NORTHWEST & ALASKA FISHERIES CENTER PROCESSED REPORT

FISH BIOMASS PARAMETER ESTIMATIONS

by
T. Laevastu and F. Favorite

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2725 Montlake Boulevard East
Seattle, Washington 98112

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* Resource Ecology and Fisheries Management Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112

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ABSTRACT

Procedures to estimate various biomass distribution parameters in a given species are described. The mean annual weights, distribution of numbers in fully exploited part of the biomass, and turnover rates are used as base data for the computations.

1. BIOMASS PARAMETER REQUIREMENTS VERSUS AVAILABLE EMPIRICAL DATA

Until recently most of the fisheries research dealt with exploited stocks. Conventional population dynamics approaches were used for which data was obtained from various measurements of catch.

Some rather unexpected collapses of many pelagic fisheries and equal unexpected shifts of the fishery on previously un- or under-exploited species and management methods, have rendered conventional fisheries data obtained from commercial catch as nonrepresentative of the true state of the stocks. Furthermore, the shortcomings of single-species population dynamics approaches in stock, recruitment, and the effect of fishery evaluation, have become increasingly apparent. Therefore attempts are being made to correct past and present shortcomings in fisheries research and management by numerical simulations of total marine ecosystems and associated processes.

For the above purpose additional derived data on all biomass components are required, such as the distribution of biomass with age in any given species, and mean biomass growth coefficients. A computer program was developed at NWAFC for the computation of various biomass parameters from easily available empirical data. These basic data are:

1) Mean annual weight of the species in a given region and time span. The mean weight of juvenile year classes is often extrapolated from these data.

2) Distribution of numbers of fish in exploited year classes. A mean is usually formed from several measurements of catch (and age determination) in different seasons and from different grounds in a given region, due to spatial and temporal variations in the age composition of catches of many species. Only the youngest fully exploited year class numbers should be considered, as there are usually one or more year classes which are only partially retained (captured) by the gear (see Figure 1).

In addition to directly measurable data mentioned above, some indirectly derived and/or auxiliary data are required:

3) Distribution of numbers of fish in juvenile year classes are computed with the help of factors by which the next-older year class numbers are multiplied (Figure 2), starting with the youngest fully exploited year class and computing toward younger year classes. These average factors are adjusted iteratively in the program to satisfy the prescribed biomass turnover rate (see computation procedure below).

4) Estimated average biomass turnover rate for a given species is obtained by the use of other models, such as the Bulk Biomass model and/or Dynamical Numerical Marine Ecosystem Model (Laevastu and Favorite 1978a and b).

The following parameters are computed by the program:

1. Annual growth rates of different year classes.
2. Monthly growth rates of different year classes.
3. Biomass distribution in different year classes.
4. Distribution of numbers of fish in different year classes.
5. Portions of exploitable and juvenile biomasses and numbers.
6. Total mortality in different year classes.

2. COMPUTATION PROCEDURE

The following formulas are used for computation of growth rates (formulas given in computational form):

Monthly growth rate (in % per month)

$$V = \log (W_{n+1} / W_n)$$

$$VM = V/12$$

$$PG = 10^{VM}$$

$$G_{mn} = (PG - 1) * 100$$

Annual growth rate (in % per year)

$$G_{an} = \left[(W_{n+1} / W_n) * 100\right] - 100$$

For the computation of biomass and number distributions, the turnover rate criterion must be satisfied. The latter requires the computation of total mortality by year classes. The following iterative procedure is used in these computations:

A first guess field of the numbers in juvenile year classes is computed by multiplying successively the next older year class with the factor F given in Figure 2, starting with the youngest fully exploited year class for which empirical data is available:

$$N_n = F_n * N_{n+1}$$

Thereafter the first guess of biomass in each year class is computed:

$$B_n = N_n * W_n$$

Thirdly, the total biomass mortality in each year class is computed, assuming it constitutes the difference between the next younger biomass plus its growth and (minus) the next older biomass (Figure 3):

$$M_n = B_n (1 + 0.01\ G_{an}) - B_{n+1}$$

The turnover rate is computed by dividing the sum of biomass mortality by the sum of the biomass:

$$T_c = \frac{\Sigma M}{\Sigma B}$$

The computed turnover rate is compared to prescribed turnover rate. If the difference is larger than a prescribed convergence criterion (e.g. $\pm$ 5%), an iterative procedure is initiated to converge the computed turnover rate to the prescribed one. This is done by increasing/decreasing the factor by which the next older year class numbers are multiplied (Figure 2) by a small prescribed amount in the juvenile year classes and new juvenile year class numbers are computed.

The numbers in the exploited year classes are left unchanged, except the youngest exploited year class is changed (smoothed) by a small amount to obtain a relatively smooth numbers/biomass distribution (curve). The computation of new biomass, mortality, and turnover rate is done as above and the new turnover rate is compared to the prescribed one and iteration repeated if necessary until the desired turnover rate is achieved.

The total numbers (sum), total biomass, and total mortality are computed by summation of corresponding year class values and the percentual distributions are computed:

$$B_{pn} = \Sigma \ (G_{mn} * B_{fn})$$

All other desired quantities are computed with simple arithmetical approaches from the computed and input data above. A computation program in FORTRAN and its documentation is available at NWAFC.

3. EXAMPLES OF COMPUTED MEAN BIOMASS PARAMETERS FOR THREE SPECIES FROM THE BERING SEA

Examples of various computed parameters for three different fish species from the Bering Sea are given in Figures 5 to 8. These three species are considerably different in several aspects: Pollock is a fast growing species (see Figure 4) and comes early under full exploitation (3rd year). It has a medium turnover rate (0.77). Herring with a relatively slow growth is fully exploited in its fifth year and has a high turnover rate (0.85). Yellowfin sole is a slow growing species and is fully exploited in its seventh year of life and has a relatively slow turnover rate (0.45). Figures 5 and 6 indicate the distributions of biomasses and numbers respectively, and Figures 7 and 8 the total mortality distributions with respect to mean year class biomasses and the distribution of mortality within the total biomass. Figures 7 and 8 show the high mortalities in younger year classes caused largely by size dependent feeding, which predominates in the marine ecosystem (see Figure 9).

4. SYMBOLS USED IN THE FORMULAS

B_n - Biomass of year class n.

B_{fn} - Decimal fraction of biomass of year class n.

B_{pn} - Percentual fraction of biomass of year class n.

G_{mb} - Mean monthly growth rate for whole biomass.

F_n - Increase factor of next oldest year class numbers.

G_{an} - Annual growth rate (%) in year class n.

G_{mn} - Monthly growth rate (%) for year class n.

N_n - Number of fish in year class n.

N_{n+1} - Number in next older year class.

M_n - Total mortality in year class n.

PG, V, VM } Intermediate parameters in computation.

T_c - Computed biomass turnover rate.

W_n - Mean weight of specimen in year class n.

W_{n+1} - Mean weight in next oldest year class.

5. REFERENCES

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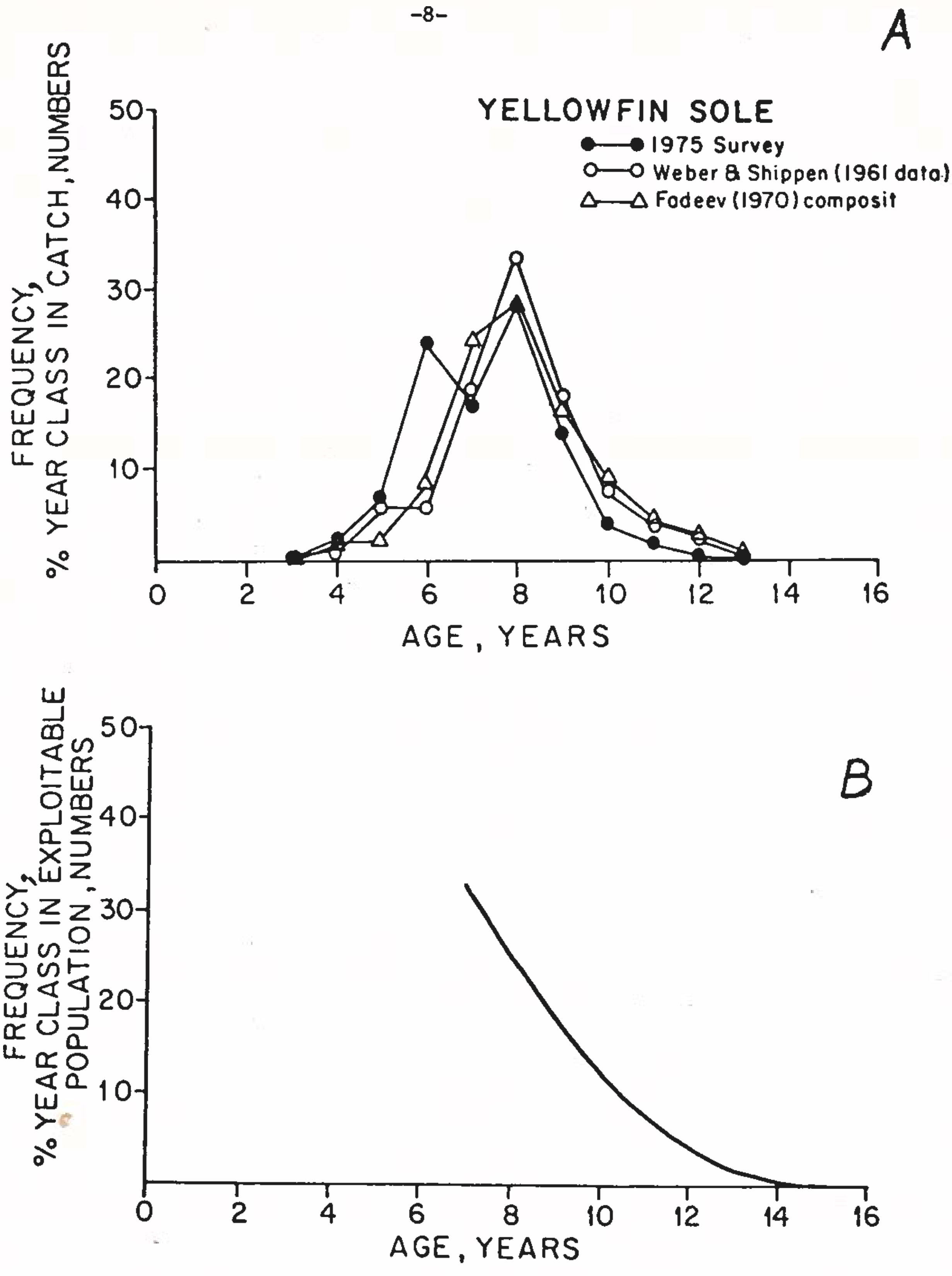

Figure 1.--Age distribution of catch (A) and estimated mean age distribution of catch of fully exploited year classes (B) of yellowfin sole from the Bering Sea.

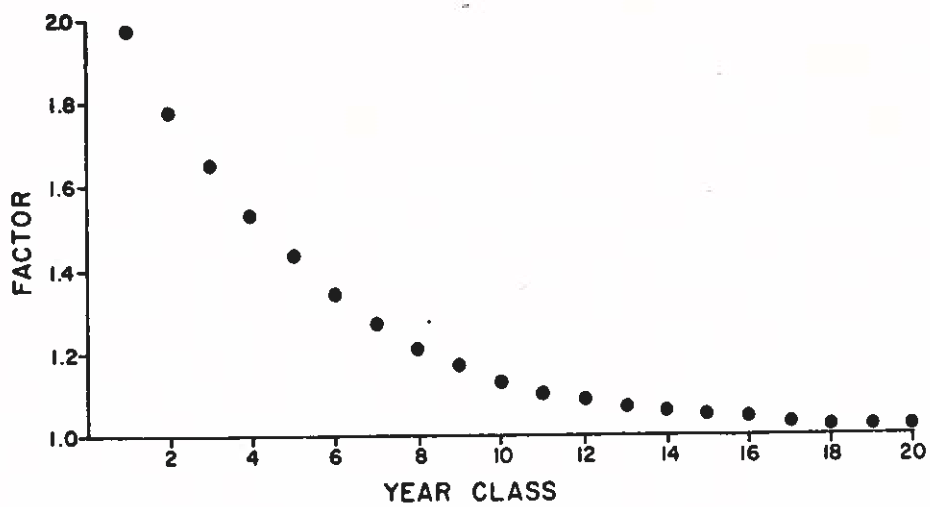

Figure 2.--Mean number increase factor, to be applied on previous year class numbers (starting with youngest fully exploited year class).

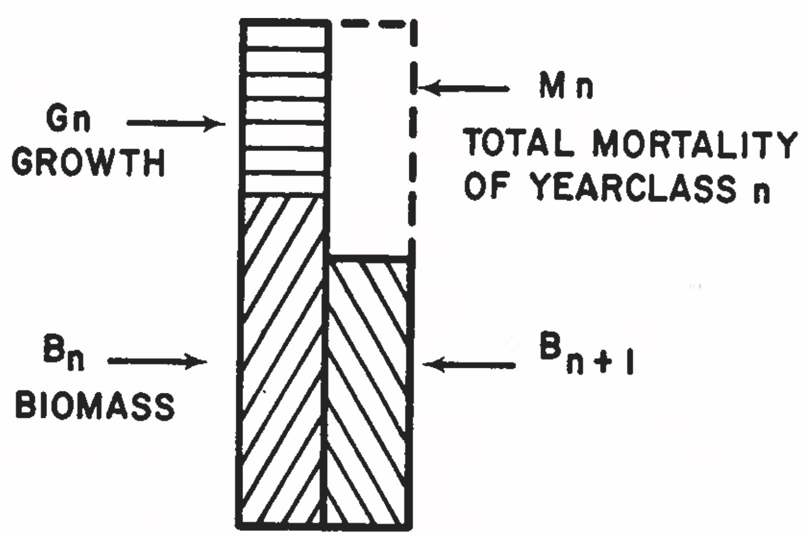

Figure 3.--Schematic presentation of total mortality of biomass of a year class.

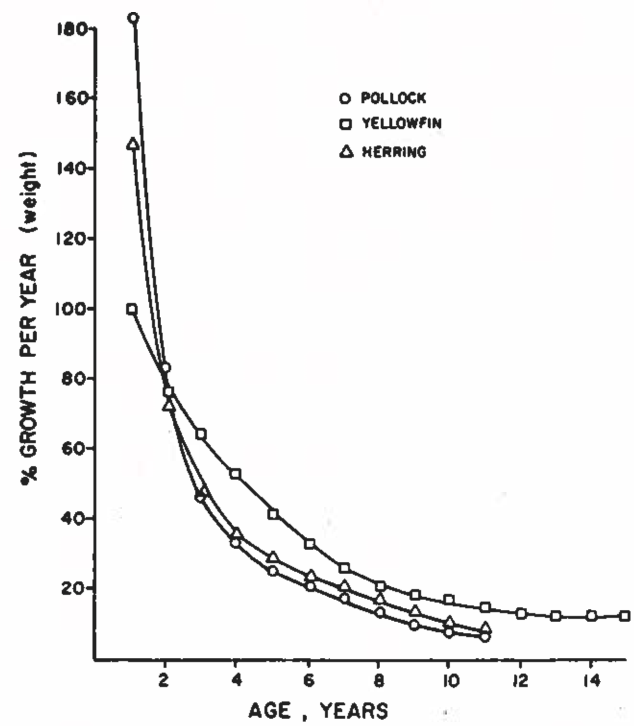

Figure 4.--Growth rates (percent per year) of pollock, yellowfin sole, and herring from the Bering Sea.

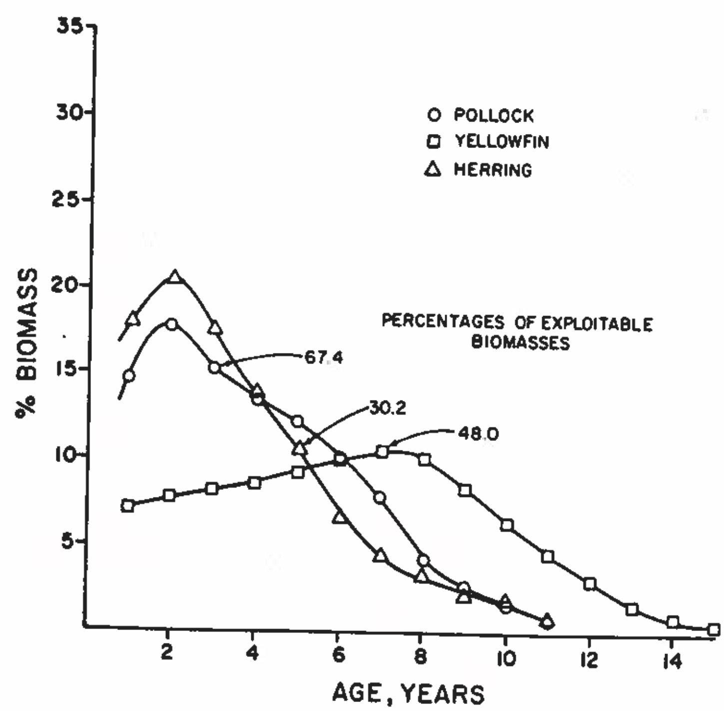

Figure 5.--Distribution of biomass in different year classes (pollock, yellowfin sole, and herring from the Bering Sea).

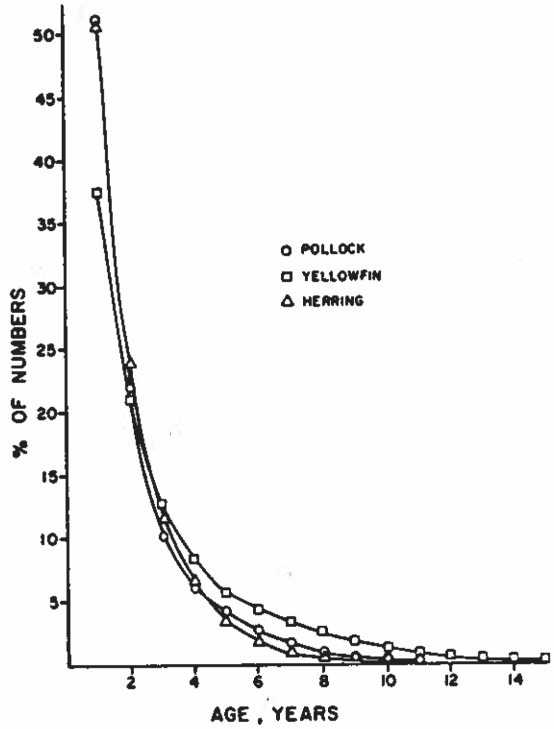

Figure 6.--Distribution of numbers in different year classes (pollock, yellowfin sole, and herring from the Bering Sea).

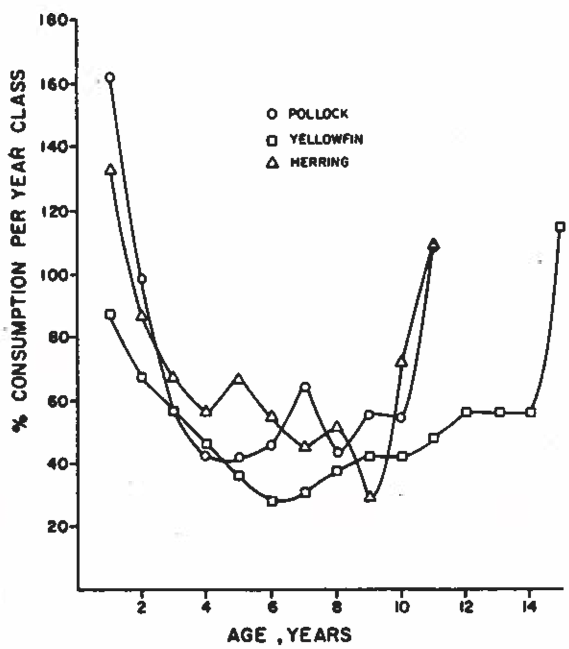

Figure 7.--Consumption (predation) of biomass as percent of mean standing stock (pollock, yellowfin sole, and herring from the Bering Sea).

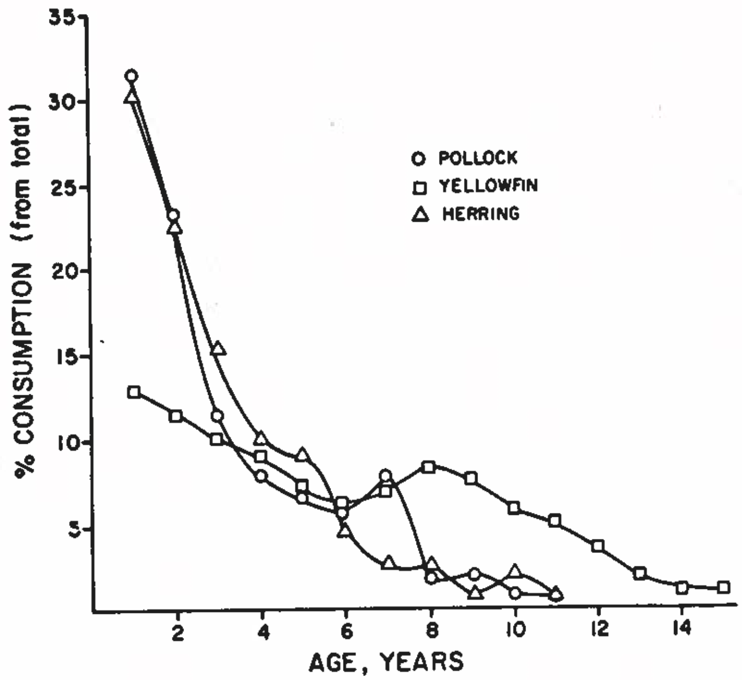

Figure 8.--Distribution of predation mortality (consumption) with age (pollock, yellowfin sole, and herring from the Bering Sea).

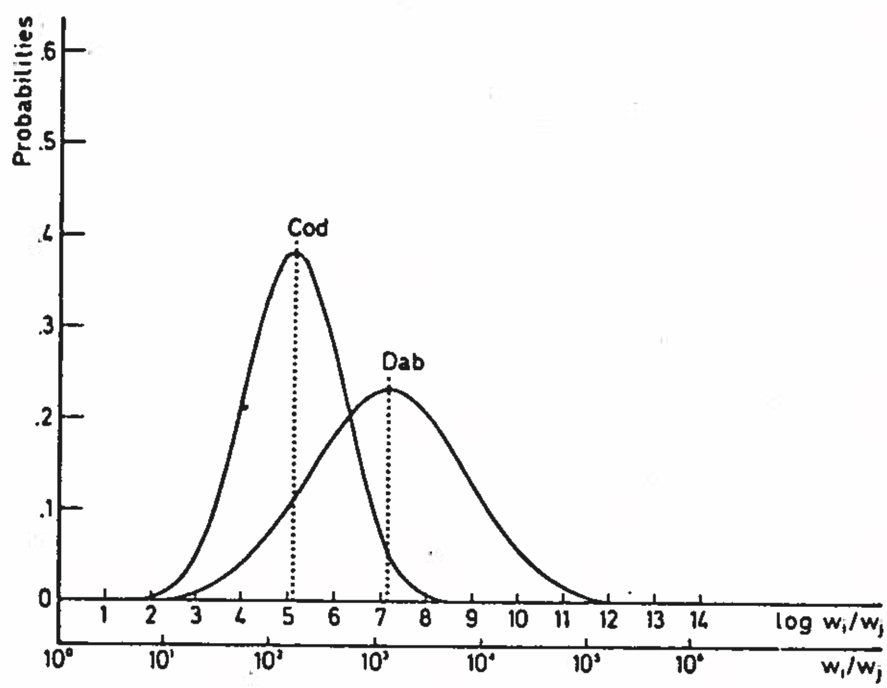

Figure 9.--Prey size selection in the simulated environment in which prey abundance is independent of prey size (from Ursin 1973).