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Decision Analysis Applied to the Fishery of the Sea Snail *Concholepas concholepas* from the Central Northern Coast of Chile

J. Tam, W. Palma, M. Riofrio, O. Aracena and M.I. Lépez

Abstract

Formal decision analysis was applied to the management of *loco* (*Concholepas concholepas*, Fam. Muricidae) in Chile, 29 - 35°S. Four interested groups were considered "Fishers", "Scientists", "Buyers" and the "State", along with three fishing effort levels and four subobjectives. The method was found to encourage the emergence of a consensus (here: halving of effort), and is recommended for use in other fisheries.

Introduction

Fishery management is a complex decisionmaking process based on multiple criteria and involving conflict of interests between subsectors. Decision analysis allows the use of subjective judgments together with information associated with the alternatives to be selected (Keeney 1982). It is considered a useful tool to assess management strategies using both biological and socioeconomic fishery data.

The sea snail or Chilean abalone (*Concholepas concholepas*), known as *loco* in Chile, is a muricid whose biology and fishery are rather well documented (Castilla 1982). The aim of this study is to explore the suitability of decision analysis to evaluate the consequences of effort variations in the *loco* fishery on the central-northern coast of Chile. Within this context, the decision problem was simplified in order to include only the more relevant fishery objectives and attributes, i.e., those which could be quantified with the available information.

Materials and Methods

The study was focused on a stock located between 29 and 35° South. Four interest groups were identified (scientists, fishers, buyers and the State) and their judgments were compiled from interviews and published literature, to establish their preference profiles. Multi-attribute decision making (MADM) involves the definition of finite alternatives, objectives and attributes (Hwang and Yoon 1981) and in this case, three fishery management alternatives were defined (*status quo effort*, *half-effort* and *double-effort*) for the *loco* fishery. To achieve the general objective of the decision problem (fishery management), three subobjectives were defined (biological sustainability, economic benefit and social welfare), each being related to four attributes (Fig. 1).

To quantify the bioeconomic attributes under the different management scenarios, a spreadsheet simulation model was developed (T. Pitcher, pers. comm., 1994) based on a virtual population analysis, and covering seven age classes and a period between 1950 and 2010.

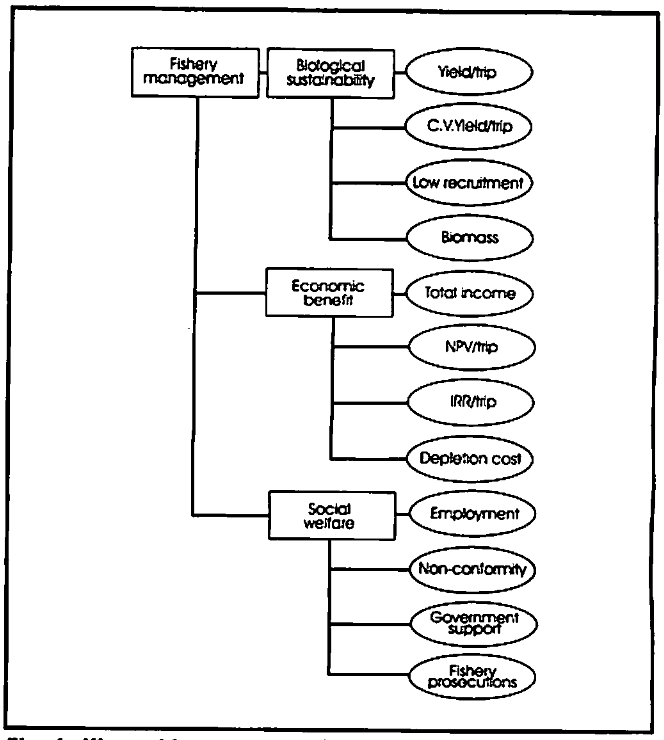

Fig. 1. Hierarchic structure of objectives [rectangles] and attributes [ellipses] for the fishery management of **Concholepas concholepas**, *Chile.*

Table 1. Parameters used in the bioeconomic simulation model of *Concholepas concholepas*.

Parameter	Value	Source
Peristomal length (mm)-total fresh weight (g)		
relationship: a	0.00008	Jeréz and Rivas (1988)
b	3.265	Jerez and Rivas (1988)
Von Bertalanffy growth equation: L_∞ (mm)	175.25	Castilla and Jeréz (1986)
K ($year^{-1}$)	0.22	Castilla and Jeréz (1986)
t_0 (year)	-0.021	Castilla and Jeréz (1986)
Foot weight to total weight ratio	0.26	Stotz and Pérez (1992)
Natural mortality range (M; $year^{-1}$)	0.10-0.22	Rivas (1991)
Catchability (q)	1.423×10^{-5}	Gonzáles (1995)
Social discount rate (%)	12	Gonzáles (1995)
Initial investment (pesos) (1US$~400 pesos)	1 300 000	Gonzáles (1995)
Stock-recruitment relationship: a	0.8	This study
P_r (individuals)	50×10^6	This study
Price (pesos/kg-foot)	3 500	This study

The value of each attribute was obtained from the average of 10 runs for the last 15 years. Input data of the model were time series of effort (trips/year), where the *status quo effort* corresponded to the official total extraction quotas of 1994 for the study area. The parameters used in this model are shown in Table 1.

Recruitment was simulated by adding a white noise component to the Ricker stock-recruitment relationship, $R = S \cdot \exp(a(1-P/P_r))$. The parameters "a" and "b" were chosen to: i) reflect a normal compensation curve, according to the density-independent characteristics suggested for *loco* (Stotz et al. 1991); and ii) improve the match between simulated and observed catches. A coefficient of variability of 30% was assigned to the white noise component, which allowed a degree of uncertainty but avoided zero recruitment. Thus, the coefficient of variability (C.V.) of yield/trip was calculated from the 10 runs of the simulation model.

The attribute "low recruitment" was measured by recording the number of years below the (geometric) mean of the recruitment values. The attribute "depletion cost" of the resource was defined as the difference between the monetary values of the unexploited and actual biomass, thus: depletion cost - (exploited value - actual value). The attribute "nonconformity" was defined according to the difference in unit price between the price wished by artisanal fishers and the market price, thus: nonconformity = (wished price - market price)/wished price. The net present value (NPV) and the internal rate of return (IRR), as well as the other economic attributes, involved only the artisanal fishery sector. The attribute "fishery prosecutions" corresponded to the number of times per year illegal catches were confiscated.

The next step in the decision analysis was to use the preference profiles established for each interest group, to define single attribute utility functions (SUF), which convert the units of each attribute (x_i) into common units, named utils (U_i), ranging from 0 to 1. For these functions, linear $U_i = a + b_i x_i$, non-linear: $U_i = a + B \cdot (\exp\text{-}cx_i)$ and mixed relationships were considered. In addition, weights were assigned to the subobjectives using the "direct entry" method, to evaluate the influence of changes in the relative importance of the attributes (k_i) over the analysis. Finally, an overall utility was calculated for each alternative by computing the multi-attribute utility function (MUF) which is a weighted sum of the SUFs: $U = S\, k_i \cdot U_i$. Thereafter, the ranking of alternatives was obtained for each group of interest, with and without weights. These computations were done using the LDW program (Logical Decisions 1993).

Results

Table 2 presents the matrix of alternatives *vs.* attributes, and shows that a doubling of effort led to a reduction of yield/trip, biomass, NPV/trip, IRR/trip and fishery prosecutions. These same attributes increased when effort was reduced to a half, while intermediate values were obtained with *status quo effort.* The attribute "low recruitment" was similar on the three altenatives, while the attribute "nonconformity" presented the more variable values.

The utility functions of the attributes are presented in Fig. 2, showing the characteristic preference profile for each group. For example, the group "scientists" established limits to utilities of total income and employment, thus favoring biological sustainability.

Table 2. Attributes matrix for the alternatives of the decision problem.

Attributes	Alternatives		
	Half-effort	Status quo effort	Double effort
Yield/trip (kg)	379	358	284
C.V. Yield/trip (%)	3.2	3.5	3.8
Low recruitment (years)	6.7	6.5	6.9
Biomass (tm)	39 615	36 315	31 023
Total income (10^6 pesos)	2 018	3 813	6 053
NPV/trip (pesos)	2 204 600	2 061 780	1 626 310
IRR/trip (%)	0.24	0.22	0.16
Depletion cost (10^6 pesos)	28 257	29 612	35 359
Employment (divers)	869	1 738	3 476
Non-conformity (%)	5	42	92
Government support (%)	35	43	60
Fishery prosecutions (confiscations)	160	140	100

The group "fishers" preferred to minimize the utility of nonconformity, while the group "buyers" had an opposite interest.

The group "State" shared several preferences with other groups, aiming to prioritize biological, social and economic subobjectives.

The ranking of alternatives are presented in Figs. 3 and 4. When the weights were not considered in the decision analysis, the group "scientists" obtained the highest utility with *status quo effort*. For the groups "fishers" and "state", utility was maximized with a reduction of effort. Only for the group "buyers" was increase of effort the best alternative (Fig. 3). When weights were applied to the subobjectives, the groups maintained its ranking of alternatives except for "scientists", whose best alternative became the reduction of effort instead of the *status quo* (Fig. 4). Table 3 presents the utilities, averages and vetoes in percentage for each alternative. It is observed that in the unweighted analysis, *status quo effort* obtained the highest average utility (35.3%) followed by the *half-effort* (35%) and double effort (29.6%). When considering weights, the best alternative, on the average, was *half-effort* (35.4%), followed by *status quo effort* (34.5%) and *double-effort* (30.1%). The alternative with the least veto was *status quo effort* (0%), followed by *half-effort* (25%) and *double effort* (75%).

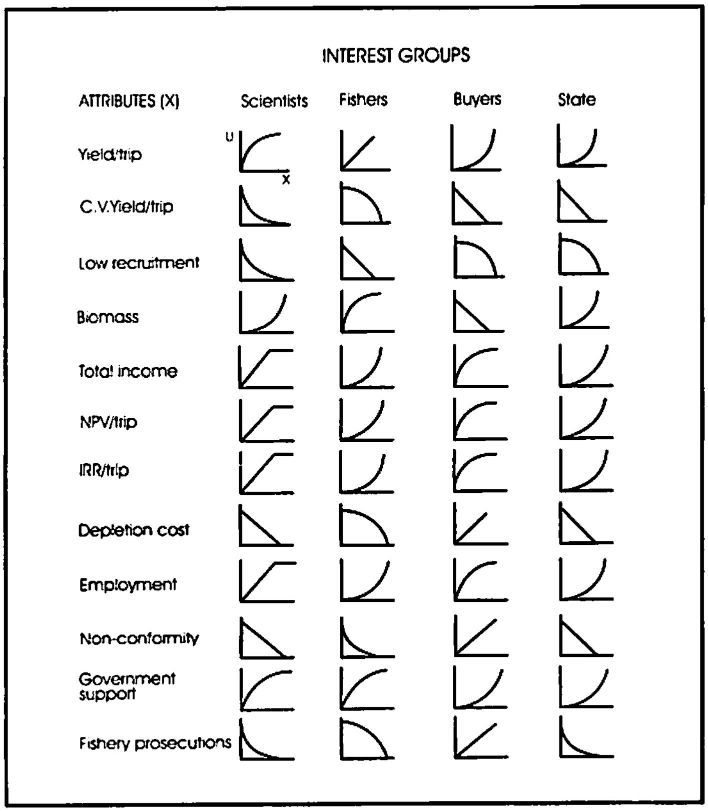

Fig. 2. Single attribute utility functions (U) for each interest group in a* Concholepas concholepas *fishery, Chile.

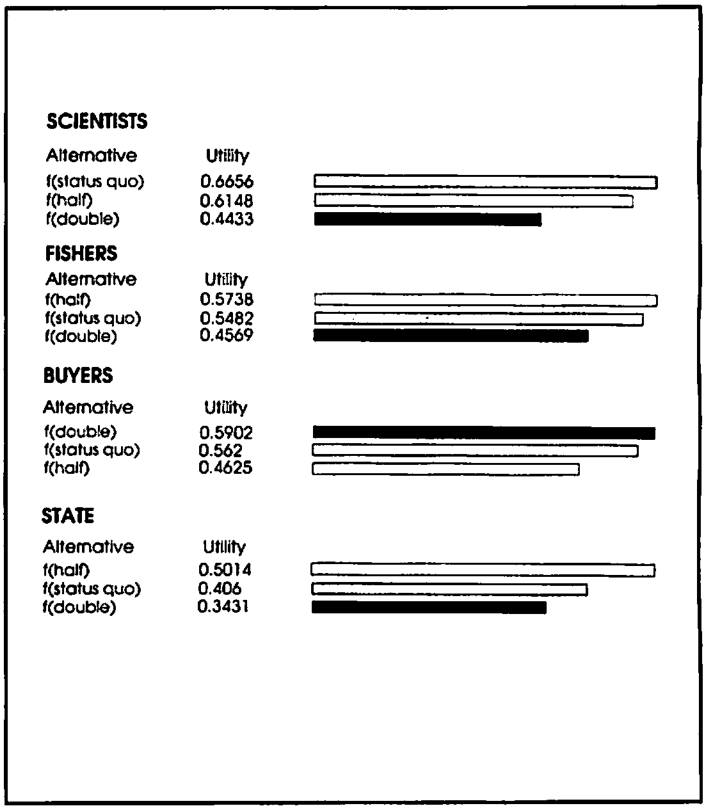

Fig. 3. Ranking of alternatives for each interest group (unweighted) in a* Concholepas concholepas *fishery, Chile.

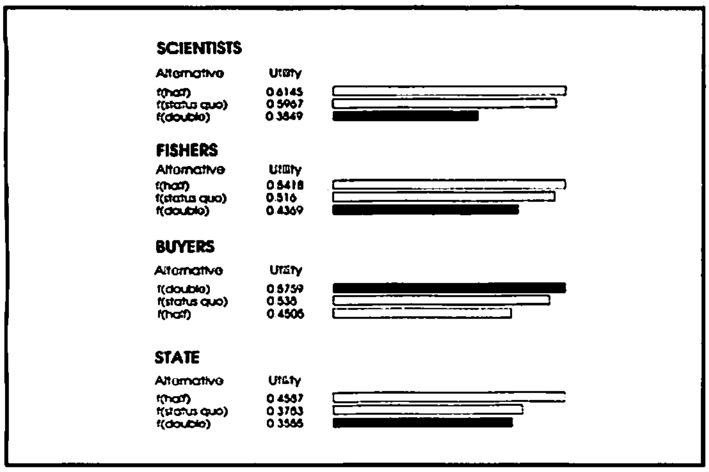

Fig. 4. Ranking of alternatives for each interest group [weighted] in a* Concholepas concholepas *fishery, Chile.

Discussion

The simple structure of subobjectives and attributes designed for the decision problem identified in the management of the *loco* fishery could be complicated by including other measures (e.g., illegal catch, exports, frozen and canned production) for which information is still scarce. Furthermore, our knowledge of biological processes (e.g., recruitment, natural mortality) needs to be refined to improve the predictive capacity of the bioeconomic model.

The decision analysis was sensible to changes in the relative importance of subobjectives. The maximum average utility obtained by *status quo effort* was preferred only by the group "scientists". When weights were considered, the ranking of alternatives changed, and favored a reduction of effort. Although the decision to decrease effort is generally considered to be politically unattractive, in this analysis, it minimized nonconformity and maximized IRR/trip and NPV/trip, thus favoring social benefits for the small-scale fisheries. Assessing weights for subobjectives is necessary in situations where the interest groups are forced to negotiate about attributes, e.g., after a drop in prices or during the resource depletion phase which will occur when fisheries develop. In the case of the *loco* resource, the average weighted ranking favored the decision to reduce effort. Based on a bioeconomic analysis, González (1995) also recommends to reduce the number of gears or the number of trips per year to achieve an optimized scenario. Specific measures could be implemented via a more diverse set of alternatives.

Decision analysis was a useful tool for the selection of the best alternative (effort reduction), for managing the *loco* fishery. The analysis considers the point of view of all the interest groups, increasing the likelihood of selecting the correct alternative. Also, it allows the formalization of subjective judgements - through the definition of utility functions and weights - and thus facilitates communication and consensus-seeking among groups. In addition, it serves as a conceptual framework to gather, standardize and generate information on the biological, economic and social aspects of a fishery. This approach therefore deserves more attention, especially for intersectoral workshops and studies at the national or international level.

Table 3. Utilities, averages and vetoes, for each interest group by alternative (in %).

Interest Group	Unweighted			Weighted		
	Half	Status	Double	Half	Double	Status quo
Scientists	35.5	39.0	25.6	38.6	37.3	24.1
Fishers	36.1	34.8	29.1	36.0	34.7	29.3
Buyers	28.6	34.8	36.6	28.7	34.4	36.9
State	40.0	32.8	27:2	38.3	31.7	30.0
Average	35.0	35.3	29.6	35.4	34.5	30.1
Veto	25	0	75	25	0	75

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