook and one treble (see Figure 6.2 for basic components). The fish bait is placed on the single hook, the length of the bait should be between 180 and 300 mm, TL. The fish bait used is cyprinids or perch (both favourite foods of catfish), which are native to the area. When catfish try to tear off the bait, they are caught by the tre-

ble hooks hanging freely under the baited hook (Vejřík et al., 2017a, 2017b, 2019a). The appropriate size of treble hooks is usually 2-2 / 0, depending on the size of the bait and the average size of the target catfish. Sizes 1/0 for single hooks and 1 for treble hooks were found to be optimal in most cases.

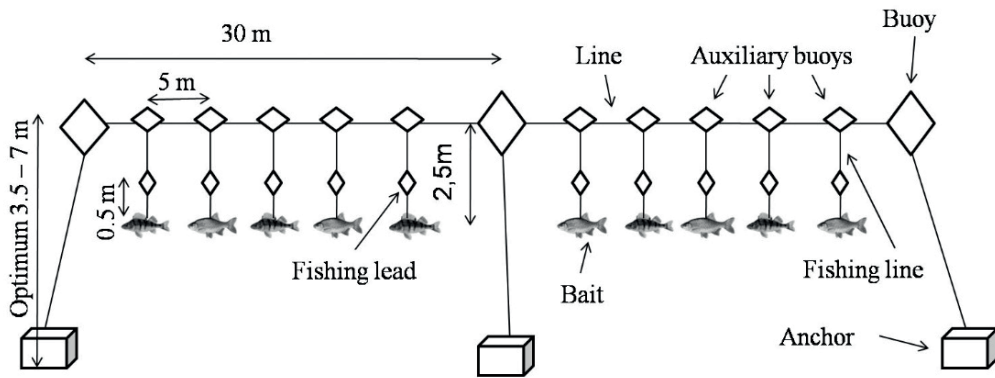


Figure 6.1. Scheme of hook-lines (the shorter version of 60 m), the fishing method used for catfish sampling according to Vejřík et al. (2017a; 2017b). The illustration made by Z. Sajdlová.

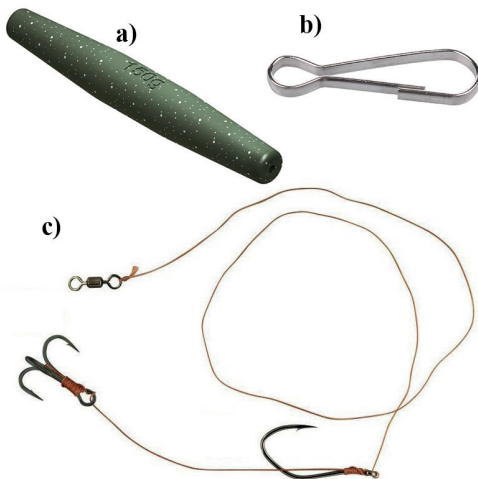


Figure 6.2. The main parts of the snood a) a 150 g fishing lead, b) carabine that can be used to attach the snood to the main line c) a multi-hooks system with one single hook (for fish bait) and one treble-hook (for hooking of the catfish).

6.1.2 Additional equipment

- Sampling boat (a punt) with a minimum load capacity of 800 kg and a length of 5 m equipped with oars for easy control of the boat when close to the hook-line
- Outboard engine for faster transport between hook-lines on the water body
- Depth sounder (a small commercially available lower-class echo-sounder)

- GPS device for recording the exact position of the hook-line
- Tank for fish bait with aeration or aeration equipment
- Tank for captured catfish with aeration or aeration equipment (it is good to keep fish bait and captured catfish separately)
- Equipment for catching and subsequent work with catfish: leather gloves, landing net, soft pad, rubber gloves
- Meter for measuring of fish size, scales (weighing up to 100 kg and more) for weighing the catch, carrier-bag allowing you to weigh the large fish
- Catch recording protocols
- Pit tags that are put under the skin, needle, and pit-tag reader
- Disinfection to treat all minor injuries of the fish and the body part where the pit-tag was injected
- Fish anaesthesia (for example, clove oil commonly available in pharmacies, 0.033 ml of clove oil per 1 L of water, depending on the water temperature, more in cold water, less in warm water).
- Tank for anaesthesia
- Other equipment for taking the required samples (tissue for stable isotopes analyses or stomach content for trophic analyses) such as scissors, Eppendorf tubes, Ziplock bags, rubber gloves for gaining of the stomach contents, wide-mouth bottles (1 L) for placing the stomach contents, technical alcohol for fixing the stomach contents.
- Catching should be done by at least 4 workers

6.2 Sampling

6.2.1 Selective sampling of catfish using hook-lines

The selectivity of the method is ensured mainly using larger baits in the size of more than 20 cm TL, ideally 25-35 cm TL. At the same time, it is advisable to place the baits at least 20 m or more from the shoreline. When these conditions are met, the remaining predatory fish species are negatively select-

ed and generally do not exceed 10 % of the total catch. The most common bycatch, apart from European catfish, is large Northern pike (*Esox lucius*). When using hook-lines in places with large pike populations that exceed a size of 85 cm TL, their share of the catch can be up to 20 %. However, such locations are extremely rare, and the proportion of predatory fish other than European catfish is usually much lower. Other species occasionally caught include pikeperch (*Sander lucioperca*), asp (*Leuciscus aspius*), and Eurasian perch (*Perca fluviatilis*) larger than 40 cm TL. However, all these species are very rarely caught on hook-lines and generally do not account for more than 5 % of the catch.

6.2.2 Sampling time

It is advisable to keep hook-lines throughout the day (24 hours) and check them regularly three times a day: at (or after) sunset, in the morning after sunrise, and once during the day. At each check, it is important to check the condition of the snoods, untangle them, and replace any missing bait. Catfish are predominantly nocturnal, meaning that about 75 % of fish are caught at sunset, sunrise, or during the night. The proportion of daytime and nighttime catches varies greatly by locality. In some places, night catches account for more than 90 %, while in other places they account for only about 60 %. Therefore, it is advisable to set hook-lines during the day as well (Vejřík et al., 2019b). Daytime The diurnal activity is not dependent on turbidity. In addition, the time of year has a significant effect on catfish catchability (Vejřík et al., 2019). As described above, the efficiency of the method is low in winter when catfish are not foraging. In our study, the most efficient period was June-July (water temperature 19.1–20.2 °C; Vejřík et al., 2019b).

6.2.3 Selection of suitable location, sampling effort and time schedule

An important factor affecting the number of catches per day is the location of the hook-line. In our experience, the most efficient area seems to be a place with a milder slope, where the shallow littoral extends far into the water body. In addition, areas with many underwater obstacles that provide shelter for catfish and the mouths of side bays are preferred habitats.

In contrast, the gradient from the tributary to the dam does not seem to have any effect (Vejřík et al., 2021). However, if we want to have comparable results with other studied sites, we should distribute the hook-lines evenly throughout the water body. Hook-lines should always be further than 20 m from the shore. The optimal number of hook-lines seems to be three lines per water body. It is advisable to move them to a new location after 48 hours. Transport should be done during daylight hours. During the four-day field-work, a total of 6 different sites (three lines and two locations of each line) per water body should be evenly sampled. In order to obtain representative results, it is useful to evenly sample the entire area of the waterbody, as catfish may hunt throughout the epipelagic zone. The only limitation where installation is not recommended is very steep banks with slopes greater than 30°. There is a risk that the anchoring weights will slip. This schedule is optimal for water bodies with an area of 50 to 400 ha. For larger waters, the effort should be increased proportionally.

6.2.4 Assembly of the hook-line, its servicing and coping with the catch

6.2.4.1 *Preparation of hook-line*

The hook-line is installed from the boat. Before the installation, the main line must be wound on a suitable spool on the boat. The snoods should be wound side by side on a wooden board. The main buoys should be fitted with a large carabine. The auxiliary buoys (empty plastic bottles), fitted with carabines should be loaded into a plastic container. The anchor weights should be prepared. The mooring lines should have loops at the ends so that they can be attached with the weight on one side and the buoy on the other. It is also necessary to have a tank of water on the boat, in which to put the necessary fishing bait.

6.2.4.2 *Assembly of the hook-line in the field*

Based on the inspection of the water body (using a bathymetric chart, depth sounder, and checking the surrounding terrain), a suitable location should be selected for attaching the hook-line. Then the hook-line is installed from the boat with the help of the oar or, in strong winds, with the boat engine.

First, the anchor weight is lowered into the water on the mooring line. The line must always be at least 10 % longer than the water depth at the site. The main buoy is attached to the end of the anchor line using a large carabiner. The main line, which is wound on a spool, is then attached to this main buoy. From that moment on, one person must reverse the boat, the second person unwinds the main line from the spool, and the third person snaps the auxiliary buoys (plastic bottles) to the loops of the main line using carabiners. The fourth person does all the servicing on the boat, handing all the necessary equipment and making sure the operation goes smoothly. In the middle of the main line, another anchor weight is placed with a mooring line and a buoy. At this point it is also possible to change the direction of the hook-line if the profile of the site requires it. The hook-line can even form a right angle (a more acute angle is not recommended). However, it is ideal to keep the hook-line as straight as possible to cover the maximum length of the water body. The straighter the line is, the more stable it is. At the end, the main line is again provided with the buoy, the mooring line and the anchor weight. In the end, the anchor is dropped into the water when the entire system is sufficiently tightened.

6.2.4.3 Mounting of the snoods

One person unwinds the prepared snoods from the wooden board and hands them to the second person. The second person must attach the fish bait to the snood as follows. The single hook is inserted into the dorsal part of the fish and then a safety rubber stop of 0.5 x 0.5 cm is placed to prevent the bait from slipping into the water. The third person hangs the snood with the fish bait on the loop of the main line with the help of a carabiner. This loop is already equipped with the auxiliary buoy, the plastic bottle (see previous paragraph). The fourth person ensures the movement of the boat along the hook-line. In case of good wind conditions, it is possible to pull on the line to get to the next auxiliary buoy and set the next snood. In windy weather, it is necessary to approach the auxiliary buoy with the boat separately with oars. After all snoods with fish baits are attached, the entire system should be retightened if necessary. This can be done at the end (or the beginning of the hook-line), the anchor weight must be pulled into the boat and the entire system is stretched by reversing the boat.

6.2.4.4 **Checking of the snoods and taking out of the caught catfish**

The snoods are checked at least 3 times a day, see chapter 6.2.2. Checking is done in a similar way as attaching the snoods, see chapter 6.2.4.3, i.e., by pulling out the snoods one by one and moving the boat from the beginning to the end of the hook-line. If the snood is tangled, it must be released immediately, or the snood must be replaced with a new one. It is always necessary to have at least two (but more are recommended) extra snoods on the wooden board.

When the catfish is found on the snood (usually it is noticed just by moving the auxiliary buoy), it is necessary to pull the line close to the boat and then use a large landing net and gently put the catfish there. The line can break on large specimens, so be careful here. If the catfish pulls strongly on the line, it is better to let it go for a while and wait until the catfish calms down and the strong pull lowers. When the catfish calms down, try to take it out of the water again. After the catfish is removed from the water, place it on a damp rubber mat that must be wet to protect the skin. This mat also serves as a weighing bag.

Before biological examination, each catfish must be anaesthetized by placing it in a tub of clove oil. The hook in the catfish's mouth is carefully removed from the mouth using forceps or pliers. Each catfish is then measured, weighed, and, if necessary, sexed based on the shape of the genital papilla. The individual can be uniquely coded with a pit tag (in the case of a capture-recapture method, Fig. 6.3). The pit tag is inserted into the dorsal muscle (Fig. 6.5) using a special needle (Fig. 6.4). The Agrident APR 350/380 reader is then placed near the back of the catfish (Fig. 6.6) and the unique code is stored in the database. If the captured catfish is already pit-tagged, its code is stored in the database and no further tagging is required. In addition, stomach content analysis can be performed to obtain information about the catfish's diet; however, it is recommended for animals larger than 80 cm TL. Stomach contents can be extracted by passing the operator's hand through the mouth and oesophagus of the resting catfish. The mouth and gullet of the catfish are wide, and it is safe for both the operator and the fish to pass the hand through (Fig. 6.7). After all data are collected, the catfish is placed in a tank with fresh water and aeration system until it wakes up and fully recovers. The recovered catfish is gently returned to the water body in the location where it was captured (Vejřík et al., 2021).

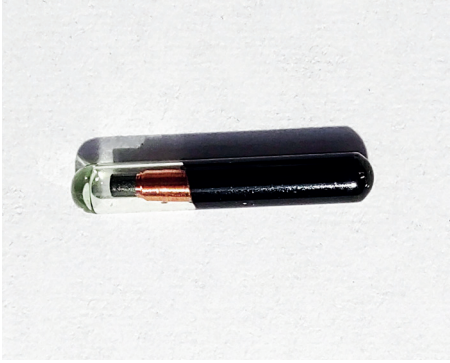


Figure 6.3. Pit-tag with a unique code.

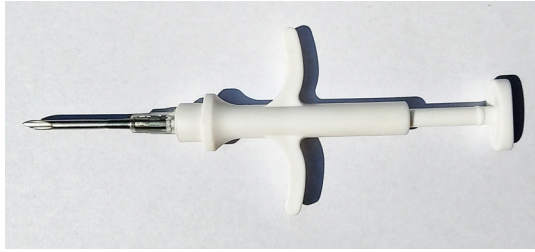


Figure 6.4. Special needle used to insert the pit-tag into the muscle.



Figure 6.5. Inserting of the pit-tag in the dorsal muscle of the catfish.



Figure 6.6. Agrident APR 350/380 reader.



Figure 6.7. Obtaining of the catfish diet from the stomach of anesthetized catfish.

6.3 Evaluation of the results

The data from the hook-lines provide information on the size range of the catfish, the average weight, and the composition of the catfish diet at each location. If we use the capture-recapture method and release tagged individuals back into the water, we can get a relatively good estimate of the size of the catfish population at the site. The efficiency of the method is high even if the number of catfish in the water body is relatively small. So, the chances of recaptures are quite high. After only four fishing trips, we can get a relatively accurate picture of the size of the catfish population in the water body. However, as the number of trips increases, the accuracy of the catfish stock estimate also improves.

Determining the size of the catfish population by the capture-recapture method is done according to Schnabel (1938). This method is based on the ratio of the number of recaptured fish to the number of newly captured untagged fish.

Population size estimate by Schnabel method:

$$N = \frac{\sum (C_t * M_t)}{\sum R_t}$$

N = Total population size

C_t = Total number of individuals captured in sample t

R_t = Number of captured tagged individuals in sample t

M_t = Number of individuals that were already tagged in the population before the sample t

In the case of limited fishing effort at a new site, we can roughly estimate catfish abundance based on catch efficiency. We need to use our experience from other localities with an already known catfish population size. In general, catch efficiency per unit effort increases as catfish population size increases. However, this method of estimating catfish population size is only a stopgap measure because the possibility of error due to various factors such as weather, time of year, etc.

Overall, the size of catfish populations at sites that have been inhabited by catfish for many years is relatively stable over time and does not show

significant fluctuations. The main reason for this is that catfish is a long-lived fish that is apparently able to control its population through cannibalism (Vejřík et al., 2019b). In a stable population, the differences in population sizes between sites are relatively small. They mainly reflect the trophic conditions of the locality and thus the carrying capacity of the locality. The size of the catfish population (estimate based on adult individuals) in the reservoirs and lakes of the Czech Republic, where recreational fishing is not allowed, ranges from 1 to 2.2 individuals per hectare, 6.2-24.5 kg / ha (Vejřík et al., 2015, 2021; Vejřík, 2019, 2020). In our study, the mean efficiency was 2.8 and 5.4 individuals per 10 baits per day in two mining lakes in June/July, while it was 1.8 individuals per 10 baits per day in a reservoir in April. For detailed results, see Vejřík et al. (2019c).

6.4 Reference

SCHNABEL Z.E., 1938: To estimation of the total fish population of a lake. American Mathematical Monthly 45:348–352. 2005 In: AMSTRUP S.C., McDONALD T.L., MANLY J.F. (Eds.), Handbook of Capture-Recapture Analysis, pp. 313 Princeton.

VEJŘÍK L., MATĚJČKOVÁ I., KUBEČKA J., PETERKA J., 2015: Simulace vlivu rekreačního rybolovu na populaci sumce velkého (*Silurus glanis*) na jezeře Most a návrh nezbytných opatření pro zajištění stabilního stavu populace dravých ryb. Souhrnná zpráva Biologické centrum AV ČR, v. v. i. Hydrobiologický ústav. 13 pp. [in Czech].

VEJŘÍK L., VEJŘÍKOVÁ I., BALBOLIL P., ELORANTA A.P., KOČVARA L., PETERKA J., SAJDLOVÁ Z., CHUNG S.H.T., ŠMEJKAL M., KILJUNEN M., ČECH M., 2017a: European catfish (*Silurus glanis*) as a freshwater apex predator drives ecosystem via its diet adaptability. Scientific Reports 7, 15970. DOI:10.1038/s41598-017-16169-9.

VEJŘÍK L., VEJŘÍKOVÁ I., KOČVARA L., SAJDLOVÁ Z., CHUNG S.H.T., ŠMEJKAL M., PETERKA J., ČECH M., 2017 b: Thirty-year-old paradigm about unpalatable perch egg strands disclaimed by the freshwater top-predator, the European catfish (*Silurus glanis*). PLoS ONE 12, e0169000.

VEJŘÍK L., VEJŘÍKOVÁ I., PETERKA J., ČECH M., 2019a: Methods for capturing catfish and potential regulation of catfish population. In: JENKINS O.P. (Ed.), Advances in Animal Science and Zoology 13, 135–142. Nova Science Publishers, Inc., NY, USA. 191 pp.

VEJŘÍK L., VEJŘÍKOVÁ I., KOČVARA L., BLABOLIL P., PETERKA J., SAJDLOVÁ Z., JŮZA J., ŠMEJKAL M., BARTOŇ D., KUBEČKA J., ČECH M., 2019 b: The pros and cons of the invasive freshwater apex predator, European catfish *Silurus glanis*, and powerful angling technique for its population control. *Journal of Environmental Management* 241, 374–382.

VEJŘÍK L., 2019c: Průzkum stavu populace a potravy sumce velkého v nádrži Římov v roce 2018. Závěrečná zpráva. Biologické centrum AV ČR, v. v. i. Hydrobiologický ústav. 10 pp. [in Czech].

VEJŘÍK L., 2020: Průzkum stavu populace sumce velkého v nádrži Žlutice v roce 2019. Závěrečná zpráva. Biologické centrum AV ČR, v. v. i. Hydrobiologický ústav. 12 pp. [in Czech]

VEJŘÍK L., VEJŘÍKOVÁ I., BLABOLIL P., 2021: Ověření technologie využití návazcových šňůr ke zjištění populační struktury sumce velkého. Biologické centrum AV ČR, v. v. i. Hydrobiologický ústav. 21 pp. [in Czech].

7 Managing data in ecology and fishery science: importance, challenges and tools

Allan Tainá De Souza^{1*}allan.souza@hbu.cas.cz, Petr Blabolil^{1,2}petr.blabolil@hbu.cas.cz

¹ *Biology Centre of the Czech Academy of Sciences, Institute of Hydrobiology, Na Sádkách 7, 370 05 České Budějovice, Czech Republic*

² *University of South Bohemia in České Budějovice, Faculty of Science, Branišovská 1760, 370 05 České Budějovice, Czech Republic*

With more and more data is generated, scientists are looking for better ways to handle, organize, store, share, and protect the integrity of data. Good data documentation is critical to ensure a smooth workflow while using appropriate data management techniques to ensure data accuracy and avoid errors and misinterpretations. Proper data management is becoming increasingly important in the scientific community, as data plays a critical role in every aspect of scientific research on a daily basis, from experiment design and data collection to data analysis and publication of results. Scientists must be able to handle large amounts of information by using appropriate data access tools that allow them to access and evaluate discoveries and communicate them with other researchers.

7.1 Increased generation and use of data in science

As data generation increases and accumulates with time, handling, processing, storing, and sharing become essential for any long-term study in ecology and fisheries. One of the key factors contributing to the increased data generation in science over time has been the evolution of increasingly sophisticated measurement and data collection methodologies. As technologies have advanced, scientists have been able to generate and collect data with greater precision and volume than ever before. Additionally, as data generation has

become a core component of scientific research across many different fields, funding and resources are often directed towards supporting these efforts. All these factors together have helped to fuel the exponential growth in data generation seen in modern science, making it an area that is central to the advancement of knowledge.

Usually, the issues related with the increased data generation in science are transversal to all fields of knowledge, and ecology and fisheries are no exception. The ever-increasing volume of data currently generated makes storage, management and analysis each day more challenging and costly. The awareness of data related issues in scientific projects nowadays have increased, and therefore issues related to inconsistencies in data generation, organizing, sharing and reproducibility are now being seriously tackled. Inconsistent data handling makes it difficult to other scientists to reproduce the results or build on previous work. While these issues are significant, they can be addressed with proper planning and resources. With the right infrastructure and qualified personnel in place, the increased generation of scientific data can be leveraged to accelerate discovery and advance our understanding of the world. However, to achieve this goal, the establishment of proper data management routine is essential. There are many approaches storing electronic records, from the simplest (saving individual text files or spreadsheets such as MS Word, Excel, OpenOffice) to sophisticated softwares such as (PasGear, MS Access, PostgreSQL, Oracle, Firebird). The choice depends on the operating system, the amount of information, the structure and the anticipated requirements.

7.2 Data management workflow in science

Data management can be divided into different steps. I) data digitization includes receiving data from field and/or lab data collection protocols; II) data processing involves methods to format data for input the database; III) data validation involves the double checking of all data entries in the database, it can be done manually or automatically by the deployment of specific validation scripts IV) data storage and back-up is a process of safely keeping data files and creating a back-up; V) data documentation involves the process of clearly documenting all steps involved in data handling, with clear descriptions of all steps that allow new users to quickly understand the data (Fig. 7.1).

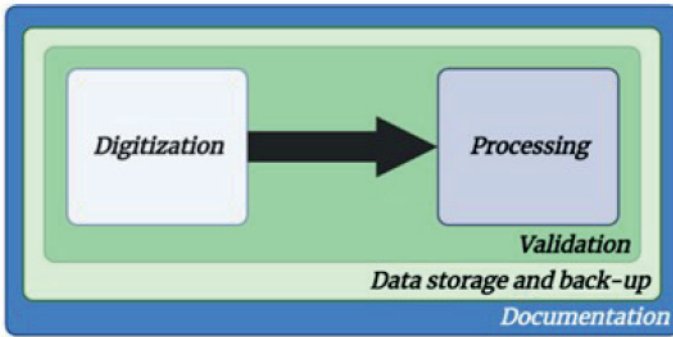


Figure 7.1. Schema of a healthy workflow of data management in science.

Each step is crucial to allowing people to find, use, and build upon data collected in past studies. At the core of data management is meticulous data care. Data must be organized and stored appropriately in order to ensure data integrity, which is essential for preventing errors in data interpretation and analysis. All these steps are usually conducted by specialized personnel and all the data professionals involved in data management need to work together effectively to build a clear and functional workflow. This requires good communication among all parties, as well as clear and specific expectations for each person's role in data management. For example, data analysts need to have access to reliable data, while data entry staff members must have clear instructions for inputting information into protocols and the database. Only by working together in a coordinated fashion that scientists can ensure that dealing with data is done correctly and efficiently. So, whether the user of the data is a data analyst or a database administrator, it is crucial that everyone always pays close attention to how data is handled and communicates clearly with the colleagues. There is little room for mistakes when dealing with scientific data.

7.3 Database basics

In our increasingly data-driven world, it is more important than ever to have a good system for storing and managing data. One of the most popular and powerful tools for doing this is a database. A database is a collection of data that can be easily accessed, updated, and manipulated. There are many different types of databases, each with their own set of unique features and uses. Broadly speaking, there are database systems for storing and retrieving text-based information, such as articles or records, as well as database systems for storing and manipulating numerical data. With-

in these categories, there are database systems for managing large quantities of heterogeneous data, database systems for tracking very specific types of data, and database systems that can be customized to suit a wide range of user needs. When it comes to scientific research specifically, database systems that specialize in organizing numeric data tend to be the best choice. These databases allow scientists to efficiently store large amounts of complex data. They also provide versatile query functionality to help users quickly retrieve specific values or perform advanced statistical analysis.

A relational database is a type of data storage system that contains a collection of data organized into tables. Each table in the database contains data organized around specific fields or categories. In addition, each table may contain data stored in various formats, such as text, numbers, dates, or images. Almost any type of data can be stored in a relational database, making it an extremely versatile and powerful tool for managing information.

Each table in a relational database stores the information about a specific type of data and a relationship is used to relate two tables in the database. There are two different types of keys in relational databases, the primary and the foreigner key. A key is a field that uniquely identifies a row in a table. A primary key is a special type of key that has some additional properties: it must be unique, it cannot be null, and it must be static (i.e., it cannot be changed). A foreign key is a key that is used to link two tables together. It is called a foreign key because it is typically defined in one table and references a primary key in another table. Foreign keys are important because they provide a way to enforce referential integrity. In other words, they help to ensure that data is consistent across multiple tables. without foreign keys, it would be possible for data to become "orphaned" or "lost" in the database. Foreign keys also allow to query data from multiple tables.

There are different options of programming languages and specialized software dedicated to interacting with relational databases. The best solution depends on the specific needs of the database, the data that will be stored in it, and the users who will be accessing it. However, some of the most popular database management systems include MySQL, Oracle, and Microsoft SQL Server.

SQL, or Structured Query Language, is a programming language developed in the 1970's, and that is used to interact with databases. Due to its simplicity and flexibility SQL is widely used in scientific projects. SQL syntax is relatively simple; it consists of a series of commands that can be used to perform various operations on a database. SQL commands can be used to insert, update, or delete data; to create or alter database objects such as tables or views; or to retrieve data from a database.

There are several important SQL commands that we can use to query data from relational databases. Perhaps the most used command is SELECT, which allows us to extract specific records from a database based on certain criteria. Another useful command is WHERE, which helps us to filter results by certain conditions or restrictions. Additionally, we can use ORDER BY to sort data in a specific order, or GROUP BY to break down records into different categories for easier analysis. Finally, the JOIN command allows us to merge multiple database tables together and perform more complex queries on related datasets. Altogether, these commands form the basic framework of database querying, and they are critical tools for any data analyst or database administrator.

7.4 Example on a relational database in fish ecology

An example of a database on freshwater fisheries would contain data on freshwater fish sampling in reservoirs and lakes across Europe. The tables in the database probably must include, among others: sampling, catch, species, reservoir/lake, locality, campaign. The data in each table would be linked by relationships. For example, the sampling table can be linked to the campaign table by `ca_campaignid`, and the catch table can be linked to the species table by `sp_speciesid` (Fig. 7.2).

In this example, the catch table contains data on all fish caught, including species, length, weight, and sex. The sampling table lists the catching methods used, such as gillnets, trawls, and electrofishing. The localities table describes the locations within the water body, including their names and GPS positions. The campaign table identifies a specific field work campaign, including the dates and the responsible staff.

To generate a SQL query in this example, a user must understand the data contained in the tables of interest and how they are related to each other (primary and foreigner keys). In our example, we are focusing on the catch of fish species in freshwater lakes. Specifically, we have two related tables: one containing data on the taxonomy of various fish species, and another containing their catch information. To begin our SQL query, we will first use the SELECT statement to indicate which specific data we want to extract from each table. For the species table, the user can specify that he/she wants to retrieve the values of the `sp_speciesid` to be equal to the northern pike (*Esox lucius*). For the second table, containing information on the catch, the user is interested in the fish weight (`ct_weight`), and then he/she can specify that he/she wants to retrieve all rows WHERE the `sp_speciesid` matches the northern pike catches.

Once these basic SELECT statements are entered into our query, the user can then join both tables together using an appropriate JOIN operator (such as INNER JOIN), allowing the user to easily see the biomass of northern pike. Overall, this simple SQL query is an efficient way to extract data from relational databases.

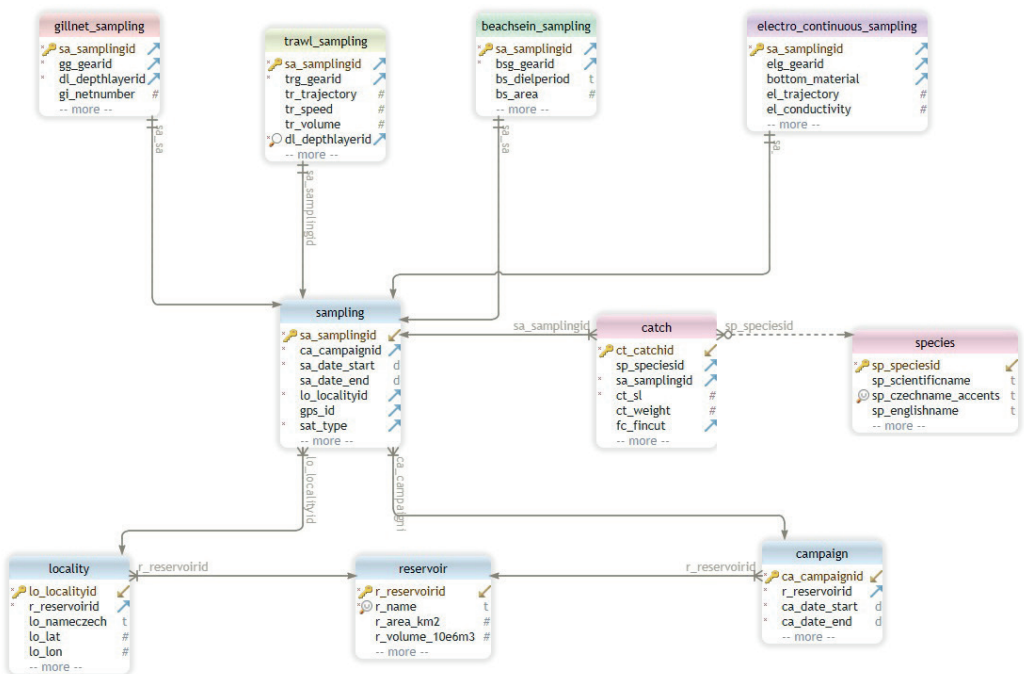


Figure 7.2. Simplified database diagram containing the most important tables, columns and links (Entity Relationship diagram).

7.5 Data accessibility

Even though all fields of science are experiencing an exponential growth in data generation and manipulation, in some fields of research the knowledge in a programming language can be an important barrier to many researchers. However, there are several ways to effectively interact with structured relational databases without having to code or learn SQL. One way is to use a data access layer, which is a software component that provides an abstraction layer between the database and the application. This way, a researcher can access data in the database without having to write any SQL code. Another way to interact with a database is to use a tool that allows the user to visually create and edit queries, such as Microsoft Access or Tableau. This can be a great way to get started with data exploration without needing to know any coding. Finally, there are many resources available online and in books that can help researchers to learn about SQL and how to query data effectively (Molinaro, 2005).

7.6 Data legacy

As anyone who has ever tried to save data knows, it can be a challenge to keep up with the changes in data processing and storage methods. The technological advancement makes old reliable tools quickly obsolete, and thus it can be tempting to just give up and let the data languish on an old system, but that can cause problems in the future. Valuable data can be lost or corrupted due to outdated storage methods, or simply become inaccessible as new systems emerge. Instead, it is important to stay ahead of the curve by regularly backing up the data and migrating it to new storage methods as needed. By taking these proactive steps, scientists can ensure that the data is always available when needed.

As data becomes increasingly central to scientific research, it is essential that researchers consider the legacy of data for future generations. Data sets can be incredibly valuable resources, providing a wealth of information for ecologists and fisheries scientists alike. However, data sets can also be very complex, and it can be difficult for new researchers to understand and interpret them. As datasets become more and more complex, it is important

that researchers take steps to ensure that they are understandable and accessible. One way to do this is to document datasets thoroughly, providing clear explanations of methods, data sources, and data interpretation. By taking these steps, our generation can help to ensure that data sets will be a useful and valuable resource for future generations of scientists.

7.7 Final remarks

In the scientific community, data management is critical for advancing research and making innovative discoveries. This is because data plays a central role in all aspects of scientific exploration, from planning experiments and collecting data to analyzing data and sharing results. Through careful data management, scientists can organize large volumes of data, enabling them to more easily access, interpret, and share findings with other researchers. Ultimately, effective data management can increase collaboration within the scientific community and contribute to the continued growth and success of research around the world. Thus, data management is essential for scientists today and will continue to be so in the future.

For an international standard protocol, we recommend the reader to refer EN 14 996 (CEN 2006) Water quality - Guidance on assuring the quality of biological and ecological assessments in the aquatic environment.

7.8 References

CEN, 2006. European standard Water quality - Guidance on assuring the quality of biological and ecological assessments in the aquatic environment. (EN 14 996) Brussels, Belgium, 2006, 25 pp.

Molinaro A., 2005: SQL cookbook. O'Reilly Media. 636 pp.



BIOLOGY
CENTRE
CAS

Methodology of monitoring fish communities in reservoirs and lakes

Published by:

Biology Centre AV ČR

Hydrobiologický ústav

Na Sádkách 7, 370 05 České Budějovice



Design & Print :

Printhouse POSEKANÝ České Budějovice

www.posekany.cz

© Biologické centrum AV ČR, v.v.i., 2022

ISBN 978-80-86668-95-6



EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education

 The Czech Academy
of Sciences
Strategy AV21
Top research in the public interest