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Editorial

# The true picture of a lake or reservoir fish stock: A review of needs and progress

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ABSTRACT

The conference 'Fish Stock Assessment Methods for Lakes and Reservoirs: Towards the True Picture of Fish Stock' (FSAMLR) was held in September 2007 in Ceske Budejovice, Czech Republic. A total of 110 participants from 34 countries attended the meeting and 93 lectures were presented. Great advances were reported in fish surveys using hydroacoustics and multimesh gillnet techniques, with nearly 60% of all presentations dealing with these topics. In contrast, the use of other active sampling gear, especially trawling and purse seining, received relatively little attention and still requires substantial further development. Reviews of standardization of fish sampling in the European Union, Russia and North America were also presented and clearly showed the benefits of standardized procedures. A number of contributions emphasized the need to use a combination of several methods for the same habitat. A true picture of the fish stock includes knowledge of the abundance, biomass, number of species, size and age compositions. Obtaining results of assured quality for all important lake and reservoir habitats and time periods still presents a significant challenge, although good progress is being made towards this important objective.



## 1. Background

The starting point for any assessment of a fish stock is necessarily some form of sampling of the fish community. How close the assessment represents a 'true picture' of the actual community present depends upon the nature and efficacy of both the sampling gear and the data analysis methodologies used in the particular study. Sampling of fish populations can be very efficient in small streams and ponds, and most quantitative freshwater fish research has been undertaken in such habitats. Nonetheless, larger freshwater systems such as lakes and reservoirs are invariably of great importance as fishery resources and these have received more attention in recent years. Gill netting, seine netting, electric fishing and angling are probably the most common techniques used for scientific purposes and all involve fish capture. However, the use of remote observation techniques such as hydroacoustics is increasingly favoured as an option.

It is often appropriate to use more than one sampling technique to obtain a 'true picture' of a fish stock in a lake or reservoir. With new drivers for the need for such knowledge, including for example the European Union Water Framework Directive (2000/60/EC) and climate change issues, the ability to develop improved methods to facilitate accurate stock assessments in such habitats has become critical. Accordingly, the international freshwater fisheries science and management community promoted a conference "Fish Stock Assessment Methods for Lakes and Reservoirs: Towards the True Picture of Fish Stock" (FSAMLR). This scientific conference, held during September 2007 in Ceske Budejovice, Czech Republic, was convened to respond specifically to the identified urgent need to improve fish stock assessment methods in large fresh waters. Attendance by 110 participants from 34 countries demonstrated that this is a significant concern among the international scientific community. This introductory article and the following papers present the outcomes of FSAMLR.

## 2. A true picture of a fish stock

A true picture of a fish stock allows us to say how many individuals of each species and each year class live in a given volume of a lake at a particular moment in time.

Therefore, a true picture should include at least the following information:

1. Fish quantity—biomass or numbers of individuals per unit of water volume or area.
2. Species composition—proportion of each species in particular volumes/habitats.
3. Size and age composition—proportion of size/age groups in particular volumes/habitats.
4. Spatial distribution patterns of the above parameters across habitats.
5. Temporal patterns of the above parameters.
6. Assessment of the accuracy and precision of the information.

Few large lakes and reservoirs would qualify as having had a true picture of their stocks determined according to these criteria

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(Bailey, 1990). Furthermore, any picture is more likely to be a snapshot valid only for a particular moment. True understanding of the dynamics of the fish populations in any waterbody can only emerge through multiple snapshots that can be joined together, so to speak, into a movie. To date we have generally failed to achieve this; the movies that have been produced are disjointed and add little to general understanding. What are the reasons for this unsatisfactory situation?

Large inland water bodies are difficult to study. The abilities of fish to escape sampling gear in three dimensions are often as good as in the sea, but the sampling methods available are often more limited in terms of vessels, number of staff, allocated time, gear and funding. This inevitably leads towards a poorer quality of information. Moreover, the quality of fisheries information from large inland waters is often worse than that from small freshwater systems (e.g. streams, ponds) which, even if they have similar funding constraints, are much easier to sample. The poor ratio between the effort needed and resources available generally forces lake and reservoir fisheries scientists to compromise with respect to the 'true picture' (for example, by extrapolating the results obtained at easily sampled shallow waters to a whole lake; by using highly selective and passive gillnets; or by the applying some hydroacoustic methods that are still theoretically unproven).

During FSAMLR, different approaches to fish stock assessment and sampling received considerably different degrees of emphasis (Table 1). Applications of hydroacoustic methods to freshwater systems received much attention, especially split- and multibeam systems, and new ways of data processing and collecting new information on scattering properties of fish and other aquatic organisms. The variability of fish behaviour and the complicated physics of underwater sound continue to restrict the use of this methodology to obtain a true picture, especially where horizontal beaming is employed close to the surface. For multispecies populations, hydroacoustic methods are effectively unable to provide standalone information. The hydroacoustic identification of individual species is at an early stage of development and is limited by serious physical uncertainties. A number of papers approached the identification problem by using acoustics in combination with another sampling method, most often gillnetting (included in categories 2 and 6 in Table 1).

A combination of several approaches is one of the most obvious solutions to obtaining a clearer picture of the state of the fish stock. If several methods give similar results in the same habitat, then we can be fairly confident that our picture gives a good representation of the actual stock. Obviously, all approaches must be robust and have reduced or corrected selectivity to produce similar results and confirm the true picture. About half of the contributions described combinations of fishing gears that did not sample exactly the same habitats or else gear selectivity was so high that they did not sample the same fish. These were cases of complementary rather than truly combined sampling. Only a few examples conducted in simple and well-defined systems, mostly on pelagic lacustrine stocks sampled by robust gear, showed encouraging agreement (Yule et al., in press).

**Table 1**
Absolute and relative frequencies of the main sampling methods used in individual contributions at FSAMLR.

| Sampling method | Number of lectures | % |
|---|---|---|
| 1. Hydroacoustics only | 20 | 21.5 |
| 2. Hydroacoustics in combination with several direct sampling methods | 18 | 19.4 |
| 3. Use of commercial and angling data | 18 | 19.4 |
| 4. Gillnets only | 11 | 11.8 |
| 5. Trawls and towed larval nets | 6 | 6.5 |
| 6. Combination of hydroacoustics and gillnets | 5 | 5.4 |
| 7. Sampling strategies in general, standardization | 5 | 5.4 |
| 8. Direct visual observations | 3 | 3.2 |
| 9. Electrofishing | 2 | 2.2 |
| 10. Seining | 2 | 2.2 |
| 11. Mark and recapture methods | 2 | 2.2 |
| 12. Ichthyocides, toxins | 1 | 1.1 |
| Total | 93 | 100.0 |

Several contributions relied on surveys of commercial and recreational fisheries for stock assessments (Table 1). This approach may have biased results and distort the picture due to the high selectivity by fishers and anglers. This is only partly balanced by the general low cost of data acquisition. Furthermore, the typical instability of fish communities in inland waters makes it difficult to apply classic fish stock assessment procedures developed for commercial fisheries that assume steady-state populations (Pauly, 1984). Similarly, fish stock assessment procedures that are based on catch and effort statistics such as surplus yield models rely on a constant catchability coefficient of the nominal effort units, which rarely exists in fresh waters (Amarasinghe and Pitcher, 1986).

The greatest number of contributions to FSAMLR came from surveys using gillnets as the major sampling tool. This situation was probably brought about in some large part by the newly accepted CEN standard (CEN, 2005) for sampling with gillnets, which was referred to in 30 papers (11 papers from category 4; 5 from category 6; and 14 from category 2; Table 1).

The use of active biological sampling gear (other than hydroacoustics, was much less represented (six papers on trawling, three on direct visual observations, two on electric fishing and two on seining). However, several of these papers showed that these approaches can overcome some of the major pitfalls of gillnetting and hydroacoustic surveys, such as the importance of fish behaviour for capture by passive gear catch and the difficulty in species identification using hydroacoustics. However, some active methods can be compromised by the high demands for expert knowledge and skills of the sampling crew and for expensive custom-built trawlers and other types of vessels. Recent progress achieved in marine science would certainly not have been not possible without the wide use of trawling technology (Misund et al., 2002; Gabriel et al., 2005). Advantages of active gears are that they can capture fish even if they do not move and they offer high efficiency and flexibility. The effective sampling season is also markedly longer compared to most other gears. Disadvantages of trawling gear are high initial costs, lack of standard design and technical specifications, and poorly understood selectivity, especially in fresh waters. Pelagic fish species pose a particularly difficult sampling problem since many of them are able to out-swim and thus escape sampling trawls, and this escape can be highly size- and species-dependent. Standardization of the sampling trawl, ancillary equipment and the sampling process is urgently required in order to increase the accuracy of this method and the quality of its results. Consequently, a pan-European initiative for the development of a scientific basis for freshwater trawling was launched during FSAMLR, which will also be open to the participation of non-European countries.

## 3. Standardization

A growing number of biologists worldwide are recommending standardization in sampling and reporting of fisheries data. If a true picture of a fish stock is obtained, standardization in data reporting is important to compare results among studies. Conversely, the true picture of a fish stock might be unattainable in a real-world situation, particularly given the limitations under which most surveying and monitoring agencies must operate. In such cases, it may be acceptable to work with a constantly biased sample as long as it can be assumed that the bias is similar in all samples. The European or North American gillnet norms (CEN, 2005; Bonar et al., in press), single run electric fishing (Noble et al., 2007) or catch-effort sampling strategies (Cowx, 1991) are good examples of such an approach. Some of these initiatives have formed the basis for national and international standards and have started to proliferate in the scientific community. Assessments of the efficiency and limitations of these standard approaches are of particular value because of their wide application, the interpretation of results and for the potential upgrading of standards. At least 31 papers presented at the conference discussed some aspects of standardized fisheries sampling and data reporting.

Standardization in industry, medicine and science has led to great advances. However, despite the potential benefits, freshwater fish sampling has generally not been standardized, or only standardized at a very local scale (Bonar and Hubert, 2002). Standardization across large regions would allow for measurement of large-scale effects of climate or geography on fish populations; larger sample sizes to evaluate management techniques; reliable means to document rare species; easier communication; and simpler data sharing. The increased interaction among fisheries professionals worldwide makes the case for wide-scale standardization more compelling than ever.

Three major international standardization efforts from North America, Europe and Russia were summarized at FSAMLR. In North America, a project to standardize freshwater fish sampling techniques is being led by the Fish Management Section of the American Fisheries Society (AFS) in collaboration with the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, U.S. Bureau of Land Management, National Park Service, USGS Cooperative Research Units Program, National Fish and Wildlife Foundation, AFS Education and Computer User's Sections, and Arizona Game and Fish Department. Their effort has resulted in a book of standard sampling methods for North America with almost 50 co-authors from the community of fish sampling experts within the United States, Canada and Mexico. Entitled *Standard Methods for Sampling North American Freshwater Fishes*, the book, currently in press, describes standard methods for sampling fish in specific environments so that population indices can be more easily compared across regions and time (Bonar et al., in press). Environments include ponds, reservoirs, natural lakes, streams and rivers containing cold and warmwater fishes. This book provides range-wide and regional averages calculated from over 4000 data sets from 42 states and provinces including size structure, catch-per-unit-effort, growth, and condition for common fishes collected using specified methods. Biologists can use these data to determine if fish from their waterbody are below, above, or at average. The book also provides other information necessary to standard sampling programs such as how to convert nonstandard to standard data; statistical and database procedures for standard sampling and methods to prevent transfer of invasive species while sampling.

The production of European standards is promoted by CEN (Comité Européen de Normalisation; the European Committee for Standardization). The most significant milestones of such standardizing efforts for freshwater fish are the electric fishing standard (CEN, 2003), the gillnet standard (CEN, 2005) and the general outline of methods available (CEN, 2006). Recently, the value of hydroacoustics in investigating inland fisheries has been recognized by CEN as it is now a formally approved fish sampling method, having high suitability for providing fish abundance estimates in the mid-water of large rivers and transitional waters, and the pelagic and profundal zones of lakes (CEN, 2006). However, despite this international endorsement, the complexity of hydroacoustics techniques currently hampers the transferability of results. There is thus a clear need for a standardization of methodologies across Europe. Following a 2-day workshop in 2006 in Dorset (UK), a draft of the European Standard was produced for the hydroacoustic sampling of lakes, reservoirs and large rivers. This specified: minimum requirements for echosounder system performance; calibration; survey design; survey data acquisition (including sonar settings); supporting environmental data; post-processing of acoustic data (to produce abundance and biomass estimates); results and reporting (including quality control and assurance). The document considered both vertical surveys of deep lakes and horizontal surveys of shallow waters including large rivers. It was agreed that the standard would be restricted to mobile hydroacoustics, and thus it does not cover fixed-location migratory fish-counting applications. It was also decided that the standard must be manufacturer-neutral with respect to both hardware and software, and that it would offer guidance for experienced operators, i.e. it would not be a training manual for inexperienced users. Finally, it was agreed that it must be applicable to a wide variety of survey needs such as varying environmental conditions, fish communities, equipment and monitoring requirements.

For Russia, the following approaches have been incorporated into a series of generally accepted methodical guidelines for research on lakes and reservoirs, published in the 1970s and 1980s (Standard Methods, 1974–1978; Otsenka Pogreshnostey, 1982).

1. Poisoning of the fish stock with a fish poison (Rudenko, 1976; Kitaev and Ilmast, 2007), applicable mainly to small lakes.
2. Hydroacoustic surveys, which are often performed by trace-counting on paper charts or using simple integrators (Yudanov et al., 1984). However, recent works (Kudryavtsev et al., 2006), report using approaches compatible with those of the international hydroacoustic community.
3. Assessment of 'sampling areas' with extrapolation of the results to the whole waterbody. The representative sampling areas are fished by seining or trawling and a calibrated net catchability coefficient is applied. A special case of the sampling areas method is the use of large ring gillnets, several hundred meters long and up to 30 m high (Poddubnyi et al., 1968; Gerasimov et al., 2007), which may need further methodical work but is worth considering for potential biomass estimates and information on fish swimming directions.
4. Mark and recapture techniques which are usually restricted to special tasks, but which in exceptional cases have been used in reservoirs as large as Rybinsk Reservoir (4550 km$^2$; Otsenka Pogreshnostey, 1982)

For the international freshwater fish research community as a whole, considerable effort is now being concentrated on assessing how far current estimates are from the true state of the stock and on how to improve the information obtained without compromising the invaluable time series data already gathered by current standard methods. In this way, recent standards may be amended, mitigated and upgraded every few years to serve a wide spectrum of studies in the best way, while at the same time taking into consideration the need for comparability between studies performed by older and newer standards.

Prompted by the economic importance of the inland fisheries resource and facilitated by reasonable capabilities for ageing fish (Gallucci et al., 1996), fisheries science has developed a robust mathematical apparatus for describing and modelling ecological processes in individual populations (summarized by Ricker, 1975; Hilborn and Walters, 1992; Gallucci et al., 1996). However, these advanced methods are of little use if the basic entry data are unreliable (Cotter et al., 2004). A number of discussions during this FSAMLR conference included the problem of the decline of fisheries in Lake Victoria, which illustrated the need to understand the systems both for the rational exploitation of the resources and for the conservation of the limnetic fauna. Many disputes and management mistakes have been caused by an excessively distorted picture of the state of the lake's stocks. So, even if obtaining a true picture looks like to be overly ambitious, it remains a goal worthy of increased efforts by the scientific community.

## 4. Conclusions

Obtaining a true picture of a fish stock is a difficult challenge but it is also an appropriate goal for scientific development. Even when knowledge of the true picture is not essential for making management decisions, it is essential to try and assess to what degree our existing knowledge deviates from it. There are several ways to approach this problem. The best outcome is obviously when several methods give the same results for the same fish species and for similar habitats. This shows the sampling to be robust and non-selective. An alternative is to scrutinize a single method to assess the accuracy and precision, efficiency, catchability and bias of the gear or sampling method. If accuracy and/or precision is low and the systematic sampling error is too high, the sampling method must be developed further. Random error can usually be mitigated by increasing sampling effort.

Standardization contributes enormously to improving the quality of data collected and the ease with which it can be applied to other situations. Therefore, standardized methods and approaches should be applied whenever possible. It is always possible for a researcher to sample for his or her specific purposes at a better level than the minimum prescribed by the standard, but in an ever more connected world it is going to become increasingly unacceptable to remain at a pre-standard level and preclude the international benefits of compliance. Fisheries scientists and stakeholders are already able to employ standardization on many key methods. The development in the near future of other standard methods is likely to enhance the quality of resulting information for lakes and reservoirs around the world.

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