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Biomass Model for the Egg Production Method

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ABSTRACT

The spawning fraction of multiple spawners is estimable when females exhibit morphological characteristics which indicate when spawning will take (or has taken) place. The length of time in which characteristics remain detectable must in itself be estimable and constant over the field sampling interval. Spawning biomass is then estimated as a function of the estimated spawning frequency and other parameters: egg production, batch fecundity, sex ratio, and average weight of mature females. Based on the delta method, approximate variance estimates for spawning biomass are derived and given.

The relationship between the spawning biomass of a fish stock and its production of eggs is easily derived. Simply stated, the production of eggs (P) must be equal to the female biomass that produced those eggs multiplied by the female batch fecundity:

$$P = (B \cdot R') \cdot F'. \tag{1}$$

The female biomass is represented as the product of the total biomass of the entire stock B, both males and females, and R', the portion of the entire stock that is egg-producing females. The batch fecundity F' is the number of eggs spawned per batch per unit weight of female.

Note that R' is not the biomass of females divided by the biomass of males plus females, a simple sex ratio in terms of biomass. Rather R' is the total biomass of females that has produced eggs in a specified period of time divided by the biomass of males and females together. If females spawn more than once during the period of time in which production is measured, R' may be greater than the simple sex ratio in terms of biomass. The converse would be true if, on the average, females spawn less than once.

It is this fundamental definition of R' that allows Equation (1) to be easily derived. However, in its present form, Equation (1) is of practical value only when each mature female spawns once during the time interval over which production is measured, in which case R' becomes the simple sex ratio estimated from biomass, say R.

In its present form, Equation (1) is not useful for multiple spawners, when population spawning appears to be continuous over the period of time over which production is measured. There is no way to relate production of eggs, P, to female biomass that produced those eggs without making an adjustment for spawning frequency.

R', the proportion of female-producing biomass, is composed of two parts: R, the simple biomass-based sex ratio (the biomass of females to that of males plus females) and f, the fraction of females spawning during the time interval,

$$R' = R \cdot f. \tag{2}$$

Parker (1980) documented the above relationship and demonstrated that spawning frequency (f) can be estimated if three conditions are met: 1) Females can be examined for a characteristic which indicates when spawning will or has taken place, 2) the length of time such a characteristic remains detectable is estimable, and 3) the spawning rate (or frequency) remains constant over the sampling interval in which f is estimated.

Under these conditions the spawning fraction (f) is the fraction of females displaying characteristic 1 above, divided by the length of time the characteristic remains detectable. For example, if from a sample of 10 females, 2 display a characteristic which lasts for 1 d and which indicates that spawning will take place in approximately 3 d, then the spawning rate can be expected to be 1/5 in 3 d. Spawning frequency so estimated is additive. For instance, a daily rate can be summed over any length of time, week, year, etc. However, if multiple spawnings occur in the time period, parameter f can exceed unity and is no longer properly a "fraction."

Having developed a condition under which the spawning frequency can be estimated, Parker (1980) rewrote Equation (1) in terms of the simple biomass sex ratio (R) and the spawning frequency (f),

$$P = B \cdot R \cdot f \cdot F'. \tag{3}$$

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Spawning biomass can be estimated directly,

$$B = P/(R \cdot f \cdot F'). \qquad (4)$$

Equation (4) is a conventional equation relating spawning biomass to egg production. The estimate of production (P) can be for any time interval, as long as the fraction of females spawning (f) is computed for the same interval. For a species that spawns but once over the time interval in which production is measured, say a year, Equation (4) is still valid, but now greatly simplified since $f = 1$.

Stauffer and Picquelle (1980) modified Equation (4) for the northern anchovy, *Engraulis mordax*, and based the biomass equation on a daily estimate of production and fraction spawning,

$$B = P \cdot A(k \cdot W)/(R \cdot F \cdot S) \qquad (5)$$

where B = spawning biomass in metric tons,
P = daily egg production, numbers of eggs produced per 0.05 m^2 per day,
W = average weight of mature females (g),
R = sex ratio, fraction of population that are mature females, by weight (g), as before,
F = batch fecundity, number of eggs spawned per mature females per batch,
S = the fraction of mature females spawning per day,
A = the total survey area (in 0.05 m^2),
k = conversion factor of grams to metric tons.

Stauffer and Picquelle (1980) found that more stable estimates of spawning biomass are achieved if Parker's batch fecundity estimate by weight is replaced by F, eggs per female per batch, and W, the average weight of mature females. Stauffer and Picquelle (1980) demonstrated estimation with an example. A detailed example is given in Picquelle and Stauffer (1985).

Based on the delta method (Seber 1973), Stauffer and Picquelle (1980) show the approximate bias and variance of the biomass estimator to be a function of sample variances and covariances. Bias (b) is given by

$$E[B] = \hat{B} + b \qquad (6)$$

where $E[B]$ is the expected value of the biomass and $\hat{B}$ is the estimate from Equation (5). The bias is approximately

$$b \cong \hat{B}(CV(R)^2 + CV(F)^2 + CV(S)^2 + COVS) \qquad (7)$$

where CV denotes coefficient of variation, and $COVS$ is the sum of terms involving covariances:

$$\begin{aligned} COVS = {} & COV(PW)/PW - COV(PR)/PR - COV(PF)/PF \\ & - COV(PS)/PS - COV(WR)/WR - COV(WF)/WF \\ & - COV(WS)/WS + COV(RF)/RF + COV(RS)/RS \\ & + COV(SF)/SF. \end{aligned} \qquad (8)$$

Ignoring the bias, approximate variance of the estimate is given by

$$Var\, B \cong \hat{B}^2(CV(P)^2 + CV(W)^2 + CV(F)^2 + CV(S)^2 + 2\, COVS) \qquad (9)$$

LITERATURE CITED

PARKER, K.
1980. A direct method for estimating northern anchovy, *Engraulis mordax*, spawning biomass. Fish. Bull., U.S. 78:541-544.

PICQUELLE, S., and G. STAUFFER.
1985. Parameter estimation for an egg production method of northern anchovy biomass assessment. *In* R. Lasker (editor), An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, *Engraulis mordax*, p. 7-15. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 36.

SEBER, G. A. F.
1973. The estimation of animal abundance and related parameters. Hafner Press, N.Y., 506 p.

STAUFFER, G. D., and S. J. PICQUELLE.
1980. Estimates of the 1980 spawning biomass of the subpopulation of northern anchovy. Natl. Mar. Fish. Serv., Southwest Fish. Cent., La Jolla, CA, Admin. Rep. LJ-80-09, 41 p.

UNITED STATES DEPARTMENT OF COMMERCE
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MEMORANDUM FOR: USERS OF THE EGG PRODUCTION METHOD FOR ESTIMATING SPAWNING BIOMASS OF PELAGIC FISH.

FROM: REUBEN LASKER

SUBJECT: ERRATA FOR NOAA TECHNICAL REPORT NMFS 36; "AN EGG PRODUCTION METHOD FOR ESTIMATING SPAWNING BIOMASS OF PELAGIC FISH: APPLICATION TO THE NORTHERN ANCHOVY".

A number of printing errors have been discovered by Dr. Sachiko Tsuji in the published account of the egg production method. These are important and warrant this memo. Please make these corrections in your copy.

p. 5, Abstract, 4th line should read:
"be estimable and spawning rate constant over the field sampling interval."

p. 12, in equation 8, $\hat{\beta}$ should be β.

p. 17, Table 1. on the January line +3.5 should be -3.5.

p. 20, two lines under the formula in the second column, "sample size" should be "sample scale" and σ_i should read σ_i^2. Five lines under the formula "larger observations" should be "bigger scales."

p. 22, 1st para., No. 3 last line should be simulation, not stimulation.

p. 23. 1st para., line 7. "Table 9" should read "Table 6."

p. 44. Temperature table in second column on the page.

The temperatures read 13.9
13.5
16.2

The correct temperatures are 13.9
15.2
16.2.

p.45. Second column, $y_{i,t,k}$ should read $y_{i,t}$.

p.46 1st Para., line 7, change the word "spawning" to "tows, $\hat{T}$".

p.49. Table 5d. Strike out the words "within or" in the second line of the heading.

p.55. 9th line from the bottom, x_1 should be x_i.

p.56. First. para. second column, sixth line, 26 should read *25.*

p.63. Under "Preservation" $Na_2H_2PO_4$ should be Na_2HPO_4.

p.93. In table 1, atretic state e, change $>$ to $<$.

p.97. In the! formula after the second para. change $<$ to $>$.

p.98. In the formula in the first column change $-Zt$ to $-Zt_h$.