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SELECTIVITY OF GILLNET SERIES IN SAMPLING OF PERCH (*PERCA FLUVIATILIS L.*) AND ROACH (*RUTILUS RUTILUS L.*) IN THE COASTAL SEA OF ESTONIA

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ABSTRACT

The selectivity pattern of perch and roach for a six net gillnet series (mesh sizes 17, 21, 25, 30, 33 and 38 mm) was studied using the gamma model. Data was collected between 1995 and 2004 during routine coastal fish monitoring surveys in Estonia covering six permanent monitoring areas along the coastline. Gamma curves were fitted to the length distributions of different mesh sizes using all strata and relative abundances of the length groups in the gillnet catches were derived. Based on relative abundances, the estimated length distributions were calculated and the representative length distributions from the gillnet series was evaluated.

Size groups in the range of 17-27 cm of both species are overrepresented using the gillnet series, i.e. the length distribution of raw data is biased. Adding nets with smaller mesh sizes to the series would solve the problem of insufficient coverage of smaller (less than 12 cm in length) size groups and small-sized species without affecting long-term data series. For better evaluation of selectivity, experimental studies in recording different ways fish are captured and tagging experiments are recommended.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Gillnets are passive gears mainly used for fishing in shallower waters, but they are also used for research purposes, e.g. in shallow coastal areas or lakes. The Estonian Marine Institute and the University of Tartu have conducted routine coastal fish monitoring using gillnet stations in Estonian coastal waters since 1992 (Saat *et al.* 2003). The main objective is to determine trends in coastal fish populations and assemblages related to natural variation and large-scale environmental changes (Appelberg *et al.* 2003). In addition, the same method has been applied to study seasonal and spatial distribution of fish and has been used in environmental impact assessment as well (Saat and Eschbaum 2002).

The most abundant species caught during gillnet sampling are typically perch (*Perca fluviatilis* L.), roach (*Rutilus rutilus* L.), herring (*Clupea harengus membras*), vimba (*Vimba vimba*), flounder (*Platichthys flesus*), white bream (*Blicca bjoerkna*), rudd (*Scardinius erythrophthalmus*), ruffe (*Gymnocephalus cernuus*), bleak (*Alburnus alburnus*) and smelt (*Osmerus eperlanus*), as well as whitefish (*Coregonus lavaretus*), pike (*Esox lucius*), pikeperch (*Sander lucioperca*), dace (*Leuciscus leuciscus*), gudgeon (*Gobio gobio*) and viviparous blenny (*Zoarces viviparus*). By far the most abundant species are perch and roach, perch occurring everywhere along the coastline and roach in shallow areas in the western coast (Eschbaum *et al.* 2004).

Besides monitoring with gillnets, experimental fishing is occasionally undertaken with other gears like trap nets and beach seines. Therefore, it is known that small-sized fish species and younger age-classes are insufficiently covered by gillnets when using minimum mesh size of 17 mm (measured from knot to knot) in the study area.

Mesh size combinations in the used gillnets series might only be selecting fish in certain size groups and therefore not reflect true population size distributions, a characteristic that may bias sampling for age and growth as well. Adding mesh sizes (especially smaller sizes) to this existing gillnet series would probably give supplementary information on e.g. recruitment, without affecting present long-term data sets. The Institute of Coastal Research in Sweden is eager to introduce new methods for coastal fish monitoring using Nordic-type multisection gillnets, which are used for fish monitoring in lakes (Appelberg *et al.* 2003). However, if this was done long-term data series would be disrupted, which should be avoided.

Studying the selectivity patterns of two different species enables better evaluation of the gillnet series used in coastal fish monitoring. On this basis, the purpose of the present project is to: i) study the gillnet selectivity pattern of perch and roach over the gillnet series in areas where these species occur; ii) find the optimal method to calculate the estimated length distributions based on the selectivity pattern; and iii) find the gaps in the present gillnet series according to the selectivity pattern, and based on available length distribution of perch and roach in the coastal areas of Estonia, suggest additional mesh sizes for the gillnet series.

2 LITERATURE REVIEW

2.1 Environmental conditions

The Baltic Sea (Figure 1) is the second largest brackish water basin in the world. The hydrography of the sea is largely regulated by the sporadic inflows of saline North Sea water and intermediate stagnation periods; the average retention time is 25-30 years (Ojaveer and Pihu 2003). In the Southern Baltic Sea, salinity is as high as 20 ppt, but it is as low as six ppt in the Northern Baltic Sea. The water is almost fresh in river estuaries.

The coastal waters of Estonia have low salinity (1-9‰, usually 5-8‰), they are often shallow, especially in the Moonsund Archipelago (Väinameri) and the Gulf of Riga area. Water temperature in shallow areas reaches 26-28º C in hot summers, and these areas are ice-covered in the winter (Ojaveer and Pihu 2003).

Figure 5: Baltic Sea and its drainage basin (ICES 2005).

The composition, distribution and diversity of the Baltic fish fauna are influenced by the brackish-water character of the Baltic Sea, the two-layered water mass and the variable environmental conditions. Fish species have immigrated at different times by different ways; the distribution pattern of the various species reflects their original habitat and salinity tolerance. Thus, the number of marine species is highest in areas near the Danish Straits and diminishes eastwards and northwards, while the number of fresh water species increases when salinity decreases. The most important marine species are cod, flatfish, sprat and herring, anadromous and catadromous species Atlantic salmon, sea trout and European eel, and the most important fresh water species are pike, perch and roach (Ojaveer and Pihu 2003).

Most species living in the Baltic Sea have adapted to the environment in various ways and differ from fish of the same species living e.g. in the North Sea or in fresh water. Marine species tend to grow slower and to be generally dwarfed due to metabolic stress caused by decreased salinity. The size of marine fish in the Baltic decreases and growth slows down from the Danish straits in SW to the Bay of Bothnia in NE as salinity decreases and the climate gets colder. Marine species tend to have higher fecundity and bigger eggs to compensate for the decreased density in brackish water. Freshwater species tend to grow bigger due to the higher productivity in the Baltic compared to many freshwater environments. The individual adult can tolerate brackish water but requires higher salinity (marine species) or almost freshwater (freshwater species) for successful reproduction (Ojaveer and Pihu 2003).

2.2 Species characteristics

2.2.1 Perch (Perca fluviatilis L.)

Perch (Figure 2) is widely distributed in fresh and brackish coastal waters of Europe (except the Pyrenean, Apennine and Balkan peninsulas, North Scotland, the greater part of Norway and Iceland) and North Asia up to the Kolyma River. Perch is a non-migratory species and usually lives in shoals which may include individuals of different sizes. Big individuals become solitary. The body is short and laterally compressed with maximum depth just anterior to the first dorsal fin. It has gill covered ends with a strong spine. In Estonian waters, perch is one of the most widespread and in most cases, abundant species. The annual catches of perch are usually between 800-1500 tons in coastal waters. Fishing for perch is practiced throughout the year, finishing in Estonian coastal waters in spring. In commercial fishing of perch mainly fyke nets, traps and gillnets are used. It is also an important sporting fish. The commercial size limit (total length) for perch in the coastal sea is 19 cm (Pihu *et al.* 2003).

Figure 6: Perch (*Perca fluviatilis* L.). Photo by author.

2.2.2 Roach (Rutilus rutilus L.)

Roach (Figure 3) is widely distributed in Europe north of the Pyrenees and the Alps and eastwards to the Urals. It is absent in Northern Scandinavia. Roach prefers fresh water but is also common in brackish waters. In Estonian inland waters roach is very common, only pike and perch are more abundant. In brackish waters, roach is abundant in the western coast of Estonia and in river estuaries. Roach is a shoaling fish and prefers the littoral zone close to the vegetation belt. Bigger individuals are also found farther from the shore. The body is flat and comparatively deep. As one of the most abundant fish species it gives rather large catches. The annual commercial catches of middle-sized and big roach have usually been 100-300 tons in coastal waters; however catches of smaller roach have not been recorded separately (Vetemaa *et al.* 2003).

Figure 7: Roach (*Rutilus rutilus* L.). Photo by author.

2.3 Gillnets

Gillnets are net walls kept more or less vertical by floating lines or floats on the upper line and by sink line or weights on the ground-line (von Brandt 1984). Gillnets are categorized as passive gears, i.e. the fish have to swim into the net to get caught (Sparre and Venema 1998). There are several ways of fish getting caught as illustrated in Figure 4:

- snagged: the mesh is around the fish just behind the eye
- gilled: the mesh is around the fish just behind the gill cover (most common method)
- wedged: the mesh is around the body above the dorsal fin
- entangled: the fish is held in the net by teeth, maxillaries, fins or other projections, without necessary penetrating the mesh, occurs mainly when the net is loosely rigged (Sparre and Venema 1998, Millar and Fryer 1999).

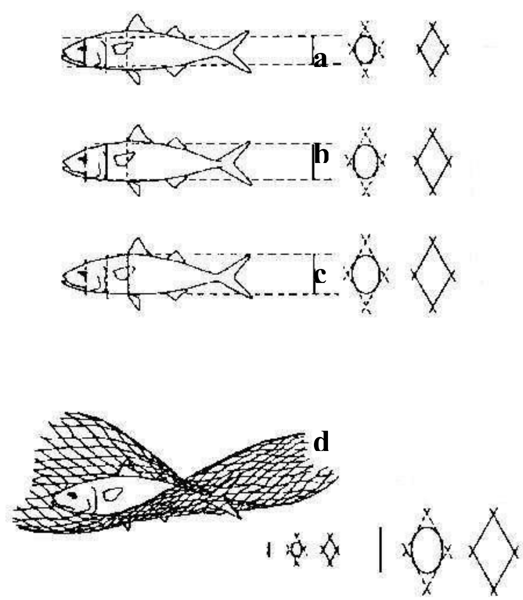

Figure 8: Diagram of how fish of the same size may get caught in gillnets of different mesh sizes (Sparre and Venema 1998). a – snagged, mesh size 100 mm; b – gilled, mesh size 120 mm; c – wedged, mesh size 140 mm; d – entangled, mesh size 60-150 mm.

In case of the same mesh size, the largest fish will be mainly snagged, whereas smaller fish are mainly gilled or wedged. Entangling is less size dependent and may affect both large and smaller individuals (Hamley 1975).

Gillnets used in fish research are often either gillnets series or multimesh gillnets. A gillnet series (station) usually consists of several nets each with a different mesh size. For example the Nordic-type multimesh gillnets used in the lakes is 1.8 m high and 45 m long with a lead line 50.5 m long and consisting of 5-9 m long randomly distributed mesh panels with mesh sizes ranging from 10-60 mm. The ratio between mesh sizes is 1.25 and mesh size composition follows a geometric series (Appelberg *et al.* 2003).

2.4 Selectivity

Holst *et al*. (1998) divided the catch process (and hence selection) into three phases:

- probability that the occurrence of fish coincides in time and space with the use of the gear;
- probability that fish encounters the gillnet provided they are present when and where the net is used, i.e. that fish are accessible to the net; and
- probability that the gillnet retains fish, provided they have encountered the gillnet, i.e. fish are vulnerable to gillnets.

The first two phases are essentially dependent on fish distribution and behavioural patterns, while in the third, the specific characteristics of the gear and morphology of the fish play a main role (Gulland and Harding 1961, Holst *et al.* 1998).

For a particular mesh size, fish of the optimum size are held most securely. Smaller or larger fish are less likely to be caught: very small fish can swim right through, and very large fish cannot penetrate deep enough into a mesh to become stuck (Nielsen and Johnson 1983). As gillnets are passive gears, the fish which move fast, have a larger probability of encountering the gear than slow moving fish (Sparre and Venema 1998). Hence the length distribution of fish available for the gear may differ from the length distribution of the entire population (Millar and Fryer 1999, Finstad *et al.* 2000). Selectivity may affect any estimates that imply random sampling, e.g. length-weight regressions, sex ratios, capture-recapture estimates of population size, and calculations of growth, age distribution as well as mortality (Hamley 1975).

Gillnet selection is known to depend on a variety of factors besides mesh size: net construction, visibility and stretchability of the net, net material as well as the shape and behaviour of the fish. Therefore, factors other than mesh size may affect the efficiency of the net (Hamley 1975). Entangling more than wedging and gilling is affected by net construction and the probability of a fish being entangled depends on the hanging ratio: the less the net is stretched, the larger probability of entangling (Sparre and Venema 1998).

Selectivity can also be affected by the way a net is used to catch the fish. As different sizes of fish may occupy different habitats, the sizes caught may depend on the location and fishing depth (Hamley 1975). The selectivity of the same net fished in the same way between different seasons or areas may not be the same, because of the differences in distribution, behaviour, or condition of the fish. Net handling techniques may also affect selectivity, for example, herring-shaped fish are often meshed loosely by head and may fall out easily. As the fish accumulate in gillnets, the efficiency of a net decreases (Olin *et al.* 2004). Also fouling with macrophytes, algae and silt decreases the efficiency. Eventually the number of fish in the net reaches a saturation level and does not increase further (Olin *et al.* 2004).

The girth is considered to be the main factor determining the size of fish caught by different mesh sizes (Kurkilahti *et al.* 2002), but longer fish of the same girth may develop greater swimming thrusts and therefore penetrate deeper into the mesh (Hamley 1975). Nevertheless, most gillnet selectivity models have been derived for fish length, the main reason is that measuring girth is difficult and time-consuming, and therefore expensive if compared to routine length and weight measurements (Millar and Fryer 1999).

2.5 Estimation of selectivity

Gillnet selection studies usually lack knowledge on the size structure of the population encountering the gear. So in practice, almost all selectivity studies are comparative i.e. indirect. The usual procedure is to simultaneously fish with different variants of the gear, usually with equal effort. Gillnets can be constructed of several panels, all of the same size and each of a different mesh size, i.e. following an arithmetic or geometric series. The order of the panels can be changed on each day to reduce the effect of any possible preference by the fish for a particular area of the net (Jensen 1986, Kurkilahti and Rask 1996, Millar and Fryer 1999, Appelberg *et al.* 2003).

Most indirect methods follow one of two basic approaches: type A curves give the probability of capture of one mesh size to various size classes of fish, while B-type selectivity gives the probability of capture of a single size-class of fish to different meshes, from them type A curves are determined (Hamley 1975, Helser *et al.* 1998, Quang and Geiger 2002). The advantage of type B curves is that estimates of selectivity are not affected by different size class abundances when sampling is carried out in a limited period of time, because catches of each mesh for a given size class of fish are proportional to selectivity of that size (Hamley 1975, Helser *et al.* 1998), but methods using type B curves involve some degree of subjectivity in fitting the data (Gulland and Harding 1961, Jensen 1986).

A typical gillnet selectivity curve is bell-shaped i.e. Gaussian, falling to zero on both sides of a maximum (Figure 5). The curve is described by its mode, width and height: the mode corresponds to the optimum length of fish caught; the width to the selection range; the height describes how efficiently the mesh catches fish of the optimum length (Hamley 1975). The width of the curve may also be dependent on the body shape of the fish (Jensen 1986, Kurkilahti *et al.* 2002).

The bell-shaped selectivity curves are often described by functions derived from probability distributions known from statistics, such as normal, log-normal or gamma distribution functions. The ability of gillnets to capture large fish by snagging or entanglement implies a skewed selection curve. The log-normal and gamma selection curves allow for a moderate amount of skewness, although in practice these expressions often lead to very similar selection curves (Millar and Fryer 1999).

Selectivity models are generally overparameterized, which has led to assumptions that prevent the estimations of height (Millar and Fryer 1999, Quang and Geiger 2002), following the principle of geometric similarity (Hamley 1975, Millar and Fryer 1999). That is to say that all meshes are equally efficient for the length class they catch the best (Hamley 1975, Holst *et al*. 1998). This assumes that selection depends only on the relative geometry of the mesh and the fish. Also the mode and the spread of a selection curve are assumed to increase proportionately to the size of mesh to decrease the parameters to be measured (Quang and Geiger 2002). The parameterization of a sample of selection curves is provided in Table 1 and Figure 5.

Table 1: A sample of selection curve expressions for gillnets. All models are formulated in accordance with the principle of geometric similarity and are expressed using the transformed length (λ=length/mesh-size = *l/m*). Selectivity curves for actual mesh or (*ms*) for fish measured in cm (*l*) are derived by using the parameters given on the right hand side (Hovgård and Lassen 2000).

Selection curve	Parameters used
NORMAL (GAUSSIAN) $S(\lambda \mid k,s) = \exp\left[\frac{-(\lambda-k)^2}{2s^2}\right]$	S(*l* | *ms*k, ms*s*)
LOG-NORMAL $S(\lambda \mid k,s) = \frac{1}{\lambda}\exp\left[k-\frac{s^2}{2}-\frac{(\text{In}(\lambda)-k)^2}{2s}\right]$	S(*l* | *1n(ms)+k, s*)
GAMMA $S(\lambda \mid \alpha,\beta) = \left[\frac{l}{(\alpha-1)\beta}\right]^{(\alpha-1)}\exp\left[\alpha-1-\frac{t}{\beta}\right]$	S(*l* |*α, ms* β*)
BI-NORMAL $S(\lambda \mid k_1,s_1,k_2,s_2,b) = B\left[\exp\left[\frac{-(\lambda-k_1)^2}{2s_1^2}\right]+b\exp\left[\frac{-(\lambda-k_2)^2}{2s_2^2}\right]\right]$	S(*l* |*m**k_1, *s**k_2,*ms**s_1, *ms**s_2, *b*)
TWO-SIDED $S(\lambda \mid k,s_1,s_2) = \begin{cases} \exp\left[\frac{-(\lambda-k)^2}{2s_1^2}\right] for \lambda \geq k \\ \exp\left[\frac{-(\lambda-k)^2}{2s_2^2}\right] for \lambda \geq k \end{cases}$	S(*l* |*ms*k, ms*s1, ms*s2*)

Previous studies concerning gillnet selectivity of perch and roach have focused on freshwater environments, for example. lake and reservoir littoral zones (gillnet series: Jensen 1986, Nordic-type multimesh gillnets: Kurkilahti and Rask 1996, Finstad *et al.* 2000, Kurkilahti *et al.* 2002) or multimesh gillnets in the coastal areas of the Baltic (Appelberg *et al.* 2003).

In selectivity studies concerning perch and roach, only B-type selection curves have been used (Jensen 1986, Kurkilahti *et al.* 2002) so far. The selectivity studies mentioned above do not include the correction of length distributions of gillnet catches according to the selectivity patterns derived.

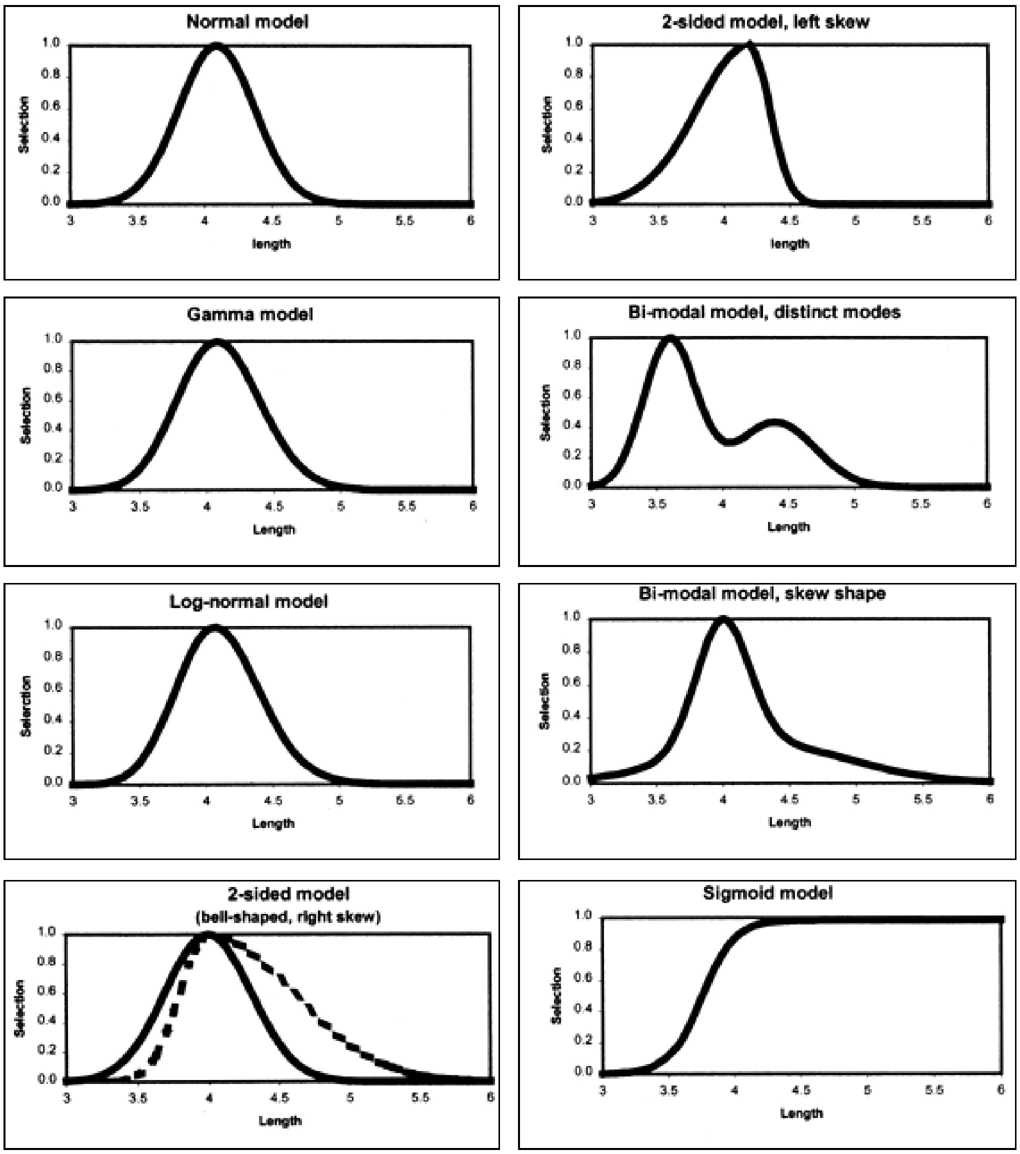

Figure 9: Examples of the potential shapes of the selection curve expressions given in Table 1 (Hovgård and Lassen 2000).

There are not many studies available on estimated size distributions. Finstad *et al*. (2000) compared the age and length distributions of arctic char from gillnet catches and estimated directly from mark-recapture experiments. The results of their study show a strong underestimation of smaller-sized fish when sampling with gillnets. The study of gillnet selectivity of the cod population in the North Sea showed the same tendency (Hovgård *et al.* 1999).

So when sampling fish for research purposes it is important to be aware of the size selectivity of various mesh sizes. A precautious approach should be followed when interpreting the data sampled with gillnets. Therefore, it is obvious that where possible, using less selective sampling gears would give less biased results.

3 MATERIAL AND METHODS

3.1 Study areas

Routine coastal fish monitoring using gillnets was initiated in 1992 in cooperation with the Institute of Coastal Research (Sweden) off the south-eastern coast of Hiiumaa Island as the Helsinki Commission (HELCOM) Co-ordination Organ for Baltic Reference Areas (COBRA) warm water fish monitoring area. Later this monitoring was extended to other permanent study areas including the gulfs of Riga and Finland (Saat *et al.* 2003). The first year's catch was not recorded separately by each net and is excluded from the current study. All six areas are included in the present study (Figure 6):

Figure 10: Location of study areas, i.e. areas of permanent warm-water species monitoring.

1. Kihnu (1997-2004). Sampling around the island, depending on weather conditions. Intensive coastal fishery.
2. Vilsandi (1997-2004). Sections a) in sheltered Kuusnõmme Bay, b) west and north of Vilsandi Island. Limited fishery in the monitoring area but intensive in adjacent areas.
3. Matsalu (1995-2004). Inner, central and outer part of bay are covered by test-fishing. Fishery in the bay increased in 1993 but has been declining in recent years.
4. Hiiumaa (1998-2004). HELCOM COBRA reference area including two sections (Saarnaki and Sarve). Both sections are fished in six fixed stations during six nights (36+36 stations altogether). Coastal fishery increased in the 1990s but is declining again.
5. Käsmu (1997-2001, 2003-2004). Käsmu Bay and adjacent bays. Coastal fishery mostly limited to salmonids and whitefish.

6. Vaindloo (1997-2004). Western coast of a remote island. Coastal fishery almost absent. (Saat *et al.* 2003).

3.1.1 Gillnetting

The survey is conducted every year in July and August in the same order of areas from south to north, Kihnu always being the first area and Vaindloo the last. In some cases (depending on weather conditions) the sampling effort has been reduced (e.g. Matsalu 2001, Tables 2 and 3).

In the Hiiumaa reference area (area 4) the location of stations is fixed, in other areas the locations are selected each day according to weather conditions and differ between years, so for each setting occasion the position of the station is recorded. For each setting the water temperature of the surface layer (0.5-1 m), the section depth, wind direction and approximate speed (ms^{-1}) are recorded. The vessels used are 5.2 and 5.4 m long open boats with 0.5-0.75 m between the board and water surface (Figure 7).

Table 2: Number of stations sampled between 1995 and 2004 in the study areas (Figure 6). NA – not available.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Kihnu (1)			13	10	11	12	20	20	20	20
Vilsandi (2)			12	11	10	12	20	20	20	21
Matsalu (3)	51	42	41	39	42	42	35	40	40	40
Hiiumaa (4)				72	72	72	72	72	72	72
Käsmu (5)			12	13	14	25	20	NA	20	22
Vaindloo (6)			3	5	4	4	5	5	4	6

Table 3: Number of fish caught (all species) between 1995 and 2004 in the study areas (Figure 6). NA – not available.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Kihnu (1)			1178	129	218	1070	2357	1691	676	409
Vilsandi (2)			792	220	997	355	875	1199	739	604
Matsalu (3)	5866	2496	1913	920	4044	3021	1742	2548	3390	1900
Hiiumaa (4)				2732	1282	2815	2748	1505	2376	1216
Käsmu (5)			1356	1058	1611	1078	732	NA	719	1304
Vaindloo (6)			469	212	608	566	674	890	358	503

The series of nets consists of six bottom gillnets with mesh sizes 17, 21, 25, 30, 33 and 38 mm, measured from knot to knot. The nets are 1.8 m (6 feet) deep and made of spun nylon. Each net consists of a 60 m long stretched net bundle which is attached to a 27 m floating line (35 cm between floats, buoyancy 6 g/m) and a 33 m lead line (weight 2.2 kg/100 m). Yarn thicknesses are no. 210/2 (2 filaments each weighing 210 g per 10 000 m) for 38-33 mm and no. 110/2 for all other sizes. The colour is green, dark blue or gray irrespective of the mesh size

Figure 11: Lifting of the gillnets in the morning at the Vaindloo study area in 2004. Photo by author.

(Thoresson 1993). Hanging ratio has not been measured, the nets are loosely rigged or a little streched. Buoys and weights are used at both ends of the station. The nets in one station are tied together at the upper corner and the bottom corner is lying in the bottom. The nets are replaced with new ones when needed.

Nets are set between 17:00 to 20:00 at the depth of 2-5 m parallel to the coastline and lifted the following day between 7:00 and 10:00. The catch of each net is recorded separately. All fish are measured individually (weighed to 0.1 g and total length measured to the nearest mm).

Fish retention is unknown and assumed to be equal throughout the series. The proportion of catch enmeshed in different ways is not recorded. In case of perch it is known that the bigger fish can be entangled by spiny dorsal fins or by gill cover. Roach is typically caught gilled or wedged.

As perch is abundant all over the coastal sea (except for Vilsandi), the data from all areas is used in the calculations (Table 4). Roach is abundant in the Moonsund Archipelago (Matsalu, Hiiumaa) and also in the shallow bays of I. Saaremaa (Vilsandi). Therefore, only data from three areas (Vilsandi, Matsalu and Hiiumaa) is used in the case of roach (Table 5).

Table 4: Number of perch caught between 1995 and 2004 in the study areas (Figure 6). (NA – not available).

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Kihnu (1)			153	27	165	179	2133	755	579	236
Vilsandi (2)			2	22	5	6	81	255	43	95
Matsalu (3)	1192	381	437	73	205	428	530	432	1113	281
Hiiumaa (4)				457	91	1975	1946	734	1182	635
Käsmu (5)			1142	589	1161	487	516	NA	594	727
Vaindloo (6)			426	146	410	468	570	757	351	459

Table 5: Number of roach caught between 1995 and 2004 in the study areas (Figure 6). (NA – not available).

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Kihnu (1)			56	0	1	1	21	159	14	13
Vilsandi (2)			307	95	6	102	307	263	173	62
Matsalu (3)	2960	1618	1126	508	2429	1720	470	610	995	671
Hiiumaa (4)				1588	714	569	515	264	294	142
Käsmu (5)			22	2	10	7	8	NA	6	13
Vaindloo (6)			7	1	0	0	1	0	3	0

3.1.2 Statistical analysis

Selection pattern calculations are based on length. The raw length data in millimetres was transformed to 0.5 cm length groups to include as much information as possible.

To estimate the selectivity of the gillnet series, three different type A selection curves are tried to fit to the catches of the mesh sizes used. Normal, lognormal, and gamma models according to Millar and Fryer (1999) are tested to fit the relative length distributions of catches of each mesh size simultaneously. All data collected from all areas and years is used in the different models. The selectivity model gives the best fit for the gamma function, which is selected for further calculations (Millar and Fryer 1999; Hovgård and Lassen 2000):

$$S(\lambda \mid \alpha, \beta) = \left[\frac{l}{(\alpha-1)\beta}\right]^{(\alpha-1)} \exp\left[\alpha - 1 - \frac{l}{\beta}\right], \qquad (1)$$

where λ is length/mesh size, α and β (k*mesh size) are the parameters estimated in the fitting process and l is the length of fish.

As there are rather few fish in some strata, the bootstrapping method (Haddon 2001) is used to find the best selection curves. Length distribution from each strata is re-sampled for each mesh size separately. The value of α is estimated from the pooled data and estimated α is then used in fitting k for each bootstrap sample. The number of bootstrap iterations is 1000. *Alpha* and mean value of k from bootstrapping analysis is used to calculate the optimal length for each mesh size:

$$(\alpha-1)\,\beta \qquad (2)$$

The selectivity curves obtained are used to calculate the estimated length distributions (in mm) from the catches using the gamma lines (*1*, Fig. 4, 10) of every mesh size. The pooled results of all mesh sizes (*4*, Figure 6, 10) are used to estimate the relative abundance of each size of fish in the population according to Gulland and Harding (1961): for a length l, if a mesh size m has a relative efficiency of ${}_mP_l$, and catches ${}_mN_l$ fish, then the abundance in the population is proportional to:

$$(3) \qquad \frac{\sum_m {}_mN_l}{\sum_m {}_mP_l}$$

For the estimated length distribution calculations, the maximum ${}_mP_l$ is taken as 1 and the ${}_mP_l$ is divided with max ${}_mP_l$:

$$(4) \qquad \frac{\sum_m {}_mN_l}{\sum_m \left({}_mP_l * \max {}_mP_l^{-1}\right)}$$

In calculations of estimated length distributions the selectivity pattern for all strata is used. The results are transformed to 1 cm length groups for better graphical presentation.

For the evaluation of the representation of the gillnet series used, the pooled selection curves of different mesh sizes are used. The suggestions of additional mesh sizes are based on the estimated parameters (*α*, *k*) of existing mesh sizes. When predicting the Nordic Multimesh gillnet selectivity curves and length distributions and also the hypothetical series, it is assumed that the twine parameters and hanging ratios are the same as in the given gillnet series.

The calculations and modelling is carried out using the programming package R (Copyright 2004, The R Foundation for Statistical Computing Version 2.0.0 (2004-10-04), ISBN 3-900051-07-0), and Microsoft Excel.

4 RESULTS

4.1 Perch

Altogether, length data of 25,704 perch caught with gillnet series from all six areas were used in the bootstrapping iterations (Table 6). The pooled length distribution was dominated by the length groups 13-24 cm (Figure 8).

Table 6: The optimal length, parameters, the 50% selection range (W) derived from bootstrapping and the number of perch used in bootstrapping.

Mesh size (mm)	17	21	25	30	33	38
Optimal length (cm)	13.376	16.467	19.038	22.046	23.580	26.660
A	207.271	146.2509	187.9596	242.9752	249.8826	276.1479
K	0.003815	0.0053984	0.004073	0.003037	0.002871	0.00255
W (cm)	1.4	2.0	2.0	2.1	2.2	2.4
No of fish (raw data)	5870	6882	6314	4014	2020	604

As the length distribution of perch was skewed to the right at mesh sizes 17-25 mm, the present model overestimates to some extent the length groups 15-27 cm according to the selectivity curves for each mesh size (Figure 9).

The 50% selection range (W, calculated as 75% relative efficiencies) increases progressively as the mesh size increases (Table 6, Figure 9). Length distribution of mesh size 38 mm in Figure 9 also shows the higher proportion of smaller length groups available for the gillnets in the study areas and

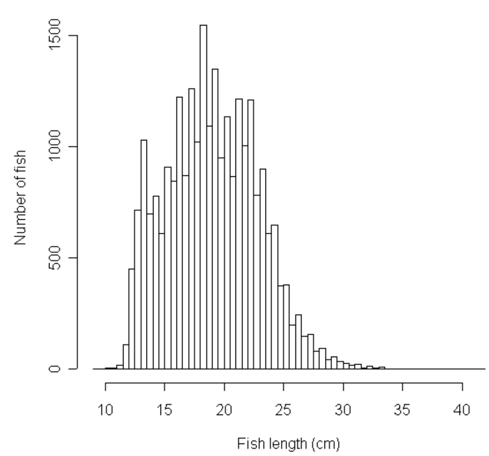

Figure 12: Length distribution of perch in 0.5 cm groups sampled with gillnet series and used in the selectivity calculations (n=25704).

scarceness of bigger fish in some study areas (Kihnu, Vaindloo).

Selection curves of meshes 30 and 33 mm showed some overlapping, but the optimal lengths over all net series showed rather even coverage of length groups (Figure 10).

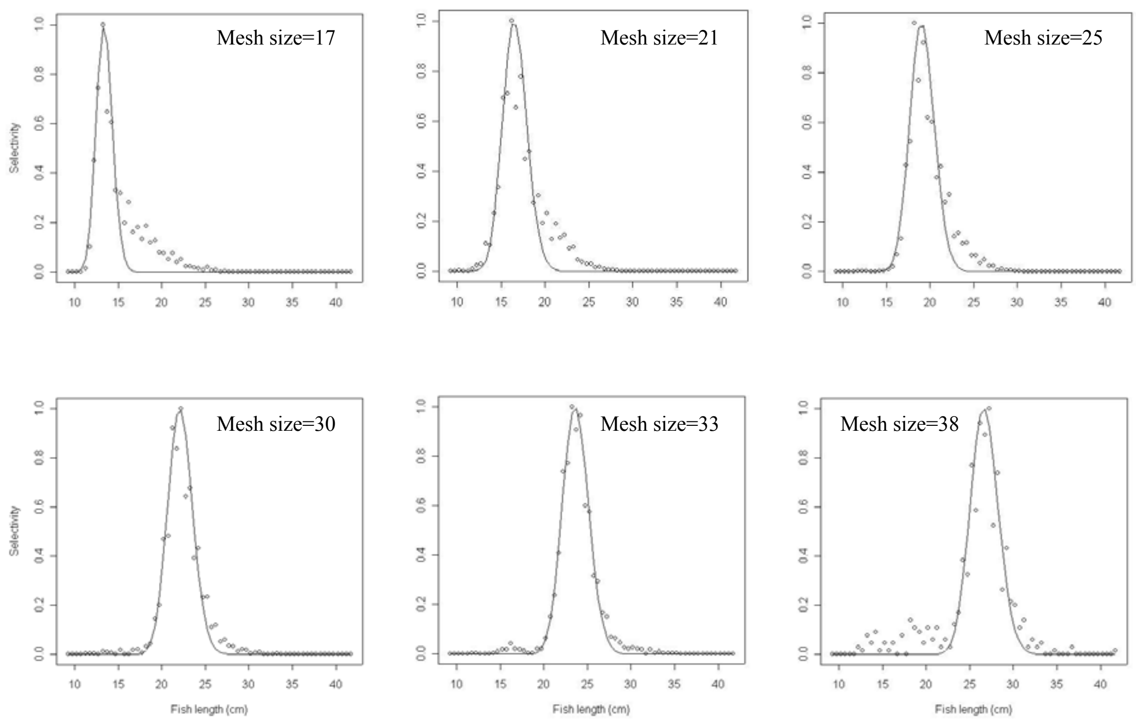

Figure 13: Fitting of the gamma curves on relative length distribution of perch over the mesh sizes.

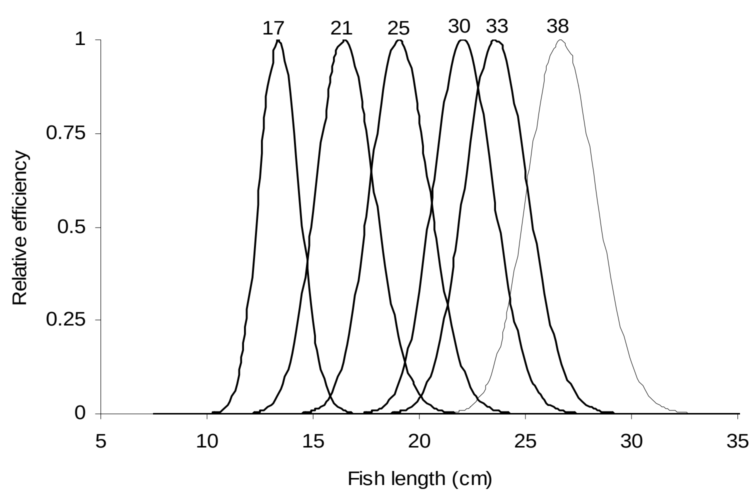

Figure 14: Gamma curves of different mesh sizes of perch over the gillnet series.

The summarized selectivity curves show that size groups 17-27 cm of perch were overrepresented in the gillnet catches (Figure 11). The transformed relative abundances were used when calculating estimated length distributions.

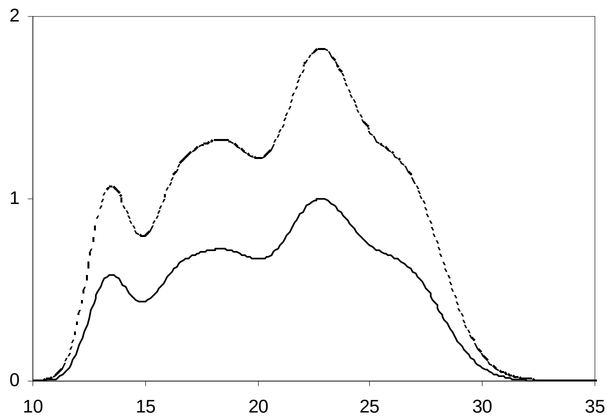

Figure 15: Relative abundance of the length groups (cm) of perch in the gillnet catches (dotted line) and transformed abundance with maximum at 1 (whole line) according to the selection pattern of different mesh sizes.

4.2 Roach

Altogether length data of 19,981 roach caught with gillnet series from three areas were used in the bootstrapping iterations (Table 7). The pooled length distribution was dominated by the length groups 14-25 cm (Figure 12).

Table 7: The optimal length, parameters, the selection range (W) derived from bootstrapping and the number of roach used in bootstrapping.

Mesh size (mm)	17	21	25	30	33	38
Optimal length (cm)	14.534	17.802	20.712	23.044	24.253	24.159
A	157.605	96.12108	108.7232	234.8075	357.526	94.12929
K	0.005459	0.0089121	0.007691	0.003285	0.0020614	0.006827
W (cm)	1.7	2.7	3.1	2.3	1.9	3.8
No of fish (raw data)	3403	5538	5711	3537	1541	251

The 50% selection range (W, calculated as 75% of relative efficiencies) increases progressively in mesh sizes 17-25 cm, and shows no pattern in mesh sizes 30-38mm (Table 7, Fig. 13). The optimal length for the biggest mesh size 38mm according to the gamma model is smaller than for 33 mm, and as seen also in Figure 13, the gamma function fitted poorly to the length distribution in the catches of mesh size 38mm and showed the scarceness of fish of optimum length and larger (Table 7). Length distribution of roach was skewed to the left at mesh sizes 30-33 mm and was uniformly distributed over the mesh sizes 17-25 mm (Fig. 13). Although the optimal length is overlapping in mesh sizes 33-38 mm, the length distribution is wider in 38 mm net (Fig. 14) and the net catches more large fish than smaller mesh sizes.

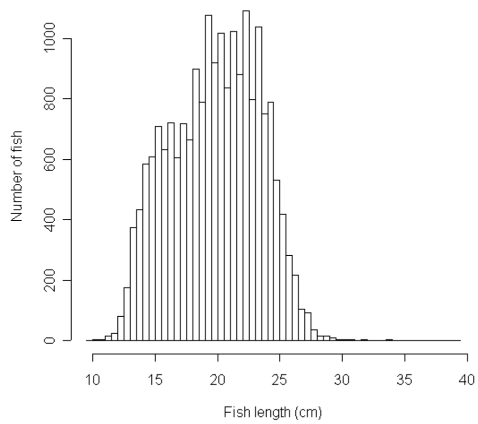

Figure 16: Length distribution of roach in 0.5 cm groups sampled with gillnet series, used in the selectivity calculations (n=19,981).

The summarized selectivity curves show that size groups 17-27 cm of roach are overrepresented in gillnet catches (Figure 15) as well as in case perch, reflecting the length distribution of raw data (Figure 12).

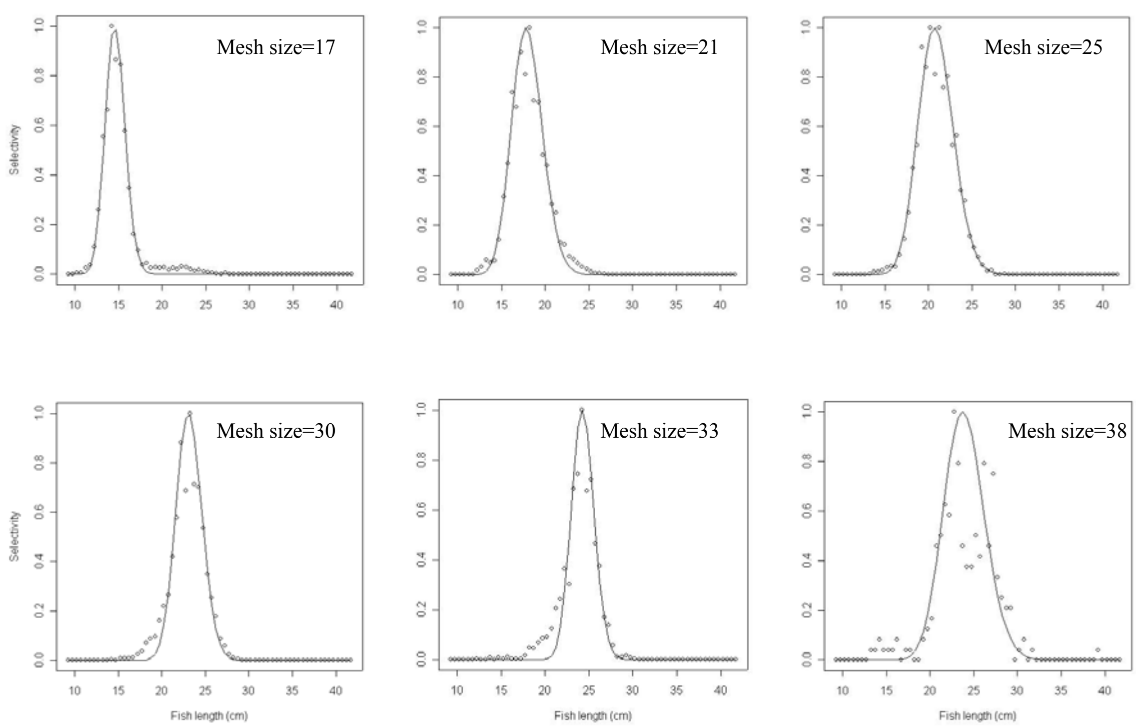

Figure 17: Fitting of the gamma curves on relative length distribution of roach over the mesh sizes.

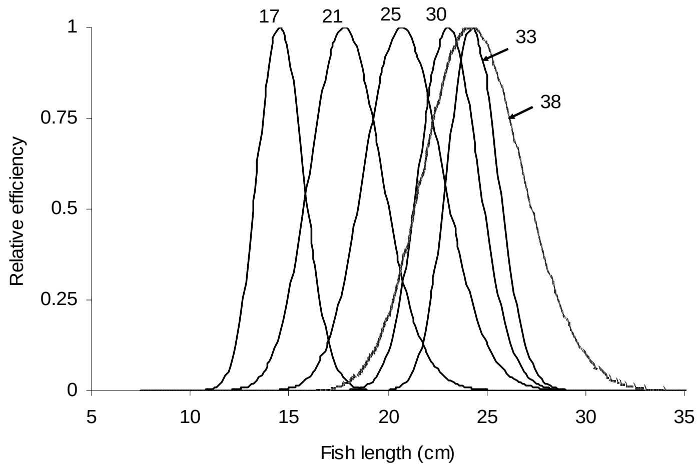

Figure 18: Gamma curves of different mesh sizes of roach over the gillnet series.

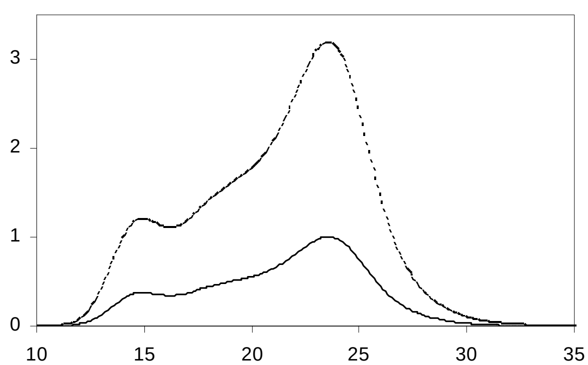

Figure 19: Relative abundance of the length groups (cm) of roach in the gillnet catches (dotted line) and transformed abundance with maximum at 1 (whole line) according to the selection pattern of different mesh sizes.

Comparison of the observed and expected weights was also used to see if there are any differences in condition factor (CF) between the areas. As expected, because of fish caught in August (the growing season has lasted longer than fish caught in July) there were slight differences between Kihnu as the first area to be studied every year and other areas. But comparing the selection patterns based on lengths between these areas the effect of CF on the broadness of the curves of the areas with different CFs was marginal and therefore the CF was not taken in the further calculations.

4.3 Estimated length distributions

The length distributions from gillnet catches and the estimated length distributions based on the summarized selection curves of perch (Fig. 16) and roach (Fig. 17) in the past four years are compared in the Matsalu study area. Using the method of pooled selectivity curves of different mesh sizes the number of smaller and bigger fish in the catches cannot be estimated because of fewer fish caught.

In the case of roach, the gamma model fitted poorly to length distribution of mesh size 38 mm. When using the parameters estimated for mesh size 30 mm, also in mesh size 38 mm, the optimal length for roach would be 29.2 cm instead of 24.2 (Table 7). As can be seen in Figure 12, there are almost no roach caught of this size. Therefore the estimated length distributions of roach are based on mesh sizes 17-33 mm.

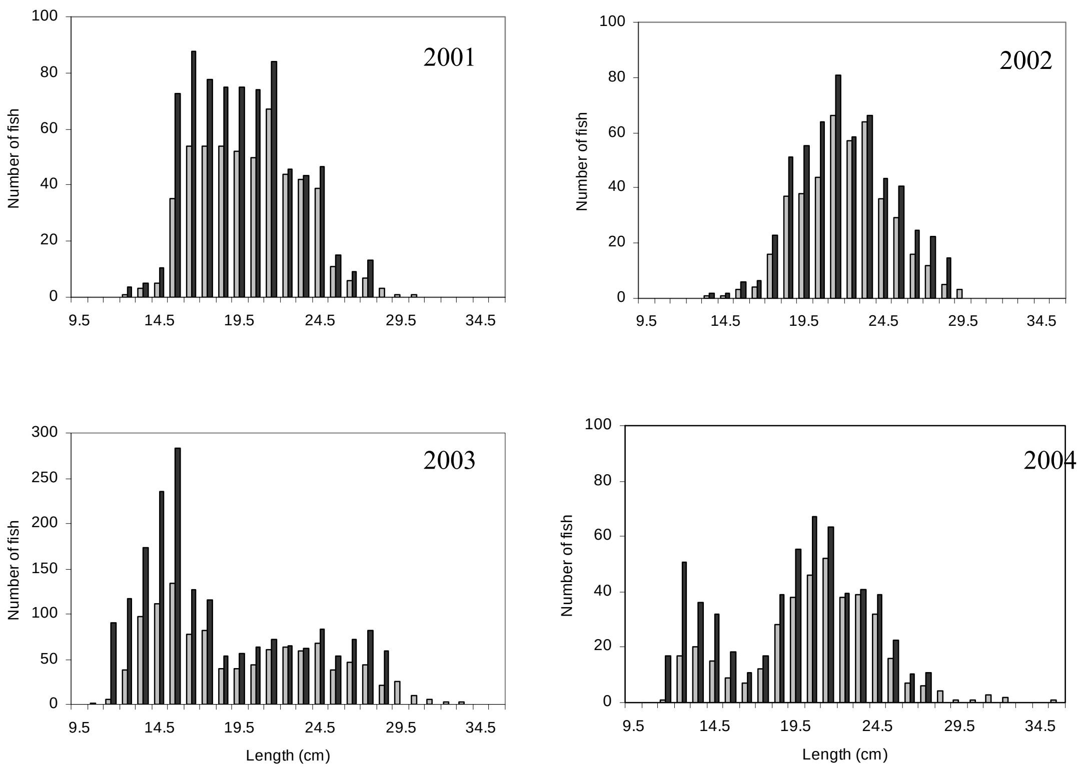

Figure 20: Length distribution of gillnet catches (grey) and estimated from the pooled selectivity pattern (black) of perch in Matsalu study area in 2001-2004.

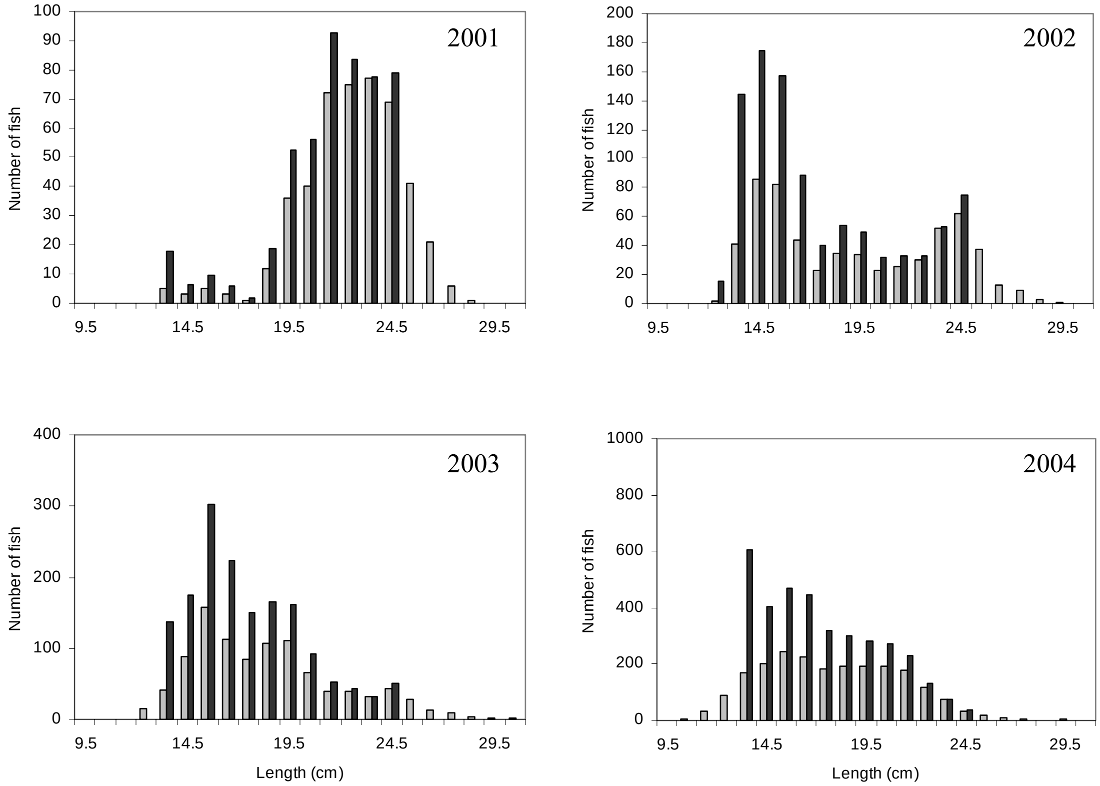

Figure 21: Length distribution of gillnet catches (grey) and estimated from the pooled selectivity pattern (black) of roach in Matsalu study area in 2001-2004.

The length range of fish caught reflects the optimal lengths of smallest and biggest mesh size. The optimal length for mesh size 17 mm is 13.4 cm for perch (Table 6) and 14.5 cm for roach (Table 7) and for mesh size 38 mm 26.7 cm for perch and 24.2 cm for roach.

The length distributions also show the strongest underestimation of the 15 cm perch in the catches. The peaks in estimated and gillnet length distributions coincide more or less in perch (Figure16).

In the case of roach, the relative underestimation of smaller fish in gillnet catches is much higher (Figure 17). This is in accordance with findings of Finstad *et al*. (2000), and Hovgård *et al*. (1999), who described the same tendency in sampling with gillnets.

4.4 Additional mesh sizes: suggestions

Size groups 17-27 cm for both species are overrepresented in the catches (Figures 11 and 15). To find better theoretical combinations of mesh sizes, some hypothetical series based on the existing series are given based on the estimated parameters. Perch is selected for calculations because of the more even coverage of length groups by the present series. Where possible, decimals are avoided.

Series 1. Dense series. Mesh sizes 14, 15.5, 17, 19, 21, 23, 25, 27, 30, 33, 35.5 and 38 mm (Figure 18). All the size groups are covered at least by 75%. The 12 mesh sizes gives the best coverage over the size range without gaps, considering that it is based on the present mesh sizes. Mesh size composition follows geometrical series; the ratio between mesh sizes is approximately 1.1 (1.07-1.12).

Series 2. Even series. Mesh sizes 13.5, 15.5, 18, 21, 25, 30, 35 and 40 mm (Figure 19). This hypothetical series is largely based on the existing series with slight modifications of mesh sizes. It follows a geometric series; the ratio between mesh sizes is approximately. 1.17 (1.142-1.2). It consists of fewer nets and in practice would give even coverage of length groups with less effort than needed with series 1.

Series 3. Nordic series: geometric series used in the freshwater and is probably soon to be used also in coastal fish monitoring in Sweden (Appelberg *et al.* 2003). Mesh sizes 10, 12, 15, 19, 24, 30 and 38 mm (Fig. 20). The ratio between mesh sizes is 1.25. The gaps are too big between mesh sizes 15 and 19mm and also between 30 and 38 mm to cover all the size ranges of fish evenly, assuming that the other net characteristics are the same.

Series 4. Series with two additional smaller mesh sizes. Mesh sizes 11.5, 14, 17, 21, 25, 30, 33 and 38 mm (Figure 21). It follows a geometric series with ratio between mesh sizes being 1.215 in meshes 11.5-30 mm.

The pooled relative abundance of all mesh sizes is given in Figure 22. Figure 23 also shows the selection curves of roach based on the series 3.

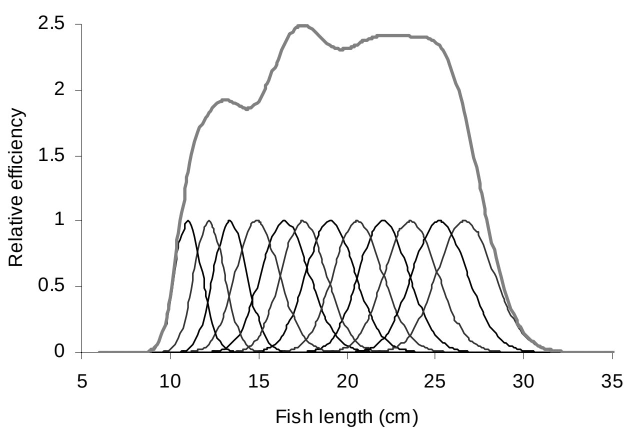

Figure 22: Series 1 (perch). Existing and additional mesh sizes with at least 75% coverage. Mesh sizes 14, 15.5, 17, 19, 21, 23, 25, 27, 30, 33, 35.5 and 38 mm.

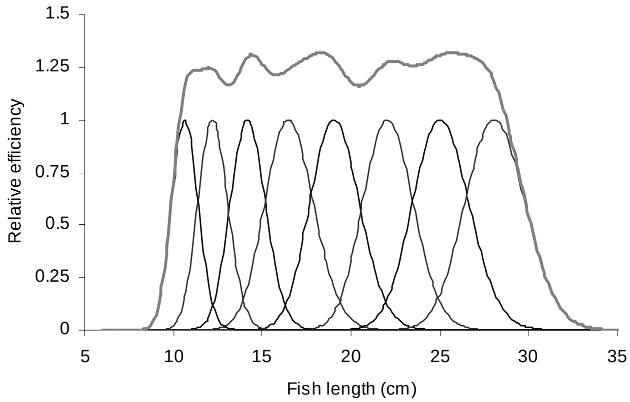

Figure 23: Series 2 (perch). Even series, largely based on the existing series. Mesh sizes 13.5, 15.5, 18, 21, 25, 30, 35 and 40 mm.

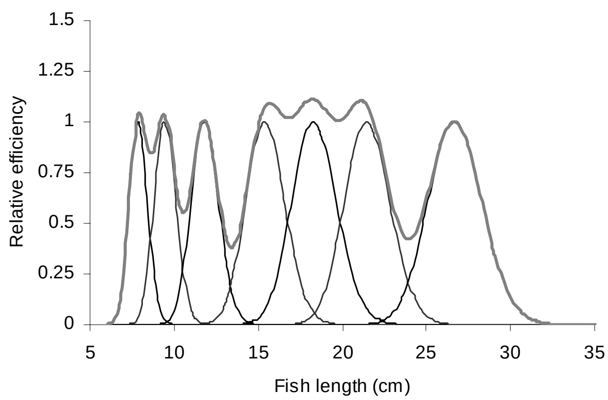

Figure 24: Series 3 (perch). Nordic multimesh series, mesh sizes 10, 12, 15, 19, 24, 30 and 38 mm.

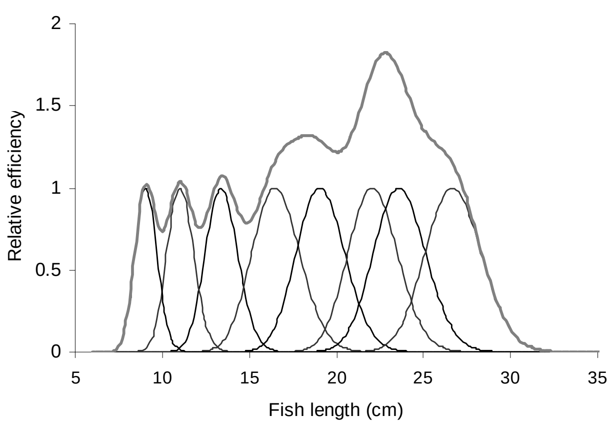

Figure 25: Series 4 (perch). Existing gillnet series with two additional mesh sizes: 11.5 and 14 mm.

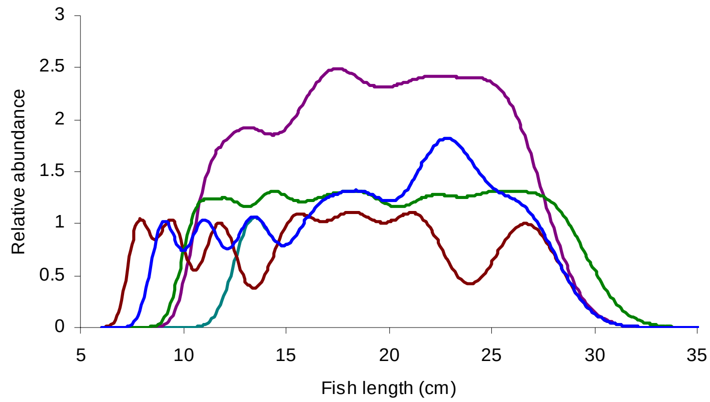

Figure 26: Comparison of relative abundances of perch of the different gillnet series: existing series; series 1; series 2; series 3; series 4.

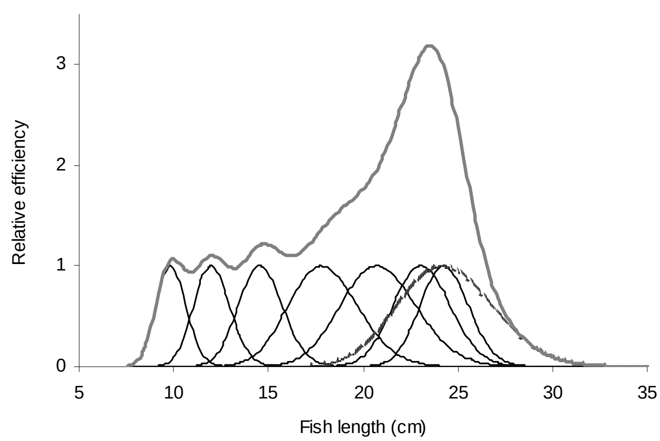

Figure 27: Series 4 (roach). Existing gillnet series with two additional mesh sizes: 11.5 and 14 mm.

5 DISCUSSION

5.1 Selectivity pattern

This study demonstrated the differences in selectivity patterns of gillnet series in sampling of perch and roach and the differences in the length distributions of gillnet catches and after estimated size distribution of the population.

The length distribution of perch and roach caught with gillnets is not the same (Figures 8 and 12) and presumably reflects the most abundant size groups in the study areas. The differences between the selection patterns of the species studied can be explained by the differences in body morphology (Figures 2 and 3); roach has a softer body and can compress more whilst perch has strong fins and a harder, less compressible body. The girth of perch and roach of the same size, although never measured, could also be different. This might be one explanation as to why roach captured in the same mesh size are longer than perch (Tables 6 and 7). However, differences in the distribution pattern may also provide an explanation. For example, perch in the Matsalu Bay study area was homogeneously distributed and abundant all over the bay with the larger fish preferring shallower areas in the inner part of the bay, whereas the abundance and size of roach increased towards deeper areas (the outermost part of the bay; (Albert *et al.* unpublished)). So in preferred areas, different size groups of roach and perch could be covered by different sampling efforts.

According to the gamma model used, size groups 17-27 cm of perch and roach are overrepresented using the current gillnet series. Due to skewed data that is not covered by the model (Figures 9 and 13), it may be assumed that the overrepresentation is not as high for size groups 17-25 cm of perch (Figure 11) and 17-22 cm of roach (Figure 15). However, Hovgård *et al*. (1999) found that the estimated size distributions of cod were largely independent of the choice of the selectivity model used.

Figures 8 and 12 also show that there were not many fish bigger than 25 cm caught with the gillnet series and therefore it may be concluded that size groups 17-25 cm are actually dominating the study areas.

There are slight differences in the twine characteristics between the nets with mesh sizes 17-30 mm and nets with mesh sizes 33-38 mm as described in the methodology (p. 13). Twine diameter has been reported to affect the catching ability of a mesh (Hamley 1975, Hovgård *et al.* 1999). But Kurkilahti and Rask (1996) suggest that the slightly different twine diameter and mesh size combination has no effect of catches of roach and perch of different gillnet types. The possible effects of twine colour on the encounter rate have been mentioned (Hamley 1975, Holst *et al.* 1998). As it depends on the amount of light and water transparency, colour is unlikely to have any relevant effects in this case, as nets were set overnight.

Hamley (1975) suggested that each way a fish is captured should be described as a normal curve and the total selectivity by the sum of these curves. In entangling (perch, meshes 17, 21 and 25 mm, Figure 9) and probably snagging (perch, mesh 38 mm; roach meshes 30, 33, 38 mm; Figures 9 and 13) it is likely that the skewed side could be described as a second curve. As the way of capture (Figure 4) is not recorded, it would be hypothetical to separate the length distributions according to this. An experimental study would enable more accurate assumptions on different curves for each mesh size.

The heights of selectivity curves of different mesh sizes describe how efficiently the mesh catches fish of the optimum length (Hamley 1975). In practice it rarely occurs that the efficiency is the same (Hovgård *et al.* 1999). So one assumption is that the catching ability remains constant over the gillnet series. Heights of the curves increase exponentially and entangling occurs over a progressively narrower range as the mesh size increases (Hamley 1975). The latter can be observed in the selection curves of perch, where the entangling component seems to be higher in the smaller mesh sizes (Figure 9), probably as a consequence of the body morphology of perch (strong fins and sharp gill cover).

The estimated length distributions (Figures 16 and 17) even out the over and under representations of the selective length distributions of size groups 12-28 cm in the gillnet catches according to the pooled selectivity curves (Figures 11 and 15).

The above estimates of selection patterns are nevertheless indirect and length distributions should therefore be regarded as estimates only. Nevertheless, the study demonstrates that the use of gillnet series for assessing population structure may result in bias with regard to interpretations of size structure, and hence further biological interactions, if the sampling bias is not taken into account. However, time series of samples obtained with gillnet series may give valuable information about relative changes in population structure, which is actually the main purpose of the monitoring.

A direct estimation of target species catch-ability and net selectivity could be done by:

a) comparison with gear of known selectivity. In the present case it is very difficult to do this kind of estimation as the study areas are shallow and using different type of gear is limited. The gears used besides gillnets are usually trap nets and beach seines with unknown selectivity and escapement rate. Using sonars or detonations with limited power (Sandström and Karås 2002) would probably give unselective results, but only in limited space.

b) fishing a known population, e.g. releasing tagged fish into the environment before the gillnetting is begun.

Tagging could be carried out in a limited space, e.g. enclosed bay. As fish can not be caught by gillnets to avoid injuries before tagging, other type of gears, e.g. trap nets and beach seines are suggested. The tags selected for selectivity studies should not increase the catch-ability of fish, i.e. the usual spaghetti tags by the dorsal fin are not suitable. Cutting of fins (Finstad *et al.* 2000) is not suggested as it may also affect the catch-ability.

However, injected colour codes could be used. In practice direct estimations are seldom used because of the expense of providing known populations of fish. Tagging would however provide us with better estimations of selectivity of the gillnet series.

5.2 Evaluation of the gillnet series and suggestions

As mentioned above, fish less than 12 cm in length are not caught in the gillnet series. There are two possible and probably true explanations for this: *a*) the mesh size is too big to catch smaller fish and *b*) there are no small fish in the areas where the nets were set (the depth of gillnetting was set according to the original method 2-5 m. Therefore habitats of smaller size classes may not be covered by gillnetting). The second explanation is related to the circumstance that fish which move fast, have a higher probability of encountering the gear compared to slow moving fish. It is known that larger fish move faster than small fish of the same species (the swimming speed can be approximated by constant times a power function of a length (Wardle 1996)) and cover larger areas (Millar and Fryer 1999), and combined with a larger mass, increased energy for entanglement (Finstad *et al.* 2000). Therefore the fishing effort with passive gears like gillnets should be progressively higher towards smaller mesh sizes.

The present gillnet series overestimates to some extent the size groups 17-27 cm, especially in roach, as mentioned above (Figures 11 and 15). Reducing the number of nets (e.g. mesh size 33mm) would lead to the opposite that is, underestimation of larger size groups (23-26 cm) as seen in Figure 21, where the consecutive mesh sizes are 30 and 38 mm. As there were rather few fish caught with nets of mesh size 38 mm, there is no reason to add larger mesh sizes to the existing series.

Figure 28: Sticklebacks in the multimesh gillnet catch in the coastal sea. Photo by M. Vetemaa.

The best solution would be to cover all the length groups as well as possible (Figure 18). In practice, this is far too expensive and time-consuming. Geometric series based on the Nordic-type multimesh gillnet seems to give leave serious gaps in the lengthdistribution according to the present model (Figure 20) and therefore can not be suggested. As the present gillnet series provides coverage sufficient enough of fish longer than 12 cm, the most optimal solution would be to add smaller mesh sizes (Figures 21 and 23). As roach captured in the same mesh size are longer than perch, the need for smaller mesh sizes is obvious especially when sampling roach. As such, the discontinuation of long-term data series can also be avoided.

Adding smaller mesh sizes to the existing series should also be followed by having more gillnet stations in shallower water. The smaller mesh sizes hopefully catch better not only smaller size-classes of perch and roach, but also the small-sized species like black goby

(*Gobius niger*) and great sandeel (*Hyperoplus lanceolatus*), which are known to be abundant (R. Eschbaum, personal communication). The negative side is the possibility of catching myriads of sticklebacks (Figure 24). Sampling with supplementary gillnets would also give experimental and more direct evaluation on the length distribution estimated here and allow more accurate estimation of selectivity in the future.

5.3 Conclusions

i. The size groups 17-27 cm of perch and roach are overrepresented in the catches using the gillnet series and the size groups less than 12 cm are covered insufficiently.
ii. The estimated length distributions even out the over and underestimations in size groups 12-28 cm.
iii. Reducing the number of nets or adding larger mesh sizes is not needed when considering species like perch and roach.
iv. Assuming the net characteristics to be same as gillnet series, the geometric series based on Nordic-type multimesh gillnet seems to leave serious gaps in the length distribution.
v. The optimal solution in terms of continuing the long-term dataset is adding nets with smaller mesh sizes to the present gillnet series.
vi. For better estimations of selectivity and evaluation of gillnet series the experimental studies e.g. recording the different ways the fish are captured and tagging experiments are recommended.

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LIST OF REFERENCES

Appelberg, M., Holmqvist, M. and Forsgren, G. 2003: An alternative strategy for coastal fish monitoring in the Baltic Sea – *ICES CM* R:03, 13 pp.

Eschbaum, R., Saat, T., Vetemaa, M., Verliin, A., Eero, M., Albert, A. and Špilev, H. 2004: Eesti rannikumere kalastiku muutused viimastel aastatel (Changes in coastal fish assemblages and populations in Estonia during recent years). – *Estonia Maritima* 6: 73-109 (in Estonian with English Summary).

Finstad, A. G., Jansen, A. and Langeland, A. 2000: Gillnet selectivity and size and age structure of an alpine Arctic char (*Salvelinus alpinus*) population [Electronic version]. – *Canadian Journal of Fisheries and Aquatic Sciences* 57: 1718-1727.

Gulland, J.A. and Harding, D. 1961: The selection of *Clarias mossambicus* (Peters) by nylon gill nets. – *J. Cons. Cons. Int. Explor.Mer*, 26: 215-222.

Haddon, M. 2001: *Modelling and quantitative methods in fisheries*. Chapman and Hall/ CRC, 406 pp.

Hamley, J.M., 1975. Review of gillnet selectivity. *Journal of Fisheries Research Board of Canada* 32: 1943-1969

Helser, T. E., Geaghan, J. P. and Condrey, R. E. 1998: Estimating gillnet selectivity using nonlinear response surface regression [Electronic version]. – *Canadian Journal of Fisheries and Aquatic Sciences* 55: 1328-1337.

Holst, R., Madsen, N., Moth-Poulsen, T., Fonseca, P. and Campos, A. 1998: *Manual for GillNet Selectivity*. European Commission, 43 pp.

Hovgård, H., Lassen, H., Madsen, N., Moth Poulsen, T. and Wileman, D. 1999: Gillnet selectivity for North Sea Atlantic cod (*Gadus morhua*): model ambiguity and data quality are related [Electronic version]. – *Canadian Journal of Fisheries and Aquatic Sciences* 56: 1307-1316.

Hovgård, H. and Lassen, H. 2000. Manual on estimation of selectivity for gillnet and longline gears in abundance surveys. – *FAO Fisheries Technical Paper* 397: 84 pp. FAO, Rome.[10.11.2004] http://www.fao.org/documents/

Jensen, J.W. 1986: Gillnet selectivity and the efficiency of alternative combinations of mesh sizes for some freshwater fish. – *Journal of Fish Biology* 28: 637-646.

Kurkilahti, M. and Rask, M. 1996: A comparative study of the usefulness and catchability of multimesh gill nets and gill net series in sampling of perch (*Perca fluviatilis* L.) and roach (*Rutilus rutilus* L.). – *Fisheries Research* 27: 243-260.

Kurkilahti, M., Appelberg, M., Hesthagen, T. and Rask, M. 2002: Effect of fish shape on gillnet selectivity: a study with Fulton's condition factor [Electronic version]. – *Fisheries Research* 54:153-170.

Millar, R.B. and Fryer, R.J. 1999: Estimating the size-selection curves of towed gears, traps, nets and hooks [Electronic version]. – *Reviews in Fish Biology and Fisheries* 9: 89-166.

Nielsen, L.A. and Johnson, D.L. 1983: *Fisheries Techniques*. American Fisheries Society, Southern Printing Company, Inc., Blacksburg, Virginia, 468 pp: 96-100.

Ojaveer, E. and Pihu, E. 2003: Estonian natural fish waters. – in: Ojaveer, E., Pihu, E. and Saat, T. (eds.): *Fishes of Estonia*. Tallinn, Estonian academy Publishers, 416 pp: 15-27.

Olin, M., Kurkilahti, M., Peitola, P. and Ruuhijärvi, J. 2004: The effects of fish accumulation on the catchability of multimesh gillnet [Electronic version]. – *Fisheries Research* 68: 135-147.

Pihu, E., Järv, L., Vetemaa, M. and Turovski, A. 2003: Perch, *Perca fluviatilis* L. – in: Ojaveer, E., Pihu, E. and Saat, T. (eds.): *Fishes of Estonia*. Tallinn, Estonian academy Publishers, 416 pp: 289-296.

Quang, P. X. and Geiger, H. J. 2002: A Review of the Net Selectivity Problem and a Model for Apportioning Species Based on Size-selective Sampling. – *Alaska Fishery Research Bulletin* 9(1): 16-26.

Saat, T. and Eschbaum, R. 2002: Väinamere kalastik ja selle muutused viimastel aastakümnetel (Fishes of the Väinameri; changes during recent decades). – in: Saat, T. (ed.): *Väinamere kalastik ja kalandus*. Tartu, Tartu Univerity Publishers: 9-45 (in Estonian with English summary).

Saat, T., Eschbaum, R., Vetemaa, M. and Verliin, A. 2003: Ten years of coastal fish monitoring in Estonia: dynamics of fish assemblages and populations [Electronic version]. – *ICES CM 2003/R:14*, 17 pp.

Sandström, A. and Karås, P. 2002: Effects of eutrophication on young-of-the-year freshwater fish communities in coastal areas of the Baltic populations [Electronic version]. – *Environmental Biology of Fishes* 63: 89-101.

Sparre, P. and Venema, S. 1998: Introduction to Tropical Fish Stock Assessment - Part 1: Manual. *FAO Fisheries Technical Paper* 306/1 Rev.2: 64 pp. Fao, Rome. [10.11.2004] http://www.fao.org/documents/

Thoresson, G. 1993. Guidelines for coastal monitoring. – *Kustrapport* 1: 1-35.

Vetemaa, M., Saat, T., Paaver, T. and Turovski, A. 2003: Roach, *Rutilus rutilus* (L.). – in: Ojaveer, E., Pihu, E. and Saat, T. (eds.): *Fishes of Estonia*. Tallinn, Estonian academy Publishers, 416 pp: 164-170.

Von Brandt, A. 1984: *Fish Catching Methods of the World*. Fishing News Books Ltd., England. 418 pp: 355-367.

Wardle, C. S. 1996: Fish behaviour and fishing gear. – in: Pitcher, T. J. (ed.): *Behaviour of Teleost Fishes*. Second edition. Fish and Fisheries Series 7. Chapman and Hall, London. 715 pp: 609-643.