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# POPULATION DYNAMICS OF FLOUNDER (*Platichthys flesus*) IN ESTONIAN WATERS

Tenno DREVS

Estonian Marine Institute, Viljandi mnt. 18b, 11216 Tallinn, Estonia

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**Abstract.** The abundance of flounder in Estonian waters is affected mainly by the inflow of saline water from the North Sea to the Baltic Sea and by fishing. The spawning stock number, biomass, and fishing mortality in the Estonian waters of the Gulf of Finland were estimated by Separable VPA. The spawning stock number and biomass have increased after the last major inflow of saline water from the North Sea to the Baltic Sea. The share of young flounder (1–2 years old) increased rapidly in 1998 (year-classes 1996 and 1997) as a result of the improved spawning conditions and an increase in the number of spawning stock.

**Key words:** flounder, biomass, fishing mortality, Separable VPA, salinity.

## INTRODUCTION

There are at least two reproductively isolated flounder populations in Estonian waters (Mikelsaar, 1984). One of them, which spawns in deep areas west from Hiiumaa Island and in the western part of the Gulf of Finland (Mikelsaar, 1984; Grauman, 1981), has pelagic eggs. These are usually found at salinity over 10‰ (Grauman, 1981). In the Gulf of Finland pelagic eggs can be found at the depths of 100–140 m in March, April, and May. The larvae are found at the depths of 80–120 m in April, May, and June. The other population spawns in shallow waters of the Gulf of Finland west from longitude 26° E (Mikelsaar, 1984). Its demersal eggs are caught at the depths of 4–22 (27) m on the bottom or near the bottom layers, at temperatures from 3.0 to 6.7 °C and salinity from 5.98 to 7.05‰ between 13 May and 10 June (Mikelsaar, 1958). It spawns also in coastal waters of southwestern Finland and probably near western islands of Estonia.

Separable virtual population analysis (VPA) was used to estimate the flounder stock in Estonian waters of the Gulf of Finland in 1991–98, and in Estonian waters of the ICES subdivision 29 (Fig. 1). Separable VPA enables in many cases more complete extraction of the information from the catch-at-age matrixes than simple VPA. It estimates also the fishing mortality of the terminal year and the oldest age group, which VPA does not. An increase in the abundance of pelagic flounder eggs and larvae after the years of the inflow of water from the North Sea into the Baltic was found before (Grauman, 1981). The same occurred also for the Gulf of Finland. A relationship between the inflow of saline water from the North Sea and Estonian flounder landings was revealed earlier (Drevs, 1995, 1996, 1997). The Estonian flounder landings in 1930–39 were 542–1213 t (Kint, 1940). In 1974–98 the maximum landing was in 1983 (1611 t) and the minimum in 1995 (102 t).

Salt water inflows seem to affect also the migrations of the flounder. After the last major inflow in 1993 the spawning stock biomass has increased in Estonian waters of the Gulf of Finland, and in 1998 the share of the 1–2-year-old flounder increased rapidly. Since 1996 the landings have increased in all Estonian waters.

The current work tries to find out the main reasons of the changes in the flounder stock in Estonian waters.

## MATERIAL AND METHODS

The analysed flounders were caught in the coastal area of the Gulf of Finland in 1991–98 with traps, a pound net, and nets with different mesh size. In 1993 a small number of fish were caught with a trawl with mesh size 12 mm (bar length). The age composition of the flounder caught with a trawl did not differ significantly from the flounder caught by other gear. A trawl was used also in the Gulf of Riga in 1998. In the waters off Hiiumaa Island the material was collected with a Danish seine (bar length 50 mm), a trap, and a net (bar length 50 mm).

From 970 to 1401 flounders were analysed from the Gulf of Finland every year in 1991–98. In addition, 542 flounders were analysed from the waters off Hiiumaa in 1996–98. The material was collected mainly in the bays of Tallinn (rectangles 138 and 141 in Fig. 1) and Keibu (rectangle 160), in a smaller amount in the bays of Hara (rectangle 118), Muuga (rectangle 134), Lohusalu (rectangle 148), Lahepera (rectangles 148 and 152), Reigi (in Hiiumaa, rectangle 290), in the Gulf of Riga (rectangle 294), and in the area of Hiiumadal (rectangle 300) (Fig. 1).

The age was determined using the otoliths (Pravdin,1966; Draganik & Kusczynski, 1993). A small number of fish from Hiiumaa was aged by scales. The 1–2-year-old specimens were not used for calculations, because they are under the legal size. Using the age composition, mean weights at age, and total catch, we can find the observed flounder catches ($C_{obs}$) in numbers by different age groups and different years (Table 1).

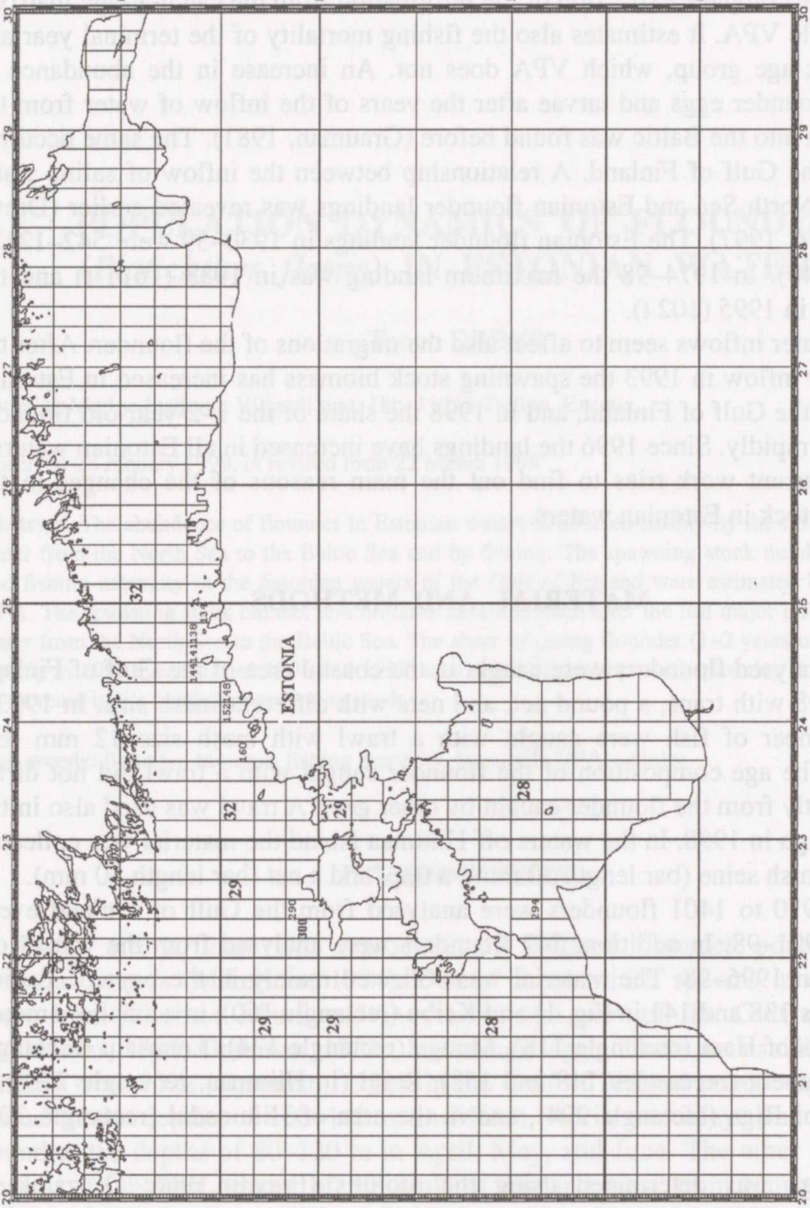


Fig. 1. Distribution of sampling areas in Estonian waters. 28, 29, 32, ICES subdivisions.

**Table 1.** Flounder catches in numbers (thousands) by different age groups (years) in 1991–98 in Estonian waters of the Gulf of Finland

| Age | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| 3 | 181.4 | 91.4 | 94.0 | 109.9 | 93.4 | 426.4 | 299.2 | 529.5 |
| 4 | 150.1 | 93.7 | 105.2 | 84.5 | 113.6 | 463.7 | 246.2 | 157.6 |
| 5 | 34.6 | 33.3 | 71.3 | 59.1 | 43.5 | 232.6 | 139.1 | 67.8 |
| 6 | 5.3 | 5.2 | 24.7 | 17.7 | 9.3 | 105.9 | 90.5 | 44.0 |
| 7 | 1.2 | 2.6 | 10.0 | 9.4 | 2.5 | 19.4 | 34.2 | 14.7 |
| 8+ | 0.8 | 2.6 | 5.8 | 1.7 | 1.4 | 3.0 | 13.2 | 12.8 |
| Total | 373.4 | 228.8 | 311.0 | 282.3 | 263.7 | 1251.0 | 822.4 | 826.4 |

The equation for starting the process of the estimation of the number at the oldest age $A$ and terminal year $Y$ is as follows (Mohn & Cook, 1992):

$$N_{A,Y} = C_{A,Y} Z_{A,Y} \big/ (F_{A,Y}(1-e^{-Z_{A,Y}})), \tag{1}$$

where

$C_{A,Y}$ catch in numbers at terminal age $A$ and terminal year $Y$,
$Z_{A,Y}$ total mortality coefficient at age $A$ and year $Y$,
$Z = F + M$,
$F_{A,Y}$ fishing mortality coefficient at terminal age $A$ and terminal year $Y$,
$M$ natural mortality coefficient.

For natural mortality the value $M = 0.2$ was used for the age groups 3–8+ years (Anon., 1997).

The equation used to step backwards down a cohort was

$$N_{a,y} = \exp Z \times N_{a+1,y+1}, \tag{2}$$

where

$N_{a,y}$ number of fish at age $a$ and year $y$,
$N_{a+1,y+1}$ number of fish at age $a+1$ years and year $y+1$ (Mohn & Cook, 1992).

The hypothesis of separability means that for all the years and age groups

$$F_{a,y} = S_a \times T_y, \tag{3}$$

where $S_a$ is proportional to the selectivity of fishery (an age effect), and $T_y$ is proportional to the fishing effort (a year effect) (Darby & Flatman, 1994; Gassioukov, 1997; Kizner & Vasilyev, 1997). In case of Simple Cohort analysis the fishing mortality is defined as follows: $F_{a,y} = -LN(N_{a+1,y+1} / N_{a,y}) - M$.

For all the $S_a$ the starting value 1 was used and for all $T_y$ the starting value was 0.5. The estimated catch ($C_{est}$) in numbers by ages and years was found by the formula

$$C_{a,y\ \mathrm{est}} = N_{a,y}(1 - e^{-Z_{a,y}}) \times F_{a,y} / Z_{a,y} \text{ (Mohn \& Cook, 1992).} \quad (4)$$

Using Eq. 4 and the starting values, $C_{est}$ was found. The sum of the squares of the differences $\ln(C_{obs}) - \ln(C_{est})$ was minimized by Solver by changing $S_a$, $T_y$, and $F_{a,y}$. The values of $F_{a,y}$, $S_a$, and $T_y$ that correspond to the minimum sum of squares were found. Using formulas 1 and 2 the new estimated numbers were found.

## RESULTS AND DISCUSSION

The total number and biomass of flounders in age groups 3–8+, estimated by Separable VPA in the Estonian waters of the Gulf of Finland, were the highest in 1998 (Figs. 2, 3). The minimum number and biomass of flounder occurred in 1991. The total number and biomass of almost all investigated age groups increased after 1991. The increase of the spawning stock number and biomass in 1992 may have been caused by a decrease in the fishing mortality (Fig. 4). In 1993 the spawning stock biomass and fishing mortality increased. Separable VPA shows the highest fishing mortality for age group 5 years and for the years 1993, 1996, and 1997 (Fig. 4). The minimum fishing mortality was found for the year 1995 and for ages 3, 7, and 8+. In 1998 the total number and biomass of

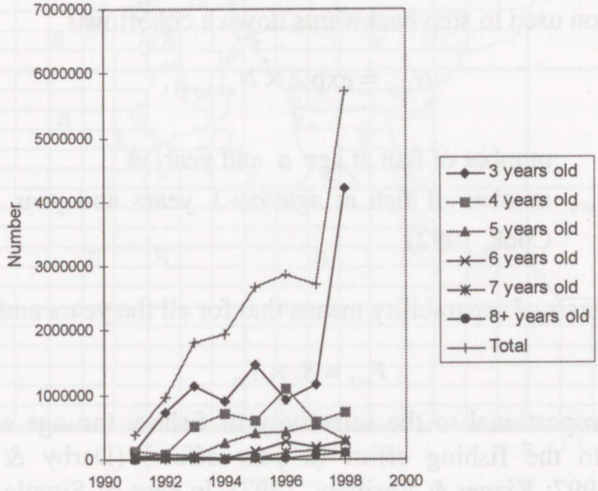


**Fig. 2.** Total number of the spawning stock of the flounder by different age groups and years in the Estonian waters of the Gulf of Finland.

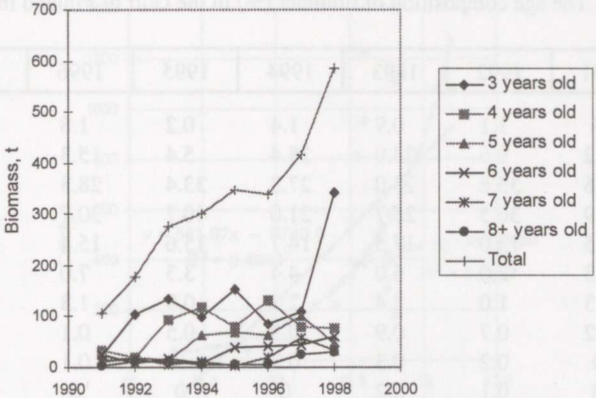


**Fig. 3.** Biomass of the spawning stock of flounder in the Estonian waters of the Gulf of Finland.

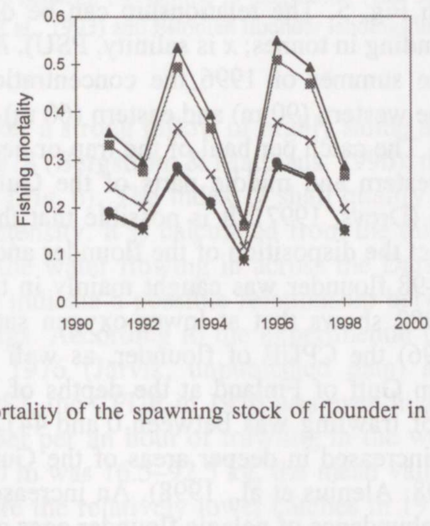


**Fig. 4.** Fishing mortality of the spawning stock of flounder in the Estonian waters of the Gulf of Finland.

3-year-old fish increased rapidly and so did the total spawning stock biomass. The fishing mortality and catch decreased.

After a moderate (in 1993) or a strong inflow (in 1978) of saline water from the North Sea to the Baltic Sea, the flounder catches increased in the Gulf of Finland. Salinity seems to affect the migrations of the flounder. The spawning stock biomass increased before the increase in the share of the young flounder (Table 2). Two flounders tagged and released near the Irbe Strait in Latvia by M. Pliksh were caught in the western part of the Gulf of Finland in August and September 1996. In 1996 also the salinity in the Gulf of Finland increased (Alenius et al., 1998). The linear correlation between salinity in the Gotland Deep and the catches in the Gulf of Finland is usually the strongest with an

**Table 2.** The age composition of flounder (%) in the Gulf of Finland in 1991–98

| Age, years | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1.1 | 0.9 | 1.4 | 0.2 | 1.8 | 0.4 | 9.2 |
| 2 | 8.2 | 9.6 | 23.0 | 28.4 | 5.4 | 15.3 | 22.8 | 42.9 |
| 3 | 44.6 | 35.6 | 23.0 | 27.3 | 33.4 | 28.3 | 27.9 | 30.7 |
| 4 | 36.9 | 36.5 | 25.7 | 21.0 | 40.7 | 30.7 | 23.0 | 9.1 |
| 5 | 8.5 | 13.0 | 17.5 | 14.7 | 15.6 | 15.4 | 13.0 | 3.9 |
| 6 | 1.3 | 2.0 | 6.0 | 4.4 | 3.3 | 7.0 | 8.5 | 2.5 |
| 7 | 0.3 | 1.0 | 2.4 | 2.3 | 0.9 | 1.3 | 3.2 | 0.8 |
| 8 | 0.2 | 0.7 | 0.9 | 0.3 | 0.5 | 0.1 | 1.1 | 0.5 |
| 9 | 0 | 0.2 | 0.3 | 0.2 | 0 | 0.1 | 0.1 | 0.1 |
| 10 | 0 | 0.1 | 0.2 | 0 | 0 | 0 | 0 | 0.1 |

interval of 3 years. The relationship between the salinity in the Gotland Deep in 1971–93 (Dahlin et al., 1993) and Estonian flounder landings 3 years later (in 1974–96) is presented in Fig. 5. The relationship can be described by the model $y = 10^{-24} x^{24.095}$ ($y$ is landing in tonnes; $x$ is salinity, PSU), $R^2 = 0.7537$.

In the second half of the summer of 1996 the concentration of dissolved oxygen in the deep area of the western (90 m) and eastern (60 m) Gulf of Finland decreased (Lips et al., 1998). The catch per haul of the trap or net (CPUE) of the flounder increased in the western and middle parts of the Gulf of Finland in August and September 1996 (Drevs, 1997). It is possible that the concentration of dissolved $O_2$ can also affect the disposition of the flounder and can, therefore, influence landings. In 1991–98 flounder was caught mainly in the coastal area. The official statistics for 1982 shows that at lower oxygen saturation than in 1990–95 (Perttilä et al., 1996) the CPUE of flounder, as well as of cod, was relatively high in the western Gulf of Finland at the depths of 70–100 m. The flounder catch per an hour of trawling was between 0 and 441.1 kg, the mean value was 36.7 kg. Salinity increased in deeper areas of the Gulf of Finland in spring 1996 (Lips et al., 1998; Alenius et al., 1998). An increase in the salinity also corresponds to a higher abundance of pelagic flounder eggs and larvae in the Gulf of Finland whereas in case of a low oxygen concentration in deep layers, flounder eggs can be found 30–60 m above the bottom (Grauman,1981). Adult flounders can also swim as pelagic in this situation (Vitinsh, 1976). In 6–7 days the hatching larvae rise to the surface (they become pelagic). The decrease in the concentration of oxygen in the bottom layers at the end of the summer of 1996 (Lips et al., 1998) could not affect the number of young flounder. Therefore the spawning conditions became better in 1996 and the percentage of young flounder could increase. In 1991–97, 3–4-year-old fish predominated in catches, while the share of the remaining age groups varied significantly in different years. In 1998 the share of 1–2-year-old flounders increased rapidly in the Gulf of Finland (Table 2).

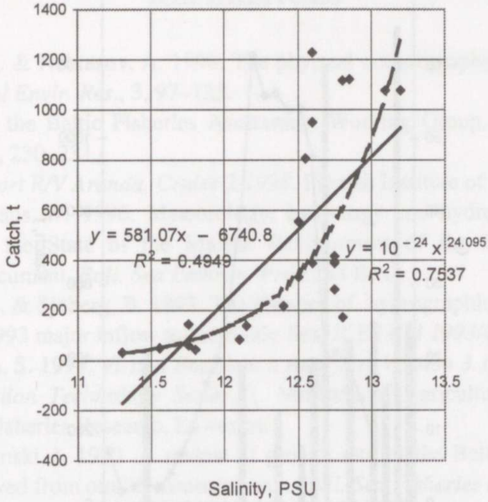


**Fig. 5.** Relationship between the salinity in deep water (200 m and more) in the Gotland Deep in 1971–93 (Dahlin et al., 1993) and Estonian flounder landings in the Gulf of Finland 3 years later.

Six years after a strong inflow of highly saline and oxygenated water into the Baltic Sea in 1978 (Bergström & Matthäus, 1996), the flounder landings began to decrease again (Fig. 6). The index *Q* shall qualify major "events" according to their relative intensity. It is calculated from the duration of the "event" and the salinity (*S*) of the water flowing in across the Darss Sill with $S > 17$ PSU. This index seems to indicate a possible relationship between the inflow intensity and flounder landings. According to the experimental trawlings in the western Gulf of Finland in 1976 (Järvik, unpublished data) and the official statistics of trawlings in 1982, the CPUE in 1976 was even higher than in 1982. In 1976 the catch of flounder per an hour of trawling in the western Gulf of Finland at the depths up to 40 m was 16.5–92.5 kg, the mean value being 46.55 kg (36.7 kg in 1982). Therefore the relatively lower catches in 1974–78 after the strong inflow in 1972 could be explained by lower fishing effort. After a moderate inflow in 1993 the flounder catches began to decrease already 4 years after the inflow, although the number of flounder did not. In 1996 a stagnation period started in the southern and central parts of the Baltic Sea (Feldman et al., 1996). In 1998 the salinity in the Gotland Deep and the Gulf of Finland increased again (Anon., 1998). This can increase the abundance of flounder as well as its catches in Estonian waters.

In Estonian waters of the ICES subdivision 29 (the area around Hiiumaa, northern Saaremaa, and the Väinameri, Fig. 1) we can compare only the years 1996–98. The spawning stock biomass was estimated at 290 t in 1996, 297 t in 1997, and 352 t in 1998. Fishing mortality was the highest in 1996, thereafter it

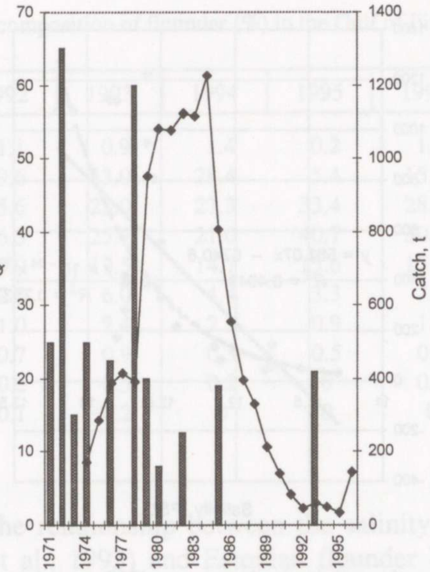


**Fig. 6.** Inflow intensity index $Q$ (bars) (Bergström & Matthäus, 1996) and Estonian flounder landings (line) in the Gulf of Finland.

decreased. The 4–6(7)-year-old fish had the highest fishing mortality. In Estonian waters of the ICES subdivision 28 (Fig. 1) the catches have increased rapidly after the saline water inflow in 1993. For example, the landing was 15.5 t in 1995, 42.8 t in 1996, 101.2 t in 1997, and 146.4 t in 1998. The mean age and size of the flounder in offshore landings in 1998 were higher than in the waters off Hiiumaa (subdivision 29). Higher mean age and size correspond usually to higher total landings. This correlation exists also for the Gulf of Finland.

## CONCLUSIONS

After an inflow of saline water from the North Sea to the Baltic Sea the spawning stock of flounder increases in the Gulf of Finland. It is possible that the spawning stock of the flounder moves with saline water towards north and east (into the Gulf of Finland). After an inflow the spawning conditions improve and therefore the abundance of young flounder increases in the Gulf of Finland. The fishing mortality changed in 1991–98 as a periodic function and it was highest for 4–6-year-old flounders. The flounder landings increased in all Estonian waters. After the increase in salinity in the deeper layers of the Gotland Deep and the Gulf of Finland in 1998 the abundance of flounder can be expected to increase again.

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# LESTA (*Platichthys flesus*) POPULATSIOONI DÜNAAMIKAST EESTI VETES

Tenno DREVS

Soolsuse tõusuga Eesti vetes kaasneb lesta kudekarja arvukuse ja biomassi kasv Soome lahes. Lestasaak rohkeneb kõigis Eesti vetes. Võimalik, et lesta kudekari liigub koos soolasema veega põhja ja ida suunas, seega Soome lahte sisse. Et paranevad kudemistingimused, siis võib lisaks kudekarja arvukuse tõusule märgata ka noorema lesta suhtelise osatähtsuse suurenemist Soome lahes. Kasutades Separable VPA meetodit, on välja arvutatud kudekarja arvukus, biomass ja tööndusliku suremuse väärtus Soome lahe Eesti vetes aastail 1991–98. Töönduslik suremus muutub nagu perioodiline funktsioon, olles suurem 4–6-aastaste lestade puhul. Mõningad lestavaru suurust iseloomustavad arvud on esitatud ka Väinamere, Hiiumaa ja Saaremaa põhjaosa vete (ICES alampiirkond 29) ning Liivi lahe (ICES alampiirkond 28) kohta.