ICES CM 2007/O:17: **“**Flying outside the ICES Assessment WG paradigm – Alternative approaches to providing fisheries management advice”

Success in fishery management by reconciling stakeholder objectives in Hilborn's "zone of new consensus"

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Abstract

The inherent conflicts between objectives in fisheries management (e.g. MSY vs. conservation interests) are a hurdle for managers and scientists. However, some objectives may be compatible (e.g. economic yield and ecosystem preservation, Hilborn 2007) and could promote stakeholder consensus. The purpose of this study is to explore the “zone of new consensus” as outline by Hilborn (2007) and to develop a formal and quantitative approach to defining fisheries management objectives through stakeholder-specific utility functions. First, multiple objectives are reflected in a clearly defined utility function for each stakeholder group. Second, simulations are run to find the resulting stakeholder groups’ utility. The preliminary results illustrate a formal route towards deriving appropriate management regimes with focus on compatible management goals to promote a new paradigm of stakeholder consensus, incentives, and success in fishery management.

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Special note: *It is our hope that stakeholders can be involved with refining this framework and D. Dankel welcomes comments from the EU RACS and is open to internal RAC presentations about this paper and to simulations using specific fisheries.*

Introduction

As fish stocks continue to face substantially higher fishing levels than advised by scientists, both in Europe and other parts of the world, the need to manage fishing activity becomes direr. New strategies for the management of marine fisheries, including the development and evaluation of management procedures and harvest control rules (HCRs) are currently important research topics for many countries (Cochrane et al. 1998, Butterworth and Punt 1999, Cadrin 1999, Geromont et al. 1999, Ibaibarriaga et al. 2005, Lillegård et al. 2005). Fisheries management in Europe has traditionally focused on short-term projections for setting quotas according to conservation measures (Kelly 2006). Today, many fisheries managers and international advisory institutions (e.g., the International Council for the Exploration of the Sea, ICES) aim at more strategic, long-term fisheries management. The scientific challenge is to understand how such management strategies may work.

Hilborn (2007) emphasizes that fisheries management needs clear objectives in order to be evaluated. In fisheries, the setting of such objectives will usually involve the resource's stakeholders (Baelde 2005, Paramor et al. 2005). However, due to the nature of multiple and conflicting objectives in fisheries (Horwood and Griffith 1992, Cochrane et al. 1998, Hilborn 2007) such as high yield vs. conservation, fisheries management objectives have often remained unclear (Horwood and Griffith 1992, ICES 2007).

One way to clarify different objectives in fisheries is through the use of utility functions. These can help to quantify and rank different biological, social, or economic objectives (Quinn and Deriso 1999). The optimizing of a utility function enables the objective derivation of a management strategy, even though the selection of a utility function will always be subjective.

Because there is no "one size fits all" management strategy for fisheries (Caddy and Seijo 2005), a need arises to understand basic patterns of harvest strategy derivation and implementation. Therefore, our approach in this study is a generic one using a simple population model. Stochasticity may cause qualitative changes in predictions relative to deterministic models (Lande et al. 1994, 1995, 2003) and therefore will be included in this approach. Especially for long-term advice, stochastic considerations should be used in designing management procedures or rules (Kelly 2006).

The motivation of this paper is the "zone of new consensus" described by Hilborn (2007) (Figure 1).

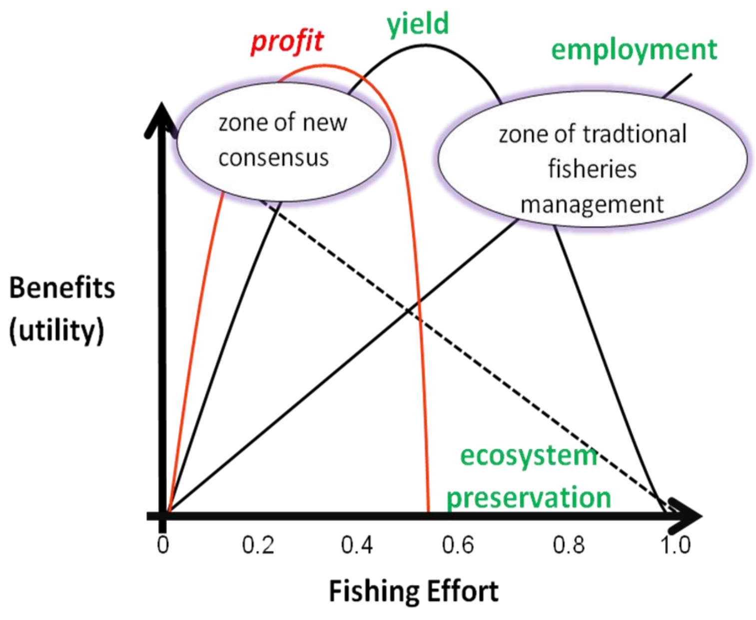


Figure 1. Hilborn's (2007) schematic drawing of conflicts between four different fisheries management objectives. This figure is the motivation for this study of the "zone of new consensus". Reproduced from Hilborn 2007.

In Figure 1, increasing fishing effort beyond certain levels leads to a decrease in yield, profit and ecosystem preservation. Employment, however, is assumed to be increasing with increasing effort and helps justify the "zone of traditional management".

Current deficiencies in fisheries management within the EU are the lack of a formal framework for drafting and ranking specific stakeholder objectives, in conjunction with the lack of a transparent and communicable approach to management. The aim for this research is therefore to work towards the development of such a framework, following a perspective outlined by Hilborn (2007).

We illustrate a formal route towards deriving appropriate management regimes with focus on compatible management goals in the "zone of new consensus" to promote stakeholder consensus, incentives, and thereby success in fishery management.

Methods

This work uses a population model semi-parameterized for a "cod-like" fish stock and a utility model to represent three different stakeholder preferences to produce a general foundation for HCR theory.

We explore different harvest regimes that reflect the trade-offs between different objectives of fisheries management (i.e., yield, employment, profit and biological conservation; after Hilborn (2007).

Population model

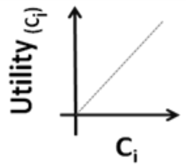
Following Heino (1998), we use an age-structured population model. The simulated population is represented by $N_a(t)$, where N is the number of individuals at time t and a represents age classes where a = 0, 1, ..., a_{max}. Individuals that reach a_{max} die. Natural mortality rate M and recruitment to the fishery are age-class specific. Stochasticity is implemented in the recruitment function and in the implementation of fishing mortality (F) to mimic variations in environment and fishing. The stock is harvested instantaneously once a year according to the F level prescribed and updated annually. Density dependence occurs at the egg stage (N_0) and length at age is derived from von Bertanlanffy's growth equation. Fecundity is weight dependent and age at maturity occurs at age 5.

The stakeholders

We use three different broadly defined stakeholder groups from which to derive the utility functions and preferences: fishermen, society and conservationists. Weights on each utility component (the concrete definitions are given in the next section) for a given stakeholder's utility function represent the stakeholder group's preferences for each utility component. The sum of all weights is equal to 1.0. Table 1 illustrates the stakeholder utility weights for the simulation scenarios. In a real world scenario, each stakeholder group would provide these weights themselves based on a consensus within the group.

In this preliminary study, we assume each stakeholder group holds a consensus within its group. We also assume each stakeholder group differs between the other two stakeholder groups in order to reproduce traditional multi-user conflicts of a common fish stock.

Table 1. Utility components (yield, employment, profit and stock level) with their units and corresponding weights for each stakeholder group (fishermen, society and conservationists). The inset histogram shows the linear realtionship bbetween the utility components (C_i) and their utility to the stakeholder group. For each stakeholder, the utility weights add up to 1.

	YIELD (tons)	EMPLOYMENT i.e.(pers. yrs)	PROFIT (€)	STOCK LEVEL (spawning stock biomass, tons)
FISHERMEN	0.4	0	0.4	0.2
SOCIETY	0.1	0.5	0.1	0.3
CONSERVATIONISTS	0.2	0	0	0.8

Utility model

Based on Hilborn (2007), four utility components that correspond to specific management objectives are used: (1) yield, *Y*; (2) employment, *E*; (3) profit, *P* and (4) ecosystem preservation, *S*. The values of these utility components will be extracted from the numerical model based on, respectively,

(1) annual yield (kilograms): $Y(t) = (1 - e^{-F_a}) \cdot N_a \cdot w_a$

(2) fishing effort: $E(t) = E_{sea}(t) + E_{shore}(t)$, where $E_{sea}(t) = E_{1/2}(\frac{B(t)}{C(t)} \text{-} 1)^{-1}$ and $E_{shore}(t) = \alpha C(t)$.

B(t) is the total stock biomass (in kilograms) at time *t* and *C(t)* is the total catch (in kilograms) at time *t*. $E_{1/2}$ and α are scaling parameters where α has the unit of *kilograms*$^{-1}$ to make E_{shore} dimensionless.

(3) difference between revenue and cost (€): $P(t) = C(t) \cdot \beta \text{ - } \mathrm{E}(t) \cdot \gamma$, where *β* is the price per kilogram and *γ* is a parameter of cost per unit effort.

(4) spawning stock biomass relative to carrying capacity ("virgin" biomass) (in kilograms), $S(t) = \sum_{a=a_{mat}}^{a_{max}} N_a(t) \cdot w_a$.

The utility at time *t* for each of the stakeholder groups is calculated once a year with their appropriate weights (ω): $\mathrm{U}(t) = \mathrm{U}_Y(t)\omega_Y + \mathrm{U}_E(t)\omega_E + \mathrm{U}_P(t)\omega_P + \mathrm{U}_S(t)\omega_S$

Total utility is then calculated through time averaging.

Utility normalization

In order for the different utility components to be comparable to each other, normalization of the units should occur. To do this, values were found for each utility component according to maximum sustainable levels; for yield: maximum sustainable yield (MSY); for employment: employment based on the harvest regime's highest allowable F level; for profit: maximum profit assuming a fixed cost of unit effort and a fixed price per kilogram of yield; for stock level: the carrying capacity of the stock at zero harvest levels.

These utility components are thus normalized individually, based on their maximum possible value, and presented as a percent of that maximum value. This approach facilitates the assessment of proposed harvest strategies by stakeholders.

Results & Discussion

First, the model was run with a range of fishing mortality (0-5.0) to show trends in the utility component values. The stock collapsed at a fishing mortality rate of 4.0. Figure 2 illustrates our model's trends which behave similarly with Hilborn's (Figure 1).

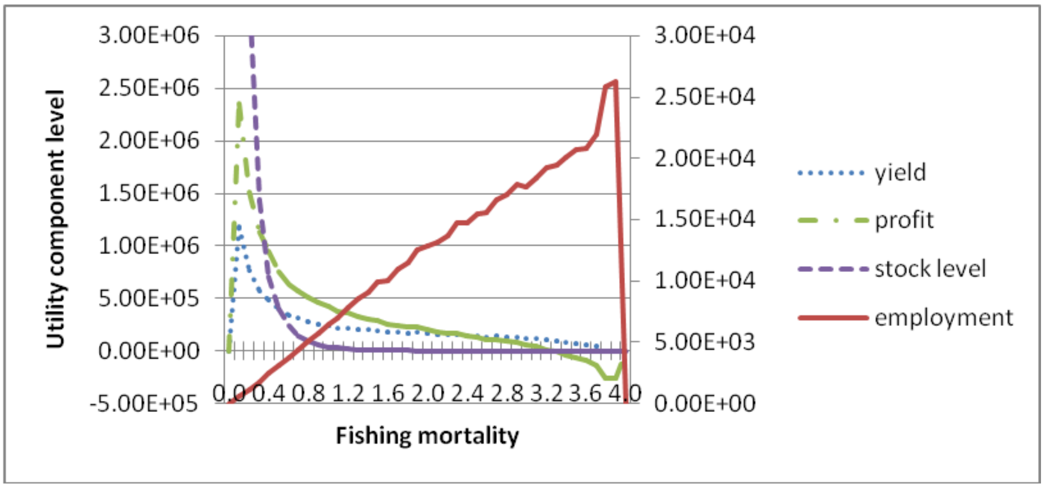


Figure 2. The four utility components (yield, employment, profit and stock level) and their values (kilograms, person years, €, and kilograms, respectively) according to increasing fishing mortality (*F*). Values for employment are plotted on the second y-axis. The stock crashed at a *F* level of 4.0. The averages for each *F* level are derived using two different *F* values , each for 1000 years after a 200 year priming phase.

We then ran two separate simulations, one to represent high fishing mortality rates and one with lower fishing mortality rates. In Figure 3, one can see the trade-offs of the utility components values and fishing mortality (*F*) rate level. Effort at shore-side proportionally increases with catches (yield), which decrease with increasing *F* due to stock depletion. However, in these two simulation scenarios we put more emphasis on employment at sea than on the shore such that increasing *F* would give increasing employment even though catches were decreasing. Therefore, one observes a linear increasing trend of employment (E_{sea} + E_{shore}) with fishing mortality in Figure 2.

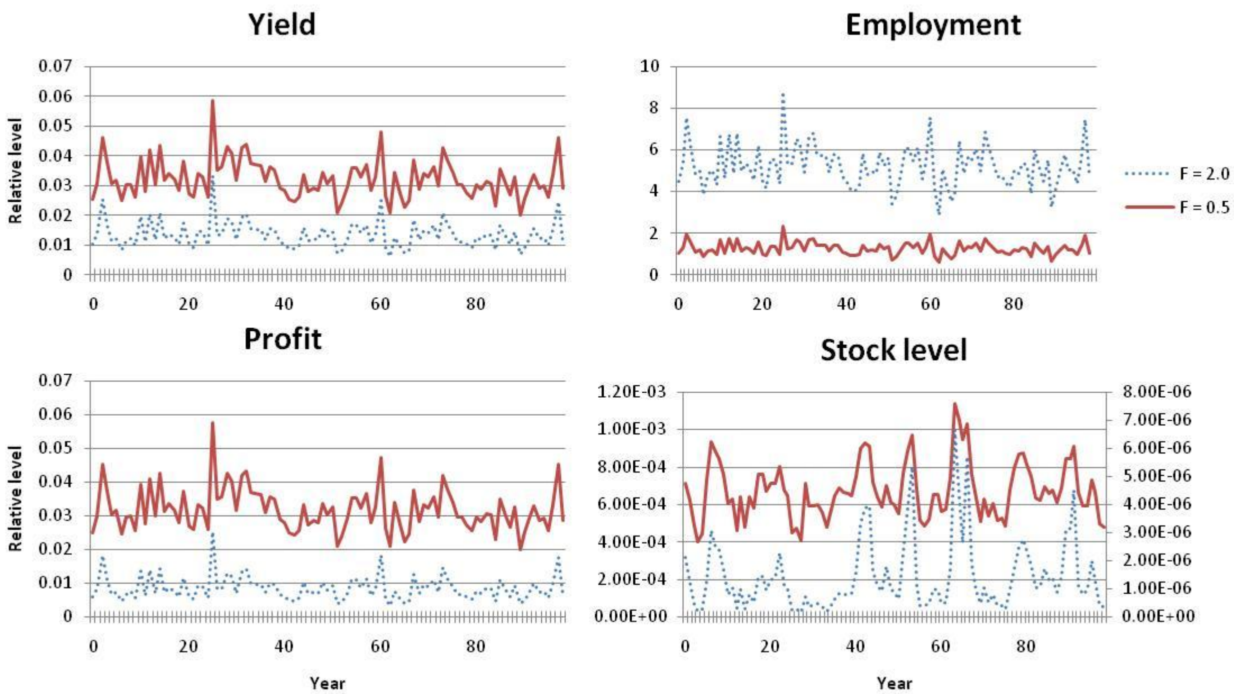


Figure 3. The four utility components (yield, employment, profit and stock level) and their relative values to their maximum through a simulation time of 100 years after a 1000 year priming phase using two different fishing mortality (*F*) values. The second axis for the "stock level" histogram corresponds to the *F* value of 2.0.

The lower *F* of 0.5 gives better values for yield, profit and stock level. Only employment, as also inferred in Hilborn (2007), has higher values with increased *F* level of 2.0. This occurs due to the model assumption that higher *F* values increase the effort out at sea ten times more than effort at the shore.

In Figure 4, both fishermen and conservationists have higher utility values with the lower F value of 0.5. Society, with the arbitrarily assumed most weight on employment (see Table 2), receives a much higher utility with higher *F* values.

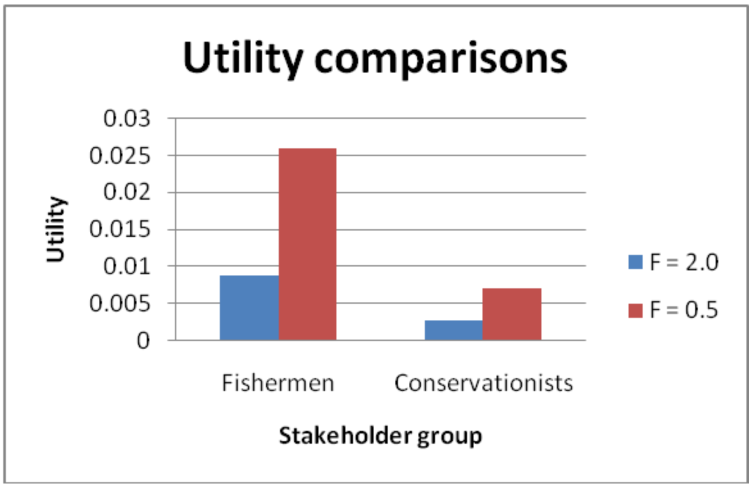


Figure 4. Two stakeholder groups and their resulting utility (dimensionless) for two different fishing mortality (*F*) values. Utility values are averages for 100 years after a 1000 year priming phase using two different fishing mortality (*F*) values. *(Society is not included in this figure due to scaling differences, see text for an explanation of Society's utility levels.)*

Figure 4 shows that fishermen do better than conservationists in both simulations. This is due to the assumption we made that conservationists put most weight on stock level, which has a baseline value at "virgin" stock levels. If the conservationists were satisfied with a more realistic baseline value (i.e. satisfied with a minimally-fished stock level instead of a non-harvest level), their utility would have increased for both simulations.

These preliminary results suggest that reducing effort (for example decommissioning of fishing vessels) would be a first logical step in reaching the "zone of new consensus". It should be specified that decommissioning small vessels only to let the largest, and most effective, boats survive does not help in reducing overall effort.

We note that the stakeholder groups' preferences for utility components would naturally be set by the stakeholder groups themselves, instead of values set here for simulation purposes. This implies consensus within the stakeholder group, something we feel the EU Regional Advisory Committees (RACs) have helped achieve in recent years. This framework we present can accommodate many more stakeholder groups than the three presented in this paper.

Future work in this project will examine the differences between linear and Holling Type 2 (diminishing returns) functional relationships of stakeholder benefits and utility components. Also discounting future returns (i.e. revenue, employment, stock level) will shed more light on the tradeoffs of management objectives and make this framework more realistic.

Conclusions

In this study, we show preliminary results that support Hilborn's described "zone of new consensus" where fishermen's profit and conservationists' ecosystem preservation are consistent with each other. We provide a new type of management framework for fisheries: one that gives a "voice" to different stakeholder groups that inherently have conflicting objectives. Through this framework, stakeholder preferences can be translated into utility functions and then weighed against different management regimes and scenarios. This approach thus makes fisheries management more transparent and more interactive between scientist and stakeholder; two goals in which ICES must excel.

Acknowledgements

This project has been completed at the International Institute of Applied Systems Analysis (IIASA) during the Young Scientists Summer Program (YSSP). D. Dankel thanks the Norwegian Research Council for full funding of this project.

Special note: *It is our hope that stakeholders can be involved with refining this framework and D. Dankel welcomes comments from the EU RAC. D. Dankel is open to internal RAC presentations regarding this ongoing study and also to using this framework for simulations using specific fisheries.*

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