ICES CM 2001/V:17

Evaluating the effectiveness of biological reference points in conserving reproductive potential

C. Tara Marshall, Nathalia A. Yaragina, and Anders Thorsen

C.T. Marshall and A. Thorsen: Institute of Marine Research, P.O. Box 1870, Nordnes, N-5817 Bergen, Norway [tel: +47 55 23 8475, fax: +47 55 23 8584, e-mail: tara@imr.no and anders.thorsen@imr.no]. N.A. Yaragina: Polar Research Institute of Marine Fisheries and Oceanography, 6, Knipovich Street, 183763, Murmansk, Russia [tel. +7 815 247 2231, fax: +7 815 247 3331, e-mail: bottfish@pinro.murmansk.ru].

Background

The management for Northeast Arctic (NA) cod defines both limit and threshold reference points for spawner biomass (B_{lim} and B_{pa}, respectively). The current value of B_{lim} (112,000 t) corresponds to the lowest SB value in the time series (i.e., B_{loss}). The B_{pa} value has been set equal to the former MBAL value of 500,000 t, however, it is impossible to unambiguously identify a value below which recruitment is impaired from the S/R relationship that was used to develop these reference points (Fig. 1a). For example, the four years having the highest recruitment (1950, 1963, 1964 and 1970) were associated with spawner biomass (SB) values that were considerably less than the B_{pa} (Fig. 1a). This variability complicates defining a limit reference point. Furthermore, because the majority of SB values in this plot were estimated using knife-edge maturity ogives (1946-1981) and constant weight-at-age values (1946-1982), the S/R relationship and the reference points derived from it are insensitive to the true effect of variation in growth on the relationship.

In reality, NA cod undergo large and rapid fluctuations in growth as a result of the high degree of variability in capelin stock biomass (Yaragina and Marshall 2000). The ICES Arctic Fisheries Working Group (AFWG) was recently asked to evaluate the appropriateness of the B_{pa} value of 500,000 t in light of the indeterminate S/R relationship (ICES ACFM 2001a). The AFWG addressed this request by compiling historical data from Russian and Norwegian sources and developing new time series for maturity- and weight-at age to replace the constant values (ICES ACFM 2001b). Despite being a more accurate reflection of the true variation in growth, there was no easily discernable improvement in the revised S/R relationship (Fig. 1b) and the status of the current reference points remains uncertain.

Estimating stock reproductive potential

A general fecundity model has been developed for NA cod that uses information on condition to represent the year effect. This model was developed using fecundity observations made during a time period when the condition of cod was changing rapidly due to the collapse and subsequent recovery of the Barents Sea capelin stock (Kjesbu et al. 1998; A. Thorsen, unpub. data). In combination with VPA estimates of numbers-at-age, the general fecundity model has been used to estimate the total egg production for the time period depicted in the S/R relationship. The relationship between total egg production and recruitment suggests that recruitment decreases with decreasing total egg production (Fig. 1c). For example, the total egg production values for 1963, 1964 and 1970 are more consistent with the high recruitment observed in these years. Given that estimates of SB and total egg production have the VPA numbers-at-age in common differences in their relationships with recruitment result from how spawner quality (maturity, weight, fecundity) is incorporated into the estimates. The SB and total egg production time series show major differences with total egg production being higher in the 1970's than in the 1990's while the opposite holds true for SB estimates (Fig. 2).

Incorporating this information into stock management

As noted above, the AFWG is currently investigating the appropriateness of the B_{pa} value in light of the revised maturity- and weight-at-age times series. However, it should also be recognized that any reference point for SB will have a degree of uncertainty resulting from the lack of proportionality between SB and total egg production (Fig. 2). Additional reference points that are explicit for reproductive potential (e.g., limit and threshold total egg production) should be developed and incorporated into medium-term stock projections.

In addition to developing additional reference points, information on reproductive potential could also be used to evaluate the performance of existing reference points. For, example, the removal of reproductive potential by the commercial fishery was estimated as the total egg production in the catch. This quantity was estimated in the same way as total egg production in the stock except that the catch numbers-at-age were used instead of the stock numbers-at-age and differences in stock weight-at-age were incorporated. The proportional removal of reproductive potential (PRR) was estimated for each year as the ratio of the total egg production in the catch to the total egg production in the stock. Over the time period

1946-2000, the PRR varied from 0.23 to 0.66 indicating that ca. twenty and sixty percent of the reproductive potential was removed annually through fishing. The PRR was significantly, positively correlated ($r^2 = 0.95$, $n = 55$; Fig. 3) with F as given by the linear regression model:

$$PRR = 0.17 + 0.47\ F \qquad (1)$$

Using this equation, the current value of F_{pa} (0.43) removes approximately 37% of the reproductive potential, whereas, F_{lim} (0.7) removes approximately 50%. Since 1994, over half of the reproductive potential of the stock has been removed annually by fishing. Although it is difficult to say what is an appropriate PRR, it would seem that values that are consistently over 0.5 would not be sustainable over the longterm.

In future, research will be undertaken to refine estimates of reproductive potential and to incorporate these data more formally into medium-term stock projections.

References

ICES ACFM. 2001a. Report of the Arctic Fisheries Working Group. ICES CM 2001/ACFM:02.

ICES ACFM. 2001b. Report of the Arctic Fisheries Working Group. ICES CM 2001/ACFM:19.

Kjesbu, O.S., Witthames, P.R., Solemdal, P., and Greer Walker, M. 1998. Temporal variations in the fecundity of Arcto-Norwegian cod (*Gadus morhua*) in response to natural changes in food and temperature. J. Sea Res. 40: 303-321.

Yaragina, N.A., and Marshall, C.T. 2000. Trophic influences on interannual and seasonal variation in the liver condition index of Northeast Arctic cod (*Gadus morhua*). ICES J. Mar. Sci. 57: 42-55.

Figure 1: The stock/recruit relationship for Northeast Arctic cod using different indices for reproductive potential. a) spawner biomass calculated with constant values of proportion mature and weight at age for pre-survey time period (ICES ACFM 2001a); b) spawner biomass calculated with year-specific values of proportion mature and weight at obtained from Russian and Norwegian historical sources (ICES ACFM 2001b); and c) total egg production. The recruitment index used is the abundance at age 3. Observations are labelled by year. The loess curve (degree=1, span=1.5) is shown for each.

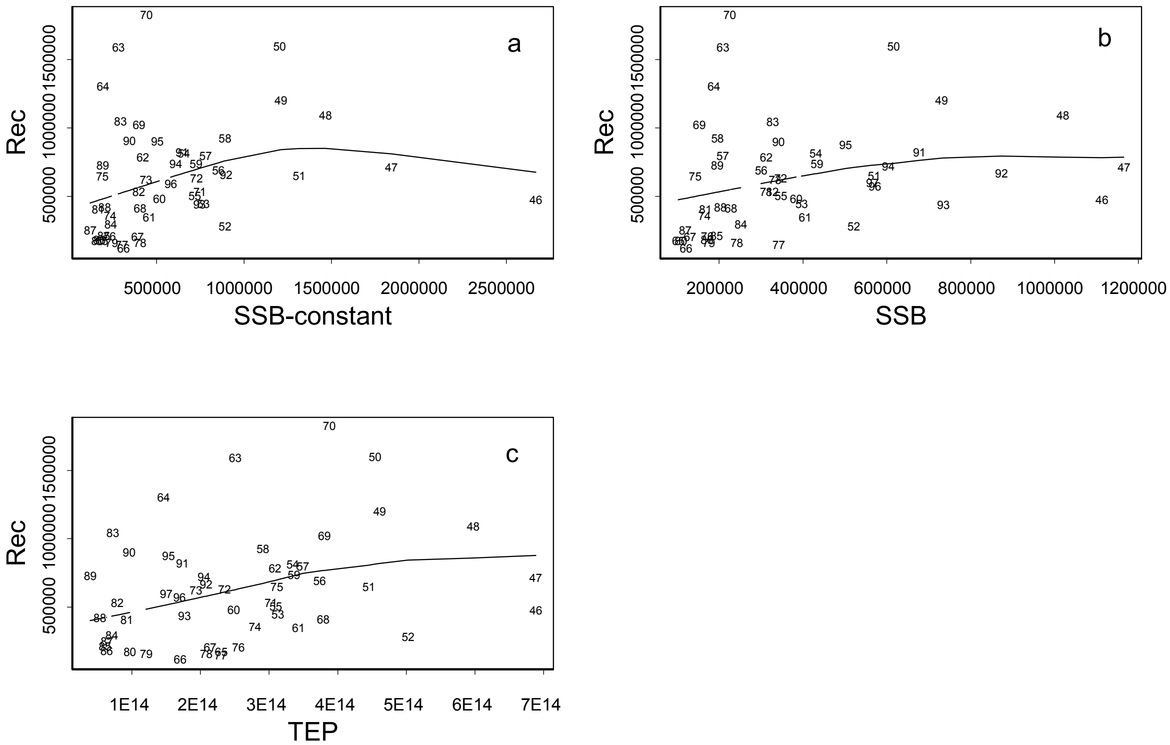

Figure 2: Time series of spawner biomass (solid line; from ICES ACFM 2001b) and total egg production (dashed line).

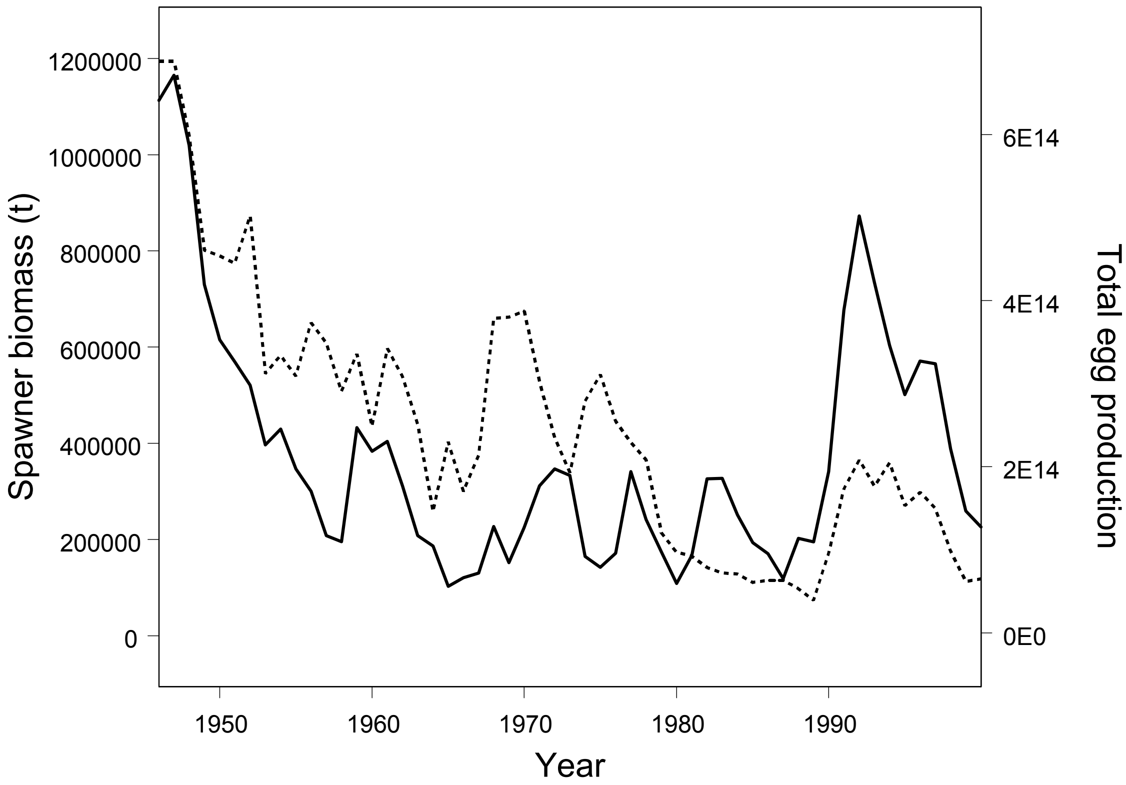

Figure 3: Bivariate plot of fishing mortality versus the proportion of total egg production removed by fishing (PRR). Observations are labelled by year. The least squares regression line (Eq. 1) is also shown.