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Patterns of Population Variability in Marine Fish Stocks, with Application to Precautionary Rebuilding Projections of the Georges Bank Haddock

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Exploited marine fish and invertebrate stocks fluctuate in myriad complex patterns, with variability on interannual, decadal, and longer time-scales. To characterize various patterns of variation, time series of catch, catch per unit effort, or biomass, 30 stocks were examined with a variety of statistical methods including autocorrelation analysis and Lowess smoothing (Spencer and Collie, 1997a). A hierarchical cluster analysis classified the stocks into six identifiable groups: steady-state; low-variation, low-frequency; cyclic; irregular; high-variation, high-frequency; and spasmodic. These patterns are consistent with life-history traits; for example, stocks with high variability are generally small pelagic species, whereas low-variability stocks are generally slow-growing demersal fish. The specific mechanisms producing population fluctuations generally remain unknown, but likely involve some interrelation of 1) the effect of harvesting on future recruitment, 2) inter- and intraspecific biotic interactions (predation, competition), and 3) environmental variability. Each of the six general patterns of variability can be produced from a simple multiple-equilibrium population model (Steele and Henderson, 1984) by varying the intrinsic rate of population growth, and the time-scale and amplitude of environmental variability.

Suitable management policies depend on the type of variation observed, and the vast majority of examined stocks did not correspond to the steady-state assumptions of classical fisheries models. Characteristic patterns of variation may suggest general management strategies; for example, management of spasmodic stocks may alternate between periods of active exploitation and rebuilding, a process enhanced by the existence of other exploitable stocks. However, a specific precautionary management strategy will likely require a focused examination that considers uncertainty in future stock production and a variety of harvest strategies and management goals.

The collapse of several northwest Atlantic groundfish stocks, including the Georges Bank haddock (*Melanogrammus aeglefinus*), has generated interest in precautionary fishery management. The sharp break between prolonged periods of high (pre-1965) and low (post-1965) haddock abundance suggests the existence of two levels of stock productivity, which would be consistent with the Steele and Henderson model. The Steele and Henderson model and the simpler Schaefer production model (Schaefer, 1957) were fit to the haddock data and used to evaluate various rebuilding strategies with two performance measures—the sum of discounted yield and sum of discounted revenue (Spencer and Collie, 1997b). The Steele and Henderson model provided plausible parameter estimates for the entire data set (1931-1993), whereas the Schaefer model provided plausible parameter estimates only for the recent years of low productivity (1976-1993). For either model, the levels of the instantaneous fishing mortality rate F that maximize either yield or revenue were lower than the recently adopted target level of $F_{0.1} = 0.24$. For both models, the time required to rebuild to 80 kt was approximately 10 years when $F \sim 0.10$; recovery times increased more rapidly with increasing F under the Steele and Henderson model. The low production in recent years provides impetus for managers to consider a variety of plausible stock-production models, and the uncertainty of production dynamics, in choosing rebuilding strategies.

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