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# An Attempt to Evaluate the Maximum Sustainable Yield (MSY) in the Baltic Cod, Flat Fish and Herring Fisheries

by

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At the end of the 'fifties and beginning of the 'sixties, the total volume of Baltic fish cought remained more or less stable at about 450,500 tons annually. There was a rapid increase in catches in the first half of the 'seventies, when the total exceeded 800,000 and approached 900,000 tons.

There is no need to mention that such an upward trend in Baltic fishery out-dated even the most daring estimates of potential catches (Gulland 1971) and seriously disturbed both marine biologists and fishery administrations of the Baltic states. This was expressed in the signing of an international convention on the conservation of the living resources of the Baltic and the calling into being of the International Commission for Fisheries in the Baltic Sea, to protect the living resources against irrational and over exploitation.

**In this** new organizational system of Baltic fisheries, the determination of the Maximum Sustainable Yield (MSY) automatically became the most important problem.

In actual fact this is a matter of the quantitative determination of such elements as: Maximum Equilibrium Yield, Maximum Sustainable Yield and $Effort_{max}$ or $F_{max}$ expressed not only as an exponential coefficient, but in absolute units of fishing effort.

Two groups of mathematical models can be used to solve this problem: dynamic pool models of the Beverton and Holt yield equation (1957) type and surplus yield or generalized production models of the type proposed by Schaefer (1954, 1957), Gulland (1961, 1968), Pella and Tomlinson (1969) and Fox Jr. (1970, 1972).

Because of the divergencies existing in the determination of the age of fish and, what follows, the differences in growth and mortality parameters, equations from the second group - particularly those of Fox Jr. (1970 and 1972) - were applied to evaluate the MSY and $X_{opt}$ (Effort optimum).

Assumptions

This paper is based on the following assumptions.

1. The basic data (mainly CPUE in cod, flounder, sprat and herring fisheries) were taken from the analysis of fishing activity of the Polish 25-metre cutter fleet operating in the fishing grounds of the southern and east-central Baltic. It was assumed that all changes in the elements of activity of this fleet were similar to those of the international fleet operating the same grounds over the past 10 years.

1.1. In bottom fish (cod and flat fish), data obtained from the use of a bottom otter trawl were applied; the basis for analyses of pelagic fish catches being data from catches by means of herring or sprat pair trawl.

As regards flat fish (c.90% flounder), the data were from 17-metre cutters working in shallower waters and fishing for such species to a greater extent than the 25-metre cutters.

2. In certain cases /cod, flat fish - mainly flounder/ an analysis of homogeneous stock in its geographical distribution area was conducted. In the cases of herring and sprat, an analysis of /a heterogenous/ but temporarily well-defined commercial community, was carried out.

3. Biological observations indicate that with the exception of spring herring of Swedish origin, over a period of two years running, each generation of fish invèstigated influenced the catch yield. For this reason, when analyzing the CPUE/Effort relationship, the mean for the last two years was taken, applying the formula:

$$\bar{X}_i = \frac{X_i + X_{i-1}}{2}$$

4. It was assumed that there was an exponential relationship between the CPUE /U/ and fishing effort /X/, expressed by the regression equations:

$$\log_e \bar{U}_i = m - b\bar{X}_i$$

whence $$\bar{U}_i = U_\infty e^{b\bar{X}_i}$$

Results

The input data to the regression equation are given in Tables Nos. 1 to 5.

The results of calculations are presented graphically in a series of figures /Nos. 1 to 5/, where the relationship CPUE/Effort is shown un the upper parts /A/. The equilibrium yield curves are drawn in the lower parts of the figures /B/. The catches against effort taken by international fisheries over the past several years have also been plotted /13 years in the case of the cod fishery, 10 years - flat fish fishery, 6 years - herring fishery/

Baltic Cod (Tables Nos. 1 and 2; Figs. Nos. 1 and 2).

Analyses and calculations were carried out for 2 variants:

1) for east-Baltic "pure" cod caught in sub-areas east of Bornholm, i.e. ICES statistical sub-areas 25 to 32 (Gulf of Finland);
2) for the above-mentioned stock, plus region No.24 (Arcona) where it is presumed that east-Baltic cod mixes with the west-Baltic stock.

Cod stock from the Baltic proper (caught in ICES sub-areas 25-32).

| | |
|---|---|
| CPUE/Effort correlation coefficient | = 0.70 |
| MSY | = 133,211 metric tons |
| Fishing Effort $_{opt}$ ($X_{opt}$) | = 80,000 fishing days |
| CPUE$_{opt}$ ($U_{opt}$) | = 1,665 kg/fishing day |

Cod stock from the Baltic proper + Arcona region (caught in ICES sub-areas 24-32).

| | |
|---|---|
| CPUE/Effort correlation coefficient | = 0.68 |
| MSY | = 146,204 metric tons |
| $X_{opt}$ | = 80,000 fishing days |
| CPUE$_{opt}$ ($U_{opt}$) | = 1,828 kg/fishing day |

Flat Fish (See Table No.2 and Fig.No.3).

Flat fish catch data was used for this analysis, although they covered at least 4 zoological species, the predominant position being occupied by flounder (from 70 to 90% in recent years) and plaice (from 25 to 5%). Several authors have observed that plaice spawns exclusively in the Bornholm Deep and forms one reproduction community in the Baltic.

The case differs as regards flounders, as they spawn in both Bornholm and Gdańsk Deeps, thus forming two separate reproduction communities.

The nursery and feeding grounds of all these species and populations are mainly located in widespread shallows in the southern Baltic.

The following parameters were obtained from flat fish assessments:

| | | |
|---|---|---|
| **CPUE/Effort correlation coeficient:** | | **0,77** |
| **MSY** | **=** | **6,228 metric tons** |
| $X_{opt}$ | **=** | **240,000 fishing days by 17-metre cutters** |
| $CPUE_{opt}$ /$U_{opt}$/ | **=** | **26 kg/day.** |

Baltic Herring (See Tables Nos. 4 and 5 and Figs. 4 and 5)

The southern and central Baltic is inhabited by a whole range of local herring populations, each differing from the other in morphometry and physiological characteristics (growth rate, natural mortality etc.). These herring are the subject of international exploitation both in the spawning phase (in the approaches to the spawning grounds and in the grounds themselves) and in the feeding phase in the open sea. For these reasons, to simplify matters, herring resources have here been treated as one commercial community for which all calculations have been carried out following the accepted scheme.

In this case the CPUE has been expressed in the form of one day's fishing by a 25-metre cutter working a pelagic pair trawl. As this technique was only universally adopted by Polish fishery after 1966, a series of annual data beginning from that year, was analyzed.

Calculations were carried out for 2 variants: for the south Baltic fishing grounds (ICES sub-areas Nos.24, 25 and 26) and for a wider area i.e. the south Baltic and southern part of the central Baltic (ICES sub-areas 24, 25, 26, 27 and 28).

Herring commercial community exploited in the southern Baltic

CPUE/Effort correlation = 0.94

MSY = 132,217 metric tons

$X_{opt}$ = 160,000 fishing days

$U_{opt}$ = 826 kg/fishing day.

Baltic Herring commercial community exploited in the southern and partly central Baltic.

CPUE/Effort correlation coefficient = 0.91

MSY = 200,907 metric tons

$X_{opt}$ = 220,000 fishing days

$U_{opt}$ = 913 kg/fish.day

Baltic Sprat

Analyses of available sprat fishing data did not show any relationship between CPUE and Fishing Effort.

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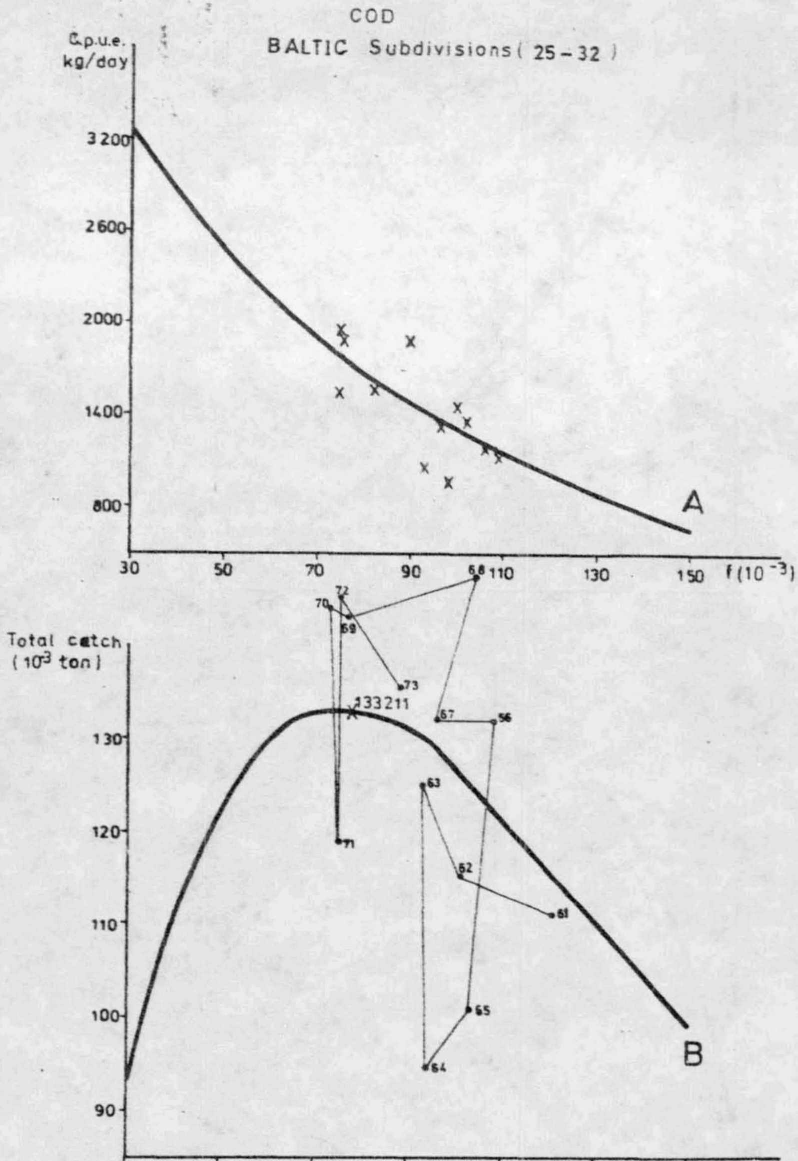


Fig.1.Relations between c.p.u.e. of cod and average effort for the two previous years (A) and curve of equilibrium yield (B).

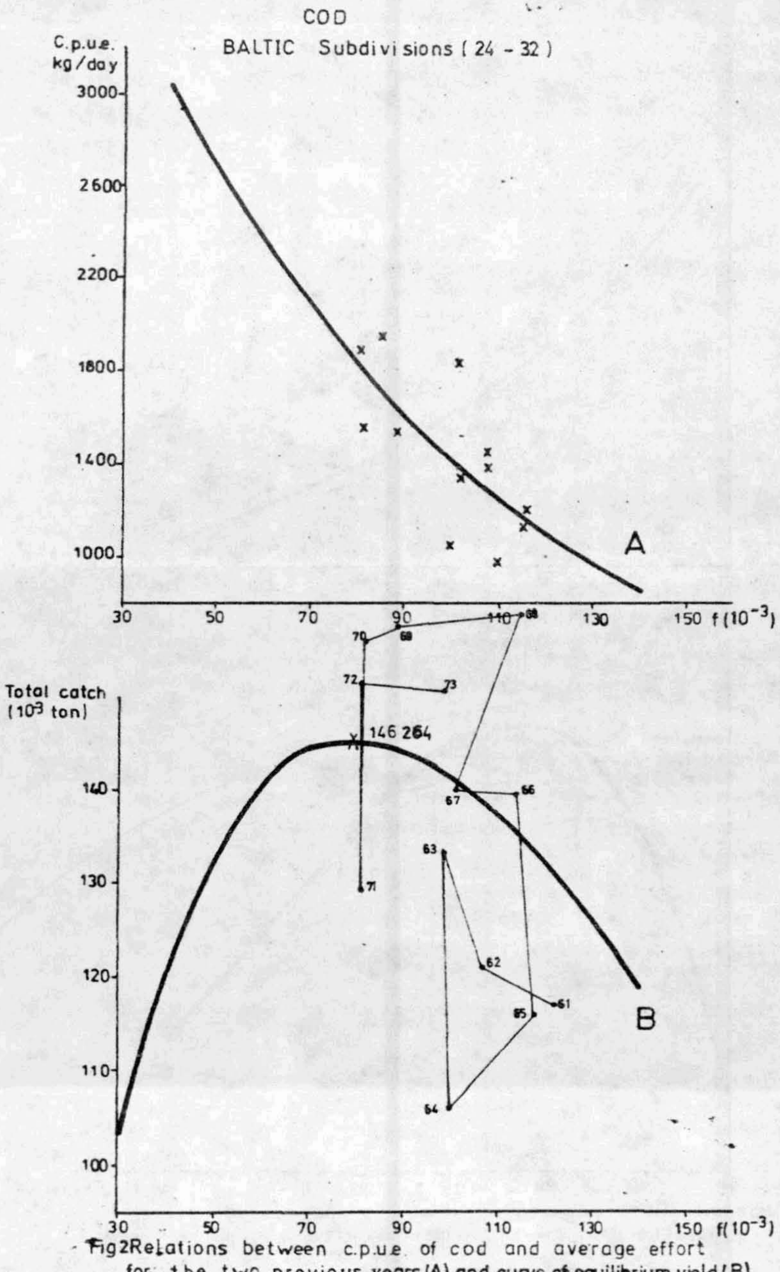


Fig 2 Relations between c.p.u.e. of cod and average effort for the two previous years (A) and curve of equilibrium yield (B).

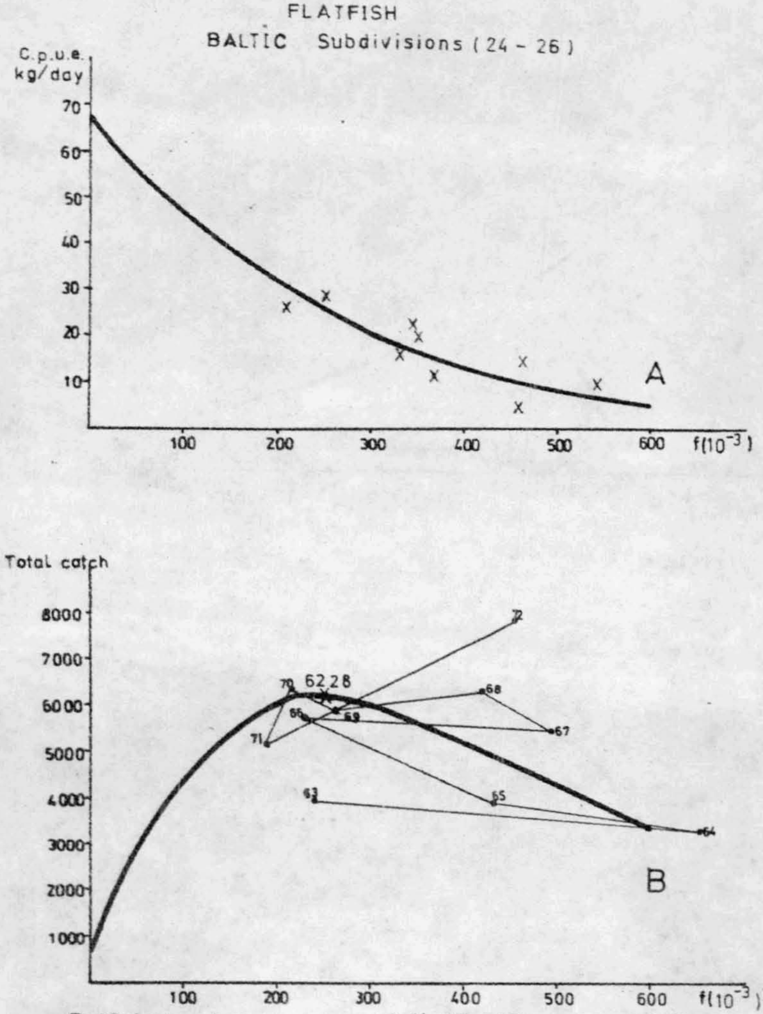


Fig.3.Relations between c.p.u.e. of flatfish (Flounder and Plaice) and average effort for the two previous years (A) and curve of equilibrium yield (B)

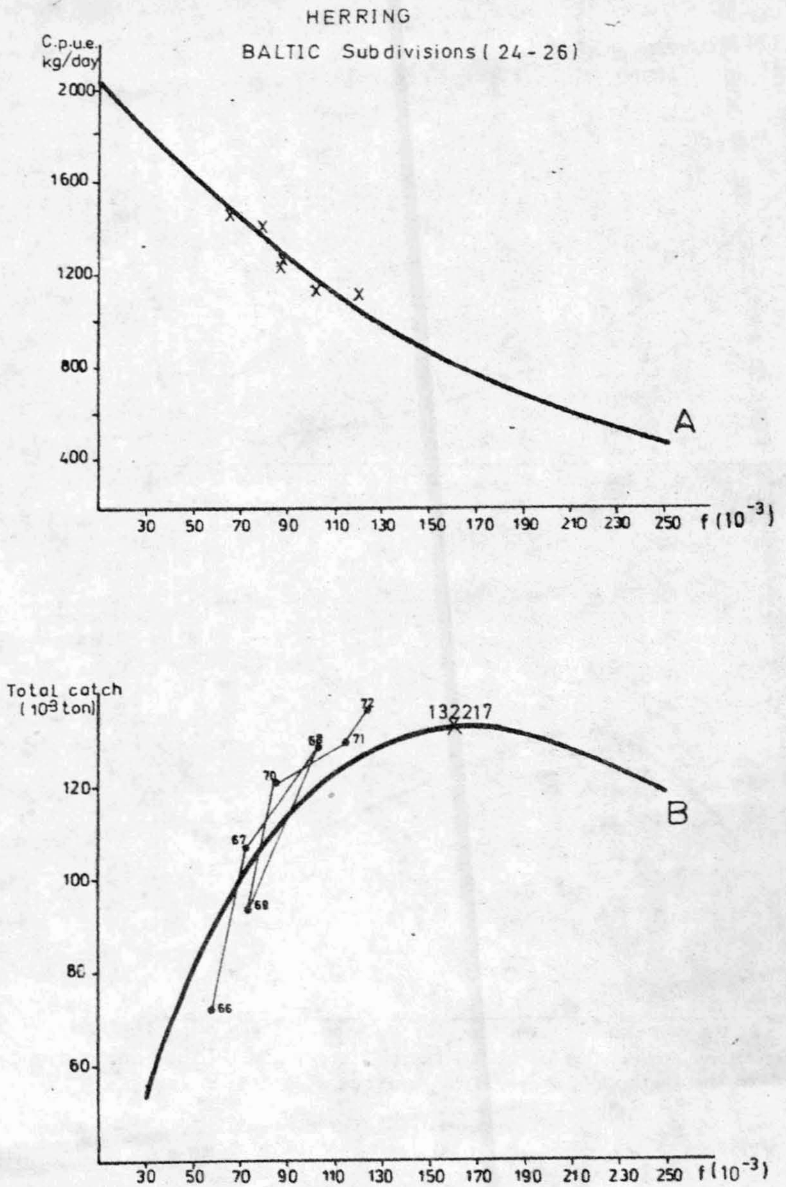


Fig. 4. Relations between c.p.u.e. of herring and average effort for the two previous years (A) and curve of equilibrium yield (B).

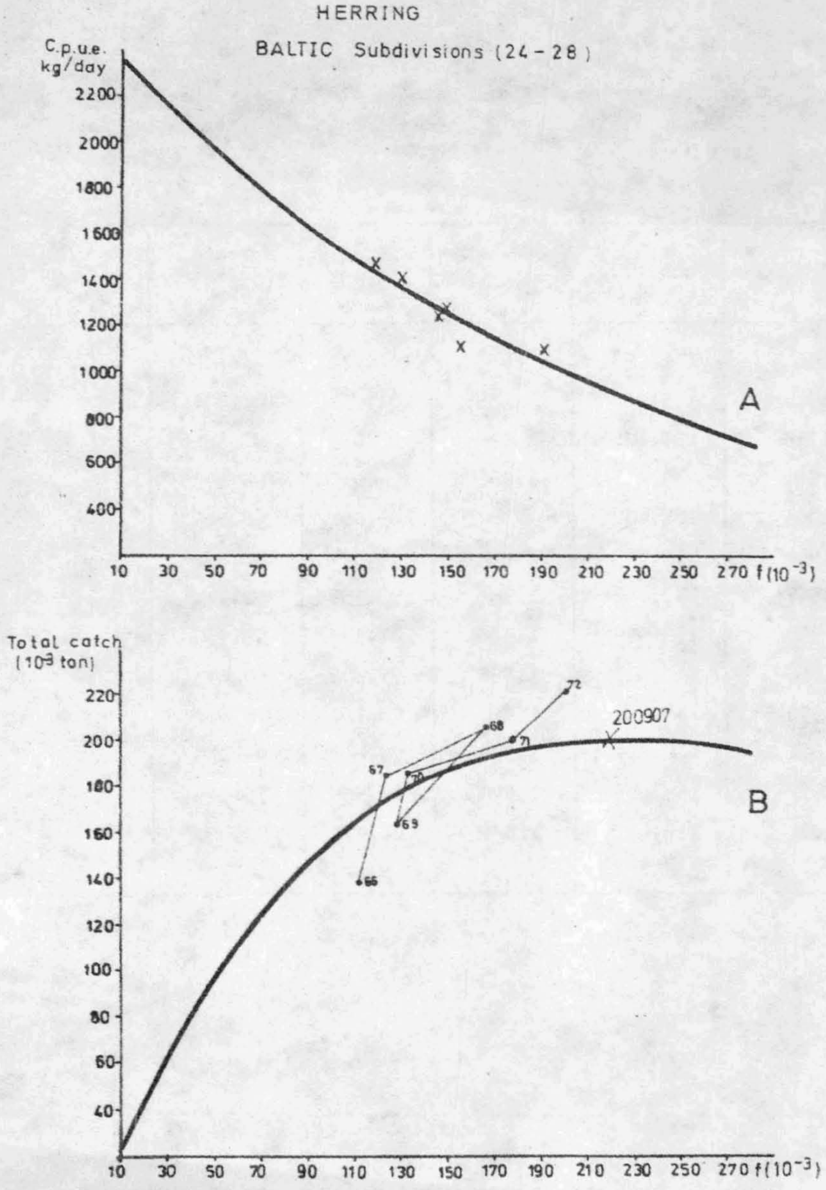


Fig.5.Relations between cpue of herring and average efford for the two previous years(A) and curve of equilibrium yield (B)

Table 1

Catch and Fishing Effort Data on Cod Fishery the Baltic ICES subdivisions Nos 25-32 Polish 25 m cutters - bottom otter trawl.

| Years | Catch subdiv. 25-32 | C.P.U.E. | Effort fishing day | 2 Years average Effort | |
|---|---|---|---|---|---|
| 1961 | 111.098 | 956 | 116.211 | - | |
| 1962 | 115.268 | 1.135 | 101.558 | 108.884 | |
| 1963 | 125.107 | 1.344 | 93.085 | 97.321 | |
| 1964 | 99,315 | 1.056 | 94.048 | 93.566 | |
| 1965 | 101.402 | 984 | 103.051 | 98.549 | |
| 1966 | 132.719 | 1.214 | 109.324 | 106.187 | |
| 1967 | 132.443 | 1.386 | 95.558 | 102.441 | |
| 1968 | 152.909 | 1.466 | 104.303 | 99.930 | |
| 1969 | 143.003 | 1.898 | 77.382 | 90.842 | |
| 1970 | 144.718 | 1.962 | 73.760 | 75,571 | |
| 1971 | 118.564 | 1.570 | 75.518 | 74.639 | |
| 1972 | 143.279 | 1.896 | 75.569 | 75.543 | |
| 1973 | 135.981 | 1.537 | 88.472 | 82.020 | |

Table 2

Catch and Fishing Effort Data on Cod Fishery in the Baltic Proper / subdivisions Nos 24-32/ Polish 25 m cutters-bottom otter trawl.

| Years | Catch subdiv. 24-32 | C.P.U.E. | Effort fishing days. | 2 Years average Effort | |
|---|---|---|---|---|---|
| 1961 | 117.100 | 956 | 122.489 | | |
| 1962 | 121.685 | 1.135 | 107.211 | 114.850 | |
| 1963 | 133.580 | 1.344 | 99.389 | 103.300 | |
| 1964 | 106.549 | 1.056 | 100.898 | 100.143 | |
| 1965 | 116.219 | 984 | 118.109 | 109.503 | |
| 1966 | 139.472 | 1.214 | 114.886 | 116.497 | |
| 1967 | 140.528 | 1.386 | 101.391 | 108.138 | |
| 1968 | 168.695 | 1.466 | 115.071 | 108.231 | |
| 1969 | 165.095 | 1.848 | 89.337 | 102.204 | |
| 1970 | 162.294 | 1.962 | 82.718 | 86.027 | |
| 1971 | 128.047 | 1.570 | 81.558 | 82.138 | |
| 1972 | 153.755 | 1.896 | 81.094 | 81.326 | |
| 1973 | 151.936 | 1.537 | 98.852 | 89.973 | |

Table 3

Catch and Fishing Effort Data on flatfish / flounder and plaice/ Fishery in southorn Baltic /subdivisions Nos 24-26/ 17 m cutters - bottom otter trawl.

| Years | Catch subdiv. 24-26 | C.P.U.E. | Effort fishing days | 2 Years average Effort | |
|---|---|---|---|---|---|
| 1963 | 3.957 | 16 | 247.312 | | |
| 1964 | 3.294 | 5 | 658.800 | 453.056 | |
| 1965 | 3.921 | 9 | 435.666 | 547.233 | |
| 1966 | 5.727 | 24 | 238.625 | 337.145 | |
| 1967 | 5.477 | 11 | 497.909 | 368.267 | |
| 1968 | 6.309 | 15 | 420.600 | 459.254 | |
| 1969 | 5.904 | 22 | 268.363 | 344.481 | |
| 1970 | 6.103 | 27 | 226.037 | 247.200 | |
| 1971 | 5.133 | 27 | 190.111 | 208.074 | |
| 1972 | 7.862 | 17 | 462.470 | 326.290 | |

Catch and Fishing Effort Data on Herring Fishery in the Baltic ICES subdivisions Nos 24 to 26 / Polish 25 m cutters pelagic pair trawl./

| Years | Catch subdiv. 24-26 | C.P.U.E. | Effort fishing days | 2 Years average Effort | |
|---|---|---|---|---|---|
| 1966 | 72.356 | 1.236 | 58.540 | | |
| 1967 | 106.475 | 1.479 | 71.991 | 65266 | |
| 1968 | 128.454 | 1.239 | 103.675 | 87.833 | |
| 1969 | 93.325 | 1.267 | 73.658 | 88.666 | |
| 1970 | 120.059 | 1.414 | 84.907 | 79.282 | |
| 1971 | 129.903 | 1.121 | 115.881 | 100.394 | |
| 1972 | 136.131 | 1.096 | 124.207 | 120.044 | |

Table 5

Catch and Fishing Effort Data on Herring Fishery in the Baltic ICES subdivisions Nos 24 to 28 / Polish 25 m cutters-pelagic pair trawl./

| Years | Catch subdiv. 24-28 | C.P.U.E. | Effort fishing days | 2 Years average Effort | |
|---|---|---|---|---|---|
| 1966 | 139.456 | 1.236 | 112.828 | 118.745 | |
| 1967 | 184.375 | 1.479 | 124.662 | 118.745 | |
| 1968 | 207.016 | 1.239 | 167.083 | 145.872 | |
| 1969 | 163.207 | 1.267 | 128.861 | 147.972 | |
| 1970 | 186.668 | 1.414 | 132.014 | 130.437 | |
| 1971 | 200.057 | 1.121 | 178.463 | 155.238 | |
| 1972 | 220.648 | 1.096 | 201.321 | 189.892 | |