Profit motive and natural resource overexploitation: Misperception of the bioeconomic dynamics; the case of a fishery.

By

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Thesis
Submitted to the Department of Geography
in Partial Fulfillment of the Requirements for the Degree of
Master of Philosophy in System Dynamics

System Dynamics Group
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University of Bergen

November 2010

Acknowledments

I wish to express my gratitude to everybody whose assistance in many different ways contributed to the writing of this thesis. First among these people is my supervisor, Erling Moxnes for his ideas, time and patience without which this work would not have been successful. The process of deciding on a topic was made easier with the help of John Ansah, who suggested possible areas to be researched into. Members of the system dynamics class were also available to share ideas, all of which contributed to writing this thesis.

Abstract

Over-exploitation of fishery resources has become a major concern not only to users of the resource but society as a whole. Management of the resource has not yielded the desired result of sustainability despite huge efforts in this area. One reason for this deficiency is what Moxnes (1998) refers to as the misperceptions of resource dynamics which accounts for policy resistance in the fishery. Since the dynamics in the resource are not thoroughly understood, the policies arrived at end up not achieving the intended results and in some cases worsen the situation. Just like the management failure of Canada's ground fish resources, well intended actions in Ghana's fishery might have resulted in the problem of declining catches. In the 1970s fish traders stepped in to provide the financial needs of the fishers. Fishers paid back such loans by supplying the traders with fish. The paper investigates how this trade relation between fishermen and fish traders might have contributed to the problem of declining catches. Existing literature and simple models will be used to provide an insight into the dynamics of the resource and help to analyse how the two main causes of the catch decline, bottom trawling and trade relation might have impacted the resource. This will contribute to the education of fisheries managers and fishers about the resource which will help to manage the resource in a better way. The study adopts the system dynamics methodology of modelling to study the problem of declining catches and suggest policies to solve the problem. The findings are that bottom trawling by the industrial fleet should be halted to help provide safe breeding grounds for fish. Secondly mesh size regulations should be implemented in the artisanal fishery to make gears more selective. To make implementation of these policies effective, stakeholders should be involved in the management process.

Keywords: fishery, misperception, dynamics, policy resistance, precautionary principle, co-management, stakeholders.

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Chapter 1
Introduction

The state of natural resources has been a major source of concern to researchers and the world as a whole. Water bodies, fisheries, forests among other natural resources have been supportive of mankind's survival. The role played by these resources in the survival of humanity provides a good reason why they should be managed properly, so that they can meet the needs of current and future generations. The Amazon forest for example is a vast (5million m^2) resource that has been beneficial to mankind's sustenance (especially those living around it) for years (Kasperson J. X. , Kasperson R. E. et al. 1995). The extraction of forest products such as dyes, wood and herbs was the main use to which the forest was put in the 1900s. Rubber extraction later took over up to the 1960s when pasture development and pulp production became dominant. Mineral resource extraction began in the 1970s and in the 80s and 90s timber extraction accelerated markedly. The resource is currently considered an area that calls for urgent attention (Kasperson et el 1995).

Fish stocks is another resource that has drawn similar attention. An estimated 50% of fish stocks for example have been labelled as fully exploited and an additional 25% is considered over exploited. 7 out of the 10 most valuable marine species are considered fully exploited or over exploited with recovery rates of such species severely compromised (PROFISH 2006). The resource is moving gradually to a state of full exploitation with under exploited and moderately exploited stocks having been reported to be declining while the fully exploited and overexploited stocks are slightly increasing (FAO 2000).

Causes of resource over exploitation

Human activities have been identified to be the driving forces behind these environmental changes. Loggers, cattle ranchers, dam builders, small farmers and plantation operators are all involved in the deforestation of the Amazon forest for example (Kasperson, Kasperson et al. 1995).

Technological advancement is another factor contributing to the overexploitation of resources. Improvement in technology has provided a general improvement in the human condition (Dalton, Coats et al. 2004). Such technological improvements have helped humanity to better exploit nature's resources through the discovery of harvesting technology that have resulted in efficient harvesting of natural resources. Over the years there have been great improvements in the harvest technology in the fishery sector such as the introduction of motorized equipments and more efficient gears for example. This technological development has resulted in high harvesting rates leading to resources being exploited beyond their sustainable levels (Moxnes 1998). This has pushed resources into a situation referred to as 'criticality' - a condition reflecting a scope of impact sufficiently wide enough to merit global concern (Kasperson, Kasperson et al. 1995). Recent investigations have revealed that such levels of exploitation cannot be maintained without depleting the resource. Unfortunately, managerial intervention in such situations usually comes a little late due to a misperception of resource dynamics (Moxnes 1998).

The tragedy of the commons has also been long associated with the overexploitation of resources. This is due to the existence of an open access regime which encourages the exploitation of a resource to be driven by the individual decisions of the users, usually motivated by the desire to make more profit (Hardin 1968). This situation arises because there is no authority to regulate or restrict the rate of fishing thus each participant in the fishery maximizes utility by building higher effort. The fishery, unable to withstand the pressure collapses and becomes unprofitable.

Another factor which accounts for this problem is the rise in global demand for fish and fish products and an attendant increase in prices (Seijo, Defeo et al. 1998). Rise in the world population has resulted in an increase in the demand for fish products. This is particularly so because fish is a relatively a cheaper source of protein compared to other sources.

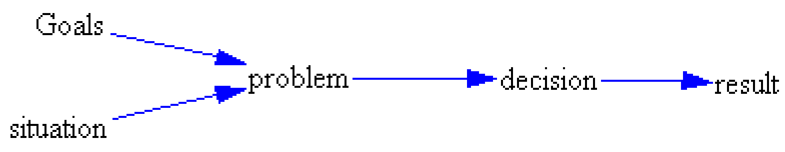
Management attempts at saving the resource such as minimum size limits, reduction in effort and catches have not been as successful as intended. Fisheries management or efforts at managing the resource has been in existence for long, yet stocks are still moving to the state of full exploitation (ibid).

Misperception and policy resistance

Moxnes (1998) identifies a reason that contributes to the inability of management to prevent overexploitation- the misperception of the bioeconomics and the dynamics of renewable natural resources. Fish stock estimates are already difficult to establish, but this is further complicated if the actual dynamics are misunderstood. Moxnes (1998) discovers that even with effective management regimes in operation, resources are still prone to be overexploited as shown in the reindeer experiment (Moxnes 1998). This situation suggests that beyond aggressive investment in harvesting effort lies the misunderstanding of how renewable resources undergo certain changes mainly due to human intervention through harvesting. Misperception of the bioeconomics leads to policy resistance; where policies are delayed, diluted, or defeated by the unforeseen reactions of other people or nature (Sterman 2000).

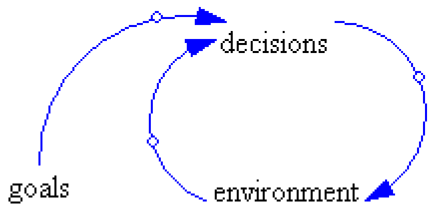
Causes of misperception in fisheries

This situation arises as a result of the event-oriented view of the world, which creates the tendency to interpret experience as a series of events for example, inventory is high because sales fell, sales fell because competitors lowered their price etc. (Sterman 2000). This way of thinking links causes and effects and ignores the feedbacks.



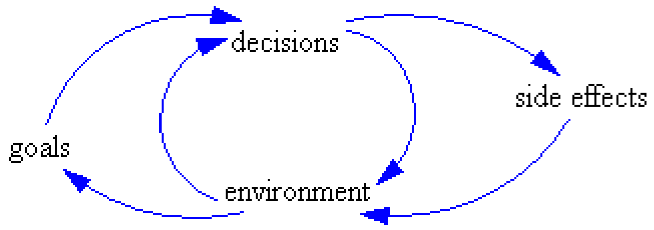
The event oriented way of thinking, Sterman (2000).

In this demonstration there is a problem (gap between the goal and the situation). Decisions are then made to correct the problem. However since the focus is only on the problem, other agents in the system (which were ignored) cause the system to react to the solution and yesterday's solution becomes today's problem (Sterman 2000). Policy resistance arises because of a lack of understanding of the full range of feedbacks operating within the system. To make effective decisions (policies), it is important to understand that decisions do not only affect the results but as shown below, the environment is also affected.



Sterman (2000)

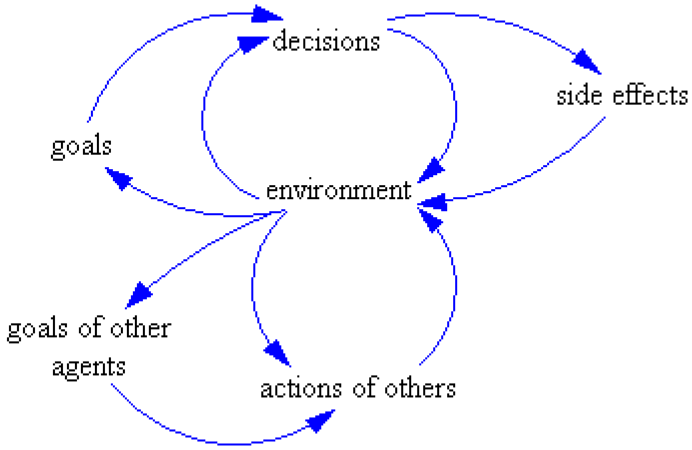
In a complex system, goals determine decision, decisions affect the environment and the environment also affects the decisions. Beyond this simple feedback loop lays an even bigger loop representing how decisions and actions result in other results other than those originally intended.



Sterman (2000)

Actions generate effects; the intended effects are the main effects while the unintended and unanticipated, policy undercutting and harmful effects are what are normally referred to as the side effects (Sterman 2000). Side effects are not a feature of reality but a sign that our understanding of the system is narrow and flawed (Sterman 2000). Such effects also have an impact on the environment and feeds back into the goals the next time round.

There is an even bigger loop in operation impacting on the environment beyond our actions and their effects. This loop involves our actions and their effects and the actions of others. Since there are many players in the system, our actions and their effects are not the only ones that affect the environment but also the actions and effects of the other agents. Similar or different decisions made by the other agents makes the impact on the environment even bigger thus creating a more complex interaction between the agents and the environment. Below is a representation of such a feedback system which forms the feedback view recommended by Sterman (2000).



The feedback view (Sterman 2000)

In a more complex system, many agents are engaged in constant interaction with the environment thus the environment is affected by and affects the decisions of all the agents.

Cases of policy resistance

A neglect or misperception of this feedback view leads to decisions or policies that are unlikely to achieve the desired results. An instance of misperception is demonstrated in the quotation below:

> 'In 1980, a Food and Agricultural Organization of the United Nations (FAO) publication, in anticipation of the EEZ regime, stated that: ''the opportunity exists, as never before, for the rational exploitation of marine fisheries. . . . The 1980s provide the threshold for a new era in the enjoyment of the ocean's wealth in fisheries'' (cited in United Nations Food and Agriculture Organization 1992). The hopes and expectations of the early 1980s have not

> been realized. The same FAO recently reported that ‘‘69% of the world’s marine [fish] stocks . . . are either fully to heavily exploited, overexploited, depleted . . .and therefore are in need of urgent conservation and management measures’’ (United Nations Food and Agriculture Organization 1995). Coastal state fishery management programs have proved, in far too many instances, to be seriously deficient’ – Lauck (1998).

The role that misperception plays in the overexploitation problem cannot be underestimated considering the fact that it is not only among resource users but present even at the high decision making bodies such as the FAO. The FAO’s hopes that the institution of the Exclusive Economic Zone was going to solve the problem of over fishing was not realized, instead it was realized few years later that the problem still persisted if not worse. The aim of instituting the EEZ was to promote conservation and management of the resource. But the well intended policies of the organisation were undercut by unforeseen factors. Another example of misperception is presented below.

> ‘One of the most dramatic and depressing examples of fishery management failure under the EEZ regime is provided by the large and extremely productive groundfish resources on the famous Grand Banks of Newfoundland, which constituted Canada’s main bonanza under the EEZ regime. These resources had been overexploited while international common property.
>
> Under conservative Canadian management, it was hoped that fish stocks would be rebuilt, to the benefit of the Canadian fishing industry. The single most important of these resources, a cod stock complex extending from southern Labrador to southeastern Newfoundland, popularly known as Northern cod (*Gadus morhua*), was expected to yield sustainable annual

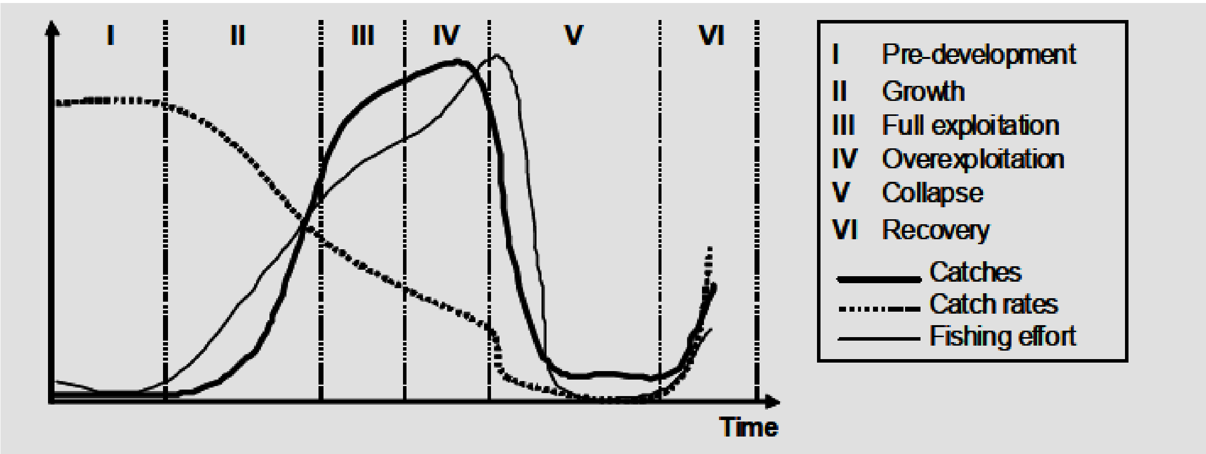
harvests of 4 _ 108 kg by the late 1980s (Canada 1983). These sustainable harvests were not achieved. In the late 1980s, the Canadian government introduced drastic cuts in the Northern cod total allowable catches (TACs). The drastic TAC cuts were not enough. In 1992, the Canadian authorities felt compelled to impose a temporary 2-yr harvest moratorium on Northern cod. The authorities were horrified to find that the resource continued to decline after the moratorium had been imposed. The harvest moratorium still remains in place (in 1996) and has ceased to be temporary. It is now indefinite. To compound the misery, the Canadian authorities have had to impose harvest moratoria on several neighboring groundfish stocks. The causes of the fishery resource collapse off Atlantic Canada are now the subject of an intense debate (Myers et al. 1997). What is clear is that the collapse came as a stunning shock to the authorities. One commentator remarked that the resource collapse would have had no credibility as a worst-case scenario, even a few years prior to the imposition of the moratorium (Roy 1996). What is equally clear is that the management of even seemingly stable fishery resources, such as groundfish, is subject to a far greater degree of uncertainty than heretofore had been realized and appreciated (Gordon and Munro 1996).'- Lauck (1998)

This represents a classic scenario of the extent to which policy resistance exists in the fishing industry. Even under stable management and property regime, fish stock collapses are possible. In a complex system such as a fishery, policy resistance is an issue which should be minimized to a large extent to avoid such closures of the resource. In as much as this is the goal of fisheries managers, certain factors make this endeavour a rather complex agenda. One of such complexities is the conflicting interests of the stakeholders involved (Bailey and Jentoft 2002). A fishery is a political issue, since the government in power will like to gain votes and following of fishermen. It is also a sector that generates political debates and politicians have an interest in the management of the resource. A fishery is also an employment issue because it is the source livelihood to those who depend on it. Being an employment issue also makes it a social issue because the resource and the users belong to a community and it is a source of food for this community. The list of stakeholders in fisheries therefore includes government, fishers, processors, environmentalists, communities to mention a few. All of them have different, sometimes conflicting interests. For example, environmentalists may be arguing for a reduction in catches while fishers and their communities may be demanding an increase. The government in power may also like to win the favour of the fisher folk so may yield to the demands of fishers even if data suggests a reduction. All these complex interplay of interests adds to the tendency to mismanage a fishery.

Fisheries management differs from livestock or forestry management for instance. Livestock and trees can be seen and counted and any changes could easily be identified. Fish on the other hand is only seen when it is caught. Any changes in the stock could only be known through fishery research, monitoring and assessment, which are expensive and are done not monthly or even yearly, especially in developing countries. Decision making under such a condition is likely to take longer time and thus lag behind the events. Such decisions may not be accurate compared to that of the forestry manager who knows how many trees were destroyed by a storm or the livestock manager who knows how many animals died of a disease or were eaten by a predator. Fisheries is therefore engulfed in uncertainties that makes it difficult to make accurate decisions based on data (Lauck, Clarke et al. 1998). This makes it even more useful to as much as possible identify as many feedbacks as possible.

The fisheries development cycle

Aside the existence of uncertainties in a fishery, the resource also goes through changes thus policies under one stage may not be appropriate for the next stage. The difficulty here relates to knowing when one stage is ending and the next one beginning. The resource goes through six stages namely, pre-development, growth, full exploitation, overexploitation, collapse and recovery.



A graph showing the various stages that a fishery goes through

Source: PROFISH (2009)

At the *pre developmental* or underexploited stage also known as the exploration stage there are low catches, a limited market and basic technology (PROFISH 2009). As is characteristic of new discoveries and markets, awareness of the fishery is low thus there are few fishers. Few fishers means low effort levels and sophisticated gears are not abundant in the fishery. Marketing channels are also not yet well developed at this stage so there is no motivation to harvest much.

The *growth or development* stage is made up of two sub stages, the initial growth and the full or exponential growth. At the initial growth, there are few pioneers, innovators and risk takers.

Over time the innovation and high profit attracts new entrants resulting in the exponential growth stage. The growth is powered by the discovery of new ideas, the use of more efficient harvest technology and the existence of a larger market. At this stage, institution and infrastructure are put in place to promote the exploitation of the resource but not the mechanisms to prevent an overshoot (PROFISH 2009).

The *full exploitation* stage is a difficult stage to detect thus it is normally noticed when it is passed (PROFISH 2009). Full exploitation according to the Law of the Sea Convention means the extraction of the Maximum Sustainable Yield (MSY) which after the institution of the United Nations agreement on fish stocks is not considered as a target but a limit (FAO 1995). This situation suggests that harvesting activities need to slow down when approaching the Maximum Sustainable Yield, however, the MSY is not a stable or constant figure. It depends on the current state of the fish stock of which current knowledge is generally inaccurate.

The difficulty in identifying the full exploitation stage results in the resource reaching the *overexploitation* stage. This stage is defined as a situation where the catch rates exceed the MSY limit. This stage is also deceptive because catches could still be high due to fish behaviour or a delay in the stock response. Abundance begins to decline and the fishery becomes less profitable.

The collapse stage is characterized by a huge decline in stocks and catches thus necessitating a reduction in the fishing effort. This leads to many fishers leaving the fishery voluntarily or on the orders of fishery authorities.

The *recovery stage* is when the decrease in the fishing effort makes room for the stocks to recover if the climatic conditions are conducive.

Evidence of the misperception of the dynamics of the fishery can be noticed in the behaviour of the three graphs; catches, catch rates and effort. The catch curve keeps rising even up to the overexploitation stage. Effort also keeps rising accordingly, suggesting that the decision to increase effort is based on the catch levels. The catch curve suddenly collapses and the effort curve follows soon after. The drastic reduction in effort means job loss, a situation which could have been prevented if attention was paid to the *catch rate* curve. Right from the growth stage the catch rate curve (Catch Per Unit Effort) has been declining. This means that even though the catch curve has been rising, it was rising at a decreasing rate. This is an indication that the increase in the effort was not yielding the desired result. This situation clearly demonstrates what Moxnes (1998) described as corrective measures coming in too late. Such late intervention is due to the fact that attention was not paid to the more critical parameter, the catch rates (CPUE).

The problem in Ghana's fishery

The fishermen in the artisanal sub-sector of Ghana's fishery sector feel the effects of the decline in the catches in Ghana's territorial waters. This is a sub-sector that employs many of the fishermen and accounts for an estimated 70% of the total landings in Ghana. Technology in this sub-sector is mainly a motorized canoe with a net and a crew of any number desired. As a result of less advanced technology, the fishing activity is done mainly close to the shore. Most of the complaints in newspapers and journals are from fishers in this sector who blame the decline of catches on the activities of the industrial fleets. The industrial sector consists of the steel hulled trawlers, tuna poles, shrimpers etc with refrigerators and processors onboard and their operation is mainly in deep waters. They are blamed for bottom trawling which reportedly disturbs the breeding grounds of marine organisms. This is the main reason that has been reported for being responsible for the decline of catches. The artisanal sector is portrayed as the victim of the bad fishing practices of the industries fleets. This however, is not the only reason behind the problem. The fishery may be facing the unanticipated and unintended consequences of well intended actions in the fishery decades ago.

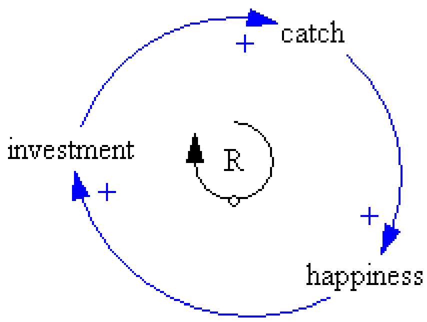
In the 1950s Ghana's fishery sector began to undergo a period of mechanization with the government being the initiator of such a process (Hernæs 1991) with the artisanal fishers being the beneficiaries of this initiative. The tedious paddling which prevented fishers from going deeper to as well as staying longer at sea was replaced by the outboard motor (Odotei 1991). A major problem faced by both government and the fishers is the latter's inability to afford the technology. After struggling to afford the motor, occasional maintenance which required the purchase of spare parts was also a problem (Hernæs 1991). To overcome this problem of financing, the government instituted a credit scheme on flexible terms to help the fishers afford the technology. Each motor cost 150 pounds and a fisher was required to pay 25% and the remainder be paid over a year at an interest rate of 3% (ibid). Some fishers were not able to comply the terms of the arrangement. There were defaults and government had to revise the terms. In 1962, a new arrangement was made which required fishers to pay 20 pounds and the remainder paid over two years (ibid). This arrangement could not solve the problem either. As a result, motorization as at the early 1970s was only 20-25% (Hernæs 1991). The banks did not help either because of the requirement of collateral. The solution finally showed up to the relief of the fishers when women stepped in. Realizing that the success of their businesses depended on the availability of fish, established and successful fish traders (women) showed interest in the problem and began offering credit to the fishermen (ibid). The terms of this arrangement was however different in the sense that unlike the government scheme, the payment under this arrangement was the supply of fish to the women. The fisher (borrower) must supply the trader (lender) with fish over a period agreed upon by the parties. The fishers benefitted from this by gaining the technology they needed and paying in 'more flexible terms'. The trader also benefitted by having a reliable supply of fish.

Not all the fish traders could afford to lend money to the fishers. Those with less solid financial abilities also adopted a method of securing their fish supply, they financed fishing trips. Fishermen embark on fishing trips that lasts for days or even weeks. Sometimes they crossed borders into other neighbouring countries such as Togo, Benin, Cote d'Voire (Odotei 1991). Fishers faced problems because of low catches in normal seasons due to their lack of technology and the short glut season (July to September). The profits during this peak season were reduced because abundance brought prices down coupled with the increasing cost of fuel. Financing trips therefore became a problem thus fishers spent less time at sea and so brought home less catch. Women responded to this need and financed the trips in exchange for fish.

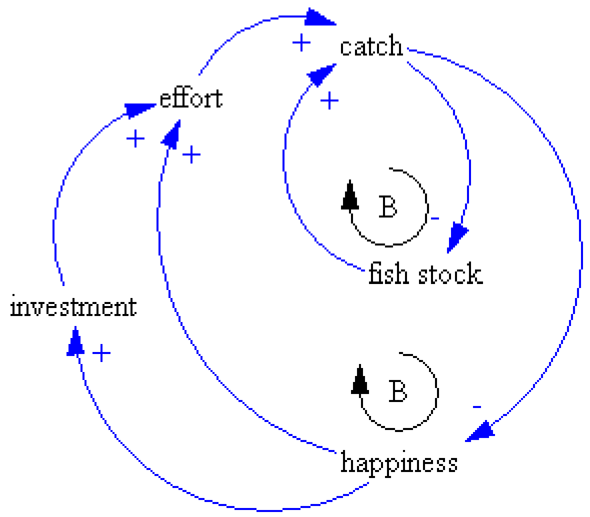
There is a third category of women in the fishery, those who own canoes (Walker 2002). As at 1992, women owned 25% of the canoes in the fishing community of Moree (Overå 1992). Ownership of the means of production such as a canoe is symbol of prestige and future security for the next generation (Odotei 1991:163, Overå 1992). The women got crew of men including their son's to work with the canoe.

There is yet another category of investors in the fishery, those who work in the formal sector but own canoes. They are known as *absentee* owners because they are not present at the shore.

The mechanization of the fishery sector in Ghana was made possible by the investment of women fish traders. Some commentators refer to them as exploitative while others classify them as entrepreneurial. Exploitative or entrepreneurial, one thing emerges – a constant supply of fish to offset the money lent to the fishers plus profits. Whether they lent money, financed trips or owned canoes, these women constantly expected fish delivery. Is it possible that this good and beneficial relationship between the fishers and traders put some pressure on the fish stock? How tolerant could a lender, financier or owner be of low catches? Will there not be pressure on the fishermen to make sure that their partners had fish all the time?



The diagram demonstrates a possible scenario where a woman invests into the fishery by any of the three ways. Catches go up and she gets good supplies and she is happy so she invests more. This continues until the stock cannot take the pressure anymore and begins to decline. The catches reduce so the investor is not happy. Maybe she verbally puts pressure on fishermen to deliver more fish so the fishermen increase effort or she puts in more money to increase harvest. To avoid the withdrawal of her support, fishermen try harder to deliver more fish. This scenario can be represented as shown below.



The increase in effort may be by purchasing more equipment or by the use of nets with smaller mesh sizes which catches more fish by being less selective thus catching young fish. This further decreases the stock until it gets to a point where increase in efforts does not yield much and losses set in. Is it possible that the above scenarios may have arisen from the financial arrangement between the fishers and the women?

Objectives of study

The objective of this study is

1. To study the dynamics of the fishery
2. To model the fishery system to identify the causes of catch decline
3. Test how the financing by women may have impacted the stock
4. Recommend policies to manage the stock.

Hypothesis

The hypothesis of this study is that the decline in catch levels in the Ghanaian marine fishery is a result of the lack of adequate understanding of the interaction between the resource base and the resource user group. The resource base has its own natural dynamics where as the resource user group also has its dynamics motivated by profits. These two groups on their own exhibit complexities but their interaction with each other creates an even bigger complexity which is counter intuitive. Inadequate understanding of this complexity has resulted in over capacity motivated by the aim of higher harvest and higher profit thereby causing the stock to decline to levels that cannot guarantee gainful employment and continued food supply. The growth in effort is not matched by the growth in fish stock but since fishers and possibly policy makers are not aware of the underlying structure of the system, they keep increasing effort in the hope that things will get better.

Significance of the study

Various attempts have been made to try to curtail the incidence of overexploitation. Among these measures are the institution of quotas and licensing systems in countries like Norway and New Zealand. These measures introduce restrictions onto the exploitation of the resource which resource users may not be happy with. As it stands however, there needs to be an intervention: An intervention first through information and then restrictions. This study becomes important in this regard in two ways. Firstly a good understanding of the resource dynamics by the managers reduces the risk of driving a resource into ‘criticality’ before instituting management measures. Resource users may be increasing effort instead of decreasing it because of the misperception that higher effort may yield more. This leads to a situation where efforts at saving the resource come at a time when the resource is overexploited. This tendency will largely be reduced if managers of a resource gain a good understanding of the resource dynamics and put measures in place to put this situation under control. The second way that this study could be important is in the area of eliciting co-operation from resource users. A lack of understanding of the dynamics of the resource by users is likely to result in them resisting the efforts by management to save the resource. Quotas and licenses may be considered by users as ways adopted by management to exclude users from benefiting from the resource. On the other hand, by understanding the dynamics, users will appreciate management effort and be more cooperative. Managing the resource will become more collaborative and will be based more on understanding rather than an imposition by an authority.

Methodology

This study will follow the system dynamics approach to studying a problem. First a reference mode will be derived to help define the problem dynamically. Due to lack of historical data the reference mode will be based on accounts gathered from news papers, journals, articles etc. Next there will be a dynamic hypothesis to try to provide an idea of what might be responsible for the behaviour observed in the reference mode. A model will then be created to try and replicate the structure of the system that generated the behaviour observed in the reference mode. The model will then be simulated to replicate the reference mode. Policies and suggestions will then be inputted into the model to see what behaviour will be generated. Recommendations will then be made based on which policies are able to strengthen favourable loops and weaken unfavourable ones.

Theoretical framework

To be able to sustainably manage the resource, policies must be made to regulate the effort level in the fishery. The effectiveness of such policies will depend on the extent to which consensus is built within the user groups as well as with the management authorities. It also follows that stakeholder groups must be identified and together they agree on the most appropriate means of managing the resource. In this regard this thesis will employ the concept of precautionary approach to management which is a proactive and preventive approach to resource management. Secondly, the concept of stakeholders will be adopted to help identify which groups could be invited to the negotiation table. Thirdly, the representation of stakeholders means that decisions cannot be made unilaterally by government representatives but in conjunction with these stakeholders. Thus the concept of co-management and in broader sense interactive governance, which is the collaborative effort between government and other stakeholders to manage a resource, will be adopted.

Problems of the study

The main problem faced during the course of writing this thesis is the difficulty in getting recorded figures about the Ghanaian fishery. There are no records of the number of fishermen, fishing boats, stock size, and daily landing figures and so on. This made it difficult to get a reference mode that is based on data. The availability of data on these variables would have provided a better model behaviour than the use of imaginary figures as done in this case.

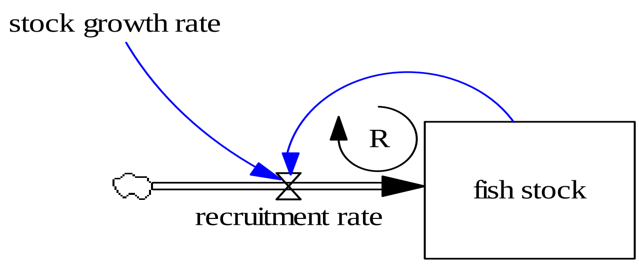
Chapter 2

The dynamics of renewable natural resources.

The difficulties encountered in fisheries management arise not only because of the different stakeholders involved, but also the dynamics within these stakeholders as well as their interaction with each other. A fishery can be decomposed into three subsystems that interact to give the resource its unique behaviour, making it a complex system. These are the resource subsystem, the resource- user subsystem and the management subsystem (Seijo, Defeo et al. 1998). The *resource subsystem* refers to the resource base itself, the biological factors (such as recruitment, growth, death etc), and environmental factors that determine abundance and distribution and ecological interdependencies. The *resource user* subsystem represents the fishing effort, gear selectivity, sizes and ages of the fleets and the economic factors that motivate users' intervention. The *Management subsystem* refers to the management regime and measures or strategies put in place to manage the resource. The three subsystems on their own are complex but when they interact, the complexities that arise from such interactions become even more difficult to comprehend. Such is the nature of the interaction between the economic and biological factors in a resources referred to as Bioeconomics. The three subsystems and their interactions (bioeconomics) can be demonstrated using the stock and flow structure to explain the dynamics of the system.

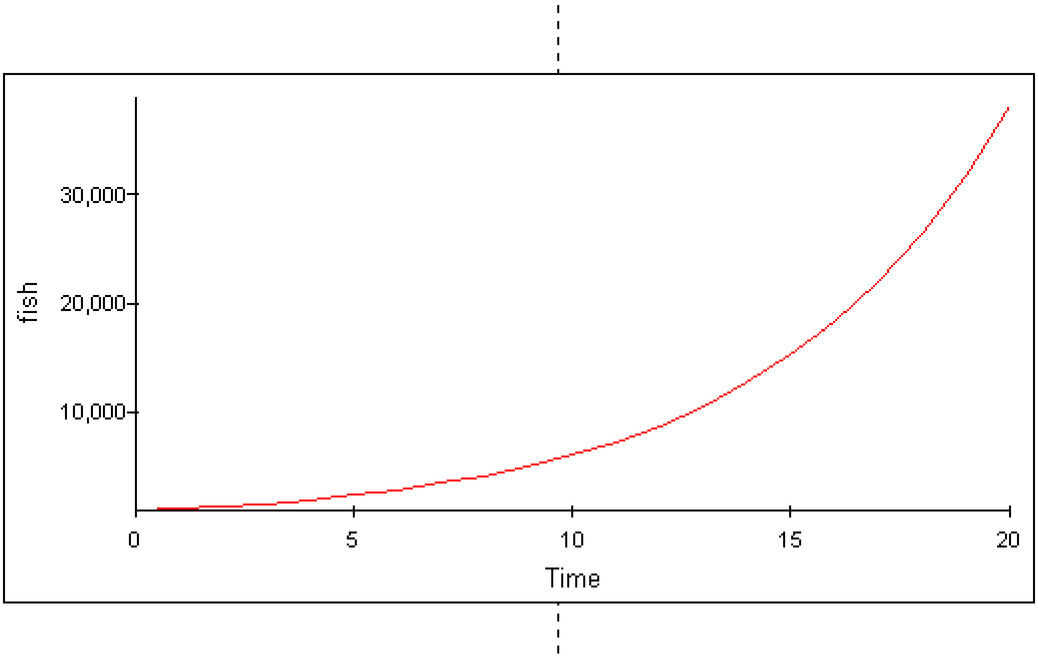
The resource (biological) subsystem

The dynamics in the resource subsystem involves the recruitment (birth) of new fish, migration of fish to other areas and death (through predation, starvation and competition). The diagram below represents the fishery as a stock with an inflow of recruitment determined by the size of the existing stock and the rate of increment of the stock. This represents the recruitment aspect of the dynamics. The encircled R denotes that the bigger the stock size the higher the recruitment and vice versa. The variable labelled ‘stock growth rate’ is determined by the time taken by new fish to grow (time to maturity).



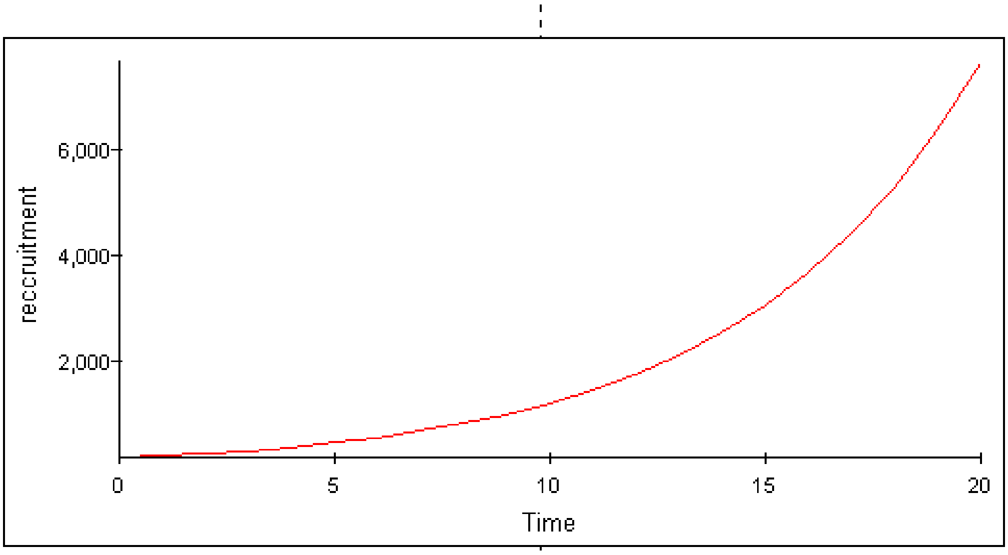
A stock and flow diagram show the growth of fish stock

This structure alone produces a stock behaviour as demonstrated in the graph below. The existing stock of fish produces young ones which are recruited into the fishery to add to the existing stock and the stock size becomes bigger. This process continues thus making the stock to assume the exponential growth observed in the graph.



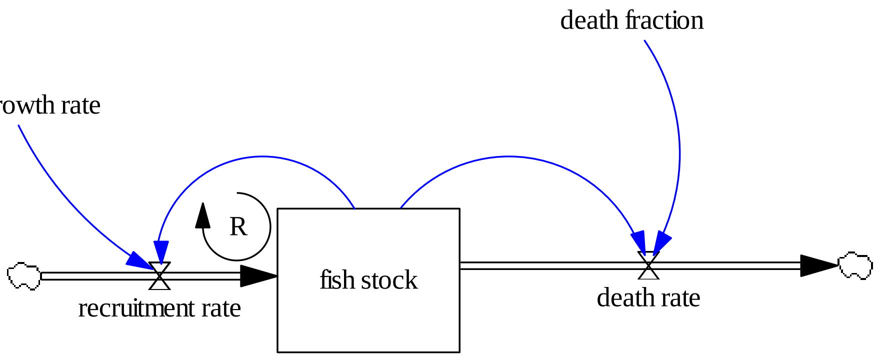
A graph showing the exponential growth of a fish stock in tons.

The number of young fish recruited into the fishery follows a similar trend as the stock. The size of the recruitment is small in the beginning, but as the stock becomes bigger more young ones are produced.



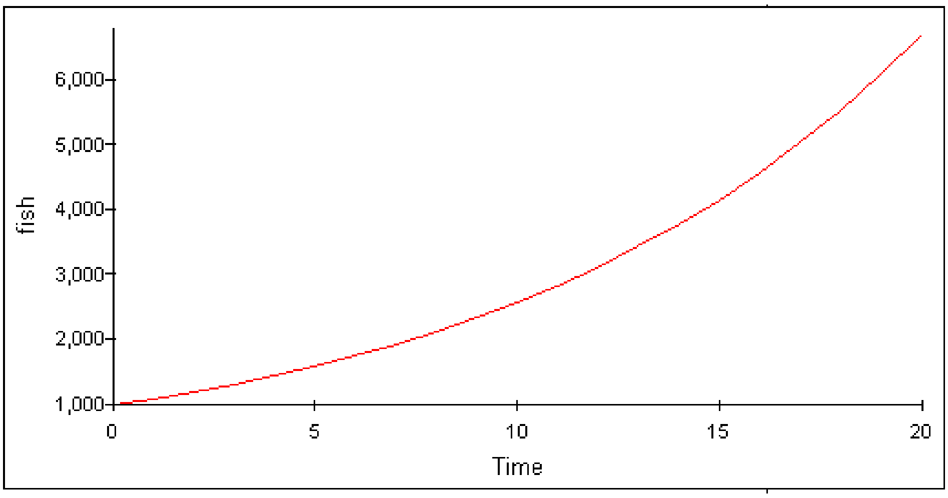
A graph showing how many tons of young fish are recruited into the fishery per year

This process of growth does not continue forever. Due to factors that will be discussed later, some of the fish begin to die. Incorporating the death aspect of the dynamics generates the structure below. The death rate (a product of the stock and death fraction) decreases the fish stock. The death fraction represents a percentage of the stock that dies within the period under consideration. The death fraction is made up of all the causes of death other than human intervention including starvation, competition and predation. The larger the death fraction the larger will be the death rate and vice versa.



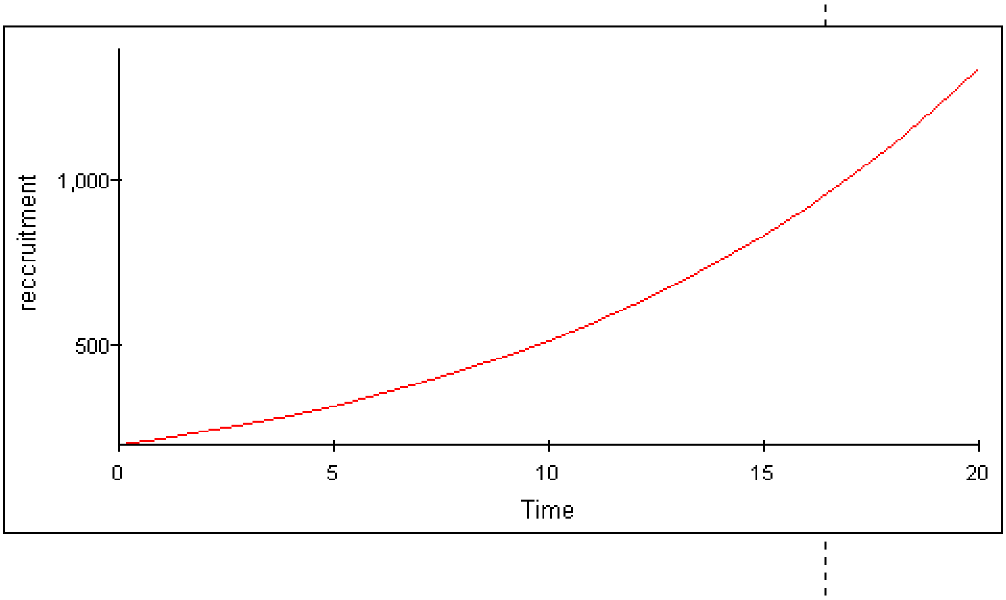
A stock and flow structure showing a stock of fish and its inflow of recruitment and outflow of death

With the inclusion of death, the stock still grows in an exponential manner as shown in the graph but only up to 6000 tons in year 20 compared to 30000 tons when there was no death.



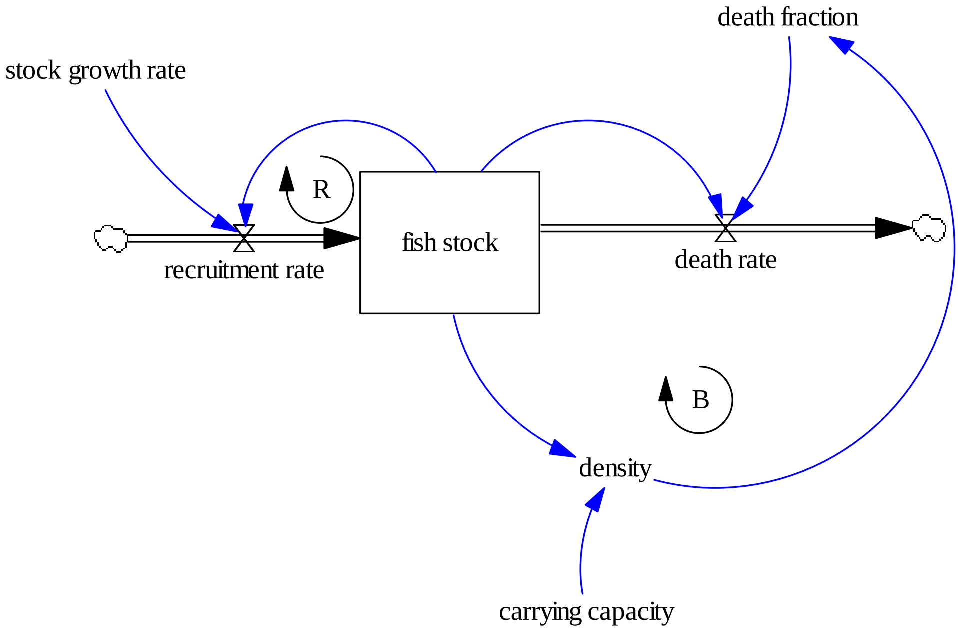
A graph showing the growth in fish stock in ton when such growth is impeded by death

The recruitment rate is also affected by the impact of death. The size of recruitment reduces from 6000 tons to 1000 tons.



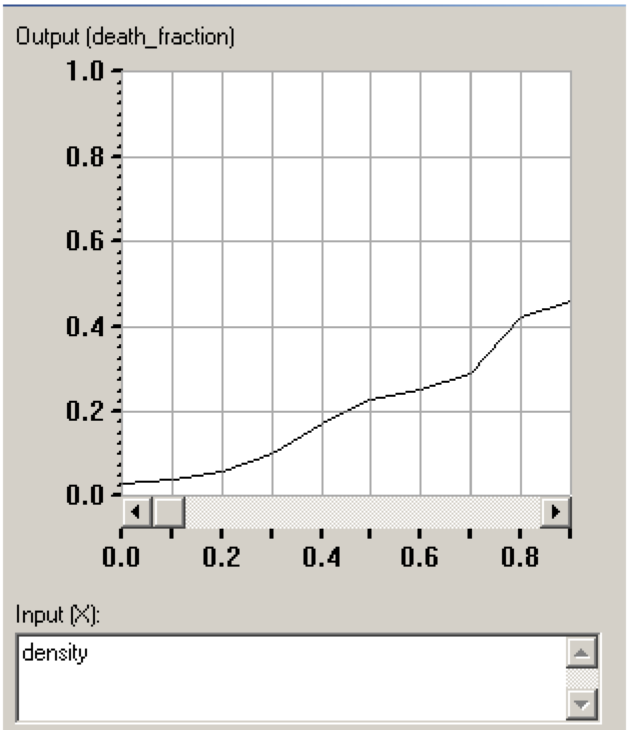
A graph showing the number of fish in tons recruited into the fishery when there is death in the fishery per year

The death in the fishery arises when the stock approaches the environment's carrying capacity. Since space (in this case water body) and food are not inexhaustible, the growth of the stock is restricted to the resources available to support the stock. This constraint is referred to as the carrying capacity. The stock grows until it reaches the carrying capacity where food and space become fully utilized. Another variable, density (Stock/carrying capacity) refers to the concentration of fish (number of fishes sharing an area or food). The higher the stock levels given a finite carrying capacity the higher the density. Higher density means that within a given area, there are so many fish to share the food and space. This results in competition for these resources which can result in starvation. This results in a higher death fraction and eventual high death rate due to competition and starvation if food is availability is low



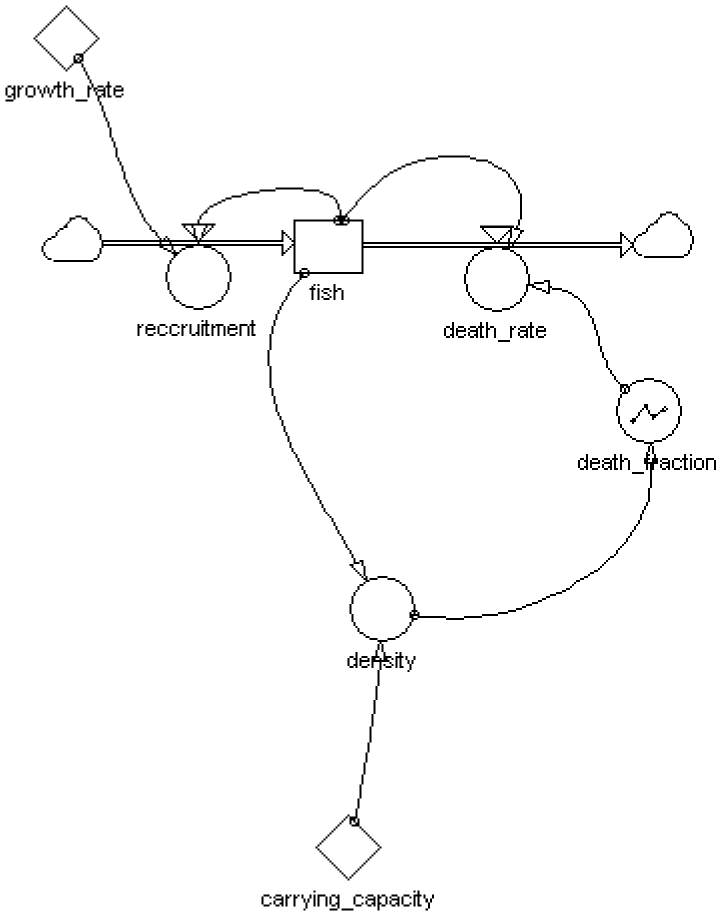
A stock and flow diagram showing the impact of the carrying capacity of the environment on the death rate

In this model the assumption is that the death fraction follows a pattern as represented in the table function below. When the density is 0.5 (50% of carrying capacity) death fraction is about 0.2 and at a density of 0.8 the death fraction is a bit over 0.4.



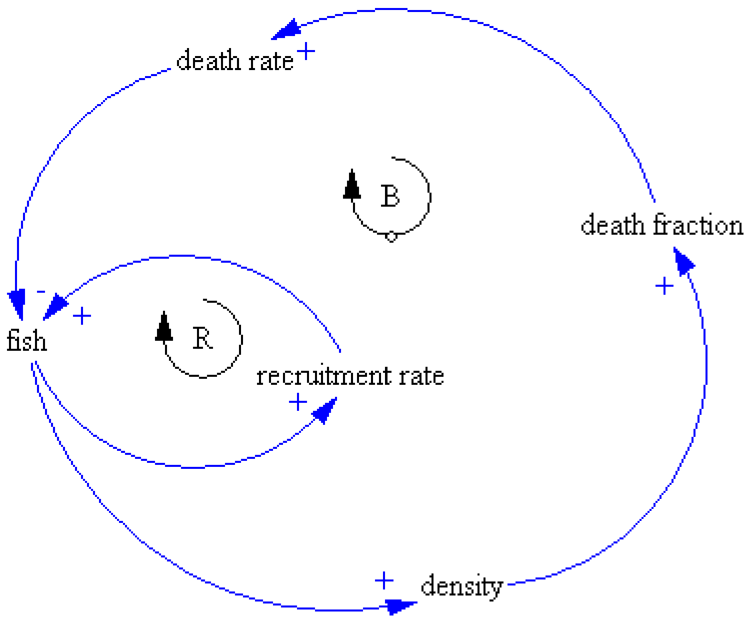
A table function showing the relationship between density and death fraction

Inputting this table function into the model produces the structure below.

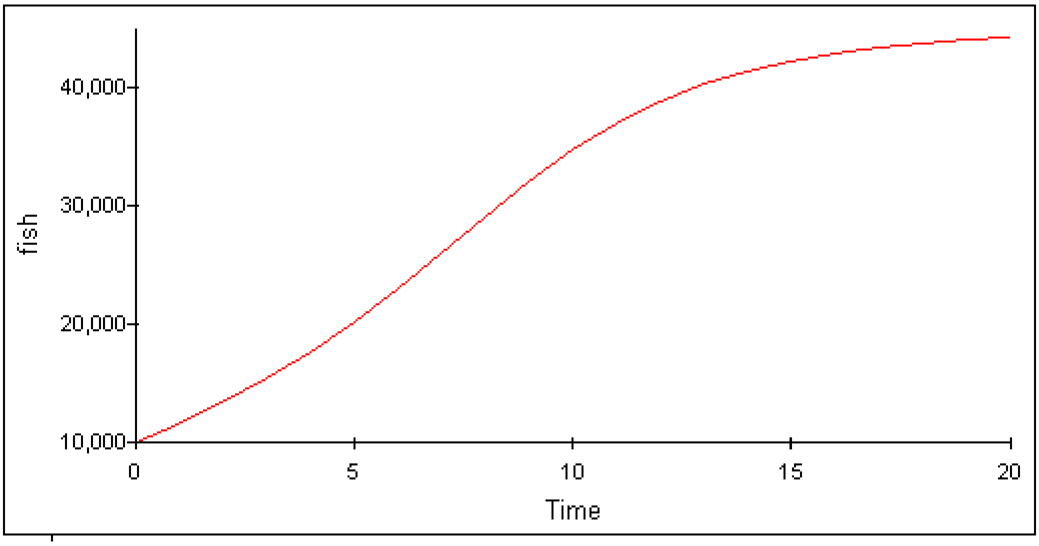


Stock and flow diagram modified to show the impact of the death fraction

This structure can be represented in the form of a causal loop diagram as shown below.

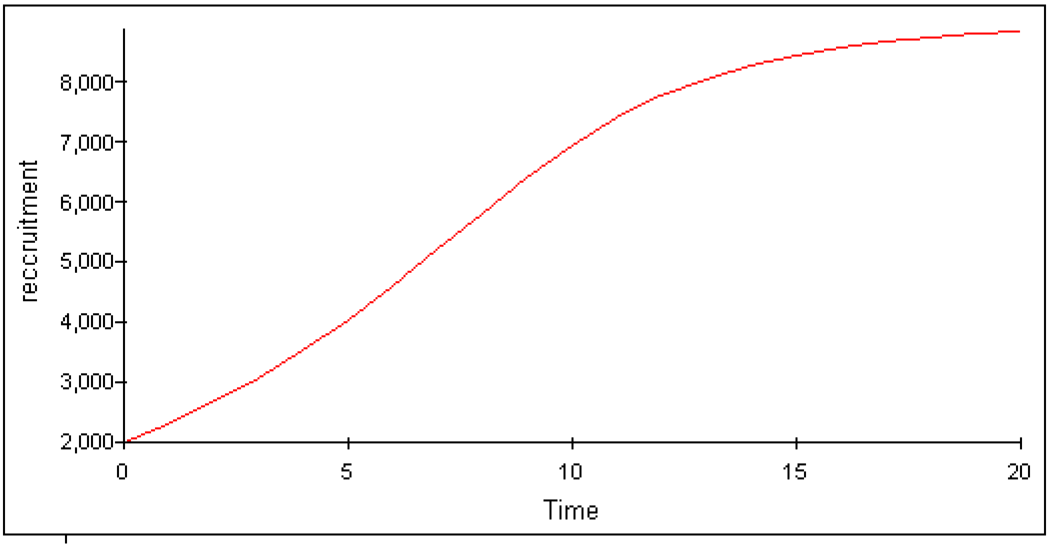


The reinforcing loop R means that fish stock produces young fish and the stock experiences growth. The balancing loop B denotes that a higher stock results in a higher density which results in a higher death fraction. Death rate increases as a result thus reducing the stock size. The interaction between the R loop and the B loop keep producing the dynamics in the biological subsystem. The fish stock increases or decreases depending on which loop is stronger at a given time. When the R loop is stronger than the B loop, the stock will be high and vice versa. The behaviour of the stock is shown in the graph below. From the initial stages up to year 10 the graph exhibited an exponential growth which indicates that the reinforcing loop (R) was stronger. This means that during this period the stock was small and so density was low thus food and space was abundant. This provided room for the stock to grow until the stock approached the carrying capacity. Density became high and competition for food and space began to cause death. Balancing loop (B) became strong at this stage and the growth flattens. The curve assumes an S shape demonstrating a shift in dominance – a situation where one loop dominates at one stage and another takes over the dominance at another time (Sterman 2000).



A graph showing the impact of the carrying capacity to cause the stock to exhibit shifting dominance

The same trend is observed in the recruitment curve. The recruitment was higher when the stock was growing up to year 10 until the balancing loop took over to reduce the growth.

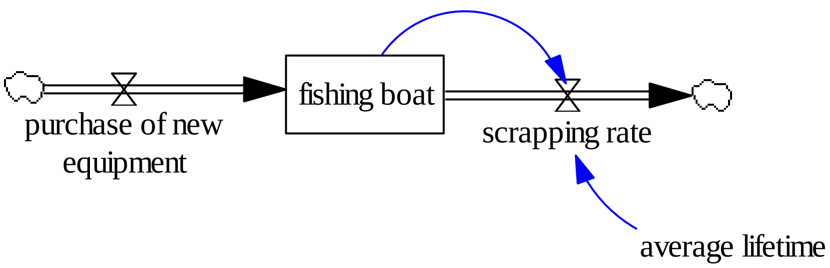


Graph showing the impact of the carrying capacity to cause the recruitment to exhibit shifting dominance

The simple structure represented here reveals that the biological system left on its own undergoes changes from time to time. There may be seasons of lack of food thus increasing competition and starvation and driving up the death rate. There may be other periods of high food supply thus death rate will be low. The dynamics become even more complex with the incorporation of environmental conditions and ecological factors. For example the abundance of a predator stock increases predation thus driving up the death fraction. On the other hand, an increase in the stock of a prey fish provides an abundance of food thus bringing down starvation. The stock therefore goes through cycles of highs and lows.

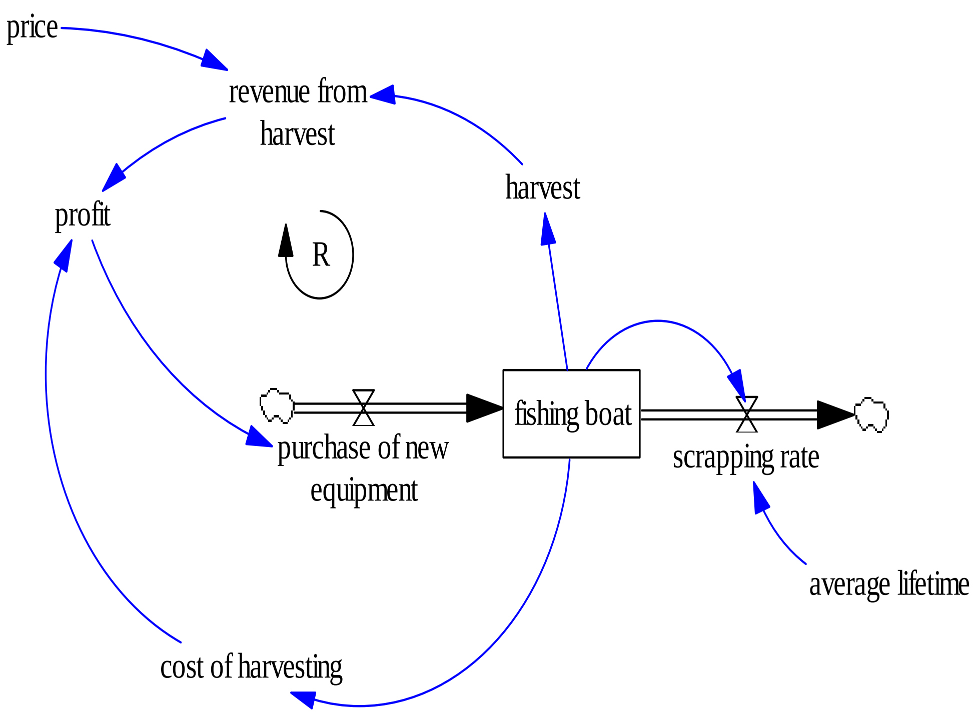
The resource users' subsystem

The resource user subsystem comprises of the fishermen and their harvesting activities. These activities are motivated by not just the need to make profit, but also as a means of survival. Fishing activities, especially in developing countries is a job done mostly by the poor and the less educated thus earning the title 'activity of last resort' (Garaway 2005). This means that the people engaged in fishing activities are mostly people with no other alternative livelihoods. This description indicates that the exploitation fishery resources is not only motivated by profit motives but by also by the need for survival. This situation generates big dynamics in this subsector. The dynamics in the resource user subsystem is denoted by a stock of harvesting equipment (in this case fishing boats) and an inflow of new purchases and outflow of scrapping determined by the number of current boats divided by the average life of the equipment.



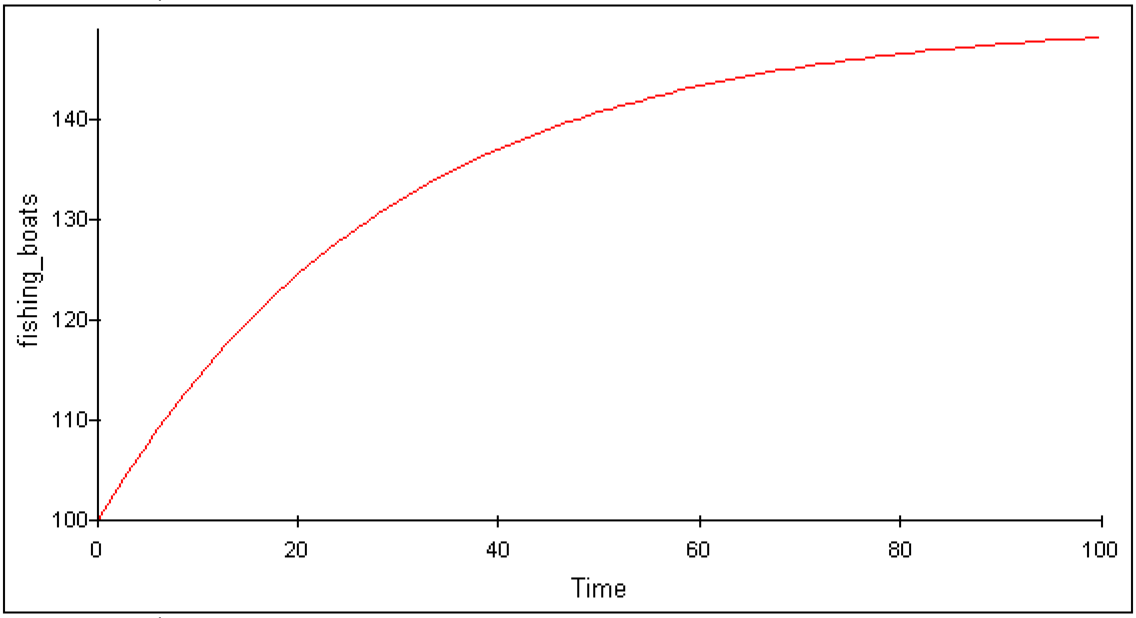
Stock and flow diagram showing a stock of harvesting equipment with its inflow of new purchases of equipment and an outflow of scrapping

The main determinant of dynamics in the resource user subsystem is profit. In the structure below, the equipment (fishing boat) is deployed in the fishery to harvest fish. Revenue is generated from the harvest which is used to meet the cost incurred in harvesting. Profitability encourages the acquisition of more equipment to increase the harvest. Loop R means that over a period the stock of fishing boats will be high if profitability keeps encouraging more purchases. Apart from profit, another incentive to keep effort high is the need to survive, which may even be stronger than the profit incentive.



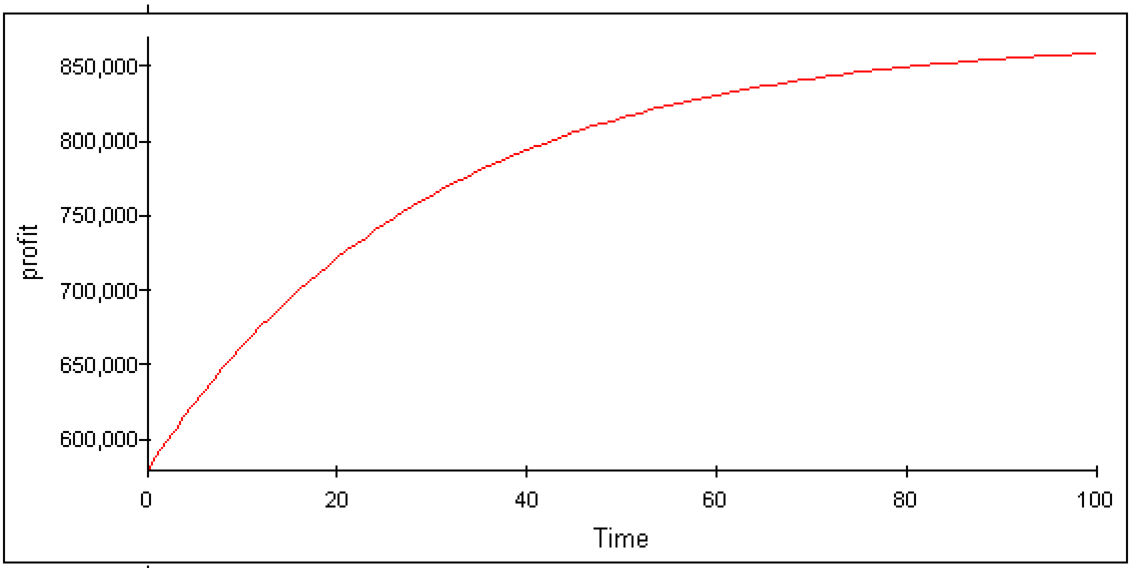
A stock and flow structure representing the harvesting activities of fishermen

Fishing boats are used to harvest fish, the fish is sold and revenue is realized. After meeting all the costs a profit may be realized which may encourage more investment in boats. If this trend continues for some time there will be a growth in the fishing boats depending on how many boats are discarded or scrapped.



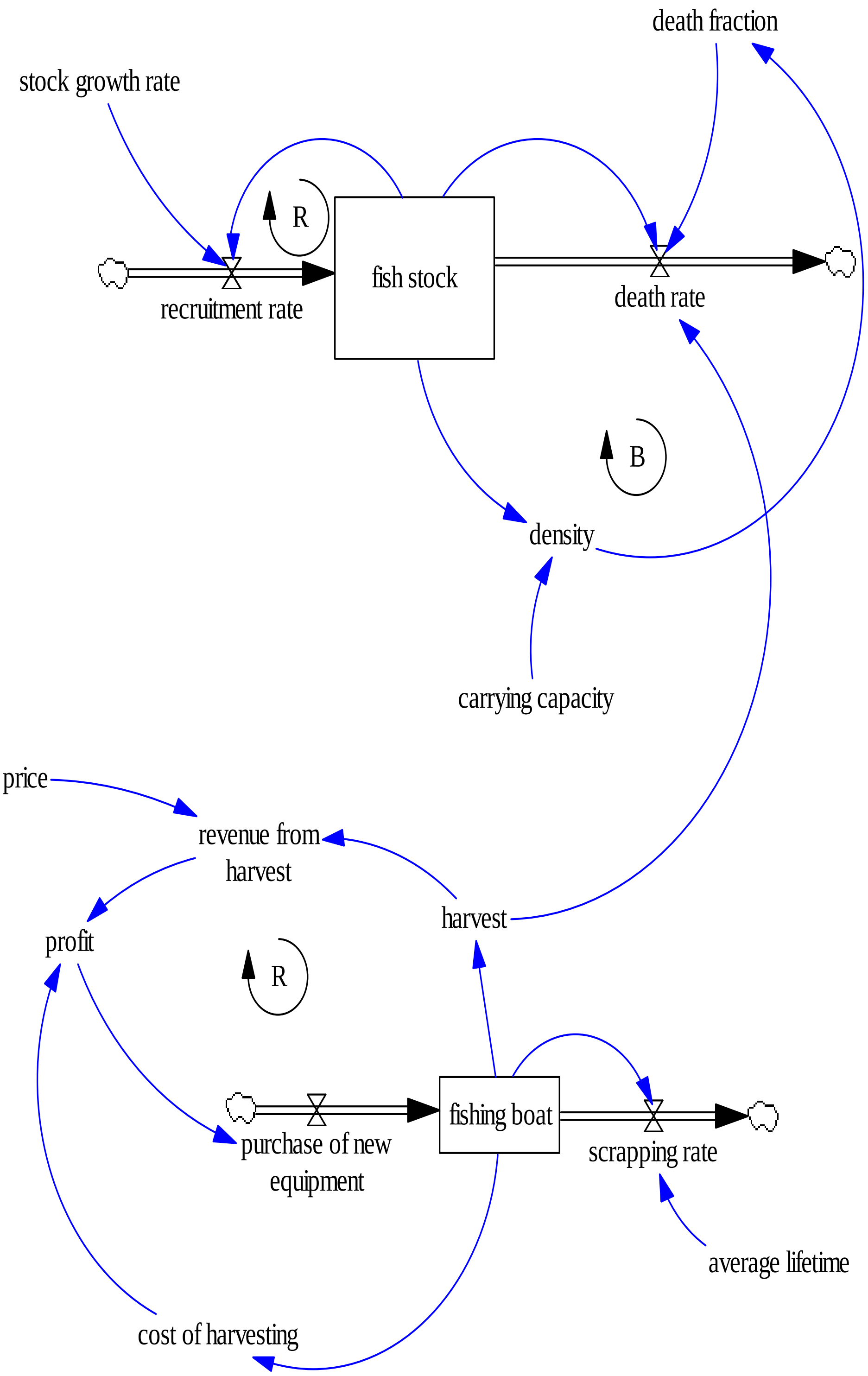
A graph showing the growth in fishing boats

The growth in the number of fishing boats yields profits as shown in the graph below assuming that fish is readily available.

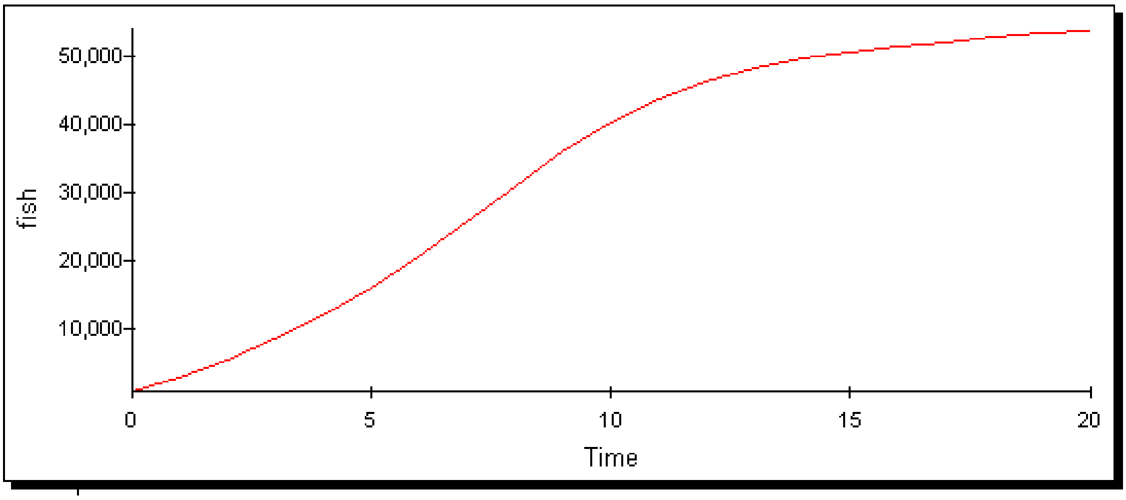


A graph showing the increase in profit.

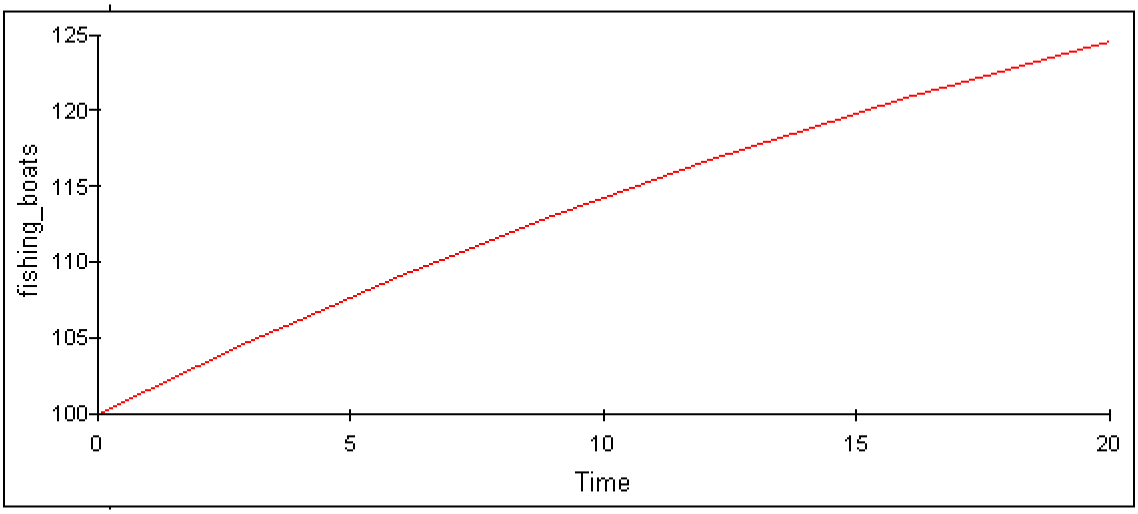
Putting the two systems together results in the structure below. The resource user subsystem motivated by profit maximization keeps investing in equipment and getting more harvest thus increasing the death rate of the resource. Loop B becomes stronger and the fish stock begins to go down. This result in lower harvest levels and the profit begins to increase in a decreasing manner.



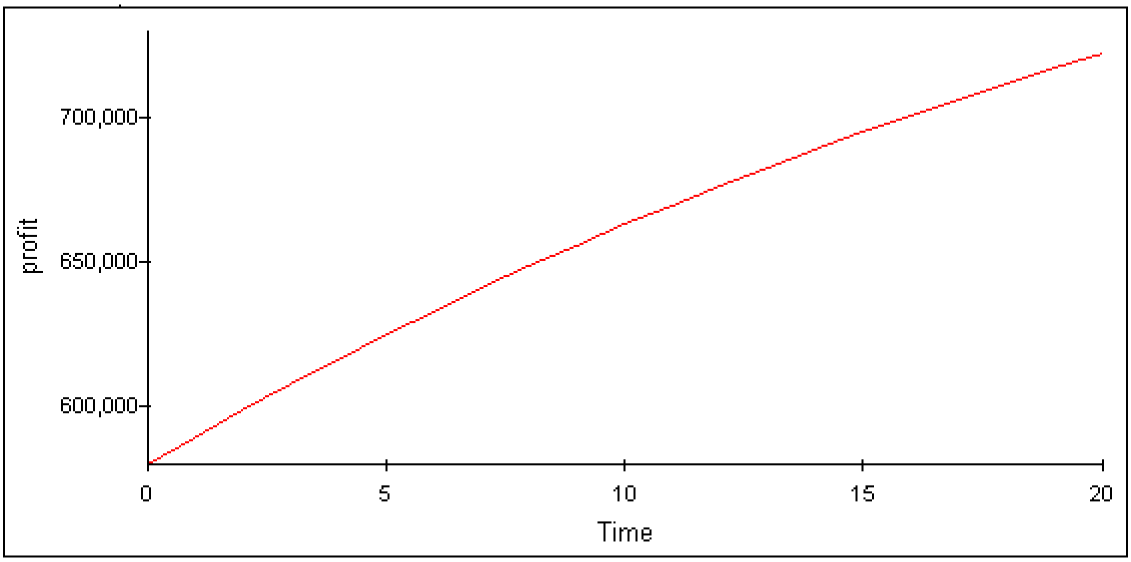
A stock and flow diagram representing the bioeconomics of the fishery.



A graph showing the behaviour of fish stock



A graph showing the growth in fishing boats



A graph showing profit in the fishery

The Management subsystem

The management subsystem is the authority responsible for restricting the operation of the resource user subsystem. This can be done by implementing policies to weaken the R loop in the user subsystem.

Management regimes

Fisheries can be subjected to four property regimes namely, state property, private property, common property and open access (Seijo, Defeo et al. 1998). The state property regime requires that access to and use of a resource is determined by a government institution that has the authority and responsibility to manage the resource.

Under the private property regime, authority and responsibility is vested in the hands of the resource users. This does not totally alienate the state from the resource; users have the responsibility of refraining from destructive practices.

The common property regime refers to a situation where the authority over and responsibility for the resource is delegated to a defined group of resource users who make the rules with respect to the resource exploitation.

Under the open access regime the resource is not considered as a property thus there are no rules governing the access and use of the resource. Any member of the society could benefit as much as possible from the resource.

Fisheries management tools

Fisheries management tools refer to the methods that are used to limit the exploitation of the resource. These tools include quotas, licenses, closed seasons, Marine Protected Areas (MPAs). Under the quota system, a specific quantity of fish is allocated to each fisher which cannot be exceeded over a certain period usually a year. A specific type of quota, the individual transferable quota (ITQ) is an entitlement of fish harvest which could be transferred to another fisher in the event that the rightful owner does not have the ability to utilize the opportunity. Such a right could also be traded, in which case it becomes an individual tradable quota.

Licensing is a means of granting exploiting rights to people deemed qualified to use the resource. The licenses are given to users and are valid over a period. Only people with valid licenses can have access to and exploit the resource.

Closed seasons are certain times within the year that a fishery is closed to users. The purpose of this measure is to allow the young fish to grow. A marine protected area (MPA) is an area where fishing activities are not allowed all together. This is done in order to conserve diversity in the ecosystem.

Another management tool is gear restriction which prescribes which harvesting gears are allowed to operate in the fishery. An example is mesh size restriction which provides the mesh size of nets. This is aimed at making the gears selective to avoid catching immature fish.

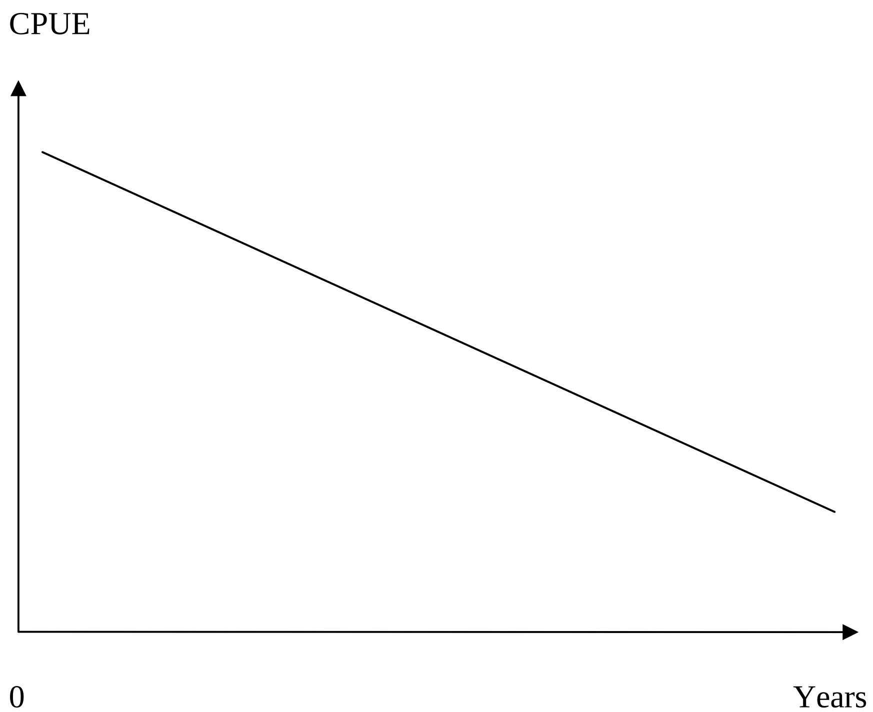
Chapter 3

A System Dynamic analysis of the Ghanaian fishery

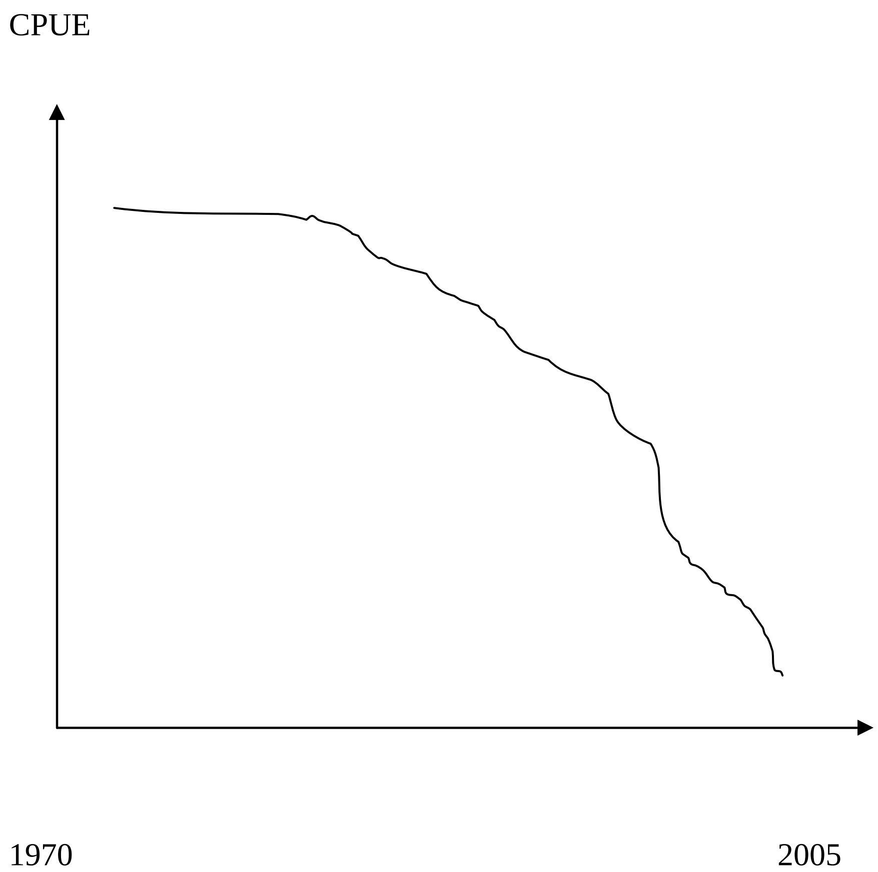
The state of fish stocks in the Ghanaian fishery is not different from the general trend of world fish stocks, especially considering the complaints from fishers and fish traders documented in the appendices. The lack of reliable data on the stocks and effort in the fishery makes it difficult to derive a reference mode based on historical data. However, reading about news items on the issue provides an idea about the nature of the reference mode.

Reference Mode

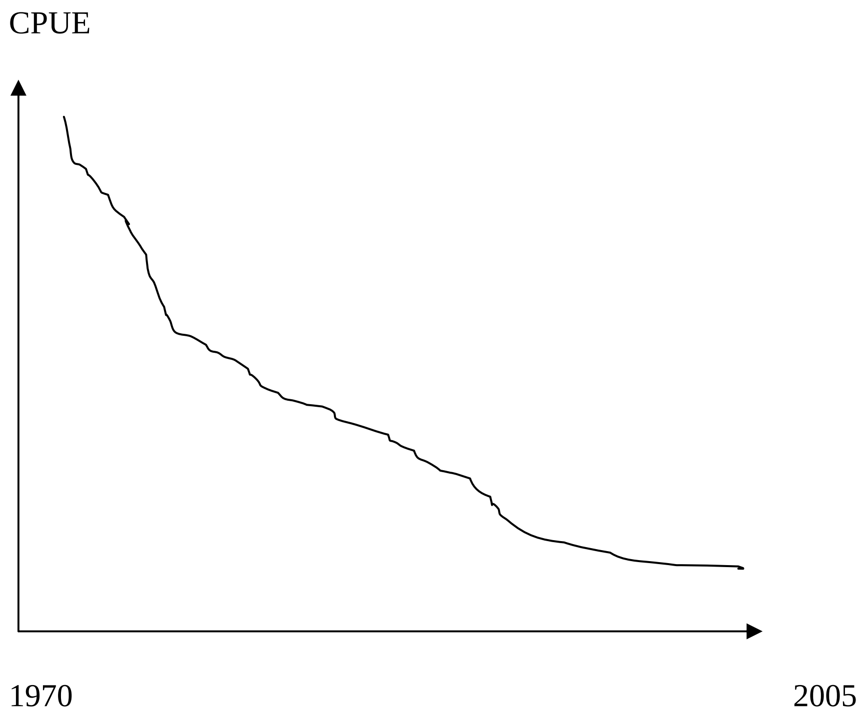
The reference mode is one of a declining nature as depicted by news items in the appendices but the shape and the slope is difficult to tell. Three types of potential reference mode curves could possibly serve the purpose but through scrutiny the most appropriate will be chosen.



A reference mode of this nature does not represent the situation because the stock, the inflow and outflows are not constant values. For example a sock value of 10 with an inflow of 3 and an outflow of 5 will yield this reference mode. As the situation stands, the fish stock varies each year, the inflow of recruitment varies as well as the outflows of harvest, death etc. This reference mode can as a result be inadequate in representing the complexity of the problem.



A possible shape of the reference mode

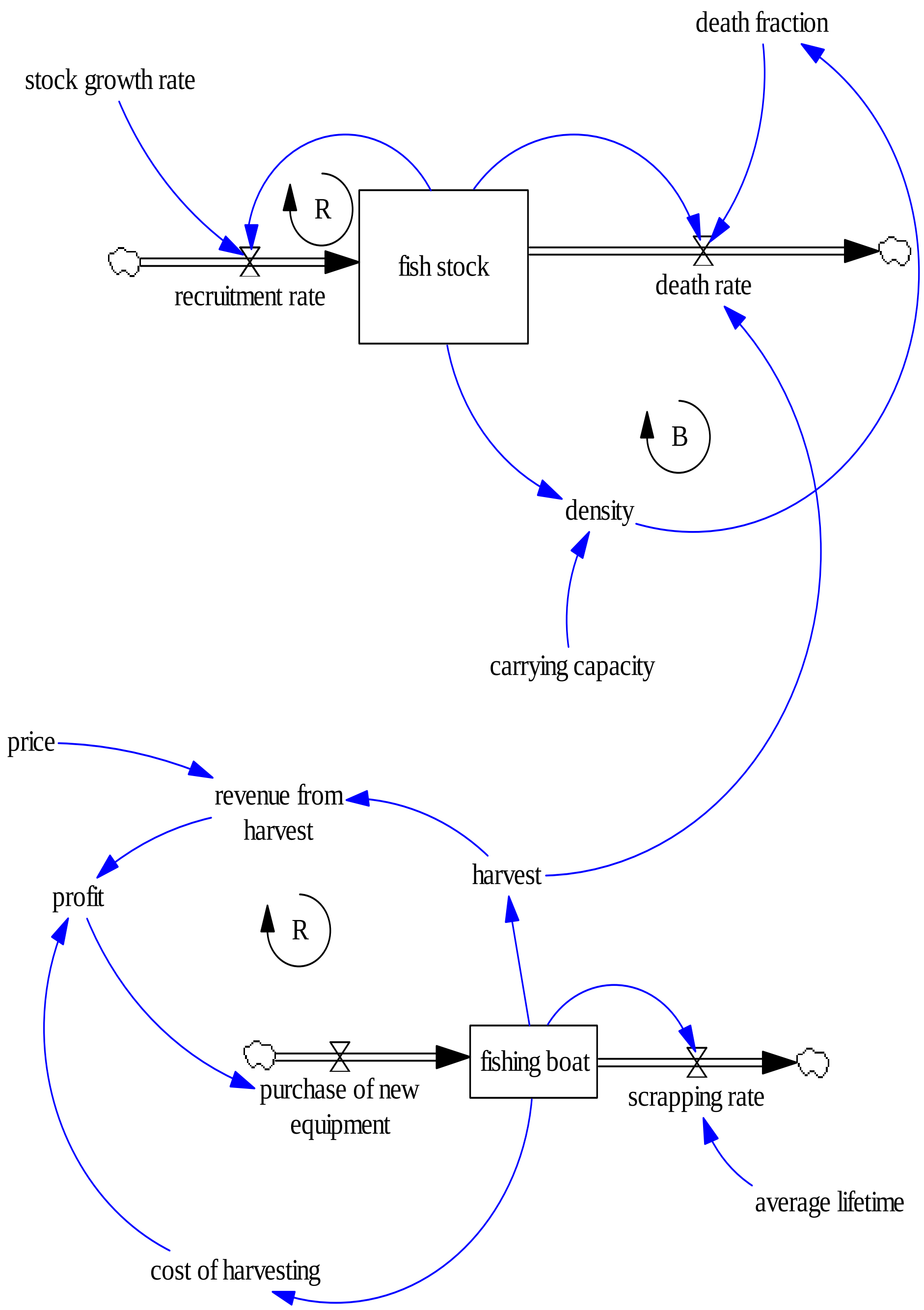


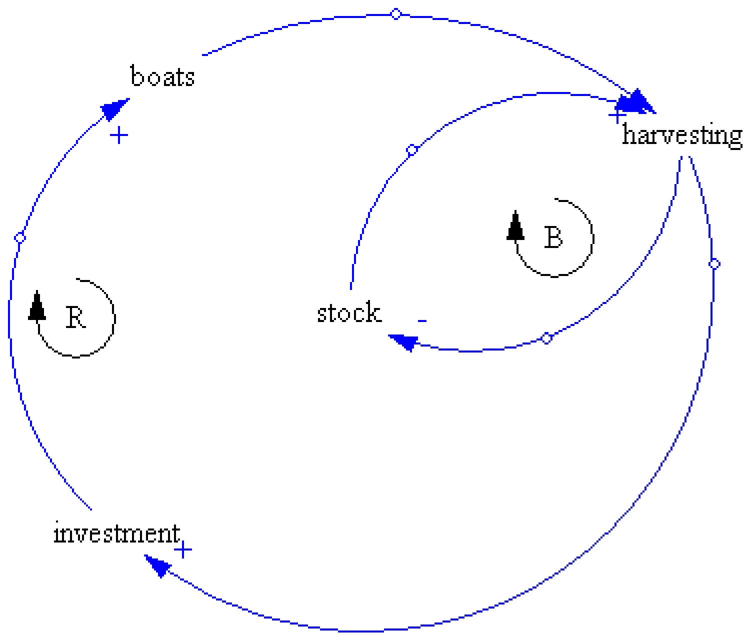
This is another possible shape of the reference mode.

Dynamic problem:

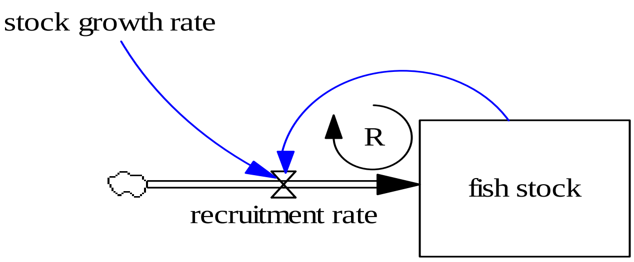
Fish catch has been declining in Ghana's fishery from 1970 to 2005 but has become more acute over the past 5 years.

Dynamic hypothesis:



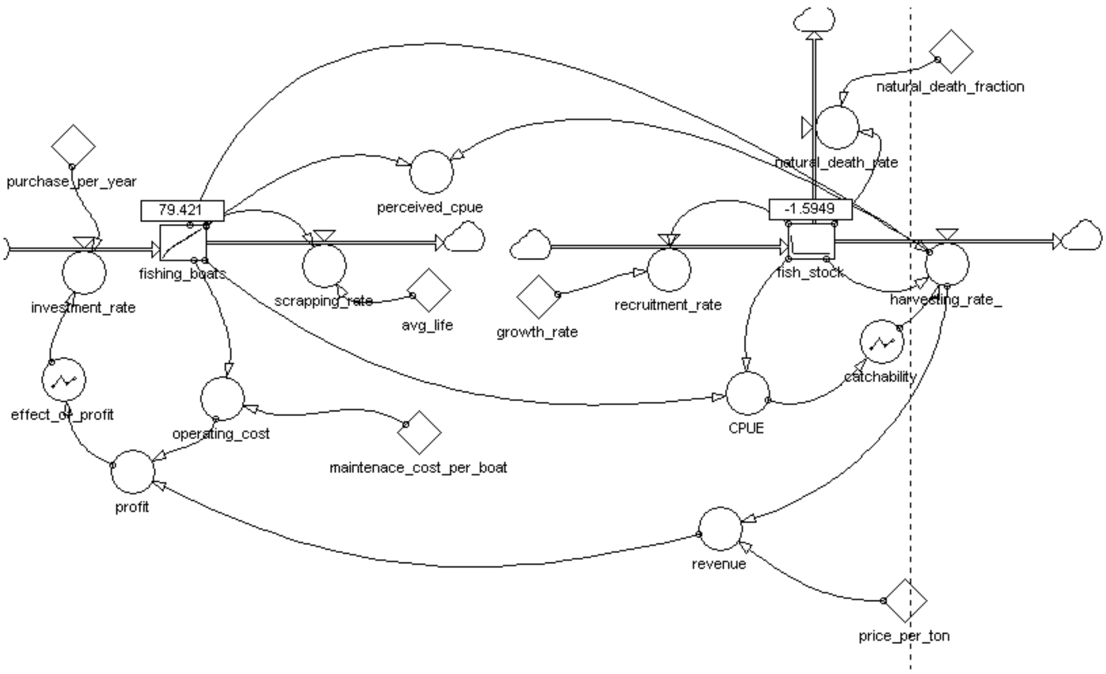


The structure above demonstrates the relationship between the harvest capacity and the fish stock that is responsible for the dynamics exhibited by the reference mode. The fish stock is increased by the recruitment as represented below



The bigger the stock the bigger the recruitment thus causing an increase in the stock size. The outflow of harvest causes the stock to decline. If the rate of harvest is not matched by the grow in stock through recruitment, the sock size will reduce eventually collapsing the stock if the trend is not halted. There are two stocks interacting in this system, the fish stock and the stock of fishing capacity (boats). The reinforcing loops R in both stocks causes them to grow but evidently, the there is a stronger growth in the capacity side than the fish side. The balancing loop B between stock and harvest means that harvest reduces stock and the next time round, harvest will be smaller than previously. Harvest is a motivation for the purchase of more boats in order to get higher harvest. However higher harvest reduces stock size and the dream of a higher harvest is not realized. Fishers might be tempted to even invest more which makes a bad situation worse or keep the current level of effort which still exerts the same pressure on a decreasing stock.

The model



Growth rate

The growth rate is the rate at which the stock grows in a year. Smaller fishes such as anchovy have high growth rate because they spawn more often and in large quantities with a shorter time to maturity. Recruitment rate is therefore higher and the stock grows faster. Such stocks are better at withstanding high effort levels and take shorter time to recover from over exploitation. For instance the anchovy has a minimum population doubling time of 15 months and is labelled as resilient with low vulnerability (fishbase). Stocks of bigger fishes such tunas have lower growth rate because they spawn not many times in a year. For instance tuna (*Thunnus albacares*) has a minimum population doubling time of 1.4- 4years and is rated moderate on resilience and moderate to high on vulnerability. A stock such as this can be easily depleted and difficult to recover (fishbase). Sharks, for example blackspot shark (*Carcharhinus sealei)* has a minimum population doubling time of 14 years and is labelled low on resilience and moderate on vulnerability. The growth rate is therefore an important variable in determining the effort level in the fishery.

Catch per unit effort (CPUE)

Catch per unit effort as the name denotes refers to the quantity of fish yielded by a unit of effort. It is calculated by dividing the catch over a period, usually a month by the effort (number of boats, people, and days at sea etc) used over that period. It is an important measure of the abundance of fish stock and it is common index used in stock assessment whether calculated from recreational or commercial fisheries (Haggarty and King R 2006). Catch and effort data from commercial fisheries can be an important source of the trends in stock biomass (Quirijns, Poos et al. 2007). There is however a deficiency in the use of CPUE thus making it a less authoritative method of stock assessment. Fish behaviour (such as schooling and gathering around light) and the efficiency of the gear could give misleading

CPUEs. For example catches may remain high even though abundance is low (hyperstability) due to high fishing efficiency or catchability (Haggarty and King R 2006). This situation could lead to mismanagement and miscommunication among stakeholders (Quirijns, Poos et al. 2007).

Natural Death fraction

Natural death fraction represents the percentage of the stock that dies through natural means such as starvation and predation. This is an important variable in the system because it varies from time to time depending on the availability of preys and predators. The availability of anchovy for instance contributes tuna abundance since the latter feeds on the former. In the same way, the abundance of sharks lowers the abundance of tuna. If effort is increased at a time when anchovy is abundant, the result may be different from when sharks are abundant.

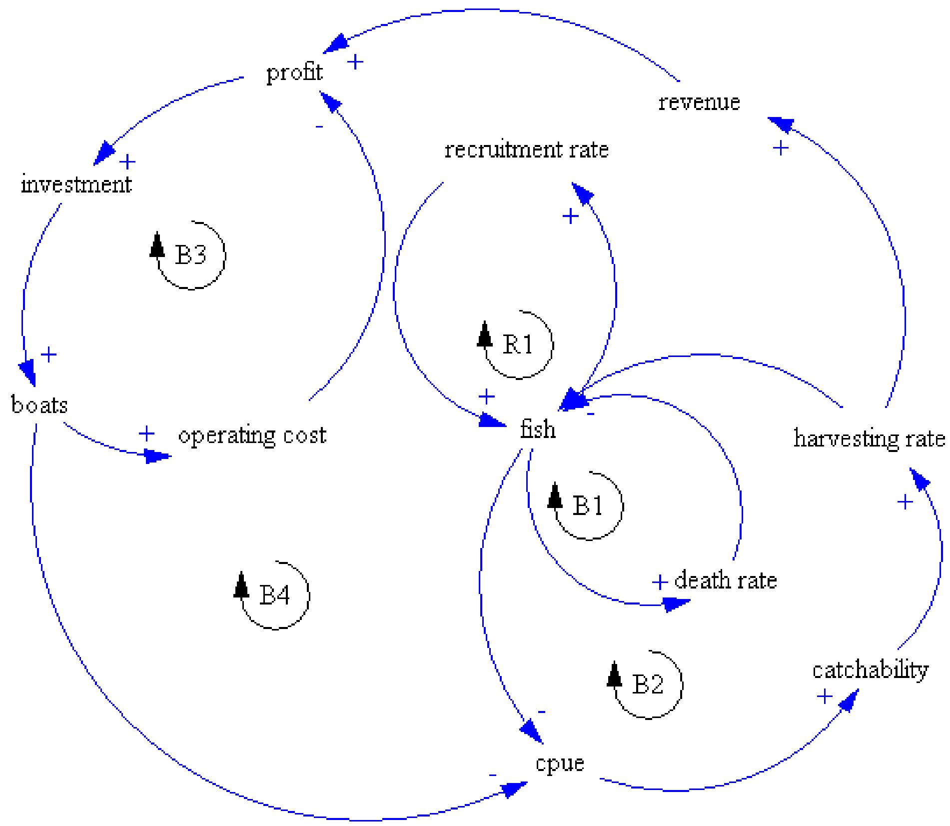
Catchability

Catchability refers to the efficiency of the gear used in the fishery ((Haggarty and King R 2006). It has a big effect on the CPUE and could be a major factor in the dynamics. An increase in catchability through the use of gears with smaller mesh sizes could result in the misleading situation of hyperstability mentioned earlier.

Average life span of a boat

Another important factor affecting the dynamics in the model is the length of time that a boat stays in the fishery. A longer life span such as 30 for example years means that aggressive purchasing of boats will result in a quick accumulation of boats (effort) which will be in operation for the next 30 years.

Causal Loop Diagram



The fishery is characterized by the five loops- one reinforcing and four balancing loops. The reinforcing loop R1 is responsible for the growth of the stock. The stronger this loop the higher the stock of fish. The balancing loop B1 is the natural death loop. It represents the fraction of the stock that dies through natural means such as starvation, predation and so on. The higher the natural death rate the smaller the stock. Balancing loop B2 represents fishers' behaviour. When stock is lower catch per unit effort (CPUE) is small. Fishers increase their catch efficiency (catchability) by using nets of smaller mesh size to increase harvest which further reduces the stock. Balancing loop B3 is the operating cost loop showing that profits encourage investment in more boats. Operating cost increases and profit reduces thus investment reduces. The balancing loop B4 represents the bioeconomic loop showing that when profit increases investment in boats also increases. This result in a fall in the CPUE, fishers respond by improving catchability to increase the harvest but this reduces the stock.

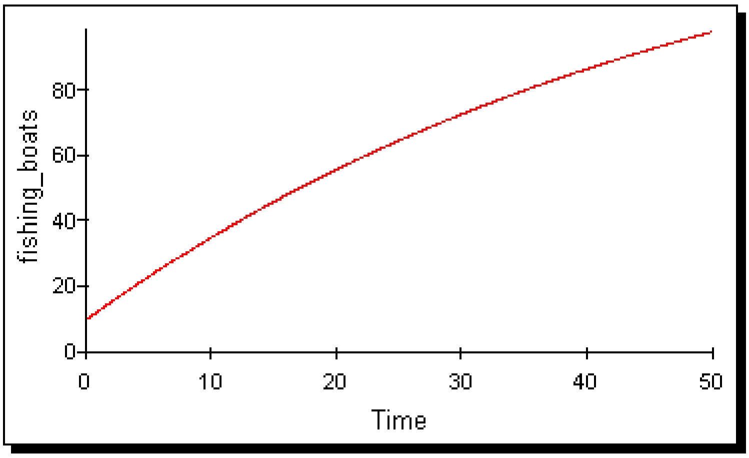
Analysis of the Ghanaian issues

One of the concerns expressed in the Ghanaian fishery (Appendix 2) is the act of bottom trawling carried out by the industrial fleets. This method of fishing is reported to disturb the breeding grounds of fish thus it should be banned. It can be observed that this problem falls in loop R1. By disturbing the breeding grounds, recruitment rate is reduced and this reduces the stock size. Banning the act will provide a good environment for recruitment and thus and increase in stock size.

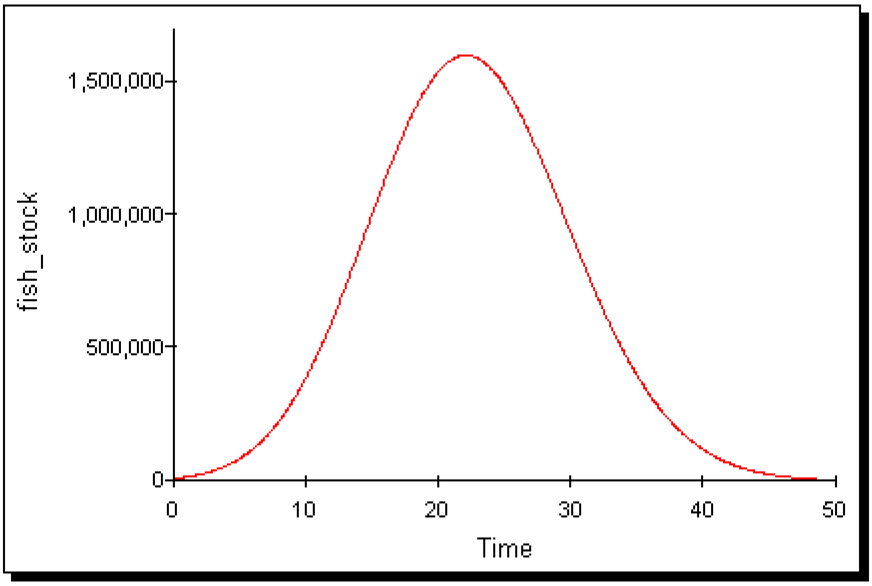
The second issue is over capacity in the industrial fleets as well as their alleged operation in shallow waters. The overcapacity suggests overfishing which reduces the stock and the recruitment ability of the stock. Also, by fishing in shallow waters (meant for artisanal fishers), catches of artisanal fishers will be smaller which could make artisanal fishers to respond in the wrong way by manipulating the mesh size to catch more as shown in loop B2. Reducing the capacity in the industrial sector and restricting them to deeper waters is necessary to improve the stock.

The third issue raised in the appendix is the operation of pirate fishers (illegal fishing). This contributes to reducing the catches to the artisanal fishers and this could be responsible for the operation of loop B2. The solution to this problem lies in monitoring and surveillance.

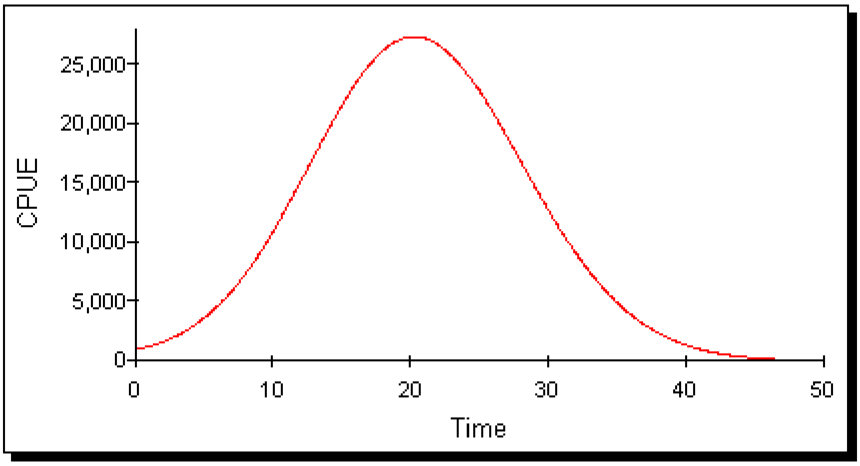
The fourth issue, the inability of fishermen to afford technology falls within loop B3. In the 1950s profits in the fishery was low thus investment in the harvest technology (boats) was low. Operating cost was high thus the need for fish traders to assist in financing fishing trips and lending money to fishers in return for fish. The activities of women reduced the impact of loop B3 but resulted in strengthening loop B2. Harvesting increased beyond what the stock could withstand so CPUE has been falling and fishers keep manipulating their gears to make the nets less selective. Recruitment is reduced as a result and the problem keeps worsening. My guess is that the interdependent relationship between the fishers and the traders whereby the fishers paid back loans with fish supply resulted in a situation where traders would not accept excuses for lack of fish. Fish had to be caught even though stock was falling. This may have resulted in fishers reducing the mesh sizes of nets to catch more fish. This act however reduces the selectivity of the nets and young fish and non target species which may be food for the target species are caught. This results in increasing discards and by-catch thus reducing diversity in the ecosystem. These results in weakening loop R1 and strengthening B1 which eventually reduce the stock.



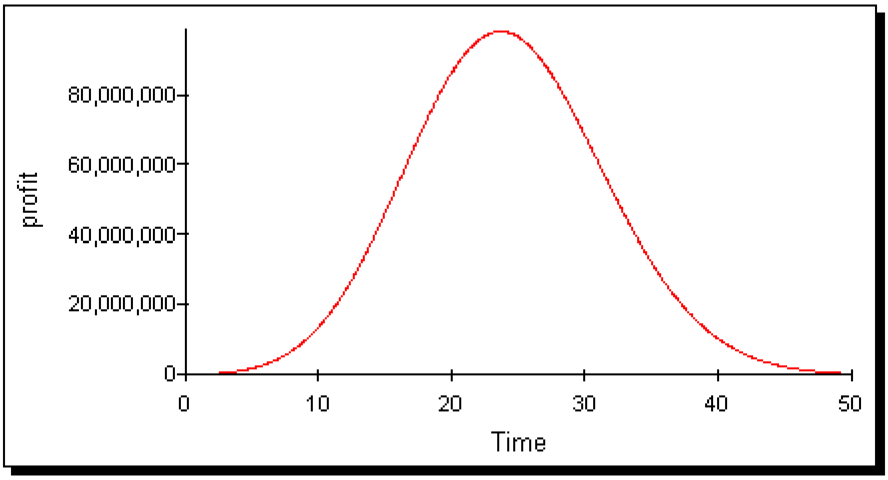
Graph showing the rise in effort level due to financing offered by the women.



Graph showing development of the fish stock as effort level increases



Graph showing the development of Catch per unit effort as effort increases



Graph showing the development of profit as effort increases.

From the graphs, the five stages of fishery development can be observed. At the initial pre developmental stage when the fishers lacked finance, profit was low because they lacked the harvesting technology required to harvest the fish. When they got the loans from the traders they afforded the technology and effort began to increase and the fishery entered the developmental stage. More women financed more fishers and effort kept building the fishery entered the full exploitation stage. Stock began to decline and effort continued to build and harvesting rate, CPUE, profit continued to fall pushing the fishery into the over exploition stage. The next stage is collapse unless the effort is reduced and the stock is allowed to recover.

Policies to revive the stock

To slow down the decline of the stock loops R1, B2 and B4 should be targeted. Loop R1 should be strengthened while B2 and B4 should be weakened. To strengthen R1, the activities of bottom trawling should be halted so as to reduce the disturbance to recruitment. B2 can be weakened by enforcing mesh size regulation. This measure ensures that only nets of a prescribed mesh size are used. The use of unprescribed nets should attract a sanction. This will stop the incidence of mesh size manipulation which will reduce by-catches and discards thereby improving diversity and improving nutrition for the stock. The use of prescribed nets will also reduce the incidence of harvesting young fish thus improving recruitment.

To weaken loop B4 efforts must be made to disable the link between profit and investment. The current situation of high profit motivating higher investment should be regulated. This can be done by issuing licenses to the current boats. This will ensure that even if profits are being made new boats will not be purchased unless the licensing authority deems it appropriate.

One policy suggested in the appendix is aquaculture. This is a way to take some pressure off the marine capture fishery. This will weaken the B4 loop and help the stock to recover. The problem however is the capital to undertake this venture. One possibility is that non fishers with capital will go into aquaculture and not necessarily the tradition marine fishers switching to aquaculture. This will increase fish availability on the market but may not result in a reduction in the effort in the marine sector.

Chapter 4

Recommendations for effective fisheries management

Precautionary approach to fisheries management

Fisheries management entails a lot of uncertainties and unknowabilities (Lauck, Clarke et al. 1998). There is uncertainty about the size of the fish stock, environmental conditions and so on. Fishery research is a major means of gaining updates about the fish stock but the cost of conducting the research is high, especially the developing countries. Even if such researches are conducted often, the limitations of science especially when studying complex systems such as the marine ecosystem make it necessary to allow a wide margin of error. It is in the face of these uncertainties that the precautionary approach to fisheries management becomes an important guiding principle. The precautionary approach is a guiding principle whose purpose is to encourage or oblige decision makers to consider the harmful effects of their decisions before pursuing them (Cameron and Abouchar 1991). The precautionary principle recognizes that changes to fisheries systems are only slowly reversible, difficult to control, not well understood, and subject to changing environmental conditions and human values (FAO 1996). This approach to management takes an anticipatory position and adopts a preventive and proactive measures to protect the environment by working with the assumption that mistakes can be made (O'riordan and Cameron 1994). The principle therefore states that 'substances or activities posing danger to the environment should be prevented from adversely affecting the environment, even if there is no conclusive scientific proof linking that substance or activity to environmental damage' (Cameron and Abouchar 1991). The burden of proof and the standard of evaluating the proof lies on the entity demanding to take the action (O'riordan and Cameron 1994). Taking into account the uncertain nature of fisheries management and the need to take action even in the face of incomplete knowledge, the FAO has outlined some guiding principles to serve as guidelines:

- The needs of future generations will be considered and irreversible changes to the environment will be avoided.
- Undesirable outcomes will be identified and preventive or corrective measures will be instituted promptly.
- Such corrective measures should achieve the goal within a time frame not exceeding three decades.
- Where the impact on the resource is uncertain, priority should be given to preserving the productive capacity of the resource.
- Harvesting and processing capacity should commensurate with the estimated sustainable level of the resource.
- All fishing activity must have prior authorization and must be subject to periodic review.
- There must be a legal and institutional framework for fishery management, within which management plans that implement the above points are instituted for each fishery.

The principle also outlines guidelines for managing the various stages of the fishery development.

New or developing fishery

- Always control access to the fishery, open access is not precautionary.
- Immediately put a conservative cap on both fishing capacity and total fishing mortality. Attention must also be paid to excessive investment in the processing sector. The caps must be in place until there is substantial evidence to increase capacity and mortality.

- Build in flexibility to make it possible to take out vessels from the fleet.
- Use area closures to limit risks to the resource and the environment.
- Establish precautionary, biological limit reference points in the planning stage.
- Encourage co-management and community management to ensure responsible conduct.
- Establish data collection and reporting systems for the fishery.

Over utilized fishery

- Immediately limit access to the fishery and put a cap on fishing capacity and fish mortality rates.
- Establish a recovery plan to rebuild the stock over a specific period
- Reduce mortality rates long enough for example closure of the fishery
- Reduce excess fishing capacity from the fishery.
- Alternatively, relocate vessels to underutilized areas.

Fully utilized fishery

- Ensure means of maintaining effort and mortality level at the current level
- Pay attention to the warning signs (Age structure of spawners shifting to unusually high proportion of young fish, shrinking spartial distribution of the stock or species composition in a catches)
- When precautionary limits are approached, ensure that they are not exceeded.
- If limit reference points are exceeded, they must be restored immediately.
- Avoid harvesting immature fish. Actions such as area closures must be taken if young fish forms a high percentage of catches.

Managing an artisanal fishery

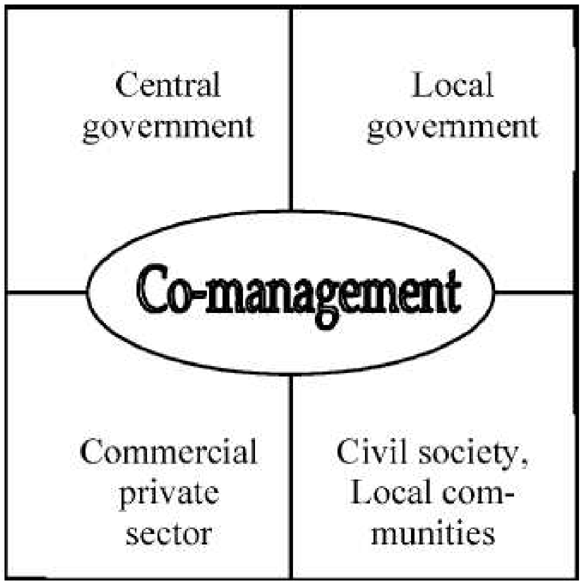
- Keep some areas closed to fishing and avoid the development of excessive fishing effort.
- Delegate some decisions for example area closures and entry limitations to local communities and cooperatives
- Ensure that fishing pressure from other segments (eg. Industrial) does not deplete the resource
- Investigate the factors that may affect the behaviour of harvesters and develop approaches to reduce intensity.

Theses are good guidelines to manage the fishery at any stage. The problem however is that again, there are misperceptions. For instance, under both fully utilized and over utilized fishery, the principle says, immediately limit access to the fishery. The misperception is that by limiting access, the current capacity will sustain the resource. This assumption ignores the natural dynamics of the resource and the fact that the resource on its own has periods of ups and downs. Natural death could be higher than usual due to a reduction in prey fish or the abundance of predator species. If this happens, the current effort level puts pressure on the stock and over fishing can occur. The principle also misunderstands that different fish species have different growth rates and resilience and vulnerability ratings. Low vulnerability stocks may be able to withstand the current effort level but not moderate or high vulnerability stocks. This guideline may work in an under fully utilized fishery but in an over utilized fishery, it is safer to reduce the current effort level.

Reducing the effort level requires education and involvement of the users. Users need to understand why effort should be reduced and how this will benefit them in the future. This requires the adoption of the co-management approach to fisheries management.

Co- management

There are debates over the world about the effectiveness of existing fisheries management regimes in achieving sustainability in view of the fact that many fisheries are in a state of overexploitation (Sen and Nielsen 1996). The government approach which is a top-down, bureaucratic approach has not only failed to yield the desired results but has exacerbated the problem through mismanagement (Jentoft, McCay et al. 1998). Concepts such as adaptive management, ecosystem manage, responsible fisheries are all results for the search for alternatives. All these models represent the growing recognition that for fisheries management to be effective, fishers must be involved in the process of regulatory decision making, implementation and enforcement (ibid). Two lines of argument support this approach; firstly, users possess knowledge through experience that may add to fishery science to produce more enlightened, effective and equitable remedies to the management challenge. Secondly, participation of the users enhances the legitimacy of the regulatory regime and compliance is achieved because users are more likely to be knowledgeable of, committed to and supportive of the regime (ibid). A common term used to describe this approach is co-management (Jentoft, McCay et al. 1998) defined as a partnership arrangement in which government agencies, the community of local resource users (fishers), non-government organisations and other stakeholders share the responsibility and authority for the management of the fishery (Pomeroy 1997). Co-management is thought to get rid of the distant, impersonal and insensitive bureaucratic approach that characterizes the role of government in fisheries management and be replaced with a system of interactive governance and co-operative democracy which entails the participation of users at local, regional and national levels (Jentoft, McCay et al. 1998). Such a system of interactive governance is depicted in the diagram below from Carlsson and Berkes (2004).



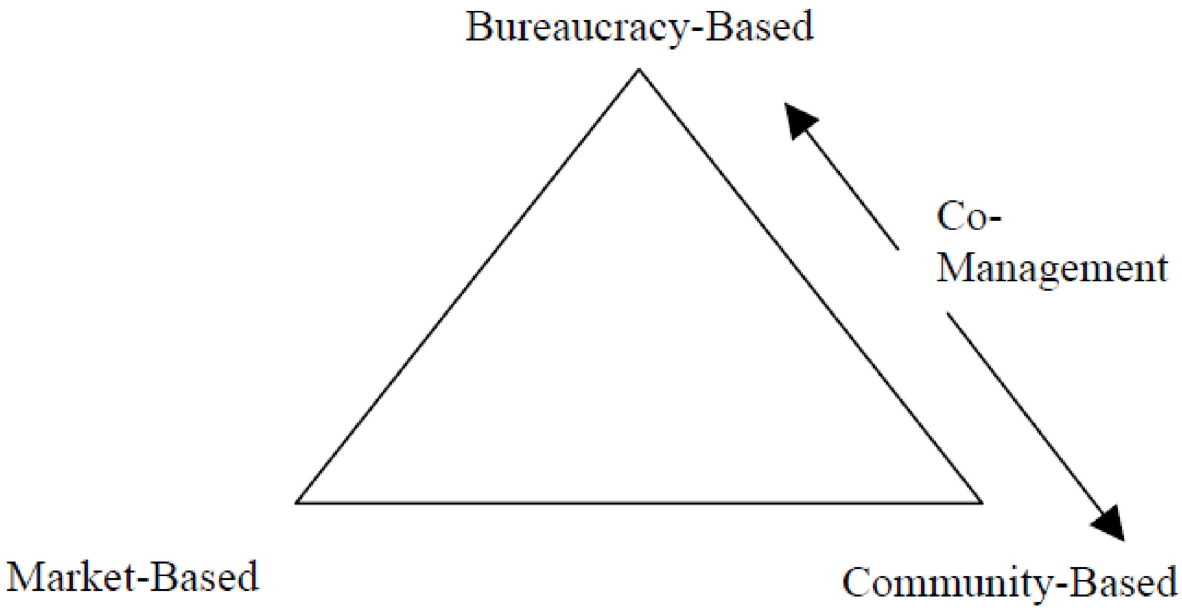
Stakeholder categories and co-management (source: The World Bank, 1999: 11).

Source: (Carlsson and Berkes 2004)

Through this system of interactive governance, co-management therefore moves from being merely formalized power sharing arrangement between government and resource users to a wider involvement of other agents in the society. In the diagram, the co-management process does not only involve collaboration between the government and resource users, but also local government, private sector and civil society. This makes the process more inclusive and this reflects in the decisions and also helps to build consensus.

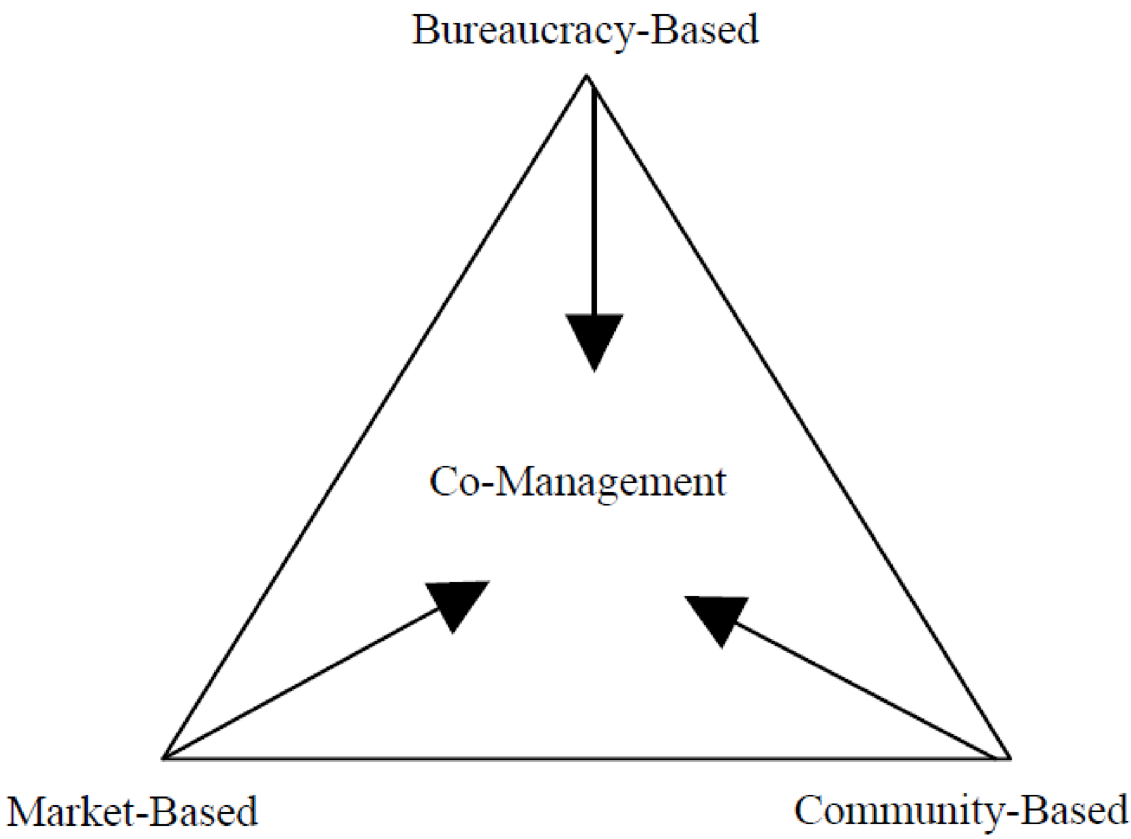
Although it is easy to witness the collaboration between the central government, local government and civil society it is often the case that the private sector is left out (Yandle

2002). One reason for this may be the lack of the private sector's direct involvement in the fishery but as demonstrated below, co-management operates best when seen as a triangle.



Source: Yandle 2002

In this diagram, the collaboration is only between the government and the community without inputs from the market. Decisions made in this arrangement will be less effective compared to decisions made with the involvement of the market (private sector). A proper representation of co-management is depicted as the interaction of the bureaucracy- based, market-base and community-based forces as shown below. Inputs from all the sectors are brought together and the decisions are better than if one is not involved.



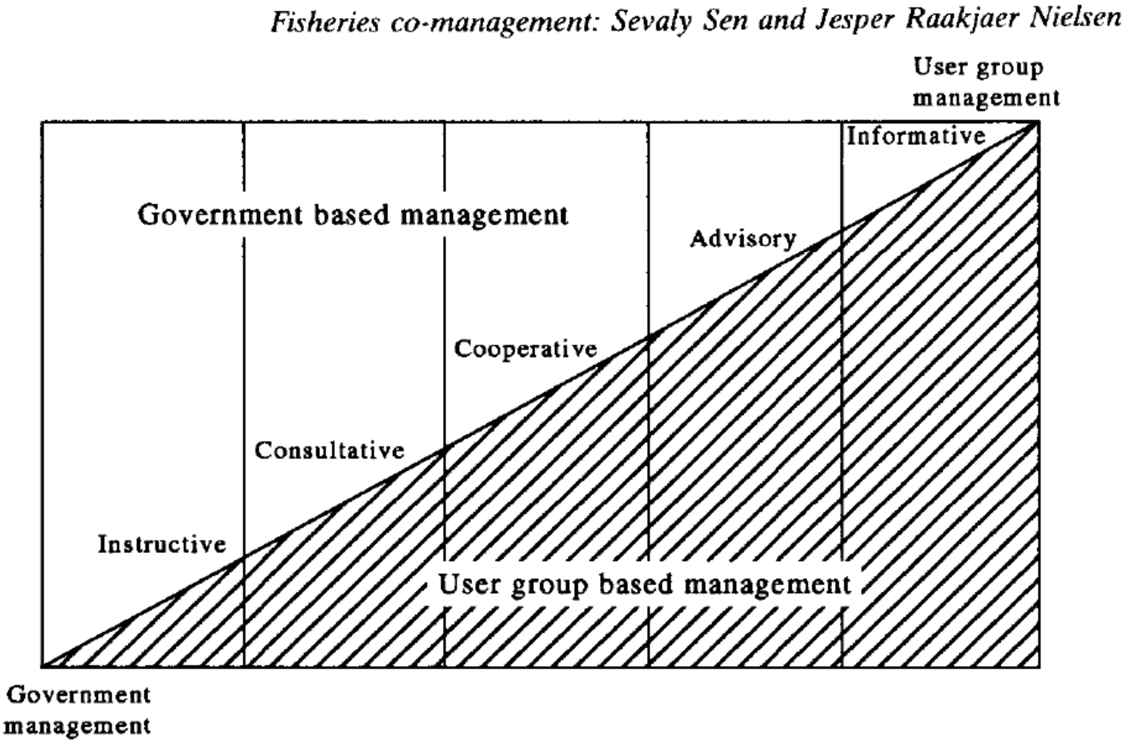
Integrative understanding of co-management approach.

Source: (Yandle 2002)

This diagram shows the right form of co-management by bringing the different sectors of the economy together for decision making. This is more effective because the short falls in management by the individual sectors are compensated for by the strength of the others. For instance, Community Based Resource Management may have good ideas but lack the formal authority to enforce sanctions. Bureaucratic based resource management has the power to enforce rules but may incur more cost for enforcing such laws because of noncompliance by resource users. By coming together through co-management these strengths are combined and the result is better.

Levels of co-management

The extent of participation has been classified into five types as instructive, consultative, cooperative, advisory and informative (Sen and Nielsen 1996). The diagram below demonstrates the different forms of co-management with the plain area representing government based management and the shaded portion representing user group management.



Source: Sen and Nielson (1996)

In *instructive*, there is minimal exchange of information between government and users. This type is only different from centralized governance in the sense that the mechanisms exist for dialogue but the process itself is one of government giving information to users on plans it has taken. In *consultative*, there are mechanisms to consult with users but decisions are made by the government. Under *co-operative*, both government and users relate as partners. Under *advisory*, users advise government on what to do. Under *informative* users make decisions but they inform government of the decisions.

Certain factors could determine the type of co-management to be adopted. One of these factors is the management task to be performed which includes policy formulation, resource estimation, access rights, harvesting regulations, market regulations, monitoring, control and enforcement (Sen and Nielsen 1996). For tasks such as policy formulation, full and equal participation of government and users is desired while others such as access rights could be decided by government in consultation with users (ibid).

Another factor that affects which type of co-management to adopt is the stage in the management process namely, planning, implementation and evaluation (Sen and Nielsen 1996). Full involvement at all stages could be costly but effective by increasing legitimacy and thus elicit compliance. A centralized planning could be cost effective but implementation, monitoring and enforcement could be ineffective (ibid).

The extent of involvement of users also depends on the level of the decision, local, regional, national and supra-national (Sen and Nielsen 1996). It is easier to involve users at the lower level but the higher the level the less participatory it becomes (ibid).

The extent of participation also depends on the representatives of the users, more articulate and informed representatives may demand more participation than less informed ones (ibid).

Stakeholder theory: From user-groups to stakeholders

Although much emphasis has been placed on the involvement of user-groups in decision making, the concept of co-management entails more than the participation of user groups. It embraces other stakeholders in the industry (Mikalsen and Jentoft 2001). This broadening of the co-management concept arises due to the many number of people with an interest in the industry. Stakeholders are thus defined as people who affect or are affected by the decisions of an entity (Mikalsen and Jentoft 2001). Two key issues regarding stakeholders are the issues of *identification* and *salience*. Identification deals with determining who has a legitimate claim on the attention of the managers and thus deserves to be called a stakeholder while salience addresses the importance of such claims.

Classification of stakeholders

The challenge in assessing claims of stakeholders is the limited span of attention of managers to attend to the concerns of all the interests in the fishery. This calls for a classification of stakeholders into *primary* and *secondary* stakeholders with the former having a direct impact on the survival of the entity and the latter lacking such ability.

Criteria for classifying stakeholder

To further simplify the process of stakeholder participation, stakeholders are classified based on their score on three attributes, legitimacy, power and urgency. *Legitimacy* measures a groups' moral or legal claim on the entity, *Power* measures the groups' ability to influence the entity's decision and urgency determines whose claims demand urgent attention.

Types of stakeholders

Using these attributes, stakeholders are then divided into three groups, namely, definitive stakeholders, expectant stakeholders and latent stakeholders. *Definitive stakeholders* are the groups that have all the attributes of legitimacy, power and urgency. They are the groups that have urgent moral or legal claims as well as the power to influence decisions. They are those groups that managers must attend to. *Expectant stakeholders* have two of the three attributes, such groups may have a moral claim but lack the power to influence or the claim may lack urgency. *Latent stakeholders* are the groups that have only one of the attributes and are thus considered the weakest among the three. Mikalsen and Jentoft (2001) provides an example of stakeholders in the Norwegian fisheries based on these three classification.

Fisheries management stakeholders (Norway)

Stakeholders	Urgency	Power	Legitimacy
Definitive			
Fishers	High	High	High
Fish-processors	High	High	High
Bureaucrats	High	High	High
Enforcement agencies	High	High	High
Scientists	High	Medium	High
Fish workers	High	Medium	High
Expectant			
Indigenous peoples	High	Increasing	High
Environmental groups	Increasing	Increasing	Increasing
Local communities	Medium	Low	High
Latent			
Citizens	Increasing	Low	Increasing
The media	Increasing	Increasing	Low
Municipal authorities	Increasing	Medium	Increasing
Future generations	Low	Low	High
Banks	Low	High	Low
Consumers	Low	Low	Increasing
Equipment suppliers	Low	High	Medium
Tourist industries	Low	Medium	Low
Sports fishers	Low	Low	Increasing

Source Mikalsen and Jentoft (2001)

Conclusion

Fisheries management is a complex exercise because of the uncertainties due to the lack of accurate data. The resource as has been described earlier supports a section of society that lacks other employment options. Mismanagement or even late measures may necessitate closure of the resource which results in unemployment, food crisis, and malnutrition and so on. A way to prevent this from happening is to take measures to limit fishing effort before stock collapses.

Although measures such as quotas cannot be implemented in the Ghanaian fishery due to certain lapses such as lack of strong monitoring and control mechanisms, simpler measures such as licenses, Marine Protected Areas (MPAs), closed seasons, and mesh size regulations and so on can be enforced to protect the stock.

This exercise should be done by the ministry of fisheries in collaboration with the fishermen and other stakeholders in the fishery. This will provide the platform to explain policies and the rationale behind such policies to the fishers in order to build consensus.

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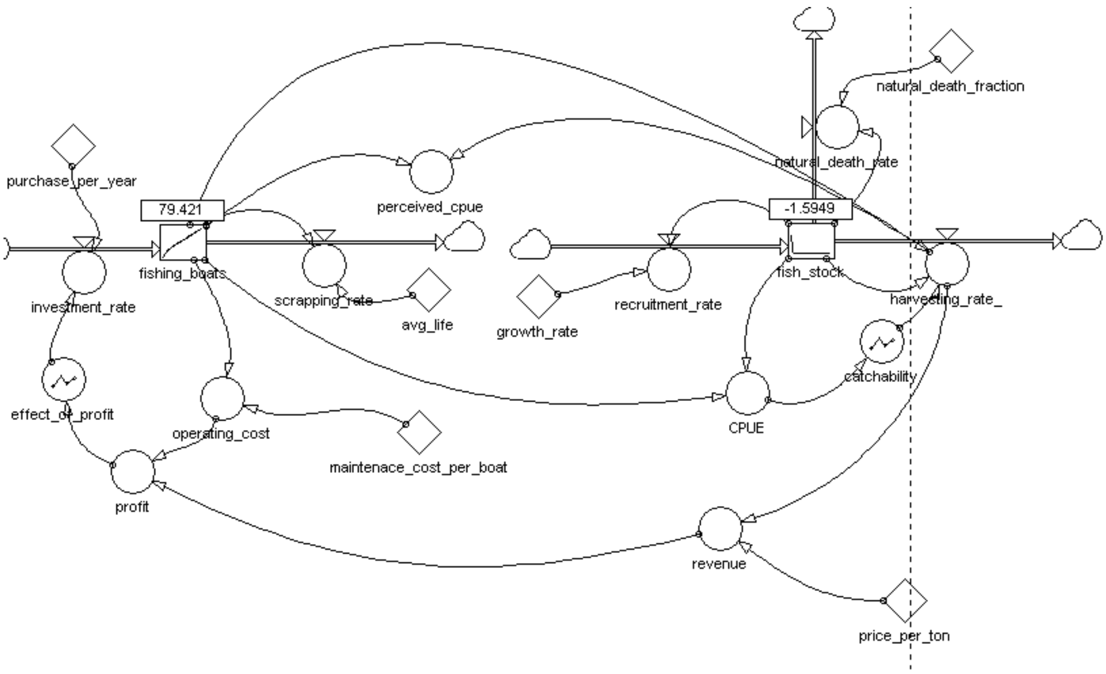
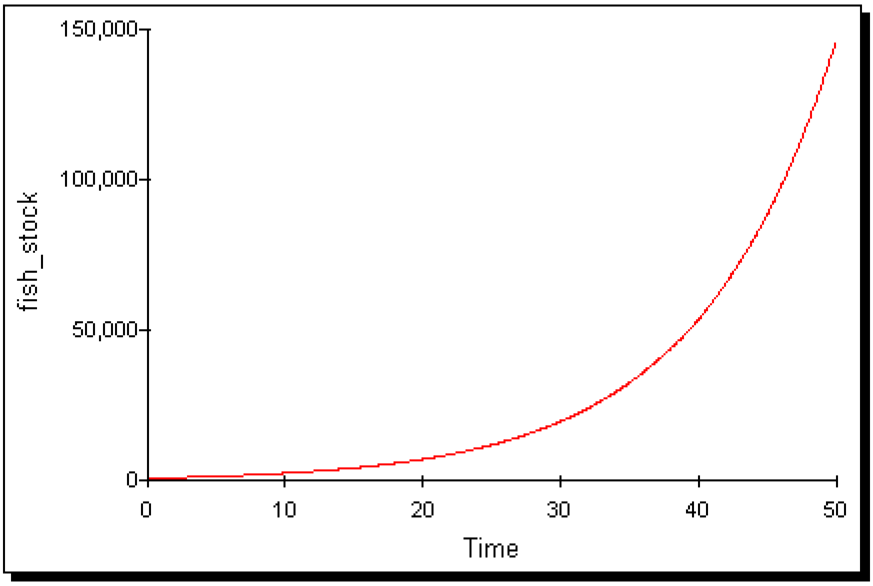
Appendix 1
Model testing



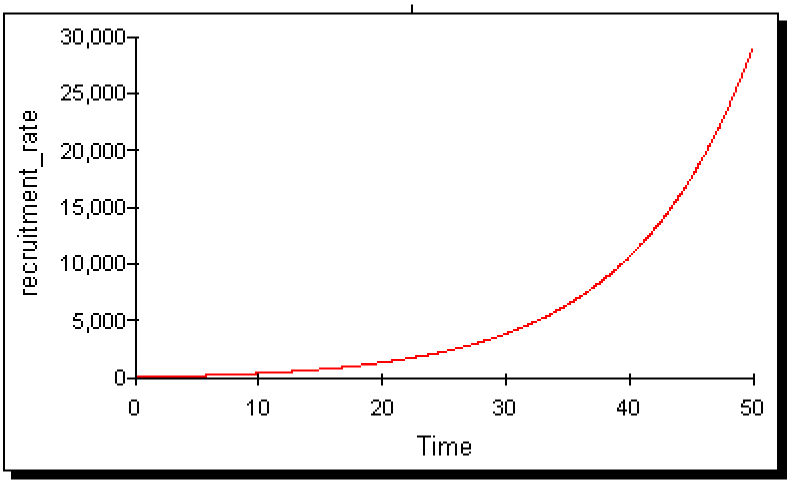
1. **Equilibrium test** (No harvesting)

In equilibrium, where number of boats = 0, purchase =0, stock=10000 growth rate = 0.2, death fraction = 0.1,

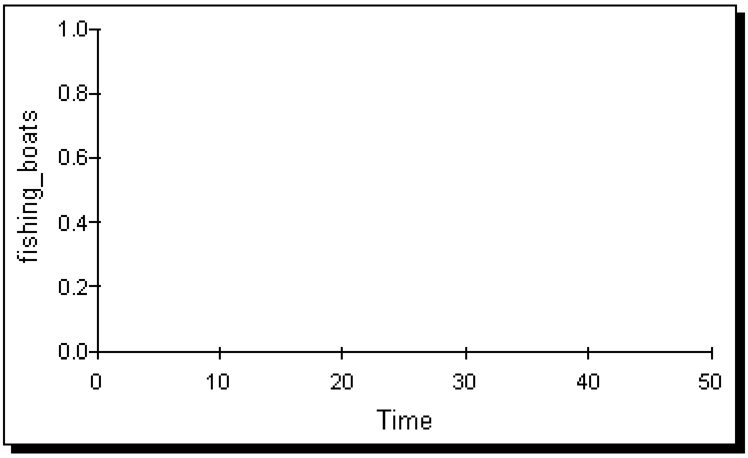
Expected result: Fish stock should grow and the other variables should be 0.



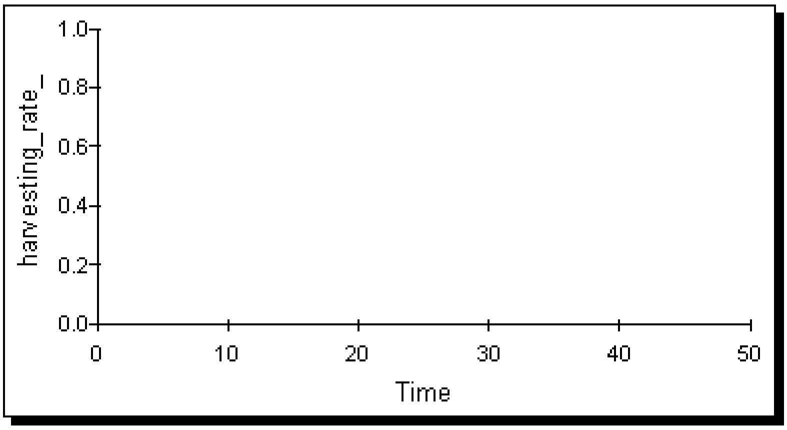
A graph showing the growth of stock (in tons) when there is no harvesting



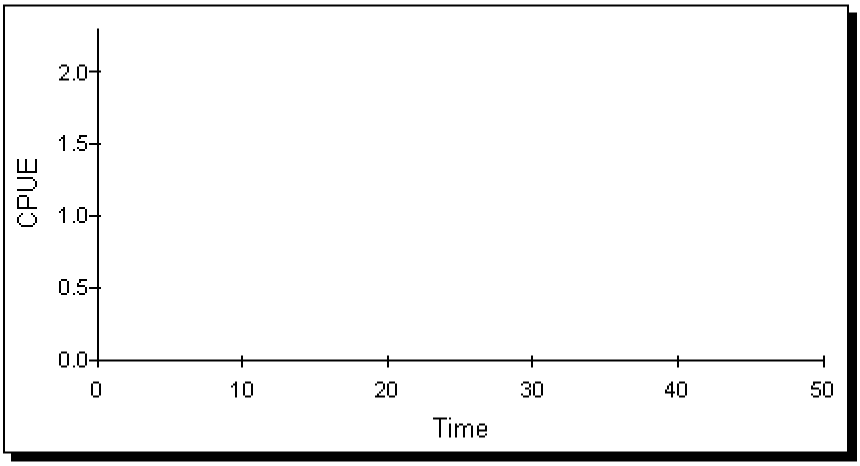
A graph showing the growth in recruitment (ton/year) when there is no harvesting



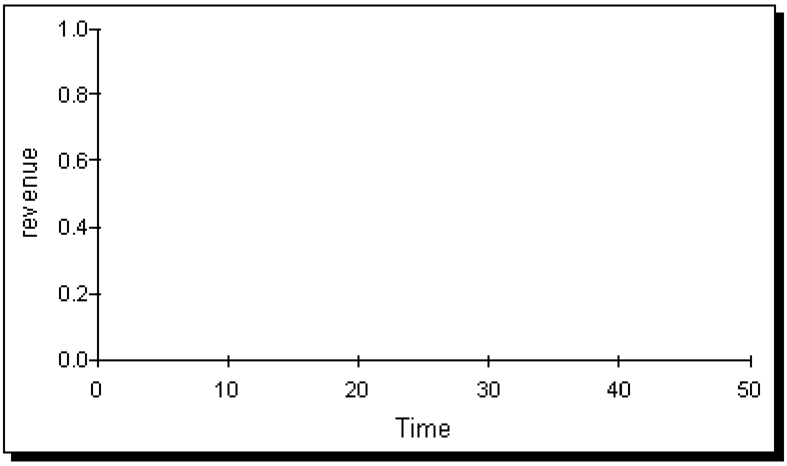
A graph showing the absence of boats in the fishery



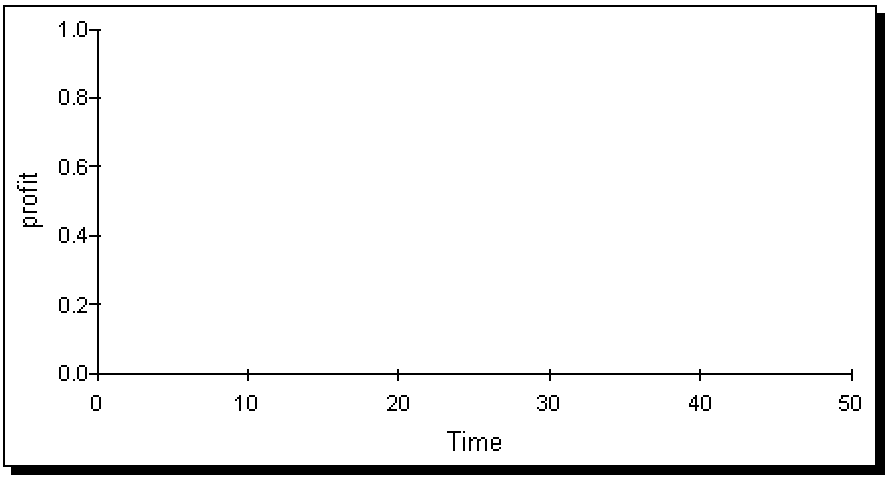
A graph showing that there is no harvesting since there are no boats



A growth showing that CPUE is zero since there is no havesting



A graph showing that there is no revenue in the fishery

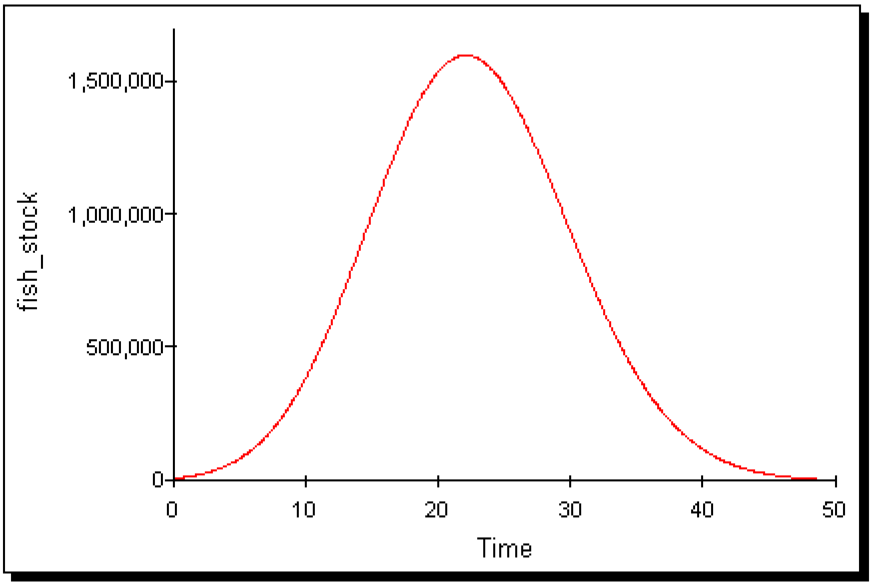


A graph showing that there is no profit in the fishery.

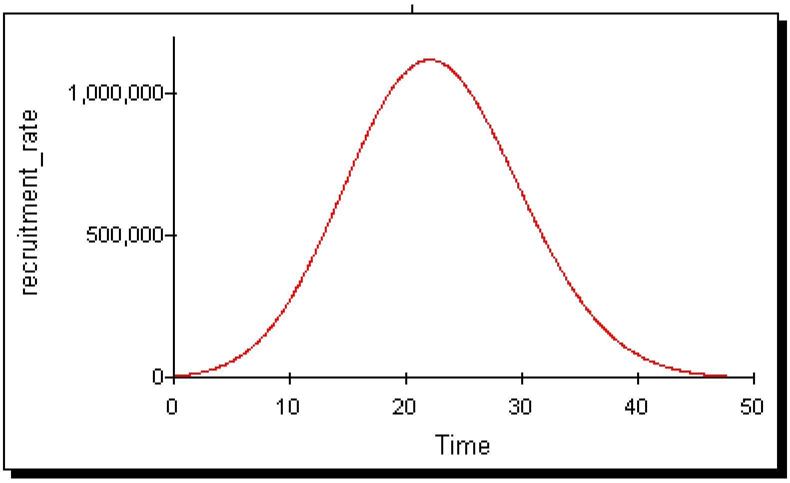
The importance of this test is to show that without harvesting, the stock grows.

2. **Behaviour reproduction test**

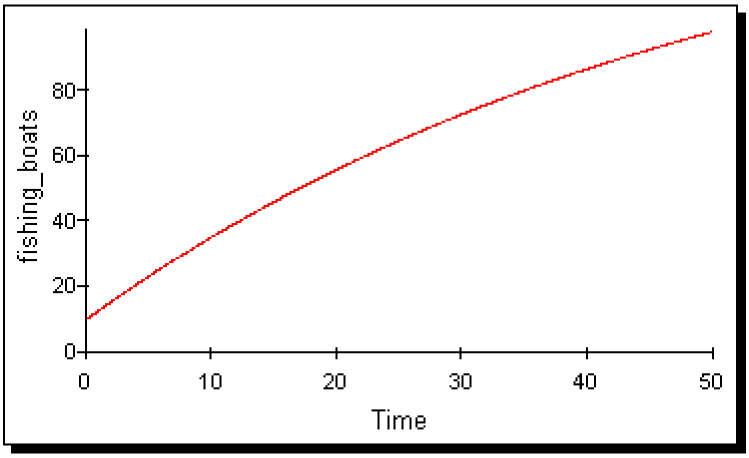
This test aims at verifying whether the model reproduces the behaviour observed in the real world. With initial values of 10 boats, boats bought per year=4, Average life=30, fish growth rate =0.2, Fish stock = 10000 tons, death rate = 0.1



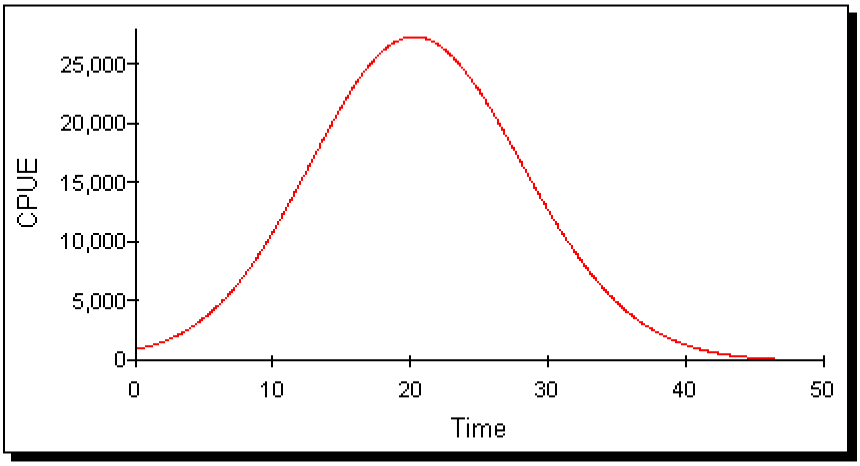
A graph showing the development of stock in tons when fishing boats are operating



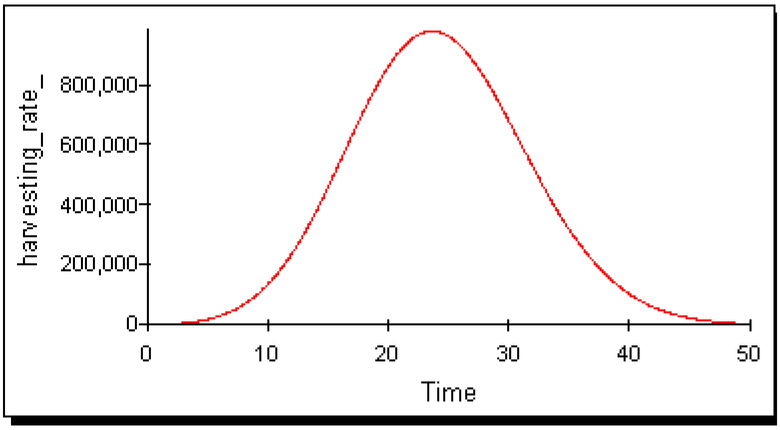
A graph showing the recruitment rate (ton/year) when there is harvesting



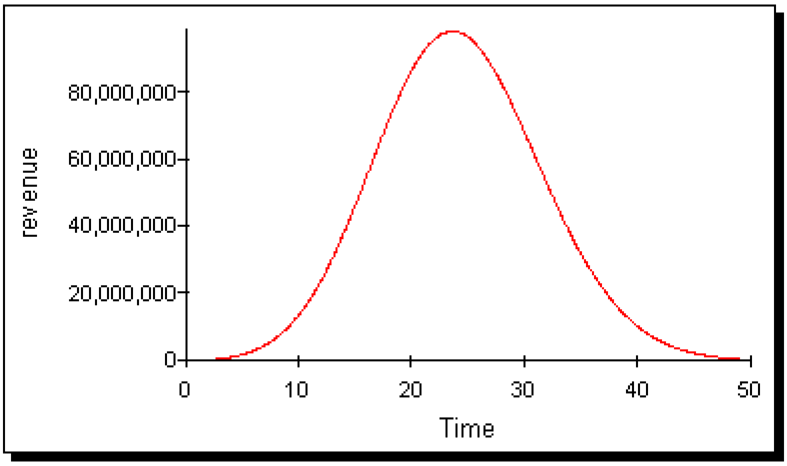
A graph showing the rise in effort(fishing boats)



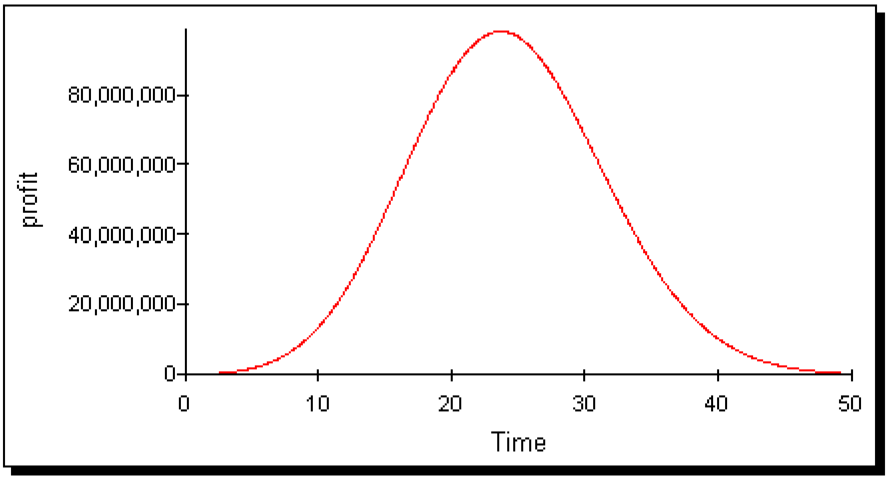
A graph showing the CPUE in the fishery



A graph showing the harvesting rate (ton/year) in the fishery



A graph showing that revenue rises and falls in the fishery



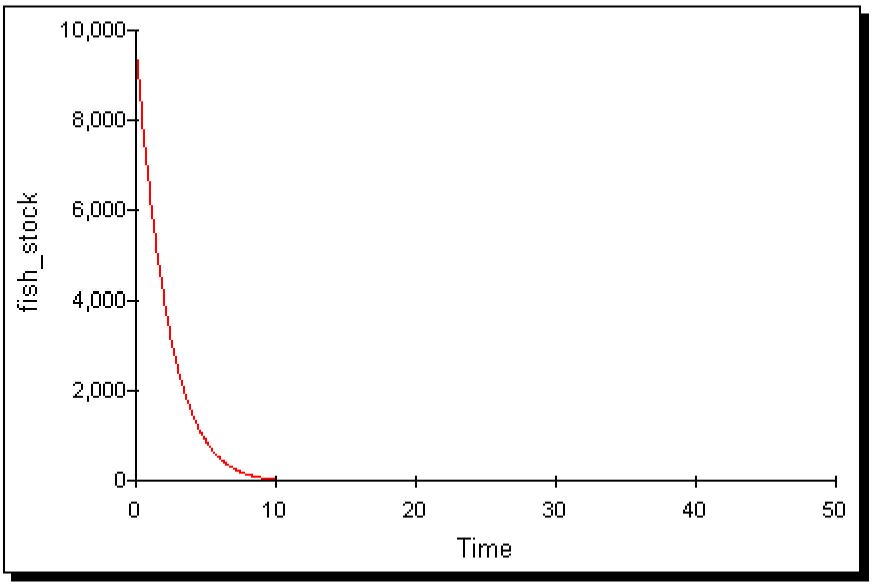
A graph showing the profit level in the fishery

This test reveals that when 10 boats are introduced and 4 are bought each year, the stock declines over time and the other variable follow suit. At the initial stages, the boats are few so the stock grows up to year 25 where it begins to decline. Harvesting rate, CPUE, and the other variables decline but the effort keeps rising. This depicts the various stages of fishery development. For the stock to recover, effort must be reduced heavily.

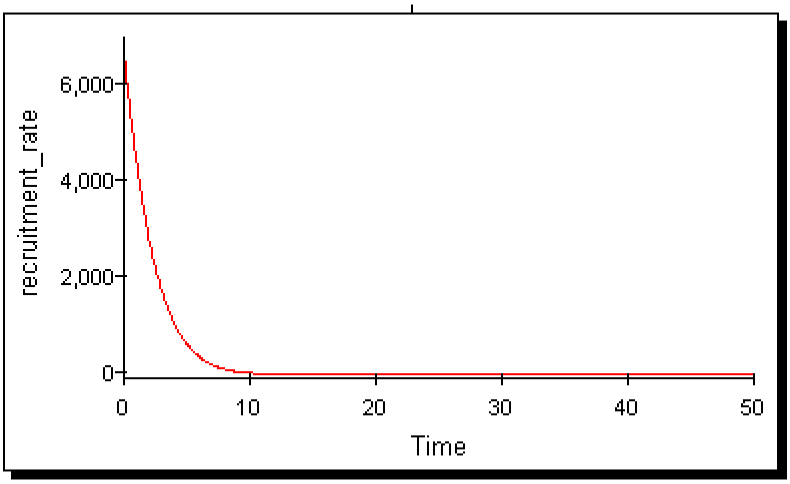
3. **Extreme conditions test**
This test aims at testing how the model reacts to extreme conditions. The flows are the main targets here and they are assigned very high values or zero values. In this model the flows are the investment rate, the scrapping rate, the recruitment rate, the death rate and the harvesting rate.

Death rate: Assuming a death fraction of 1 (100%) meaning all the fish die. I expect the fish stock to be zero, recruitment zero, harvesting zero.

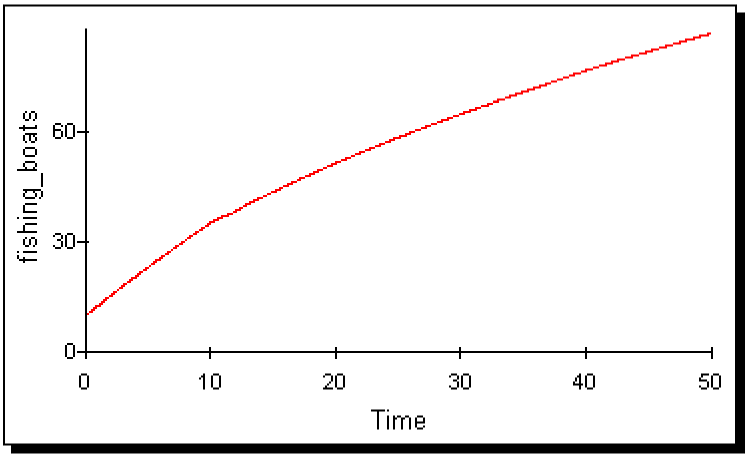
Expected behaviour: Stock should decline along with all the other variables



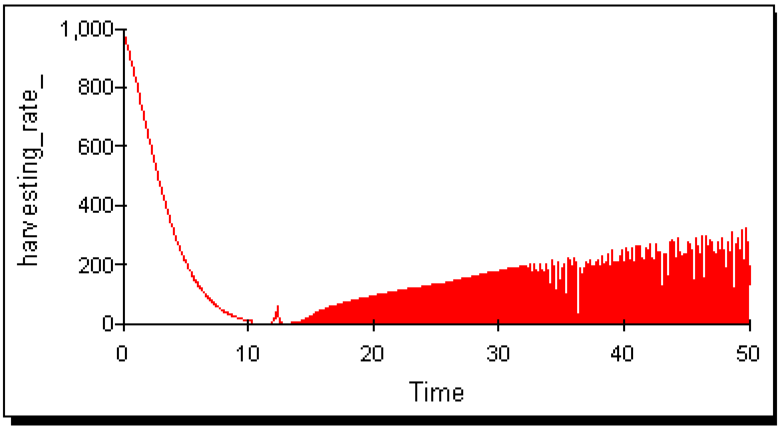
A graph showing that stock falls to zero when natural death fraction is 100%



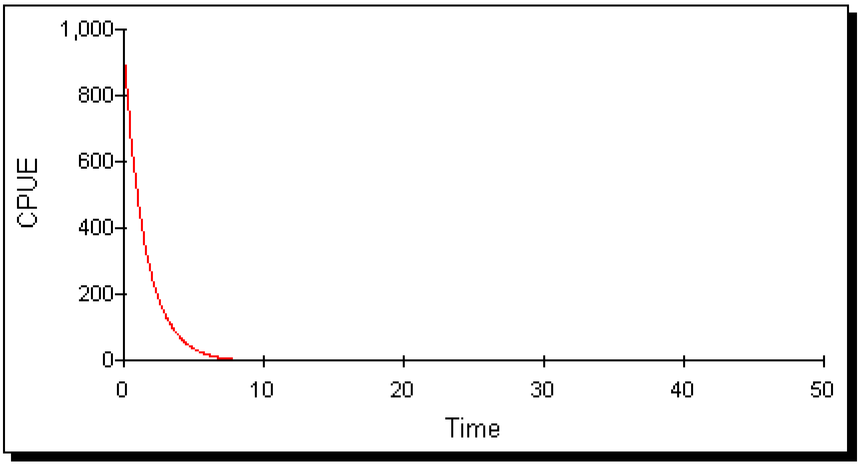
A graph showing that recruitment falls to zero when natural death fraction is 100%



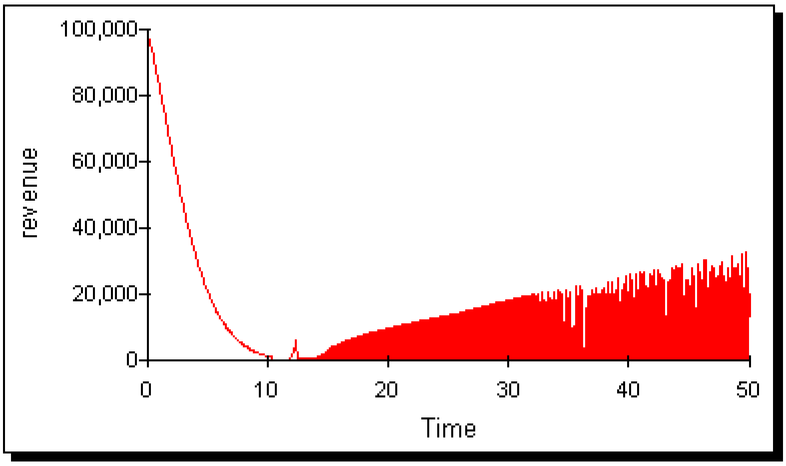
A graph showing the development of fishing boats when natural death rate is 100%



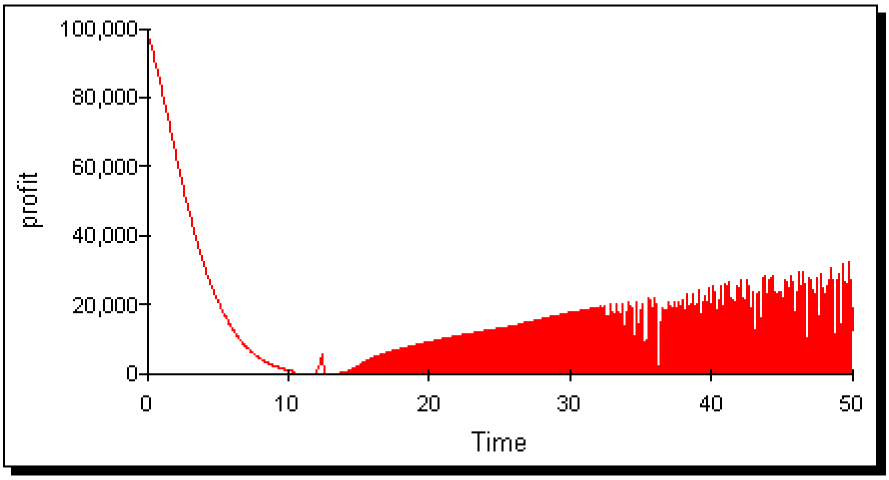
A graph showing that when natural death rate is 100%, harvesting declines to zero



A graph showing that CPUE falls to zero when natural death rate is 100%

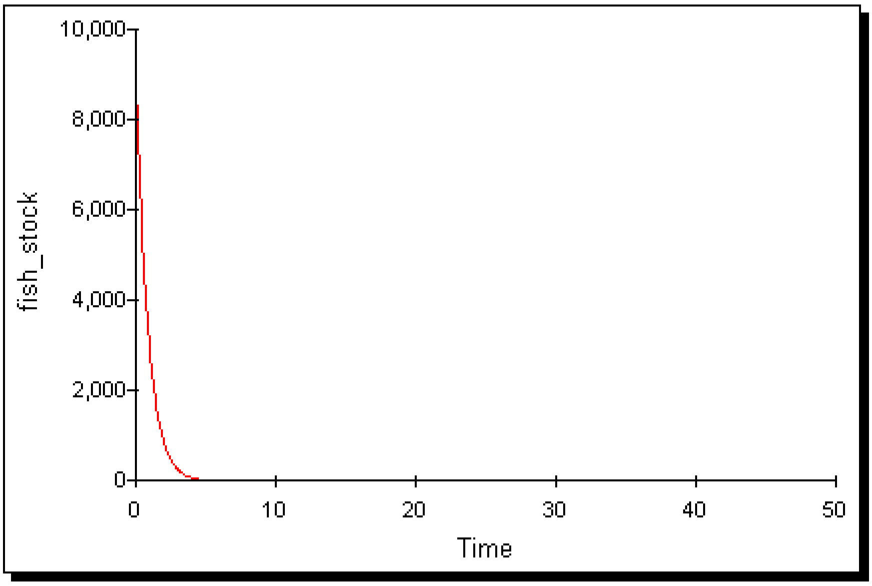


A graph showing that with a natural death fraction of 100% revenue falls to zero.

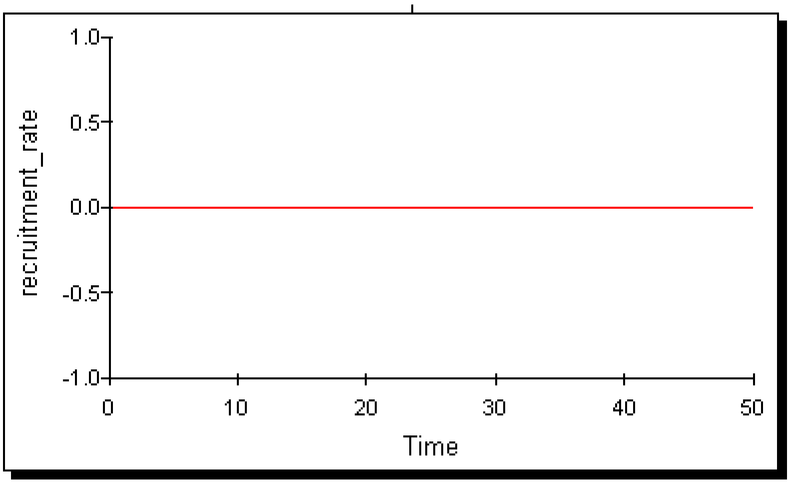


A graph showing that with a natural death fraction of 100% profit falls to zero

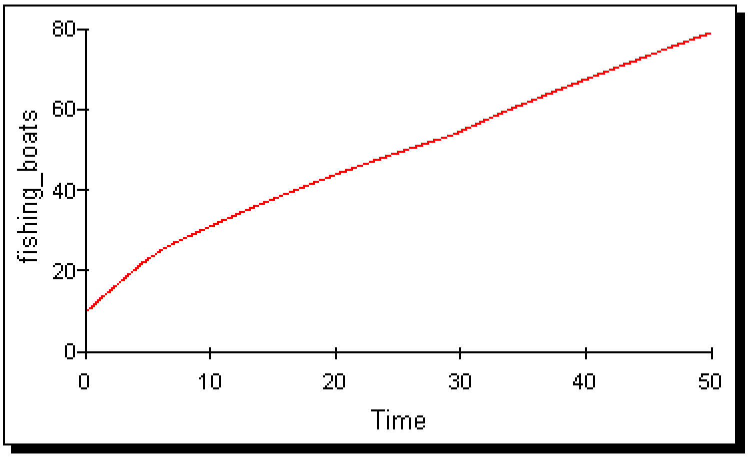
Recruitment rate at =0, I expect stock not to grow and thus the other variables will be zero as well.



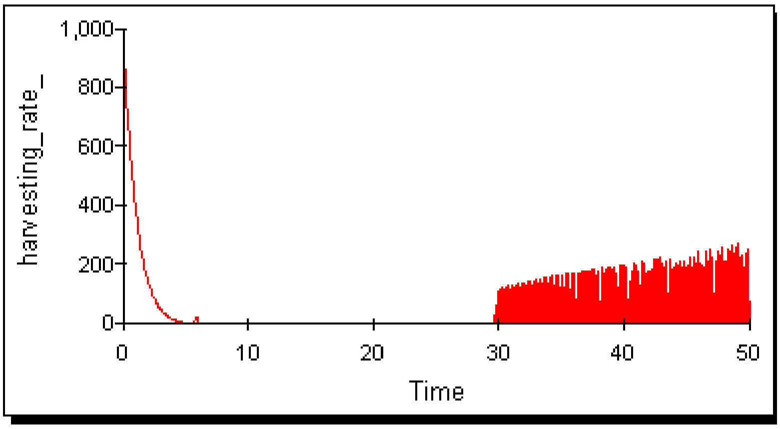
A graph showing that when recruitment is zero stock falls to zero



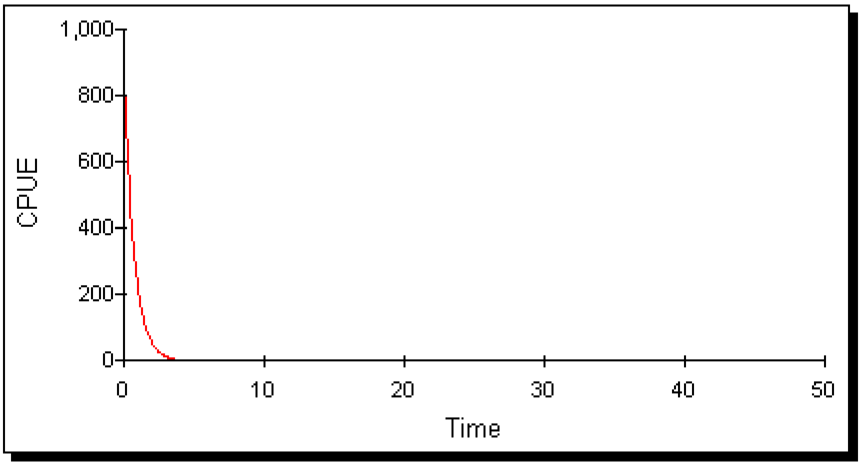
A graph showing that recruitment is zero



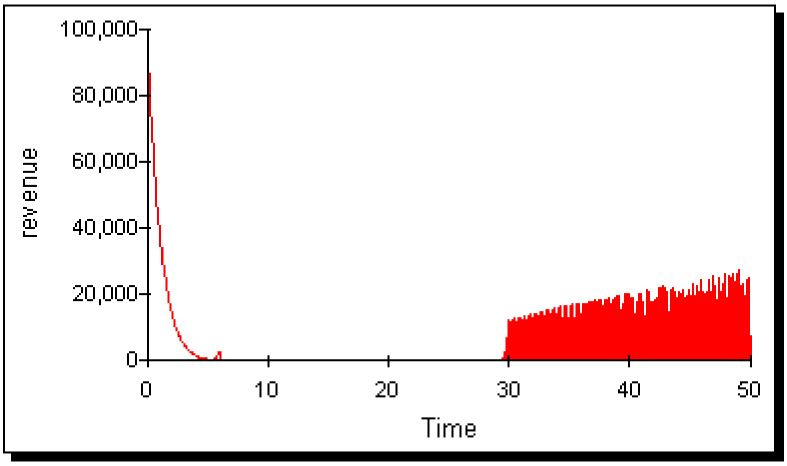
A graph showing the rise in number of boats when recruitment is 0



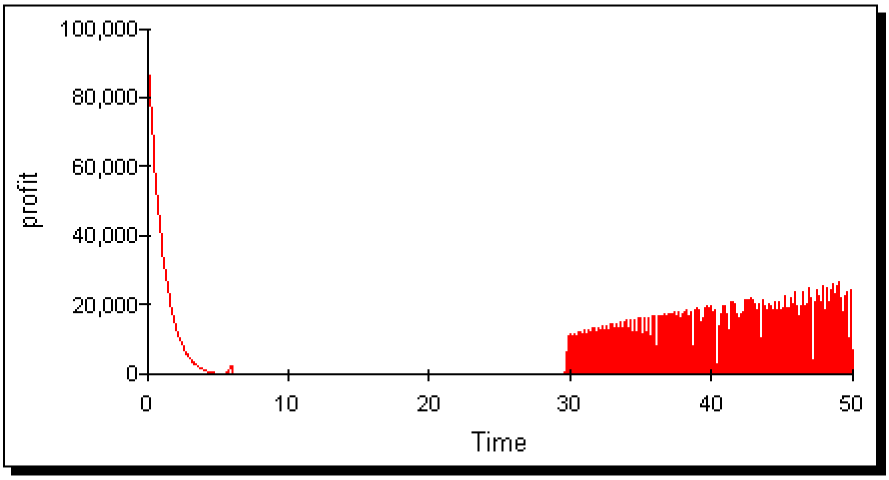
A graph showing that harvesting rate when there is no recruitment rate.



A graph showing CPUE when recruitment is 0



A graph showing revenue when recruitment is 0

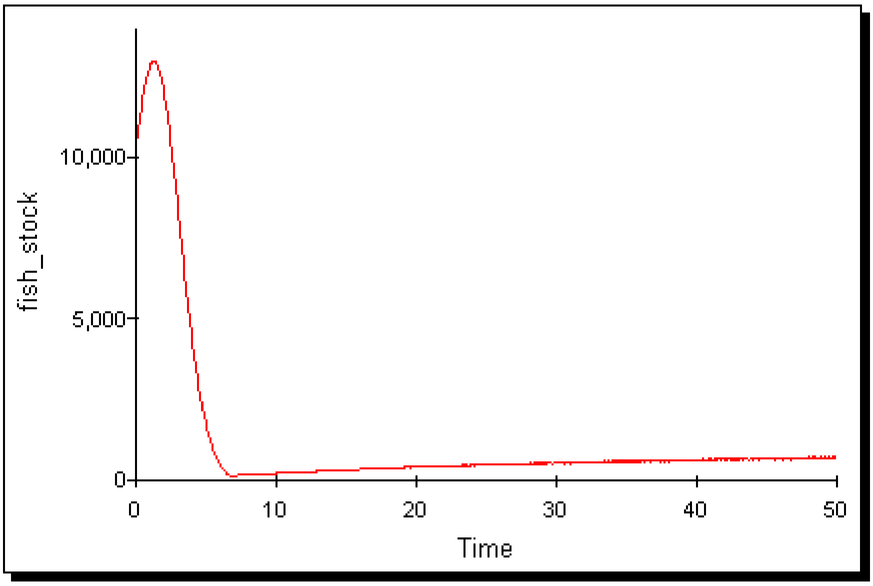


A graph showing profit when recruitment is zero.

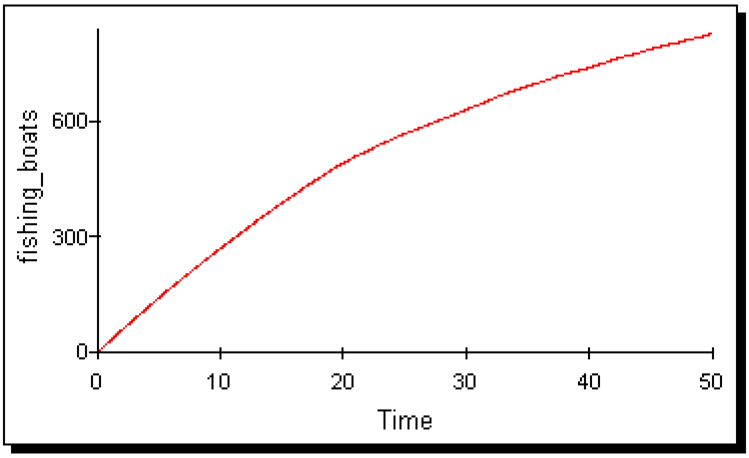
5. **Sensitivity test**

This test aims at finding out how sensitive the model is to certain important variables.

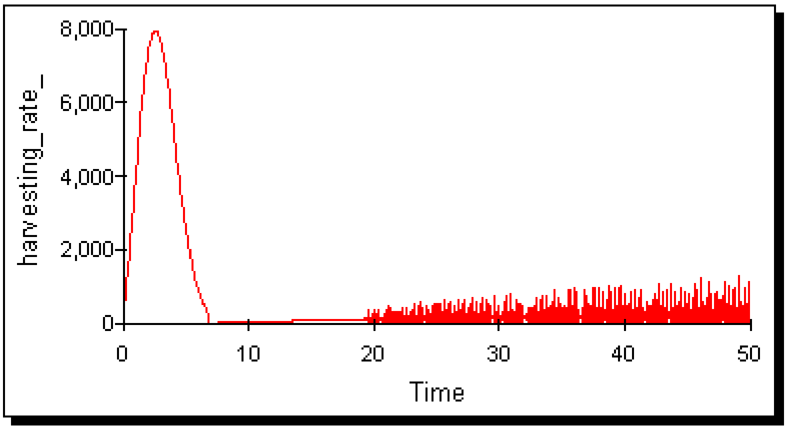
Assuming there is one boat in the fishery but 40 new boats are bought each year.



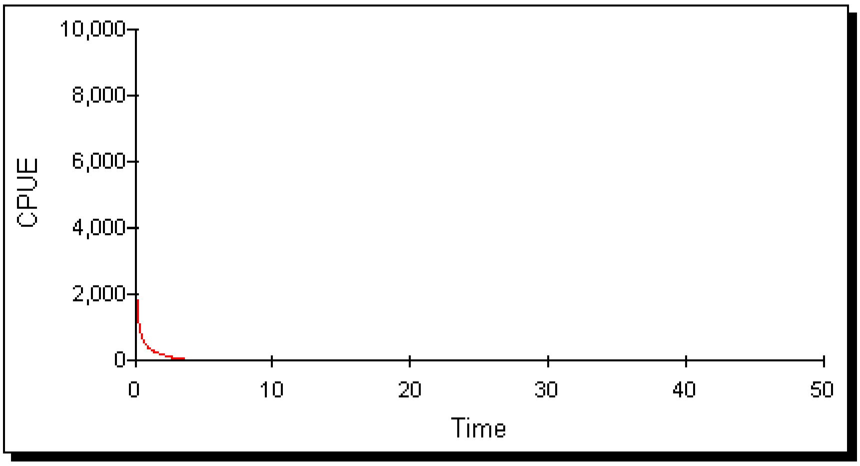
A graph showing the response of the stock to high purchase of boats per year



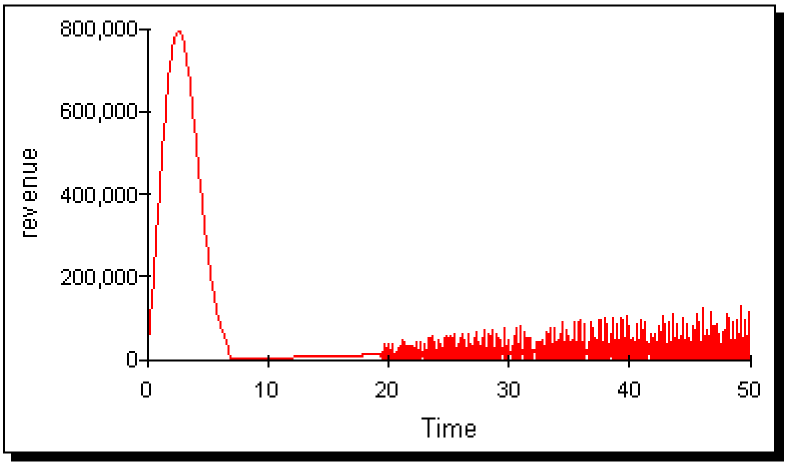
A graph showing high purchase of boats per year



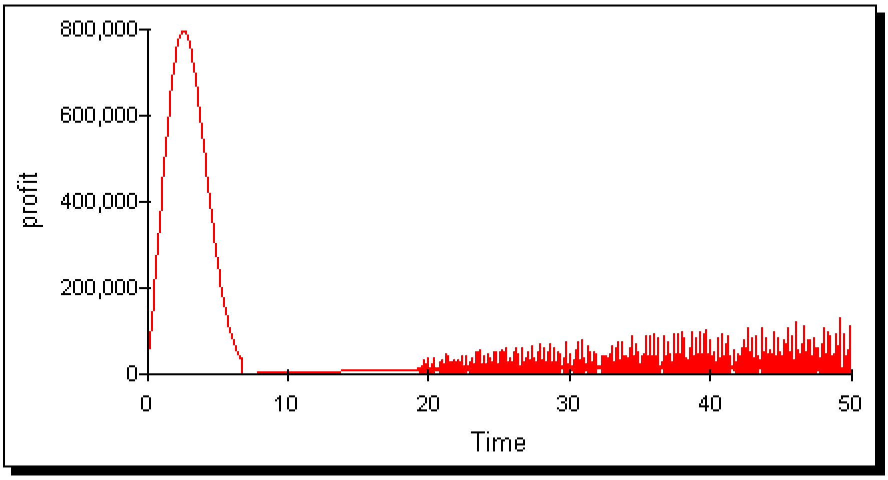
A graph showing the response of harvesting rate to high purchase of boats per year



A graph showing the response of CPUE to high purchase of boats per year



A graph showing the response of revenue to high purchase of boats per year



A graph showing the response of profit to high purchase of boats per year

This test reveals that the sudden increase in the purchase rate results in a quick rise in harvesting, revenue and profits but reduces the stock and recruitment rate very quickly as well.

5. **Equations**

Investment rate (boat/year) = purchase_per_year*effect_of_profit

Scrapping rate (boat/year) = fishing_boats/avg_life

Recruitment rate (ton/year) = fish_stock*growth_rate

Natural death rate (ton/year) = fish_stock*natural_death_fraction

Harvesting rate (ton/year) = fishing_boats*catchability*fish stock

Catch per unit effort (CPUE) (ton/boat) = (fish_stock/fishing_boats)

Revenue (dollar) = harvesting*price_per_ton

Operating cost(dollar) = fishing_boats*maintenace_cost_per_boat

Profit (dollar) = revenue-operating_cost

Appendix 2
News reports

Ghana's fishermen battle with pirates

Elmina relies on the fishing industry

By Penny Dale in Elmina, Ghana

Abeeku Osei leaves nothing to chance.

Like other Fante fishermen in the bustling port of Elmina, 125km west of Ghana's capital Accra, he makes regular visits to the shrine to ask for good fortune and protection before setting out to sea in his dug-out canoe.

Nowadays, 45-year-old Osei and his crew have to travel further afield in search of shoals of fish that were once plentiful closer to shore. But braving the Atlantic's unpredictable waters does not always result in bigger catches.

> **Since the foreign boats arrived, we've really struggled**
>
> **Abeeku Osei**

Like other West African fishing communities, Ghana's small-scale fishermen find themselves having to compete with pirate ships and industrial trawlers for ever-dwindling stocks of fish.

Already poor communities, with little viable alternatives, now find their livelihoods are increasingly threatened by these well-equipped, larger vessels.

International competition

Osei blames the foreign boats for dwindling catches of smaller and smaller fish: "Since the foreign boats arrived, we've really struggled.

There are no longer so many fish, and the ones you do catch are very small, too small really but we still sell and eat them. Otherwise we'd go hungry and have no money."

The fishermen cannot compete with the industrial trawlers

He adds: "The days when we could go out in the boat at dawn knowing that we' d return by early afternoon with a boat full of fish are gone. Now we often come back empty-handed."

In Ghana, about 1.5 million people, including fishermen, fishmongers and processors, depend on the sea. Fish is a valuable source of animal protein, accounting for 60% of the country's intake.

With the rapid depletion of stocks in European and Asian waters, trawlers from Italy, Spain, the Netherlands, former Soviet countries, Greece, China, Japan, Korea and Taiwan have moved into more fertile waters off West Africa.

Some are there legally, others not.

Stocks dwindling

Over fishing and pirate fishing pose a significant threat to West African fish stocks, which now hang in the balance. The arrival in July of two high-tech surveillance boats will provide a much-needed boost to the

Ghanaian navy's meagre arsenal in what has so far been a losing battle against illegal fishing.

But fishermen and industry officials are also keen to see the government put an end to what they call a "glut" of trawlers operating in the country's waters.

Some 93 foreign-owned industrial trawlers, which export tuna, squid, sea bream and snappers to Europe and the Far East, were licensed by the previous Jerry Rawlings administration to fish in Ghana's waters.

Samuel Manu: withdraw the trawlers

Ghana's relatively high population growth, now about 3% per year, first put pressure on fish stocks. But industrial fishing over the past few years has escalated the problem of over-fishing, according to recent studies by the Rome-based Food and Agriculture Organisation and the International Committee for the Conservation of the Atlantic Tuna.

"If the scientists say Ghana's fish stocks cannot support major trawling, the answer is to withdraw what is a glut of trawlers," says Samuel Manu, senior fisheries officer in Elmina.

Government action

The new government of President John Kufuor has promised to tackle the environmental damage to Ghana's fishing resources. But it is unlikely that it will go very far.

"The 93 vessels currently operating in the country are far more than the

Annual earnings from fish exports are close to $60m. The government has not, however, issued any new licences since coming to power in January.

> **number required by law**
>
> **Ghana's fisheries minister**

It is also in the process of inspecting all industrial vessels, which have been required to re-register, possibly with an eye to revoking some licences.

The minister of state responsible for fisheries, Ishmael Ashietey, said: "The 93 vessels currently operating in the country are far more than the number required by law."

The fishermen in Elmina welcome government moves to control the number of vessels, which they claim also fish illegally.

Trawlers are not allowed to fish in waters shallower than 30 metres, but fishermen complain that they often operate in shallower waters closer to the shore, especially under the cover of darkness.

In the meantime, until effective action is taken Abeeku Osei will continue praying for good fortune.

Ghana's local fishermen pay the price of overfishing

afrol News / IRIN, 14 February - While their men were out fishing, the women of the Ghanaian village of Prampram used to carefully clean, smoke, preserve and then sell the fish. But now the men are coming home with less and less fish, and women say they can no longer make ends meet. Industrial fishing is blamed for dwindling fish stocks.

"The fishing industry along the whole coast is collapsing," said Christina Sackey, secretary of the fishmongers association in Prampram, a fishing community about 45 minutes east of the capital, Accra.

Ms Sackey said the shortfall has been especially acute in the last five years. She hopes her children will not go into fishing but she is also finding it hard to pay for their schooling.

Fish is still one of Ghana's most important sources of protein, and a traditional mainstay of people's diets. But, despite 550 kilometres of coastline and an abundance of lakes and streams, more than 30 percent of the fish that Ghanaians eat is imported from other countries, according to government statistics.

"I have been a fisherman my whole life," said Joshua Quaye, 29, as he drags his brightly painted wooden canoe up the beach in Prampram, after an unsuccessful day on the ocean. "How will I live? How will I raise my children? No one seems concerned about us."

The Ghanaian Ministry of Fisheries estimates there are about 500,000 fishermen and fishmongers in Ghana, the vast majority of whom are struggling, like Ms Sackey and Mr Quaye, to make ends meet. The number of workers in the fish industry jumps to 2 million, or about 10 percent of Ghana's population when peripheral jobs are included, such as canoe building.

Depletion of Ghana's fish stocks is not a new problem. In 1998, European researchers said that nearly 75 percent of Ghana's wild animals killed and sold since 1970 were related to the problem of dwindling fish stocks.

David Eli, chairman of FoodSPAN, a network of 50 non-governmental organisations in Ghana working on food security, blames the dwindling fish stocks on industrial fishing which uses nets dragged along the sea bottom, a practice known as "bottom trawling".

"Policies need to change in favour of artisanal fishermen because they cannot compete with large trawlers," Mr Eli said.

Ghana's Ministry of Fisheries has tightened regulations on the number of licences it issues the types of nets that trawlers can use.

But according to Ghana's national statistics, artisanal fishing accounts for about 75 percent of the country's whole national production caught for consumption, dwarfing the output of the industrial fleets.

But also other solutions are sought. The Ministry of Fisheries is working to increase the number of fish farming so that eventually they will account for 20 percent of local fish production.

It is providing technical advice and workshops to entrepreneurs. Currently 1,040 fish farmers have registered 2,800 ponds in the country. "More and more people are expressing interest in the business," said Lionel Awity, head of aquaculture for the Ministry of Fisheries.

"There is a huge local market that is not being satisfied," said David Sackey, 36, a fish farmer whose farm produced 1.6 tonnes of fish last year. "It is a lucrative business." But fish farming requires access to land and capital which are in short supply and even if the industry grows it is not going to help coastal fishing communities any time soon.