International Commission for the Northwest Atlantic Fisheries

Serial No. 4068
(D.c.9)

ICNAF Res.Doc. 76/XII/172

NINTH SPECIAL COMMISSION MEETING – DECEMBER 1976

A note on a method to determine the total allowable catch of shrimps (Pandalus borealis) at West Greenland

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Publ. in ICNAF Sel. Papers No. 4: 43-44

The question about the "correct" level of TAC on the offshore component of the West Greenland deep sea shrimp stock is extremely difficult because either is the present stock size known with any accuracy nor is the percentage of the stock which safely could be removed known.

With the present mesh size (about 40 mm stretched for most fleets) an unlimited fishing effort would do no harm from a yield per recruit point of view. Most of the shrimp in the catch will be 4 years old and older (Ulltang and Øynes, 1976), and it is known that after an age of 4–5 years the natural mortality probably is very high.

For management purposes, the important question therefore is how much the reproductive potential is reduced by the fishing, and how much this could be reduced without a substantial decrease in recruitment. This note is an attempt to describe the effect of fishing on the stock in terms of a few parameters such that our knowledge, though very limited, could be utilized to reduce the question to a question about the value of one or two key parameters.

Assume that the recruitment to the fishery is knife-edged at an age of r years and that the shrimp produce recruits for the first time at an age of r + t (time of hatching) and thereafter each year. Assume further that the natural mortality is equal to M before age r + t and M_1 thereafter. The mean annual fishable stock, in numbers (Beverton and Holt, 1957) will then be

$$\bar{P}_N = \frac{R}{F+M}\left(1-e^{-(F+M)}\right) + \frac{Re^{-(F+M)t}}{F+M_1}$$

where R is the recruitment at age r and F the instantaneous fishing mortality.

The annual catch in numbers is given by

$$C = \frac{FR}{F+M}\left(1-e^{-(F+M)t}\right) + \frac{FRe^{-(F+M)t}}{F+M_1}$$

i.e.

$$F = \frac{C}{\bar{P}_N} \qquad (1)$$

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The stock (in numbers) producing recruits will be

$$S_N = Re^{-(F+M)t}\,(1+e^{-(F+M_1)} + e^{-2(F+M_1)} + \ldots) = \frac{Re^{-(F+M)t}}{1-e^{-(F+M_1)}}$$

and

$$S/S_o = \frac{Re^{-(F+M)t}}{1-e^{-(F+M_1)}} \cdot \frac{1-e^{-M_1}}{Re^{-Mt}} = e^{-Ft} \cdot \frac{1-e^{-M_1}}{1-e^{-(F+M_1)}} \qquad (2)$$

where S_o is the "virgin" stock, i.e. the stock producing recruits when there is no fishing, still assuming a recruitment R at age r.

t in equation (2) may be estimated from general biological information on the shrimp and data on the size composition of the shrimps in catch. M_1 is not known, but for high values of M_1 compared to F, S/S_o will not depend on M_1 to any high extent, and by setting a minimum value for M_1 into the equation one gets a minimum value for S/S_o.

If one by some criteria can determine the lowest level S/S_o should be allowed to reach, say $(S/S_o)_{critical}$, the upper limit for TAC could be found from equation (2).

In the table below are shown S/S_o for different values of F, assuming $M_1 = 1.5$ and $t = 1.5$.

F	S/S_o
0.1	0.84
0.2	0.70
0.3	0.59
0.4	0.50
0.5	0.42
0.6	0.36
0.7	0.31
0.8	0.26
0.9	0.22
1.0	0.19

References

Beverton, R.J.H., and S.J. Holt. 1957. On the dynamics of exploited fish populations. Fish. Invest., Lond., ser. 2, 19:553 pp.

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