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Research Article

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Bio-economics of fisheries Assessment and management

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Abstract

The principles on which the evaluation of fisheries is based are described; a semblance is made of the initial stages that are required to satisfy the analysis of the dynamics of each population. The biological evaluation process requires the social and economic evaluation of each case study, in such a way that the maximum levels of biological, economic and social performance to be evaluated under certain fishing intensities together with the age of first catch. This evaluation offers useful exploitation scenarios for planning and decision-making aimed at conservation and sustainable exploitation of fisheries.

Keywords: Management Objectives, Optimal Exploitation, Maximum Biological Yield, Maximum Economic Return, Sustainability

Introduction

The processes governing the dynamics of each fishery should be known, as well as the levels of performance (with biological and socio-economic criteria) leading the management strategies and policies to be oriented towards a sustainable exploitation [1-3, 7-8, 43].

The evaluation of optimal fisheries strategies should accomplish the following purposes:

1. Determine the levels of optimum biological performance and optimum economic return;
2. Determine the level of direct jobs that each of the two options mentioned above could create;
3. Evaluate the consequences (biological, economic and social) of all feasible exploitation options;
4. Evaluate the optimal strategies for exploitation of the resources analyzed;
5. Planning and managing each stock on a basis such that ensures its sustained development.

The management of fishery resources with modern simulation tools, makes it possible that not only specialists can understand the consequences in the fishery, or in the conservation of the resource, of any strategies adopted for managing the fisheries.

A demonstration of the capabilities of a simulation model, should allow us to glimpse the consequences on the exploited population and the fishery as a whole, just by applying logical exploitation options of any kind; for example, evaluating the socio-economic and biological consequences of an abrupt and excessive increase of fleet size, which in practice has occasionally occurred in some fisheries, or the effects of a change in the mesh opening, which means leaving a certain proportion of adults in the sea, allowing to replace those who die from natural causes and fishing.

The Future of Fisheries and Fisheries Science

Among all the problems that society faces, in the context of a population explosion and uncontrolled environmental pollution, the future of fisheries is burdened by political trends and the economic and social factors conditioning them. The development of fisheries is in the midst of the need to feed a growing human population and the consequences of depletion of exploited resources, motivated by economic interests and is constrained by the finite volume of stocks. Economic, social and fishing dynamics face each one, multiple problems that interact, but have their own dynamics and complicate the possibility of finding isolated and independent solutions. Aquaculture seems to offer a light of hope to humanity for helping to solve the problem of food production from the aquatic environment. However, this is not a permanent solution. There are certain trends in fisheries development which, in practice, contribute to a future that can contribute that fisheries become truly sustainable, such as the reduction of discharges, the gradual reduction of the manufacture of large vessels, the improvement of management measures of fisheries, the increasing participation of the public involved, the eco-labeling of fishery products, the reduction of illegal fishing, a relative price stability and the certification of many fisheries, among others. All these factors open a window of hope that allows us to expect that the sustainability of fishing can become a reality, rather than a utopia.

Methods

Knowledge of population parameters can be achieved with the help of length frequency data, or by reading growth marks, as well as based on estimates of abundance from log data or statistical information. The FISMO model (FIsheries Simulation MOdel) is based on the general principles of the evaluation of fishery resources using the traditional equations that are usually applied in this procedure, with the difference that in the simulation process, the equations and the intermediate results of the process are linked to each other, in addition to the analysis of the costs and benefits of the exploitation of each fishery being analyzed [1-6]. This last option allows to evaluate the socio-economic performance of the exploitation, as well as an easy way to determine the optimal biological, economic and social values of the same.

Catch Data and Fishing Effort

The catch data must be obtained for a minimum period of fifteen years, generally available in the FAO statistical yearbooks. This information is necessary to estimate the Maximum Sustainable Yield (*MSY*), the Maximum Economic Yield (*MEY*), to determine how the fishing effort affects recruitment, biomass and profits. All this can be achieved with the use of the FISMO fisheries simulation program [7, 8].

Growth, Age Structure and Mortality

The growth rate, particularly the parameters of the von Bertalanffy model, must be evaluated from sampling data and can be analyzed with the help of the FISAT package, which also allows estimating mortality [9]. The age structure should be determined with reference to the catch data. One method to apply may be the analysis of the catch by age group, which starts from the assumption that the relative abundance between these groups remains constant over time (Fig. 1A).

Lengths and Weight-Length Ratio

From sampling data, the size composition in the population and the weight-length ratio are determined by the corresponding regressions (Fig. 1B). For the estimation of recruitment. the abundance of adults over the years should be used to determine the recruitment rate, that is, the number of juveniles in the age group I that is annually incorporated into the population as a result of reproduction. This relationship can be evaluated with the Beverton & Holt model [1].

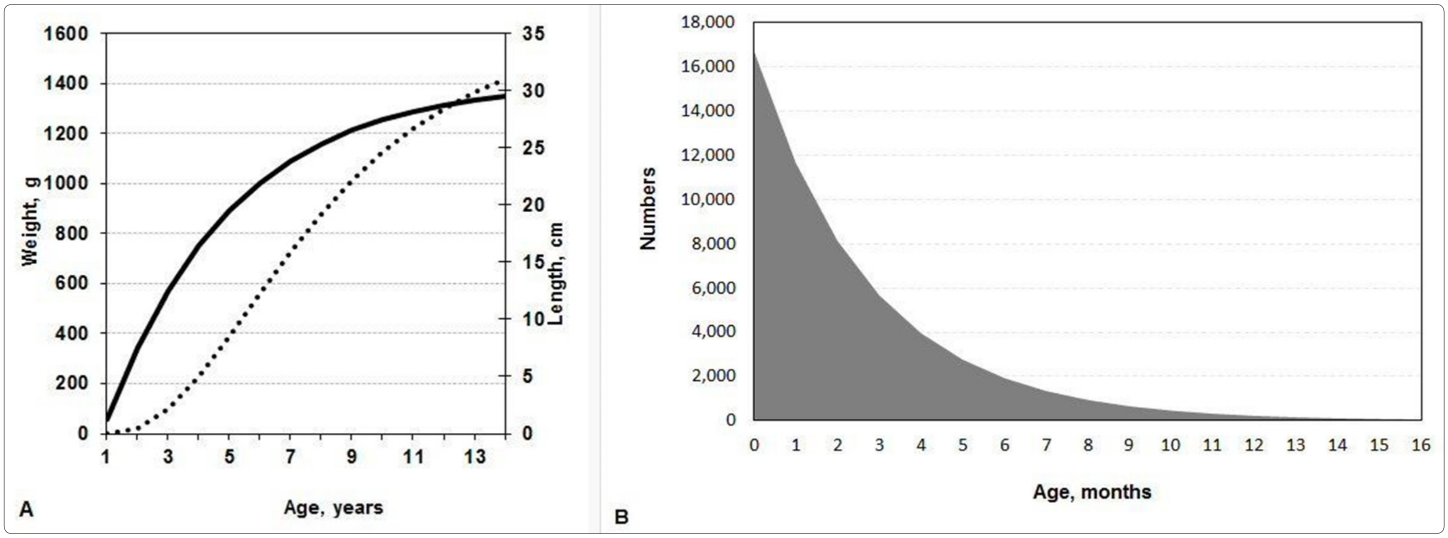

Fig. 1A. Growth rate in length and weight of the Caribbean spiny lobster.
Population parameter values are K = 0.24; L = 0.31 cm; W = 1,619 g; to = -0.17 (Ley & Chávez 2010).
B. Survival of the Caribbean lobster stock as a function of age, with a Natural mortality of M = 0.36.

Results

Biomass and Yield

The number of individuals in each age group can be estimated using the equation that describes the rate of exponential decay (Fig. 1B) and the value of fishing mortality (*F*) is taken into account in the case of age groups exploited The numerical abundance must be transformed into the corresponding biomass and with the capture equation, the *F* is estimated (Fig. 2); the model of Beverton & Holt allows to determine the values of the age of first capture and of the *F* producing the highest yields; the one that corresponds to the Maximum Sustainable Yield (*MSY*), can be estimated from the values of the population parameters (Fig. 3). Once an F_{MSY} value is evaluated, other reference points necessary for planning the fishery can be defined [11].

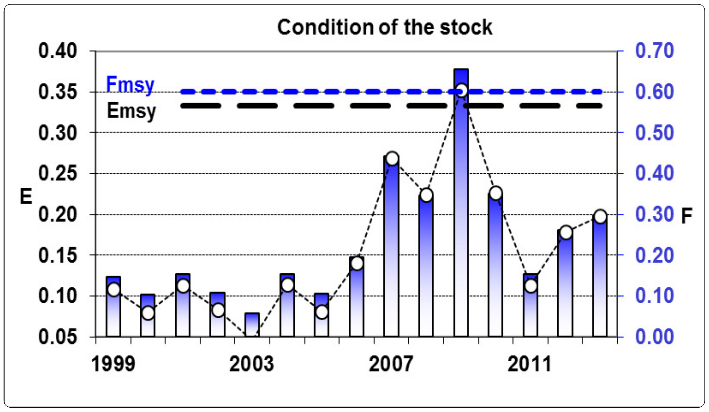

Fig. 2. Fishing mortality (*F*) and exploitation rate (*E*). F_{MSY} and E_{MSY} are the levels of these variables at the Maximum Sustainable Yield and are represented as horizontal lines, as a reference to identify the fishing seasons where the green crab of the southern Baja California fishery was under or overexploited [12].

Socio-Economic Variables

The data required by the model can be obtained from interviews conducted with fishers of each resource, from which the approximate number of vessels operating, the number of days of the fishing season, the number of fishers per vessel, the daily costs of fishing activity, costs of equipment and replacement time, daily catch, the cost per Kg at the dock, before adding value. It is also required to know the proportion of earnings that is distributed among the crew members. Due to the frequent difficulty in obtaining some data from those mentioned in this paragraph, the model simplifies the input information and makes realistic estimations that allows the socio-economic diagnosis to be made with a very reasonable approximation.

Yield Per Recruit and Maximum Yield

A pertinent consideration it to recall that Beverton & Holt described in detail the yield per recruit, and clearly showing the enormous difference that can be obtained after the use of a closed mesh opening capturing many juveniles, in contrast with the use of larger mesh catching only adults [1]. Many papers have been published after that classical book and unexpectedly, just a few take into account explicitly, the age or size of first entry to the fishery as a key factor of fisheries assessment required for attaining optimum yields and the explicit consideration for ruling the criterion for management [2-6, 9]. The use of the elegant graphic display describing the yield per recruit seems to have been neglected over time, probably because it may be considered too static and fisheries management requires a dynamic scheme that can be adopted for decision-making [1].

Modelling may provide a versatile tool that can be adapted to particular situations, and supporting many different scenarios and life cycles of exploited stocks. Apart from the possibility of simulating the stock response under many different scenarios, it is capable of provide answers addressed to test the output of any combination of the fishing mortality and the age/length of first entry to the fishery.

Potential Impact

To the extent that tools before mentioned are adopted for decision-making in the administration of fisheries, it will be possible to evaluate optimal strategies for exploitation of fishery resources in which they are applied. In the following paragraphs the stock response of the fishery under the current age of first catch are described, and graphically represented in Figs. 3A and 3B, which means,

A. From the Point of View of Capture

- Determine in advance the maximum catch volume that can be extracted sustainably.
- Forecast the optimal exploitable volume in the following season, with known risk margins.

B. From the Social Point of View

- Determine the optimal number of fishers that can be used in that activity without over-exploiting the resource.
- Evaluate for forecasting purposes, the maximum number of fishermen who should fish in the following season, to ensure that the fishery operates with profits and without being overexploited.

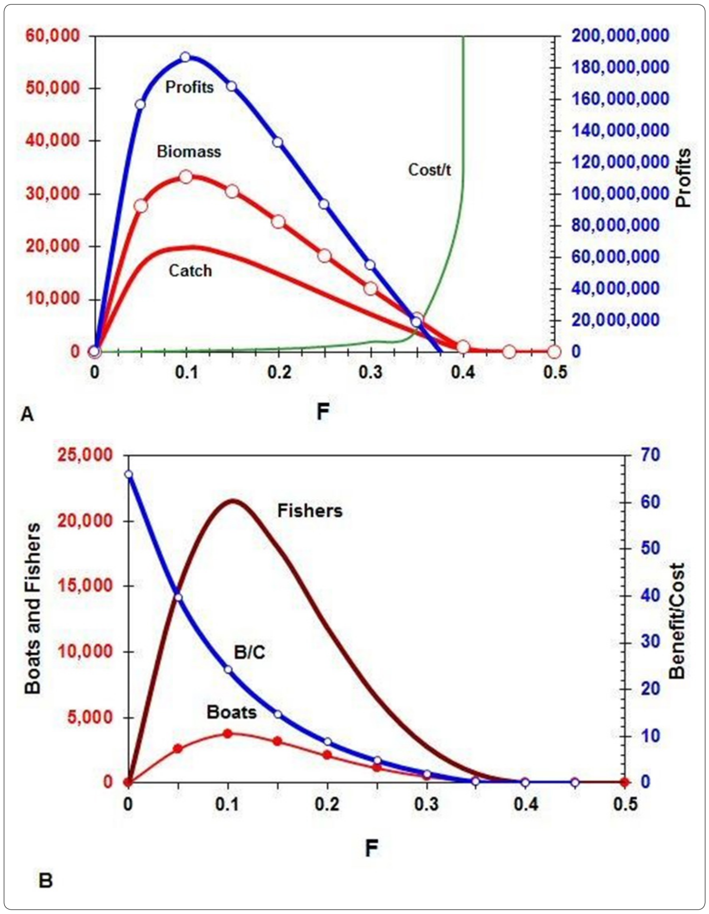

Fig. 3. Biologic and economic potential yield of the brown shrimp exploited at the Gulf of California as a function of the fishing mortality (*F*).

C. From the Economic Point of View

- Evaluate the levels of effort and capture that "maximize" the benefit / cost ratio.
- Evaluate the optimum level of employment that the activity can generate in the short and long term.
- Determine the maximum level of fishing effort that the fishery can sustain without reaching the level of economic equilibrium (benefit/cost ratio = 1) and bankruptcy.

D. From A Biological and Resource Conservation Point of View

- Evaluate the levels of fishing effort that guarantee the conservation of the population as a sustainably exploitable resource.
- Evaluate the intensity levels of the critical fishing effort that should not be exceeded due to their consequences on the over-exploitation of the population and the risk of its eventual collapse.

Services to the Fishing Industry

It is necessary to put at the service of the fishing industry the capacity that allows,

- Making forecasts of the catch volume in the following year by facilitating communication between managers and stake holders of the resource. A possible option could be the use of interactive graphics that are easily accessible, without having previous experience in the use of the computer.
- Perceive and assess the consequences (biological, economic and social) of all exploitation options that are feasible to apply.
- Identify and evaluate optimal biological, economic and social strategies for exploitation of fishery resources.
- Have a tool for planning and administration of fisheries resources to ensure their sustained development.

Conclusions

The expected impact is to offer alternatives for the conservation of resources that tend to guarantee the maintenance of the economic and social activity depending on them.

If the recommendations proposed here are taken into account and strict control measures are applied, most fisheries could be exploited sustainably. This option may be an appropriate procedure to apply management options aimed to the conservation and sustainable exploitation of fisheries (Grafton et al., 2007) [13].

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Appendix

Stocks evaluated with the model FISMO. As a result of the studies carried out, scientific articles have been published (copies of them can be provided by request) of the fisheries mentioned below (taken from Chávez-Ortiz, 2014, with additions). The numbers mentioned in the reference list with (*), correspond to those in the cited literature.

Species	**Region**	**Reference***
Green abalone (*Haliotis fulgens*)	W Baja California	34
Bigeye tuna (*Tunnus obesus*)	Pacific Ocean	20
Barrilete (*Katsuwonus pelamis*)	Pacific Ocean	7
Giant squid (*Dosidicus gigas*)	Gulf of California	40
White shrimp (*Penaeus vannamei*)	Gulf of Nicoya, C. R.	38
White shrimp (*Penaeus vannamei*)	Sinaloa	13
Brown shrimp (*Penaeus californiensis*)	Magdalena Bay, BCS	12
Blue shrimp (*Penaeus stylirosrtis*)	Magdalena Bay, BCS	23
Rock shrimp (*Sicyonia penicillata*)	Gulf of California	30, 31
Queen conch (*Strombus gigas*)	Caribbean sea	17
Red snapper (*Lutjanus peru*)	Eastern Pacific	22
Caribbean spiny lobster (*Panulirus argus*)	Caribbean sea	6, 9, 29
Red spiny lobster (*Panulirus inflatus*)	W Baja California	15
Red grouper (*Epinephelus morio*)	Campeche Bank	14
Sea cucumber (*Isostichopus fuscus*)	Gulf of California	26
Warty sea cucumber (*Parastichopus parvimensis*)	NW Baja California	18, 36
King mackerel (*Scomberomorus cavalla*)	Veracruz	2, 11
Octopus (*Octopus maya*)	Campeche Bank	5
Yellowtail (*Lutjanus synagris*)	Campeche Bank	39
Sardine (*Sardinops caeruleus*)	Gulf of California	19, 32
Spanish mackerel (*Scomberomorus maculatus*)	Veracruz	2, 3
Totoaba (*Totoaba macdonaldi*)	Upper Gulf of California	28
Green crab (*Callinectes bellicosus*)	SW Baja California	41