A Simulation of Fishery Management Strategies for Overexploited Queen Conch Stocks

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ABSTRACT

It is well known that many queen conch (*Strombus gigas*) stocks throughout the Caribbean have been depleted or are undergoing serious declines in abundance due to overfishing. Thorough quantitative analyses are needed to assess stock status relative to fishing pressure, to design appropriate management programs, and to predict the effect of regulations. The goal of this study was to evaluate alternative management strategies for overfished queen conch stocks via simulation.

A simulation model was developed that incorporates essential features of conch biology, population dynamics, and fisheries, and that represents a range of plausible management scenarios. The current model configuration is loosely based on the Puerto Rican conch fishery, but has the flexibility to replicate other real situations. A series of simulations were carried out to evaluate management regulations in the form of gradual reductions in effort, seasonal closures, moratoria, minimum size limits, and different combinations of these.

Projections based on current fishing practices were not sustainable and led to stock collapse, while the implementation of management strategies showed that stock recovery may be achieved within a reasonable period. Performance indices (stock size, spawning biomass, and yield) suggested that the use of shell-lip limits in combination with other methods would promote conservation of the resource and secure future yields. These findings, and further application of the model to other case studies, may have important implications for conch fisheries management in the region.

KEY WORDS: Fishery management strategies, simulation model, *Strombus gigas*

Simulación de Estrategias de Manejo Pesquero en Poblaciones Sobreexplotadas de Caracol Rosado, *Strombus gigas*

Actualmente se sabe que varias poblaciones de caracol (*Strombus gigas*) a lo largo del Caribe están disminuyendo ó han sido agotadas por sobrepesca. Para evaluar el estado de los stocks en relación a la presión de pesca, diseñar programas de manejo adecuados y medir el efecto de las regulaciones existentes, es necesario hacer análisis cuantitativos detallados. El objetivo del presente trabajo fue realizar una evaluación de distintas estrategias de manejo en poblaciones de caracol sobreexplotadas utilizando técnicas de simulación.

Se desarrolló un modelo de simulación que incorpora características esenciales de la biología, la dinámica poblacional y las pesquerías de la especie y que representa el efecto de posibles escenarios de manejo. La configuración actual del modelo está basada someramente en la pesquería de Puerto Rico pero tiene la flexibilidad para reproducir otras situaciones reales. Se llevaron a cabo una serie de simulaciones para evaluar estrategias de manejo consistentes en reducciones graduales de esfuerzo, clausuras temporales, tamaños mínimos de captura y distintas combinaciones de éstas.

Las proyecciones de la pesquería a futuro mostraron que las prácticas actuales no son sostenibles y que pronto llevarían al colapso del stock; mientras que la utilización de estrategias de manejo mostró que es posible lograr la recuperación del stock dentro de un plazo razonable. Los índices utilizados para evaluar la eficacia de cada método (tamaño de la población, biomasa reproductiva y captura) sugirieron que los límites en el grosor del labio de la concha, utilizados en combinación con otros métodos, impulsarían la conservación del recurso y su rendimiento a futuro. Estos resultados y la aplicación del modelo a otros casos específicos pueden tener implicaciones importantes para el manejo de caracol en la región.

PALABRAS CLAVES: Estrategias de manejo, modelo de simulación, *Strombus gigas*

INTRODUCTION

Queen conch fisheries occur throughout the range of the specie's distribution in the Caribbean. Many conch stocks are undergoing serious declines in abundance or have collapsed as a result of intense fishing pressure. For this reason, a variety of management regulations have been implemented at the local and international levels to rebuild the stocks and restore fishery yields. These include regulations that control fishing effort, limit access to the resource, protect breeding or immature conchs through size limits, limit commercial trade, or replenish the stocks through mariculture (Rathier 1989, Appeldoorn and Rodriguez 1994, CARICOM 1995, Stoner 1997, CITES 2003).

Rigorous quantitative analyses are needed to assess stock status relative to fishing pressure, to design appropriate management programs, and to predict the effect of regulations. Given the long-term data requirements to

conduct such analyses, one feasible approach is through simulation. The goal of this study was to design a flexible, generalized age and size-structured simulation model that explicitly characterizes uncertainty to evaluate a range of management alternatives for overexploited queen conch stocks.

APPROACH AND METHODS

A simulation model that incorporates the most important characteristics of the biology, population dynamics, and fisheries of queen conch was developed to assess the impact of alternative management strategies on the recovery of overfished stocks and their future productivity (Valle-Esquivel 2003). The model consists of three interacting components:

i) A population dynamics model that represents the biological system,
ii) A fishery model that mimics the exploitation pattern, and
iii) A management-prediction model that projects alternative management scenarios into the future.

The population model is structured by age and shell size (length and lip-thickness); growth, recruitment, and maturity are stochastic variables; shell growth occurs in two dimensions (juveniles grow in length; adults grow in lip-thickness); and natural mortality can be constant or age-specific. The fishery model includes commercial and recreational sectors with distinct seasons of operation, selectivity, catchability, and effort patterns. The management model predicts the future condition of severely depleted stocks under different scenarios. The current model configuration is loosely based on the characteristics and status (i.e., overfished and overfishing) of the Puerto Rican conch fishery (Valle-Esquivel 2002a, 2002b), but has the flexibility to reflect other real situations.

A variety of 'what if' scenarios were tested by changing assumptions about the biology, the fishery, and the nature of the management plan (gradual reductions in effort, minimum size limits, seasonal/total closures of the fishery, or combinations of these). In all cases, a high level of fishing pressure was applied for twenty years to a population in equilibrium to produce an overfished stock at the end of the historical period. Management measures were then introduced and applied for a ten-year rebuilding period. Four performance indices were calculated to assess the state of the system before and after management: average annual yield, annual variation in yield, stock abundance, and spawning stock size.

RESULTS AND DISCUSSION

Model results were very sensitive to the biological assumptions, in particular regarding natural mortality (M) and recruitment. The results discussed below were focused on a base-case configuration, characterized by age-specific M and density-dependent recruitment. Under this scenario, immediate management action was needed to prevent further declines in abundance and yield and to rebuild stock structure.

Projections indicated that stock abundance and age structure would be seriously impacted with the current fishing practices and that an unregulated fishery would soon collapse. Conversely, the introduction of regulations showed that stock recovery may be achieved within a reasonable period of time, and that sustainable yield levels could be attained in the longer term.

In general, under severely overfished conditions, stock recovery and yield could not be optimized simultaneously; a compromise must be made to achieve both objectives. Tighter measures (i.e., larger effort reductions, larger size limits, longer closures) resulted in faster recovery, but did not improve yield in the short term. Effort controls were effective in increasing stock size, but not in restoring age-structure or spawner abundance. The application of size restrictions also showed that the level of stock recovery was proportional to the size limit, with shell-thickness limits being particularly effective in the protection of older conchs and in the restoration of the stock's reproductive potential. With temporal or permanent bans on fishing, progressive recovery was observed as longer closures were applied. Finally, performance indices suggested that optimal management solutions should include combinations of moderate strategies, such as reasonable limits on lip-thickness after a closed season or combined with effort controls (Valle-Esquivel 2003).

Overall, results from this study suggested that there are several alternatives to achieve successful management of overexploited queen conch stocks in the short or medium term. These alternatives and further application of the model to other case studies may serve as general guidelines for the management of the species in the region.

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