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Incorporating a Consensus-based Approach as a Tool for Sustainable Fisheries Management and Stock Rebuilding

WILLY CORNELIUS KWIRI[1] and SANG-GO LEE[2*]

[1] *Eccelenzia Consorzio Research and Management (ECRAM), P.O. Box 27573. Kampala, Uganda*
[2] *College of Fisheries Science, Pukyong National University, 599-1 Daeyeon 3-dong, Nam-gu, Busan, South Korea***.**
*Corresponding Author. E-mail: sglee@pknu.ac.kr

Abstract

Consensus based fisheries management approach was modelled, it was assumed that; stakeholders utilizing a fishery collectively agree to reduce fishing effort depending on the high input and low catches. Linear regression and backward and forward forecasting of fish catches before and after consensus generated a buffer stock or minimum sustainable biomass (*MSB*) as an intercept of the regression line of the natural logarithms of catches after consensus and this was also the limit reference point; the maximum sustainable yield after consensus (MSY_a) was calculated from the changes in catches before and after consensus and was also generated as a point of intersection of the regression lines of the catches before and after consensus, and it was also the target reference point. As a result the production possibility frontier (PPF) was produced and this gave the borderline between sustainable yield and the buffer stock, and also the optimization point, the MSY_a.

Key words: Consensus based approach, sustainable fisheries management, minimum sustainable biomass, fishery buffer stock, fisheries stock rebuilding.

Introduction

The consensus-based fisheries management approach is based on the idea that the involvement of all stakeholders (including fishers, traders, managers, researchers and consumers) in the policy decision-making process makes the fishery more understandable and a common understanding fishing effort reduction and conservation measures. Over the last two decades, the marine fishery resources of the world have been increasingly subjected to overexploitation (FAO, 2012) and capture fisheries across the world have reached their limits. In 2009 it was estimated that 30% of the stocks monitored by FAO were overexploited and 58% fully exploited and could no longer attain their maximum potential yield owing to excess fishing capacity and there was a need for rebuilding stocks (FAO, 2012).

Imperfections in the fisheries management system, including uncertainties in management objectives, fishery and biological data, environmental oscillations, stock assessment methods, economic parameters, management advice, management measures and fishermen's behaviour have long been recognised (Gulland, 1983; Larkin, 1972). Effective fisheries management therefore requires that regulators should consider the questions of how, when and where fish are caught, rather than simply focusing on the total harvests (Wilson *et a*l., 1994). Fisheries everywhere are considered to be common property resources (FAO, 2002b) and capture fisheries treated as common pool resources are subject to severe economic inefficiency, which appears as overexploited fish stocks, excessive fishing fleets and effort, and generally low profitability of the fisheries (Shotton, 2000).

The common property management of these fisheries is the source of the problem and in open access fisheries; the bio-economic equilibrium is reached with increasing economic inefficiency (Clark, 1985). Under these conditions the management approach is commonly through command and control regulations such as catch quotas, size limits, and restrictions on fishing effort or some aspect that influences effective fishing effort (FAO, 2003a). These types of restrictions may be considered as output or input controls and, while possibly realizing biological objectives of management (Färe et al., 1994), they do not address the open access nature of fisheries, and so do not reduce excess capacity. Indeed, their failure often leads to the imposition of even more restrictions, which increases production costs while failing to address the underlying problem of excess capacity (FAO, 2003a).

Fishers should therefore be encouraged to engage in responsible fishing (France and Exel, 2000) and provided with good fisheries governance (Sinclair et al., 2002) as ecosystems themselves cannot be managed, and it is only the human exploitation of them that can be regulated (FAO, 2003a). Several management approaches and strategies have been proposed, among them ecosystem-based, incentive-based and rights-based approaches, in addition to traditional command and control approaches (Grafton et al., 2006). But there are few studies on how consensus among different stakeholders can be modelled and used as a tool to combat overcapacity and overexploitation of fisheries resources. This paper describes and models the consensus-based approach as a tool for managing fisheries resources. It also attempts to demonstrate the importance of the link between all stakeholders in order to develop collective action and a common understanding on the sustainable utilisation of the resource and establish the minimum stock biomass to be conserved to maintain the sustainability of a fishery.

Modelling

The purpose of consensus in fisheries is to ensure that all stakeholders can bring forward issues affecting both them (the resource users) and the resource, and then reach at a consensus on the maximum sustainable yield (MSY), which is based on the catch per unit effort (CPUE) over time. This model used here shows that if there is a common understanding amongst beneficiaries a fishery becomes biologically and economically efficient, thus leading to the maintenance of a minimum biomass and a sustainable consensus-based yield curve. This is a function of maximum sustainable yield after consensus, minimum sustainable biomass and CPUE before and after consensus as shown in the following expression

$$Y = f(MSY_a, MSB, CPUE_a, CPUE_b) \quad (1)$$

where Y denotes sustainable yield, MSY_b represents initial maximum sustainable yield before consensus, and MSB is the minimum sustainable biomass or buffer, $CPUE_a$ represents catch per unit effort after consensus, and $CPUE_b$ represents catch per unit effort before consensus.

The maximum fish catch before consensus can be fixed as the total allowable catch (TAC) or maximum sustainable yield (MSY_b), the minimum sustainable biomass (MSB) or buffer stock is agreed upon by consensus amongst the different beneficiaries of a fishery. The maximum sustainable yield after consensus (MSY_a) is based on catches after consensus and a backward forecast on catches made before consensus. Therefore both MSY_b and MSB are constants since they are fixed. In order to maximise yield at consensus and control MSB the following yield equation was expressed:

$$Y = \frac{MSY_b - MSB}{\Delta CPUE_a - \Delta CPUE_b} \quad (2)$$

The catch per unit effort after consensus ($CPUE_a$) over a given period of time after consensus was expressed as

$$CPUE_a = C_a / E_a \quad (3)$$

where C_a represents catch after consensus and E_a represents fishing effort after consensus, and the catch per unit effort before consensus ($CPUE_b$) was expressed as

$$CPUE_b = C_b / E_b \quad (4)$$

where C_b represents catch before consensus and E_b represents fishing effort before consensus and the changes in catches and fishing effort over time and the initial catches and effort generated changes catch per unit effort

$$C_b = C_t - C_o \quad (5)$$

where C_t denotes catch after a given period of time and C_o denotes the initial catch. Thus

$$E_b = E_t - E_o \quad (6)$$

with E_t being the fishing effort over time while E_o is the initial fishing effort.

During harvesting, there are expected changes in the catches depending on effort levels whether there is consensus or not. The change which occurs in catch per unit effort before consensus over a given period of time can be expressed as

$$\Delta CPUE_b = (C_t - C_o)/(E_t - E_o)\,. \quad (7)$$

The change which occurs in fish catches and effort levels after consensus is then expressed as

$$\Delta CPUE_a = (C_{at} - C_{ao})/(E_{at} - E_{ao}) \quad (8)$$

where C_{at} represents catch after a given period of time, C_{ao} is initial catch, E_{at} denotes fishing effort after a given period of time and E_{ao} denotes initial effort level after consensus. By plotting a catch curve after consensus on effort reduction, conservation measures and establishment of the minimum sustainable biomass, a positive slope was attained. It is assumed that after a reduction in the fishing effort, the remaining biomass can reproduce and the stock increases. By substituting equations 7 and 8 into equation 2, the yield of a fishery can be expressed as

$$Y = \frac{MSY_b - MSB}{\left(\frac{C_{at} - C_{ao}}{E_{at} - E_{ao}}\right) - \left(\frac{C_t - C_o}{E_t - E_o}\right)} \quad (9)$$

Maximum sustainable yield (*MSY*) and minimum sustainable biomass (*MSB*) after consensus

To construct a catch curve and obtain estimates of maximum sustainable yield and minimum sustainable biomass after consensus, the catch data over time from (King, 1995) are converted into natural logarithms catch curves before and after consensus plotted with a linear regression fitted to the data by the equation

$$y = bx + a \tag{10}$$

where the slope (b) represents the change in catch per unit effort (CPUE) over time and the intercept (a) is either the maximum sustainable biomass (MSB) after consensus or the maximum sustainable yield (MSY_b) before consensus, and these parameters are therefore constants.

The maximum sustainable yield after consensus (MSY_a) can be estimated from the maximisation equation in two ways. The first is by multiplying changes in CPUE after consensus by the catch and add the minimum sustainable biomass (MSB) or the buffer stock, on the curve of catches after consensus as expressed in equation (11) below

$$MSY_a = \Delta CPUE_a Y + MSB$$

or

$$MSY_a = \frac{\Delta C_a}{\Delta E_a} Y + MSB \,. \tag{11}$$

Therefore, from equation (9) where yield (Y) was expressed and from equation (11) the maximum sustainable yield after consensus (MSY_a) was expressed as

$$MSY_a = \left(\frac{\Delta C_a}{\Delta E_a}\right) * \left[\frac{MSY_b - MSB}{\left(\frac{C_{at} - C_{ao}}{E_{at} - E_{ao}}\right) - \left(\frac{C_t - C_o}{E_t - E_o}\right)}\right] + MSB \tag{12}$$

Table 1: Hypothetical fish catches for years before (years 3-11) and after (years 12-14) consensus on conservation and fishing effort reduction.

Time (years)	Catch (t)	Time (years)	Catch (t)
3	365	9	21
4	305	10	12
5	193	11	7
6	100	12	200
7	71	13	403
8	33	14	384

Plotting catch curves, maximum sustainable yield and consensus based minimum sustainable biomass

A catch or yield curve was plotted using hypothetical data in table 1, which was extracted from (King, 1995) and modified in the way that fish catches between 3-5 year were put in the last column of table 1 as catches after consensus and this was done to suite the assumption that fish catches increase after reaching a consensus to reduce effort and improve on management. When this data was plotted as natural logarithms it was observed that fish stocks continue to decrease with increasing fishing effort until a consensus is reached to reduce fishing effort and improve on management and conservation strategies (Figure 1).

The minimum stock biomass, being consensus based, was supposed to be conserved and the catches before and after consensus were regressed to produce the production possibility frontier of a fishery (Figure 1).

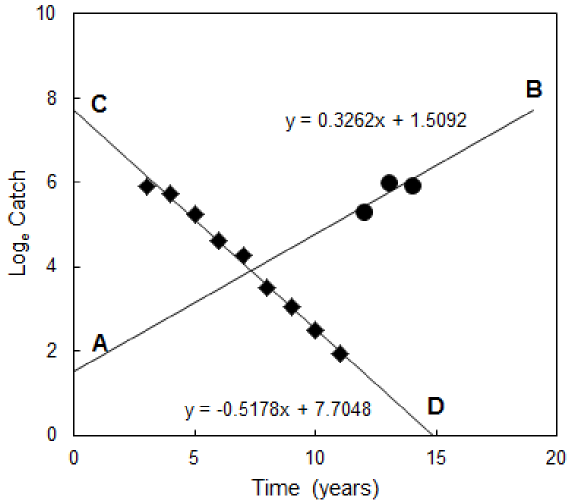

Figure 1: Changes in the hypothetical fish catches in relation to time, before (♦) and after (●) consensus, based on data in Table 1, with the catch expressed as natural logarithms.

After reaching a consensus to reduce fishing effort, the increment in fish catches could attract more fishing effort and result in resource depletion; to avoid the boom and bust scenario, the catches were forecasted one forward and three for twelve years backward for the after consensus regression line AB and three years backward and four years forward on the before consensus line CB and an optimization was got at the point of intersection. This generated a production possibility frontier which limits the input and output for economic and biological maximization of the fishery without depletion.

Yield, Optimisation and Production Possibility Frontier

From equation (9), the yield and regressions on lines AB and CD, the yield or catch was calculated as

$$Y = (7.70 - 1.53)/(0.33 + 0.52) = 7.26$$

and the maximum sustainable yield after consensus was calculated using regression equations on either line AB or line CD and it can also be obtained by calculating equation (12) as follows:

$$MSY_a = (0.33 * 7.30) + 1.53 = 3.94 \quad \text{(for line AB)}$$

and

$$MSY_a = (-0.27 * 7.30) + 7.70 = 6.02 \quad \text{(for line CD).}$$

Unlike other fisheries management approaches, this approach generates the production possibility curve to limit the input and maximizes the output as earlier mentioned. Consensus drawn on resource conservation without visible limits can be difficult to mitigate overexploitation and depletion. The production possibility frontier sets the limit and consensus and this frontier results in resource conservation and avoids the boom and bust scenario in fish catches. Forward and backward forecasting of the future catches using previous fish catches and fishing effort over a period of time generated a production possibility frontier in which the input and output in a fishery is maximised. A region of sustainable yield and an optimisation point were also generated which gave an estimate of the maximum sustainable yield after consensus and the minimum sustainable biomass (or buffer stock) generated as the intercept of the catch data line after consensus.

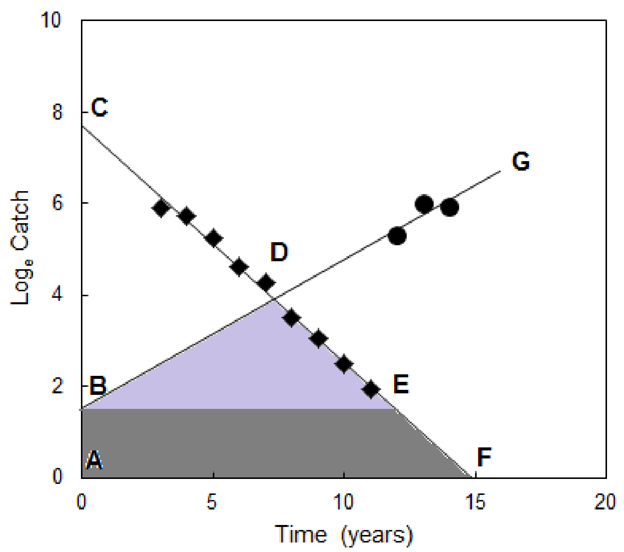

Figure 2: Hypothetical fish catches plotted against time, before and after consensus-based management (symbols as in Figure 1). Line BG indicates the increasing fish catches after consensus and line CF shows the decreasing catches before consensus. Point C represents maximum sustainable yield before consensus (MSY_b) at point C and, point D: is the maximum sustainable yield after consensus (MSY_a) and was generated at the point of intersection after forecasting; line BE represents the borderline of minimum sustainable biomass (MSB), region ABEF; represents a buffer stock, region BDE is sustainable yield or catch and region ABDF denotes production possibility frontier of a fishery.

While many management approaches focus on the openness of the fishery, this approach empowers all stakeholders to establish a production possibility frontier (PPF) which limits the fishing effort and the minimum sustainable biomass as a buffer stock that must be conserved for purposes of reproduction and enhance resource sustainability. The maximum sustainable yield after consensus was calculated by getting the antilog of MSY_a (3.9) and was 49 t, the minimum sustainable biomass was estimated from the intercept (1.525) of the regression equations of the catches after consensus and was 4.6 t and the initial maximum yield before consensus was also calculated as the antilog of the intercept (7.7012) and was 1480 t (see figure 1). Therefore the minimum stock biomass or the buffer stock was not supposed to go below 4.6 t as the limit reference point (LRP) and the maximum catch from a fishery was not supposed to go above 49 tons as the target reference point (TRP).

Discussion

Sustainable utilisation, controlled and forecasted fish catches and minimum biomass were found to be efficient instruments for managing fisheries resources without compromising future benefits. Forecasted fish catches with time before and after consensus generated a production possibility frontier (PPF) which generated a consensus-based minimum or buffer stock (MSB) and maximum sustainable yield after consensus (MSY_a) and these were calculated and worked as the limit reference point and target reference point respectively. It was found that PPF can prevent overcapitalization, overfishing and sustainability as it sets the minimum or buffer stock and harvest limit over time.

Under an open access regime where MSY is regarded as a target reference point, and consensus is minimal, the equilibrium is reached when the fishing cost is very high; the biomass is at its carrying capacity and the total revenue is almost zero (Seijo and Defeo, 1994); in this approach, knowledge of the previous catches enabled backward forecasting to produce lower and target catch limits which prevent overexploitation and it is often supposed that preventive (or proactive) approaches to management are more precautionary than reactive ones because they anticipate unwanted events through knowledge of the system (FAO, 1996). The principle of preventive action is based on the recognition or assumption that it is cheaper, safer, and more desirable (in the long term) to prevent environmental harm than to rectify it later (Boelaert-Suominen and Cullinan, 1994).

Effective management and control of a fish stock involves maintaining the fish biomass at a level adequate enough to support the catches while reducing losses due to over overcapacity before a fishery collapses. A fishery stock can be managed successfully when the consensus-based minimum biomass and the maximum sustainable yield after consensus can be controlled as shown in Figures 1 and 2. The production possibility curve ABDF provides the limit for fishing effort and thus reduces overcapacity, overcapitalisation, and overexploitation of the fishery. Region ABEF represents the minimum or buffer stock which was set by backward and forward forecasting of fish catches and this has to be agreed upon by all fishery stakeholders to be conserved as the fishing activities go on.

Consensus-based fishing was shown in the region BDE while the maximum sustainable yield was shown to be at point D. From the regressions and calculations which gave the buffer stock as 4.6 t as the limit reference point and MSY_a of 49 t as the target reference point, the fishing according to the catches of this fishery was vibrant at the harvests between 30 and 49 t and less vibrant between 20 and 30 t. Fishing activity below 10 t was harmful as it was towards the limit reference point which is also the buffer stock and this was supposed to be conserved for purposes of sustainability. According to table 1, fish catches from the 3rd to the 11th year declined from the initial high harvests of over 300 tons to 7 tons which is almost at the level of minimum stock biomass or buffer stock (4.6), this meant that if there was no consensus to reduce the fishing effort on the 12th year, the fishery was soon collapsing. However, after a reduction in fishing effort, perhaps through buy-back or decommissioning programmes or closed fishing, the production possibility curve, the limit and target reference points were established by forecasting backwards to avoid further boom and bust cycles.

In conclusion, integrating the consensus-based fisheries management approach which anticipates the production possibility frontier of the catch and policy making that involves all stakeholders in a fishery was one of the strongest tools that can be used to rebuild and manage overexploited fisheries resources. It further illustrates that under the consensus approach, the fishery cannot collapse if the yield is well forecasted and optimised, and if the production possibility frontier and buffer stock are collectively understood and appreciated. From the equations and plots, a good stock management scheme should maximise efficiency of production, minimise over capitalization, and maximise profit.

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