Conflicting Interests in Multi-Species Catch Quota Share Fisheries Regimes

Már Kristjónsson

BA thesis
Faculty of Economics
School of Social Sciences
Advisor: Þórólfur Matthíasson
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Abstract

In this thesis a potential conflict of interest is examined in multi-species fisheries, managed under a catch quota share system, where stocks are interdependent.

A theoretical model is presented and the optimal harvest strategies for individual harvesters analyzed and compared with the socially optimal harvest strategies. The results of the analysis is that the management strategy that maximizes the profit of an individual harvester is different from the strategy that maximizes the profits of another if their catch quota share holdings are differently distributed for harvested stocks.

The cod and capelin fisheries of Iceland are examined to see whether they correspond with the model. Cod and capelin are interrelated as the cod relies on the capelin as a food source. Therefore the profits from the cod fishery are affected by the harvest strategy for capelin. As most harvesters hold unevenly distributed catch quota shares for cod and capelin, it is reasoned that it is at least plausible that a conflict of interest exists between harvesters, in regards to harvest strategies, as the model would imply.

Foreword

This thesis is presented as a final dissertation for a BA degree in economics from the University of Iceland. It has the value of 12 ECTS credits.

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1 Introduction

In this thesis the potential conflict of interest of stakeholders, that hold unevenly distributed catch quota shares for different fish stocks in a multi-species fishery, managed under an individual catch quota share system, will be examined.

Individual catch quota share systems have become a fairly widespread instrument in managing the exploitation of fish stocks in recent decades. Under such management systems, a total allowable catch (TAC) for the stocks being managed is decided upon, often measured in some unit of weight, for a certain period, such as the fishing year. If successfully implemented, the catch of the managed stocks does not exceed its TACs in any given period. For an entity to be able to fish from a managed stock, it must hold a catch quota share for it.[1] The catch quota share a harvester holds determines the proportion of the TAC he can fish: his catch quota for any given period.

If catch quotas and catch quota shares can be moved from entity to entity for remuneration the system is dubbed individual transferable quota (ITQ) system. It has been argued that ITQ systems can reduce overfishing, overinvestment and other inefficiencies associated with common property fisheries. For a discussion of the common property problem see for example Gordon (1954). For a theoretical model that proposes that ITQ systems lead to efficiency see, for example, Arnason (1990). Although few argue against ITQ systems being able to alleviate at least some of the inefficiencies found in common property fisheries, they need to be properly designed to do so. Some argue that other managements systems are more efficient, at least in some cases. For a critical review of ITQ systems see Copes (1995).

Matthiasson (1995) examines a case of conflict interests, in regards to how TACs are set, between those that hold catch quota shares and those that lease catch quota from the share holders. He points out that the political weight of either group could potentially influence the manager when setting the TACs. In this thesis a different kind of a potential conflict of interest will be examined in regards to how TACs are set: between individual catch quota share holders in a multi-species fishery. Due to the interdependency of marine stocks, the TAC for one stock can influence the profitability of exploiting other stocks. It will be argued that if individual catch quota

[1] Or it can lease catch quota, if that is allowed for.

share holders have an uneven distribution of shares for different stocks, as is most often the case under catch quota share systems, their interests will differ. If someone would, for example, hold a catch quota share only for one stock, it would be in his interest that the TACs for every stock would be set as to maximize the profitability of exploiting the stock he holds a share for, without regards for the profitability of exploiting other stocks. As in Matthiasson's case the conflict of interest would create an incentive for each stakeholder to try to sway the manager to set the TACs in his own interest. The manager submitting to the pressure of some quota share holders, rather than that of others, could very well contradict the official objective of the management system, whether it would be to maximize the aggregate profits of the fishing industry or something else.

The thesis is organized as follows: The second chapter is concerned with how the interests of stakeholders in a multi-stock ecosystem vary. First, the optimal management of marine ecosystems – where aggregate profits from exploiting all stocks is maximized – will be discussed. Than the harvest policy that maximises the profits of a single exploiter. Finally a simple model of the exploitation of an ecosystem consisting of two stocks will be presented to show that the harvest policy that maximizes the profits of a particular catch quota share holder can be differ from the policy that maximizes the profits of another and from the policy that maximize aggregate profits from exploiting a marine ecosystem as a whole. In the third chapter the cod and capelin fisheries in Iceland will be examined to see if a potential conflict of interests exists between these fisheries (the Icelandic cod and capelin stocks are interdependent as the cod relies heavily on the capelin as a food source). In the fourth chapter the results will be discussed.

2 Conflicting Interests in Multi-Species Catch Quota Share Fisheries Regimes

Under an optimal fisheries management regime, a marine ecosystem would be managed as a single resource. The state of one marine stock can have great influence on the state of another. All marine species depend on other species for survival, except for photosynthetic stocks that depend on the sun. They, however, are a food source for other species. And individuals of different species can interact in other ways than eating one another. Therefore, because of the interdependency of marine stocks, the exploitation of one stock affects the whole ecosystem it belongs to.

If a stock is managed optimally, but individually, externalities will be neglected. The way in which the state of the managed stock affects the exploitability of other stocks that make up the ecosystem will not play a role in the management, and vice versa. Further, if it will be worthwhile to cull stocks that negatively influence the managed stock – analogous to controlling mink populations to reduce natural predation of salmon – it will be neglected.

In some cases the interdependence of stocks might not matter, for example in ecosystem where it would be economically viable to exploit a single stock only, or in ecosystems where the interdependency of valuable stocks would be insignificant due to biological facts. However, in most modern fisheries, this is not the case.

In this chapter a model of the exploitation of interrelated species will be presented to examine if the interests of individual stakeholders differ from each other's and the social optimum. In chapter 2.1 steady state models of stock exploitation and the possibility of employing them to model the growth of multiple interrelated species will be discussed.[2] Further, the logistic function, which is commonly used to model stock growth, will be introduced. In chapter 2.2 a simple model of the exploitation of multiple interrelated stocks will be put forward and in chapter 2.3 the model will be expanded to account for catch quota share management. Optimal harvest policies will not be examined thoroughly in chapters 2.2 and 2.3. Instead a model of the

[2] In steady state models the growth of a stock equals its yield so that stock size does not change over time.

exploitation of two interdependent stocks will be presented in chapter 2.4 and the interests of particular stakeholders compared with each other's and the social optimum.

2.1 Steady State Models of Stock Exploitation

In steady state models of single stock exploitation it is assumed that if catch per time unit is fixed, and within certain limits to prevent extinction, the stock size will ultimately reach equilibrium at a point where the catch per time unit is equal to the growth per time unit: the steady state situation.[3]

The assumption is based on the rationale that the natural growth of a small stock will be slow due to few breeders.[4] If the stock were to grow in size, and thus the number of breeders increase, stock growth would accelerate up to a certain point of maximum growth. As it is possible to reach equilibrium at that point with the catch equal to the maximum growth, the maximum growth of a stock is often referred to as the maximum sustainable yield (MSY). This can be thought of as the "peak production" point for the stock. If stock size were to increase beyond this point, growth would slow down, due to factors such as competition for food and overcrowding, until the stock size would reach a maximum and the stock stop growing. The maximum stock size is referred to as the carrying capacity of the stock, and sometimes as the virgin stock level.

Although the assumptions of steady state models seldom hold to be true in reality because of unstable exogenous factors, such as changes in temperature and salinity, and stochasticity that affect the natural growth rates, they can provide valuable insights.

2.1.1 Steady State Models of Exploitation of Multiple Interrelated stocks

The steady state assumption could be made for each stock in a model of the exploitation of an ecosystem. In such a model the carrying capacity could be defined as a function of every other stock, and thus the stocks' growth rates would depend on

[3] If the catch per time unit is of such scale that it renders a stock extinct the stock size will also reach an equilibrium, but at zero stock size.
[4] In some models it is assumed that if a stock is small enough, its growth will be negative. A stock this small will eventually die out even if not harvested.

the size of every other stock. If the management objective were to maximize profits, an equilibrium point would be selected for each stock that would maximize the profits from the exploitation of the ecosystem as a whole, constituting steady state levels of all stock sizes, and taking into account the externalities of the exploitation of each stock on other stocks. As is argued by Hannesson (1978):

> It would seem that maximizing the social welfare of the top predator, man, would require that the exploitation of interrelated fish species be optimized simultaneously, whereas managing each fishery independently could fail to attain the optimal optimorum; (p. 94).

Hannesson goes on to present a steady state model of the exploitation of two interdependent stocks with a predator-prey relation. The stock size of the predator species negatively affects the growth rate of the prey, while the stock size of the prey species positively affects the growth rate of the predator. He reasons that as the relative price of the predator increases, less of the prey should be harvested to maximize total profits, even to a point of no harvesting of the prey; and as the relative price of the prey increases, the predator should be harvested more aggressively, diminishing its stock and the steady state catch.

Thus, a relative increase in the price of one species means that in the long term it would be beneficial to increase the catch of that species, and thus increase the profits from harvesting it, at a cost of a decrease in the long term catch of the other species and a decrease in the profits from harvesting it. The increase in the profits from harvesting the first-mentioned species would outweigh the decrease in the profits from harvesting the latter. It follows that if some entities involved in the two species fishery Hannesson describes held a great interest in the predator fishery and some held a great interest in the pray fishery, these changes would benefit one group at a cost to the other, although the aggregate profits from exploiting both species would increase.[5]

Intuitively, if two stocks compete with one another, a relative increase in the price of one means that the other should be harvested so that its stock size decreases, to reduce the competition that the stock that increased in value faces. If more species were added to the model, their interactions with all other species would have to be taken into consideration when maximizing total profits.

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[5] In case of aggressive harvesting to decrease the size of a stock, profits could increase in the short term. In thesis only the steady state situation will be discussed, not the path leading to it.

2.1.2 The Logistic Function

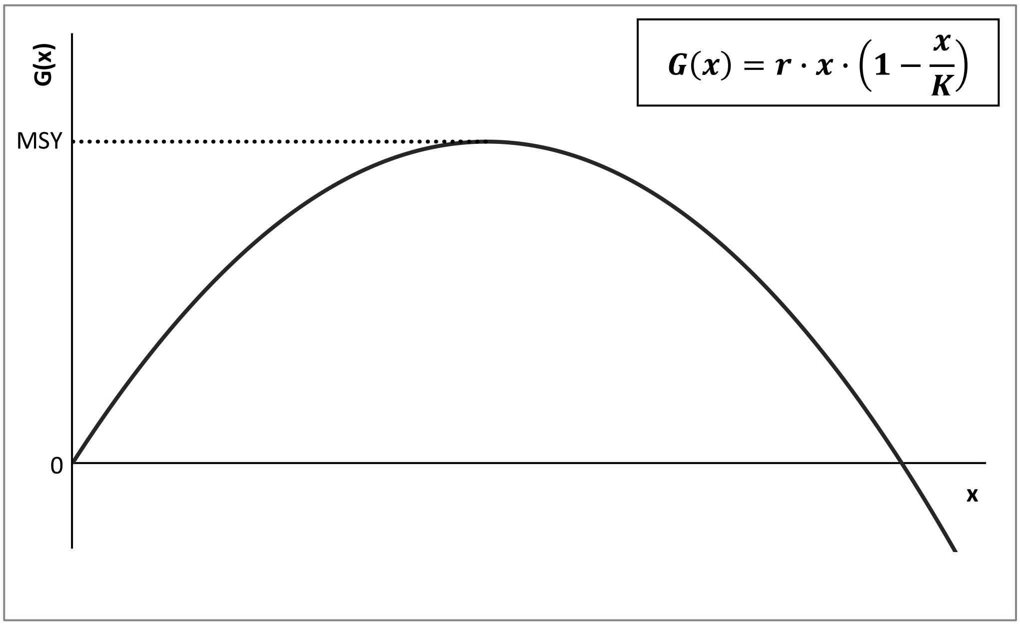
A function that is commonly used to model stock growth, and which carries the abovementioned qualities, is the logistic function:

$$G(x) = r \cdot x \cdot \left(1 - \frac{x}{K}\right), \qquad 0 < r < 1 \tag{1}$$

Here, $G(x)$ is the growth of a stock per time unit, x denotes stock size, r is the so called intrinsic growth rate (a constant), and K is the carrying capacity (also a constant). Figure 2.1 graphs the growth of a stock that follows the logistic function. The function would be equivalent to a function of interest on money, where x would correspond to funds and r to interest rate, if it were not for the latter part of it, $(1 - x/K)$, which approaches zero as the stock size increases and more negatively affects stock growth the larger it is:

$$\lim_{x \to K} \left(1 - \frac{x}{K}\right) = 0 \Rightarrow \lim_{x \to K} G(x) = 0 \tag{2}$$

Figure 2.1 Growth of a stock that follows the logistic function



It is possible to reach equilibrium at any stock size below the maximum stock size.[6] All levels of growth, other than the MSY, and correspondingly all levels of sustainable catch, can be found at two different stock sizes, to the left or to the right of

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[6] Or at the point of zero growth, witch denotes either extinction, or, in the case of no harvesting, the maximum stock size.

the MSY, as can be seen in Figure 1. Whether the stock reaches equilibrium to the left or the right of the MSY depends on the stock size at the time the catch is fixed. If the stock size were at a level to the left of the MSY, it would be necessary to temporarily lower catch, allowing the stock to recover, in order to get to a point to the right of the MSY.

2.2 Optimal Exploitation of Multiple Interrelated Stocks

Assume an ecosystem exists, consisting of n stocks. Each stock's natural growth follows the logistic function:

$$G_i(x_1, x_2, \dots, x_n) = r_i \cdot x_i \cdot \left(1 - \frac{x_i}{K_i(x_1, x_2, \dots, x_n)}\right) \quad (3)$$

Here, r_i denotes the intrinsic growth rate of stock i, x_i denotes the size of stock i and $K_i(\cdot)$ represents its carrying capacity. $K_i(\cdot)$ is a function of the sizes of all the stocks in the ecosystem, indicating that the carrying capacity of each stock, and thus the growth of each stock, is dependent on the size of the other stocks that form the ecosystem. If a partial derivative of $K_i(\cdot)$ with respect to the size of some other stock equals zero, the size of that particular stock has no influence on the growth of stock i. An exception is $\delta K_i/\delta x_i$ which is set to equal zero as the influence of a stock on itself is already represented in growth function. If a partial derivative of $K_i(\cdot)$ with respect to the size of some stock is negative, it indicates that this particular stock has a negative effect on the growth of stock i, while a positive derivative indicates a positive influence. In the steady state situation, which we will be examining, catch equals growth for all stocks. In case of no harvesting of a stock its growth equals zero and the stock size equals its carrying capacity.

Each stock can be harvested. The catch of stock i (q_i) depends on units of effort (e_i) and stock size:

$$q_i = \alpha_i \cdot e_i \cdot x_i \quad (4)$$

Here, α_i is a constant. The above catch function implies that by doubling the units of effort the catch will double, but as catch influences stock size, increasing the effort can very well reduce catch in the long term.

We will assume that the social optimum will be found at a level of harvest for each stock that maximizes aggregate profits. The management objective might very well be some other than to simply maximize profits, for example, to preserve a certain stock. Even if such constraint would be taken into account it should not alter the main conclusions derived from the model significantly.

In order to maximize profits, the manager would have to maximize the aggregate profit function:

$$\Pi^* = \sum_{i=1}^{n} (p_i \cdot q_i - c \cdot e_i) \qquad (5)$$

Here, p_i denotes the output price for stock i (a constant) and c denotes the unit cost of effort (also a constant).[7] In order to maximize profits, the manager would have to take into account the externalities of exploiting each stock on the profitability of exploiting other stocks, arriving at the optimal steady state equilibrium point.

2.3 Stakeholders Interests in a Multi-Species Catch Quota Share Fishery

In reality, as a general rule, marine ecosystems are exploited by more than one entity. It has been compellingly argued that the widespread overexploitation of fishery resources is related to their common-property nature (Gordon, 1954). Many fisheries management systems are designed to alleviate the problems stemming from the common-property nature of fishery resources, so that they will be exploited more optimally. One way is to allocate individual catch quota shares amongst a number of exploiters, letting a manager set the total allowable catch (TAC) for each stock. It has been argued that under such regimes it would be in the interest of each exploiter that the ecosystem would be managed optimally. Below it is argued that if exploiters do not hold the same catch quota shares for all species, that is, if their distribution of catch quota shares varies between stocks, their interests contrast in regards to how the TACs are set.

[7] In many models p_i and c are not set to be constant. That would be the case if the supply of the catch would affect its price or if the demand for labour would affect its cost.

Assume the ecosystem described in chapter 2.1 is within the exclusive fishing zone of a sovereign state. A political fisheries manager sets the TAC for each stock at a level where it is profitable to exploit it. Accordingly, the total catch of each stock equals the TAC for it. As the manager thinks in the long term and as the model is deterministic, the manager aims at a steady state equilibrium point for all stocks.

k profit seeking fisheries companies exist. Each holds catch quota shares in one or more species. The catch quota share of company j in stock i is denoted with $\theta_{j,i}$. At least some companies exist that do not hold the same catch quota shares for all stocks. That is, if a company holds for example 1% of the catch quota shares for a given stock, it doesn't necessarily hold 1% of the catch quota shares for all others stocks. The catch quota of firm j in stock i defined as is $\alpha_{j,i} \cdot TAC_i = q_{j,i}$. If companies have no influence on the setting of the TACs, maximizing profits involves only using up all catch quota:

$$\Pi_{\mathrm{j}} = \sum_{i=1}^{n} (p_i \cdot q_{j,i} - c \cdot e_{j,i}) \tag{6}$$

Here, $e_{j,i}$ denotes the effort needed to meet the catch quota of company k in stock i and c denotes the unit cost of effort.

For each company there exists a set of TACs (and a corresponding level of stock sizes) that would maximize its profits. If company j could unilaterally set the TACs, it would take into consideration the externalities of exploiting all stocks on the profitability of exploiting the stocks it holds catch quota share for. If company j would, for example, hold catch quota share only for stock i, its optimal TAC levels would maximize the carrying capacity of stock i and thus the profitability of exploiting it. If it would hold catch quota shares for more than one stock, its optimal management strategy would depend on the externalities of exploiting every stock on the profitability of exploiting the stocks it holds quota shares for. As the stocks are interdependent, and as the distribution of catch quota shares in different stocks varies between companies, the TACs that maximize the profits of individual companies will vary, and be different from the socially optimal TACs.

The manager's decision on TAC levels could be influenced by considerations other than maximizing the total profits from exploiting the ecosystem, or fulfilling some other socially optimal goal. If the manager were a member of parliament, it might be in his interest to hold the profits of companies in his home constituency in higher regard than the profits of other companies. Companies, or a group of companies, could lobby for a certain management strategy. Accordingly he might base his decision on the profitability of exploiting species for which catch quota shares were widely held in his constituency.

The manager himself, his relatives or friends, might also be connected to the fishing industry, which could influence his decision on TACs.

Under the circumstance where the manager holds the interests of some companies in higher regards than the interests of other, the equilibrium point arrived at would be different from the socially optimal steady state equilibrium point.[8]

2.4 The Case of Two Exploitable Stocks

In order to examine the difference between the optimal harvest policies of different exploiters and compare it with the social optimum, a two stock model will now be presented.

In an ocean area where there are two exploitable fish stocks, stock A and stock B, the growth of stock A follows the logistic function, with its maximum stock size being a function of the size of stock B:

$$G_A(x_A, x_B) = r_A \cdot x_A \cdot \left(1 - \frac{x_A}{K_A(x_B)}\right) \tag{7}$$

Here, x_A is the size of stock A, x_B is the size of stock B, r_A is the intrinsic growth rate for stock A, and K_A its maximum size. The growth for stock B is parallel, and dependant on the size of stock A.

We define K_A as:

$$K_A = \varepsilon_A + \eta_A \cdot x_B \tag{8}$$

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[8] Even if the manager would disregard political pressure he could not necessarily set the TAC at levels that would guarantee optimal exploitation as he has to set them at levels where it is profitable to exploit stocks. He could not control the size of a stock by issuing a TAC for a stock at a level that would make the exploitation of it unprofitable, even if it would increase the profitability of exploiting the whole ecosystem. Optimal exploitation levels might still be reached with other instruments than quotas, such as Pigovian subsidies for the exploitation of certain stocks.

Here, ε_A and η_A are constant.[9] The sign of η_A in (9) and the sign of η_B in the parallel function for B, indicate the nature of the interdependency between the two stocks. If both constants would be negative, that would indicate competition between the stocks of some sort. If η_A would be positive and η_B negative, that would indicate a predator-prey relation, with stock A being the predator.

Substituting K_A in (9) into (8) gives:

$$G_A(x_A, x_B) = r_A \cdot x_A \cdot \left(1 - \frac{x_A}{\varepsilon_A + \eta_A \cdot x_B}\right) \qquad (7')$$

The harvest of stock A depends on its stock size and effort:

$$q_A = \alpha_A \cdot x_A \cdot e_A, \qquad 0 < \alpha_A < 1 \qquad (9)$$

The harvest function for stock B is parallel.[10]

As we are examining the steady state situation, the harvest of stock A must be equal to its growth:

$$G_A - q_A = r_A \cdot x_A \cdot \left(1 - \frac{x_A}{\varepsilon_A + \eta_A \cdot x_B}\right) - \alpha_A \cdot x_A \cdot e_A = 0 \qquad (10)$$

Solving for the steady state level of x_A gives:

$$x_A = (\varepsilon_A + \eta_A \cdot x_B) \cdot \left(1 - \frac{\alpha_A \cdot e_A}{r_A}\right) \qquad (11)$$

Solving for the steady state level of e_A gives

$$e_A = \frac{r_A}{\alpha_A} \cdot \left(1 - \frac{x_A}{(\varepsilon_A + \eta_A \cdot x_B)}\right) \qquad (12)$$

By substituting e_A from (12) into (9) the harvest function for stock A can be defined as a function of x_A and x_B:

$$q_A = r_A \cdot x_A - \frac{r_A \cdot x_A^2}{(\varepsilon_A + \eta_A \cdot x_B)} \qquad (9')$$

The aggregate profit function is:

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[9] It might be more plausible that K_A would take the form of $K_A = \varepsilon_A + \eta_A \cdot x_A^{\omega}$, where $0 < \omega < 1$, but skipping the exponent should not alter the conclusions from examining the model.

[10] Indeed, all functions for stock B are identical to functions for stock A, with the As and Bs having been swapped.

$$\Pi = p_A \cdot q_A - c \cdot e_A + p_B \cdot q_B - c \cdot e_B$$

$$= p_A \cdot \left(r_A \cdot x_A - \frac{r_A \cdot x_A^2}{(\varepsilon_A + \eta_A \cdot x_B)} \right) - c \cdot \frac{r_A}{\alpha_A} \cdot \left(1 - \frac{x_A}{(\varepsilon_A + \eta_A \cdot x_B)} \right) \quad (13)$$

$$+ p_B \cdot \left(r_B \cdot x_B - \frac{r_B \cdot x_B^2}{(\varepsilon_B + \eta_B \cdot x_A)} \right) - c \cdot \frac{r_B}{\alpha_B} \cdot \left(1 - \frac{x_B}{(\varepsilon_B + \eta_B \cdot x_A)} \right)$$

If the two stocks were managed with the goal of maximizing aggregate profits, which we assume is the social optimum, the aggregate profit function would be maximized:

$$\max_{x_A, x_B} \Pi = p_A \cdot \left(r_A x_A - \frac{r_A \cdot x_A^2}{(\varepsilon_A + \eta_A \cdot x_B)} \right) - c \cdot \frac{r_A}{\alpha_A} \cdot \left(1 - \frac{x_A}{(\varepsilon_A + \eta_A \cdot x_B)} \right)$$

$$+ p_B \cdot \left(r_B x_B - \frac{r_B \cdot x_B^2}{(\varepsilon_B + \eta_B \cdot x_A)} \right) - c \cdot \frac{r_B}{\alpha_B} \cdot \left(1 - \frac{x_B}{(\varepsilon_B + \eta_B \cdot x_A)} \right) \quad (14)$$

The first-order condition with respect to x_A would be:

$$\frac{\delta \Pi}{\delta x_A} = p_A \left(r_A - \frac{2 \cdot r_A \cdot x_A}{(\varepsilon_A + \eta_A \cdot x_B)} \right) + \frac{c \cdot r_A}{\alpha_A \cdot (\varepsilon_A + \eta_A \cdot x_B)} + \frac{p_B \cdot r_B \cdot \eta_B \cdot x_B^2}{(\varepsilon_B + \eta_B \cdot x_A)^2}$$

$$- \frac{c \cdot r_B \cdot \eta_B \cdot x_B}{\alpha_B \cdot (\varepsilon_B + \eta_B \cdot x_A)^2} = 0 \quad (15)$$

In order to find the size of stocks A and B that would maximize profits, we would need to solve (15) – and the parallel function for B – for x_A and x_B, but as we are not examining the maximum itself, but rather the difference between the socially optimal stock sizes and the stock sizes that maximize the profit of individual exploiters under catch quota share management, it is not be necessary. Next we examine the profit function of an individual harvester, in the case where the two stocks would be managed under a catch quota share system.[11] If an entity K would hold the catch quota share $\theta_{K,A}$ for stock A, $0 < \theta_{K,A} < 1$, and the catch quota share $\theta_{K,B}$ for stock B, $0 < \theta_{K,B} < 1$, this would be its profit function:

$$\Pi_K = \theta_{K,A} \cdot \left[p_A \cdot \left(r_A \cdot x_A - \frac{r_A \cdot x_A^2}{(\varepsilon_A + \eta_A \cdot x_B)} \right) - c \cdot \frac{r_A}{\alpha_A} \cdot \left(1 - \frac{x_A}{(\varepsilon_A + \eta_A \cdot x_B)} \right) \right]$$

$$+ \theta_{K,B} \cdot \left[p_B \cdot \left(r_B \cdot x_B - \frac{r_B \cdot x_B^2}{(\varepsilon_B + \eta_B \cdot x_A)} \right) - c \cdot \frac{r_B}{\alpha_B} \cdot \left(1 - \frac{x_B}{(\varepsilon_B + \eta_B \cdot x_A)} \right) \right] \quad (16)$$

[11] As in chapter 2.3 we assume that TACs are set at levels where it is profitable to catch the full TACs.

The first order condition with regards to x_A would be:

$$\frac{\delta\Pi}{\delta x_A} = \theta_{K,A} \cdot p_A \left(r_A - \frac{2 \cdot r_A \cdot x_A}{(\varepsilon_A + \eta_A \cdot x_B)}\right) + \theta_{K,A} \cdot \frac{c \cdot r_A}{\alpha_A \cdot (\varepsilon_A + \eta_A \cdot x_B)} + \theta_{K,B} \cdot \frac{p_B \cdot r_B \cdot \eta_B \cdot x_B^2}{(\varepsilon_B + \eta_B \cdot x_A)^2} - \theta_{K,B} \cdot \frac{c \cdot r_B \cdot \eta_B \cdot x_B}{\alpha_B \cdot (\varepsilon_B + \eta_B \cdot x_A)^2} = 0 \quad (17)$$

In order to compare the difference between the stock sizes that maximize of total profits and stock sized that maximize entity K‘s profits, we rearrange (15) and (17) for x_A^* and x_A^K. Rearranging (15) gives:

$$x_A^* = \frac{(\varepsilon_A + \eta_A \cdot x_B)}{2} + \frac{c}{2 \cdot p_A \cdot \alpha_A} + \frac{p_B \cdot r_B \cdot \eta_B \cdot x_B^2 \cdot (\varepsilon_A + \eta_A \cdot x_B)}{2 \cdot p_A \cdot r_A \cdot (\varepsilon_B + \eta_B \cdot x_A)^2} - \frac{c \cdot r_B \cdot \eta_B \cdot x_B \cdot (\varepsilon_A + \eta_A \cdot x_B)}{2 \cdot p_A \cdot r_A \cdot \alpha_B \cdot (\varepsilon_B + \eta_B \cdot x_A)^2} \quad (18)$$

Rearranging (17) gives:

$$x_A^K = \frac{(\varepsilon_A + \eta_A \cdot x_B)}{2} + \frac{c}{2 \cdot p_A \cdot \alpha_A} + \frac{\theta_{K,B}}{\theta_{K,A}} \cdot \frac{p_B \cdot r_B \cdot \eta_B \cdot x_B^2(\varepsilon_A + \eta_A \cdot x_B)}{2 \cdot p_A \cdot r_A \cdot (\varepsilon_B + \eta_B \cdot x_A)^2} - \frac{\theta_{K,B}}{\theta_{K,A}} \cdot \frac{c \cdot r_B \cdot \eta_B \cdot x_B(\varepsilon_A + \eta_A \cdot x_B)}{p_A \cdot r_A \cdot \alpha_B \cdot (\varepsilon_B + \eta_B \cdot x_A)^2} \quad (19)$$

$x_A^* - x_A^K$, the deviation of the size of stock A that maximizes entity K’s profits from the socially optimal stock size is:

$$x_A^* - x_A^K = \left(1 - \frac{\theta_{K,B}}{\theta_{K,A}}\right) \cdot \left(\frac{r_B \cdot \eta_B \cdot (\varepsilon_A + \eta_A \cdot x_B)}{2 \cdot p_A \cdot r_A \cdot (\varepsilon_B + \eta_B \cdot x_A)^2}\right) \cdot \left(p_B \cdot x_B^2 - \frac{c \cdot x_B}{\alpha_B}\right) \quad (20)$$

$x_B^* - x_B^K$ is parallel to $x_A^* - x_A^K$.

If $\theta_{K,B} \neq \theta_{K,A}$, that is, if the catch quota shares are unevenly distributed between stocks, the stock sizes that maximize entity K‘s profits are different from the stock sizes that maximize total profits – the socially optimal stock sizes.[12, 13] However the

[12] If maximum profits are socially optimal, as is assumed here, the stock sizes that maximize the aggregate profits of all companies involved in the fishery are the socially optimal ones.

[13] Also, if any two companies would have differently distributed catch quota shares between stocks, the sizes of the stocks that would maximize their total profits would different. The less the difference would between the ratio of catch quota shares they would hold for the two stocks, the closer their interests would lie.

less the difference is between $\theta_{K,A}$ and $\theta_{K,B}$, the closer entity K's interests are to the interests of the whole:

$$\lim_{\theta_{K,A} \to \theta_{K,B}} x_A^K = x_A^* \tag{21}$$

2.4.1 Implications of Model Imperfections

Marine ecosystems – and their exploitation – are very complex phenomena. Therefore building an accurate model of the exploitation of an ecosystem is unachievable. Estimating the parameters of stock growth functions accurately is for most stocks very difficult, because of lack of data and as the natural growth of real marine stocks does not any simple function perfectly, even if functions such as the logistic function can very well capture the basic characteristics of the growth of many marine stocks. In the model above, many attributes of the fisheries are ignored for simplicity's sake. It is for example assumed, at least implicitly, that all harvesters have the same profit functions and that there are no economics of scale.

Still the simple two-stock model above shares some fundamental attributes with the real fisheries. Fish stocks are interdependent. Their growth is dependant on their stock size and the state of other stocks. Exploitation affects stocks and the state of a stock affects the profitability of exploiting it. Exploiters rarely, if ever, hold the same catch quota share for every harvested stock of an ecosystem managed under a catch quota share system. Therefore, the results of the model that a conflict of interest exists in catch quota share fisheries, and that the TACs that are optimal for individual exploiters are different from the socially optimal TACs, should hold to be true in real fisheries.

3 Potential Conflicting Interests in the Icelandic Cod and Capelin Fisheries

In this chapter the Icelandic cod and capelin fisheries will be examined to see if a potential conflict of interest exists between stakeholders in the two fisheries.

The cod and capelin stocks in Icelandic waters, as well as most other commercially valuable stocks, are managed by a catch quota system. The minister of fisheries sets TACs for the stocks after hearing suggestions from the Marine Research Institute. The majority of TACs are allocated to ships that hold catch quota share for the respective species, while a small part of it is used for regional policy and such. The perpetual catch quota shares, as well as the catch quota for a single fishing year, can be transferred from ship to ship for remuneration and are thus referred to as individual transferable quotas (ITQs).

The stakeholders' interests in the fisheries will be gauged by examining the lease value of catch quota allotted to companies, based on the ships they own. There are much fewer companies that hold catch quota shares in capelin than cod.[14] Therefore it is sufficient to examine the share holding for both species of companies that hold capelin quota share (cod quota share not held by them are of course held by companies that hold no capelin quota share). Thus, the aggregate catch quota share for cod, of all companies that hold any catch quota share for capelin, will be used to measure the stakes that the whole capelin fishery holds in the cod fishery (ignoring the interests of owners of processing plants and other stakeholders that hold no catch quota shares). Data for catch quota shares was obtained from several tables available on the website of the Icelandic Directorate of Fisheries (n.d.a, n.d.b, n.d.d). The data is composed of cod and capelin catch quota shares of different ships in the fishing year of 2009-2010.

The importance of either fishery can also vary between constituencies. So, in addition to looking at the interest of different ship-owners, the potential conflicting interests of different constituencies will also be examined. The importance of the cod

[14] Almost every company that holds capelin quota shares also holds cod quota shares.

and capelin fisheries in constituencies will be gauged by looking at the home ports of ships that hold cod and capelin quota shares.

3.1 The Interdependency of Cod and Capelin

Cod is the most valuable stock for the Icelandic fisheries industry. While its total catch value, relative to other species', has been going down in the last years, the value of cod catches was still more than twice the value of haddock catches, which were second in value, in 2009 (Statistics Iceland, n.d.). The capelin is the most important food source for cod in Icelandic waters, especially at the cod's later stages of life (Icelandic Marine Research Institute, 1997).

Agnarsson et al. (2008) examine the cod and capelin fisheries in Iceland[15] using both single and two species feedback models. According to the two species model the capelin positively impacts cod biomass growth substantially, while the (negative) impact of the cod on the capelin is insignificant. While the model implies both species should be harvested more conservatively, this is particularly true for the capelin. They argue:

> Capelin catches have […] far exceeded the optimal feedback harvesting policy. […] Actual harvest have been close to the single species optimum, but when the interaction with cod is also taken into account, it becomes clear that the capelin has been overfished; (p. 36).

The results of Agnarsson et al. are that it would be optimal that the capelin stock would not be exploited at all to increase the profits from the cod fisheries. Those who hold big stakes in capelin, and not in cod, are likely to oppose such policies, while those that hold big stakes in cod, and not in capelin, are likely to argue for more conservative exploitation of capelin, or simply against any exploitation of it.

Danielsson, Stefansson, Baldursson, and Thorarinsson, K. (1997) construct a bioeconomic model of the exploitation of the Icelandic cod, capelin and shrimp stocks. The results of the model are that a harvesting policy that would lead to an increase in the catch of cod at the cost of a big decrease in the catch of capelin would be optimal.

[15] As well as the cod and capelin fisheries in Norway and the cod and herring fisheries in Denmark.

3.2 Conflicting Interests of Ship-owners

Twenty-eight ships, owned by 12 companies, hold capelin quota shares. Of those, all but one also hold cod quota shares. The aggregate cod quota share of these companies is 26.95%. That is, the whole capelin fishery holds about a quarter of the catch quota shares for cod. Table 3.1 shows the cod and capelin quota share holding of the 12 companies.

Table 3.1 Cod and capelin quota share of companies that own ships that hold capelin quota shares (in %)

Company	Capelin quota share	Cod quota share
1	19.99	2.27
2	18.68	5.56
3	17.99	1.79
4	10.25	1.04
5	8.81	1.63
6	8.14	2.81
7	5.66	1.04
8	4.20	5.99
9	2.50	0.01
10	1.75	0.91
11	1.40	0.00
12	0.65	3.88
Sum	100	26.95

Directorate of Fisheries (n.d.a, n.d.b, n.d.d)

In order to roughly estimate the profits of the companies for both fisheries, the value of catch quota allocated to them, based on the catch quota shares they hold, can be evaluated using the price of leased catch quota. In the fishing year 2009-2010 the total allocated catch quota for cod was 132,179 tons and for capelin 109,805 tons (Directorate of Fisheries, n.d.e). The average price of cod catch quota was 258.75 ISK/kg and of capelin 15.22 ISK/kg (Icelandic Directorate of Fisheries, n.d.c).[16] Accordingly we can estimate the total profits of cod catch quota share holders at 34.20 billion ISK and the total profits of capelin catch quota share holders at 1.67 billion ISK. Table 3.2 shows the estimates for profits of the 12 capelin quota share holding companies from both fisheries.

[16] Although transactions involving the leasing of cod quota are quite common, this is not the case for capelin, with only a few capelin catch quota transactions a year taking place. The capelin stock is also much more volatile than the cod stock and the TAC issued for it fluctuates considerably over time. The profit estimations are therefore, as has already been stated, rough. But as the TAC for capelin has historically often been much higher, this indicates that the value of catch quota shares in it is underestimated rather than overestimated, which would mean that the conflict of interest would be underestimated.

As the cod fishery is a much bigger industry than the capelin fishery many companies that holds a very small part of the total cod quota share, but a considerable part of the capelin quota share, are still more dependant on the cod. It is important to note that this does not mean that these companies' optimal TACs for cod and capelin would be the same as for a company that holds no capelin quota share. For all companies holding catch quota shares for capelin, we estimate that the capelin fishery profits are equal to about 18% of the profits they earn from the cod fishery. So for the companies as a whole, it would be suboptimal that the exploitation of capelin would be halted unless it would increase the profits from harvesting cod by at least 18%. If we exclude companies 2, 6, 8, 10 and 12 the ratio changes from 18% to 42%. Based on the same rational, if the rest of the companies were to lobby jointly, they should argue against banning capelin fishing unless it would increase the profits of the cod fishery by more than 42% (if they are profit maximizing). However, using the same numbers, it would increase the aggregate profits of both fisheries to ban capelin fishing – reducing the profit of exploiting it to nothing – if it would lead to a 5% increase of profits in the cod fishery. So, if the profits of the cod fishery could be increased by 10% by banning capelin fishing, it would be socially optimal, while it would reduce profits of the holders of capelin catch quota significantly.[17, 18]

Table 3.2 Profits from the cod and capelin fisheries of companies that own ships that hold capelin quota share (in millions of ISK)

Company	Capelin profits	Cod profits
1	334	775
2	312	1,900
3	301	612
4	171	356
5	147	559
6	136	962
7	95	356
8	70	2,050
9	42	5
10	29	313
11	23	0
12	11	1,329
Sum	1,671	9,216

Directorate of Fisheries (n.d.e)

[17] Of course, marginal changes in the TAC for capelin could also lead to similar conclusions.
[18] Perhaps, in order to compensate the holders of catch quota share for capelin if its exploitation would be halted, they could be allowed to exchange their shares for capelin for shares for cod.

For those capelin quota share holders that hold no or very little cod quota share it might be optimal to set the TAC for cod at a level that would severely diminish the stock, or even wipe it out, although it is unlikely that they would seriously advocate a fishing strategy that would have such adverse effects on the Icelandic economy. It is interesting to note that if the TAC for the cod would be set at a level that would seriously harm the cod fishery, it would still be optimal for each company to take part in the overfishing as long as they would gain in the short term. The cod quota holders would face individualistic competition in the exploitation of a limited resource, as they would in the open fishery described by Gordon (1954), although there would be barriers to entry unlike in an open fishery.

3.3 Conflict of Interests of Constituencies

There are six constituencies in Iceland: NW-Iceland, NE-Iceland, S-Iceland, SW-Iceland (the municipalities surrounding Reykjavík), N-Reykjavík and S-Reykjavík (below Reykjavík will be handled like a single constituency). The three first mentioned are most dependent on fisheries. Table 3.3 shows the division of the catch quota shares for cod and capelin between constituencies based on the home port of ships.

Table 3.3 Division of the catch quota share for cod and capelin between constituencies (in %)

	NW-Iceland	NE-Iceland	S-Iceland	SW-Iceland	Reykjavik	Sum
Cod quota shares	32.15	26.17	31.57	1.93	8.17	100
Capelin quota shares	8.73	50.44	34.61	0.00	6.23	100

Directorate of Fisheries (n.d.a, n.d.b, n.d.d)

Table 3.4 shows the profits from the cod and capelin fisheries in the constituencies, using the same numbers for profits as in chapter 3.2.

Table 3.4 Profits from the cod and capelin fisheries in constituencies (in millions of ISK)

	NW-Iceland	NE-Iceland	S-Iceland	SW-Iceland	Reykjavik	Sum
Cod profits	10.996	8.951	10,797	660	2,795	34,198
Capelin profits	146	843	579	0	104	1,671

Directorate of Fisheries (n.d.e)

It is clear that the capelin fishery is way more important in the NE-constituency and the S-constituency than in the other. No ships in the municipalities surrounding Reykjavík hold quota share in capelin. Only a single ship registered in Reykjavik holds capelin quota share, but a very considerable share. These numbers imply that the optimal cod and capelin fishing strategies for the constituencies could vary. Further, that if the Minister of Fisheries would rather act in the interests of his home constituency than the others, he would not set the TACs at levels that would maximize the total profits of these fisheries.

4 Discussion

In this thesis it is argued that harvest policies that would maximize the profits of individual catch quota share holders, in a multi-species catch quota share fisheries regime, are different between companies, and different from the policies that would be socially optimal. According to the model presented in chapter 2, the more varied the catch quota shares individual harvesters hold are for different stocks, the more the harvesting strategy that would maximize their profits differs from the socially optimal one. This implies that if some harvesters are able to influence the manager that sets the total allowable catches (TACs), he might diverge from the socially optimal strategy in deciding upon them. This is not to say that individual transferable quota fisheries management systems lead to socially suboptimal harvest strategies.[19] The manager who sets the TACs is of course not necessarily influenced by the interests of particular exploiters. But it does contradict the notion that it is in the best interest of those that hold catch quota shares that fish stocks are managed optimally.

An analysis of the Icelandic cod and capelin fisheries is presented in chapter 3. It is in many ways primitive, although it strongly supports the results of chapter 2's model. There is ample room for further studies, both of the cod and capelin fisheries of Iceland and of other fisheries involving interrelated stock. A good deal of literature exists on bioeconomic models that estimate parameters for real fisheries. Two examples that focus on the cod and capelin fisheries in Iceland are named in chapter 3.1 (Agnarsson et al., 2008; Danielsson et al. 1997). It would require little work to calibrate such models to estimate optimal harvest strategies for different harvesters based on their catch quota share holdings, as the parameters for stock growth and profit functions have already been estimated. However, the fact that both aforementioned models advocate a strategy that would increase profits in the cod fishery at a cost to the capelin fishery strongly implies that a conflict of interests exists between cod and capelin quota share holders.

[19] The Icelandic ITQ system is very controversial, but the main arguments are mostly about if the catch quota shares were allocated fairly when it was established, rather than about if it leads to optimal harvest strategies.

There are many examples of those having stakes in the capelin fishery advocating aggressive harvesting policies for it, for example on the blog sites of ship crews, which further supports the findings of chapter 3. As an example, in February 2009, when it was still unclear whether a TAC would be issued or not for capelin, the municipal government of Vestmannaeyjar issued a resolution urging the Minister to issue a TAC for the capelin (ships registered in Vestmannaeyjar hold about 26.47% of the capelin quota shares) (Bæjarráð Vestmanneyja, 2009).[20]

[20] The capelin stock is of such nature that the Minister of Fisheries has to make a decision on whether to issue a TAC or if no harvesting will be allowed over the fishing year, shortly after hearing advice from the Marine Research Institute (MRI). The MRI's advice is based on assessments of the stock size.

References:

Agnarsson, S., Arnason, R., Johannesdottir, K., Ravn-Jonsen, L., Sandal, L.K., Steinshamn, S.I. et al. (2008). *SNF-Report No. 25/07: Comparative Evaluation of the Fisheries Policies in Denmark, Iceland and Norway: Multispecies and Stochastic issues*. Bergen: Institute for Research in Economics and Business Administration.

Arnason, R. (1990). Minimum information management in fisheries. *The Canadian Journal of Economics*, *23*(3), 630-653.

Bæjarráð Vestmannaeyja (2009). Fundargerð 2864. Fundar Bæjarráðs Vestmannaeyja. Retrieved November 24, 2010, from http://www.vestmannaeyjar.is/?p=200.

Copes, P. (1995). Problems with ITQs in Fisheries Management with Tentative Comments on Relevance for Faroe Islands Fisheries. In Samal Trondur Finnsson Johansen (editor), *Nordic Fishing Communities in the Future*, (19-37). Copenhagen: Nordic Council of Ministers.

Danielsson, A., Stefansson, G, Baldursson, F.M and Thorarinsson, K. (1997). Utilization of the Icelandic Cod Stock in a Multispecies Context. *Marine Research Economics*, *12*(14), 239-344.

Directorate of Fisheries (n.d.a). Aflahlutdeildalisti. *Vefur Fiskistofu*. Retrieved November 19, 2010, from http://www.fiskistofa.is/veidar/aflaheimildir/aflahlutdeildalisti.

Directorate of Fisheries (n.d.b). Aflaheimildir: Fyrirtæki – mörg skip. *Vefur Fiskistofu*. Retrieved November 19, 2010, from http://www2.fiskistofa.is/skip_aflastodur2.php.

Directorate of Fisheries (n.d.c). Aflamarksviðskipti. *Vefur Fiskistofu*. Retrieved January 8, 2011, from http://www.fiskistofa.is/veidar/aflaheimildir/aflamarksvidskipti/

Directorate of Fisheries (n.d.d). Aflastaða: Einstök skip. *Vefur Fiskistofu*. Retrieved November 19, 2010, from http://www.fiskistofa.is/veidar/aflastada/einstokskip.

Directorate of Fisheries (n.d.e). Heildaraflamarksstaða. *Vefur Fiskistofu*. Retrieved January 8, 2011, from http://www.fiskistofa.is/veidar/aflaupplysingar/heildaraflamarksstada/.

Gordon, H.S. (1954). The Economic Theory of a Common-Property Resource: The Fishery. *The Journal of Political Economy*, *62*(2), 124-142.

Matthiasson, T (2005). *Possible stakeholder conflicts in quota regulated fisheries*. ICES CM Documents 2005. Copenhagen: International Council for the Exporation of the see.

Hannesson, R. (1978). *Economics of fisheries: An introduction*. Bergen: Universitetsforlaget.

Icelandic Marine Research Institute (1997). *Fjölstofnarannsóknir: 1992-1995*. Reykjavík: Icelandic Marine Research Institute.

Statistics Iceland (n.d). Catch and value of catch. Retrieved January 4, 2011 from http://www.statice.is/Statistics/Fisheries-and-agriculture/Catch-and-value-of-catch.