# Chapter 20
# Using the Gill Nets Survey for Assessment of Fish Stock and Allowable Catch in the Vistytis Lake, Kaliningrad Oblast, Russia

**Sergey Shibaev, Oleg Novozhilov, and Pavel Baranovsky**

**Abstract** The paper describes a method to estimate the abundance of benthic fishes in the Vistytis Lake (area of 1.8 thousand ha, maximum depth of 52 m) using bottom gill nets with 12–60 mm mesh size. Annual 10-day surveys were performed from 2007 to 2020 at 30 stations located throughout the water area. The gill nets are not suitable for assessment of absolute number of fishes since it is unknown catching square of the net and catchability coefficient. However, the integration of catches per unit effort (in number of fishes or in kilograms per 25 m of net length per fishing day) and the area of the respective depth ranges and mesh size, can be used to calculate the relative abundance and biomass of the stock as well as the species composition of ichthyocenosis. The net mesh size can be considered as an identifier of the fish size group. This gives an opportunity to analyse the length structure of the population. The catches per unit effort for each mesh size can be interpreted as a total allowable catch (TAC), provided each hectare of the water body is fished once a year with a 25 m long net with each mesh size. The average stock abundance estimated with application of this approach gives the number of fishes 681.9 ± 144.8 thousand specimens and 38.44 ± 7.61 tons correspondingly, and the interannual variation coefficient for different species ranges from 50 to 100%. With regard to the water body area, the fish population density is 378 specimens/ha and 21.7 kg/ha, which is comparable to the ichthyofauna characteristics of the oligotrophic lakes in northwestern Russia. The method can be applied to any water body inappropriate for fishing by gears such as a trawl to assess the numbers of fish.

**Keywords** Fish stock assessment · Gill nets · Mesh size · Demersal ichthyocenosis · Species composition · Small scale fisheries · Allowable catch · The Vistytis Lake · Spatial distribution · Population length structure

S. Shibaev (✉) · O. Novozhilov · P. Baranovsky
Kaliningrad State Technical University, Sovetsky avenue, 1, 236022 Kaliningrad, Russia
e-mail: shibaev@klgtu.ru



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## 20.1 Introduction

The estimation of fish stocks in exploited small lakes, which is mandatory for the calculation of the total allowable catch, is specific and differs significantly from the approaches used for large inland waters. These peculiarities related to the impossibility of using active fishing gear such as a trawl or seine with known catching square to estimate fish population density, high variability of biotopes and therefore fluctuation of the spatial distribution of fish resulting in a large statistical error in mean values. In addition, each fish species may have different patterns of behavior, catchability and selectivity towards the fishing gear used, which also contributes to uncertainty in stock assessment.

A typical example of a small exploited water body is the Vistytis Lake, which is important for local small-scale fisheries in the Kaliningrad region, Russia. Preliminary studies have shown that active fishing methods cannot be used to assess fish abundance due to the specific morphology of the water body, spatial–temporal distribution of fish, and high water transparency, which allows fish to see and actively avoid moving fishing gear such as trawls or seines.

The only fishing gear that allows effective catch of any commercial fish species are the gill nets, which can be used anywhere in the water. Nevertheless, nets do not allow the catching square to be taken into account and therefore do not provide an opportunity to estimate the absolute abundance of the stock (Shibaev 2014).

The objective of this study is to develop a methodology for estimation of the status of stocks and allowable catch according to the relative indicators obtained using gill nets catches.

## 20.2 Materials and Methods

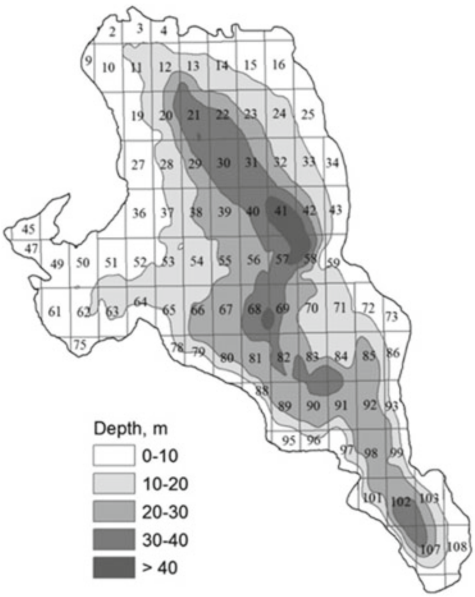
The investigation of the Vistytis Lake from 2007 to 2020, which was aimed at assessing the fish stock by means of the bottom gill nets, provided material for this study. A set of gill nets with mesh size 12, 14, 16, 18, 20, 22, 24, 30, 35, 40, 45, 50, 55, and 60 mm was used. The net length varied from 10 m for small-mesh nets up to 50 m for large-mesh nets, and was selected to make the catch sufficient to estimate the species and length composition of catch and to avoid excessively big catch which takes much processing time. The net height was 1.8–2.3 m also depending on mesh size.

Scientific catching was carried out at 30 standard stations located in a different depth. The depth interval was 5 m and the number of catchings for each depth range was up to 5 depending on the range area. Thus on each station up to 15 catchings were performed for each mesh size (12–60 mm). Fishing duration was about 24 h to avoid the impact of daily fish migrations. The survey lasted up to 10 days annually and the total number of catchings reached 450. The result of survey was a mass of catches per unit effort (CPUE) for each gill net. These data were used for estimation of fish stock and allowable catch of each fish species (Shibaev, Sokolov, 2014).

The total number of scientific catchings performed to estimate the stock amounted to 6.8 thousand, the number of fish involved for mass measurements was 114 thousand. The data were processed using the Rybvod information and analytical system that allowed automatic analysis of a considerably large bulk of information on scientific catching (Shibaev 2004).

## 20.3 Results

The Vistytis Lake is an oligotrophic water body with a total area of 1.8 thousand hectares. It is about 8 km long from north to south and 4 km from west to east. The lake is transboundary: the western part is located within the Russian Federation (81% of the area), and the eastern part belongs to the Republic of Lithuania (19% of the area) (Vistytis Lake 2008). The presence of three deep-water basins, narrow shallow-water zones in most parts of the water body and small macrophyte areas determine the spatial distribution of fish. The shallow water zone with depths of up to 10 m is about 30% of the lake area, while the zone with depths of 10–40 m covers about 60% of the area (see Fig. 20.1). Roach and perch are confined to the shallow water area and migrate daily to the shore at night and offshore during the day. The




| Depth, m | Square | |
|---|---|---|
| | ha | % |
| 0-5 | 433,2 | 24,1 |
| 5-10 | 258.1 | 14.3 |
| 10-15 | 257.8 | 14.3 |
| 15-20 | 218.1 | 12.1 |
| 20-25 | 218.7 | 12.2 |
| 25-30 | 182.6 | 10.1 |
| 30-35 | 108.1 | 6.0 |
| 35-40 | 96.5 | 5.4 |
| 40-45 | 22.8 | 1.2 |
| 45-50 | 4.9 | 0.2 |
| 50-55 | 0.1 | 0.1 |
| Total | 1800,9 | 100,0 |

**Fig. 20.1** Morphological properties of Lake Vistytis (compiled by the authors)

deeper part is inhabited by whitefish and burbot, which prefer colder water below the thermocline. Pike and tench are associated with the macrophyte beds in the bays or in the coastal zone at shallow depths, although they can occasionally occur in the open part of the lake. The maximum depth of the water is 52 m, resulting in the formation of two relatively isolated fish communities—the pelagic community which for over 90% consists of vendace, dweller of the water layer from 15 to 45 m, and the demersal one (Vistytis Lake 2008; Shibaev, Aldushin 2011; Shibaev et al. 2017). The demersal ichthyocenosis includes seven species: roach, perch, whitefish, tench, pike, burbot and bream, which are caught with bottom nets. However, typical pelagic species such as vendace and bleak, the latter particularly at shallow depths, can also be met in bottom catches (see Table 20.1). The distribution of fish in the lake is extremely irregular and is subject not only to seasonal but also to significant daily fluctuations due to weather conditions (Shibaev et al. 2008). This makes it

**Table 20.1** Species composition of gill net catches (mesh size 12–60 mm) in the Vistytis Lake (2007–2020), frequency of occurrence, % (authors' data)

| Species | Mesh size, mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–60 |
| Perch (*Perca fluviatilis* L.) | 52.3 | 52.6 | 59.0 | 59.7 | 60.7 | 33.1 | 32.9 | 14.3 | 9.3 |
| Ruff (*Gymnocephalus cernuus* L.) | 76.1 | 71.0 | 42.2 | 16.5 | 12.4 | 5.2 | 2.6 | 2.7 | 1.3 |
| Roach (*Rutilus rutilus* L.) | 19.8 | 23.4 | 28.7 | 33.5 | 35.9 | 27.1 | 18.4 | 13.9 | 2.7 |
| Whitefish (*Coregonus lavaretus* L.) | 0.8 | 2.7 | 9.5 | 11.0 | 19.6 | 21.8 | 42.1 | 30.4 | 25.3 |
| Vendace (*Coregonus albula* L.) | 51.6 | 28.6 | 9.2 | 5.8 | 5.6 | 2.1 | 3.9 | 4.2 | 1.3 |
| Pike (*Esox lucius* L.) | 2.1 | 3.2 | 9.0 | 13.3 | 19.7 | 16.0 | 7.9 | 17.8 | 5.3 |
| Burbot (*Lota lota* L.) | 6.7 | 7.0 | 8.5 | 10.3 | 11.6 | 6.7 | 10.5 | 5.7 | 9.1 |
| Bream (*Abramis brama* L.) | 1.0 | 1.6 | 2.4 | 3.1 | 4.4 | 4.4 | 6.6 | 6.1 | 4.5 |
| Tench (*Tinca tinca* L.) | 1.8 | 0.5 | 0.5 | 0.2 | 0.9 | 2.4 | 3.9 | 5.7 | 0.0 |
| Bleak (*Alburnus alburnus* L.) | 8.6 | 2.4 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |

very difficult to estimate the abundance of fish, which is dependent on the survey conditions each particular year.

The main commercial fishing gear currently used in the lake are gill nets with a mesh size of 16–18 (pelagic nets for vendace), 40–50 and 70 mm (bottom nets), although in the 1970s–1980s an important gear was 500 m seine, which was used for roach, perch and whitefish. For spatial management of fisheries, the water is divided into quadrats. Fishing takes place in the northern and central parts. In the bay (locally called the Tikhaya Bay) located on the western coast, the main spawning grounds of phytophilous fish, commercial fishing is prohibited. The historical maximum yield since 1962 was about 30 tons. Fishery regulation based on Total Allowable Catch (TAC), which should be estimated annually for each species with regard to the current state of its stock.

The stock status is assessed based on annual surveys performed in June–July with bottom gill nets. The calculation algorithm is as follows. Each catch per effort can be presented as amount of fish YN (specimens) or weight YW (kg)

$$Y_N[i, d, f, L, h] \tag{20.1}$$

$$Y_W[i, d, f, L, h] \tag{20.2}$$

with the following identifiers:

i—a catch number;

d—net mesh size in millimeters;

f—fish species;

L—fish length group in centimeters;

h—station depth.

Thus, summarizing the data on all catches during the survey enables assessment of fish abundance in the water body in terms of numbers or biomass. The following should be considered.

1. Each of the fish species has its own parameters of selectivity and catchability relative to the mesh size of a net. The general dependence of fish length on the mesh size is described by the linear function L = bd, where b is the species-specific coefficient; however, this dependence can be violated due to morphological characteristics of different species. For example, it is obvious that owing to the presence of spines and spiny rays of fins the catchability and selectivity ogive of perch should be different from that of spine-free species like roach.

On the other hand, the size of the fish caught is directly related to the mesh size, but the range of length fluctuation in each net is only a few centimeters. In this regard, mesh size seems to be an appropriate identifier of fish size to analyse the population structure. In this case, generalizing the catch data of the entire range of meshes provides information on some certain virtual size population structure.

2. The second feature is the need to consider the spatial distribution that is specific to each species. For example, tench is usually found in shallow water, while burbot

occurs at depths over 30 m. This makes it expedient to calculate the statistical abundance of the fish population separately for each mesh size and the depth range. Subsequently the average fish catch by the net with mesh size (d) in a given depth range (h) is the abundance index BN or the biomass index BW of a given species (f):

$$B_N[d,\ f,\ h] = \frac{\sum_{i=1}^{N_h} Y_N[i,\ d,\ f,\ h]}{N_h} S_h \tag{20.3}$$

$$B_W[d,\ f,\ h] = \frac{\sum_{i=1}^{N_h} Y_W[i,\ d,\ f,\ h]}{N_h} S_h \tag{20.4}$$

where: $N_h$ is the number of stations in the given depth range; $S_h$ is the area of the given depth range.

The basic statistics like standard deviation, mean error and confidence interval can be calculated in a similar way.

The total stock of fish species (f) will consist of number and biomass calculated for each mesh size (d) and for each depth range (h):

$$B_N[f] = \sum_{h_{\min}}^{h_{\max}} \sum_{d_{\min}}^{d_{\max}} B_N[d,\ f, h] \tag{20.5}$$

$$B_W[f] = \sum_{h_{\min}}^{h_{\max}} \sum_{d_{\min}}^{d_{\max}} B_W[d,\ f, h] \tag{20.6}$$

As an example, the Table 20.2 shows the calculations of the perch biomass taking into account the population length structure, which is represented as catches of nets with different mesh sizes with 5 cm interval, and the spatial distribution of 5 m over

**Table 20.2** An example of calculation of perch biomass in the Vistytis Lake (2009), kg (authors' data)

| Depth, m | Mesh size, mm | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | 10–14 | 15–19 | 20–24 | 25–29 | 30–34 | 40–44 | 45–60 | |
| 0–5 | 117.9 | 180.2 | 582.8 | 471.1 | 964.1 | 194.7 | 8.2 | 2518.9 |
| 5–10 | 133.5 | 387.3 | 627.8 | 728.4 | 588.1 | 53.1 | 22.8 | 2541.1 |
| 10–15 | 277.4 | 2678.6 | 689.4 | 1748.0 | 1175.2 | 249.3 | 6.6 | 6824.5 |
| 15–20 | 188.3 | 70.4 | 132.3 | 366.0 | 185.3 | 29.5 | 28.4 | 1000.3 |
| 20–25 | 25.7 | 18.3 | 155.0 | 255.7 | 225.3 | 40.7 | | 720.7 |
| 25–30 | | | 8.5 | | 32.0 | | | 40.5 |
| 30–35 | 0.9 | 4.7 | 10.6 | 27.5 | 38.1 | | | 81.8 |
| 35–40 | | | 2.7 | | | | | 2.7 |
| Total | 743.8 | 3339.5 | 2209.1 | 3596.7 | 3208.1 | 567.3 | 66.0 | 13,730.5 |

the depth ranges. The data on survey catches in 2009 were considered. According to the data, the size groups of fish caught by nets with a mesh size of 25–40 mm, which were found at depths of 10–15 m, provided the largest stock biomass (1.75 tons). With regard to the abundance of all age groups, the total biomass in this zone amounted to 6.8 tons. In deeper waters, the perch biomass decreases, and at a depth exceeding 45 m, it declines to only 66 kg. Summing the catches over all depths and all applied mesh sizes gives a total stock biomass of 13.73 tons.

## 20.4 Discussion

Let us consider the results of assessing the abundance of fish in the Vishtytis Lake using the above algorithm. It was found that over the 14 year period of investigation (see Fig. 20.2) the estimated biomass of the stock varied over a very wide range from 70 tons in 2008 to 23 tons in 2010. At the same time, the interannual variations in the species structure of ichthyocenosis were not so significant (see Fig. 20.2). All this may indicate that the observed fluctuations in the density of the fish population are associated with the survey conditions in each particular year, since no significant changes in the habitat of fish in the lake were observed, and the fishing intensity here has been quite low over the last 20 years. In this regard, it seems necessary to use the average long-term estimates of the stock in order to characterize the ichthycenosis of the lake as a whole.

The calculation of ichthyofauna parameters has shown that the average stock abundance and biomass amounts to 681.9 ± 144.8 thousand specimens and 38.44 ± 7.61 tons correspondingly (see Table 20.3), and the interannual variation coefficient

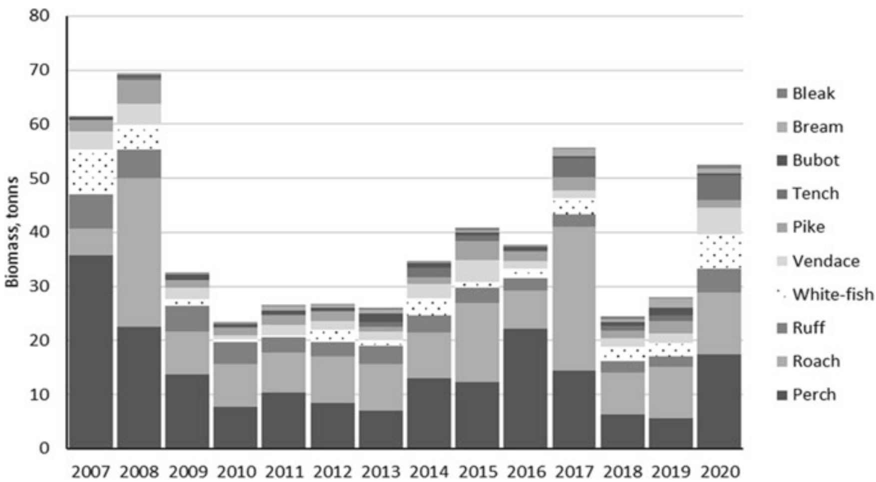



**Fig. 20.2** Dynamics of demersal ichthyocenosis biomass

**Table 20.3** Average annual statistical characteristics of the fish stock in the Vistytis Lake (2007–2020) (authors' data)

| Species | Numbers, thousand | | | | | Biomass, ton | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | x | σ | v | Δ | % | x | σ | v | Δ | % |
| Perch | 171.7 | 101.3 | 0.59 | 53.0 | 25.2 | 13.99 | 7.96 | 0.6 | 4.17 | 36.4 |
| Roach | 143.6 | 144.4 | 1.01 | 75.6 | 21.1 | 11.27 | 6.65 | 0.6 | 3.48 | 29.3 |
| Ruff | 248.6 | 84.2 | 0.34 | 44.1 | 36.5 | 3.45 | 1.29 | 0.4 | 0.68 | 9.0 |
| Whitefish | 5.8 | 5.0 | 0.86 | 2.6 | 0.9 | 2.76 | 2.17 | 0.8 | 1.14 | 7.2 |
| Vendace | 94.4 | 49.5 | 0.52 | 25.9 | 13.8 | 2.36 | 1.22 | 0.5 | 0.64 | 6.1 |
| Pike | 2.9 | 1.4 | 0.48 | 0.7 | 0.4 | 2.00 | 0.90 | 0.5 | 0.47 | 5.2 |
| Tench | 1.0 | 0.9 | 0.92 | 0.5 | 0.2 | 1.06 | 1.34 | 1.3 | 0.70 | 2.8 |
| Burbot | 2.1 | 0.9 | 0.44 | 0.5 | 0.3 | 0.74 | 0.36 | 0.5 | 0.19 | 1.9 |
| Bream | 2.0 | 1.4 | 0.72 | 0.8 | 0.3 | 0.58 | 0.48 | 0.8 | 0.26 | 1.5 |
| Bleak | 9.8 | 11.3 | 1.15 | 5.9 | 1.4 | 0.22 | 0.23 | 1.0 | 0.12 | 0.6 |
| Total | 681.9 | 276.5 | | 144.8 | 100.0 | 38.44 | 14.53 | | 7.61 | 100.0 |

x—average, σ—standard deviation, v—coefficient of variation, Δ—confidence interval

for different species ranges from 50 to 100%. With regard to the water body area, the fish population density is 378 specimens/ha and 21.7 kg/ha, which is comparable to the ichthyofauna characteristics of the oligotrophic lakes in northwestern Russia (Kitaev 2007).

Pursuant to the multi-year averages, the main fish species that form the abundance of ichthyofauna are perch, roach and ruff, while roach and perch dominate in biomass and provide more than half of the stock. Commercially valuable species such as whitefish, pike, burbot, and bream make up about 20% of biomass. At the same time, as exactly these species are the most caught ones, the quota in recent years was used up to 100% while quotas for perch and roach remained significantly underutilized.

The results not only provide an estimate of the stock status, but also an assessment of possible fish yield in the water body. This may be based on the following considerations. Abundance and biomass showed in the Table 20.3 are calculated as the catch per unit effort, per 25 m of the net per fishing day multiplied by the water body area. This value can be interpreted as the total catch of gill nets with different mesh sizes that could be harvested if each hectare of water surface were caught once a year. Such fishing cannot adversely affect the stock status as the absolute catchability coefficient of nets is rather small and probably does not exceed 0.1. Thus, the biomass values in the table are in fact the total allowable catch (TAC) that can be targeted by the fishery. Thus, the biomass values in the table are essentially the total allowable catch that can be targeted by the fishery. Consequently, bottom-net fishing can yield a total catch of about 38 tons and corresponding catches of each species. In fact, it may be necessary to consider only the nets with the mesh size that are actually used in the fisheries, as well as allowable fishing intensity and deployment, but the calculation scheme remains the same.

## 20.5 Conclusion

Thus, surveys with gill nets with different mesh sizes allow to assess the fish abundance and the allowable catch. This approach is quite objective since it is based on actual catch data and reflects the current state of fish stocks.

The method can be applied to any small water body inappropriate for fishing by gears such as a trawl or seine to calculate the fish absolute abundance.

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