NOTE

The relationship between stock and recruitment: are the assumptions valid?

M. Cardinale*, F. Arrhenius

Institute of Marine Research, National Board of Fisheries, PO Box 4, 45321 Lysekil, Sweden

ABSTRACT: The management of exploited fish populations is, at present, based on stock assessment methods which assume that spawning biomass is proportional to the reproductive potential of the stock. This implies that the survival rates of offspring do not substantially change with the age or size of the spawner. However, the commercial extinction of many fish stock worldwide has provoked concern about the techniques used in stock assessment. Is the contribution of different age classes to recruitment equal, irrespective of the age of the fish? Here we show that not only do older individuals contribute the largest amount of eggs to the reproductive potential of cod Gadus morhua, but that they also have the largest number of recruits likely to produce offspring with higher rates of survival. This important effect of population structure on recruitment should be taken into account in fisheries science and fisheries management.

KEY WORDS: Stock assessment · Recruitment · Parental age · Population structure · Generalized Additive Model

Quantifying the reproductive potential of fish populations represents a high priority in fisheries science (Trippel et al. 1997). The most important and usually most difficult task in the assessment of fisheries resources is the establishment of the relationship between stock and recruitment (SR) (Hilborn & Walters 1992). The Beverton & Holt model (Beverton & Holt 1955) and Ricker functions (Ricker 1957) are among the 2 most widely accepted approaches for describing the SR relationship. They assume that spawning biomass is proportional to reproductive potential, which implies that survival rates of progeny do not vary substantially with adult age or size (Trippel et al. 1997). Although the classical models provide important insights into SR dynamics, they may not include other key factors or specific situations that may contribute significantly to explaining the observed recruitment variability in fish stocks (Clark 1976, De Angelis 1988, Fogarty 1993). The assumption that spawning biomass is proportional to the number of potential recruits (reproductive potential) produced by the stock remains one of the largest untested assumptions in fisheries science, and different authors have recently challenged this paradigm (Trippel et al. 1997, Marshall et al. 1998, Marteinsdottir & Thorarinsson 1998).

The overexploitation of marine fish populations typically results in the loss of the large members of the stocks (Policansky 1993, Garrod & Schumacher 1994). The depletion of large individuals may not only affect the quantitative reproductive potential of the population but, if poorer gamete quality is exhibited by younger fish as compared to older fish, the qualitative reproductive output of the stock may also be seriously depleted (Trippel et al. 1997).

The influence of parental size or age on the viability of eggs and larvae is an open question. The effect of parental age on the offspring has been defined as strong, multidirectional and manifested in a long-lasting way in various aspects of the progeny’s life (Kamler 1992). The age of a parental fish influences the chemical composition of ovaries, egg size, egg metabolism, fertilization and larva and juvenile survival (Kamler 1992). As suggested by Kjesbu et al. (1996), larger cod larvae, derived from larger and older individuals, for both physiological and ecological (food availability) reasons should be in a better survival situation than smaller larvae. Previous management strategies have only considered the quantitative impact of age structure on recruitment, neglecting the importance of the age of the spawners on the quality of the offspring (survival rates). Yet, population structure may be a key factor in explaining recruitment variability; the aim of this study was to test this hypothesis.

Materials and methods. We analysed fishery-dependent and -independent data from the Kattegat, Arctic

*E-mail: mascar@imr.se

© Inter-Research 2000

Resume of full article not permitted
The table above indicates the number of factors identified in the study. The study reveals that 99 factors were initially identified, but after applying a significance level of 0.05, only 9 factors remained significant. These factors include: (1) attendance, (2) academic performance, (3) socioeconomic status, (4) parental involvement, (5) school resources, (6) community support, (7) peer influence, (8) student motivation, and (9) educational goals.

These factors were chosen based on their statistical significance and their potential impact on student achievement. The study also found that these factors are interrelated, with each having a unique contribution to overall academic success. The results suggest that a comprehensive approach to education, addressing these factors, could lead to improved academic outcomes for students.

The study highlights the importance of considering multiple factors when designing educational programs. By addressing these factors, educators can work towards creating a more supportive and effective learning environment for students.
dependent on the age population structure, with SS and, mostly, RS providing both the largest amounts of potential recruits and likely the highest offspring survival rates.

**Discussion.** The purpose of fisheries management is to ensure sustainable production of fish stocks over time and to make quantitative predictions about the reactions of fish populations to alternative management choices (Hilborn & Walters 1992). A crucial assumption in fisheries science is that the spawning biomass is proportional to the reproductive potential of the stock. However, the commercial extinction of many marine fisheries worldwide (Cook et al. 1997, Myers et al. 1997) has raised concern about the management of renewable resources (Pitcher et al. 1998) and even that central assumption has been challenged (Gilbert 1997). Here we show that for cod the influence of parental age on recruitment is substantial and that population stock structure has a significant effect on recruitment. RS explained most of the variability of recruitment. Data from this study showed that recruitment is strongly depleted when the reproductive contribution from RS, in terms of number of produced eggs, is at its lowest level, while the effect on recruitment is positive when RS eggs are abundant. Our results agreed with the hypothesis of Kjesbu et al. (1996), who argued that the presence of a rich variety of age classes in the

**Fig. 1.** GAM-derived effects of number of potential eggs ($10^{12}$) produced by the repeated spawners (RS) on the recruitment ($10^6$ individuals) of (a) Arctic, (b) North Sea and (c) Kattegat cod.

**Fig. 2.** GAM-derived effects of number of potential eggs ($10^{12}$) produced by the second spawners (SS) on the recruitment ($10^6$ individuals) of North Sea cod.
Spawning population should increase the probability of
successful recruitment. This positive effect of older
recruitment on local population growth may also
contribute to higher
local productivity and survival (Spaull, 1996). Longer
spawning periods may influence local recruitment to
exceed local extinction rates and a slight increase in
local productivity can occur. However, the positive
effect of older recruitment should be balanced by the
potential age on recruitment. If the local recruitment
is high, the age of spawned eggs may be lower.
Local eggs may be hatched and the age of recruitment
may increase with higher recruitment.
fish stocks. Can J Fish Aquat Sci 54:969–977

Submitted: November 4, 1999. Accepted: February 17, 2000
Proofs received from author(s): March 16, 2000