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Using GENMOD to Develop Harvesting Policies for Multiaged Fish Stocks

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Abstract.—Program GENMOD is a microcomputer-based simulation program that applies an age-structured population model to problems of optimal harvesting policy. It can be used to explore alternative harvesting policies and determine the policy that best satisfies conflicting objectives of fishery management. This public-domain program is written for IBM PC and PC-compatible systems.

The GENMOD microcomputer program links a generalized age-structured population model with an optimization routine. The program can be used to obtain optimal harvesting policies for a range of management objectives, including maximization of harvest and minimization of variability about a target harvest, stock biomass, or spawning stock. The program also can be used to simulate the behavior of the fishery when either optimal or suboptimal policies are implemented. For each policy examined, the program provides a time series of estimates of stock size, fishing mortality, and yield that can be used to determine if the stock would be maintained at or restored to an appropriate level, if yield would deviate unacceptably from historical levels, and if yield or fishing effort would vary unacceptably from year to year. The program is best used to explore alternative harvesting policies in order to determine which policy best satisfies the conflicting objectives encountered in managing a fishery. It is written in Turbo Pascal for use with IBM PC and PC-compatible systems. Copies of the program and documentation can be obtained from the American Fisheries Society Computer Users Section library.

The model is a slightly generalized version of a deterministic model presented by Getz (1980). Models of this form frequently are used in conjunction with cohort analysis to analyze historical catch data and to develop recommendations for future harvests. The model can be used for stocks with up to 30 age-classes, and natural mortality, catchability, weight, and fecundity can vary by age. Males and females are pooled, however, so sex-specific differences in growth or mortality should not be large if this model is used. The spawner–recruit relationship can be represented by a constant or by a Ricker or Beverton–Holt curve, and spawning can occur either before or after a fishing season of variable length. The model should be useful for a wide range of single-species fisheries, as long as a single gear type is used to harvest the stock.

Program Options

Optimization

The first optimization routine is used to determine the levels of fishing effort that maximize (or minimize) a specific objective function over an N-year planning horizon. This is a deterministic approach; therefore, random variability in recruitment is not considered. The routine can be used to predict the expected outcome of implementing alternative optimal harvesting policies; for example, policies for rehabilitating overexploited stocks (Hightower and Grossman 1987). The following objective functions can be used: (1) maximize harvest; (2) maximize log(harvest + 1); (3) minimize the squared difference between annual harvests and a target harvest; (4) minimize the squared difference between stock biomass at the end of each fishing season and a target stock biomass; and (5) minimize the squared difference between the spawning stock at the end of each fishing season and a target spawning stock. An end-point penalty can be used to force the stock to converge on a desired end point; otherwise, the final status of the stock is not considered. Under a harvest-maximizing policy, stock depletion will occur unless an end point is used.

The second optimization routine is used to develop harvesting policies of the type proposed by Ruppert et al. (1984, 1985), in which harvest is either a linear or nonlinear function of stock size. These policies are obtained from a stochastic model and would be appropriate, therefore, for stocks in which year-class strength varies widely (Hightower and Lenarz 1989, this volume).

Simulation

The simulation routine is used to examine the short- and long-term behavior of the model when recruitment is assumed to be a random variable. This routine can be used to evaluate the performance of policies developed in the optimization routines, or to compare those routines with suboptimal alternatives. The program will estimate the steady-stage mean and variance or the frequency distribution for yield, spawning stock, or recruitment. For a more detailed examination of model behavior, a short-term option can be used to produce annual estimates of yield, spawning stock, and the number-at-age vector.

References

Getz, W. M. 1980. Harvesting models and stock recruitment curves in fisheries management. Pages 284–304 *in* W. M. Getz, editor. Mathematical modelling in biology and ecology. Springer-Verlag, Berlin.

Hightower, J. E., and G. D. Grossman. 1987. Optimal policies for rehabilitation of overexploited fish stocks using a deterministic model. Canadian Journal of Fisheries and Aquatic Sciences 44:803–810.

Hightower, J. E., and W. H. Lenarz. 1989. Optimal harvesting policies for the widow rockfish fishery. American Fisheries Society Symposium 6:83–91.

Ruppert, D., R. L. Reish, R. B. Deriso, and R. J. Carroll. 1984. Optimization using stochastic approximation and Monte Carlo simulation (with application to harvesting of Atlantic menhaden). Biometrics 40:535–545.

Ruppert, D., R. L. Reish, R. B. Deriso, and R. J. Carroll. 1985. A stochastic population model for managing the Atlantic menhaden *(Brevoortia tyrannus)* fishery and assessing managerial risks. Canadian Journal of Fisheries and Aquatic Sciences 42:1371–1379.