Three methods to evaluate ITQ-based self-governance in New Zealand fisheries management and their application to the Bluff oyster fishery

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Abstract

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Fisheries economists consider ITQ-based self-governance to be the future of fisheries management. In theory, this management regime is argued to have a positive impact on fisheries performance. To evaluate its merits, researchers often use individual unstructured case studies– there is a lack of theoretical framework to guide systematic assessments. As a result, those case studies are often too descriptive to separate the contribution of self-governance from ITQs, which is itself an effective fisheries management tool. Furthermore, the lack of theoretical framework makes it difficult to analyse data and synthesise findings. The lack of rigorous research to date, calls for systematic approaches to examine self-governance regimes and to enable better-informed judgement whether the merits of ITQ-based self-governance are being realised.

This thesis has developed three methods to systematically evaluate ITQ-based self-governance from a New Zealand perspective. In the first method, a new bio-economic model is used to project a fishery's stock status and the fishing industry's profitability. By applying a Bayesian statistics approach in the biological sub-model and a system dynamics approach in the economic sub-model, this method is able to identify the contribution of self-governance to the value of ITQs.

The second method is the Minimum Information Management System (MIMS). MIM theory is a relatively new concept to fisheries management that suggests that fish quota prices can reflect the overall status of fisheries. The theory provides a way to assess the value of self-governance because not only is it theoretically sound but also simple to apply. However, the application of MIMS is limited due largely to a number of prerequisites about the quota

system to which it can be applied. Despite the prerequisites, the theory can become a good tool to evaluate self-governance in New Zealand due to the country's high quality quota systems.

The last approach is the Indicator System (IS). Indicators have been used extensively to study the sustainability of fisheries resources. However, there is a lack of a set of indicators for self-governance in fisheries management. From the natural resource management literature, discussion has led to an indicator system and a new reference points system designed specifically to examine the merits of ITQ-based self-governance.

The self-governed Bluff oyster fishery is analysed as a case study to test the practicality of the three methods and to discover the impact of self-governance to the fishery's management. The analysis yields results that shed some light on ITQ-based self-governance. First, supporting the theoretical literature, the self-governance regime promotes economic efficiency in the fishery. In addition, ITQ-based self-governance adds value to fish stock management because of the positive relationship between profitability and stock abundance in the Bluff oyster fishery. Finally, unlike most arguments in both the theoretical and empirical literature, this thesis finds that self-governance does little for fishing environment management.

This thesis contributes to the body of literature of ITQs and self-governance in two ways. Theoretically, this thesis develops and adopts three methods that can be used to systematically evaluate the merits of ITQ-based self-governance. Empirically, by applying the three methods to the Bluff oyster fishery, this thesis facilitates a deeper understanding of the dynamics of self-governance in a real fishery.

Furthermore, based on the findings in the Bluff oyster fishery, this thesis is able to offer a number of policy implications for New Zealand's fisheries management. To a certain extent, New Zealand has promoted fisheries self-governance. Being able to evaluate the performance of self-governance is valuable to policy makers in that it enables them to determine if self-governance can elevate the performance of fisheries above the level achievable by the ITQ programme under the Quota Management System (QMS).

Keywords: Bio-economic model, Bluff oyster fishery, Fisheries, Indicators, Individual Transferable Quota, Minimum Information Management System, New Zealand, Quota Management System, Quota Owner Association, Self-governance.

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ACE:	Annual Catch Entitlement
ADL:	Autoregressive Distributed Lag regression
BOMC:	Bluff Oyster Management Company
CASAL:	C++ Algorithmic Stock Assessment Laboratory
CBM:	Community-Based Management
CPUE:	Catch Per Unit Effort
CSA7:	Scallops fisheries area 7 (the Challenger scallop fishery)
CSEC:	Challenger Scallop Enhancement Company
CSO:	Commercial Stakeholders Organisation
CV:	Coefficient of Variation
DV:	Deemed Value
EEZ :	Exclusive Economic Zone
ESD:	Ecologically Sustainable Development framework
FAO:	Food and Agriculture Organisation
GDP:	Gross Domestic Product
IS:	Indicator System
ITQ:	Individual Transferable Quota
MCMC:	Markov Chain Monte Carlo sampling method
MEY:	Maximum Economic Yield
MFish	the New Zealand Ministry of Fisheries
MIMS:	Minimum Information Management System
MSE:	Marginal Stock Effect
MSY:	Maximum Sustainable Yield
NABIS:	National Aquatic Biodiversity Information System
NEACS:	North East Atlantic Cod Stock
NIWA:	National Institute of Water and Atmospheric Research
NSSH:	Norwegian Spring Spawning Herring
NZRLIC:	New Zealand Rock Lobster Industry Council
OAY:	Open Access Yield
OECD:	Organisation for Economic Co-operation and Development
OLS:	Ordinary Least Square
ORMC:	Orange Roughy Management System
OYU5:	Oyster fisheries area 5 (the Bluff oyster fishery)
PSR:	Pressure-State-Response
QMR:	Quota Monthly Report

QMR:	Quota Monthly Report
QMS:	Quota Management System
QOA:	Quota Owners Association
SeaFIC:	Seafood Industry Council
SNA1:	Snapper fisheries area 1 (the Auckland snapper fishery)
SSB:	Spawning Stock Biomass
StatsNZ:	Statistics New Zealand
TAC:	Total Allowable Catch
TACC:	Total Allowable Commercial Catch
UBC:	University of British Columbia
UN:	United Nations
UNCLOS:	The United Nations Convention on the Law of the Sea

Chapter 1
Introduction

Fisheries management is a pressing issue. A great proportion of the world's fisheries are on the verge of collapse; there is inadequate management to protect fish stocks and generate return on fisheries resources. Studies have shown that amongst major marine fish stocks and species groups, approximately 75% are fully exploited or over-exploited (Food and Agricultural Organisation (FAO), 2002, 2004, 2007). FAO experts and many marine biologists have argued that the world's catch of wild fish is not sustainable ("The tragedy of the oceans", 1994). As a result of this unsustainable catch, it is estimated that approximately U.S. $50 billion has been lost in rent in fisheries production every year around the globe (Arnason, 2007a).

Fisheries management has long been regarded as a 'wicked problem'. In fact, the problems in the catch sector are so severe that it is often described as the 'fish war'. The war is not only fought amongst fishers in competing for fish, but also between fishers and the fisheries managers, who struggle to manage fish stock sustainably and efficiently. These conflicts create enormous pressure on catch sectors where there has been fish stock depletion, increased catch cost, increased management costs, lowered returns, ever-shorter fishing seasons, deteriorated working environment for fishers, loss in fishers' livelihoods and ecosystem degradation.

These concerns over the management of fisheries have already resulted in fishery collapse. For example, a well-known disaster of modern fisheries management is the failure of the Canadian Newfoundland cod fishery in 1993. The subsequent moratorium on the fishery after its collapse has resulted in the devastation of the 400 Newfoundland coastal communities that relied heavily on cod fishing as their main source of livelihood. In fact, a total 10,000 fishers and 12,400 plant workers lost their jobs (Gien, 2000). The cod stock has not rebuilt since the collapse and remains at an all-time low (Bundy and Fanning, 2005). Although there has been some evidence that cod stocks might be rebuilding, the population is still only a fraction of what it was half a century ago ("The World", 2010).

From a general perspective, the on-going fisheries crisis and management failure is associated with two features of the catch sector: rivalry and non-excludability. Rivalry over fish resources arise because the catching of fish by one individual reduces the availability of fish for others. This rival nature of fisheries promotes competitive behaviour amongst fishers and can result in over-capitalisation of each boat in order to out-compete rivals. The non-excludability of fish stocks means there are few barriers to prevent fishers from entering the industry and more fishers will enter the fishery with powerful gear so long as it is still profitable to do so. Together, rivalry and non-excludability lead to over-exploitation of fish stocks, fishing costs soaring and economic rents diminishing.

There is a range of fisheries management tools available to address the 'wicked' fisheries problems. This thesis investigates ITQ-based self-governance, a relatively new management instrument, as a means for fisheries management. It is aimed at contributing to the understanding of this management regime by developing and adopting appropriate methods to provide systematic evaluations. Furthermore, by applying the methods to the Bluff oyster fishery, this thesis provides a response to the question whether ITQ-based self-governance adds value to fisheries management.

1.1 Fisheries problems and management evolution: from input controls to property rights

Before ITQ-based self-governance regimes is discussed in any detail, it is important to introduce the conventional instruments for fisheries management. It is because of the inadequacy of those management instruments that the ITQ-based self-governance regime is examined to see if it is a valuable alternative.

Since the 1950s, the most frequently used regulations for the majority of fisheries are to restrict fishing activities or input controls (Arnason, 2007b; Hannesson, 1991). The well-known set of input controls includes fishing season/area closure, gear restrictions and licensing. However, these regulatory controls do very little for fish stock conservation or fishing effort control. In fact, the result of these regulations is that more fishing effort is invested to catch fish more quickly within the shortened season and to reach fishing grounds faster to out-compete rivals. Examples of such regulation failure can be found throughout the world. Jones (2003, as cited in Sporer, 2008) recorded that under a limited entry regime in the Canadian sablefish the fish season went down from 245 days to a mere 14 days.

Opposite to input controls, economists rely on the allocation of property rights to address fisheries problems. The original economic solution to fish stock depletion and rent dissipation was the sole-ownership approach introduced by Gordon (1954) and Scott (1955). Their arguments can be interpreted as all externalities are internalised when a fishery is harvested by one entity. Thus, the common resource of fisheries converts to a private good without provision or appropriation problems.

The original sole-ownership solution was later developed for fisheries co-operatives (Arnason, 2007b). Following Scott (1955), the 'Swiss Corporation', an economics school led by fisheries economists including Munro (1979) and Jones, Pearse and Scott (1980), also promoted sole-owner fisheries. However, the single owner institution was developed to include a fisher or a company that was owned by fisheries users. In other words, for the 'Swiss Corporation', fisheries management is about user co-operation.

Despite the possible effectiveness of sole-ownership in fisheries management, it was not popular in practice. Instead, a catch share scheme has been one of the most recommended management mechanisms in the field; it is used in 148 major fisheries globally as at 2008 (Costello, Gaines and Lynham, 2008). Depending on the rules of sharing the catch (*e.g.*, catch entitlement and length of the entitlement), the scheme can differ significantly from fishery to fishery. One of the most popular and familiar forms of the catch share scheme is the Individual Transferable Quota (ITQ) programme.

ITQ is an instrument that grants holders of the quota access to the fishery. Rather than granting total freedom of catch, each quota has a specific harvest rate (*e.g.*, as a percentage of the TAC). Total Allowable Catch (TAC) is the maximum catch amount in a particular fishery that is often set by the government in consultation with fishery scientists and stakeholders. The criteria for TAC setting differs. TAC can be set at the Maximum Sustainable Yield (MSY), the largest average catch that can be taken from a stock over an infinite period (*e.g.*, in New Zealand). Alternatively, TAC can be set at the Maximum Economic Yield (MEY), the average catch taken from a stock that maximises the resource rent (*e.g.*, in Australia). The quotas are normally allocated initially by the government on historical catches and might be reallocated by holders through trading or leasing.

Since it was first introduced by Christy (1973) in the 1970s, the ITQ programme has become increasingly popular in fisheries management and its impact has expanded significantly. The earliest field experiment of ITQs started from a small number of fisheries in the Netherlands and Iceland in the 1970s. New Zealand then adopted the ITQ programme in the mid-1980s to manage its commercial fisheries and became the first nation to operate a comprehensive ITQ programme for its fisheries management. ITQs have now become a major component of fisheries management systems in a number of fishing nations (*e.g.,* Australia, Canada, Iceland, New Zealand, Norway and the U.S.) managing about 15% of the world's fish catch (Arnason, 2007c).

ITQs are favoured by fisheries economists because they are designed for increasing economic efficiency and rent generation for the fishing industry. An ITQ programme has a number of benefits; the most significant is easing the 'race to fish'. Specifically, the race to fish problem is addressed with ITQs because the quota guarantees a fixed amount of catch, the holder does not have any incentive to out-compete other fishers.

However, the ITQ programme is not a universal remedy for every problem in fisheries management. The ability of the ITQ programme to meet biological goals is continuously debated. There is considerable scientific uncertainty when setting the 'correct' level of TAC due to the complexity and uncertainty of fish stocks. Moreover, the real-time management of fisheries is almost impossible for the same reason. In addition, the implementation of an ITQ programme is costly. Those costs are driven mainly by stock monitoring, administration and enforcement, which are all necessary aspects for the operation of this rights-based regime. Finally, there are perverse incentives for fishers to adopt problematic practices such as 'high-grading' and 'by-catch dumping'.

Because of the drawbacks of the ITQ programme, the latest development of fisheries management saw scholars and managers favour the Eco-based Management (EBM) system (Aswani, Christie, Muthiga, Mahon, Primavera, et al.). The EBM strives for multi-species management and accounts for environmental uncertainties (Browman and Stergiou, 2004). The most common management strategies in an EBM programme involve by-catch accounting, observation programme and fishery marine protected areas. Like most management instruments, the EBM has its own pros and cons. For example, while it is a precautionary approach that accounts for the inherent uncertainties in fisheries, it is also difficult and costly to monitor (Hofmann and Powell 1998). In 2005, the New Zealand Ministry of Fisheries outlined its approach to EBM. However, while some initiatives to deal with specific environmental issues have been put into places (*e.g.*, observer programmes and marine mammal bycatch limits), the EBM has still been reactive and uncoordinated. The EBM is not the main focus of this thesis, an overview of this management regime can be found in Curtin and Prellezo (2010).

1.2 Self-governance and ITQ-based self-governance

Since the 1990s the form of management has taken on a new direction. Governance has become a keyword in the social sciences and some authors are starting to address the governance frameworks that inform the management of fisheries. Governance has grown to embrace not only the nature of organisations (*i.e.*, the act of governing), but also the nature of relationships between organisations. Kooiman and Bavinck (2005) observed that governance perspectives have three features. First, it is believed that governing is a matter of both public and private actors. That is, though the government is equipped with laws and procedures, money and staff to undertake governing actions, it is not the only actor capable of addressing management issues. Second, the lines between the public and private actors are blurred and interests are not sharply delineated, but rather shared. Moreover, the role of the State is not so much shrinking as shifting because there is a growing awareness of the limitations of top-down governing. Third, governance is neither static nor monolithic; it is grounded in wider societal developments and may change over time.

There are two quite separate ideas about self-governance in fisheries management literature. The first definition stresses shared responsibilities between fisheries managers (usually the government) and fishery users in every aspect of fisheries management. Jentoft (1989, p. 144) defined participatory management as “a meeting point between overall government concern for efficient resource utilisation and protection, and local concern for equal opportunity, self-determination and self-control”. Following Noble (2000), communities and fishers have greater access to and control over decisions affecting local fishery resources. This access and control invokes interaction and co-operation to address political, economic and administrative functions. Additionally, these authors have argued that self-governance is often community-based and could be a substitute for rights-based management regimes (*e.g.*, licence, permits and ITQs).

The Community-Based Management (CBM[1]) regime is a form of institutional arrangement where the management responsibilities are shared between the government and fishery users (*e.g.*, Charles, 1992; Ostrom, 1990). This decentralised regime allows community members to directly access, harvest and manage the resource. Ostrom (1990, p. 56), amongst others, argued that CBM can potentially "… allocate resource units and at the same time avoid the conflict, uncertainty, and perceived unfairness of a poorly solved assignment problem, the overinvestment in appropriation efforts involved in an inadequately solved rent dissipation problem, or the deterioration or destruction of the resources involved…". Perhaps because of CBM's ability to promote income equality, this management regime has been promoted mainly by anthropologists, sociologists and political scientists (Imperial and Yandle, 1998).

Economists, in contrast, generally advocate another form of self-governance – a management regime that relies mainly on a private decision-making process rather than government involvement being part of the management force. Fishing rights (*e.g.*, licences, permits or ITQs) based self-governance falls into this category. In other words, self-governance is about users self-managing the fisheries within the existing institutions, whatever the existing management regime might be (Munro, Bingham and Pikitch, 1998; Townsend and Shotton, 2008). As Hughey, Cullen and Kerr (2000, p. 122) noted, self-governance pushes "fishers to decide on own operating regime but within a framework established by government that is applied to all fisheries". Thus, self-governance is about commercial participants making governance decisions. Ostensibly, self-governance provides incentives for the industry to increase value derived from the resource by minimising or reducing management costs.

The form of self-governance adopted in New Zealand is the ITQ-based self-governance, as opposed to CBM or permit/license-based self-governance. In essence, ITQ-based self-governance in New Zealand relates to a management structure that enables fishery users management autonomy through fisheries plans under the existing management framework. Figure 1.1 shows the institutional structure of ITQ-based self-governance, where the government sets out the overall frame of management for commercial and non-commercial fishing. On the other hand, fishery users manage the fishery through the

[1] The application of a CBM regime is not limitedto fisheries but can be used in almost all types of natural resource management including forestry, water and irrigation. See for example, Ostrom (1999) and Pinkerton (1989).

fisheries plans within the overall management regime. The ITQ management regime, as an important regime of fisheries management, provides incentives for self-governance.

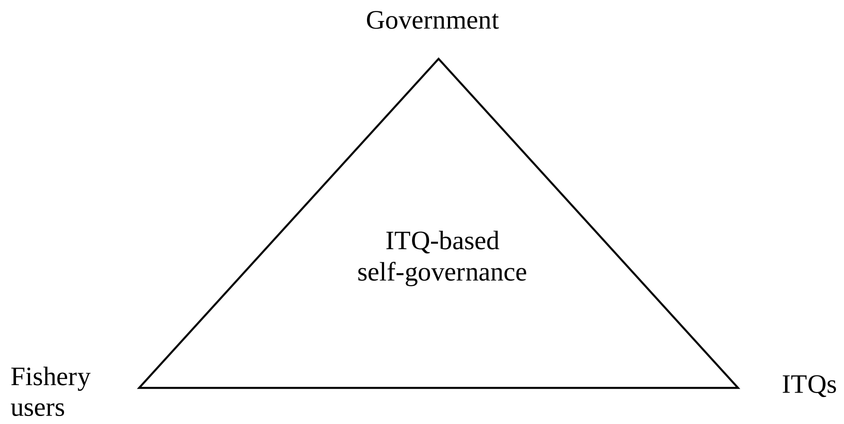

Figure 1.1 The institutional structure of ITQ-based self-governance in fisheries management

Source: adapted from Yandle (2003)

The management regime shift from ITQs to ITQ-based self-governance in New Zealand represents a reform in fisheries management. In fact, Scott (1988, 2000a) and Munro *et al.* (1998), amongst others, have argued that fishing rights naturally progress towards a self-regulated framework by rights holders. Sometimes called ‘the future direction’ of fisheries management, self-governance of ITQ fisheries is hypothesised to have three main benefits: enhanced economic efficiency, improved institutional effectiveness and greater resource and environmental stewardship. These benefits will be discussed in detail in the next chapter but in short, the self-governance regime is argued to achieve enhanced economic efficiency by arranging and managing fishing activities collectively. Institutional effectiveness is promoted by direct communication amongst stakeholders (*e.g.,* commercial users and non-commercial users and between all users and the government). Finally, self-governance is seen to contribute to fish resource and environmental stewardship because it provides users the incentives to “… deal with pollution, stock enhancement [and] habitat protection ….” (Scott, 2000b, p. 12).

However, the above arguments for ITQ-based self-governance often remain theoretical, and the empirical validity of the merits of this management regime remains debatable. It is argued that the promises of self-governance in enhancing fisheries’ performance are conditional. For example, compliance effectiveness relies largely on the legitimacy status of the self-governance institution (Jentoft, 2000a). The degree to which Quota Owner

Associations (QOAs) would go to address environmental problems is also questionable (Townsend, 2010). Possible conflicts between commercial and non-commercial interests are further reasons for pondering the merits of self-governance regimes. In addition, because the ITQs are efficient on their own, whether self-governance adds any value to the existing ITQ programme is also debatable.

1.3 Methods used to empirically evaluate ITQ-based self-governance

There is a lack of systematic evaluation of self-governance. As a consequence, there is a need for developing theory-based methods that allow an evaluation that produces a reliable outcome and enables reasoned generalisations about ITQ-based self-governance. Previous studies of this management regime have relied solely on isolated and unstructured case studies. Figure 1.2 provides a flow chart of the analysis used in the literature for empirical self-governance studies.

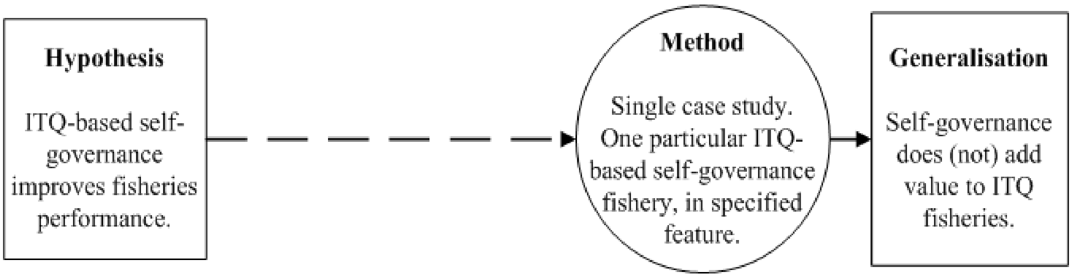

Figure 1.2 The existing methods used to empirically evaluate ITQ-based self-governance.

As discussed in the previous section, fisheries management literature has hypothesised that ITQ-based self-governance has a number of merits, *i.e.*, improving economic efficiency, institutional effectiveness, and resource and environmental stewardship (Figure 1.2, box 1). To empirically test the validity of these hypotheses, researchers have previously used the single method approach (*i.e.*, unstructured individual case studies) (Figure 1.2, circle), and then a conclusion is delivered regarding the realisation and generalisation of the potential benefits (Figure 1.2, box 3).

The case study approach to evaluate the empirical validity of ITQ-based self-governance has its advantages. Case studies can suggest hypotheses about relationships and processes (Ragin and Becker, 1992, as cited in Poteete, Janssen and Ostrom, 2010). In addition, case studies can reveal insights from different disciplinary areas (*e.g.*, economics and ecology) (Poteete *et al.*, 2010). Furthermore, case studies allow both qualitative (relying on observations and interviews, *etc*.) and quantitative (using a formal modelling or statistical approach) analysis, depending on which is more appropriate.

An unstructured case study approach alone, however, is not sufficient to evaluate the merits of ITQ-based self-governance because this approach lacks determinacy and is difficult to synthesise the findings. Indeterminacy arises when observations depend on more than one cause or hypothesis (Poteete *et al.,* 2010). In terms of evaluating ITQ-based self-governance, indeterminacy occurs because improvement of fisheries performance can be consistent with several assumptions. In particular, the ITQ programme is an efficient management tool on its own and the benefits brought about by ITQs and ITQ-based self-governance are so intimately intertwined a case study might fail to identify their separate contributions. It is important to not only study ITQ-based self-governance, but to also be able to identify the contribution from self-governance before promoting or restricting its application. Because institutional changes can be costly, there might be significant transaction costs involved as well as the potential gain or loss brought about by the new regime.

Additionally, it is difficult to synthesise findings across all case studies. This is because each case study might specialise in a different area or disciplinary divisions (Poteete, *et al*., 2010). Case studies might discover connecting relationships and new phenomena (Sekhon, 2004), but the uniqueness of each individual case study hinders the amalgamation of causal relationships. Moreover, different case studies are likely to apply different research designs, sampling methods and data collection techniques, which make comparison and synthesis difficult (Agrawal, 2002). For example, the rock lobster fishery case study (Yandle, 2008) focused mainly on the catch effort improvement, but not economic return or environmental effects. The orange roughy fishery case (Clement *et al.*, 2008) discussed the Orange Roughy Management Company's (ORMC) proposal to incorporate ecologically-friendly management, but did not document the effects of such management. Therefore, it is difficult to conclude if self-governance is beneficial for rent-generation or environmental protection.

1.4 New Zealand and the Bluff oyster fishery

Though ITQ-based self-governance can be found in several nations, it is most common in New Zealand, which is not a coincidence (Townsend, McColl and Young, 2006). First, the ITQ programme – the foundation of self-governance – is the dominant means of fisheries management in New Zealand. Furthermore, the high quality of its ITQs helps shape the co-operation of quota holders. Arnason (2007c) found New Zealand's quotas have the highest quality in terms of security, durability, exclusivity and transferability compared with the two other ITQ pioneer nations, Iceland and Norway. The importance of the four characteristics of property rights will be discussed further in Chapter 3.

In addition, the New Zealand government appears to be the only one that recognises and endorses the self-governance of ITQ-holders (Connor, 2000; Townsend, 2006). Developments, up until 2008, within the Ministry of Fisheries (MFish) of New Zealand indicated a clear trend of encouragement of this participatory regime. This included the launch of a collaborative governance research project from 2008/09 to 2010/11, the introduction of shared fisheries policy in 2006 and the preparation of a plan for every ITQ fishery by 2011 (MFish, 2008). However, toward the end of this research period (2010), the development of government facilitated devolution has changed direction. The original arrangement of developing a plan for every QMS fishery has changed into developing one plan for deepwater fishery, one plan for pelagic fishery and three for inshore fisheries. This change was brought about by the lack of outcomes from stakeholders-led plans. In fact, there have been policy inter-changes endorsing and indifferent towards self-governance over the years for New Zealand fisheries management, which will be discussed in detail in Chapter 3. Hence, it is appropriate and timely at this cross roads to consider the benefits of implementing this management regime.

As well as the policy introduction, the New Zealand fishing industry also shows a certain degree of interest in and capacity to assume fisheries management responsibilities. Perhaps the most sophisticated model of self-governance by ITQ-holders is the Challenger scallop fishery under the management of the Challenger Scallop Enhancement Company (CSEC) (Harte, 2000a; Mincher, 2008). However, the CSEC is certainly not the only successful case. Two other fisheries, the rock lobster fishery and some deepwater fisheries (orange roughy, squid and hoki) are self-governing on a wider scale (Townsend, 2010). Self-governance is also emerging in the deepsea crab fishery (*e.g.,* Soboil and Craig, 2008) and the Bluff oyster fishery (*e.g.,* Yang, Frazer and Rees, 2010).

The Bluff oyster fishery was chosen for this study for three reasons. First, the Bluff Oyster Management Plan is the only stakeholder-led plan approved by the Minister of Fisheries in recent years. Its degree and intensity of self-governance, from initial research, made it a good candidate for further investigation. Secondly, the initial analysis by Yang *et al*. (2010) called for new methods and more detailed analysis in order to examine the effectiveness of self-governance in the Bluff oyster fishery. Finally, the realisation of self-governance benefits in Bluff might provide more convincing evidence for the generalisation of self-governance benefits. This is because the Bluff oyster fishery is not the most sophisticated self-governance mode in New Zealand. Other fisheries (*e.g.*, the Challenger scallop fishery, the rock lobster fisheries and the deepwater fisheries discussed above) have more mature self-governance structures (Townsend, 2010). Therefore, the realisation of self-governance merits in the Bluff case can be more robustly generalised to other more established self-governance fisheries.

1.5 Research objective and questions

Despite the promotion of self-governance management by fishery economists and the encouragement of industry input by the New Zealand fisheries officials, study of the regime is limited. There is, to date, a lack of rigorous research that evaluates the merits of ITQ-based self-governance. For one, there is a lack of theory-based methods to assess its value to fisheries management. Secondly, and also because of the lack of analytical methods, no formalised conclusions can be drawn regarding the potential benefits widely promoted in the literature. However, if ITQ-based self-governance is to be promoted for fisheries management, the perceived opportunities attributed to this management regime must be examined carefully.

Therefore, I propose to test the premise that self-governance leads to improved economic efficiency, institutional effectiveness and resource and environmental stewardship. From this, the objective of the thesis emerges: *To evaluate the merits of ITQ-based self-governance in New Zealand.* Specifically there are two interrelated research questions from this research objective: *(1). What methods can be used to effectively assess the merits of the ITQ-based self-governance regime? (2). Have the benefits attributed to ITQ-based self-governance been realised?*

By answering these two research questions, this thesis provides two necessary contributions. First and the main contribution is that from a research point of view, there has been a lack of theory-based approaches to assess the value of ITQ-based self-governance to fisheries management. Accordingly, by answering the first research question (outline above), the thesis verifies the means by which this unique management regime can be examined. By developing appropriate methods to evaluate the ITQ-based self-management regime, a valid generalisation of it merits is made possible.

Secondly, the thesis engages in the debate that asks if strengthening property rights can improve fisheries management. By answering the second research question (outlined above), the thesis addresses the question whether moving from an ITQ programme to ITQ-based self-governance can improve fisheries management. More to the point, the question is whether this management regime is worth pursuing further. However, because only one fishery (the Bluff oyster fishery) is studied, the findings are limited and more extensive studies are needed in order to deliver a more general inference regarding this management regime.

It is clear now that this thesis seeks mainly to verify the value of this newly emerged fisheries management regime. This should be separated from the popular topic of identifying the underlying design principles of self-governance regimes (*e.g.*,Baland and Platteau, 1996; Bardhan, 1993; Ostrom, 1990, 1999). This is because, unlike the extensively studied CBM regime that embraces multi-nation and multi-resources, the study of ITQ-based self-governance is still in its infancy. Therefore, it is dangerous to assume the success of this institution without first examining it.

In addition, unlike CBM regimes that often developed from an unsuccessful management regime (*e.g.*, open-access or government regulation), there is already a successful management tool – ITQs – used in ITQ-based self-governance regimes. Therefore, it is less obvious if the ‘success’ of an ITQ-based self-governance fishery is brought about by the self-governance component or the ITQ component. If it is mainly the ITQ that contributes positively to fisheries management, the promotion of self-governance becomes unnecessary.

1.6 Organisation of the thesis

There are three main parts to this thesis. The first part, Chapters 1, 2 and 3, provides the environment in which ITQ-based self-governance is analysed. Chapter 2 critiques property rights as a means to achieve fisheries management; it sets out the theoretical background within which ITQ-based self-governance will be examined. Chapter 3 sets out the empirical background; it gives an overview of both the New Zealand fisheries management history leading to self-governance, describes the Bluff oyster fishery and its management history and presents an initial assessment of the performance of self-governance.

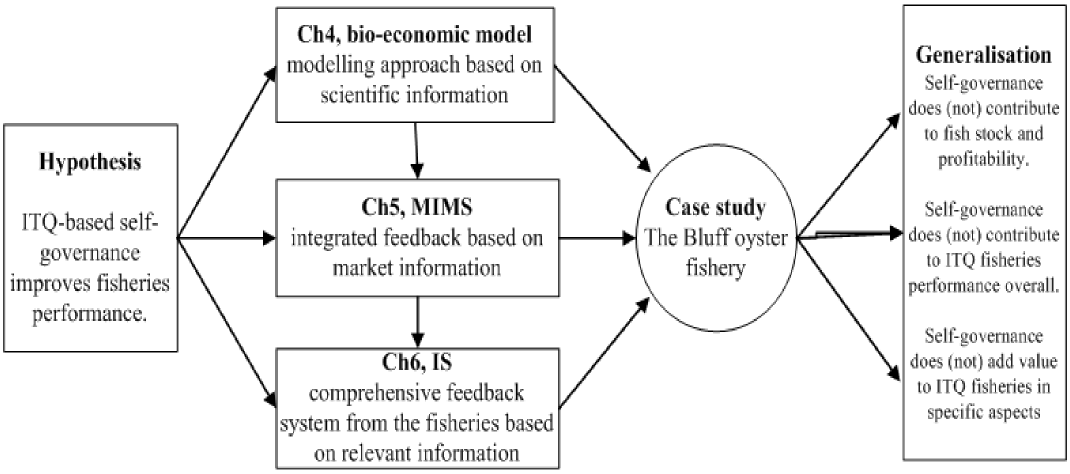

Figure 1.3 The approaches used in the thesis to empirically evaluate ITQ-based self-governance

The second part of the thesis, Chapters 4 to 6, evaluates the merits of ITQ-based self-governance. The evaluation was accomplished by applying a different method in each of the three chapters (Figure 1.3, the three boxes in the middle). In Chapter 4, a new bio-economic model is developed to estimate the stock biomass and the profitability using mainly scientific information. The chapter follows the literature review section that critiques the modelling methods used in recent fisheries research. From the literature review, the methods section outlines the available means for fisheries modelling and the modelling method used in this chapter. The case study section then applies the bio-economic model to the Bluff oyster fishery to evaluate the management of ITQ-based self-governance. The results section shows the impact of self-governance on fish stock and profit in the Bluff oyster fishery. The conclusions section provides a summary of the findings about the ITQ-based self-governance regime from the modelling method.

Chapter 5 applies the Minimum Information Management System (MIMS) to evaluate ITQ-based self-governance regimes at an integrated level using only market information (*i.e.*, the quota price). The structure of this chapter is similar to Chapter 4 in that it begins with a literature review, followed by the discussion of the method, applies the method to a case study and, finally, the results and conclusions are presented. Chapter 6, the Indicator System (IS), provides a comprehensive evaluation of ITQ-based self-governance. The IS evaluates self-governance based on relevant information about the fishery, including economic, institutional, resource and environmental performance. Thus, the benefits of self-governance can be verified separately and policy advice can be made accordingly. The structure of this chapter is the same as Chapters 4 and 5.

One case study, the Bluff oyster fishery, will be used to generate results as well as test the applicability of the three methods used in this thesis (Figure 1.3, circle). Ideally, all self-governed fisheries should be examined in order to obtain a conclusive result about the possible realisation of the merits of ITQ-based self-governance regimes[2]. However, because the degree and intensity of self-governance varies for different fisheries, studying the whole population might produce ambiguous results. In addition, time and resource limitations make studying the whole population impracticable. However, applying the three methods in a case study makes future comparative studies possible because all cases will have a standardised outcome to compare with.

The order of the evaluations, and hence the order of Chapters 4 to 6, rest on the importance of the particular area to New Zealand fisheries management, as well as the interconnection amongst the three methods. Specifically, Chapter 4 examines the benefits of self-governance on fish stock and profitability improvements. These two aspects are examined first because fish stock and profitability are the two priorities of New Zealand fisheries management. After understanding the dynamics between fish stock utilisation and conservation, Chapter 5evaluates the combined effects of self-governance on fisheries using just one piece of information. Chapter 6 provides a more detailed analysis of the merits of the management regime.

The three evaluations (methods) are also interconnected. Chapter 4 the bio-economic model provides an *ex-ante* estimation of a fishery's resource and profitability performance by simulating future scenarios. The data used in the model came mainly from scientific survey and research. Following estimation of the future profitability in the modelling approach, the positive relationship between expected future return and asset price led to the use of MIMS in Chapter 5 as a means to evaluate the performance of ITQ-based self-governance regime in aggregate. Not only is MIMS simple to apply, it relies on feedback from the market (quota price behaviour)and, therefore, can assist mitigating the scientific uncertainties in the modelling approach (Batstone and Sharp, 2008). However, it is also important to disaggregate the contribution of ITQ-based self-governance to

[2]There are 97 QMS species or species complexes (MFish, 2010b) in New Zealand, but only 28 QOAs (SeaFIC, 2009). Of all QOAs, some are general QOAs (such as Fishing Vessel Owners' Association, New Zealand Federation of Commercial Fishermen, NZ Fishing Industry Association Inc., NZ Fishing Industry Guild, and New Zealand Seafood Retailers and Wholesalers Association Inc.) rather than QOAs for specific fisheries management.

provide a complete review of the value of this management regime. Chapter 6, the IS approach, provides an *ex-post* investigation to assess the most relevant aspects of fisheries management. The IS uses historical data collected from the fishery. Hence, the three methods together evaluate ITQ-based self-governance looking back and looking forward, and in aggregate and disaggregate.

The final part of the thesis, Chapter 7, provides conclusions about the three methods developed to evaluate ITQ-based self-governance (research question 1) and the value of this management regime to fisheries management (research question 2). The concluding chapter also includes research and policy implications of the findings. Finally, the limitations of this research and future research opportunities are also discussed. The research limitations point to future research directions to further validate the evaluation of ITQ-based self-governance. Some preliminary suggestions are provided about the methods that can be applied and the scope of the evaluation that can be pursued.

Chapter 2
A critique of property rights for fisheries management

2.1 Introduction

In Chapter 1, the objective of the thesis to evaluate ITQ-based self-governance in New Zealand was stated. In this chapter, the flaws and merits of the ITQ-based self-governance regime will be discussed. First, ITQ-based self-governance will be discussed within the larger literature on self-governance (license-based and community-based *etc*.). This discussion will unfold the uniqueness of ITQ-based self-governance against other forms of self-governance. It will become clear that ITQ-based self-governance is not a branch of the well-known Community-Based Management (CBM) and hence, should be studied separately. Secondly ITQ-based self-governance will be discussed within the context of property rights – especially ITQS – as a means to improve fisheries management. A critique of property rights will reveal the benefits of ITQ-based self-governance over ITQs. The review of the main debates over property rights in fisheries management sets the evaluation of ITQ-based self-governance in the wider fisheries management discussion – is strengthening property rights, *i.e.*, from ITQ to ITQ-based self-governance, beneficial?

This chapter is arranged as follows: Section 2.2 discusses ITQ-based self-governance and other forms of self-governance. Section 2.3 discusses the theory of open access and three property rights regimes – sole-ownership, ITQs and ITQ-based self-governance. The perverse outcome from the theory of open access is the foundation for promoting property rights. The discussion of sole-ownership elaborates the economic origin for turning an open access resource into a private property. It is followed by a critique of the ITQ programme (merits and flaws). The ITQ programme is the foundation from which ITQ-based self-governance emerges and is the reference point against which ITQ-based self-governance should be compared. Finally in this section, the ITQ-based self-governance discussion provides a rich analysis of the merits and flaws of this management regime. This discussion reveals that the ITQ-based self-governance regime retains the merits, but reduces the flaws of the ITQ programme.

Section 2.4 discusses the optimal extinction theory, and the policy implication derived from the theory is the possible failure of property rights allocation and the need for government intervention. If the theory of open access in section 2.3 emphasises the reason for advocating property rights, this section highlights the economic rationale for opposing property rights allocation alone. Following optimal extinction theory, government intervention becomes a necessary part of a fisheries management regime. Then, departing from Section 2.4, Section 2.5 provides the recent theoretical developments that contradict optimal extinction theory and the relevance of those findings for the use of private property rights in fisheries management. This theoretical development 'echoes' the open access theory and calls for strengthening of property rights. Finally, Section 2.6 offers conclusions about the knowledge of property rights for fisheries management and the relevance of property rights for the application of ITQ-based self-governance.

2.2 ITQ-based self-governance and other forms of self-governance

This section discusses ITQ-based self-governance within a wider literature on self-governance, especially on Community-Based Management (CBM). After reviewing this literature, it will become clear that ITQ-based self-governance has its own merits and demerits. It is because of those unique characteristics that ITQ-based self-governance aids the management of fisheries in certain areas.

The two main self-governance forms in fisheries management, as briefly discussed in Chapter 1, are CBM and ITQ-based self-governance. Some writers, mainly non-economic social scientists, have argued extensively against the use of ITQs and other rights-based instruments. They have, in the meanwhile, promoted CBM as a better management regime (*e.g.,* Baland and Platteau, 1996; Bardhan, 1993; Ostrom, 1990). Their main argument is that economic efficiency and rent maximisation are only two aspects to fisheries management, along with other (arguably more important) considerations (*e.g.,* resource conservation, employment and distribution of rent) (Copes 1986; Copes and Charles, 2004; Scott, 1988). Consequently, CBM is promoted because it is considered to be able to manage fisheries from many more angles, not just economic-focused ones.

However, the set-up purpose of the two regimes is different. Briefly, CBM and ITQ-based self-governance are applied for different management purposes; the former is a social planning tool for equitable utilisation of fishery resources and the latter is an economic instrument for efficiency enhancement in the catch sector. Imperial and Yandle (1998) argued that a CBM regime rests on the purpose of handing control of the resource to the community. The focus of fisheries management is on the fisheries social and biological performance (Agrawal, 2002). On the other hand, a market-based regime is created to generate wealth for the fishing industry. It centres on achieving economic efficiency while keeping the catch sustainable.

Specifically, when evaluating management regimes, the goal of management should be used as the standard to measure its success. CBM might be a better choice when a balance needs to be achieved for the livelihood of fishing communities (*e.g.*, Ostrom, 1990; Yamamoto, 1995). For that reason, CBM is commonly seen in less developed regimes where fisheries are the only life line of coastal communities. Under such a situation, central planning for job security and income equality are indeed important. However, in choosing CBM, because the goal of fisheries management is to balance every aspect of fisheries management, economic efficiency might be compromised to make up for employment or stock conservation.

In contrast, ITQs might be preferred if fisheries are seen as one part of the economy. That is, the fishing industry is similar to every other sector in which productivity and efficiency are relevant priorities to contribute to the welfare of a region. Therefore, private rights are more commonly seen in developed nations and their commercially significant fisheries (*e.g.*, Arnason, 1996; Grafton, 1996). Furthermore, in those ‘developed’ and ‘rich’ regions, human resources are relatively more malleable because there are more opportunities outside fisheries and more social security. Those relatively advanced social conditions might provide some compensation for the loss of social aspects (*e.g.*, employment) of fisheries management.

Even for fisheries in developed areas, there still needs to be a relative balance between all factors (*e.g.*, the sustainability of the resource and distribution of rents). Rights-based management regimes can provide a satisfying outcome for these considerations. With respect to stock conservation, there can be a ‘win win’ situation where economic rents are maximised and fish stocks are protected. Grafton, Kompas, Chu and Che (2010) demonstrated that there are situations where profit-maximisation requires more abundant stock (*i.e.*, $B_{\mathrm{MEY}}>B_{\mathrm{MSY}}$). In terms of income distribution, the QMS in New Zealand imposes a quota limit to any individual of 20% maximum holding of the total quota for any single species. This limit can help prevent monopolisation in fisheries. Thus, the rights (*e.g.*, ITQs) might be economic-focused, but there can be added regulations within the rights system (*e.g.*, the QMS) to achieve specific management goals.

Therefore, the choice between ITQ-based self-governance and CBM depends on the management objectives. Market-based instruments are preferred if economic performance is desired as the objective because efficiency improvements brought about by such a regime will be evident (*e.g.*, Annala, 1996; Arnason, 1996; Eythórsson, 2003; Grafton, 1996). In contrast, CBM might be preferred if social and biological performance is the emphasis, where distributional equality and social security are the top two priorities in the management of the natural resource (*e.g.*, Ostrom, 1990, 1999; Ostrom, Gardner and Walker, 1994). Therefore, modern capitalist fishing nations are more likely to be better off by choosing a market-based instrument. This is because, in those nations, the fishery are more likely to be regarded as a 'normal' industry that is similar to any other sector in which production efficiency is one of the key objectives of management. On the other hand, small developing fishing nations might be better off with CBM, where the fisheries are more likely to be the life line for their coastal communities. In those countries, sustainability of the fish resource provides both dietary needs and social security.

Apart from the different management goals, compared with other forms of self-governance (*e.g.*, CBM, permit-based self-governance or license-based self-governance), an ITQ-based self-governance regime has its unique advantages. That is, the predetermined catch-distribution mechanism makes ITQ-based self-governance more stable. In a self-governance regime based on an ITQ programme, individual output is prearranged by the distribution of the quota-holdings of individual members. On the other hand, in a CBM regime or license-based self-governance regime, other rules of distribution or negotiation are required to share the catch (Clark, 2006). For example, in the West and Central Pacific tuna fishery – a shared high-sea fishery – the stability of co-operation amongst fishing nations is based on a number of prerequisites including: member fishing nations are involved in management; the majority of users accept the total harvest rates; and all members have a long-term interest in the resource (Chand, Grafton and Petersen, 2003). If any one of these conditions is not met, instability can occur where individual members pursue their own interests.

Furthermore, in the event of the collapse of co-operation, ITQ-based self-governance provides double security to safeguard the fishery. That is, the benefits of ITQs will still stand even if self-governance fails. Other self-governance regimes might stand a similar chance of success, but they do not have a back-up plan if user co-operation fails. For example, Basurto and Coleman's (2010) study found that for the Mexico pen shells fishery, small changes in the ecological carrying capacity can affect the success of a collective action. Even in a long-lived CBM regime, the resource might be abused if the community perceives a loss of management control (Baland and Platteau, 1996). A similar argument applies to the license-holders' self-governance. If co-operation collapses, the fishery will go back to licensed management and still suffer from the drawbacks of a licence system, which is ineffective in preventing stock over-exploitation and capital-stuffing.

2.3 ITQ-based self-governance and its foundations

After establishing the uniqueness of ITQ-based self-governance in the last section, this section explores the origins of this management regime in order to gain a better understanding of its benefits. ITQ-based self-governance has its root in property rights, ITQs in particular, for fisheries management. It evolves from ITQs and hence assumes its advantages while mitigating some of ITQs' disadvantages.

The earliest discussion of the economics of fisheries management by Gordon (1954) and Scott (1955) promoted sole-ownership – a complete property right; Christy (1973) introduced a quota system – a quasi-property right; and Scott (1988, 2000a, b), and other economists (*e.g.*, Munro, 1979; Jones *et al.*, 1980; Munro *et al.*, 1998; Arnason, 1990, 2000; Townsend and Shotton, 2008) endorsed quota owner co-operatives – a system in between sole-ownership and quotas.

Gordon's (1954, p. 131) seminal work reduced fishery problems to the open access nature of fisheries: "in the sea fisheries the natural resource is not private property … Each fisherman is more or less free to fish wherever he pleases". Hence, in order to beat catch rivals, excess fishing effort is invested. This, in turn, leads to a 'lose lose' situation, where fish stocks are over exploited and economic rents are dissipated.

Gordon's (1954) single species Gordon-Schaefer bio-economic model provided a general intuitive explanation of the dynamics between fish populations and fishing activities. In the model, sustainable fishing activity is given by:

$$Y_s = AE - BE^2 \tag{2.1}$$

Where $A = qK$ and $B = q^2K/r$,

Y_s is the sustainable harvest,

q is the catchability coefficient,

E is the harvest effort,

K is the carrying capacity of the fishery, and

r is the intrinsic growth rate of the fish stock.

The economics of fishing activity is given by:

$$TR(E) = Y_s p = (AE - BE^2)p \tag{2.2}$$

$$TC(E) = eE \tag{2.3}$$

Where TR is the total revenue,

p is the price of the harvested fish,

TC is the total cost of catch effort, and

e is the cost per unit of effort.

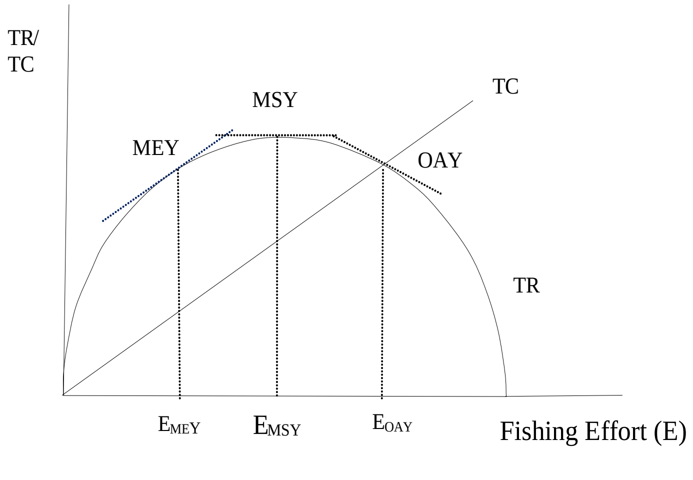

Figure 2.1 Sustainable revenue and cost of fishing effort.

Source: adapted from Gordon (1954)

Presenting Equations 2.1 to 2.3 graphically with a logistic fisheries population growth function, Figure 2.1 shows the relationship between rent and fishing effort; economic rent is maximised at Maximum Economic Yield (MEY), when fishing effort $E = E_{MEY}$ (*i.e.*, marginal cost equals marginal revenue). Suppose an open-access fishery starts at E_{MEY}, the abnormal profit attracts new fishers into the fishery, therefore increasing fishing effort (Gordon, 1954). As fishing effort increases, more fish are caught, but the MSY level of effort yields the greatest amounts of fish and still provides supernormal profits to fishers. Perfect competition and the zero profit theorem predict that the effort level would increase to Open Access Yield (OAY), where total cost meets total revenue and the resource rent is fully dissipated.

The Gordon-Schaefer model implies that fisheries may be in equilibrium at a sustainable level, at point OAY in the diagram, where total revenue equates to total cost and normal profit is earned. However, Gordon (1954) argued that the actual fishing effort could go beyond E_{OAY} for two reasons. First, most fishers are economically immobile. Not only are they specialised in fishing, they lack the savings needed to make other investments and they also are 'romantically' involved with the sea. In addition, fishers' optimism, believing in the next lucky catch, leads to over-investment in fishing effort. Therefore, the fish stock may be prone to collapse and fishers may earn less than normal profit if fishing effort does not cease at E_{OAY}.

However, the above Gordon-Schaefer bio-economic model does not represent all fisheries. The model uses the Schaefer biological model to depict the fishery's biological dynamics; it is not suitable for every fish type. This is because the Schafer biological model is a 'general production' model where all fish population variables (*e.g.*, natural growth and mortality) are combined into one variable called the intrinsic growth rate (*r*). Hence, this type of biological model ignores the possible different sub-stock dynamics and makes population estimation less robust. There are other biological models, such as the Beverton-Holt model (Beverton and Holt, 1957) and Ricker model (Ricker, 1958), that might better estimate the stock-recruit relationship for some stocks. The general application of various types of biological models will be elaborated further in Chapter 4. Despite its shortcomings, the Gordon-Schaefer model has been used frequently in capture fisheries (Bjørndal and Munro, 1998) due to its explanatory power as a generic fisheries model. Therefore, the possible stock over-exploitation and rent dissipation outcome depicted by the model remains insightful and should not be ignored.

Corresponding to the theory of open access resources, the very first solution to fisheries problems is to assign property rights or appoint a rent appropriator. Gordon (1954, p. 132) suggested that fisheries should be managed "... under a form of social control that turns the open [access] resource into property rights". With property rights, fish in the ocean are turned into private property, like a piece of land, so that fisheries are no longer an open access resource.

Scott (1955) further developed Gordon's (1954) property rights solution. He argued that private property rights alone would not solve the problem, but sole-ownership would do so. This is because, though competition makes rights holders focus on short-run profitability, the sole-owner operates in a non-competitive environment, which enables the potential maximisation of long-run profit. In addition, the sole-owner's rent-generating behaviour can promote stock conservation. Figure 2.1 implies that the level of catch to achieve MEY is always less than MSY and B_{MEY} (the biomass that supports MEY) is greater than B_{MSY} (the biomass that supports MSY). In fact, this profit maximisation and stock conservation 'win win' situation might be the key for advocating the sole-ownership solution.

However, Scott's (1955) argument for sole-ownership was valid at the time when property rights were not adequately defined. The competition amongst rights holders depicted in Scott (1955) implied that the property rights might not be secure or permanent. More importantly, the fact that each boat is able to increase production according to its needs indicated that the property right in Scott's study did not limit individual output. Having the advantage of hindsight, security, duration and individual output restrictions are essential attributes for well-defined property rights. Therefore, given the improvement in understanding of property rights since the 1950s, the solution to fisheries problems should no longer be about the number of rent appropriators (Arnason, 2007b), but about the quality of the property rights.

In economics, a property right is required to possess the following characteristics: duration, quality of title, transferability, exclusivity and divisibility (Arnason, 2007c; Scott, 1988, 2000b). Each characteristic has its application and is indispensable. Only titles with well-grounded private property rights characteristics can benefit management (Grafton, 1996).

Durability refers to the time length of the rights. If rights are issued for a limited duration, the owners are likely to only maximise their profit within that duration. In contrast, if the right is permanent, holders are more likely to consider the long-term interests of the fishery, which coincides with the social interest to manage the resource in a sustainable manner (Arnason, 2007c). Therefore, permanent rights allow fishers to plan for the future, thus changing their fishing behaviour and being more conscious about the fish resource and perhaps the fishing environment.

Quality or security refers to the certainty of rights owners to maintain their rights under any situation. Uncertainty is especially great when the title is not defined properly under the law, which leaves the holders vulnerable to the possibility of losing their rights. Insecure property rights might force owners to increase production at the initial stage (Arnason, 2007c). This rush to fish spoils the original intention of rights to enable fishers to allocate their fishing effort more efficiently. Furthermore, uncertainties about future fishing activity can also lead to irresponsible fishing practices and the abuse of fish stocks and the fishing environment.

Transferability refers to the tradability of property rights as an asset. Often, divisibility is necessary to facilitate transfer if only a part of the right is exchanged (Scott, 2007). Transferability is widely argued by economists to be the key to achieve economic efficiency because it facilitates the optimal allocation of the resource. The reason is that if a positive fee is attached to the rights, theoretically, the rights can be transferred to the most efficient users who value the resource the most. Simply, fishers who can earn a positive return by acquiring one more unit of the right will keeping purchasing until the return vanishes, whereas the converse holds true for fishers who can earn a positive return by selling one more unit of the fishing rights.

The last characteristic of property rights, exclusivity, refers to the rights holders' ability to exclude others from extracting the resource. Without exclusivity, rights-holders will find themselves facing an open access situation, where property rights become redundant. On the other hand, exclusivity accompanied by durability grants fishers the certainty and freedom to catch the allocated amount of fish. Hence, this removes excess fishing effort in the fishery (Grafton, 1996). Unfortunately, even with well-defined property rights (*e.g.*, ITQs in New Zealand), exclusivity is limited. The property rights might protect quota owners against other commercial fishers, but not other non-commercial users such as recreational fishers (Scott, 2007; Townsend, 2006).

2.3.1 Individual Transferable Quotas

The sole-ownership solution has not been accepted in practice because fisheries are public resources and it is politically impractical to assign the fisheries to any single owner as a private property. However, quasi-property rights – the Individual Transferable Quotas (ITQs) – were first introduced by Christy (1973) to address the unsolved economic rent dissipation problems in fisheries management. Generally speaking, ITQs are not strict private property rights. Rather, ITQs are harvesting rights that grant the holders access to the fishery. That is, they are not rights to the fishery resources altogether. Instead, each quota provides a mandate for a specific harvest rate. Hence, ITQs are designed to function as property rights.

The nature of each individual ITQ programme can vary significantly due to differences in the characteristics (security, durability, exclusivity and transferability) of the quota. Arnason (2002) noted that there are a great number of different ITQ programmes around the world. Arnason (2000, 2007c) rated fisheries ITQs based on the four property rights characteristics. Each of the four characteristics was assigned a nominal value, using a scale from zero to one, zero being the lowest and one the highest. Accordingly, a property rights system can provide benefit to fisheries management if all four characteristics are well embodied in the fishing quotas (*i.e.,* the closer to 1 each trait is, the more effective the rights programme becomes). Similarly, Connor (2000) identified five main types of ITQ programmes. Ranking from the ITQs that more closely resemble property rights to those that resemble property rights the least, those five types of ITQ programmes are the 'Fully Privatised Fisheries Model', the 'Property Rights in Fishing Model', the 'Quantified Licence Model', the 'Revocable Privileges Model' and the 'To Hell With the Model'.

Combining Conner's (2000) property rights types and Arnason's (2000, 2007c) rating, Figure 2.2 depicts the five types of ITQ programmes by their characteristics and their abilities to address fisheries management issues. The four characteristics are measured on the two axes and the ITQs ability to manage the fisheries is represented by the area in the centre of the figure (*i.e.,* fish stock protection and rent generation). An important point to note is that the positions of the four property right characteristics on the map are arbitrary and the relative positions of the management regimes are deliberate.

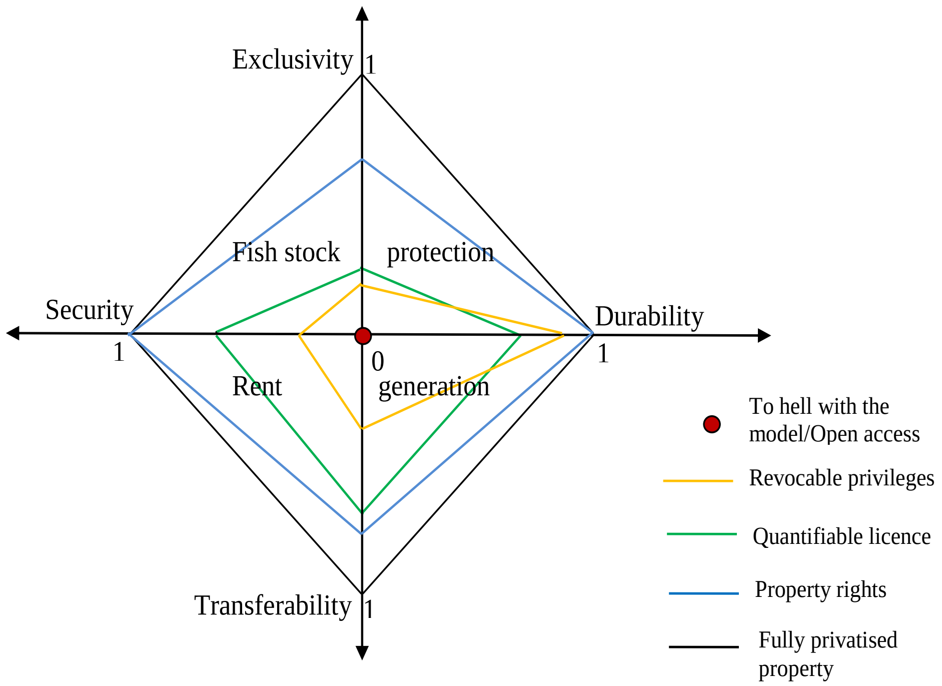

Figure 2.2 The quality map of ITQ programmes in fisheries management according to their property rights characteristics.

Source: adapted from Arnason (2007c, p. 36) and Connor (2000)

The black diamond in the figure represents the 'Fully Privatised Property' ITQ model, the rights grant the holders the right to certain fisheries resources, the habitat and the right of management (Connor, 2000). In fact, the rights under such a definition are no longer the right to property (*i.e.*, the use of property), but are actual private property, like a piece of land. Therefore, the rights are perfectly secure, permanent, transferable and excludable. Under this type of rights system, according to the zero profit theorem, the fishery can achieve full efficiency if the market is competitive. The sole-ownership discussed in Scott (1955) resembles this model. However, no fisheries are known to be managed under this model. Seldom, if any, ITQ programmes in practice are perfect and, therefore, the effectiveness of real ITQ programme will not be perfect.

The blue diamond in Figure 2.2 represents the 'Property Rights Model'. This type of rights are the actual 'property rights' and the quotas possess the characteristics of property rights – secure, permanent, transferable and divisible (Connor, 2000). However, the quotas still grant the owners only a share of fish stock, but not the fisheries resource.

This type of ITQ programme can be found in New Zealand (Connor, 2000), whereby the quotas are defined as property rights by the Fisheries Act 1996. Arnason (2000, 2007c) argued that New Zealand ITQs have perfect security, durability and transferability, as defined in the Act. However, the transferability of the ITQs might be hindered by the nature of the underlying fishery, because the quota demand for commercially insignificant fisheries can be small. In such cases, the transferability/tradability of ITQs is often less than perfect, as indicated in Figure 2.2, the transferability being placed lower than 1. Similarly, New Zealand ITQs are not perfectly excludable because there are other non-commercial fishery users who are able to access the fishery resource without the permission of the quota holders. Although less than perfect, this type of ITQs can still provide freedom to fish and, therefore, promote fish stock conservation and rent generation.

The green diamond in Figure 2.2 represents the ‘Quantified Licence Model’. The holders of this type of ITQs are granted a certain share of the catch and the titles may be transferred or divided. However, security is still an issue because they can be confiscated without compensation (Arnason, 2002; Connor, 2000). Connor (2000) argued that the Australian ITQ programme has these qualities. Although the characteristics of ITQs in Australian fisheries differ hugely, their ITQs are generally treated as property rights by courts with certain security (Kaufmann *et al.*, 1999, as cited in Arnason, 2002).However, the ITQs are not permanent and need to be renewed with a fishing licence (Arnason, 2002). Because this type of ITQ programme more resembles property rights, it might provide more incentive for fishers to protect fish stock and promote economic efficiency.

The orange diamond in Figure 2.2 represents the four characteristics of the ‘Revocable Privileges ITQ model’. In such a system, the rights are a form of revocable privileges to use a resource that belongs to the general public (Connor, 2000). Defined as such, the rights do not provide a secure title of use of fisheries resources. Therefore, rights holders might still race to fish out of the fear of losing the title unexpectedly. The ITQs used in fisheries found in the U.S. closely resemble this type of model (Connor, 2000). Arnason (2002) noted that the ITQs in U.S. fisheries are reasonably durable, but they are not secure because they are revocable. In addition, the ITQs’ transferability is limited under the U.S. fisheries regulations. Furthermore, because the quota holders are merely one group of fishery users, the ITQs cannot exclude other users who share the fishery resource. Because the property rights characteristics of this type of ITQ programmes are weak, they might not be able to achieve the desired results for fish stock protection and rent generation.

The open access or ‘To Hell with the Model’ model is represented by the red dot in Figure 2.2. Strictly speaking, there are no property rights in this type of programme. Open-access is the preferred ‘management’ method of fisheries (Connor, 2000). The fishery is indeed open access if there are no imposed regulations. In such a regime, fishers do not have any incentive to protect fish stocks or the freedom to allocate fishing resources efficiently. Fish stock degradation and economic rent dissipation are likely as fishers compete with each other.

Depending on the quality of the ITQs, they can provide a number of benefits to fisheries management with different effects. In particular, the ITQ programme that resembles a property right the most is likely to benefit fisheries management the most. The ITQs in New Zealand fisheries are defined as property rights by law and have the full set of characteristics as property rights (Arnason, 2000a, 2007c; Connor, 2000).The claimed advantages of such ITQs include that they can promote economic efficiency, simplify management institutions and support fish stock sustainability.

2.3.1.1 ***Advantages***

Perhaps a less controversial advantage of ITQs is their economic benefit. Christy (1973) argued that fishing quotas could encourage innovation to reduce fishing costs. It is because the quota guarantees a fixed amount of catch in relation to the TAC and the security of a certain portion of fish catch, quota-owning fishers have the freedom to minimise fishing costs and choose to operate in the most cost effective way (Hersoug, 2002; Townsend, 1995).

There is empirical evidence of ITQs’ success in improving fisheries’ economic performance because of the easing of the ‘race to fish’. Newell, Sanchirico and Kerr (2005) found that between 1990 and 2003, the asset value of New Zealand ITQ fisheries more than doubled. In terms of profitability increasing, there was substantial profit improvement in both the Australian bluefin tuna fishery (A $6.7 million) and Icelandic fishery (US $15 million) only one year after implementing the ITQ programmes (Eythórsson, 2003).

As well as eliminating the incentive for ‘race to fish’, the catch sector’s economic efficiency is also enhanced by quota transferring from less-efficient fishers to more-efficient fishers. Grafton (1996) found that vessel numbers reduced relatively quickly in a number of Canadian ITQ fisheries. McCay *et al*. (1995) found a dramatic drop in boat numbers in the two fisheries they investigated (the U.S. surf clam and ocean quahog and the Canadian Under 65' mobile gear groundfish fishery).

However, ITQs’ ability to achieve consolidation does not apply to all ITQ fisheries. In New Zealand, Annala (1996) found that the quota concentration ratio did not decrease but fluctuated for the 10 years of the ITQ programme between 1987 and 1996. The lack of quota consolidation might be explained by the inflexibility of vessel usage and fewer employment opportunities outside the fishing industry in New Zealand (Lindner, Campbell and Bevin, 1992). In fact, there was a 17% increase in the number of vessels between 1987 and 1995 (Batstone and Sharp, 1999). Part of the increase, Batstone and Sharp suggested, was attributable to the replacement of foreign vessels by domestic ones. However, recently, there has been a drop in New Zealand domestic vessel numbers in the deepwater fisheries (*e.g.*, snapper and ling) (Henderson, 2011).

The reason for vessel consolidation, however, is debatable. The buy-out of high-cost fishers can be one reason. In addition, Grafton (1996) suggested that whether the consolidation occurred depended on the characteristics of the fishery: smaller and older vessels might be more cost-effective because of lower fixed costs. Furthermore, in the New Zealand deepwater fisheries, domestic vessels were replaced by foreign vessels because of their cheaper labour (Henderson, 2011).

Not only boat numbers, but employment in fisheries can reduce due to quota concentration because fewer vessels remaining in the fishery means fewer employment opportunities. There was evidence of a shrinking labour force in the U.S. surf clam and ocean quahog and the Canadian Under 65' mobile gear groundfish fishery (McCay *et al.*, 1995). In contrast, employment in the New Zealand ITQ fisheries expanded between 1990 and 1995 (Batstone and Sharp, 1999). Although most of the increase was in the processing sector, the numbers employed in the catch sector did not decrease as predicted by ITQ theory. However, the increase in employment was consistent with the increased number of vessels in New Zealand.

In addition to the above discussed economic benefits, an ITQ programme can also provide savings in administration. Crothers (1988) and Arnason (1990; 2007c) claimed that, if properly designed, the ITQ programme can minimise the need for government intervention and regulation. This is because when ITQs are compared with traditional input control fisheries, ITQs provide a specified harvest volume that can reduce the externalities associated with irresponsible fishing behaviour that occurred when fishing was regulated. For example, fishers might avoid the use of destructive fishing gear if they were not competing with other fishers. Hence, it is not necessary to restrict fishing gear.

However, there are opposing views about institutional requirements. Scott (1988) argued that ITQs require continuous regulation. Experience with ITQs in New Zealand agrees with Scott's (1988) prediction. Annala (1996) concluded that there was more government intervention with the ITQ programme than without it. Particularly, there was still a need for traditional input controls (*e.g.*, closed season/area, gear restriction) and new regulations relating to monitoring and enforcement of the ITQ regime are often required. This is because there are still incentives for fishers to exercise practices such as high-grading and by-catch discarding that require government monitoring.

ITQs are also believed to be able to maintain fish stock sustainability. In fact, the ability to maintain a sustainable yield is one of the advantages proposed by Christy (1973). Fish stocks might be preserved because only a fixed number of fish (*i.e.*, TAC) is allowed to be caught annually. Furthermore, regulators can adjust the stock level by adjusting TACs. Decreasing TACs will help stock rebuild and *vice versa*. However, Dewees (1998 p. s133) noted "the role of individual quotas in sustaining marine fisheries continues to be hotly debated". Hersoug (2002) argued that the TAC amount set is not necessarily sustainable because of the complex dynamics of fisheries and the infeasibility of real-time management.

Field results about stock conservation in ITQ fisheries are indeed mixed. In the two surveys conducted in New Zealand in 1987 and 1995, more than half of the ITQ fishers saw ITQs as beneficial for stock conservation (Dewees, 1998). Newell *et al*. (2005) examined the general condition of the New Zealand fisheries and found ITQs to be beneficial to stock rebuilding. In contrast, in Iceland, Arnason (1996) found that ITQ management was not beneficial for the stock rebuilding in the capelin fishery.

2.3.1.2 ***Issues***

Although ITQs can improve economic efficiency for fisheries, the efficiency gain from an ITQ programme is not optimal. The second-best economic efficiency issue of the ITQ programme is not its shortcomings relative to other approaches (*e.g.,* licensing or taxation), but is a limitation borne within the system. Grafton (2000) argued that though private rights managed to secure a share of the resource flow to the users, this partial claim about the flow as opposed to the stock, is not sufficient to eliminate all stock externalities.

Specifically, ITQs are not fully efficient due to stock and congestion externalities incurred during production, which can lead to cost-increasing behaviour (Boyce, 1992). Stock externalities occur when the productivity of one unit of effort correlates with stock abundance. Congestion externalities occur when the Catch Per Unit Effort (CPUE) in one location is correlated with the total amount of effort being applied. ITQs cannot address those two externalities because fishers do not internalise those externalities when fishing, therefore fishing effort in the fishery will not be optimised to maximise profit.

Mathematically, this stock externality induced economic inefficiency can be shown as the follows.

The objective for fisheries management is to maximise the economic value of the fishery:

$$Maximise V = \int_0^{\infty} \sum_{j=1}^{N} y_j(E_j(t), E_{-j}(t), x(t))\, dt \qquad (2.4)$$

Where V is the economic value of the fishery,

y is production,

E is the fishing effort,

x is the fish population biomass, and

N is the total number of firms in the fishery.

If the individual company's objective is to maximise the value of its quota holdings, that is:

$$Maximise v_i = \int_0^{\infty} (p \cdot y_i(E_i, E_{-i}, x) - C_i(E_i(\alpha_i \cdot Q, x) - s \cdot z_i) \cdot dt \qquad (2.5)$$

Subject to (a) $\alpha_i' = - y_i(E_i, E_{-i}, x) + z_i$ (2.5.1)

(b) $\alpha_{-i}' = \sum_{i \neq j}^{N} y_i(E_i, E_{-i}, x) - z_i$ (2.5.2)

Where *i* denotes company *i*,

p is the price of catch and $p > 0$,

y is production,

E is the fishing effort,

x is the fish population biomass,

$C(.)$ represents the harvest costs,

α is quota share,

Q is the total catch quotas in the fishery,

$p \cdot \alpha(i) \cdot Q$ represents the revenue received by the *i*th company,

s is the instantaneous quota price,

z is the amount of additional quota acquired,

$\alpha(-i)$ is rest of the quota share

N is the total number of firms in the fishery, and

j is one of the remaining firms in the fishery.

To solve this maximisation problem, a current value of the Hamiltonian function is established as:

$$H_i = (p - v_i) y_i(E_i, E_{-i}, x) - C_i(E_i(\alpha_i \cdot Q, x) - s \cdot z_i - v_{-i}\left[\sum_{i \neq j}^{N} y_i(E_i, E_{-i}, x) + z_i\right] + v_i z_i \qquad (2.6)$$

The necessary conditions of Equation (2.5) with respect to x_i and z_i are:

$$\frac{\partial H_i}{\partial x_i} = 0,\ i.e., (p - v_i)\frac{\partial y_i}{\partial x_i} = \frac{\partial C_i}{\partial x_i} + v_{-i}\sum_{i \neq j}^{N}\frac{\partial y_i}{\partial x_{-j}}, \text{for } i = 1, \ldots, N, \qquad (2.6.1)$$

$$\frac{\partial H_i}{\partial z} = 0,\ i.e., s = v_i - v_{-i}, \text{for } i = 1, \ldots, N. \qquad (2.6.2)$$

Boyce (1992) showed that one of the necessary conditions for maximising the social economic value of the fishery (Equation 2.4) is:

$$s = p \qquad (2.7)$$

However, the goal of social economic value maximisation (Equation 2.4) cannot be achieved because the equality between the instantaneous price of quota (s) and output price (p) (Equation 2.7) is not valid. In fact, in order that the quota buyer profits from one additional unit of quota, the purchasing price of that unit of quota (*s*) must be less than the output price (*p*) resulting from the purchase. This is because the additional catch cost will incur extra to the cost of the quota; the equilibrium condition is $s + c = p$.

As well as the inability to achieve the first-best economic outcome, the implementation of ITQs is costly. Christy (1973) anticipated a large management cost that was mainly driven by research costs. This occurs because TACs set by the government for each species every year requires extensive resources in information gathering and analysis. The enforcement of quota limits also contributes to the high management costs of ITQ implementation. Enforcement of ITQ regulations is the foundation of a successful ITQ programme (Grafton, 1996) because the implementation of ITQ programmes does not automatically eliminate non-compliance behaviour such as quota-busting, high grading and by-catch dumping (Clark, 2006; Copes, 1986). Without compliance, the fishery will turn into an open-access resource and hence lose all the benefits brought about by ITQs. No fishers will be willing to purchase quotas if they are able to freely take fish in excess of their quota.

The total management cost of ITQs is indeed high. It took up to 8% of the total landed value of the New Zealand catch in 1997 (Wallis and Flaaten, 2003). In Norway, the enforcement cost of the ITQs amounted to 68% of the total management expenditure in 2000 (OECD, 2003). In the Canadian 4WX herring fishery, despite the failure of catch monitoring, compliance costs still took 2.5% of the total landed value (Grafton, 1996). In New Zealand, the amount of illegal catch in some individual fisheries can be as high as 68% of the total catch (Annala, 1996). Although accurate numbers are often impossible to obtain, Annala (1996) and Burns (2005) noted that there was a discrepancy between by-catch numbers in the presence and absence of observers in New Zealand, which indicated the possibility of by-catch discarding.

Perhaps the biggest argument against ITQs as an institution is their impact on access and income distribution equality. The general public and excluded fishers often view the economic improvement enjoyed by the current quota owners as windfall. Before the existence of any ITQ programme, Christy (1973) anticipated the difficulty in establishing such a system. Indeed, the initial discussions and concerns over ITQs were mainly about the transition to such a management regime (Scott, 1988). Jentoft (1989, p.138) believed that “keeping the industry viable while at the same time securing equitable income distribution may be mutually exclusive goals". Bardhan (1993) argued that straightforward privatisation of common property resources often led to serious distributional consequences.

Christy's (1973) suspicion was found to be well grounded in practice, which explains why ITQs have not yet been adopted systematically by some core fishing nations. McCay *et al*. (1995) noted that the access and distribution issue borne with ITQs has delayed their application. Iceland's ITQ programme was challenged by the Icelandic Supreme Court in the late 1990s because quota allocation contradicts equal employment rights (Eythórsson, 2003). Consequently, all new vessels are able to receive fishing license despite their lack of catch history (Eythórsson, 2003).The access and income equality issue is also the reason why ITQs have been banned by the U.S. Congress for a number of fisheries (Clark, 2006).

Concerns about distributional equality can be viewed differently. What economists consider a successful management practice might not be supported by other social scientists. Specifically, economists might believe that fishing rights should be allocated by the market, but other social scientists may attest that priority should be given to existing users or fishery-dependent entities (McCay, 1995). Furthermore, it is one thing to argue access and income distribution equality, it is another to deny the efficiency gains brought about by the ITQ programme. In fact, the economic enhancement achieved by the ITQ programme might be the reason why access and income equality is debated (Arnason, 1996).

A response, from the economics point of view, to this distributional issue embedded in the ITQ programme is fairly straightforward. It is often more efficient to grant production to the rich, who are likely to be well-equipped, because more resource rent can be generated by such specialisation. A more effective way to achieve social optima is therefore not by initially 'equal' allocation of resources, but rather by redistribution of the 'unequally' gained yet enhanced resource proceeds through appropriate tax systems. In this way, the 'inequality' can be internalised and the rental payment or the income tax can be compensation to people who are left out. However, the definition of the 'left-outers' can be difficult to determine and, to date there, remains little research on this issue of income redistribution (Eythórsson, 2003).

Besides the issue of equality, Seabright (1993) argued that a critical characteristic of private property, that is, its transferability, may jeopardise the reliability of long-term relationships built up amongst users to steward common resources. The importance of reliable relationships that was stressed by Seabright is, in fact, a form of social capital. The so-called social capital is a broad term used to describe "connections amongst individuals—social networks, and the norms of reciprocity and trustworthiness that arise from them", such as trust and social networks (Putnam, 2000, as cited in Grafton, 2005, p. 754).

The possible response to the social capital argument above is three-fold. First, social capital does not necessarily improve fishery resources management. Grafton and Knowles (2004) used cross-sectional data and empirically tested the relationship between social capital and environmental performance in various countries and found little causal relationship between the two. Secondly, even if social capital can generate a positive influence on resource management, because a stable ITQ programme might foster co-operation and self-governing of fisheries resources, it is possible that quota holders will build such a bond amongst themselves (*e.g.*, Grafton, 2005). Finally, Townsend (1995) saw this instability of ownership as a possibility for economic gain. This is because transferability is necessary to promote efficiency.

As discussed above, ITQs, in general, can maintain fish stock sustainability and are effective in preventing rent dissipation. However, their effectiveness is hindered either by the nature of the fishery or the quality of quotas as a private right to the flow of fish stock. However, as some authors noted (*e.g.*, Costello and Deacon, 2007) the performance of ITQs can be improved through holder self-organisation.

2.3.2 ITQ-based self-governance

From sole-ownership (Gordon, 1954; Scott, 1955) to ITQs (Christy, 1973), economists have seen property rights as the key to fisheries management. For that reason, ITQ-based self-governance is argued to be able to improve fisheries management by making the property rights of commercial fishers more complete (Arnason, 2007b; Scott, 2000a, b; Townsend, 1995), though the improvement depends on the initial qualities of the quotas (Townsend, 2010). Specifically, the transferability and excludability of ITQs might be strengthened. This is because, when operating as a collective, the bargaining power of quota owners is fortified. Hence, the ITQs are more excludable from external challenges and intrusions. Furthermore, communication effectiveness is strengthened by self-government, which might well facilitate the transferability of quotas because of the direct communication amongst quota owners. The potential improvement of rights quality from an ITQ programme to ITQ-based self-governance is shown in Figure 2.3 below.

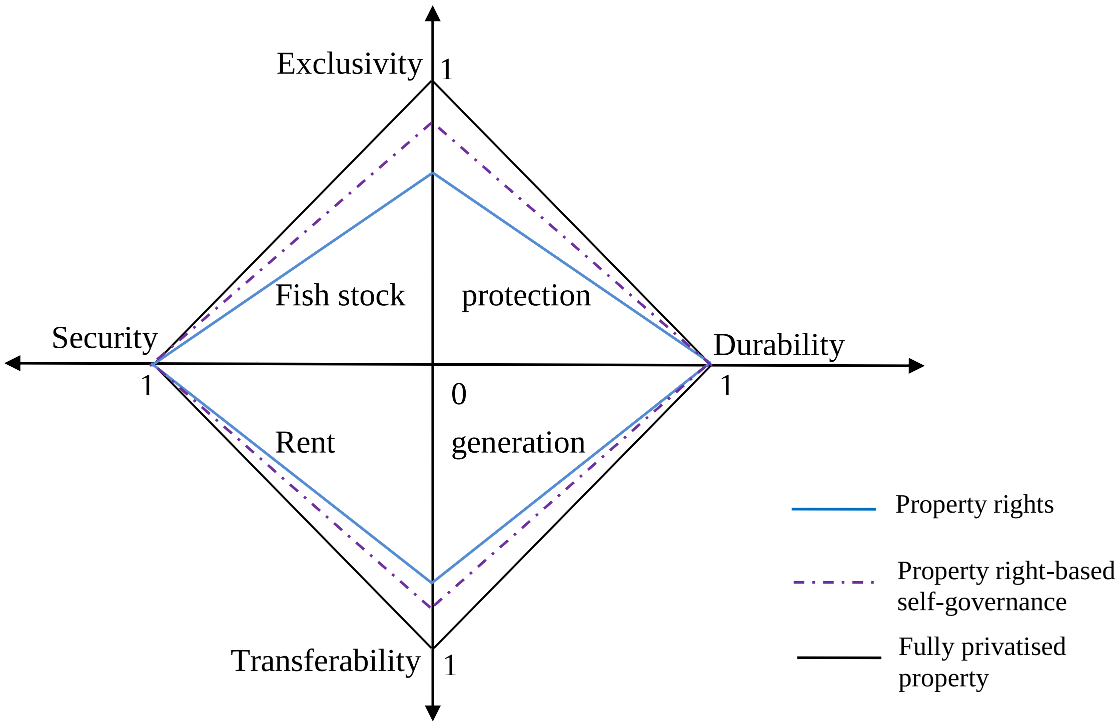

Figure 2.3 The quality map of the 'property rights model' type of ITQ programmes versus their corresponding ITQ-based self-governance and their effectiveness.

Figure 2.3 compares the ITQ programme (the blue diamond) with its corresponding ITQ-based self-governance regime (the purple diamond with dashed borderlines). It is because the two characteristics (exclusivity and transferability) of quota rights are likely to improve when quota holders co-operate, that the effectiveness of the rights is illustrated to grow accordingly. Thus, a self-governance regime can potentially be more effective in fisheries management (*e.g.*, protecting fish stock and generating economic rent, as shown in the central area of Figure 2.3).

2.3.2.1 ***Advantages***

The strengthened property rights of quotas in a self-governance regime bring a number of benefits to fisheries management. More complete fishing rights can eliminate a good part of individual quota holder's incentives to abuse the resource (Arnason, 2007b). The reason is that 'without' self-governance, the quota owner incurs the full cost of good practice (*e.g.*, avoid high-grading and take care of the fishing environment.), but only enjoys part of the benefit of this good practice. In contrast, with co-operation, the benefit of good management or the cost of mismanagement will affect each quota holder's return proportionally (Townsend, 1995). However, the self-governance entity still lacks complete exclusivity because there are non-commercial users in a shared fishery and other water users in general. Specifically, there are three main types of advantage that can be brought about by self-governance. They touch most aspects of fisheries management, including economic, institutional, resource and environmental factors.

2.3.2.1.1 Economic benefits

In terms of economic efficiency, the inefficiencies under a typical ITQ programme might be remedied in an ITQ-based self-governance regime. Specifically, Costello and Deacon (2007) argued that a heterogeneous fishery contains fish sub-stock that has a different economic value because of location or market preference. This heterogeneity creates a different shadow value for the same unit of ITQ. However, because the standard ITQ programme assigns undifferentiated TACs to differentiated fish sub-stocks, it will inevitably generate inefficiency. Furthermore, even in the absence of stock heterogeneity, fishers might need to search for productive fishing grounds, which lead to repetitive effort. Hence, Costello and Deacon (2007) concluded that inefficiency arises when TACs do not reflect the differences in fish sub-stocks and their locations.

The mathematical reasoning by Costello and Deacon (2007) follows below, assuming an identical value of sub-stocks, but a different value in terms of location, then the industry's total profit from catching *k* sub-stocks is:

$$J(k) = k - eE \tag{2.8}$$

Where *J* denotes the total profit from harvesting for the fishing industry,

K is the number of sub-stocks,

e is marginal cost of effort, and

E is the total fishing effort.

If there is no spatial assignment in the ITQ programme, the industry's total profit from catching *k* sub-stocks is:

$$J(k) = k - e\,[\frac{\ln(1-\frac{k}{N})}{\ln(1-\frac{1}{N})}] \tag{2.9}$$

Where N is the total number of locations.

If there is spatial assignment in the ITQ programme, the industry's total profit from catching k sub-stocks becomes:

$$J(k) = k - ek = k\,(1-e) \tag{2.10}$$

Comparing Equations 2.9 and 2.10, the industry profit without spatial assignment will always be less than that with spatial assignment. This is because the marginal cost of harvesting (e) is increasing without full assignment of ITQs, but is constant with full assignment. Therefore, the harvest cost in an undifferentiated ITQ programme increases because of the redundant effort.

To address the problems of a standard ITQ programme, Costello and Deacon (2007) demonstrated that the allocation of TACs based on spatial and fish sub-stock differences provides the potential to capture greater economic rents. However, such precise ITQ programmes are yet to be designed and tested in practice. The lack of such a delineated ITQ programme could be the result of two practical difficulties. First, each fishery is unique and, therefore, an enormous amount of research is needed to incorporate spatial allocation and market conditions in order to determine the optimal ITQ policy for a particular fishery. Secondly, even if an optimal ITQ programme can be designed for the fishery, fishing conditions and fish markets are dynamic, which requires constant adjustments to such an ITQ policy. These two reasons make the task of setting 'perfect' ITQ policies challenging.

Another approach besides the precise ITQ programme suggested by Costello and Deacon (2007) is the formation of co-operatives by ITQ participants. For example, fishers can achieve cost-savings by information sharing. Thus, effort is minimised for each co-operative member and costs are saved on searching for and racing to better fishing grounds. Furthermore, there might be extra benefit from marketing co-ordination, which allows individual fishers to fish according to market demand. Cancino, Uchida and Wilen (2007) suggested that there were several tasks that a co-operative can achieve that ITQs fail to exploit. They included the spatial allocation of effort, self-monitoring, enforcement and sanctions, multi-species management and habitat enhancement, market co-ordination and the development of other ecosystem services.

Self-governance also improves the economic performance of fisheries by reducing the management cost associated with information gathering, research and compliance. Data, such as fish stock mortality and abundance, are essential for sustainable fisheries management, but they are costly to obtain. In fact, records from the New Zealand Ministry of Fisheries confirm that stock research accounted for around half of the total management costs in the past decade (MFish, 2010a). However, the information needed in fisheries management is readily available from the fisheries and fishers' daily activities and is of better quality (Berkes, Colding and Folke, 2000; Neis, Schneider, Felt, Haedrich, Fischer and Hutchings, 1999). For example, in the orange roughy fishery in New Zealand, the Orange Roughy Management Company (ORMC) has organised its ITQ holders to report their catch, landings, location and effort every month, and compares this catch information with the Ministry of Fisheries every quarter. However, the other side of the coin is that it is possible for fishers to disguise the real situation to keep their business open. Stock abundance data from cod fishers in Newfoundland was higher than from the scientific research, which played a role in the collapse of the fishery (Spurgeon, 1997).

Arguments applied to information gathering can also apply to research. Instead of relying on government research providers (*e.g.*, MFish and NIWA), the ITQ-holders co-operative would seek the best option to carry out research by the cheapest possible source. Townsend (2008, p. 6) noted that "conducting research on research vessels ('fishery-independent platforms'), the historic approach of government scientists, may be much more expensive than generating the same information concurrently with fishing activities". For example, the Challenger Scallop Enhancement Company (CSEC) has successfully conducted a bio-toxins monitoring programme. By taking samples during the peak harvest times, the company has managed to increase the reliability of its tests and achieve significant cost-savings (Mincher, 2008).

Self-governance is argued to provide cost-saving effects in compliance. Indeed, unlike government agencies that exercise compliance based on rules and budgets, the ITQ owners' target is first and foremost to maximise the value of their fishing business. The differing goals of fisheries management ensures the company that bears the costs does not allow the cost of compliance to exceed the benefits (Townsend and Shotton, 2008). On the other hand, the cost of enforcement might be lowered if the fishery were operated more efficiently when the number of vessels decreased. It is not necessary that there are fewer quota owners, but it is helpful if there are fewer fishers in the fishery. For example, in the Alaska Chignik salmon fishery, 22 fishers caught the entire quota for the co-operative of 77 members while sharing the revenue with the remainder of the 55 quota holders who did not fish (Costello and Deacon, 2007).

However, it is difficult to find a direct relationship between economic improvement and self-governance from the examples given because ITQs were already in place to provide the mechanism for consolidation. There is no reason to doubt that the fishers would start negotiations on catch co-operation even without self-governance. Furthermore, since the empirical side of self-governance is mostly documented by unstructured case studies, the evidence of self-governance remains too case specific to generalise further improved economic benefit from ITQs to ITQ-based self-governance.

2.3.2.1.2 Institutional benefits

In addition to economic improvement, ITQ-based self-governance is also argued to improve institutional effectiveness. Government-centred regulations, such as licensing and ITQs, operate in a top-down format, where the government makes rules, which the fishers subsequently observe. In contrast, the ITQ-based self-management regime allows users to co-ordinate themselves. This unique ‘bottom-to-bottom’ management structure enables different user groups the opportunity for co-ordination to achieve a balance between commercial and non-commercial interests. Often, conflicts arise amongst different user groups because of different management objectives. Private negotiation between users in a self-governed fishery may solve these conflicts and achieve an efficient outcome (Coase, 1960). However, the possibility of reaching a coherent decision amongst users and the effectiveness of the outcome will depend on the level of transaction costs associated with the negotiation.

The examples of such negotiation include: (1), reallocation (trading) of quotas with customary and recreational users; (2), defining the no-take zone with environmentalists, and (3), decreasing or limiting pollution with the tourism industry. An example of such a case was noted by Mincher (2008) with respect to the Challenger Scallop Enhancement Company (CSEC) in New Zealand. This company has reached a special agreement with the fishery’s recreational users by allowing them to share some of the commercial fishing grounds. The recreational group chairman became an observer on the company’s board and recreational representatives have since gained a directorship in the fishery.

However, there are legitimacy issues regarding the leadership of a fisheries self-governance body. First, unlike government, the quota owners' authority in setting fishing regulations is limited and often depends on the structure and formality of the organisation. For the same reason, the co-operative's ability to carry out sanctions when its own members breach guidelines is often limited. Furthermore, though there might be sanction problems with members, the situation is more complicated with non-members, non-commercial users and illegal fishing activities. In these cases, government intervention would be essential to ensure that the investment of quota owners in good management is not violated.

2.3.2.1.3 Stock and environment benefits

As well as economic and institutional advantages, self-governance is also suggested to have positive effects on fish stock and protection of the aquatic environment (Scott, 2000b). Although some of these benefits are debatable, the general argument is that self-governance is at least no worse than other management regimes in handling issues such as fish stock conservation and ecological protection.

Self-governance's fish stock stewardship benefit can be indicated in three ways. First, self-governance is argued to address some of the unintended consequences of management. For example, as discussed at some length above, the incentive of high-grading is lowered because of less competition between commercial users in a QOA. As well as protecting the existing fish resource, self-governance creates incentives and opportunities for QOAs to enhance fish stocks (*e.g.*, Arbuckle, 2000; Mincher, 2008). Furthermore, negotiation amongst users, especially the involvement of environmental groups, ensures adequate pressure is maintained for the conservation of fish stocks (*e.g.*, Mincher, 2008).

Unlike fish stock conservation, pollution-control and fishing habitat protection are more controversial. On the one hand, Scott (2000b) argued that fisheries' co-operatives would be more conscious about protecting the fish stocks and their habitat. This is because, unlike an individual fisher, a co-operative has more complete harvest rights and more control over the fishery. Accordingly, the fishery more resembles a private good than a common good for the members of the co-operative. This change, in turn, encourages the members to protect the resource. Hughey *et al.* (2000) suggested that environmental externalities might be addressed when the users are involved in managing the fishery. The authors noted that the Challenger Scallop Enhancement Company (CSEC) is recognised by local government to be environmentally responsible.

Townsend (2006) noted that environmental externalities are third-party externalities that cannot be directly addressed by fishers or users groups. The reason is that environmental protection normally creates extra costs to harvesters through the requirement for investment in environment-friendly equipment or the need to change fishing behaviour. However, the benefit of 'good' behaviour could be enjoyed by all users of the fishery. In other words, fishing habitat protection and pollution control might be desirable for all parties, but it would be compromised when, as is often the case, costs outweigh private benefits.

Thus, there are two aspects of the ability of self-governance to protect the fishing environment. There are areas where self-governance matches private interests with public interests, especially when there is only a commercial interest in the fishery. However, often there are discrepancies between the two. Where the social interest and the private interest conflict, the government is expected to protect fisheries (Scott, 2000a, b) and Arnason, 2007c). Self-governance, on the other hand, should not be expected to correct all wrongs, but it is not inferior to other management instruments including the ITQ programme.

2.3.2.2 ***Issues***

Arguments against ITQ-based self-governance are often two-fold: first, there is opposition to market-based instruments (*e.g.*, ITQs); second, there is doubt about users' self-managing a fishery. The anti-property rights mentality mainly comes from CBM advocators. They cast doubts on the fundamental necessity of using a property-based rights system. The literature (*e.g.*, Bardhan, 1993; Ostrom, 1990) opposing ITQs usually begins its argument by distinguishing open access resources from common property resources (Townsend, 1995). They argue that open access resources belong to no one, so everyone could get access, whereas common property resources belong to a group of users with certain extraction rules defined within the group. This difference leads to the conclusion that though open access resources are almost destined to depletion and rent dissipation without external intervention, it is not necessarily the case for common property resources.

The main implication of the difference between open-access resources and common property resources is that private rights allocation is unnecessary in common property resource management. With open access resources, an individual’s payoff is thought to be irrelevant to his/her individual behaviour due to the large number of users. In contrast, for common property resources, because there are a relatively fixed number of users, the individual’s outcome is very much related to his/her decision that affects the other group member’s actions. Consequently, the smaller the group, the more concerns the users would have about their negative impact on the overall outcome and *vice versa* (Baland and Platteau, 1996). Therefore, participants’ strategic considerations in common property resource management, as opposed to unregulated open access, can lead to resource conservation and rent accumulation.

Although the distinction between open access resources and common pool resources results in the conclusion that external regulation is unnecessary, this proposition should not be applied universally. Just as ‘the tragedy of the commons’ does not apply to some common pool resources that have a small number of local users, external intervention is necessary in other resources with more diverse users. Nor should the distinction between open access and common pool resources become an argument against ITQs. This is because ITQs are similar to the internal incentives of local users. That is, ITQs create a closed set of participators who have the incentive to better manage a fishery.

Besides anti-rights-system mentality, there are doubts about the self-governance regime, ITQs-based or community-based. Singleton (2000) argued that fisheries’ users, instead of co-managing the resource with governments, sometimes take advantage of such a relationship to capture regulators. That is, government agencies might find it difficult to protect a neutral position or the general public’s interests because their interests may be intertwined with those of the resource users. In addition, there is also the risk of management being captured by small elite groups within the self-governance management structure (Davis and Conner, 2000, as cited in Yandle, 2003). This elite-capture might create an uneven income distribution (Jentoft, 2000b; Townsend, 2006). In this regard, self-governance is similar to property rights where ‘power’ can shift to the ‘powerful’.

To sum up the discussion on ITQ-based self-governance, it can improve on ITQ programmes by adding the co-operation component into fisheries management regimes.

The theory behind ITQs and self-governance suggests that it might be possible to improve the performance of an ITQ programme by strengthening property rights. As a result, there might be improvements in economic efficiency, institutional effectiveness, and resource and environmental stewardship.

Like other fisheries management tools, though ITQ-based self-governance has several advantages, there are also a number of trade-offs. Agent-capturing and elite-capturing might be dilemmas created by the self-governance regime. It is society's judgement whether these problems would happen in every fishery and, if it does happen, would it be significant? Furthermore, there might be some remedies that the regulators could use in order to prevent these problems from happening.

Like ITQ regimes, the effectiveness of ITQ-based self-governance relies on a number of things, such as the quality of the property rights and the legitimacy of the self-governance entity. Specifically, the stronger the property rights, the easier it is to form such a self-governing organisation because it is easier to identify the group of users in a fishery and reinforce the management functions. However, if ITQs are well-defined in terms of security, durability, tradability and excludability, the gain from moving to ITQ-based self-governance might be limited (Townsend, 2010). In such a case, it is important to examine if there is actual improvement in moving towards ITQ-based self-governance or if the gain is 'chewed up' by such a transition. More importantly, if there is improvement, one must ask which fisheries management areas are realised and which ones are not?

2.4 Economics of fisheries management – property rights are inadequate

Using property rights as a solution to fisheries management problems is controversial. Assigning property rights (*e.g.*, sole-owners, ITQs or ITQ-based self-governance) for fisheries was motivated greatly by Gordon's (1954) open access theory of fisheries. The advocators (*e.g.*, Arnason, 2000a; Christy, 1973; Scott, 1955; Townsend, 1995) have argued that property rights can help manage fish stocks and maximise economic rent. In contrast, using a dynamic model, Clark (1973) concluded that profit-maximisation can be the reason for fishery resources degradation. Hence allocation of property rights alone is not sufficient for fisheries management.

The different conclusions of these two theories are the result of differing assumptions. Gordon's model was static and thus there was only one stock level (x) that corresponded to one effort level (*E*). Therefore, the unit catch cost (*c*) is constant and independent of fish stock biomass. Clark's model was dynamic and assumed that unit catch cost was proportional to stock biomass, that is,

$$c(x) = b/qx \qquad (2.11)$$

Where *b* and *q* are two parameters.

This cost and abundance relationship (Equation 2.11) implies that there is a so-called Marginal Stock Effect (MSE), which states that catch cost decreases as stock abundance increases and as catch cost approaches infinity abundance approaches zero ($lim_{x \to 0} C(x) = \infty$). Furthermore, Equation 2.11 also implies a linear relationship between catch cost and stock abundance, a 1% increase (decrease) in *x* will lead to a 1% decrease (increase) in *c*. When the discount rate was entered into Clark's (1973) model, he found that profit-maximisation might lead to optimal extinction under two conditions: (1) when the unit price of the fish product was greater than the unit cost of catching the fish ($p > c(0)$); and (2) when the discount rate was more than double the stock maximum intrinsic growth rate ($\delta > 2r$). Neither of these assumptions is unreasonable and may occur for many fisheries around the world.

Following Clark's theory, it appears that assigning property rights was not sufficient to address the problems of fisheries management. This is because even if the fishery was managed by a sole-owner or a co-operative, private owners' profit-maximisation behaviour will irreversibly destroy fish stock under the two probable conditions: $p > c(0)$ and $\delta > 2r$. Therefore, sole-ownership is no longer optimal as demonstrated by the open-access theory. Instead, governance intervention becomes one of the necessary conditions for successful fisheries management. In fact, Clark (1973, p. 634) called for "continual public surveillance and control of the physical yield and the condition of the stocks". Clark, Munro and Sumaila (2010, pp. 216-7) further reinforced Clark's (1973) theory and stated that "… the ultimate management powers, however, must rest with the public sector".

The optimal extinction illustrated by Clark (1973), however, does not necessarily hold true for all fisheries. There is not necessarily a linear relationship between stock abundance and catch cost. Grafton, Kompas and Hilborn (2007) found four fish stocks whose MSE is greater than a one-to-one relationship (*i.e.*, a drop in stock abundance causes a greater proportional increase in the catch cost). In those fisheries, the strong MSE means a sharp increase in cost when stock level decreases. Therefore the strong MSE prevents fishers from harvesting the stock to extinction. Moreover, even when the strong MSE is absent, there still exists certain conditions that allow stock conservation. The next section will discuss these conditions as proposed by Grafton *et al.* (2010).

Empirically, the successful self-management of several fish stocks around the world suggested that profit-maximisation did not lead to stock abuse. Arbuckle (2000) found that, in the Challenger scallop fishery, though the amount of catch is restricted by the catch limit set by the government, the fishers within the fishery agreed to harvest less than the catch restriction to allow the stock to recover. Yang *et al*. (2010) found that fishers in the New Zealand Bluff oyster fishery have voluntarily reduced their annual catch to half the legal limit. Those two cases, however, might be exceptions to Clark's theory because shell fish stock has a high growth rate (*e.g.*, 28% for Maryland oysters (Wieland and Kasperski, 2008)), compared with the 2.5% growth rate of orange roughy. However, given the high disease mortality of Bluff oysters, the real growth rate of that stock might be much lower than its intrinsic growth rate.

2.5 Economics of fisheries management – property rights are adequate for some fisheries

The discrepancy between Gordon's (1954) and Clark's (1973) findings is indeed a fundamental controversy for fisheries management. That is, according to Gordon (1954), property rights can be a solution that leads to a 'win win' situation in fisheries. In contrast, according to Clark (1973), even when there is a strong one-to-one MSE, profit-maximisation can cause stock degradation. Therefore, no form of property rights alone can guarantee success in fisheries management, when the conditions $p > c(0)$ and $\delta > 2r$ hold.

Nevertheless, their seemingly contradictory view about property rights for fisheries management rest on the assumptions of their models and the restrictions they imposed on the model parameters. Grafton *et al*. (2007) found that for four fish stocks, within a range of reasonable parameters, the level of biomass that supported Maximum Economic Yield (MEY) was greater than that for Maximum Sustainable Yield (MSY) ($B_{MEY} > B_{MSY}$). In other words, it is in the fishers own interest to preserve fish stock. Grafton *et al*. (2010) further explained the conditions under which profit-maximisation led to stock conservation (B_{MEY}>B_{MSY}). The amount of catch in a fishery depends on catch costs in relation to stock size (the MSE), intrinsic growth rates, social discount rates, and input and output prices. Specifically, those conditions include, cost-price is greater than zero ($c/p > 0$); effort coefficient is less than or equal to one ($\alpha \leq 1$); and costs is greater than a certain range of parameters (*i.e.*, $c>p*\alpha(r/4)^{1-1/\alpha}$). When these conditions are met, even when $\delta > r$, $\mathrm{B}_{\mathrm{MEY}}$ can be positive (*i.e.*, no optimal stock extinction even with profit-maximisation) and dynamic B_{MEY} can be greater than B_{MSY}.

The generalisation of Grafton *et al.* (2007) and Grafton *et al*. (2010) might be far reaching given that one of the four fish stocks is orange roughy, whose intrinsic growth rate (r) is only 2.5%. This growth rate might well be less than half that of the social discount rate. For example, in 2007, the risk free rate in New Zealand (one of the two home bases of orange roughy fishery, the other is Australia) is around 7%. In Chapter 7, the case study of Bluff oyster fishery's stock abundance and harvest level will be used to test the empirical application of this theory.

Based on different models and parameter restrictions, the causes of the problems in fisheries management vary. Following Grafton *et al.* (2007) and Grafton *et al.* (2010), fisheries management problems can be the result of, (1) the open access nature of the fisheries as proposed by Gordon (1954); (2) profit-maximisation as proposed by Clark (1973); (3) both of these two aspects; or (4) neither of these two. For example, Grafton *et al.* (2007) suggested the reason for fish stock degradation and rent dissipation could be that the transition costs to achieve $\mathrm{B}_{\mathrm{MEY}}$, which requires fishers to forgo harvest for a period of time, were too high. Hilborn (2007) suggested that the conflicting goals of profit-maximisation, employment maximisation and fish stock conservation might have caused fisheries management failure. Specifically, success in one area might lead to failure in other areas, profit-maximisation might come at a cost of a lower employment rate because of production efficiency and lower stock levels. Grafton, Sandal and Steinshamn (2000) suggested that the causes of over-exploitation can be the adverse environmental impact on the resource, misguided policies or poverty.

Based on different causes of fisheries management problems, the recommendations for fisheries management will differ. One of the implications from the research of Grafton *et al.* (2007) and Grafton *et al.* (2010) is the possible need to revisit fisheries management strategy. Specifically, if profit-maximisation is not the (only) reason for fish stock collapse, property rights allocation need not be opposed because of rights holders' fundamental incentives for profit-maximisation. In fact, Bjørndal and Munro (1998, p. 173) related the fisheries management problems of stock depletion and rent dissipation to "ill-defined, or nonexistent, property rights result in a perverse incentive system leading to overexploitation if the authorities do not attempt to control harvests; and to overcapitalisation if they do". Grafton, Arnason, Bjørndal, Campbell, D., Campbell, H. F., *et al*. (2006) also argued that creating incentives for sustainable fishing is a key for successful fisheries management. One means to create incentives is to assign property rights to fishers.

2.6 Conclusion

The take home message from comparing the three theories developed by Gordon (1954), Clark (1973) and Grafton *et al.* (2007) is the realisation that fisheries management problems are complicated and there is no universal solution to address all problems. In a fishery that resembles that modelled by Gordon (1954), property rights allocation might be the best solution. In contrast, in a fishery that resembles that modelled by Clark (1973), rights allocation will fail the fishery. However, in a fishery that resembles that modelled by Grafton *et al.*, (2007), rights allocation should not be discarded outright.

Yet, it might not be possible to design 'the best' strategy for each individual fishery. This is because specific solutions to a specific fishery come at a cost. The different treatments for different fisheries require a huge amount of information and specific knowledge about the fishery. Moreover, fisheries are ever changing, the regulations that fit the fishery today might become obsolete tomorrow. In this regard, the 'best strategy' for a fishery might be adding a self-governance component to a property rights system. In this way, while the general wellbeing of the fishery (*e.g.*, stock level and economic efficiency) can be protected under the rights system, specific controls can be formulated to regulate individual fisheries.

ITQ-based self-governance is regarded as a fisheries management regime that can further strengthen the property rights of ITQs and, therefore, further improve the performance of fisheries. The literature in fisheries economics has established a number of theoretical merits of ITQ-based self-governance. Those merits include the enhancement of economic efficiency, the improvement of institutional performance in managing the catch, and the conservation of fish resources and fishing environment (*e.g.*, Arnason 2007, b; Scott, 2000a, b). Empirical study of ITQ-based self-governance regimes has also provided support for the improved performance of these areas in a number of fisheries (*e.g.*, Mincher, 2008; Yandle, 2008).

There is, however, doubt about the reliability of those empirical studies to support the merits of ITQ-based self-governance. This is because those studies apply an unstructured case study approach that provides descriptive results of an ITQ-based self-governance regime. Without rigorous methods, the conclusions drawn about the benefit of ITQ-based self-governance can be unreliable. One of the most concerning reliability issues is derived from the lack of a counter-factual – the inability to separate ITQs and self-governance, and hence, the conflation of the benefits brought about by ITQs and self-governance.

Chapter 3
The development of ITQ-based self-governance in New Zealand fisheries management and in the Bluff oyster fishery

3.1 Introduction

Chapter 1 established the following research objective: *to evaluate the merits of ITQ-based self-governance in New Zealand.* It is followed by a detailed analysis of the theoretical pros and cons of the ITQ-based self-governance regime in Chapter 2.This chapter introduces the evolution of fisheries management regimes in New Zealand – the general political background in which self-governance is embodied (Section 3.2). It is because of the failure and inefficiency of the management regime before the Quota Management System (QMS) that the ITQ-based self-governance was promoted. It is followed by a summary of the Bluff oyster fishery and its management history (Section 3.3). It will become clear that the Bluff oyster management move towards self-governance is embodied deeply in and promoted by the overall management evolution in New Zealand. In addition, a preliminary evaluation of ITQ-based self-governance will also be given in this chapter (Section 3.4) to provide a background for the evaluation of ITQ-based self-governance in this fishery in Chapters 4 to 6. A conclusion is offered in Section 3.5.

3.2 New Zealand fishing rights evolution

The development of self-governance in New Zealand is closely related to its fishing rights' evolution and the introduction of a property rights-based management system. Although the beginning of such a practice in New Zealand fisheries is difficult to trace, the introduction of the rights-based management regime in the 1980s has nevertheless built grounds for its evolution. In other words, in the New Zealand context, self-governance is not an independent fisheries management regime, but one that extends the current property rights-based management system. However, before the emergence of self-governance, there were three main phases in New Zealand fisheries management: limited entry (1908 – 1963), regulated open-access (1963 – 1986) and property rights-based system (1978 to date) (Harte, 2000b).

3.2.1 Limited entry (1908-1963)

Regulation of fisheries began with the Fisheries Act 1908, the first[3] overall statutory guideline in New Zealand. It covers most aspects of fisheries management from licensing and trading to aquaculture and harvesting. After signs of over-fishing became evident in the late 1920s, conservation and restriction became the main themes of fisheries management (Harte, 2000b; Johnson and Haworth, 2004).

The limited entry regime was abandoned for regulated open access during the 1960s when economic development, rather than conservation of fish stocks, became the dominant force. This change was brought about, above all, for three reasons. First, the government doubted the effectiveness of limited entry to protect fish stocks (Johnson and Haworth, 2004). Secondly, Professor Richardson, an independent reviewer, suggested that New Zealand fisheries had the potential for further development (Hersoug, 2002). Finally, there was pressure from Japanese fishers competing for fish. Because non-New Zealand fishers were not regulated by licensing, New Zealand fishers were out-competed outside the three-mile territorial limit (Hersoug, 2002).

3.2.2 Regulated open-access (1963-1986)

As a result of both economic and political pressure, the Fisheries Amendment Act 1963 opened up all fisheries to every individual New Zealander and company with at least 50% New Zealand ownership. Not only were the fisheries opened up, fishing was also encouraged by a Supplementary Loans and Mortgage Guarantee System passed in 1965 (Johnson and Haworth, 2004). Although there were still area, season and size regulations, New Zealand fisheries grew significantly in fleet size in the first 10 years (727 vessels in 1963 to 5178 in 1973) following de-licensing and landings grew 3.5 times in the 20 years of open access from 1963 to 1983 (Hersoug, 2002).

3.2.3 Property rights-based system and the Quota Management System (QMS) (1978-present)

After over 50 years of limited-entry and 20 years of deregulation (1963-1983), New Zealand fisheries management saw the introduction of a property rights based tool – the Individual Transferable Quota (ITQ). In 1978, after the United Nations Convention on the

[3]There are other individual and specific fisheries acts, such as the Oyster Act (1866, 1869, 1892), the Fisheries Protection Act 1877, the Fisheries Conservation Act 1884, and the Fish Auction Act 1886, before the Fisheries Act 1908. See Slack (1969) and Hersoug (2002) for further detail.

Law of the Sea (UNCLOS), New Zealand's Exclusive Economic Zone (EEZ) expanded from 12 miles to 200 miles from the coastline. After the sudden expansion of the EEZ, New Zealand fisheries faced a great amount of uncertainty. ITQs were first introduced informally in 1984 to manage the deep-sea fisheries (Falloon, 1993). In the meantime, some inshore fisheries were showing signs of overfishing and depletion, so, in 1986 ITQs were also applied to inshore fisheries to address these problems (Hersoug, 2002).

Compared with limited entry that primarily aims at fish stock conservation, ITQs are more economic in orientation. With this fisheries management regime reform, the Fisheries Act 1983 brought economic objectives to the catch sector, along with biological objectives. The Act and its economic objectives were introduced by an amendment bill in 1986 where the Quota Management System (QMS), with ITQs as one of its core instruments, was created for 28 fish species (Hersoug, 2002). Today, the QMS is the main tool to manage the majority of commercially valuable species within New Zealand's 200-nautical-mile EEZ. In 2010, 97 species are covered by the QMS, comprising 75% of commercially fished species.

The QMS addressed two key challenges – fish stock sustainability and economic efficiency of the catch sector. The current system has evolved since 1986 and is now more complex but the core premise still remains. The QMS protects New Zealand fisheries in two ways. First, it protects the fish stock and eases over-fishing by determining the level of Total Allowable Catch (TAC). Secondly, the QMS increases efficiency by way of quota allocations, because it internalises both the benefits and costs of fishing decisions to stakeholders. After examining the fisheries in the Auckland region, Yandle and Dewees (2003) concluded that the QMS has made the fishing industry better off and that the fish stocks have been preserved more effectively.

In addition, the QMS also provides a secure environment for New Zealand's indigenous fishing companies. Under the Treaty of Waitangi Settlement Act 1992, Maori people received $150 million, which was used to purchase a 50% share of New Zealand's largest sea food company, Sealord Products Limited (Lock and Leslie, 2007). In addition, they have also received a 20% share of quota allocation for all new QMS species (Lock and Leslie, 2007). Therefore, though the QMS is a tool to manage commercial fisheries in New Zealand, it is also a mechanism to fulfil the government's commitment to meet Treaty obligations.

The QMS, however, is also a complex system that contains a number of requirements, such as setting of MSYs and TACs. According to the Fisheries Act 1996 Section 13, MSY is the bench mark for the government to set TACs. MSY approximations of the fishery are based on the annual stock assessment surveys that are carried out by the National Institute of Water and Atmospheric (NIWA) on behalf of MFish. The cost of the stock assessments is partly recovered from the fishing industry depending on the proportion of commercial catch to the overall catch. The TAC is set annually based on the recommendations from stock assessment reports and the feedback from fishery companies.

It has been established that the quotas are best expressed as a percentage of TAC, rather than in tonnage, because of the likelihood of TAC alteration when the condition of stocks change. In New Zealand, 100 million shares are allocated to each QMS fish stock. However, quota shares alone do not allow the holder to take fish but they do determine the amount of Annual Catch Entitlement (ACE). ACE is a one-year property right, which gives holders rights to catch certain weights of a fish stock in a fishing year. ACEs are created to meet flexibility needs so that quota holders could choose between giving up fishing totally (*i.e.*, selling the quota) or giving up the fishing rights for a period of time (*i.e.*, selling the ACE). The amount of ACE for each fisher is generated from quota shares at the beginning of each fishing year, which allows the quota owner to either fish for themselves or sell to others to fish.

The actual weight that the ACE carries is determined by the Total Allowable Commercial Catch (TACC), which is the amount of TAC minus non-commercial catch and pre-allowed natural mortality. Therefore, fisher *i*'s ACE is jointly determined by the TACC of the fish species and *i*'s quota shares, that is ACE_i = TACC * $Quota_i$ / 100 million. For example, if the TACC for a fishery is 1,000,000 kg, given there are 100 million shares outstanding, a fisher *i* with 1,000 quotas will be allocated 10 kg of ACE. Following the allocation principle indicated, quotas are traded in shares whereas ACE is traded in kilograms. One exception is the Bluff oyster fishery (OYU5[4]), where the TACC is set and ACE is traded in individual oysters.

[4]The Bluff oyster fishery belongs to the Fisheries Management Area (FMA) 5, and hence, OYU5. The Fisheries Act 1996 divides New Zealand's 200 nautical miles Exclusive Economic Zone (EEZ) into 10 FMAs according to likely stock boundaries and administrative considerations.

Although New Zealand was not the first country to implement the ITQ programme to manage its fisheries, it was the first to use it comprehensively. Because of New Zealand's pioneering position in fishing rights development, the effectiveness of its ITQ programme has been studied extensively. The general finding is that it has been a success. For example, Dewees (1998) and Batstone and Sharp (1999) noted an overall improvement in efficiency, recognised by both the industry and government. Newell *et al.,* (2005) found that for the commercially significant fisheries, their quota markets are fairly competitive. Perman, McGilvray and Common (1999) noted that the size of the fleet has been reduced to a cost-effective level. Besides the economic improvement, a number of previously over-exploited fish species are now rebuilding (Annala, 1996; Perman *et al.,* 1999).

Despite the success of the QMS in fisheries management, suggestions have been made about how to improve the system. One recommendation made by Pearse (1991, p. 7), was "[t]hose who hold rights to fish should have more responsibility for managing them". He suggested, in his report to the Minister of Fisheries, that the role of the government is to provide standards and the role of fishery users is to manage the resource. Craig (2000), too, pointed out that the QMS is only a necessary but not a sufficient condition for fisheries management, the fishing industry needs to be more involved in management, whereas the government's role is only to set out guidelines and provide assistance.

The above recommendations were made after assessing the overall performance of ITQ fisheries, including environmental, fish stock, economic and institutional factors. Often, ITQs are expected to enhance the economic performance of fisheries, but their ability to better non-economic performance is debatable, as will be discussed in Chapter 3. There is insufficient evidence to support the argument that industry involvement improves non-economic performance (*e.g.,* biodiversity) of the fisheries. In other words, without careful examination of the contribution of fishers' participation in management, self-governance should not be expected to address every problem of the fisheries.

3.2.4 Self-governance (1980s-present)

Following Pearse's (1991) suggestion, self-governance emerged several years after the implementation of the QMS. The intention of government to achieve fishing management devolution was shown in the early 1980s when the fishery plan concepts were introduced in the Fisheries Act 1983. The aim of the plan was to ease over-fishing and over-capitalisation in the inshore fisheries and also to devolve some fisheries management responsibilities (Hersoug, 2002). The intention was that the government would be responsible for providing policy direction while leaving administration and resource allocation management to fishery users. However, this policy was shelved in 1986 after the introduction of QMS, which primarily relies on market-adjustments rather than central planning (Hersoug, 2002).

From the late 1990s until 2005, planning made a comeback (Lock and Leslie, 2007). The Fisheries Act 1996 Amendment Act 1999, section 11A made this policy available to the catch sector, promoted stakeholder-led plans and encouraged input from all user groups. The Ministry’s initial proposal was to leave fisheries plans to commercial groups - the Quota Owner’s Association (QOA) - the most organised entity amongst all users, while gradually introducing the involvement of other stakeholder groups (Hersoug, 2002). Munro *et al.* (1998) noted the growth of such a management framework in the form of Quota Management Companies. The authors commented that “[t]he company currently do not yet have clear legal status, but as they evolve, it would be surprising if they did not press for and ultimately obtain, the desired legal status” (Munro *et al.*, 1998).

However, the complexity and informal status of industry-led fisheries plans created several challenges. First, there was confusion over who the stakeholders were and therefore entitled to be involved in the fisheries plans (Gary, 2006; Rees, 2006). Additionally, distrust between commercial and non-commercial groups created communication barriers in both creating and implementing a commercial-led plan. Further, there was hesitation within commercial groups in taking the leading position. Townsend (2006) noted that the lack of enthusiasm by the industry was mainly caused by the high transaction costs both within the fishery (*i.e.*, difficulty in getting unanimous decisions) and with the government (*i.e.*, the possibility of rejection of the commercial-led plan).

As a result of the aforementioned concerns, when the 2005-2008 Statement of Intent (SOI) made the planning concept well-recognised, the Ministry of Fisheries attitude towards the plan changed from stakeholder-led to government-led. It is stated in the SOI that “[m]anagement plans will be facilitated by government, but developed in collaboration with relevant stakeholders, and will incorporate government, tangata whenua and stakeholder objectives … If appropriate, tangata whenua-led and stakeholder-led initiatives could become s11A fisheries plans”. (MFish, 2005)

3.3 Bluff oyster fishery

The Foveaux Strait dredge oyster fishery has been fished for over 140 years. Foveaux Strait dredge oyster (*Ostrea chilensis*), or bluff oyster, is an iconic delicacy in New Zealand, prized for its high quality and size. The Foveaux Strait stock area (OYU5) covers 3300 km^2. Almost all the commercial fishery operates in a relatively small (1055 km^2) area and only a small proportion of the fishery supports commercial densities of oysters, of which only a small part is actually fished (MFish, 2009a). There are about 50 commercially viable oyster beds within the Strait. Though the beds themselves may change in size, there was no evidence showing the appearance of new beds (Bluff Oyster Planning Group, 1995). The fishery is managed as a single stock and current assessments are undertaken in a fishery defined by the 1999 survey.

Figure 3.1 Foveaux Strait (OYU 5) stock boundary and outer boundary of the 1999 dredge survey area encompassing almost all the commercial fishery.

Source: MFish (2009a, p. 166)

Boundaries of statistical areas for recording catch and effort were established in 1960 and the outer boundary of the licensed oyster fishery in 1979. The western fishery boundary in Foveaux Strait is a line from Oraka Point to Centre Island to Black Rock Point (Codfish Island) to North Head (Stewart Island). The eastern boundary is from Slope Point, south to East Cape, Stewart Island (Figure 3.1). The commercial fishing year for oysters is 1 October to 30 September. Oysters have been traditionally harvested over a six-month season, 1 March to 31 August, although many vessels have filled their quota before 31 August. Because fishing in the Strait is very much controlled by weather, the fishing days total around 60 to 75 with one third of the ACE being caught within the first month (Skeggs, pers. comm., 2009).

In recent years, environmental factors have significantly restricted commercial fishing. In 1986, a *Bonamiaexitiosa (Bonamia)* epizootic caused major levels of mortality in the oyster population and the fishery was closed half way through the season to minimise disturbance to the remaining oysters. Management of the fishery has been modified in response to continuing mortality from *Bonamia*. Responses have, at various times, included a combination of closing infected areas to dredging (to minimise disturbance and reduce distribution of *Bonamia*), reducing the TACC, promoting in-season adjustments, shifting effort to low density areas and, at the most extreme, closure of the fishery to all commercial activities. In 1987, the infected area was closed to dredging to reduce disturbance and the catch limit reduced in proportion to the population of the closed area. In many respects, industry behaviour in response to this crisis required the industry taking initiatives to manage its own fishery and has driven the shift toward self-governance.

3.3.1 Management evolution

The evolution of the management of the Bluff oyster fishery is loosely allied with the overall management framework that has unfolded in New Zealand’s recent fishing history. The commercial fishery was managed under a limited entry regime from 1937 to 1963 and boat numbers were limited to a maximum of 12. Following de-regulation of the fishing industry in 1963, the number of boats increased dramatically to 30 by the end of 1969. Although there was a yearly limit of 132 million oysters for the period between 1963 and 1968, actual landings were often lower (Michael, 2007). In 1970, Bluff oyster fishing once again went back to limited entry, supposedly to preserve oyster beds and maintain a biologically healthy fishery (Riley, 1980). The fishery has operated under limited entry since 1970[5].

Between 1986 and 1992, fishing was disrupted by the outbreak of *Bonamia* and the fishery was closed by the government between 1993 and 1995 to allow the beds to recover. In April 1997, individual quotas were granted and quota holders permitted to fish their entire quota on one vessel. Boat specific catch limits were dropped in favour of non-

[5] Further details of this policy transition for this period and its effect on Bluff oyster fishery can be found in Riley (1980), and the general management of the fishery can be found in Anderson *et al*. (1984).

transferable individual quotas for boat owners, allowing the fleet to consolidate in line with the reduced catch from the fishery. At the same time, the Crown purchased20% of the available quota from quota holders and transferred it to the Waitangi Fisheries Commission. The oyster fishery entered the Quota Management System in 1998. The number of vessels in the fishery has dropped from 23 in 1996, to 15 in 1997, and to 11 in 2006 and has remained the same since then.

The recreational catch level in the Bluff oyster fishery is uncertain due to the lack of an official recording requirement. The bag limit of Bluff oysters is 50 per person per day. In 2002, MFish estimated that there were between 70-100 recreational vessels active in the fishery. In addition, there are also charter boats and a small number of commercial dredge vessels that take groups out for recreational fishing. Dredge oysters (tio) are an important diet for Maori[6]. This customary fishing occurs mostly by commercial vessels under customary authorisation. Like commercial fishing, both recreational and customary fishing were affected by *Bonamia* and the catches decreased during the years of the *Bonamia* outbreak.

3.3.2 Introduction to the QMS and self-governance

ITQs, along with the *Bonamia* disruption and the introduction of cost recovery in 1994, provided the industry with incentives to self-govern the fishery. The earliest attempt at self-governing the fishery was through the establishment of the Bluff Oyster Enhancement Company in 1992, when the impact of the *Bonamia* was at its peak. Industry participants sought to find ways to enhance the fishery. Soon, in February 1994, during the closure of the fishery, the Fishing Industry Board's Foveaux Strait Oyster Advisory Committee proposed the need to have a small scale coordinating committee. Two months later, the Oyster Planning Group had its first meeting and initiated the first plan – A Plan for the Foveaux Strait oyster fishery. The members of the group came from only two sources, MFish and commercial fishers (both the boat owners and the skippers).

That plan was completed and many components were implemented. For example, the plan resulted in changes to the total catch recording mechanism from sacks to the number of oysters to avoid high-grading and to fund scientific research on minimising incidental mortality of juvenile oyster during dredging (Bluff Oyster Planning Group, 1995).

[6]Maori, the indigenous people of New Zealand, have customary non-commercial access rights that are not limited by recreational regulations. Differing from commercial and recreational catch, customary harvest permits are issued by tängata tiaki (guardians), individuals who are appointed by local runanga (a local iwi tribal council) and MFish to manage customary fishing.

Additional components of the plan included a voluntary code of practice for skippers, which have not been fully taken up.

During the late 1990s, when planning regained popularity, two Quota Owners Associations (QOAs), the Challenger Scallop Enhancement Company and the Orange Roughy Company, submitted their Plans to MFish (Hersoug, 2002). Soon after that in 2003, the Bluff Oyster Management Company (BOMC) revisited self-governing of the shellfish fishery for a second time by drafting the commercial-led Management Plan – Foveaux Strait Dredge Oysters (OYU 5) through Fisheries Consultancy (NZ) Ltd. The draft plan was finalised in 2005 and informally handed to the Ministry of Fisheries for review. However, the participants of the BOMC are solely commercial stakeholders, other groups (recreational, environmental and customary) did not have input to the draft plan except some general consultation offered by the BOMC on issues that may arise. The lack of consultation and proof of broad stakeholder engagement, accompanied by an MFish policy change from industry-led to government-led plans during 2005-2008, meant that the BOMC was left with two choices: either they further refine the plan and hope for a successful outcome from MFish or invest in an MFish-led planning process.

3.3.3 Foveaux Strait dredge oyster fisheries plan

At the time (2006), MFish offered to incorporate the industry-led plan as a part of the ‘Proof of Concept’ MFish-led plans, with Foveaux Oyster fishery one of the three fisheries that would signal how MFish would proceed with all its fish plans. The directors of BOMC chose to accept the MFish-led plan option and worked with the representatives of other groups in developing the ‘Foveaux Strait Dredge Oyster Fisheries Plan – proof of concept’. Built on the BOMC’s 2005 Plan, this proof of concept plan invited all users groups’ participation from the outset. The plan has recently been finalised and formally approved by the Minister of Fisheries. It covers most aspects of the fishery with an emphasis on its sustainability, environmental concerns, as well as value maximisation for all users groups, how ever that might be construed.

3.3.4 The Bluff Oyster Management Company

The Bluff Oyster Management Company (BOMC) is a QOA. It represents all the quota holders in the fishery (BOMC, 2005). The BOMC was initially established in 1992 as the Bluff Oyster Enhancement Company Limited, in response to the *Bonamia* crisis, as a means of seeking to enhance the fishery. It operated under a special permit during the closure of the fishery (1993-1996). The company mandates almost every aspect of the commercial fishery, from fishing stock and effort management, information gathering and assessment, to compliance, communication and consultation with all industry stakeholders (ACE holders, fishers, processors, *etc*.).

The company manages commercial fishing by quota holder consensus. Under the QMS, the Minister sets the TAC and TACC, but the company maintains the right to modify or 'shelve' the commercial catch limit through mutually agreed in-season adjustments of ACE. The shelving process is done by first getting the consent of all ACE holders and then the agreed amount of ACE are transferred from each ACE holder to the BOMC before fishing season begins. The transferring of ACE is a critical step in the shelving process and it prevents possible cheating behaviour by actually taking away the catch title from the fishers. In addition, if the fish stock condition improves during the fishing season, the BOMC can transfer a certain amount of ACE back to the ACE holders, with mutual consent. Following this shelving process, the BOMC shelved half the TACC for the fishing years from 2002 to 2008, after the second outbreak of the *Bonamia* between 2000 and 2002. In 2009, the BOMC first shelved half of the ACE (*i.e.*, 7.5 million oysters) and then transferred a total of 0.7 million oysters back to the ACE holders due to fish stock condition improvement.

The company has engaged in various management responsibilities. A logbook programme has been instituted by the BOMC. It is used by fishers to record the oyster beds' condition and is an important input into managing the effects of *Bonamia*. In addition, fishery statistics are gathered by various oyster stock assessment surveys; the cost of these surveys is directly recovered from quota holders. The BOMC manages commercial fishing effort to match the unique features of the oyster fishery. Because it takes about four years for oysters to become mature, the company, in consultation with skippers, organises harvesting by rotating of fishing beds on an annual basis. The BOMC also sponsors trials to refine fishing gear and to minimise the harvesting effects on the seabed and co-ordinates oyster stock enhancement and seeding programmes.

Under the Foveaux Strait Dredge Oyster Fisheries Plan, it is the BOMC's responsibility to communicate its decisions to other parties involved in the fishery. Because the BOMC is solely owned by commercial users, communication between the commercial users and other users groups is vital. In order to gain non-commercial groups' co-operation, it is important that those users are also involved in managing the fishery. As well as the concerns within the fishery, there is external interest in this iconic species and the company is therefore accountable for keeping the general public and the media informed on the status of the fishery.

3.4 Initial analysis of the performance of the fishery

Commercial oyster fishers have been seeking a self-managed framework since the 1990s. The current management structure has evolved from a centralised, input based management framework to one that resembles a self-governance regime. In this section, the administrative and biological performance of the fishery is briefly considered by checking against the criteria set by Arbuckle (2000) for the Challenger Scallop fishery – often considered to be a sophisticated industry self-governance model (Arbuckle, 2000; Mincher, 2008; Yandle, 2003).

Arbuckle (2000) applied three criteria in rating the performance of the Challenger Scallop Fishery: the level of agreement within the fishery and between different sectors that utilise the resource, stock biomass trend and the implicit discount rate. Although these three indicators do not cover all aspects of the fishery's performance, they represent the fishery's administrative, biological and economic performance, respectively.

The level of agreement is three-fold in the Bluff oyster fishery. First, agreement amongst commercial quota holders can be achieved relatively easily because of the common profit-seeking objective. Second, the decision-making process within the Foveaux Strait Dredge Oyster Fisheries Plan invites all stakeholders into the management circle. Finally, contracts or agreements are reached between the company quota holders and harvesters before going fishing to make sure certain protocols (*e.g.*, logbook registration) are followed.

Another indicator, oyster stock abundance, appears to be influenced more by *Bonamia* (Dunn, 2005, 2007; Fu and Dunn, 2009) than catch, which is controlled by management. However, fish stock condition can still be used to examine management effectiveness if the *Bonamia* impact can be factored out (Figure3.2).

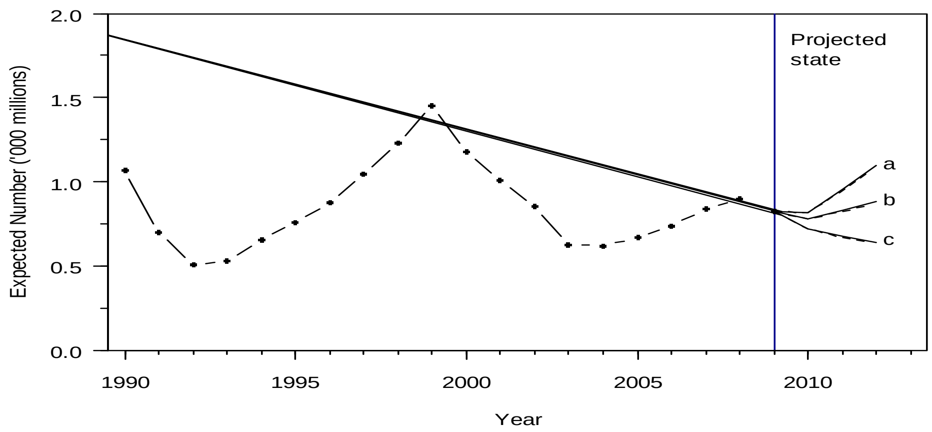

Figure 3.2 Estimate of recent recruit-sized stock abundance and projected recruit-sized stock abundance for 2010–2012, under assumptions of (a) no disease mortality, (b) disease mortality of 10% per year and (c) disease mortality of 20% per year.

Source: Ministry of Fisheries (2009, p. 183)

From Figure 3.2, the first outbreak of *Bonamia* (1986–1992) saw a sharp decline in the oyster population followed by the stock rebuilding during 1993 – 1995 when the fishery was closed. Since the establishment of the BOMC and implementation of fishing-related protocols in 1995, the stock size recovered faster than in the closed period even with fishing activity, until the second outbreak of *Bonamia* from 2000 to 2002. The figure also shows that the stock is in recovery under scenario (a) no *Bonamia* disturbance and (b) minor *Bonamia* disturbance. Stock population estimation will be discussed further in the bio-economic modelling method in Chapter 4.

The level and trend of the implicit discount rate is the third element that can be used to examine the quality of a management regime. In a competitive market, the quota lease price (ACE price) represents the expected annual income of the fishery. Quota price reflects the present value of the future profit for that fishery (Newell *et al.*, 2005). The discount rate is calculated by dividing the one-year quota lease price (ACE price) by the quota asset price. According to Akroyd *et al.* (1999, as cited in Arbuckle, 2000) the convergence of the discount rate to the risk free interest rate shows the rationalisation of harvest and stock biomass level.

3.5 Conclusion

Fisheries management in New Zealand has evolved through an iterative process where successive efforts have sought to shape a wider, more inclusive form of self-governance.

The establishment of the QMS has laid a strong foundation for the development of self-governance regimes in various fisheries. The New Zealand government's intention of devolving fisheries management responsibility to local users who address local management problems has also played an important role in this process. Under such a policy environment, the Bluff oyster fishery has developed a self-governance structure that, from the preliminary evaluation, might have benefited the fisheries management. Equally important is the unique nature and features of the Bluff oyster fishery. The challenging fishing conditions in the Strait create a natural barrier to entry, the sedentary nature of the oysters return management benefits to the investors and the limited number of users makes the efficiency gain attainable.

The preliminary evaluation of self-governance in the Bluff oyster fishery, however, did not demonstrate the depth of the contribution of this management regime. For example, how does self-governance further improve economic efficiency of the fishery or how is biological performance enhanced in the long-run? The next three chapters apply three theory-based methods to systematically evaluate ITQ-based self-governance.

Chapter 4
A bio-economic fisheries model applying Bayesian inferences and system dynamics

4.1 Introduction

In economics of fisheries management studies, formal models are often used to carry out *ex-ante* analyses of institutional arrangements. In this chapter the focus is on modelling the dynamics of fisheries, as one of the three methods, to evaluate the contribution of self-governance. The two most crucial areas of fisheries management: fish stock abundance and profitability will be examined. Specifically, a simulation estimation method will be applied to the bio-economic model to project future performances of the Bluff oyster fishery under the hypothetical 'without' self-governance regime and the current 'with' self-governance regime.

Fish abundance and profitability were chosen to be investigated further for two reasons. First, stock conservation and utilisation are two critical aspects of a sound fisheries management regime. In New Zealand, the guideline for fisheries management is found in the Fisheries Act 1996, part II. 8, which states that the purpose of managing the fisheries resource is to … "provide for the utilisation of fisheries resources while ensuring sustainability". Accordingly, the most recent fisheries management strategy in New Zealand (Fisheries 2030) states that the current goal is "… to have New Zealanders maximising benefits from the use of fisheries within environmental limits" (MFish, 2009b).

The second reason is that stock conservation and utilisation are two aspects of fisheries management to which self-governance can add value, as discussed in Chapter 2. Briefly, for stock conservation, the argument is that self-governance conveys more complete resource rights to ITQ-holders, which in turn provides quota owners with more incentives to protect the resource (Scott, 2000b). Further, management co-operation and communication can reduce competition amongst commercial fishers. Similarly, more efficient stock utilisation can be brought about by co-operation over catch effort consolidation (*e.g.,* Clement *et al.*, 2008; Soboil and Craig, 2008) and possible cost-saving for information sharing, research rationing and catch compliance (Berkes *et al.*, 2000; Costello and Deacon, 2007; Neis *et al.*, 1999;Scott, 2000a, b).It makes intuitive sense that fishing industries seek self-governance because of the economic benefit it brings. However, it is one thing to believe that self-governance improves the fishery's economic performance in theory and based upon intuitively, but quite another to provide hard evidence to support this argument.

In this chapter, a generic bio-economic model that applies Bayesian inferences and system dynamics is developed to investigate fish stock abundance and fishing industry profitability in an ITQ-based self-governance regime. The aim of building such a model is to separate the contribution of self-governance and ITQs. The generic model is then applied to the Bluff oyster fishery. For the Bluff oyster fishery, the biological sub-model is based on the traditional Beverton-Holt model. The economic sub-model uses a dynamic profit function that features the uniqueness of QMS management in New Zealand. A 10 year stock abundance and profitability level is then estimated.

The remainder of this chapter is arranged as follows. Section 4.2 provides a review of the basic bio-economic modelling methods used in fisheries management literature. Section 4.3 offers the modelling methods that will be applied in this chapter for evaluating ITQ-based self-governance for New Zealand fisheries. Section 4.4 applies the model created in Section 4.3 to the Bluff oyster fishery. The fishery's stock status and profit level are simulated under the hypothetical scenario of 'without' self-governance regime (*i.e.*, the status quo of an ITQ fishery) and the current 'with' self-governance regime respectively from 2008 to 2017. Section 4.5 provides the results generated from the model. By comparing the outcomes of the two regimes, Section 4.6 offers insights on whether self-governance adds value to fish stock and profitability management.

4.2 Literature review

Research literature frequently reports the use of bio-economic models to analyse fishery dynamics and policy effectiveness. In a fishery bio-economic model, there is a biological component and an economic component. The biological sub-model often describes fish population dynamics and interactions between fish population and the aqua-environment (Clark, 1990; Ussif and Sumaila, 2005). The economic sub-model, on the other hand, describes the interactions between fish populations, fishing activities, profitability and market conditions.

4.2.1 Biological sub-model

Fish biology is an important area of fisheries management research. A well-fitted biological model reveals the stock-recruitment relationship of a fishery and provides fisheries managers with much information necessary to make reasoned choices to regulate the fishery. Specifically, when a harvest limit is set below the net yield, the fish population is likely to increase; when the limit is set above the net yield, fish population might decrease. This, in turn, allows the simultaneous management of resource conservation and utilisation.

Broadly categorising, there are two approaches to fisheries biological modelling: the 'general production' (*i.e.*, Schaefer-type) approach and the Beverton-Holt approach (Bjørndal and Munro, 1998; Bjørndal, Ussif and Sumaila, 2004). The general production model treats the fish stock as a whole and measures population by numbers or biomass. The Schaefer model (Schaefer, 1954) is a classic example of such a model that does not distinguish fish population parameters. The mathematical form of the Schaefer model will make the model's general feature clear:

$$F(x) = rx(1-\frac{x}{K}) \tag{4.1}$$

Where *F(x)*is the growth of the resource,

x is the stock biomass,

r is the intrinsic growth rate of the fish stock, and

K is the carrying capacity of the fishery.

As indicated by Equation 4.1, in the Schaefer model, individual fish are treated the same (x) regardless of differences in age, length or weight. In addition, the net growth of the fish population, which comprises new recruitment, growth and mortality, is lumped into one parameter: the intrinsic growth rate, r.

The general production biological model has been used extensively by economists when developing models for capture fisheries (Bjørndal and Munro, 1998; Homans and Wilen, 1997). Bjørndal and Munro (1998) argued that the popularity of this type of model in economic analysis is due to the nature of capture fisheries, which are harvested on a multi-cohort basis, but which do not distinguish fish by age or length. However, this reason might not be able to justify the application of the general production model. This is because, although fish are caught on a multi-cohort basis, fish stock recruitment and growth are not. Instead, the stock-recruitment relationship relates to the structure and make-up of a fishery. Hence, the general production approach can be inadequate for the purpose of estimating stock abundance for the biological part of the bio-economic model.

Ussif and Sumaila (2005) applied the general production model to analyse the impact of setting the TAC at the MSY for the North East Arctic Cod Stock (NEACS) fishery. The use of the general production model was justified by the fact that it was previously applied for the cod stock and had proven to be useful. The paper concluded that the cod stock could recover by gradually adjusting the TAC to its desired biological level (MSY). In other words, no urgent shut down of the fishery was necessary in order that the fishery rebuild to the MSY level. This finding contrasted with the recommended 'bang bang' policy put forward by Clark and Munro (1975). This policy states that if the fish stock is above the desired level x_d, fish the stock down to x_d; if the fish stock is above x_d, shut the fishery down until the stock is recovered back to x_d.

The general production model used by Ussif and Sumaila (2005), however, can be inadequate in modelling the biology of the cod fishery. This is because the cod stock often has variable year classes and individual fish can live for up to 25 years (ICES, 2007) and the dynamics in fish stock differs with age or length. Specifically, the cod stock (or fish generally) grow faster before maturity and the growth stagnates after a certain age (ICES, 2007). In addition, different population structures lead to different intrinsic growth rates (r). The cod population might grow faster if the majority of the fish stock is young and, conversely, if the fish stock is relatively mature. Hence, treating cod stock as identical (x) and assigning one single growth rate (r) can lead to false estimations of the general net growth or natural mortality. Therefore, this model can produce unreliable population estimates. Because stock estimation can be biased using the general production model in the NWACS case, the reliability of its outcome – gradually adjusting the TAC to the desired biological goal (MSY) – might be compromised. Instead, Clark and Munro's (1975) 'bang bang' approach might be a better choice for the recovery of the NEACS.

The use of the Beverton-Holt type model can refine the stock-recruitment relationship in a fishery because unlike the general production model, the Beverton-Holt type model bases the stock-recruitment estimation on cohorts. That is, in this type of model, the stock-recruitment relationship is based on age or length of the fish stock. Compared with the general production model, Beverton-Holt models are preferred in two situations. First, they can represent the stock-recruitment relationships better if the fish stock has significant year class differences and the age/length-based data are available. The age/length based data are often available for commercially significant fisheries in which scientific research is the main source of stock assessment. In New Zealand, the QMS fish stocks are assessed by NIWA and the fisheries biological data are gathered at the beginning of each fishing season.

Secondly, the Beverton-Holt type model is more appropriate for providing policy advice because it can provide insights for evaluating a variety of management tools (Mesnil, 2003). This is because the age/length-based model separates the population into sub-stocks so that the dynamics of each sub-stock can be examined individually. For example, the impact of stock enhancement will only be on recruitment, but not mortality. Therefore, age/length based models are preferred to general production models when evaluating self-governance because the actual impact of management action on each sub-stock can be taken into account.

There is a range of age/length-based models to choose from and the choice depends on the nature of the fishery. The Beverton-Holt model (Beverton and Holt, 1957) is one of the most widely applied models (Bjørndal *et al*., 2004; Cadima, 2003; Hilborn and Walters, 1992). The Beverton-Holt model is density-dependent (*i.e.*, the model assumes that stock recruitment depends on population size) and estimates recruitment and mortality at each point in time (Fogarty, Sissenwine and Cohen, 1991). Because this type of model is simple yet competent, it has been applied extensively in fisheries management (Clark, 1990).

The Beverton-Holt model was applied by Bjørndal *et al*. (2004) to estimate the optimal harvest rate for the Norwegian Spring Spawning Herring (NSSH). The Beverton-Holt recruit-biomass relationship can better represent the fishery than the general production model because the NSSH stock has many cohorts with variable year-class strength. This age-based model allows different natural mortality to be applied to different-aged sub-stocks, which can lead to a more reliable stock abundance estimate. Subsequently, the paper estimated the optimal extraction rate to be an annual catch of 15% of the total stock.

There is, however, a downside to this biological model developed by Bjørndal *et al*. (2004). The stock abundance estimate is, as noted by the authors, sensitive to the assumed values of the key variables of the fishery such as recruitment and natural mortality. In other words, the validity of the stock abundance estimate depends on the precision of the recruitment and natural mortality values, which are also estimates. In the analysis, the optimal catch rate differs with varied assumptions of mortality. Specifically, when the assumed natural mortality rate differs according to the year-class of the stock (*i.e.*, a 0.9 mortality for fish age 0-2 and 0.15 for ages 3-16), the optimal catch rate was estimated at 15% of the total biomass annually for the next 20 years. In contrast, when the natural mortality was held at 0.15 for all stocks, the optimal catch rate dropped to 8.2% for the same time period.

This variability in stock abundance estimate is often unavoidable because the key variable inputs used for estimation (*e.g.*, natural mortality) are also estimates or assumptions. The nature of fishery resources makes it difficult to obtain an accurate numeral value for any of these inputs. However, this estimation deficiency can be improved by the incorporation of more input variables in the biological model. Normally, there are three key variables for stock abundance estimation: recruitment, natural mortality and growth rate. The use of other assisting variables (*e.g.*, commercial CPUE data and scientific survey updates) in the biological model can often improve the quality of stock abundance estimation. The reason is that more information is incorporated in the model to reduce uncertainties in estimation.

The incorporation of more variables in the biological model requires a more adaptive estimation method. While biological models (*e.g*., general production and age/length-based models) define fisheries population dynamics, it is the estimation methods that decide the way each population component connects. There are two main estimation methods available, the frequentist (classic) approach and the Bayesian approach.

This chapter uses the Bayesian approach. Gelman, Carlin, Stern, and Rubin (2004, p. 1) define Bayesian estimation as "... the process of fitting a probability model to a set of data and summarising the result by a probability distribution on the parameters of the model and on unobserved quantities such as predictions for new observations…". In other words, it is a statistical inference that includes the probability distribution of hypotheses and/or parameters based on updated observations and/or evidence. The mathematical presentation of the discrete Bayesian estimate is written as:

$$P(H \mid E) = \frac{L(E \mid H)P(H)}{P(E)} \tag{4.3}$$

Where H is a hypothesis of interest,

E is some new observation or evidence,

$P(H|E)$ is the posterior probability of H given the new observation or evidence.

$L(E|H)$ is the likelihood probability of observing evidence E when H is true,

$P(H)$ is the prior probability of H before new evidence or E is available, and

$P(E)$ is the marginal probability of E, the a priori probability of observing E under all possible hypotheses.

$P(E)$can be calculated as the sum of the product of all probabilities of any complete set of mutually exclusive hypotheses and corresponding conditional probabilities:

$$P(E) = \Sigma L(E \mid H_i) P(H_i) \tag{4.4}$$

The choice of Bayesian approach is based on the purpose of estimation in this chapter– estimating the recruit-sized biomass (the parameter) based on existing sets of data (*e.g.*, scientific surveys and catch data) with certain confidence. Bayesian inferences are designed to provide such estimation. For example, the Bayesian's 95% credible interval for biomass[100million, 120million] means that there is a 95% probability that the true value of the biomass lies between 100 million and 120 million oysters. In contrast, the frequentist's approach is designed to produce parameters based on long-run hypothetical set of identical experiments (samples), *i.e.*, frequentist inferences aim at long-run frequency guarantees(O'Hagan, 2011) instead of short-term confidence. For example, the frequentist's 95% confidence interval for biomass [100 million, 120 million] means that if the same experiments (*e.g.*, scientific survey) was repeated a great number of times, then 95% of the time the true value of the biomass lies between 100 million and 120 million oysters.

Another reason for choosing the Bayesian approach is that it allows the incorporation of all available information, observed and undated (*e.g.*, stock information and the judgement of experts) (Millar and Stewart, 2005; Punt and Hilborn, 2001, O'Hagan, 2011). In contrast, the frequentist approach bases estimation on observed data only. The unique learning and adapting ability of Bayesian inferences is relevant for fishery managers who want to learn the population dynamics for three reasons. First, the Bayesian approach is able to minimises uncertainties by incorporating more and richer data (Hammond, 2004; Magnusson and Hilborn, 2007), which in turn reduces variability of estimates.

Secondly, the dynamics of the fishery changes constantly and, therefore, it is unrealistic to base estimations on a repeated sampling process while excluding newly emerged information as the frequentist method does. Furthermore, the changing dynamics of fisheries mean that long-run frequencies can be unreliable. Hence, an estimated population based on repeated sampling for the long-run does not aid the purpose of determining TAC for the short-run, *e.g.*, a year.

In addition, the inclusion of expert opinion and user knowledge can increase the reliability of estimators for fisheries that lack scientific data. Even for fisheries with relatively sufficient data, user knowledge of their fishery resources can help consolidate or verify scientific conclusions (Neis, Schneider, Felt, Haedrich, Fischer and Hutchings, 1999). This is because objective data sets are often generated from scientific stock assessments, which can be expensive and narrowly-focused. In contrast, users' knowledge comes from their daily activities and touches a wide variety of topics. Local knowledge can range from seasonal and directional fish movements through stock structure to fish abundance (Hutchings, 1996). Self-governance, effectively, makes use of user knowledge by allowing users to self-manage the fishery.

However, there are also disadvantages embodied in the Bayesian approach. In order to generate a Bayesian estimate, there is a need to choose prior distributions that represents some prior information. This information often relies on subjective and non-scientific opinions (O'Hagan, 2011). Therefore, there are still uncertainties in the Bayesian analysis that come from the prior beliefs about empirical evidence (Nielsen and Lewy, 2002). Furthermore, it is also difficult to convert those beliefs into distributions without advanced computing software (O'Hagan, 2011). However, these disadvantages should not be the reason for forgoing Bayesian analysis. A careful selection of prior beliefs from experts and experienced local fishers can minimise the unreliability of prior distributions. The difficulties of converting beliefs into a distribution will become less concerning as technology develops; the computing software used in this thesis (CASAL) is adequate to accomplish the task.

Despite the advantages of the Bayesian approach and its application to fishery biology studies, it is not popular in fishery economics research. The previously reviewed paper, Bjørndal *et al.* (2004), used unspecified non-Bayesian methods to estimate the stock abundance for the NSSH. The method allowed the incorporation of two sources of data: (1) objective data for fishing mortality and (2) estimates for natural mortality and recruitment. The estimated results might be improved by using Bayesian inferences, which allow the inclusion of both objective data and subjective opinions (*e.g.*, experts' opinions, fishers' experiences and commercial information such as CPUE). In the NSSH case, as a commercially significant fishery, CPUE data might be one additional source for stock estimates.

The biological sub-model developed in this chapter is designed to evaluate self-governance. As discussed earlier in this section, the traditional general production model and non-

Bayesian estimation might not be able to provide a reliable estimate of stock abundance. Therefore, the age/length-based model instead of a general production model will be used to represent the biological dynamics of the fishery. In this way, stock abundance estimation can be more reliable because it takes into account the different recruit-biomass dynamics amongst sub-stock classes. Bayesian inferences will be used as the estimation method to incorporate as much information as possible about the fishery, including both subjective expert opinion and additional data available, such as commercial CPUE and scientific surveys.

4.2.2 Economic sub-model

There are two types of economic models applied to fisheries management: the static model and the dynamic model. A well-known example of a static model is the Gordon-Schaefer model developed by Gordon (1954). Despite the continued application of static models in fisheries economics (Munro, 2008), dynamic models provide a more 'realistic' view of the economics of fisheries management (Bjørndal and Munro, 1998). One reason for the realism is that dynamic models incorporate uncertainties (*e.g.*, stock level change and environmental shocks), which is evident in natural resources such as fisheries (Bjørndal and Munro, 1998). Specifically, the widely applied standard continuous profit function of a fishery in a dynamic time model can be expressed as (Clark, 1990; Clark and Munro, 1975):

$$\pi(x,h) = (p-c(x))h(t) \tag{4.5}$$

Where π is the profit,

x is the stock level,

h is the level of harvest,

p is the unit price of catch,

c is the unit cost of catch, and

t is the time.

The harvest, $h(t)$, often follows a standard Cobb-Douglas production function (Bjørndal and Munro, 1998; Jerry and Raïssi, 2002),

$$h(t) = qE^{\alpha}X^{\beta}(t) \tag{4.6}$$

Where q is the catchability coefficient,

E is fishing effort,

α is the coefficient of effort, and

β is the coefficient of biomass.

The two coefficients, α and β, are assumed to be constant (often 1 in the literature) (*e.g.*, Arceo-Briseno, 2001; Bjørndal *et al.*, 2004; Bjørndal and Munro, 1998; Homans and Wilen, 1997). Keeping other factors constant, $\alpha = 1$ means a 1% increase/decrease in fishing effort will result in a 1% increase/decrease in catch. This assumption is valid if technology remains constant and the fish stock is by and large uniformly distributed. However, $\beta = 1$ means there is a one-to-one relationship between fish abundance and catch, which can be an over-simplified assumption. In fact, in the original discussion by Clark and Munro (1975), β is restricted only to be greater than 0 ($\beta > 0$). This assumption ($\beta > 0$) is more realistic since the relationship between catch and stock abundance is often not unity. Therefore, if assuming $\alpha = 1$ and $\beta > 0$, the harvest function is reduced to:

$$h(t) = qEX^{\beta}(t) \quad (4.7)$$

Therefore, the amount of effort E used to catch $h(t)$ is:

$$E = h(t)/qX^{\beta}(t) \quad (4.8)$$

Therefore, the total cost of catch becomes:

$$C(x,h) = eE = e^{*}\, h(t)/qX^{\beta}(t) \quad (4.9)$$

Where e is unit cost of effort.
The unit cost of catch is:

$$c(x) = e/qX^{\beta}(t) \quad (4.10)$$

In addition to economic models, whether static or dynamic, estimation methods are an essential component in modelling the economic performance of fisheries management. Estimation methods depict how profitability relates to other variables in the fishery (*e.g.*, stock abundance, catch, price of output, cost of catch and allowable catch). The traditional estimation methods are often equation-based and use mathematical or statistical modelling techniques (Gilbert and Troitzsch, 2005). The issue with a statistical technique is that it requires a sufficient amount of 'hard' and accurate data. First, data are required to actually perform the estimation in a mathematical equation or statistical regression. Secondly, sufficient data are required to overcome the degrees of freedom problem in statistical modelling. That is, the data for estimation will have to be greater than the number of variables so the regression can estimate the parameter values. Therefore, it becomes statistically challenging to incorporate more variables in the model, even when the modelling requires more variable inputs in the estimation.

Furthermore, the mathematical technique emphasises more the statistical relationships (correlations) amongst agents (variables) (Dudley, 2004; Gilbert and Troitzsch, 2005), which can restrict the model's ability to demonstrate the dynamics and processes of how each variable contributes to final profitability. Nevertheless, being able to show the dynamics between profitability and the contributing variables is important. This is because the process of how each element interacts and finally affects the profitability of the fishery is the key reason for research. After the inter-relationships within the fishery are determined, policies can then be designed to better manage the controllable variables (*e.g.,* catch rate) to optimise economic performance or biological or social performance, depending on the goal of fisheries management.

System dynamics simulation can improve on traditional mathematical modelling to provide more dimensions into fisheries modelling in a communicative way. System dynamics simulation "… is the process of using a model to mimic, or trace through step by step, the behaviour of the system …" (Grant, 1986, p. 11). Although simulation is similar to mathematical and statistical techniques in that it provides a way of formalising a social event, it is more readily communicated and intuitive to the user (Dudley, 2004).

In fact, system dynamics simulations include mathematical equations in their estimation process. Gilbert and Troitzsch (2005) showed the common set of difference equations used in system dynamics estimation often have the form:

$$x_{t+1} = f(x_t; \upsilon) \tag{4.11}$$

Where x_{t+1} is the state of the target system at time $t+1$.

Therefore, the state of the target system in the next period ($t+1$) is determined by its state at time t and some other factors υ. Both x and υ may be vectors that have several elements and f is normally a continuous function.

The set of differential equations have the form:

$$\dot{x}(t) = \frac{dx}{dt} = g(x(t); (\upsilon)) \tag{4.12}$$

Where $\dot{x}(t)$ is the change of the target system within an infinitesimally short period of time *dt.*

That is to say, the change of the target system in this time period *t* depends on the state of the target system at time, *x(t)*, and on other factors, υ, in the same time period. Furthermore, *g* is normally a continuous function. However, instead of solving the equations continuously, system dynamics uses discrete time, by reducing the change in *t* (Δt) to an infinitesimally short time period, to derive numerical solutions. A change in *t* (Δt) can be defined as short or as long and can be sufficiently short to resemble a continuous equation.

System dynamics can be a more suitable estimation method than traditional mathematical techniques to estimate the economic performance of a self-governed fishery. This is because profit related data can often be scarce and system dynamics does not require as much data as a traditional mathematical or statistical modelling process. In addition, updating the model is possible and easy once better quality information becomes available. Furthermore, system dynamics simulations provide a way to formalise the structure of the management of self-governance and demonstrate the dynamics between profitability and the contributing variables. For example, a change in fishing method can be incorporated into the simulation model run to show how that affects profitability. The inclusion of actual management undertakings will yield a result that is inclusive, as well as offering an intuitive outcome when communicating with users.

The modelling of fishing effort in Dudley (2008) will make the improvement to system dynamics from traditional mathematical modelling clear. Dudley (2008) discussed the impact of management strategies on fish stock and fishing activities. Figure 4.1 shows a selected part of the components that make up the model and the dynamics that changes fishing effort in the paper. Specifically, the dynamics of fishing effort (*E*) was defined as the difference between the entering fleet and the retiring fleet, each of which are affected by several components. For example, the entering fleet is determined by several factors including actual vessel entry rate, which is determined by management desired vessel entry rate. Hence, the fishing effort in the fishery will be also altered by changing the ‘desired vessel entry rate’ – a controllable management decision.

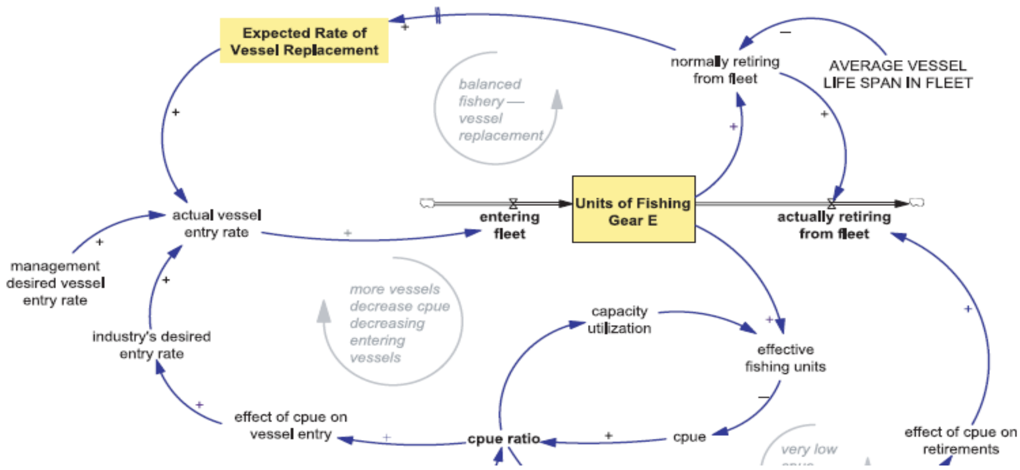

Figure 4.1 A demonstration of applying system dynamics to model fishing effort (*E*).

Source: adapted from Dudley (2008)

Dudley's (2008) model also allows the comparison of different scenarios. The model includes the interactions amongst stocks, fishing activities and management strategies and, therefore, provides the users with a comprehensive view of the dynamics in the fishery. The users can manipulate any component to test its impact on other components. For example, the user can change the level of fish stock to examine how it affects catches, or *vice versa*. The model can also answer the question: "How does an increase in fishing gear efficiency affect fish stock or catch?" holding other elements constant. More importantly, it is the management strategy that is often controllable and studied. By incorporating management dynamics in the model, the user can change management strategies to study the impact on both fish stock and catches.

There are also some flaws with such a comprehensive model. Since more elements are incorporated into the model, the inter-relationships amongst them can be difficult to illustrate. For example, it is predicted by Dudley's (2008) model that the higher the gear efficiency, the higher the CPUE. Although this positive relationship might be true in some fisheries, the accurate estimation of this relationship relies on the nature of the fish stock on a case by case basis. Particularly in fisheries where fish stocks are highly variable (*e.g.*, the New Zealand Challenger scallop fishery), more efficient searching devices and gear might lead to high CPUE even if stock abundance declined suddenly.

Nevertheless, the complications in inter-relationship estimation should not be seen as an obstacle in applying dynamic models. For one thing, the models' complexities are justified by the actual complexities evident in real-world fisheries. Further, the same problem exists in traditional static bio-economic models where the fish stock-recruitment relationship is often not known with certainty. Although more variables in the model can make the results more dependent on assumptions, as long as the assumptions amongst components are well justified and based on the best knowledge available, the outcomes from a dynamic model should be able to depict a more reliable representation of the fishery.

The estimation for the economic sub-model therefore, will use system dynamics. Three features of system dynamics simulation are essential in order to evaluate self-governance. First, it allows the estimation of profit based on limited information. Secondly, it allows the dynamics of self-governance management to be visually demonstrated. Finally, it allows the incorporation of management strategies in the model and, therefore, makes the evaluation of self-governance's contribution possible.

4.3 Method

By creating a bio-economic model that imitates fish and fishers behaviour under 'without' and 'with' self-governance in a QMS fishery, the management impact of self-governance can be separated from ITQs and evaluated. In other words, this approach should be separated from the traditional use of bio-economic models in research literature, which resembles the ideal situation. That is, profit-maximisation is often set as the goal of fisheries management and the catch level is derived accordingly. In contrast, the bio-economic model in this chapter is created to reproduce the real situation in the QMS fishery where catch is pre-determined by the TACC – a catch level that enables the fish stock to remain at or above the MSY level.

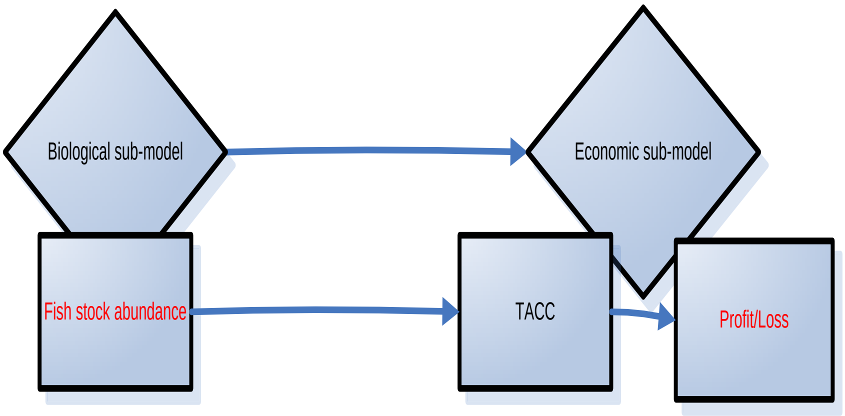

Figure 4.2 Bio-economic model structures under the New Zealand QMS.

Figure 4.2 provides an overview of the bio-economic representation of the key elements in a QMS fishery. A biological sub-model can be used to model the fish population dynamics. One of the outcomes of the biological sub-model is the fish stock abundance estimate, which is highlighted in red in the above figure. An economic sub-model is used to model the behaviour of regulators and fishers. Regulators use the stock abundance estimates to set a catch limit, TACC, for the fishery. Fishers, limited by the TACC, harvest and make profits (or losses) accordingly.

4.3.1 Biological sub-model

The general mathematical representation of a fish biological model takes the form:

$$\dot{B} \equiv \frac{dB}{dt} = \dot{P} - \dot{Y} = \dot{R} + \dot{G} - \dot{M} - \dot{Y} \tag{4.13}$$

Where $\dot{B}$ is the rate of change in biomass with time,

t is time,

$\dot{P}$ is productivity – inflow of stock,

$\dot{Y}$ is the yield – outflow of stock,

$\dot{R}$ is new recruitment,

$\dot{G}$ is the growth of the existing population,

$\dot{M}$ is the natural mortality, and

$\dot{Y}$ is the human fishing yield.

Graphically, the general fisheries biological model can be summarised as a simple inflow and outflow diagram as follows:

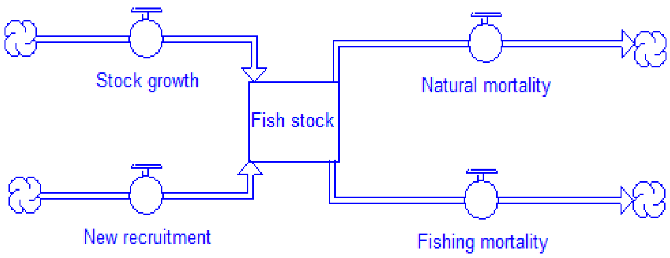

Figure 4.3 General fisheries population dynamics.

Figure 4.3 shows the generic population dynamics in a fishery (*i.e.*, the inflow and outflow of biomass). In the figure, fish stock/biomass increases by the growth of existing stock and the recruitment of new stocks (indicated on the left hand side of the figure) and decreases by natural mortality and fishing mortality (indicated on the right hand side of the figure). Fishing mortality, depending on the nature of the fishery, can be further broken down into several other components. For example, in a shared fishery, fishing mortality includes commercial catch, non-commercial catch and illegal catch. In a deepwater fishery, fishing mortality could include only commercial catch. Generally speaking, stock inflow and natural mortality are at the mercy of nature, but fishing mortality depends on fishing behaviour. However, it is also possible that human activities have some impact on stock inflow. For example, successful stock enhancement can add more recruitment into the fish population.

Following the literature review, the Beverton-Holt model will be used to study fisheries management in New Zealand. One reason is that age/length-based data are widely available for the major QMS fisheries in New Zealand. Moreover, this study aims at comparing two management regimes, the 'without' self-governance and 'with' self-governance. The Beverton-Holt model allows the management impact of self-governance on fish stock to be assessed through each component of the inflows and outflows of the fish population. For example, catch limit will have an immediate impact on stock outflow but not inflow.

Bayesian inference will be used as the estimation method for the biological sub-model. It will allow the incorporation of all available information about the fishery (*e.g.*, scientific survey data, commercial CPUE or stock density data and experts opinion). The inclusion of the additional information will, in turn, decrease uncertainties in estimating stock abundance. Furthermore, using Bayesian estimation might improve the stock abundance estimation by allowing the use of prior distributions rather than an arbitrary constant value to estimate parameters. Stock assessment models often require generating parameters based on limited information and, therefore, the key variables (*e.g.*, recruitment and mortality) are often assumed to be constant. On the other hand, if Bayesian inferences are applied, those key variables will be estimated as a posterior distribution, which increases the reliability of the variable values.

In order to perform Bayesian analysis to generate Bayesian estimates, posterior distributions, ($P(H|E)$ in Equation 4.3) are required. It is relatively easy to produce simple posteriors such as $p(H|E) \propto p(H)p(E|H)$ ($\propto$ means proportional to). However, for a posterior that involves the likelihood component, for example, $p(H|E) \propto p(H)l(E|H)$ (l is the likelihood probability), a numerical integration is required to generate the parameter for the posterior (Lee, 1997).

There are several ways[7] to reach integration using algorithms. One of the most common algorithms used to explore the posterior distribution and to draw inferences for models and parameters is the Markov Chain Monte Carlo (MCMC) sampling method[8] (Gelman *et al.*, 2004; Hammond, 2004; Punt and Hilborn, 2001). The MCMC method involves setting up a Markov chain simulation algorithm to generate a sample of desired distributions (*i.e.*, the equilibrium distribution) of parameter vectors from a set of probability distributions with pre-determined parameters (Punt and Hilborn, 2001). Specifically, the Markov chain simulates the equilibrium distribution by randomly drawing values of parameters from "approximate distributions then correcting those draws to better approximate the target posterior distribution" (Gelman *et al.*, 2004). Most likely the MCMC method is carried out by computing simulations, which generates a great number of parameters. These parameters can then be used to compute the marginal posterior distributions.

Two computing software programs are available for stock assessment; one is used by Food and Agricultural Organisation (FAO) and the other is used by National Institute of Water and Atmospheric Research (NIWA) for New Zealand fisheries assessments. The FAO program is a computing program that was mainly designed for population analysis and studying the interaction between fishing methods. This study will use CASAL[9] (C++ Algorithmic Stock Assessment Laboratory) to carry out long-term recruit-sized stock projections because it is capable of carrying out similar tasks as VIT and is readily available. Specifically, CASAL is a software package developed by NIWA for general fish stock assessment (Bull, Francis, Dunn, McKenzie, Gilbert *et al*., 2008). It can perform tasks such as estimations, projections and simulations. It has been used previously for New Zealand fisheries stock assessment, such as CPUE estimation, and spawning and recruit-sized stock population projection.

When performing Bayesian analysis, CASAL generates Bayesian estimates for recruit-sized stock projection based on two input command files (population.csl and estimation.csl) and one output command file (output.csl). The population.csl file allows free choice of population dynamics input. Specifically, in the population.csl file[10], the population dynamics of the species are incorporated in the model run as an input choice by users. They can be either one of, or a combination of, the following: the species' recruitment, natural mortality, migration

[7]The other two effective methods, according to Punt and Hilborn (2001), are the Grid Search and the Sampling Importance Resampling (SIR) method. The Grid Search is conducted mostly for problems with few variables (Hammond, 2004).

[8]The process of a MCMC run can be found in Appendix A MCMC process.

[9]For more technical details about CASAL please refer to Bull, B., Francis, R.I.C.C., Dunn, A., McKenzie, A., Gilbert, D.J., Smith, M.H. (2005). CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v2.07-2005/08/21. *NIWA Technical Report 127*.272 p.

[10]Please see Appendix B Population file for examples of items included in the population file.

habits and social impact such as fishing. For example, the binomial knife-edge selectivity is used to describe the vulnerability of different size class subjects to fishing gear, 1 being vulnerable and 0 being not.

The other input file, estimation.csl file[11] carries out the actual parameter estimation. It is used to uncover point parameter estimates that minimise the objective function – often negative log likelihood or negative log posterior (Bull *et al.*, 2008). That is, the file directs CASAL to find the point estimates; the set of parameters that minimises the objective function. Specifically, each set of observations in the population file contributes to the total likelihood distribution and that, plus prior distributions, will equal the total objective function, which is minimised in point estimation. The main use of the estimation file in this study is to produce free parameter values to project recruit-sized stock biomass (Bull *et al.*, 2008).

The process of generating point estimates directed by the estimation file is described as follows. The MCMC command directs CASAL to generate the posterior distribution by random walk[12] around the equilibrium distribution in small steps until it covers all the space (Bull *et al.*, 2008). After a posterior distribution is generated by the MCMC run, CASAL produces an output file called samples, which provides a list of samples of free parameters from the posterior distribution. The samples file is then used as an input file in which it provides the sets of point estimates for CASAL to base the projection of recruit-sized oyster biomass on.

Finally, the output file[13], output.scl, allows a choice of which parameters are to be estimated and produces results. It is a file that directs CASAL to estimate and print information that is required by the user, such as the point estimates (*e.g.*, spawning stock biomass and recruitment biomass) and the objective function.

4.3.2 Economic sub-model

System dynamics simulation was chosen to carry out the profitability estimation in the economic sub-model. System dynamics allows the incorporation of multi-aspects in a fishery. This serves the purpose of this study, which is to simulate the economic performance of a self-governed fishery by taking fish stock, catch and management strategy into consideration. Furthermore, system dynamics allows feedback of critical parameters influencing the system

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[11]Please see Appendix C Estimation file for examples of items included in the Estimation file.
[12]The methods of MCMC random walk include, but are not limited to, Metropolis–Hastings algorithm, Gibbs sampling, Slice sampling, and Multiple-try Metropolis.
[13]Please see Appendix D Output file for examples of items included in the Output file.

(Stave, 2002, as cited in Bueno and Basurto, 2009). This is particularly useful in this study because the goal is to test how different management regimes affect fish stock and the profitability of a fishery.

According to Equation 4.5, *p*, *c(x)* and *h(t)* are required in order to calculate the profit level. Graphically, the economic dynamics are demonstrated in Figure 4.4. In the figure, from the top, the biomass level (*x*), simulated in the biological model, affects the profit level by having an impact on both catch (*h(t)*) and fishing costs (*C*). Comparing an open access fishery with a QMS fishery, *p* and *c(x)* are determined in the same way, but *h(t)* is not. Those three key variables will be discussed in detail in the following sections. Briefly, following the left side of the diagram, the level of harvest (*h(t)*) under the QMS is set to maintain the recruitment biomass level at or above the MSY. Therefore, it is determined either by the TACC (*hTACC(t)*) or the amount set by the self-governance entity (*hSG(t)*) within the limit of the TACC. The unit price of catch (*p*) can be exogenous or depend on the catch if the industry has a certain degree of market power. The product of commercial catch and unit price of these catches determines the amount of revenue in a given year. Following the right side of the diagram, total fishing cost (*C*) is a product of the total amount of catch and the amount of fishing effort. The three variables, *p, h(t)* and *C* will now be discussed .

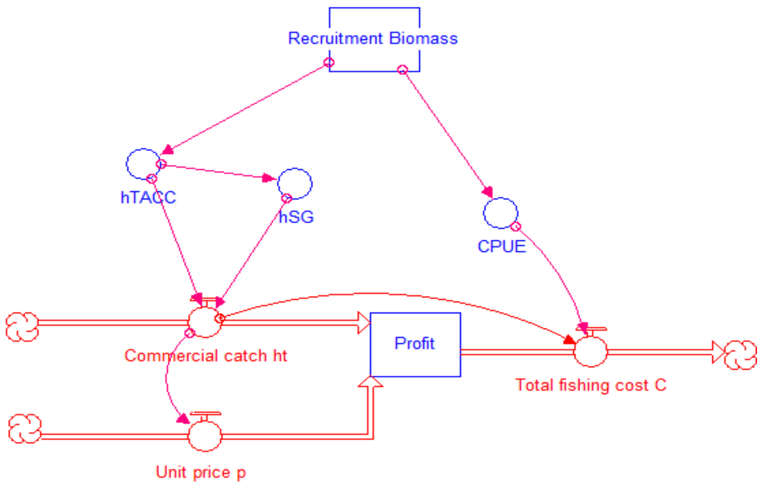

Figure 4.4 Economic dynamics of New Zealand QMS fisheries.

The price of harvested fish, *p*, is often assumed to be constant. This is a justified assumption for fisheries that compete in international markets, where prices tend to be perfectly elastic. The NSSH (Bjørndal *et al.*, 2004) and the NEACS (Ussif and Sumaila, 2005) are two such examples. In addition, the constant price assumption is also a norm in various theory papers on fisheries management (*e.g.*, Bjørndal and Munro, 1998; Clark, 1973; Grafton *et al.*, 2010).

In contrast, a constant price assumption appears to lack validity when the fishery is domestically-oriented or fish suppliers retain some market power. In such situations, a demand equation for estimating the price is more appropriate if market information is available (*e.g.*, Anderson, 1977, Chapter 6; Kompas, Dichmont, Punt, Deng, Che *et al.*, 2010).

There are several ways that a catch level, $h(t)$, can be determined. In an open access fishery, according to Equation 4.7 ($h(t) = qEX^{\beta}(t)$), catch level is driven by the level of effort (E) and fish stock abundance (x). On the other hand, in a regulated fishery, catch level is often predetermined by a catch limit. For example, a catch level can be set at a fixed rate so that an equal amount of fish is caught every year, *i.e.*,$h(t) = h(t+1) = h$ (*e.g.*, Ussif and Sumaila, 2005). The $F_{0.1}$ exploitation strategy is one such example where the catch level is set below the MSY level of catch (Hilborn and Walters, 1992). Alternatively, a catch level can be set so that it is linearly related to the stock biomass, *i.e.*,$h(t)= max(0, a+bx(t))$ (*e.g.*,Bjørndal *et al*., 2004; Homans and Wilen, 1997; Ussif and Sumaila, 2005).

In a QMS fishery, the catch level allowed is predetermined by the TACC. Therefore, the catch rule is similar to the above, $h_{TACC} = max(0, a+bx)$. This restriction is imposed by the Fisheries Act 1996, part 3.13 (2), the TAC is set to maintain "… the stock at or above a level that can produce the maximum sustainable yield (MSY) …." Specifically, the Act states that if the stock is above/under the MSY level, the TAC should be set so that it allows the stock to move toward the targeted level. The following figure summarises the catch rules applied by QMS.

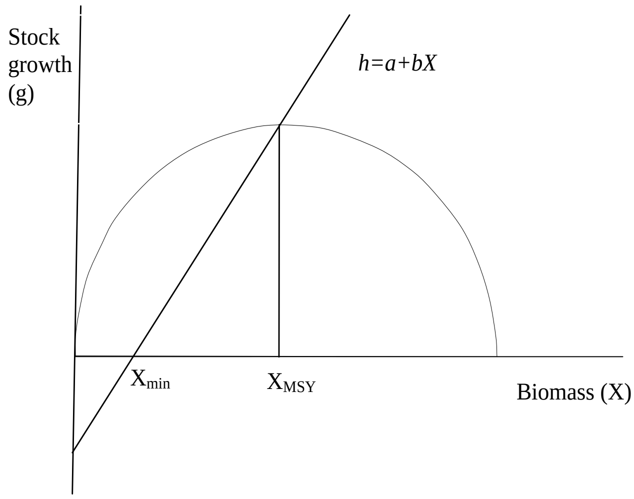

Figure 4.5 QMS catch limit (*i.e.*, TAC).

Source: adapted from Homans and Wilen (1997)

Figure 4.5 shows a quadratic yield function with a linear harvest rule that restricts the catch level h at $a+bx$ when the stock level is above X_{min} and 0 if below. When the stock level is above X_{min}, the catch limit (TAC) is set so that the stock level is adjusted back to the MSY level. Specifically, when the stock biomass x is below the MSY level, the TAC is set below the net yield of fish stock so that the net stock growth is positive and the opposite holds true when stock biomass is above the MSY.

Catch cost, C, can be estimated through the catch rate (CPUE). Although the relationship between fish abundance and CPUE can vary hugely from fishery to fishery[14], the commercial CPUE can be an index of stock abundance and has been used in fisheries science and management (*e.g.,* Danielsson, 2002; Graham, Carcamo, Rhodes, Roberts and Requen, 2008; Lancia, Bishir, Conner and Rosenberry, 1996) (Dunn, Harley, Doonan and Bull, 2000).

Following Equation 4.10 ($c(x) = e/qX(t)$), unit cost of catch ($c(x)$) is a function of unit cost of effort, e and $qX^{\beta}(t)$. The $qX(t)$ is the so-called Catch Per Unit Effort (CPUE) (*i.e.*, $qX^{\beta}(t) = h(t)/E = CPUE$by definition),

$$CPUE = qX^{\beta}(t) \tag{4.14}$$

Equation 4.14 suggests that CPUE is related to the average stock abundance biomass (x). Therefore, catch cost, C, is related to stock abundance if the catchability coefficient (q) remains constant over time. Theoretically, q reflects the mass of a relative fishing ground and the efficiency of fishing gear (Arreguin-Shchez, 1996). Hence, q is likely to remain constant if fish density is uniformly distributed in the fishery and there is no change in fishing gear power over the observed period. However, the use of CPUE to estimate catch cost should be tested by the relationship between catch and stock abundance.

After forming the relationship amongst each variable in the system dynamics model, STELLA[15] is used to run the profitability simulation. It is a graphical program developed to facilitate system dynamics simulation. It is, according to Senge (2010), a senior lecturer of Massachusetts Institute of Technology (MIT), "... an increasingly valuable tool for constructing understanding about all kinds of dynamic systems from natural environments to team dynamics to economic markets". The software is one of the most used programs in

[14]In some extreme cases, commercial CPUEs can increase while the actual fish abundance falls. This happened because of the concentration of fish and fishery (Roseand Kulka, 1999).

[15]There is a range of software available for simulation, such as Vensim, Excel, Powersim and STELLA (Cavana and Ford, 2004; Maani and Cavana, 2007). They are similar and can perform both basic and complex simulations (Maani and Cavana, 2007).

system dynamics simulation (Gilbert and Troitzsch, 2005). Hannon and Ruth (1994) used STELLA to run simulations of various disciplines such as ecology, economics and genetics.

The simulation processes in STELLA are intuitive and visually straightforward. Simulations start with graphic symbols, which consist of stocks (*e.g.*, population and profit), flows (*e.g.*, birth and death rates), converters (facts or rules that influence the behaviour of both stocks and flows) and action connectors, which connect the three symbols to identify the relationships amongst them[16]. Then, diagrams of those symbols are developed to reflect the properties of the targeted systems in the study. This is followed by STELLA converting the diagram into computing program code (Gilbert and Troitzsch, 2005) and calculating the variable values of interest.

The calculation of the variables in STELLA is based on a set of difference and differential equations (Forrester, 1980, as cited in Gilbert and Troitzsch, 2005). The target system, with its properties and dynamics, is described using a system of equations that derive the future state of the target system from its actual state. The general form of the equations is presented by Equations 4.11 and 4.12.

4.4 Case study

4.4.1 Biological sub-model

The Foveaux Strait oyster biological sub-model is a single-sex, length-based model where all oysters were assumed to reside in a homogeneous area. This model is based on the population dynamics model used in the Bluff oyster stock assessment (*i.e.*, Dunn, 2005, 2007; Fu and Dunn, 2009) – the most structured stock assessment for the New Zealand Bluff oysters conducted by NIWA on behalf of MFish. The use of a length-based model is justified by three features of the fishery: (1) there is good information on oyster population size structure (Dunn, 2007); (2) there is a range of cohorts in the fishery with differing lengths; and (3) the size restriction limits all catch to be above 58 mm in diagonal length (recruit-sized oysters), which requires the model to take length into consideration. However, the assumption of homogeneous habitat might not be ideal. The residing area of the oysters contains diverse density patches that support different growth patterns. This spatial heterogeneity can be managed by incorporating area structure in the model. However, more information on the

16

residing area and the distribution of density patches is needed in order to make the improvement.

The model accounted for the numbers of oysters by length class within an annual cycle, where movement between length classes was determined by the growth parameters. The oyster life cycle is shown in Figure 4.6.

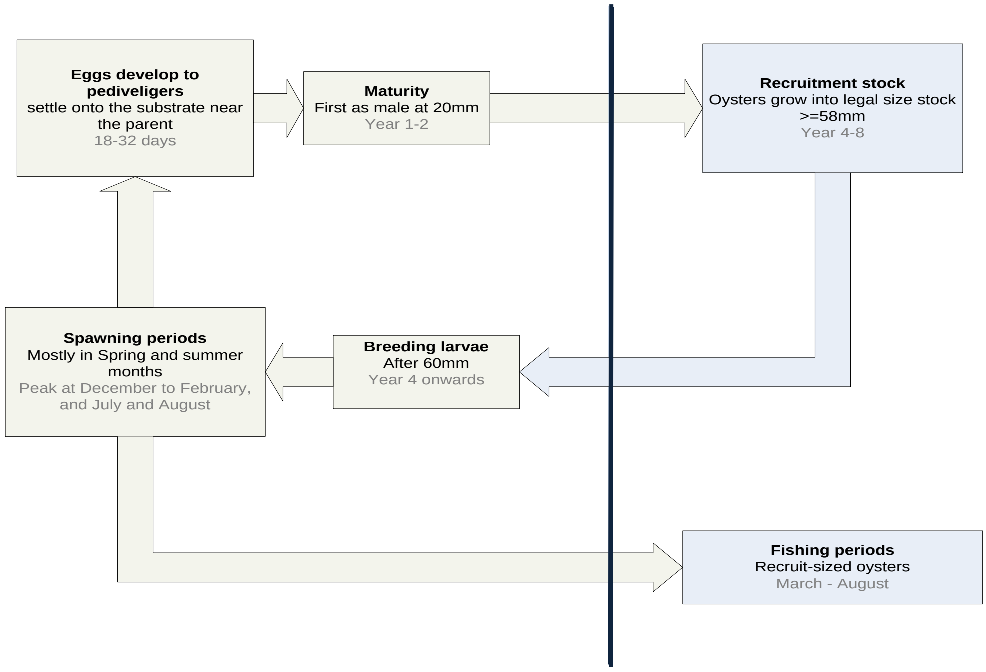

Figure 4.6 General life cycle of the Bluff oysters.

The line in the graph separates the oysters' life phases into the two studied stages and the other four life stages. Following the graph clockwise from the top left corner, in stage one, the eggs settle on the nearby substrate after being released into the water[17]. Oysters are sequential hermaphrodite species that change sexuality at different stages of their lives. They mature first as males at one or two years, then start developing female reproductive organs in stage two. On average, in four to eight years, oysters can grow to over 58 mm in diameter when they enter into recruitment stock stage (stage three, studied stage). The reproductive phase happens when oysters become sexually mature, mostly after year four with sizes larger than 60 mm (stage four). Oysters spawning peak happens in spring and summer in New Zealand (December to February) but also possibly in July and August (stage five). Therefore, in order to avoid the spawning season and let the oyster beds recover, fishing activities take place in autumn and winter times, from March to August (stage six, studied stage).

[17]Recent study show that eggs might travel to settle on a surface far away from the parent. Because oyster shells are an easier settlement substrate, the original high density patches with an ample number of shells are attached to by more new settlements therefore remain high density, and vice versa for low density patches (Michael, pers. comm., 2010).

Building on the general fisheries population dynamics (Figure 4.3), the base oyster biological model is presented as an inflow and outflow diagram in Figure 4.7.

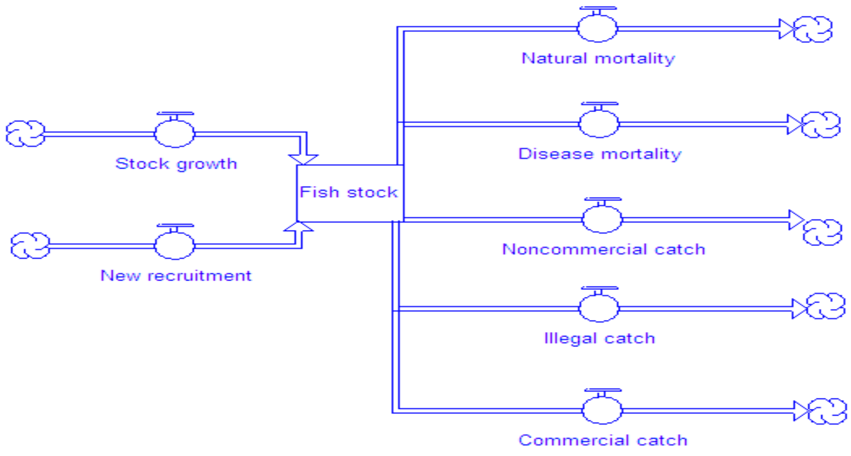

Figure 4.7 Base oyster population dynamics.

Figure 4.7 shows the population dynamics in the Bluff oyster fishery based on Dunn (2005). In the model, oysters entered the population following recruitment and were removed by natural mortality, disease mortality and fishing mortality (non-commercial catch, commercial catch and illegal catch). The data, both biological and catch, are updated to February 2007, which is the starting year of the simulation. The simulation runs for 10 years from 2008 to 2017. To accommodate the needs of the study alterations are made to model the biological performance of the fishery under two scenarios: ‘without’ self-governance and ‘with’ self-governance.

4.4.1.1 *Model structures of ‘without’ and ‘with’ self-governance regimes*

The biological sub-model was developed to capture the possible management impact of self-governance on fish stock in the Bluff oyster fishery. In order to do so, a comparison of specific management measures between the two regimes is necessary. The management differences between the two regimes are reflected on both inflow and outflow of the fish stock, as shown in Figure 4.8.

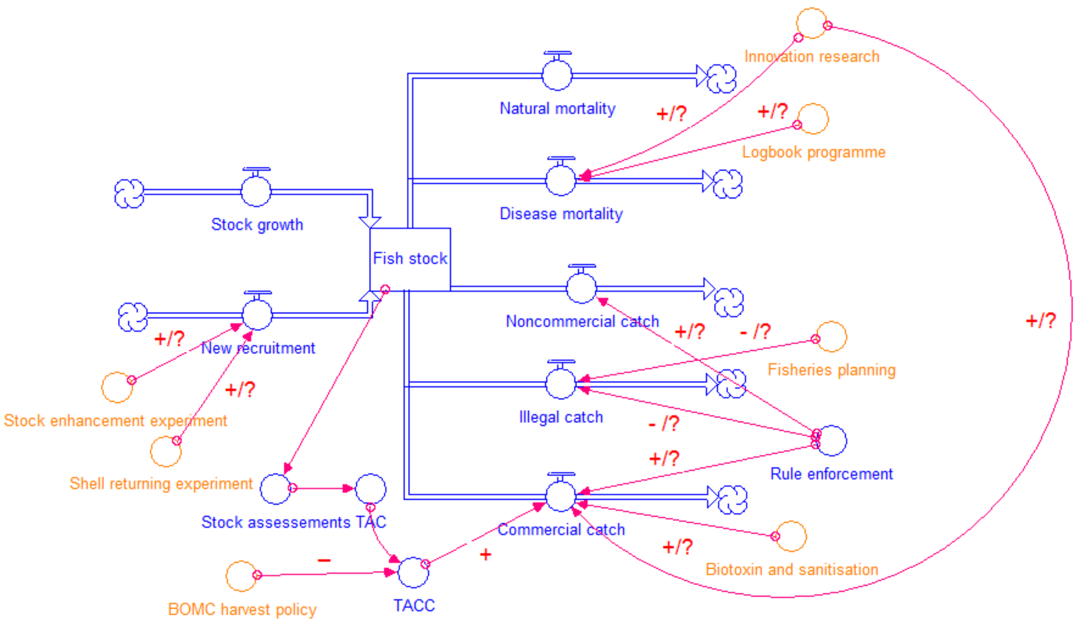

Figure 4.8 The Bluff oyster population dynamics, 'without' and 'with' self-governance.

Figure 4.8 shows the oyster stock dynamics under the two management regimes. The blue colour reflects the stock dynamics 'without' self-governance; the orange colour combining with the blue represents stock dynamics under the current 'with' self-governance regime. The additional management actions brought about by self-governance in the Bluff oyster fishery was discussed previously in Chapter 3. The management measures impact on the seven fish stock inflow and outflow variables. The '+' sign reflects that the management action strengthens the variable, whereas the '-' sign reflects the management action weakens the variable. If the sign '?' is added, the relationship between the management action and the variable may be positive or negative, but the actual impact is not known with certainty. The variable values will be discussed in the next section.

Without self-governance, the standard management measures under the QMS remains. The government initiates standard stock assessment (Figure 4.8, the blue circle on the lower left corner) to evaluate the fish stock conditions. An important part of the stock assessment is the *Bonamia* survey carried out annually by NIWA. The purpose of the survey is to assess the disease mortality and to understand how *B. exitiosa* interacts with the fishery. There are other research projects (*e.g.*, recreational harvest research) carried out as part of the stock assessment project.

Following stock assessment, the fishing limit is set yearly in the form of the TAC by the Minister of Fisheries (Figure 4.8, the blue circle to the right of stock assessment). Commercial fishers get their shares (TACC) after non-commercial fishing needs are met (Figure 4.8, the blue circle named TACC). In a QMS fishery, the commercial catch 'without' self-governance is determined by the amount of TACC. In addition to stock assessment and TAC settings, another management action taken under the QMS is the catch rules enforcement (Figure 4.8, the blue circle on the lower right corner). Fisheries regulation enforcement monitors all fishing related mortalities – commercial, non-commercial and illegal catch.

In contrast, 'with' self-governance, there are extra management controls put in place for the fishery, which are shown by the orange circles extra to the blue stock flow diagram. Chapter 3 identified seven BOMC-initiated management measures that might have an impact on the population dynamics of oyster stock (Figure 4.7, the orange circles extra to the blue stock flow diagram). They are, clockwise from top right in Figure 4.7, innovation research, the logbook programme, the fishery planning, the biotoxin and sanitation programme, the BOMC harvest policy, the shell returning experiment and the stock enhancement experiment.

Amongst all industry-initiated management, the most significant control method is the BOMC harvest policy (Figure 4.7, the orange circle on the lower left corner). The policy determines the actual commercial catch in Bluff, which directed the company to shelve half of the yearly catch each year since 2003. As discussed in Chapter 3 the shelving of ACE eliminates the potential cheating behaviour of fishers by requiring them to transfer the agreed amount of ACE to the BOMC before the fishing season begins. In addition to shelving, the BOMC directs all fishers to carry out a rotational harvest strategy, which requires fishers to rotationally harvest oyster beds in order to allow oyster patches to recover (Yang *et al.*, 2010).

In addition to setting commercial catch limits, self-governance management affects both the inflow and outflow of the stock dynamics[18]. From the inflow side, the stock enhancement trials and the return of shell experiments (Figure 4.7, the two orange circles on the middle left side in the diagram) are believed to be beneficial to new recruitment.

From the outflow side, the BOMC and SeaFIC joint innovation research (Figure 4.7, the orange circle on the top right corner) targets the *Bonamia* investigation and commercial harvest methods' improvement. In addition, the logbook[19] programme initiated by BOMC in 2006 (Figure 4.7, the second orange circle on the top right) improves the understanding of *Bonamia* and the overall health of the fishery. All these commercial fisher initiated

[18]Please see Appendix E Extra management actions by BOMC, 1996 – 2007 for details of research that are initiated by the BOMC, the associated benefits and costs.
[19]Please see Appendix F Sample logbook sheet for more information.

management actions are supposed to minimise disease mortality and improve commercial catch efficiency.

Also from the outflow side, the stakeholder groups have achieved a certain level of understanding and co-operation by developing a fisheries plan[20] (Figure 4.7, the third orange circle on the mid-left). By enabling communication amongst managers and the users of the fishery, the fisheries planning process may lead to a decrease in illegal catch. Furthermore, the biotoxin and sanitation testing (Figure 4.7, the orange circle on the bottom right corner) is also an additional item of self-governance management. The biotoxin and sanitation programmes are mainly for commercial purposes. Specifically, in order to operate commercially, the industry has to comply with food and safety standards in New Zealand, of which obtaining a water sanitation qualification is necessary. Although the water quality investigation is for commercial purposes, a safe fishing environment benefits all users of the fishery.

4.4.1.2 *Variable values of 'without' and 'with' self-governance regimes*

In the last section, the different management measures were identified in the Bluff oyster fishery for the two compared regimes. This section will assign values to quantify the effects of these management actions on each population component under the two management regimes. Table 4.1 summarises the variable values used in the model under the two management regimes. Each variable will now be discussed.

Table 4.1 Summary of variable values in the oyster biological sub-model.

	Values				
Variables	'Without' self-governance	'With' self-governance	Parameters	Values	Source
Growth	$\Delta L = \left(\frac{\beta g_\alpha - \alpha g_\beta}{g_\alpha - g_\beta} - L_1\right)\left(1 - \left[1 + \frac{g_\alpha - g_\beta}{\alpha - \beta}\right]^{\Delta t}\right)$		gα (α = 30 mm)	11.91 mm	Dunn, 2005, 2007; Fu and Dunn, 2009
			gβ (β = 55 mm)	3.61 mm	Dunn, 2005, 2007; Fu and Dunn, 2009
			L	50 classes range from 2 mm to 100 + mm	Dunn, 2005, 2007; Fu and Dunn, 2009
New Recruitment	R = (SSB/B0) / (1-(5h-1)/(4h)*(1-SSB/B0))		B0 (Virgin biomass, carrying capacity)	5,210 million in 1907	Dunn, 2007
			SSB (Spawning stock biomass)	1,090 million in 2007	Dunn, 2007
			h	0.9	Fu, pers. comm., 2009
Natural mortality	10% of total fish stock				Dunn, 2007
Disease mortality	20% 2012, 30% in 2013, 20% in 2014 and ranging from 1 - 4% for the other years between 2008 and 2017				Michael pers. comm., 2010
Non-commercial catch	0.67 million per year at 2007 level				Dunn, 2005, 2007; Fu and Dunn, 2009
Illegal catch	0.07 million per year at 2007 level				Dunn, 2005, 2007; Fu and Dunn, 2009
Commercial catch	15 million per year	7.5 million per year			MFish, 2009a

[20]Please refer back to Chapter 2 for the details of the Plan.

In the stock assessment (Dunn, 2005, 2007; Fu and Dunn, 2009), the stock-growth relationship is assumed to follow the maximum likelihood von Bertalanffy model and the parameters used were based on Francis (1988, as cited in Bull *et al.*, 2008). As shown in Table 4.1, mathematically, the relationship is:

$$\Delta L = \left(\frac{\beta g_\alpha - \alpha g_\beta}{g_\alpha - g_\beta} - L_1 \right) \left(1 - \left[1 + \frac{g_\alpha - g_\beta}{\alpha - \beta} \right]^{\Delta t} \right)$$

Where ΔL is the expected increment for an oyster of initial size L_1,

$g_\alpha$and $g_\beta$are the mean annual growth increments for oysters with arbitrary lengths α = 30 and β = 55.

The stock growth rate is assumed to be the same under both regimes. This is because stock growth is driven mainly by the internal dynamics of the fishery (nature) not the management regime. Further, there is no management action taken to manage stock growth.

Following Dunn (2005, 2007) and Fu and Dunn (2009), it is assumed that the oyster stock-recruitment follows the Beverton-Holt recruitment relationship. Fu (pers. comm., 2009) argued that though the exact stock recruitment relationship is unknown, as shown in Table 4.1, the best fitted recruitment model follows:

$$R = (SSB/B_0) / (1-(5h-1)/(4h)*(1-SSB/B_0))$$

Where R is the recruitment,

SSB is the spawning stock biomass,

$B_0$is the virgin stock biomass (biomass of the year 1907, when the commercial fishing first started), and

h the height of the model, is assumed to be 0.9 – low abundance leads to high recruitment and *vice versa* (Fu, pers. comm., 2010).

The new recruitment inflow is assumed to be the same under both regimes. There are two extra management actions taken to enhance new recruitment in the fishery. The oyster stock enhancement experiment funded by BOMC is undertaken through an independent company (Southern Shellfish Ltd.). This experiment is argued to add value to stock reseeding and add knowledge to the future development of stock improvement. However, the research's current contribution to harvest remains unknown (Wright, pers. comm., 2010). Similarly, the shell return experiment encourages fishers to return empty oyster shells to the sea to fortify the natural habitat for juveniles. However, it is still at its initial stage of development and has not yet significantly contributed to the population abundance (Wright, pers. comm., 2010).

From the outflow side, the model assumes natural mortality to be 10% of the oyster population, as show in Table 4.1. This assumption is based on the previous tagged experiments (Dunn, 2005, 2007; Fu and Dunn, 2009). Natural mortality is also assumed to be the same under both regimes because it cannot be affected by management measures.

In order to simulate the stock abundance for the fishery, assumptions about disease mortality are required. In the model, disease mortalities are assumed to be zero in the year when there is no detection of *Bonamia* or an estimation of the actual mortality in the years when there is a disease outbreak (Dunn, 2005, 2007; Fu and Dunn, 2009).

In contrast, the future pattern of disease mortality or even the possibility of disease outbreak is impossible to simulate. It would be easy to manage the fishery if disease mortality could be known with some certainty. Therefore, only assumptions can be made in terms of the occurrences and severity of *Bonamia*. Michael (pers. comm., 2010) suggested that, according to the historical *Bonamia* recurrence, as stated in Table 4.1, it is reasonable to assume that the disease repeatedly occurs every 10 years with mortalities of 20 – 30% and mortalities of 2 – 3% in the years where there is no large scale outbreak. Therefore, it is assumed that there will be a disease outbreak with a mortality of 20% in 2012, 30% in 2013 and 20% in 2014. The mortality levels for the rest of the years are assumed to range between 1 and 4%. This assumption is based on the *Bonamia*'s historical occurrence pattern (*i.e.*, a large outbreak between 1992 and 1995 and between 2000 and 2002. However, the disease mortalities can be simply updated in the model if there is any new evidence that suggests otherwise.

Disease mortality is assumed to be constant and does not change with management regimes. The cause of *Bonamia* outbreaks is unknown[21] (Dunn, 2005, 2007; Michael, pers. comm., 2010). The recent BOMC and SeaFIC joint innovation research aims at disease investigation and fishing method improvements for reducing incidental mortality (*i.e.*, the portion of oysters that are killed by dredging). However, the research took place in 2007 and its benefit is still to be confirmed. Similarly, the logbook programme records the fishery's condition (*e.g.*, disease coverage and by-catch rate) and provides more information about the disease, but does not prevent or reduce the effect of the disease. Its positive contribution might be scientifically proven in the future, but it is assumed to be neutral for the study period.

[21]There have been concerns that excessive fishing activity might worsen the situation (Knight, 2007), but there is no hard evidence to support this conjecture.

Non-commercial catch includes both recreational catch and customary catch. Yang *et al.*, (2010) noted that the non-commercial catch level is unknown due to a lack of recording requirements. Although self-governance opens a 'window' of co-operation amongst fisheries managers and stakeholders, it is unlikely to change the amount of the non-commercial catch. The historical estimates of total non-commercial catch range from 0.15 million oysters per year in the 1900s to 0.67 million during the past two years (2006 and 2007) (MFish, 2009a). The stock biomass estimation in this biological model assumes that the level of non-commercial catch will remain at 0.67 million oysters for the next 10 years, as shown in Table 4.1). There is another source of mortality – incidental mortality caused by dredging. However, it is ignored in the biological model because the amount is too insignificant to be considered (Fu, pers. comm., 2010).

The number of oysters taken illegally is insignificant compared with normal fishing activities (MFish, 2009a) or disease mortalities. Illegal fishing activities are assumed to remain at the 2007 level of 0.07 million oysters per year, as shown in Table 4.1. The model also assumes the same amount of illegal catch under both 'without' and 'with' self-governance regimes. This is because even if there is any difference in catch compliance, it is difficult to translate this reduction in non-compliance to a reduction of illegal catch. Furthermore, because illegal catches are relatively small, it will not significantly affect the model outcome.

The model requires both historic catch data and assumed future catch levels to simulate the stock abundance for the next 10 years. Historic commercial catch figures are relatively accurate because they were recorded by the industry annually since the beginning of the fishery in the early 1900s. The future catch level is assumed to remain at the TACC (15 million oysters) under the QMS, as shown in Table 4.1, unless the population falls below a certain threshold. The population threshold is set at 500 million oysters. This threshold number was set because the fishery was closed down in 1992 when the recruit stock abundance fell below 500 million.

Commercial catch is the only variable that has observable differences with the management regimes. Without self-governance, the catch level would be at the TACC level set by the government at about 15 million per year. With self-governance, the catch limit is set by the BOMC, which is at half of the TACC. This catch limit was set in 2003, after a round of a *Bonamia* outbreak. The catch limit has not been lifted despite the stock level gradually recovering since then. The biotoxin and sanitisation programmes enable commercial activities, but do not change the amount of commercial catch.

4.4.2 Economic sub-model

After establishing the biological model to assess the impact of self-governance on stock abundance, this section constructs an economic model to study the impact of self-governance on the fishery's profitability. Corresponding to the biological study, the duration of the economic study runs for 10 years from 2008 to 2017.

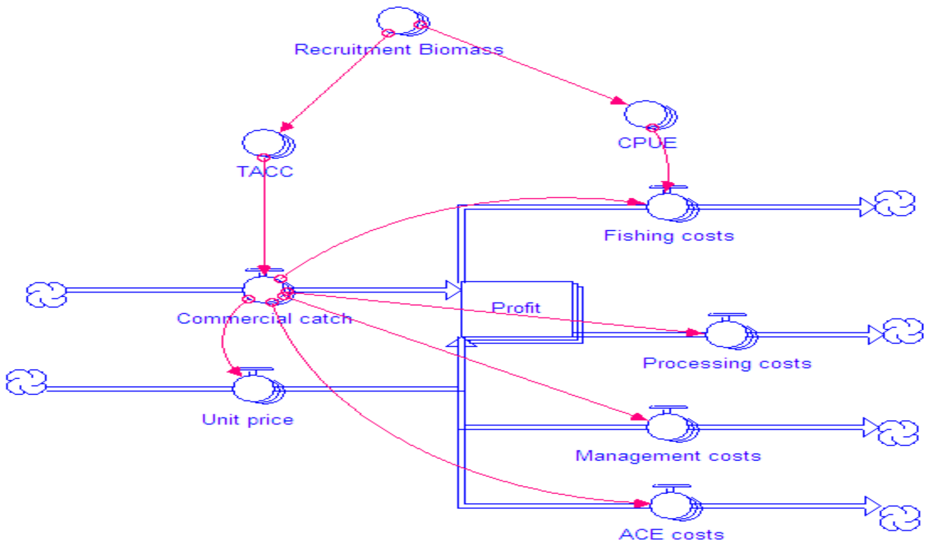

Figure 4.9 Base oyster fishery profitability dynamics.

Figure 4.9 above shows the dynamics of the economic model. In contrast to the general model depicted in Figure 4.4, fishing costs are broken down into four categories: actual fishing cost, processing costs, management costs and the ACE costs (*i.e.*, opportunity costs). The separation of fishing costs is for the purpose of showing the possible impact of self-governance on each cost component. Further, though different fisheries will have a different cost structure, those four components are the main cost drivers in the Bluff oyster fishery (Wright, pers. comm., 2009).

4.4.2.1 ***Model structures of 'without' and 'with' self-governance regimes***

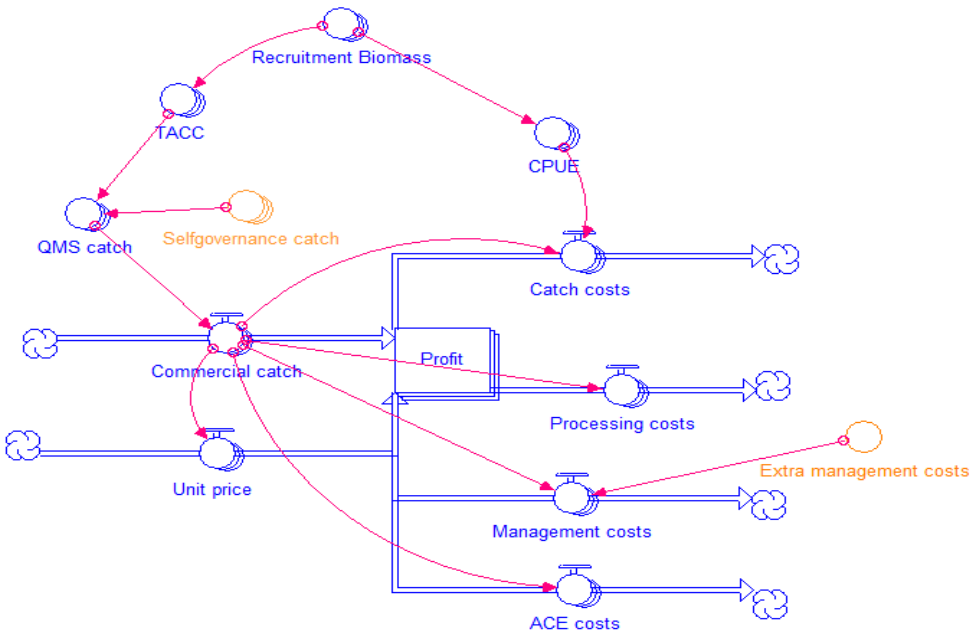

Figure 4.10 The Bluff oyster fishery profitability dynamics, 'without' and 'with' self-governance.

The management differences between the two regimes are reflected by the model variables. Figure 4.10 shows the profitability level under the two management regimes. The blue colour in the graph shows the profit dynamics without self-governance. The catch cost is driven by CPUE as well as the total catch, whereas the remaining costs are driven only by the amount of commercial fishing. This assumption will be discussed further in the next section. With the orange circle added to the blue diagram, the graph shows the economic performance with stakeholders' self-governance. There are two differences between the two regimes. First, commercial catches under self-governance are restricted by the BOMC (Figure 4.10, the orange circle in the middle left corner). The above discussed differences in variable values will become clear in the next section, where each variable under the two regions is discussed.

4.4.2.2 ***Variable values of 'without' and 'with' self-governance regimes***

In order to simulate the economic performance of the Bluff oyster fishery under the two examined regimes, the values of the six variables in the economic sub-model need to be identified. Those variable values will be based on either actual observations (commercial catch and management costs), estimates (unit price and fishing costs), or industry averages (processing costs and ACE costs). A summary of the variables and their values are provided in Table 4.2. Each variable will be discussed in detail in the remainder of this section.

Table 4.2 Summary of variable values in the oyster economic sub-model.

	Values		
Variables	'Without' self-governance	'With' self-governance	Source
Commercial catch, *h(x)*	15 million per year	7.5 million per year	MFish, 2009a
Unit price, *p*	$Q = 3.34*10^7 - 1.55*10^7 p$		MFish, 2009a; Industry data (2007); OLS Estimation
Catch costs, *C(x)*	*1.035*[1144*(h(t)/e(2.82*ln(q)+1.086*Ln(x)]*		StatsNZ (2009); OLS estimation
Processing costs	0.28+0.05*[1144*(h(t)/e(2.82*ln(q)+1.086*Ln(x)]		Industry data (2007); OLS estimation
Management costs	$0.32 per dozen oysters	$0.32+$0.05 per dozen oysters	1.MFish (2010a); Industry data (2007)
ACE costs	$0.38 per oyster	$0.38 per oyster	Industry data

Commercial catch, *h(x)*, as a variable, is shared by the economic sub-model and the biological sub-model. Its value was discussed previously. Briefly, the level of catch under the 'without' self-governance regime is assumed at the TACC level of 15 million oysters, whereas for the 'with' self-governance regime it is half of the TACC (*i.e.*, 7.5 million) (MFish, 2009a).

In conventional fisheries economic models, the price of fish is often assumed to be constant. However, this is not the case in the Bluff oyster fishery. Riley (1980) argued that, as an iconic delicacy in New Zealand, the price elasticity of Bluff oysters is inelastic. Further, although demand for oysters varies, people are willing to pay high prices at the beginning of the season and days near Queen's Birthday (beginning of June) (Skeggs, pers. comm., 2009).

In order to estimate the quantity and price relationship, Ordinary Least Squares (OLS) regression analysis is used. A caution about the linear regression analysis is that it relies upon the Gauss-Markov assumptions (Verbeek, 2004): $E(\varepsilon_i)=0, i = 1, \ldots, N$, $\{\varepsilon_1, \ldots, \varepsilon_N\}$ and $\{x_1, \ldots, x_N\}$are independent, $Var(\varepsilon_i) = \sigma^2, i = 1, \ldots, N$, and $Cov(\varepsilon_i, \varepsilon_j) = 0, i, j = 1, \ldots, N, i \neq j$. The first condition means the expected value of the error term is zero. That is, one average, the independent variable is measured without error, or at least with negligible error in relation to the inherent variance in the dependent variable. The second assumption conditions that the error terms and the independent variables are not correlated. The third assumption means all error terms have the same variance, i.e., homoscadasticity. Finally, the last assumption refers to zero correlation between different error terms, that is, no autocorrelation.
If those four assumptions are met, the OLS estimator b for the population parameter β is the best linear unbiased estimator – the so called small sample properties of OLS estimators22.

[22]Please see Verbeek (2004) for mathematical verification.

That is, b, in repeated sampling and on average, equal to the true value of β. However, the Gauss-Markov assumptions are restrictive and therefore, in many cases impossible to derive such estimators with small sample properties. What is more, b is a random variable and the actual estimates depend on the set of data. Therefore, the sample mean may differ from the population mean, especially for small samples.

In those cases, instead of evaluating the small sample properties, the alternative is to test the estimators'‘approximate’ properties assuming the sample size increases to infinity – the asymptotic properties (Verbeek, 2004). The reason is that asymptotically, based on central limit theorem, the estimators are often consistent (Verbeek, 2004). Consistency means that when the sample size gets larger, it is more likely that b gets closer to the true value of β. However, the question is how large is large. If the population is small, the sample size can be relatively small but still be sufficiently large. In contrast, if the population size approaches infinity, a big sample size can still be too small.

In the estimation of oyster price and quantity relationship, seven sets of average prices (from two anonymous industry sources) and quantity (from MFish, 2009a) time series data are incorporated in the OLS regression analysis. The estimation gave the following result as shown in Table 4.3. The sample size (7) is small and the lack of data is an inherent feature in fisheries management research. One way to test the accurate estimators’ properties is to carry out a Monte Carlo study[23]. However, a Monte Carlo analysis is beyond scope because this case study is done mainly to establish the validity of the bio-economic model; more data can be added if they become available. What is more, the small sample properties might still apply despite of the small sample size for two reasons. First, based on the result of the OLS estimation (Table 4.3), there is no evidence of autocorrelation and the residual serial correlation is rejected at 5% significant level by the Lagrange multiplier test. In addition, the independent variables are statistically significant at the 5% significance level.

There is only one independent variable in the equation, the price of oysters (p). Income is not included in the equation because Bluff oysters are a rare seasonal treat that a number of consumers buy only a few times a season. Hence income level does not greatly influence the demand for oysters. Further, the prices of substitutes are not included in the demand equation because there are no close substitutes for Bluff oysters. There are other oyster products but they are farmed, which are not yet well established substitutes for Bluff oysters (Wright, pers.

[23]Verbeek (2004) has a good example of how to carry out a Monte Carlo study for estimators’ properties.

comm., 2010). Because most farmed oysters grow faster, they lack the desirable texture of their wild counterparts (*e.g.*, Bluff oysters). Additionally, the cost of oyster farming and the risk of disease outbreaks among farmed oysters are too high to sustain a certain market share.

Table 4.3 OLS output, oyster price-quantity relationship.

Dependent variable is QUANTITY 7 observations used for estimation from 2002 to 2008			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	3.34E+07	4587978	7.2814[.001]
P	-1.55E+07	2840976	-5.4585[.003]
R-Squared	0.8563	R-Bar-Squared	0.82756
S.E. of Regression	1096074	F-stat. F(1, 5)	29.7948[.003]
Mean of Dependent Variable	8465714	S.D. of Dependent Variable	2639500
Residual Sum of Squares	6.01E+12	Equation Log-likelihood	-106.1056
Akaike Info. Criterion	-108.1056	Schwarz Bayesian Criterion	-108.0515
DW-statistic	0.31675		
	Diagnostic Tests		
Test Statistics	LM Version	F Version	
A:Serial Correlation	CHSQ(1) = 5.0485[.025]	F(1, 4) = 10.3480[.032]	
B:Functional Form	CHSQ(1) = 6.8614[.009]	F(1, 4) = 198.0098[.000]	
C:Normality	CHSQ(2) = .82060[.663]	Not applicable	
D:Heteroscedasticity	CHSQ(1) = .038546[.844]	F(1, 5) = .027685[.874]	
A:Lagrange multiplier test of residual serial correlation			
B:Ramsey's RESET test using the square of the fitted values			
C:Based on a test of skewness and kurtosis of residuals			
D:Based on the regression of squared residuals on squared fitted values			

Based on Table 4.3, the oyster supply equation can be given by:

$$Q = 3.34*10^7 - 1.55*10^7 p \qquad (4.15)$$

Where Q is the quantity supplied in number of oysters, *i.e.*, the actual catch of the year, and

p is the inflation adjusted price of one oyster.

According to the equation, there is a difference in unit price between the ‘without’ and ‘with’ self-governance regime. Equation 4.15 suggests that the price elasticity for the Bluff oysters is -0.87. Therefore, the reduction in quantity supplied will result in a difference in unit price in the economic sub-model. Specifically, in 2007, the price is NZ \$1.19 per oyster ‘without’ self-governance when the quantity supplied is 15 million oysters, but NZ \$1.67 ‘with’ self-governance when the quantity supplied is 7.5 million oysters.

Moving from the revenue side to the costs side, expenses incurred at sea such as fuel and crew wages are driven by units of effort, E (fishing hours). Given that the total amount of catch is predetermined by either the TACC or the BOMC’s harvest limit, the amount of effort is determined mainly by the CPUE. CPUE is, in turn, correlated with the density of oyster beds, which is positively related to population abundance (Michael, pers. comm., 2010). Therefore, catch costs in a particular year can be expressed as a function of CPUE, which is a function of stock abundance. In other words, fishers benefit from the growth of oyster population by way of increased CPUE, which drives down fishing cost as stock grows in size.

Two steps were taken to estimate fishing costs for the 10 years investigated. The first step was to estimate the relationship between CPUE and the recruit biomass (the portion of oysters that are allowed to be taken). In this way, the biological sub-model is connected to the economic sub-model. It is then followed by estimating cost per unit of effort for the year 2007[24] based on the cost per dozen oysters. The simulations run between 2008 and 2017 are based on cost per unit of effort data in 2007.

The first step is to estimate the relationship between CPUE and the recruitment stock abundance. It was established previously that if the catchability coefficient (q) remains constant over time, CPUE can be proportional to the average stock abundance (x) ($CPUE = qX^{\beta}(t)$). It is assumed in this study that the catchability q remains constant for the period between 1996 and 2006. This assumption is justified for two reasons. First, the most significant factor that affects the catchability is the oyster legal catch size, which has not changed in the last three decades (Michael, pers. comm., 2010).

Secondly, oyster bed density and gear efficiency might also affect catchability. However, oyster density stayed relatively level during recent years when *Bonamia* did not prevail (MFish, 2009a). Similarly, fishing gear type remained reasonably constant for the relevant period (1996 to 2007). Dunn (2007) suggested that though the dredge weight was possibly lighter before 1984, the typical commercial dredge’s weight has been set at about 530 kg since then. Moreover, there is a suggestion that the dredge size and methods have not changed since the beginning of the fishery in the 1900s. The size and weight of dredges have always been different amongst fishers, some use heavyweight dredges, whereas others use light ones (Wright, pers. comm., 2010). Similarly, there have been various fishing methods favoured by skippers, some use single-tow and others use double-tow.

Finally, estimating CPUE as a function of stock abundance is justified by a preliminary examination of the relationship between the two. As shown in Figure 4.10 the CPUE and stock abundance appear to be positively related. The CUPE data are recorded by commercial

[24] The 2007 cost figures are from an anonymous industry source, which is the only year that actual data are available for the fishery.

fishers whereas the stock abundance data are survey estimates from stock assessments. The two sets of data are gathered by different sources yet show similar patterns, which indicates that catch is more likely to be related to abundance.

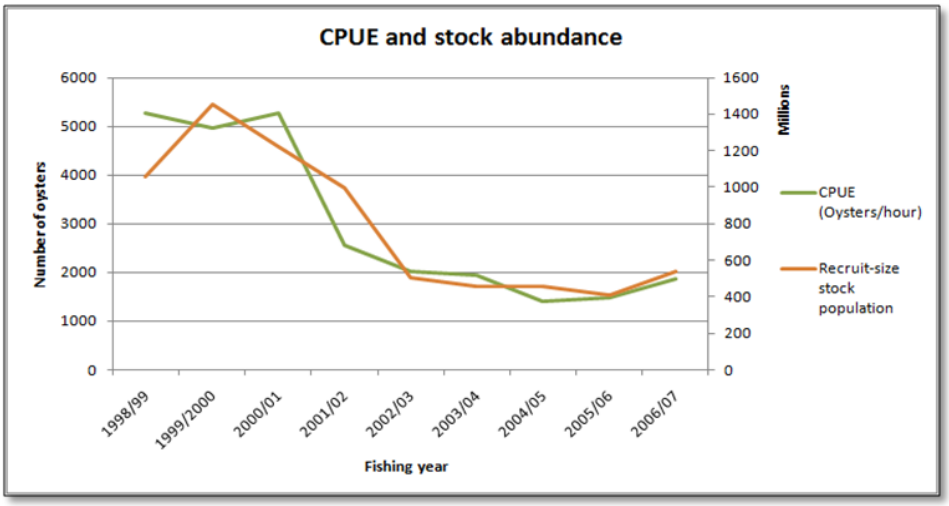

Figure 4.11 CPUE and stock abundance relationship, OYU5, 1999-2007.

The power curve version $h/E = qX^{\beta}$ of Equation 4.11 ($CPUE = qX^{\beta}(t)$) is used to estimate the relationship between stock biomass and CPUE. Although using the power curve limits the possibility of other forms of the relationship, this functional form allows estimation of the direct relationship between biomass and CPUE through β (Harley, Myers and Dunn, 2001).

Using 10 pairs of stock abundance and CPUE data, their relationships are estimated using OLS. The nuisance parameter, q, is estimated from the previous CASAL estimation to be 0.0065 since 1984. The OLS estimated result is given in Table 4.4.

Table 4.4 OLS output, oyster CPUE-abundance relationship.

Dependent variable is LCPUE 10 observations used for estimation from 1998 to 2007			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
Lq	2.8222	0.70271	4.0162[.004]
LRX	1.0868	0.17363	6.2591[.000]
R-Squared	0.83042	R-Bar-Squared	0.80922
S.E. of Regression	0.24472	F-stat. F(1, 8)	39.1758[.000]
Mean of Dependent Variable	7.9279	S.D. of Dependent Variable	0.56029
Residual Sum of Squares	0.47912	Equation Log-likelihood	1.0026
Akaike Info. Criterion	-0.99745	Schwarz Bayesian Criterion	-1.3
DW-statistic	0.68677		
	Diagnostic Tests		
Test Statistics	LM Version	F Version	
A:Serial Correlation	CHSQ(1) = 3.7665[.052]	F(1, 7) = 4.2296[.079]	
B:Functional Form	CHSQ(1) = .0045503[.946]	F(1, 7) = .0031867[.957]	
C:Normality	CHSQ(2) = .84301[.656]	CHSQ(2) = .84301[.656]	
D:Heteroscedasticity	CHSQ(1) = .29624[.586]	F(1, 8) = .24423[.634]	
A:Lagrange multiplier test of residual serial correlation			
B:Ramsey's RESET test using the square of the fitted values			
C:Based on a test of skewness and kurtosis of residuals			
D:Based on the regression of squared residuals on squared fitted values			

All variables are statistically significant at the 5% level and autocorrelation is rejected at the 5% significance level by the Lagrangian Multiplier test. The CPUE to abundance relationship is estimated to be:

$Ln(CPUE) = 2.82*Ln(q) + 1.086*Ln(x)$.

Where Ln is the natural log.

$$i.e., CPUE = e(2.82*Ln(q) + 1.086*Ln(x)) \quad (4.16)$$

The estimated relationship between CPUE and the recruitment stock abundance is represented by the stock abundance coefficient β. According Equation 4.16, β equals 1.086, which means that when the stock abundance increases by 1%, the CPUE increases by 1.086%[25]. This indicates that the change of CPUE is slightly more elastic to the change of stock abundance. In other words, not only does change in stock abundance affect catch positively, it affects catch on a larger scale.

After the relationship between CPUE and stock abundance is established in the first step, the second step is to estimate cost per unit effort of the year 2007 based on cost per dozen oysters. Following Equation 4.10 $(c(x) = e/qx(t))$, $e = c(x)*qx^{\beta}(t) = c(x)*CPUE$ and according to Equation 4.11, $CPUE = e(2.82*Ln(q) + 1.086*Ln(x)$, Therefore,

$$e = c(x)*e(2.82*Ln(q) + 1.086*Ln(x)) \quad (4.17)$$

Applying the above catch cost relationship, the catch costs of the two regimes in 2007 can be calculated based on the unit cost of catch (c) and stock abundance (x). In 2007, c was \$4.87/dozen (\$0.4056/oyster), based on the port price gathered by MFish. The estimated recruit-sized stock abundance (x) was 714,626,500 oysters. Therefore, the estimated CPUE, using the above abundance-CPUE relation (Equation 4.16), was 2820 oysters/hour dredging. Thus, the base unit cost of effort (e) in 2007, is \$1144/hour (= c*CPUE = \$0.4056/oyster*2820 oysters/hour*). Any future year's catch costs can be estimated by $C(x) = eE = e(h(t)/CPUE) = 1144*(h(t)/e(2.82*Ln(q)+1.086*Ln(x))$.

Hence, there is a difference in catch cost between the two regimes, which is driven by catch level and CPUE. First, the catch level difference ($h(t)$) in the two regimes will affect the catch

[25]CPUE data are readily available from commercial catch in stock assessment surveys. According to Dunn (2005, 2007), catch (total sacks harvested in a fishing year) and effort (total fishing hours for a fishing year) have been recorded in the OYU5 fishery since 1948 by various parties. For the relevant period in this study (1996-2007), the catch and effort data have been collected and reported by the Ministry of fisheries (MFish). The stock abundance data are from the stock assessment survey. For the years that the survey was not conducted, the average figure is used.

cost directly. Secondly, the difference in catch level affects stock abundance (*x(t)*). If such an impact is significant enough, the CPUEs will differ. These differences will be captured in the simulation and reflected in level of profits in the two regimes.

Apart from the variable catch cost, there are also fixed vessel costs (*i.e.*, the costs of maintaining a vessel). Although there are other overhead costs of running a vessel, in the Bluff oyster fishery, the maintenance and depreciation expense of a vessel is argued to be the most significant (Wright, pers. comm., 2010). Accordingly, these costs are used as proxies of total fixed overhead costs.

Because of the lack of reliable data for the Bluff oyster fishery, the fishing industry average rate of depreciation is used as a benchmark for the oyster fishery. In 2007, according to Statistics New Zealand (StatsNZ) Annual Enterprise Survey (StatsNZ, 2009), depreciation accounted for 5% of the operating (fishing related activities) expense. However, in Bluff, most boats are also used for catching other fish, and the average usage of a vessel to catch oysters is about 70% (by fishing days). Therefore, this study assumes that, on average, the fixed cost of a vessel amounts to 3.5% (= 5%*70%) of the total catch costs.

It is assumed that there is no difference in terms of fixed vessel costs under the two management regimes. Although the vessel number has decreased from 15 to 11 in Bluff under self-governance since 1996, this difference is not incorporated in the model. This is because, in the future, it is less likely that the vessel numbers will decrease further from 11 if total catch does not decrease significantly. Therefore, the vessel overhead cost is assumed to be3.5% of the total catch cost.

There are two parts in processing costs, a variable part and a fixed part. The variable part is driven by the amount of total catch, which includes the expenses of opening oysters, packaging and distribution. The 2007 processing costs from an anonymous source suggested that the average per dozen cost of processing amounted to $3.35, *i.e.*, $0.28 per oyster. The fixed part of the processing costs is the overhead of processing facilities, which includes rents of factory plants and the utility costs of the factories. Again, the overhead cost of processing is difficult to obtain due to a lack of information. Accordingly, fishing industry average depreciation of equipment in 2007 is used as a proxy, which is 5% of the total operating cost. It is assumed that there is no difference in unit processing cost or processing overhead costs between the ‘without’ and ‘with’ self-governance regime. This is because like the vessel maintenance costs, processing overheads are less likely to decrease in the future unless there is a significant decrease in catch levels.

Management cost differences between the two regimes. With regard to the ‘without’ self-governance regime, only an MFish levy was imposed on the fishery. According to MFish levy data, the average levy from the industry in 2007 was $0.23 per oyster. In contrast, the ‘with’ self-governance regime, extra management controls and research have been conducted on top of what was done by the government. The average amount spent by the industry between 1996 and 2007 is $0.05/dozen (MFish, 2010a).

The opportunity cost of fishing is represented by ACE costs. One can either sell ACE or catch the fish and, therefore, it is reasonable to assume that the proceeds of selling ACE should be similar to the net gain from fishing. However, the ACE price is unattainable for the fishery because ACE is not actively traded. There has been, nevertheless, a share of catch by several ACE holders using one fishing vessel. The price per dozen paid to catch the ACE in 2007 ranged from $4 to $5 per dozen oysters. Therefore, an average of $4.50 per dozen, or $0.38 per oyster for ACE cost is used in the model.

It is assumed that the ACE cost is the same under the two management regimes. Because of the lack of trade, the value of ACE is difficult to capture. It is possible that ACE value would increase as the fishery becomes more organised ‘with’ self-governance components. However, this conjecture remains as speculative because there is yet no empirical evidence to support it.

4.5 Results

4.5.1 Stock abundance based on the biological sub-model

The oyster biological sub-model is built on a length-based Beverton-Holt stock-recruitment relationship. Bayesian inferences are used to incorporate all available information to generate recruitment stock abundance estimates. The projection from this biological model produces reasonable outcomes for a short period of time and the setting of the official TACCs have been based on this model (Dunn, 2005, 2007). Fu and Dunn (2009, p. 3) noted that the “... model estimates of recent and current status agree closely with recent CPUE trends and survey abundance indices”. However, its ability to project long-term outcomes is unknown (Michael, pers. comm., 2010). This is why the projection is restricted to 10 years.

4.5.1.1 ***Comparison between 'without' and 'with' self-governance regimes***

From the analysis in Section 4.3, the only difference between the two management regimes that can be identified with certainty is the catch level. This difference, in turn, affects the level of recruit-sized population. Table 4.5 shows the results from running the recruitment biomass projection in CASAL.

Table 4.5 Recruit-sized oyster biomass projections, 2008-2017.

Year	Bonamia mortality	Recruit-sized population (Million oysters) [95% credible intervals]				Relative size
		'With' self-governance (Catch=7.5) (million)		'Without' self-governance (Catch=15) (million)		
2008	0.01	908.0185	[715.98, 1081.49]	908.0185	[715.98, 1081.49]	1.00
2009	0.02	1140.975	[912.32, 1385.64]	1134.255	[905.60, 1378.92]	1.01
2010	0.02	1372.67	[1084.23, 1734.47]	1360.065	[1071.61, 1721.87]	1.01
2011	0.03	1582.915	[1247.58, 2003.89]	1565.255	[1229.92, 1986.27]	1.01
2012	0.2	1547.94	[1209.77, 1952.18]	1528.915	[1190.91, 1933.21]	1.01
2013	0.3	1227.62	[968.35, 1552.65]	1211.715	[952.39, 1536.68]	1.01
2014	0.2	1002.365	[790.77, 1277.56]	988.3145	[776.80, 1236.38]	1.01
2015	0.02	1048.42	[823.61, 1325.92]	1031.8	[807.20, 1309.74]	1.02
2016	0.03	1242.89	[975.77, 1560.82]	1221.705	[954.81, 1539.61]	1.02
2017	0.01	1465.96	[1129.79, 1854.93]	1440.345	[1104.52, 1829.55]	1.02

The table shows the number of projected recruit-sized oysters (in millions) for 'without' and 'with' self-governance regimes from 2008 to 2017. The second column, *Bonamia* mortality, is the presumed disease mortality based on historical observations. The third column shows the median of projections of stock biomass and their 95% credible intervals under the current self-governance regime where 7.5 million oysters are taken yearly. In contrast, the fourth column is the projection of stock abundance and their 95% credible intervals under the QMS ('without' self-governance) regime where fishers are allowed to take 15 million oysters per year. The differences that the catches make on the medians of estimated abundance are shown in the last column as the relative size between 'with' and 'without' self-governance regimes. There is a maximum of 2% difference in any given year during the 10 year simulation period.

4.5.1.2 ***Model validity***

There will be inevitable discrepancies between the model implications and real-world variations. However, the model's short-term estimation of population abundance is dependable given the close match between the surveyed estimates of recruit-sized oyster abundance (663 million oysters) and the model estimated oyster population (720 million oysters). Furthermore, the latest model estimates of recruit-sized biomass for 2009 (data updated to 2009) were "about 20% (17–23%) of initial state" (Fu and Dunn, 2009, p.3), which converts to 1042 million oysters. The stock abundance estimate for 2009 in the thesis (data updated to 2007, figures shown in Table 4.5) is about 1140 million oysters. The two model runs based on different base figures are different as expected, but are not too far apart.

4.5.1.3 *Sensitivity analysis*

The validity of the model can also be tested through sensitivity analysis. This is because as a variable changes, it is expected that the result will change accordingly, in the same direction and to the according magnitude, if the model is valid. Sensitivity analyses were carried out to assess the uncertainties of the model estimates that arose from variations of key model assumptions. The following analysis aims at testing the sensitivity of output (*i.e.*, recruitment abundance) to the two main inputs – a biological factor: the disease mortality rate and an economic factor: the commercial catch level. Other biological inputs, such as recruitment and growth, can affect stock abundance but they are less likely to vary providing the marine environment is relatively stable.

The significance of disease mortality to the abundance projection is obvious. Not only does the *Bonamia* mortality reduce stock abundance directly by removing a large mass of stocks, it also changes the size and age structure of the remaining population. Specifically, *Bonamia* has more effect on recruit-sized oysters (oysters larger than 58 mm in diameter) than on small ones (Michael pers. comm., 2010). Since the recruit-sized oysters constitute the bulk of the reproductive population, it would usually take many years, after a major outbreak of *Bonamia*, for the population to recover to the previous level while the small oysters grow to maturity.

Table 4.6 Sensitivity analysis, disease mortality 0 versus 40%.

	No catch (Catch=0) (million)			'Without' self-governance (Catch=15) (million)		
Year	Disease mortality=0	Disease mortality=0.4	Relative size	Disease mortality=0	Disease mortality=0.4	Relative size
2008	914.90	678.41	1.35	914.90	678.41	1.35
2009	1181	522	2.26	1167	515	2.27
2010	1462	421	3.48	1436	410	3.50
2011	1739	362	4.80	1701	349	4.87
2012	2010	328	6.12	1962	315	6.23
2013	2251	308	7.30	2193	295	7.44
2014	2489	297	8.39	2423	282	8.58
2015	2707	290	9.32	2633	276	9.54
2016	2915	286	10.18	2834	272	10.44
2017	3099	282	11.01	3012	267	11.30

Table 4.6 shows projected stock biomass under two scenarios, with future disease mortality assumed to be zero and 40%. Two catch rates, no catch and an annual catch of 15 million oysters, were tested under the two disease mortality assumptions. Two catch rates were used to examine the human (management) impact on stock abundance given the same disease level. The simulation shows, when the future catch is assumed to be zero, that the differences in the relative population size under the two disease mortality scenario increases from 1.35 times in 2008 to 11 times in 2017 (Table 4.6, column four). When the catch is set at 15 million oysters, the differences in oyster abundance between the two disease mortality assumptions are slightly larger (Table 4.6, column seven). The result shows that whether there is no catch or a 15 million catch, disease mortality affects the population abundance negatively and significantly.

Catch level also affects the population abundance but on a much smaller scale. Like *Bonamia*, fishing takes away recruited oysters that might reproduce. However, because fishing takes place from March to August (after the peak spawning months of December to February), it is less destructive than the disease, which can happen randomly and last for years. According to Wright (pers. comm., 2010), on average, there were four to five reproducing oysters per sack (774 oysters) taken by fishing in previous years. Further, the number of oysters taken from fishing (15 million oysters) is insignificant compared with the number of oysters killed by the disease (approximately 1.5 billion in the three years between 2000 and 2002).

Table 4.7 Sensitivity analysis, fishing mortality 0 versus 15 million catch per year.

	Disease mortality = 0.00 per year			Disease mortality = 0.40 per year		
Year	No catch (Catch=0)	'Without' self-governance (Catch=15) (million)	Relative size	No catch (Catch=0) (million)	'Without' self-governance (Catch=15) (million)	Relative size
2008	915	915	1.00	678	678	1.00
2009	1181	1167	1.01	522	515	1.01
2010	1462	1436	1.02	421	410	1.03
2011	1739	1701	1.02	362	349	1.04
2012	2010	1962	1.02	328	315	1.04
2013	2251	2193	1.03	308	295	1.05
2014	2489	2423	1.03	297	282	1.05
2015	2707	2633	1.03	290	276	1.05
2016	2915	2834	1.03	286	272	1.05
2017	3099	3012	1.03	282	267	1.06

Table 4.7 above shows the projected recruitment stock abundance under two scenarios: no fishing and a yearly catch of 15 million oysters. Under the no disease mortality scenario, as shown in column 4 in the table, the relative population size can range from no difference in

2008 to 3% in 2017. In contrast, if the disease mortality was 40% per year, the difference between no catch and yearly catch of 15 million oysters ranged from zero to 6%. Although a 6% difference (*i.e.*, 15 million oysters) appears to be large, it is insignificant compared with the 1100% difference (*i.e.*, 2740 million oysters) created by the zero and 40% disease mortality difference.

4.5.2 Profitability based on the economic sub-model

4.5.2.1 *Comparison between 'without' and 'with' self-governance regimes*

The profit simulation incorporates three catch levels: the 'without' self-governance catch level of 15 million oysters per year, the current 'with' self-governance catch level of 7.5 million and the possible Maximum Economic Yield (MEY) catch level of approximately 8 to 9 million per year. The arbitrary MEY catch level assumes that the BOMC adjusts catch levels according to the stock population size and the demand of oysters to achieve maximum profitability. Tables 4.8, 4.9 and 4.11 show the profitability level of the fishery under the three catch levels.

Table 4.8 Profit, 'without' self-governance (15 million catch per year), 2008-2017.

Years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2008	3.06	3.27	3.48	3.69	3.90	4.11	4.32	4.53	4.74	4.95
2009		4.11	5.37	6.63	7.89	9.16	10.42	11.68	12.94	14.20
2010			4.79	6.74	8.68	10.63	12.58	14.52	16.47	18.41
2011				5.24	7.62	10.01	12.40	14.79	17.18	19.56
2012					5.17	7.49	9.81	12.13	14.45	16.77
2013						4.39	5.92	7.46	9.00	10.54
2014							3.52	4.19	4.86	5.53
2015								3.72	4.60	5.47
2016									4.43	6.00
2017										4.99

In Table 4.8, the red figures are the industry's estimated yearly profits based on the assumptions that the future fishing mortality stays at 15 million oyster caught per year from 2008 to 2017. The profitability stays at approximately NZ $3 – 5 million. In contrast, the figures in each row show the profit if the stock population stays the same as the previous year. For example, the second row shows the fishery's profitability if fish abundance stays at 2008 level, and the third row shows the profitability if abundance stays at the 2009 level, and so on.

Table 4.9 Profit, 'with' self-governance (7.5 million catch per year), 2008-2017.

Years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2008	5.13	5.24	5.34	5.45	5.55	5.66	5.76	5.87	5.97	6.08
2009		5.66	6.29	6.92	7.55	8.18	8.81	9.44	10.07	10.71
2010			6.00	6.97	7.95	8.92	9.89	10.86	11.84	12.81
2011				6.22	7.42	8.61	9.80	11.00	12.19	13.39
2012					6.19	7.35	8.51	9.67	10.83	11.99
2013						5.80	6.57	7.34	8.10	8.87
2014							5.36	5.70	6.03	6.37
2015								5.47	5.90	6.34
2016									5.82	6.61
2017										6.10

Compared with the 'without' self-governance catch of 15 million oysters, the Table 4.9 shows the profitability for the same period if catch levels were 7.5 million oysters under the current 'with' self-governance regime. The profit level of the 'with' self-governance is greater than that of the 'without' self-governance regime. On average, $1.43 million more is earned per year under self-governance. This is because the oysters are price inelastic and the price effect of decreased supply over-weighs the quantity effect. There were 16 quota holders in the fishery in 2008, therefore the average return for each quota holder is approximately $320,000 based on the current catch level.

However, there is no reason why the self-governance entity would hold catches at 7.5 million oysters indefinitely. The industry-agreed 7.5 million oyster catch was based on fishers' suggestions in 2003 and it could vary within the range of the TACC. If one assumes that self-governance unitisation aims at maximising profit, the catch level could be set at the MEY level. The following two tables show the maximum economic catch level and the profitability generated by maximum economic catch.

Table 4.10 Estimated Bluff oyster MEY catch levels, 2008-2017.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MEY	8.84	9.38	9.74	9.97	9.93	9.53	9.08	9.18	9.55	9.84

The level of MEY catch ranges from 8 to 9 million oysters per year. The average MEY catch level lies between the self-governance catch restrictions and the TACC, but closer to the former (7.5 million oysters caught) than the latter (15 million oysters caught). Coincidentally, in 2009, the BOMC sought to increase the level of catch from 7.5 million oysters as stock recovered from the recent *Bonamia* outbreak with an increased CPUE. The catch limit was adjusted to 8.2 million oysters in 2009 and 9.5 million oysters in 2010. The estimated MEY catches for 2009 and 2010 are 9.38 million oysters and 9.74 million, respectively.

Table 4.11 Projected Bluff oyster MEY profit, 2008-2017.

Years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2008	5.29	5.42	5.54	5.66	5.79	5.91	6.04	6.16	6.28	6.41
2009		5.95	6.74	7.53	8.32	9.12	9.91	10.70	11.49	12.28
2010			6.40	7.66	8.93	10.20	11.47	12.73	14.00	15.27
2011				6.69	8.29	9.88	11.47	13.06	14.65	16.25
2012					6.65	8.19	9.73	11.27	12.82	14.36
2013						6.13	7.11	8.09	9.07	10.05
2014							5.57	5.98	6.39	6.80
2015								5.70	6.24	6.78
2016									6.15	7.16
2017										6.53

Table 4.11 shows the maximum profit for the fishery every year at the catch level of the MEY, where the marginal revenue and marginal costs equalise. The average profitability is \$6.5 million dollars per year. Comparing this result to the profit levels under both 'without' and the current 'with' self-governance catch, it is apparent that the MEY catch level brings most profit to the fishery.

4.5.2.2 ***Sensitivity analysis***

Following the sensitivity test for the biological model, this section reports the sensitivity tests of profitability against the main biological factor, *Bonamia* and the main economic factor, catch level. Other economic inputs such as unit price of oysters, fishing costs and processing costs, are related to commercial catch level. Therefore, by changing catch levels the sensitivity of profit to the rest of economic inputs is tested automatically. The *Bonamia* scenarios are set at the extreme situations where there is no *Bonamia* and 40% disease mortality in the next 10 years. The impact of three catch levels (the 'without' self-governance catch level of 15 million oysters per year, the current 'with' self-governance catch level of 7.5 million oysters per year and the possible MEY catch level) on profit are compared.

Table 4.12 Sensitivity analysis of the oyster model, profitability against disease mortality.

	QMS (Catch=15) (million)			Self-governance (Catch=7.5)			MEY (Catch=8-9) (million)		
Year	Bonamia = 0	Bonamia = 0.4	Relative size	Bonamia = 0	Bonamia = 0.4	Relative size	Bonamia = 0	Bonamia = 0.4	Relative size
2008	3.03	1.17	2.60	5.12	4.19	1.22	5.28	4.21	1.25
2009	4.19	-1.11	NA	5.70	3.05	1.87	6.00	3.07	1.96
2010	4.95	0	NA	6.08	0	NA	6.50	0	NA
2011	5.45	0	NA	6.33	0	NA	6.84	0	NA
2012	5.81	0	NA	6.51	0	NA	7.09	0	NA
2013	6.05	0	NA	6.63	0	NA	7.26	0	NA
2014	6.24	0	NA	6.72	0	NA	7.40	0	NA
2015	6.38	0	NA	6.80	0	NA	7.50	0	NA
2016	6.50	0	NA	6.85	0	NA	7.58	0	NA
2017	6.59	0	NA	6.90	0	NA	7.65	0	NA

Table 4.12 shows the relative differences of the simulated profit levels under 0 and 40% disease mortality levels. The first three columns, after the year column, show the profitability under the hypothetical 'without' self-governance regime (catch equals 15 million oysters per year). Without *Bonamia* mortality, the fishery would have made 2.6 times more profit in the first year than if the disease mortality was 40%. The 40% disease mortality difference can send the profitable fishery to a loss in the second year. From the third year (2010), the fishery would be closed because the recruitment biomass dropped below the threshold biomass (500 million oysters by assumption). Similar conclusions apply for the 'with' self-governance regime where the catch level equals 7.5 million oysters per year and MEY catch level (8 to 9 million oysters per year depending on the biomass of that year). That is, the 40% difference in disease mortality would cause a significant difference in profitability.

Table 4.13 Sensitivity analysis of the oyster model, profitability against catch level.

Year	Bonamia	QMS	Self-governance (Catch=7.45) (million)	Relative size	MEY (Catch=8-9) (million)	Relative size
				SG/QMS		MEY/QMS
2008	0.01	3.06	5.13	1.68	5.29	1.03
2009	0.02	4.11	5.66	1.38	5.95	1.05
2010	0.02	4.79	6.00	1.25	6.40	1.07
2011	0.03	5.24	6.22	1.19	6.69	1.08
2012	0.20	5.17	6.19	1.20	6.65	1.07
2013	0.30	4.39	5.80	1.32	6.13	1.06
2014	0.20	3.52	5.36	1.52	5.57	1.04
2015	0.02	3.72	5.47	1.47	5.70	1.04
2016	0.03	4.43	5.82	1.31	6.15	1.06
2017	0.01	4.99	6.10	1.22	6.53	1.07

Catch level also affects profitability but in a different scale as shown in Table 4.13 above. The table above shows the simulated profit level under three catch levels: ‘without’ self-governance catch of 15 million, ‘with’ self-governance catch of 7.5 million oysters and MEY catch that vary from 8 to 9 million oysters. Based on the arbitrary disease mortality postulation (shown in the second column), the differences in profit between the two regimes are significant, as shown in the fifth column. On average, 35% more profit is made each year with self-governance. However, more profit is generated from catching the MEY catch. The last column shows that if the industry adjusts catch level to the MEY the industry can earn 3 – 8% more than the current ‘with’ self-governance regime. The profit difference between ‘with’ and ‘without’ self-governance regime is larger than between self-governance and MEY catch because the current catch of 7.5 million oysters per year is closer to the MEY catch level.

4.6 Conclusion

In this chapter, an *ex-ante* analysis was carried out to evaluate the effects of self-governance on fish stock abundance and profitability. The method applied involved developing a bio-economic model to project the future performance of the fishery. It is common to use bio-economic models to analyse management impact on a fishery (*e.g.*, Bjørndal *et al*., 2004; Bueno and Basurto, 2009). However, conventional bio-economic models of fisheries either ignore the non-biological information (*e.g.*, commercial CPUE data) or the effects of interim management actions (*e.g.*, enhancement programme or ACE shelving). By using Bayesian methods and system dynamics, the bio-economic model in this chapter is able to incorporate most available information in the fisheries (*e.g.*, scientific survey, catch data, CPUE data, and management actions) to reduce estimation uncertainties.

Based on the analysis in this chapter, both the biological and economic performance of the Bluff oyster fishery can be improved. These improvements were demonstrated herein to be the direct results of self-governance. Biologically, oyster stock is preserved by the ACE-shelving co-ordinated by the BOMC. The ‘shelving’ required the ACE holders to transfer the agreed amount of ACE to the company and successfully eliminates fishers’ potential cheating behaviour. Without the transferring mechanism, the ACE holders are able to and can cheat and catch more than they had agreed on. The ‘shelving’ agreement also allowed for real-time management based on the most current condition of the oyster stock. In 2009, after deferring half of the ACE at the beginning of the fishing season, the company transferred 0.7 million ACE back to the holders since there was a recovery of oyster beds. In so doing, the economic return from the fishery improved from NZ $5.66 million for catching 7.5 million oysters (Table 4.9) to NZ $5.95 million for catching 8.2 million oysters (Table 4.11, assuming the 8.2 million oysters is close to the MEY of the fishery).

4.6.1 Biological sub-model

The dynamics of the oyster population was captured by the Berverton-Holt model through Bayesian inferences. The analysis leads to the following findings for the Bluff oyster fishery. First, according to the model run, the benefit of self-governance to stock abundance is obvious. By foregoing half of the TACC not only are 7.5 million oysters directly preserved annually, but an additional 6 to 25 million are preserved by the flow-on effect between 2008 and 2017, as shown in Table 4.5. That is, self-governance contributed to the conservation of a total of 13.5 to 32.5 million oysters per year for the 10 years simulated. Although the amount not harvested is insignificant to the total population, 13.5 to 32.5 million oysters could have supported another commercial fishery in Bluff given the current TACC of 14.95 million oysters.

Another conclusion from this study is that fishing mortality has little impact on the Bluff oyster fishery's viability. Dunn (2005, 2007) found that a catch level of 15 million or 7.5 million oysters per year was unlikely to put any significant pressure on stock for the next four years from 2007 to 2012; Fu and Dunn (2009) reached the same conclusion for the period between 2008 and 2014. This study also shows that the recruitment stock population differs from 0 to 2% between the 7.5 million catch level and the 15 million catch level. However, also from Table 4.5, the impact of human activity on fish stocks increases with disease mortality. When there is no disease mortality, the difference between a 15 million yearly catch and no catch on the stock population is 3%; when the mortality is 40% per year, the difference increases to 6%.

4.6.2 Economic sub-model

The profitability levels were estimated through a standard economic model in the system dynamics environment. The analysis leads to the following two findings. First, the effect of self-governance on profitability is obvious. Under the 'with' self-governance regime, the annual profit of the fishery is, on average, $1.43 million higher than that under the 'without' self-governance regime (Tables 4.8 and 4.9). The economic gain is established from both the revenue and cost sides. Although the catch is decreased by a half, the revenue from oysters decreases by less than a half because the loss in quantity sold is compensated for by the increase in unit price (own price inelastic as estimated in Equation 4.14). In addition, the decrease in catch also leads to decrease in catch costs. Moreover, as more oysters are left uncaught, unit catch cost decreases through increased CPUE.

Furthermore, if the catch level were adjusted to aim for making the most profit from the fishery at the MEY level (Table 4.10-4.11), an extra $0.33 million profit can be earned compared with the profit from the current catch level of 7.5 million oysters. Therefore, in terms of profit, within the TACC limit, more profit can be made by self-governance and by adjusting the catch level to optimal levels.

Secondly, and perhaps not surprisingly, *Bonamia* is established as the major factor affecting profitability in the fishery. An increase in disease mortality from 0 to 40% could send the fishery from a lucrative business to shut-down. Table 4.12 indicated that if the disease mortality stays at 40%, the fishery would collapse in the third year (2010) under any catch level.

There are scientific uncertainties in estimating oyster stock abundance. A number of assumptions are used in the model. For example, the stock-growth relationship is assumed to follow the maximum likelihood von Bertalanffy and the natural mortality is assumed to be constant at 10% for all length classes. Although the assumptions made are based on the previous studies and best possible knowledge, estimation errors are inevitable. The underlying assumptions and the related uncertainties should be taken into consideration when using the model result to make management decisions and policy recommendations.

Despite the limitations of simulations from this *ex-ante* analysis, it seems clear that self-governance offers significant payoffs in stock size and profitability in the Bluff oyster fishery. Self-governance, from the analysis, also enhances the long-term viability of the industry. However, the improvement of stock abundance and profitability under self-governance rests on two features of the Bluff oyster fishery. First, the historic data suggest that catch cost is related to stock size, which makes stock conservation profitable. Secondly, based on quantity and price data, Bluff oysters are price inelastic. That is, a decrease in quantity supplied will lead to a price increase. Therefore, lowering catch is also profitable.

Chapter 5
Minimum Information Management System (MIMS)

5.1 Introduction

Chapter 4 found that, using the modelling approach, self-governance improves fisheries management. Specifically, the model suggests that both the biological and economic performance of the Bluff oyster fishery can be improved by having the self-governance component in the management regime. However, the modelling approach has its limitations. For one, there are assumptions and, therefore, uncertainties attached to the modelling approach. Secondly, although the modelling approach provides a theoretically sound analysis of ITQ-based self-governance, the information needed (*e.g.* expert opinions and CPUE data) in the model can be time and resource consuming to collect.

The Minimum Information Management System (MIMS) approach can provide a simple short-cut for fisheries managers to evaluate ITQ-based self-governance regimes. This approach involves using ITQ price as an approximator of fisheries performance to evaluate the ITQ-based self-governance regime. The extra benefit of self-governance to fisheries management might be captured by quota prices. Arnason (1989, 1990) proposed that fishing quota price contains a variety of information about fisheries, which can help fisheries managers determine the optimal catch level. Gudmundsson (2002) suggested that better management can lead to more valuable resources, which results in a higher resource asset value. Hence, asset price can reflect the condition of the underlying resource. Batstone and Sharp (2003) tested the information contained in the ITQ price in one fishery in New Zealand and found evidence that supports such an argument.

Because only one piece of information, the quota price, is required to evaluate fisheries management, it is called the Minimum Information Management (MIM) theory. The method of using quota prices to assist fisheries management is called the Minimum Information Management System (MIMS). The MIMS was first formally discussed by Arnason (1989), who pointed out the need for a simple instrument to assist fisheries management. The reason is that, in order to manage a fishery (*e.g.*, setting the optimal catch level), large amounts of information are required in order for some management tools (*e.g.*, tax and subsidies) to work.

There are four reasons for choosing the MIMS as the second method to examine ITQ-based self-governance. First, it can add confidence to the evaluation. Batstone and Sharp (2008) argued that since the MIMS relies on information from market mechanisms, it can mitigate the uncertainties attached to the modelling approach. Secondly, the application of MIMS following the modelling approach can test whether quota price can indeed convey expectations of impacts on profitability. Specifically, the bio-economic modelling approach is able to identify profitability improvement. Therefore, if the model estimates a profit improvement, there should be a positive return on the fishery's quota price and *vice versa*.

Thirdly, MIMS is simple to use, management qualities might be revealed by just one data set on quota prices. Therefore, if the MIMS theory is valid, the simplicity is valuable to management. That is, fisheries managers would be able to evaluate the value (disvalue) of self-governance by assessing only the quota price and, therefore, design policy to encourage or discourage self-governance.

Finally, the MIM theory itself has its interesting and captivating features, but there is a lack of application to real fisheries. This chapter intends to contribute to that body of literature. Specifically, Copes (1989, p. 254) commented on Arnason's (1989) MIMS as mathematically beyond reproach and daring of imagination of an ideal quota system, but called for "realistic prospects of useful implementation … (t)here is a great deal more pioneering work left for all of us who would like to contribute to this potentially important development in fisheries management". Indeed, over 20 years after Arnason's original research and Copes' comments, there have been only a handful of applications, including Gudmundsson (2002) and Batstone and Sharp (2003). Gudmundsson (2002) applied the MIMS to a case by assuming the assumptions underlying the MIMS theory were met. Batstone and Sharp (2003) found evidence that supports the MIMS approach using the New Zealand snapper fishery as a case study. Different from Gudmundsson (2002) and Batstone and Sharp (2003), this chapter aims at first examining the applicability of the MIMS and then applying the method to evaluate self-governance.

The remainder of this chapter is arranged as follows: Section 5.2 provides a literature review on the theoretical origins of the MIMS, as well as applications to date, and New Zealand quota markets. Section 5.3 is the method segment, which examines in detail the application of MIMS, its prerequisites and application procedures. Section 5.4 applies the procedures developed in Section 5.3 to the case study, the Bluff oyster fishery, to check if the promises of self-governance can be fulfilled, as well as examining the practicality of the MIMS method. It is followed by Section 5.5, a conclusion of the findings in the case study.

5.2 Literature review

5.2.1 Mathematical presentation of the MIMS

Mathematically, MIM theory in Arnason (1989, 1990) was expressed as follows, starting from the goal of maximising a fishery's economic benefits, *i.e.*,

$$\mathrm{Maximise} J = \sum_i \int_0^\infty (p \cdot \alpha(i) \cdot Q\text{-}C(E(\alpha(i) \cdot Q, x)) \cdot \exp\left(\text{-}r \cdot t\right) dt \qquad (5.1)$$

Subject to: $(a)\ x' = G(x) - Q,$ (5.1.1)

$(b)\ \sum_i \alpha(i) = 1,$ (5.1.2)

$(c)\ \alpha(i) \geq 0,\ all\ i,$ (5.1.3)

$(d)\ Q \geq 0.$ (5.1.4)

Where J is the sum of the present values of the profits generated by i number of firms,

$p{\cdot}\alpha(i){\cdot}Q$ represents the revenue received by the ith company,

p is the price of catch and $p > 0$,

$\alpha(i)$ is company i's quota share,

Q is the total catch quotas in the fishery

$C(.)$ represents the harvest costs,

E is the fishing effort,

x is the fish population biomass,

$exp(\text{-}r{\cdot}t)$ shows profit decreases proportionally to the interest rate r $(r > 0)$ with time t.

The maximisation problem is subject to four conditions:

The change in stock biomass, x', equals the natural growth of the current stock, G(x), minus harvest, Q,

The sum of all quota shares in the fishery, $\sum_i \alpha(i)$, *should equal 1,*

The quota share for any company i, $\alpha(i)$, *cannot be negative,*

The total allowable catch, Q, for the fishery is non-negative.

To solve the maximisation problem, a current value of Hamiltonian function is established as follows:

$$H = \sum_i (p \cdot \alpha(i) \cdot Q - C\big(E(\alpha(i) \cdot Q, x)\big) + \mu \cdot (G(x) - Q) \quad (5.2)$$

Where *p, α(i), Q, C, E, x,* and *G(x)* are defined as above,

μ is the shadow price of the fish, *i.e.*, the value of one unit of additional biomass when harvest maximises profit.

The necessary conditions of Equation 5.2 are:

$(p - C_E \cdot E_{q(i)}) = \mu$, for all active firms

(5.2.1)

$(p - C_E \cdot E_{q(i)}(0,x)) < \mu \Longrightarrow \alpha(i) = q(i) = 0$, for all inactive firms,

$$\mu' = \sum_i C_E \cdot E_x + \mu\,(r - G_x) \quad (5.2.2)$$

Where *p, α(i), Q, C, E, x, G(x)* and μ are defined as above,

q(i) is the volume of quota company *i* holds.

The left-hand side (LHS) of Equations 5.2.1, is the marginal benefit of one more unit of quota to the profit of company *i*. The equations reveal that company *i* should acquire more quota until the marginal benefit of the next unit of quota equates to the shadow price of the resource. On the other hand, Equation 5.2.2 shows that the change of stock shadow price, the impact of one unit of biomass to the total profit (*J*) equals the sum of the impact of biomass on harvest costs ($\sum_i C_E \cdot E_x$) and the net value of the stock's marginal value ($\mu\,(r - G_x)$) (Batstone and Sharp, 2003).

Therefore, the *i*th company's profit maximising function is:

$$\text{Maximise}\, j = \int_0^\infty (p \cdot \alpha \cdot Q - C(E(\alpha \cdot Q, x) - s \cdot z) \cdot \exp(-r \cdot t)\, dt \quad (5.3)$$

Subject to $(a)\ \alpha' \equiv \sigma\alpha/\sigma t = z$ (5.3.1)

$(b)\ 1 \geq \alpha \geq 0$ (5.3.2)

Where *p, α, Q, C, E, x* and *r* are defined as per above,

σ indicates the partial derivative of quota alteration,

s is the instantaneous quota price,

z is the amount of additional quota acquired.

The maximisation problem is subject to two conditions:

The change of quota holdings of company i, α, equals the additional quota acquired, z.

The quota holdings of company i is less than the sum of total shares in the fishery, which is 1, but greater than 0.

To solve this individual company's maximisation problem, a current value of the Hamiltonian function is established as follows:

$$H = p \cdot \alpha \cdot Q\text{-}C\big(E(\alpha \cdot Q, x)\big)\text{-}s \cdot z + \sigma \cdot z \qquad (5.4)$$

Where *p, α, Q, C, E, x, s* and *z* are defined as above and

σ is the shadow value of one additional unit of quota to company *i*.

The solution to Equation 5.4 must satisfy

$$s = \sigma\text{, for all active firms,} \qquad (5.4.1)$$

$$s \geq \sigma\text{, for all inactive firms,}$$

$$\sigma' - r\sigma = -(p - C_E \cdot E_q) \cdot Q \qquad (5.4.2)$$

Equation (5.4.1) shows that a company should acquire more quota until the shadow values of the next unit of quota equates its market price and *vice versa*. Equation 5.4.2 is the change of shadow price of quotas. Combining Equations 5.4.1 and 5.4.2, the time path of quota prices becomes:

$$r \cdot s - s' = (p - C_E \cdot E_q) \cdot Q \qquad (5.5)$$

or $$s = \frac{s'}{r} + \frac{(p - C_E E_q)Q}{r} \qquad (5.6)$$

The RHS of Equation (5.6), the instantaneous quota price (s) equals the present value of change in quota price ($\frac{s'}{r}$) plus the present value of marginal profit of quota holdings ($\frac{(p-C_E E_q)Q}{r}$). Following Equation 5.6, Batstone and Sharp (2003) argued that the market price of quota provides information on the current and future conditions of the fishery. Perhaps more importantly for the study of self-governance, quota prices can capture fisheries bio-economic information. This is because *s* is derived from the bio-economic maximisation Equation 5.1, which includes fish biomass *x*, exogenous fish product price *p* and total quota volume *Q*, the benefits of self-governance (more complete property rights hence more efficient management) are also capitalised into the market value of the ITQs. Following this argument, the quota price of a self-governance fishery should outperform the quota price for a similar non self-governed fishery, or the average quota price of the average market (wherein majority of the fisheries are not self-governed), because of the efficiency gain from better management.

Arnason (1998, 2000) extended the MIMS application from single to multiple species management from an ecosystem perspective. The two papers showed that under the ITQ programme[26] described in Arnason (1990), the management task of determining the current optimal vector of TACs for all species in the ecosystem is the same as maximizing the quota prices of those species. However, Batstone and Sharp (2008) noted that the MIMS maximises economic rents, which are based on the expectations of the fishing industry. The MIMS can fail if fishers' expectations or their tacit knowledge deviates from reality.

5.2.2 MIM theory origin – rational pricing and competitive markets

MIM theory can be traced back to neoclassical and Austrian economic perspectives (Batstone and Sharp, 2008). One Austrian scholar, Hayek (1945), suggested a relationship exists between pricing and information and knowledge contained within the pricing system (Batstone and Sharp, 2003). Following their argument, although no fisheries management literature has formally traced the origin of the MIMS, it seems reasonable to connect it with the rational pricing theory in finance. Rational pricing theory contends that the market prices of assets are fair and arbitrage-free. This is because, if the market is competitive, any deviation from arbitrage-free price level will result in trading until arbitrage opportunities disappear. For example, if two identical assets are priced differently in two markets and, assuming no transaction costs, traders can buy the assets at a lower price in one market and sell it in another with guaranteed profits. The buying activity pushes the price up whereas selling pulls the price down. If there is enough trading, the price difference would eventually vanish.

Building on the arbitrage-free pricing assumption, rational pricing theory further argues that the price of an asset should be the sum of the present value of its future returns (Campbell, 2000). In fact, calculating the present value of the asset's future income has been the basis of a number of finance theories (Gudmundsson, Chapter 5, 2002). If the asset is priced more than the present value of its future returns, short selling of the asset and buying the asset back when its price falls would guarantee risk-free profit. The opposite holds true for an asset

[26] Arnason (1990) described the quota system as Individual Transferable Shared Quota (ITSQ) system, which is similar to the ITQ programme in New Zealand.

priced lower than its future return. In other words, the competitive market will ensure the asset's excess return diminishes and the price remains arbitrage-free.

However, it is obvious that in order for the arbitrage mechanism to work the market would have to be competitive. Specifically, Smith (1982) argued that, amongst other conditions, the market should be competitive to the degree where relevant information is accessible to all investors (Complete Information Hypothesis), so that mispricing could be discovered. Additionally, there should be a sufficient number of participants and volume of trading to trade away the price discrepancies (Price Taking Hypothesis). Further, well regulated markets and institutions and well protected privacy (Hayek Hypothesis) yield competitive markets. Smith (1982) argued, after testing each of the hypotheses above, that the competitive equilibrium is possible under certain conditions.

Therefore, the application of rational pricing in asset pricing is limited. First, as discussed before, the underlying market in which the asset is traded must be competitive. The degree of competitiveness varies from market to market. No market, quota markets included, in reality is perfectly competitive. Additionally, because future returns are used in calculating prices of assets, the rational pricing theory works better for fixed income assets (*e.g.*, bonds). Additionally, the theory in general works better for assets that are traded within a finite period (Santos and Woodford, 1997). New Zealand ITQs, on the other hand, are perpetuities that can be traded infinitely. Therefore, the quotas can generate similar streams of income in the short-run (the holding period of the quotas) given that the fishery is in a stable condition.

5.2.3 MIMS and the New Zealand Quota Management System

New Zealand ITQs are similar to regular financial assets except they are traded in quota markets instead of financial markets. Therefore, according to the rational pricing theory, prices of ITQs should reflect the biological and economic conditions, amongst others, of their respective fisheries if the quota market is competitive. Hundloe (2000, p. 490) noted that "[i]n fisheries subject to buying and selling of licenses and/or ITQs, the stability of prices of these entitlements is a rough guide to economic sustainability". Even if quota prices do not reflect their true values, change of price, along with fish products derivative prices, could be good approximators of current and future conditions of the fish market (Gudmundsson, Chapter 5, 2002). Mathematically, Arnason (1990) showed that under certain assumptions, not only is quota price an approximator of the underlying fishery's profitability, but also for the fishery's biological condition, as the profitability of the fishery depends in part on the condition of both the fish stock and the fish market.

In fact, the essential quota system Arnason (1990, p. 640) described that supports the MIMS is comparable to the New Zealand Quota Management System (QMS). The basic assumptions are:

1. The individual catch quotas are shares in the total allowable rate of catch. These quotas are referred to as share quotas.

2. The share quotas impose an upper limit on the company's permitted rate of catch.

3. The share quotas are permanent in the sense that they allow the holder the stated share in the total quota in perpetuity.

4. The share quotas are transferable and perfectly divisible.

5. There exists a market for share quotas. This market is perfect in the sense that it is open to everyone interested in trading, all the traders are price takers, and the market equilibrates supply and demand instantaneously.

6. The quota authority issues the initial shares and subsequently decides on the total quota at each point of time.

The New Zealand QMS matches the properties one to four above. The fishing quotas were initially allocated to firms and individuals as a permanent right in volume (kilograms). However, after experiencing difficulties in adjusting total catches according to fish stock conditions, the quota were soon adjusted to a percentage (share) of the Total Allowable Catch (TAC) (Hersoug, 2002). TAC limits the maximum amount quota holders are allowed to catch. Further, the quotas are permanent fishing rights and are perfectly transferable and divisible (Arnason, 2000a; Fisheries Act, 1996; Hersoug, 2002).

However, the other two assumptions, five and six, only remain as theoretical concepts. Arnason’s (1990) fifth property assumes the quota market is perfectly competitive. A competitive market, by standard economics definition, requires an ample number of participants who can willingly enter or exit the market and all are price takers. Although the New Zealand quota market is relatively competitive (Newell *et al.*, 2005) and there might be sufficient number of players in quota markets for major commercially important fisheries, it might not be the case for the rest of the fisheries. Further, not every interested party can participate freely. Stavins (1998) suggested that tightly held permits create an entry barrier, as new entrants must purchase permits from existing holders. In terms of New Zealand, Edwards (2000) argued that lack of access for new entrants because of the cost of quota is one of the disadvantages of its ITQ programme.

The sixth property of the essential quota system in Arnason (1989, 1990) assumed that the quota is issued continuously, so that the total catch rate is adjusted constantly to optimal. Not only is it impossible to compute the optimal catch level continuously given the changing condition of fisheries, it also is unattainable to carry out such a system administratively. However, Arnason (1993) further argued that setting up quotas for the entire time path is unnecessary. The reason is that fishers buy or sell quotas based on their expectations of the future, thus the prices time path tends to merge to optimal. Consequently, fisheries managers can just set the initial Total Allowable Commercial Catch (TACC) that maximises the current quota price (Batstone and Sharp, 2008). Accordingly, although the ITQs in New Zealand are managed discretely (the managers adjust catch levels, in the form of TAC, once a year), it is still possible to achieve optimisation.

However, there might be a time lag between fishers' future expectations and quota trading activities. Therefore, instead of letting quota prices adjust with time by exchange, users can help set optimal TACCs (Arnason, 1993). Under self-governance, it is possible to adjust TACC more frequently so that all quota holders in a fishery can reach an agreement on the catch rate within the limit of the official TACC if necessary. An example is the Bluff oyster fishery, where the catch quota since 2003 has been half of the TACC. This collective action addresses the issue of increasing fishing cost due to temporary stock decline, which is not biologically significant enough to lower the official TAC.

Further to the six properties above, Arnason (1990) also assumed homogeneity of quota traded in the market. That is, all quotas are identical regardless of the respective fish species or fishing area. This assumption does not hold true in practice. The value of fish species varies greatly: in 2007, the average quota price for hoki was \$6.93 per share, but \$0.85 for oreo. Even for the same species, quotas from different areas have different values. As at July, 2007, the quota price of paua in QMA2 was \$390 per kilo, whereas in QMA4 it sold for \$334 (Fish Serve QMR, 2007). However, this assumption may be avoided by focusing on quota trading in one QMA, as did Batstone and Sharp (2003), who restricted analysis to the fishery in SNA1.

There is also better news regarding the exogenous price assumption of the MIMS application, which can be relaxed further. Arnason (1990) showed that it is a prerequisite of the MIMS firms that they do not have market power and that demand is perfectly inelastic. However, Gudmundsson (Chapter 5, 2002) proved numerically that Arnason's (1990) Lemma 1: high quality fishing rights systems yield the most efficient economic and social outcomes, can apply to fisheries with a downward sloping demand curve (*i.e.*, fishers do have some market power and demand could be elastic).

Mathematically, the current value Hamiltonian function, (Equation 5.2), is established as:

$$\mathrm{H} = \textstyle\sum_{\mathrm{i}}(\mathrm{p} \cdot \alpha(\mathrm{i}) \cdot \mathrm{Q}\text{-}\mathrm{C}\big(\mathrm{E}(\alpha(\mathrm{i}) \cdot \mathrm{Q}, \mathrm{x})\big) + \mu \cdot (\mathrm{G}(\mathrm{x})\text{-}\mathrm{Q}) \qquad (5.2)$$

One of the conditions for the optimal solution is:

$$\frac{\partial H}{\partial Q} = \frac{\partial p}{\partial Q} \cdot \alpha(i) \cdot Q + p(Q) \cdot \alpha(i) - \frac{\partial C}{\partial E}\frac{\partial E}{\partial Q} - \mu = 0 \qquad (5.7)$$

Hence the social optimal solution implies:

$$\frac{\partial p}{\partial Q} \cdot \alpha(i) \cdot Q + p(Q) \cdot \alpha(i) - \frac{\partial C}{\partial E}\frac{\partial E}{\partial Q} - \mu = \frac{\partial p}{\partial Q} \cdot \alpha(j) \cdot Q + p(Q) \cdot \alpha(j) - \frac{\partial C}{\partial E}\frac{\partial E}{\partial Q} - \mu \quad (5.8)$$

Where firms *i* and *j* are active firms in the fishery.

Repeat the same reasoning for a private company current value Hamiltonian function, Equation 5.4, the solution to private company maximisation becomes:

$$[p(Q) - \frac{\partial C}{\partial E}\frac{\partial E}{\partial \alpha(i)}] \cdot Q = [p(Q) - \frac{\partial C}{\partial E}\frac{\partial E}{\partial \alpha(j)}) \cdot Q] \qquad (5.9)$$

Because the quota share constraint, $\sum \alpha(i) = 1$, *i.e.*, the total quota shares sum to one, Equations 5.8 and 5.9 become, $\frac{\partial \mathrm{C}}{\partial \mathrm{E}}\frac{\partial \mathrm{E}}{\partial \mathrm{Q}} \equiv \frac{\partial \mathrm{C}}{\partial \mathrm{E}}\frac{\partial \mathrm{E}}{\partial \mathrm{Q}}$ and $\frac{\partial \mathrm{C}}{\partial \mathrm{E}}\frac{\partial \mathrm{E}}{\partial \mathrm{Q}} \equiv \frac{\partial \mathrm{C}}{\partial \mathrm{E}}\frac{\partial \mathrm{E}}{\partial \mathrm{Q}}$, respectively.

Therefore, the optimal quota allocation is the same for social and private profit-maximisation as indicated in Arnason's Lemma I. Moreover, the price (*p*), which determines the nature of the demand curve, is not needed to get the solution. In other words, the optimal problem is satisfied even with a finitely elastic demand curve.

5.2.4 MIMS application

The discussion above demonstrates that the seemingly rigorous assumptions in Arnason (1990) are achievable, especially with a self-governance component in management. Yet, the application of this theory to fisheries management is still in its infancy with limited literature developed following Arnason's (1989, 1990, 1998, 2000b) work (Batstone and Sharp, 2008). Not only have ITQ programmes been implemented by only a small number of nations (Batstone and Sharp, 2008), but the idea of making management decisions on one piece of information, the quota price, is somewhat unconventional and likely to be politically infeasible.

The two well established applications of the MIMS in fisheries management literature found were Gudmundsson (2002) and Batstone and Sharp (2003). It is not surprising that the two case studies are based on Iceland and New Zealand fisheries, respectively, because these two nations have long established quota systems that are closest to the ITQ programmes envisioned by Arnason (1989, 1990). The two studies are nevertheless different. Gudmundsson (2002), in his PhD thesis, applied the MIMS in one of his chapters to the Icelandic cod fishery. However, the study is based on a series of assumptions of the quota systems that do not hold true. As a result, this research demonstrated MIMS could work if such fisheries existed, which is a reverse application of Arnason (1990)'s theory, rather than an analysis of the current situation.

There are several aspects that hinder Gudmundsson's (2002) ability to paint an insightful picture of MIMS and its application. The first aspect is the quality of the ITQ programme in Iceland. Although the Icelandic ITQ programme is similar to the QMS in New Zealand, it is not as well-developed (Arnason, 2000a). That is, the New Zealand QMS matches four of the six propositions in Arnason (1990), Iceland's ITQ matches only the first two. The third feature of Arnason (1990), quotas are permanent, is violated. The continuation of Iceland's fishing quotas is threatened by significant socio-political factors (Arnason, 2000a).

Further, transferability is more restricted in Iceland (Arnason, 2000a), which made the quota system differ from Arnason's (1990) fourth assumption.In addition, Gudmundsson (2002) also assumed a well developed market for quota shares and quota options. However, only vessel owners can be invloved in quota transfers and exchanges in Iceland (Arnason, 2000a), as opposed to everyone except for foreigners being able to acquire quota in New Zealand, which reduces the efficiency of the Icelandic quota market.

Finally, the author uses options, a derivative of the asset price, to reveal information about stock condition. Although using option price emphasises participants' future expectations in the analysis, the lack of a competitive quota market certainly indicates a lack of a quota derivative market, which further restricts the application of MIMS. Similarly, Lauck (1996, as cited in Dudley, 2008) reported that the use of derivatives in fisheries management makes the already complex system even more complicated, which limits the practicality of such instruments in addressing management problems.

Gudmundsson's (2002) study is nevertheless significant. Although the study does not show the actual application of MIMS to fisheries management, it demonstrated a relationship between the quota-based option price and fishery conditions. The analysis showed that option prices can help provide insights about current and future harvest levels. Specifically, a theoretical option price calculated from historical price volatility can be compared to the current price. It is because the price and volatility represent return and risk respectively in the financial market, the comparison revealed that whether the market expects the fishery to be more or less risky (volatile). The author further suggested that it is possible, with the advancement of rights based management instruments, that trading will be developed in the public exchange market.

In contrast to Gudmundsson (2002), Batstone and Sharp (2003) combined both theory and case study with real data. Instead of showing the possible function of a competitive market, they found practical evidence supporting the findings in Arnason (1990). The testing process was done by conducting both a classic regression and an Autoregressive Distributed Lag (ADL) regression. The ADL (1, 1)[27] is particularly effective in explaining the relationships and in generating a statistically significant function.

The ADL (1,1) process, by regressing 10 years (October 1988 – September 1998) of quota prices for snapper fishery in management area 1 (SNA 1) on various independent variables, demonstrated evidence supporting the hypothesis that ITQ prices reveal the underlying conditions of the fishery. Specifically, Equation 5.6 derived in Arnason (1990) indicated that the current asset price is a function of the change in asset price, profit, the opportunity cost of capital and the allowable harvest. These factors provide a series of independent variables for the model, (*i.e.*, asset prices, lease price, total allowable commercial catch, output prices and interest rates). Not surprisingly, quota prices are positively related to owner changes, lease prices and output prices, but are negatively related to interest rates because holding quotas becomes more costly when interest rates are high. Perhaps more relevant to this study, Batstone and Sharp (2003) showed that the price of SNA1 quota is related, amongst other

[27] ADL (m, r) is the expression used to indicate the orders of the lag operator. For example, ADL (1,1) means both the dependent variable and independent variables lag 1 period.

things, to the harvest level (total allowable catch) and the profitability (output price) of the fishery.

However, there is one particular issue to note in the analysis. The authors noted that Arnason (1990) assumed that firms are homogeneous in the fishery (*i.e.,* all firms are efficient and operate at the bottom of the average cost curve). This assumption is one of the bases of Arnason's hypothesis, on which Batstone and Sharp (2003) based their analysis. However, this assumption was challenged by Copes (1989, as cited in Heaps, 1993) who suggested fishers' efficiency, hence profits, can differ hugely from one another. Heaps (1993) further showed that for the same level of catch, total profit can be very different for a fishery with homogeneous firms compared with another with heterogeneous fishers.

However, this homogeneity argument should not affect the analysis of MIMS, especially MIMS under self-governance. In theory, according to Equation 5.5, $r \cdot s - s' = (p - C_E \cdot E_q) \cdot Q$, a rational company will hold on to one unit of quota if it brings more marginal profit than selling it and sell it if otherwise. Specifically, the LHS of Equation 5.5 shows the total cost of holding one unit of quota. The $r \cdot s$ part is the opportunity cost, the interest revenue forgone from investing at the market rate by holding one unit of quota. The s' part represents the capital gain/loss of holding that quota when its instantaneous price increases/decreases. The LHS of the equation, $(p - C_E \cdot E_q) \cdot Q$, shows the profit gain of holding that unit of quota. In this way, the private profit-maximisation incentive induces the quota market equilibrium. Therefore, firms are practically homogeneous in that catches are allocated in the most efficient way. In practice, self-governance provides a platform for fishers to exchange quotas as the trading needs are more efficiently communicated amongst the group of fishers who are in the management circle. In the New Zealand rock lobster fishery, self-governed by the New Zealand Rock Lobster Industry Council (NZRLIC), some larger operators fish for small operators and there is greater utilization of fleet and vessels (Yandle, 2008).

The more successful application of the MIMS in Batstone and Sharp (2003) is perhaps not coincidental. Not only does the New Zealand QMS match four out of six of Arnason's essential features of a quota system for the MIMS, the SNA1 quota market is also fairly competitive. On the other hand, the Icelandic cod fishery case appears divorced from Arnason's (1990) theory because of its less efficient quota system. Hence, although no quota system is perfect, so long as the quota quality is as high as New Zealand ITQs and the fishing quota market is relatively competitive, the application of the MIMS in fisheries management can advance beyond models and theories.

From both the theoretical model of Arnason (1990) and the two MIMS applications discussed above, it appears that the quality of the quota and the competitiveness of quota markets are two keys when applying the MIMS in practice. New Zealand fisheries hence are ideal candidates to apply the MIMS as the new management tool. For one, its QMS is argued to be one of most advanced quota system in the world (Hersoug, 2002). Further, its ITQs are perfectly secure and durable, highly transferable and relatively excludable (Arnason, 2000a). Obviously quota qualities are the same for all fisheries under the QMS, which makes every QMS fishery a candidate for a MIMS experiment.

Encouragingly, the functionality of the New Zealand quota market as a whole is relatively competitive. Newell *et al.* (2005) analysed 150 fishing quota markets for 33 species for a 15-year period (1986 to 2000) in New Zealand by exploring the time series data of the average number of participants, number of transactions and price dispersion. Their result suggested that the New Zealand quota market is competitive for fish stocks that are significant in size and catch value. Moreover, the result also showed that quota price reflects publicly available information. That is, the quota prices depends on its lease (ACE) price, input and output price, and other underlying factors such as quota demand and ecological uncertainties.

To conclude, the MIMS has been under-rated in both fisheries management literature and in practice. The reasons for the under-utilisation of the MIMS are two-fold. First, MIMS's seemingly rigorous assumptions under which it can be applied and the lack of a perfect quota system can reduce researchers' interest in further exploring the method. Additionally, it is possible that regulatory bodies are over-cautious toward this new and unconventional management evaluation instrument because of the lack of real-world applications. Moreover, there may be political awkwardness over using such a simple method for decision-making. These two reasons are intertwined and reinforce each other.

However, if we look closer, the MIMS deserves a place in the fisheries management evaluation tool kit, especially in New Zealand. The reason is that the behaviour of ITQs prices is potentially a good approximator of fisheries management as discussed in Arnason (1990). In addition, it works in practice for the New Zealand snapper fishery (Batstone and Sharp, 2003). Furthermore, the quality of New Zealand ITQs is reasonably high (Arnason, 2000a) and the quota markets for major species is relatively competitive (Newell *et al.,* 2005).

Moreover, the MIMS can be a good method for evaluating self-governance because the literature review above suggested that a number of the theory assumptions can be relaxed under self-governance regimes. For example, the homogeneity of ITQs can be achieved by analysing one QMA at a time and the TACC can be altered more frequently by the self-governance entity according to stock conditions.

5.3 Method

This section aims at using the MIMS to examine the potential benefits of self-governance. Section 5.3.1 identifies three prerequisites of applying the MIMS. Then, based on those three prerequisites, Section 5.3.2 develops the procedures of applying the MIMS accordingly. The three prerequisites will lead to three steps for applying MIMS to evaluate ITQ-based self-governance.

5.3.1 Prerequisites

There are three elements that need to be considered before applying the MIMS and using the quota price as a means to assess management qualities of a fishery. The first prerequisite of applying the MIMS is a competitive quota market[28]. The competitiveness of the asset market has a direct influence on the ITQ price, therefore its ability to reflect the underlying fisheries condition and management quality. Perhaps inconveniently, self-governance fisheries are often ones that have a relatively small number of players. Hence the efficiency gain from good management can be realised by a few players (Townsend, 2008). By definition, a competitive or active market requires sufficient buyers and sellers. Further, even if the market is reasonably active, for the quota price to reflect the underlying condition of a fishery, there might not be enough transaction data to base the analysis on or to reveal the asset price movement. Therefore the question is how small is too small to be competitive? It is possible that even with only a small number of players the market can be fairly competitive, which forces prices to approach equilibrium given that they do not co-operate in any matter.

The second prerequisite concerns the complexity of the fishery. Hundloe (2000) and Lindner *et al.* (1992) noted that knowledge of the fishery is needed in order to use asset prices to indicate the fishery's true condition. The reason is that asset prices can be impacted by

[28]According to the assumptions underlying the MIMS theory in Arnason (1990), two elements require consideration before ITQ price can be applied to real fisheries. The first element is the quality of the quota system. MIMS is based on a series of rigorous conditions about the quota system, and high quality ITQs are its foundation. However, as previously analysed, the quality of New Zealand QMS and its ITQs are close to what is required to support the MIMS, so they are not examined here.

external influences such as demand changes as well as management improvements. Some of the external impacts in the literature include the following factors. Besides good management, an increase in fish demand and, therefore, quota demand will lead to quota price increases. In such a situation, an increase in quota price might be mistaken for better condition in the fishery (Gudmundsson, 2002). Further, increase of ITQ price could also be brought about by positive prediction of the future, which might not be realised in practice. Ever falling fishing costs (technological advance) is another reason why the ITQ price might appear to be increasing over time (Lindner *et al.*, 1992). Natural disasters, (*e.g.*, diseases causing major fish stock mortality) can also have an effect on quotas prices. Because of those external factors, the reasons for quota price fluctuations should be studied carefully before conclusions can be drawn about their usefulness as an approximator of management effectiveness.

The last prerequisite of applying the MIMS to evaluate ITQ-based self-governance is to establish a proper reference point with which to compare the performance of the fishery. Because the MIMS is used to assess the value of self-governance, it is necessary to judge the performance of the fishery against a similar yet non-self-governed fishery. The similarity of natures (*e.g.*, inshore or offshore, finfish or shellfish) and features (*e.g.*, number of fishers, fishing methods) will allow the comparison to be focused on the different management regime (self-governance versus non-self-governance). However, fisheries are unique and it can be hard to find comparable equals. In such case, when a comparable fishery is absent, the performance of all QMS fisheries in New Zealand will be used as a reference point.

5.3.2 Procedures

The three prerequisites discussed above lead to three steps to examine the potential benefits of self-governance. A three-step checklist was developed for the MIMS application, which includes items shown in the following Table 5.1.

The first step is to study the competitiveness of the fishery's quota market. The relative competitiveness of the quota market suggests that the ITQ price might be useful to indicate the fishery's condition. This is then followed by examination of the fishery in order to rule out other reasons for changes in quota prices. Lastly, in order to conclude if the behaviour of the self-governed fishery under study is better managed, it is necessary to compare its asset performance with a non-self-governed counterpart, or the overall quota price performance in New Zealand.

Table 5.1 MIMS application checklist for New Zealand fisheries self-governance studies.

	Before applying MIMS	
Check	Competitiveness of the quota market	
By		Market participation, entry, and exit
		Market activity
		Trading methods
		Number of quota sales and percentage of quota shares traded
		Price dispersion
	When applying MIMS	
Check	The quota price behaviour	
	Other non-management influences	**Not limited to**
By		Changing fish demand
		Changing expectations regarding future conditions
		Significant technological advancement causing fishing costs to fall
		Natural influences, such as disease and/disasters
	After applying MIMS	
Check	The quota price behaviour of the overall quota market	

As show in the above Table 5.1, the first step in applying the MIMS in a fishery is to examine the competitive of the quota market in the fishery (Table 5.3, second column, top part). There are several ways to test the competitiveness of a market. Newell *et al.* (2005) used three variables generated from the New Zealand quota market to illustrate its functionality. They are market participation (entry and exit), market activity and price dispersion (Table 5.3, third column, top part). An ample number of market participants and activity and diminishing price dispersion over time are evidence of a well-functioning market.

Market participation refers to the number of players hence the level of interest for a particular market. The more participation the easier will players will find trading partners, hence reduce transaction costs and induce trading (Stavins, 1995). The number of new entrants and leavers in a market shows the change of interests in that market and how open the market is to potential participants. A market attracts new interests if the number of net entrants is positive.

Market activity is the number of trades in a quota market. Although market activity might be positively related to market participation, it also shows more information about the competitiveness of a market. It is possible that some participants do not actively trade quota but hold it as a long-term asset for their portfolio. In this study, trading includes buying and selling both quota and ACE.

In addition to market participation and market activity, price dispersion also shows market functionality. Theory suggests that when a market is perfectly competitive there would be no price dispersion for the identical asset to eliminate any arbitrage opportunity. In practice, if a market is relatively competitive, one would expect a low level of price dispersion. In a well-functioning market, the price variation should decrease as the market matures (Newell *et al.*, 2005).

Following the market-competitiveness test, the second step is to study the underlying fishery and the environment it is managed under (Table 5.3, second column, middle part), because, as discussed in the previous section, a change in quota price could be caused by external influences that are beyond management control. There might be several reasons for the quota price changing, the main elements to be watched for include, but are not limited to, the overall demand for the fish product, the health of the fish stock and the disease mortality count, and changes in policy that favour or disfavour the catch sector (Table 5.3, third column, middle part). Abnormal fluctuations or changes in any of the above areas would compromise the ability of the quota price to indicate the management quality.

After studying the quota market and the fishery, for the purpose of examining self-governance's contribution to fisheries management, it is necessary to compare the asset performance of the fishery with a comparable non-self-governed fishery, or the overall performance of New Zealand quota market if such fishery is missing (Table 5.3, second column, bottom part). All else being equal, because of the extra benefits of self-governance, the asset price of the self-governed fishery is expected to outperform its counter partner, or the market where the majority of fisheries are managed only by ITQs. Therefore if the ITQ price of a self-governed fishery outperforms the selected reference, given its quota market is fairly competitive and there are no major external pressures affecting the quota price, this would provide evidence that self-governance adds value to fisheries management. The opposite holds if the ITQ price performance of the fishery in question cannot be differentiated from the market.

5.4 Case study

5.4.1 Examining the competitiveness of the quota markets

Following the MIMS application procedures, before using quota price to indicate the effectiveness of the management of OYU5 the quota market needs to be investigated. The functionality of the OYU5 quota market can be tested by three key market performance measures: number of participants, number of transactions and price dispersion. These three measures are used by Newell *et al.* (2005) to examine the competitiveness of the New Zealand fishing quota markets. As discussed in the literature review section that, by using these three measurements, the authors found the quota markets for major commercial fisheries in New Zealand are competitive.

In addition, in order to set the benchmark of competitiveness, those three measures of OYU5 were compared with those of the snapper fishery in quota management area one (SNA1) – a major New Zealand fishery with a relatively competitive quota market (Batstone, 1999; Batstone and Sharp, 2003). The OYU5 quota market was compared with SNA1 for market functionality because SNA1's fishing quota market has been argued to be competitive. Newell *et al.* (2005) argued that quota markets for major commercial fisheries in New Zealand are competitive. SNA1 is an important fishery in both size and value. In 2008, the snapper fishery (SNA) was the fourth largest fishery in terms of quota value ($264.90 million) of 96 QMS species (after hoki, paua and orange roughy), the tenth largest in terms of export earnings ($32.36 million) and the thirteenth largest in terms of export weight (3460 tonnes). SNA1 is the most productive area amongst seven snapper fisheries management areas, it accounted for 74% of both export earnings and weight in the 2007/08 fishing year. SNA1 alone is the eighth largest fishery in export value in New Zealand (MFish, 2009c).

Furthermore, the competitiveness of SNA1 fishing quota market is supported by the significant statistical relation between the quota price and publicly available information. Batstone and Sharp (2003) explored the information contained in SNA1's quota price using nine years of data (1989-1998) from the quota market. They found that the price of SNA1 quota is functionally related to the quota lease price, the profitability of the fishery, the TACC and interest rates.

Compared with the snapper fishery, the dredge oyster fishery in Bluff is not significant in either value or size. The quota value amounted to $18 million in the 2007/08 fishing year, compared with the $729.60 million hoki fishery or $264.90 million snapper fishery (StatsNZ, 2008). Further, OYU5 is a domestic market oriented fishery in which 100% of the product is sold in New Zealand.

Although the size and value of the OYU5 fishery might have a negative impact on the competitiveness of the quota market, further formal examination is still needed. The following section compares OYU5 and SNA1 quota markets in three areas: number of participants, number of transactions and price dispersion. Bluff oysters were introduced into the QMS in 1998, but because of data limitations, some statistics used in this study start from 2001/02 and end in the 2007/08 fishing year.

5.4.1.1 *Market participation, entry and exit*

Table 5.2 The number of Quota and ACE owners, SNA1 and OYU5, 2002-2010.

Fishing Year	Number of quota holders		Number of ACE holders	
	SNA1	OYU5	SNA1	OYU5
2001/02	159	19	229	15
2002/03	160	19	242	15
2003/04	158	18	216	13
2004/05	156	17	192	13
2005/06	152	17	183	13
2006/07	152	16	178	12
2007/08	149	17	168	13
2008/09	146	17	133	13
2009/10	150	17	141	16
Average	154	17	187	14

As shown in Table 5.2, between the 2001/02 and 2009/10 fishing years, on average, there were 154 quota owners in SNA1 compared with 17 in OYU5. Similarly, there were 187 ACE holders in SNA1 compared with 14 in OYU5.However, the difference in number of participants alone does not mean that the OYU5 fishing quota market was uncompetitive because the size of the two fisheries and the numbers of fishers they can sustain differ. Furthermore, there might be active change in quota or ACE ownership despite the number of owners remaining relatively constant in the Bluff oyster fishery. However, both data from MFish and local knowledge indicates that the OYU5 ACE marker is uncompetitive because of the lack of change in ACE ownership. According to MFish ACE-holder registration data, there was only one new entry and one exit per year on average respectively between 2002 and 2009. In addition, Skeggs (2009) suggested that there has been only one substantial exit (Jones Group Limited) and two new entries (Sanford Limited and Foodstuffs Auckland) in the oyster fishery since it was introduced into the QMS.

There was one significant difference between the two fisheries. There were more quota holders than ACE holders in SNA1, but the opposite occurs in OYU5. Because owning ACE, not quota, gives the owner the right to fish, it is normal to have more ACE holders who lease from the quota holders to fish. However, there were more quota holders (17) than ACE holders (14) in OYU5, which means that there was co-operation in fishing. Indeed, several quota holders fish together through one ACE holder to save fishing costs.

5.4.1.2 *Market activity*

A competitive fishing quota market not only has multiple participants and possible new entrants, it also has trading activity generated by participants. There are two ways to measure trading activity: trading methods and quantity traded (Newell *et al.*, 2005). Trading methods are the ways in which quota share and/or ACE are transferred; the more public the trading methods, the more market activity can be expected. The other way of measuring market activities – quantity traded – includes the number of transactions and total trading quantities with respect to TACC.

There are two ways that the quota/ACE can be traded: through quota brokers or by direct contact. Though normal corporate shares are traded in stock exchanges, there is no physical location for fisheries participants making quota exchanges. Instead, quota brokers serve as middlemen bringing buyers and sellers together. Similarly, direct contact[29] of existing quota and ACE holders is also common. In New Zealand, small to medium-sized exchanges normally take place through brokers, whereas bulk trades often occur amongst large companies through their own direct contacts (Newell *et al.*, 2005).

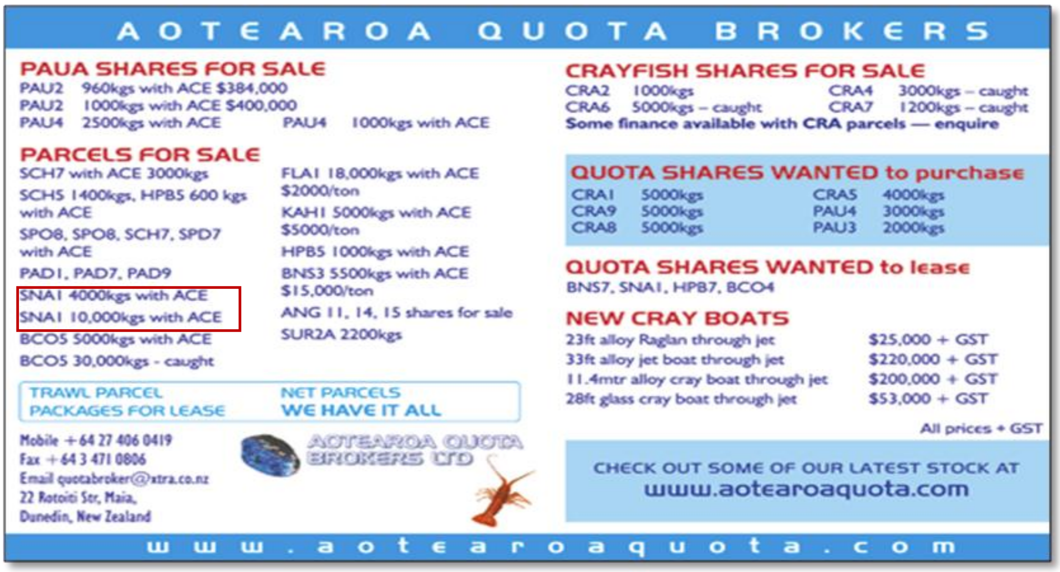

Figure 5.1 An advertisement for SNA1, ACE and related goods.

Source: adapted from Yandle (2008, p. 297)

Because brokers normally serve thick markets with high demand quotas, the number of brokers in a particular quota market and the number of transactions through brokerage can indicate how active the quota market is. Although there is no official record of the registered number of brokers in a particular fishery or the number of broker mediated trades, Figure 5.1, shows the trades of SNA1 ACE (circled by a red rectangle). Information from the fishing industry shows that at least two brokers serve the SNA1 fishery with one of them negotiating, on average, 40 to 50 transactions per year. The OYU5 quota market is very inactive. Skeggs

[29]The list of quota and ACE holders of any fishery is available for purchase from Fish Serve: a subsidiary of New Zealand Seafood Industry Council (SeaFIC), which provides administrative services, such as quota and ACE registration, to commercial fishing industries.

(pers. comm., 2009) noted that no ITQ or ACE was traded through brokers; all quota sale and lease changes were done through direct contact amongst fishers.

Table 5.3 Quota transactions, SNA1 and OYU5, 2002-2010.

Fishing Year	Number of valid transactions		Percentage of quota Traded (%)	
	SNA1	OYU5	SNA1	OYU5
2001/02	37	0	4.01	0.00
2002/03	26	5	1.46	27.17
2003/04	5	0	0.43	0.00
2004/05	10	0	12.99	0.00
2005/06	13	0	1.14	0.00
2006/07	20	0	4.39	0.00
2007/08	15	0	4.50	0.00
2008/09	9	0	1.24	0.00
2009/10	5	0	0.07	0.00
Average	16	1	3.36	3.02

Table 5.3 shows the number of quota sales and the percentage of quota traded in SNA1 and OYU5 between the 2001/02 and 2009/10 fishing years. The number of quota sales is self-explanatory, and the percentage of quota traded shows the ratio of total number of quota shares traded to the total 100 million outstanding quota shares. The number of valid quota transactions in SNA1 was considerably higher than in OYU5; there were quota transactions every year with an average of 16 trades per year. The percentage of shares traded fluctuated through the years with, on average, three per cent of the total shares traded every year. In contrast, there were only five legitimate quota trades in OYU5 in the seven years. Although the annual average was also three per cent, all these transactions occurred in 2002/03.

The percentage of quota shares traded is likely to show the activeness of the quota market. Quotas are permanent fishing rights, the primary reason for buying or selling the asset is to enter or exit the fishing market. Therefore, quota is likely to be traded once within the year and hence reveal the demand and supply relationship for fishing. The lack of trades in OYU5 is caused by approximately 95% of the fishers and families owning quota, fish themselves and therefore do not actively trade quota (Skeggs, 2009).

Table 5.4 ACE transactions, SNA1 and OYU5, 2002-2010.

Fishing Year	Number of Transactions		Percentage of ACE Traded (%)	
	SNA1	OYU5	SNA1	OYU5
2001/02	1495	50	114	97
2002/03	1712	60	141	128
2003/04	1359	47	138	150
2004/05	1374	60	142	154
2005/06	1393	57	158	157
2006/07	1307	51	160	153
2007/08	1298	57	160	165
2008/09	1217	68	157	148
2009/10	1228	87	168	136
Average	1376	60	149	143

Compared with the quota markets, ACE markets are much more active because fishers need to balance their catch with the amount of ACE instead of quota. As shown in Table 5.4, both fisheries had ACE transactions every year, but SNA1, on average, had 22 times more trades. However, this is likely to be a result of a much bigger participant group in SNA1 than OYU5.

Unlike the annual percentage of quota share transactions, the percentage of ACE trades is less likely to indicate the activeness of the quota leasing market. As can be seen in Table 5.4, except for the 2001/02 fishing year for OYU5, almost all percentages of ACE trades for both SAN1 and OYU5 exceeded 100%, which means the amount of ACE traded is greater than the amount of TACC. This can only happen when some ACE was traded more than once per year.

There are two reasons for multiple trading. The first is for catch balancing. Normally, ACE is traded twice a year; in the middle of the fishing season when fishers were required by MFish to show that they have enough ACE to cover up-to-date catch or paying the interim Deemed Value (a fine that fishers pay for the amount over their catch limit) and at the end of the season for residual balancing. However, fishers can choose to balance their ACE holdings with catch at any time to cover their catch. They might also wait if they think the price of ACE will drop, or buy some ACE early on while anticipating their future catch based on their fishing plan. However, if the catch is lower than expected, they will be left with a surplus of ACE that they may resell later on and *vice versa*.

Another reason for multiple ACE trading is for arbitrage profiting. For certain fish stocks the Deemed Values (DVs) differ with CATCH/ACE ratio: DV increases incrementally. Table 5.5 provides an example that illustrated the differential DV system for the Auckland East snapper fishery (SNA1). As the overfished amount (first column) increases, the DV rate increases for any incremental amount (third column).

Table 5.5 Differential DV system, SNA1.

Amount overfished	Differential Rate	Deemed Value Rate
0 to 20%	Annual Rate	$13.00 per kg
More than 20% to 40%	120% of Annual Rate	$15.60 per kg
More than 40% to 60%	140% of Annual Rate	$18.20 per kg
More than 60% to 80%	160% of Annual Rate	$20.80 per kg
More than 80% to 100%	180% of Annual Rate	$23.40 per kg
More than 100%	200% of Annual Rate	$26.00 per kg

Source: Fish Serve http://www.Fish Serve.co.nz/information/ace/

Because the differential DV system can represent a serious financial burden for companies catching significantly above their ACE holdings, some companies acquire ACE during the year and sell it to the ones in need at the mid-year point or end of the fishing year. A company that needs the ACE could choose to buy the ACE or pay the high differential DV. The ACE price normally is cheaper than the DV and buyers lose less acquiring ACE than paying the differential DV. Though sellers profit from the difference between the high DV and the ACE price, they charge depending on the bargaining power of both parties.

5.4.1.3 *Price dispersion*

Before using price dispersion as the third pointer to market competitiveness, the reliability of the quota and ACE prices needs to be examined. The quality of quota sale and ACE prices is questionable (Lindner *et al.,* 1992). The reason is that quota trading prices are not required by law to be registered accurately nor are they kept by fisheries authorities in an official database. Instead, participants register their trades with the privately owned fisheries service provider Fish Serve and are free to write down any number they see fit at the time of transaction.

There are other reasons for the quota/ACE price to fail to provide a realistic view of asset value. Some transactions are in-house trading between parent companies and their subsidiaries. For these transactions, the prices could be purely nominal, which reflect the initial cost of the quota at the time of acquisition. Alternatively, the price can be the port prices of the fish stock, which are the costs of fishing rather than the market prices of fishing rights. There are also other trades that do not involve money transactions but are barters of quotas or ACEs (Lindner *et al.,* 1992). In this case, the prices of quotas the parties register with Fish Serve have lost the original meaning and are there to fulfil book-keeping requirements.

Table 5.6 Percentage of valid quota transactions, SNA1 and OYU5, 2002-2010.

Fishing Year	SNA1			OYU5		
	Number of valid transactions	Total number of transactions	Valid to total transactions (%)	Number of valid transactions	Total number of transactions	Valid to total transactions (%)
2001/02	37	46	80.43	0	3	0.00
2002/03	26	31	83.87	5	6	83.33
2003/04	5	14	35.71	0	2	0.00
2004/05	10	27	37.04	0	2	0.00
2005/06	13	25	52.00	0	1	0.00
2006/07	20	23	86.96	0	1	0.00
2007/08	15	21	71.43	0	1	0.00
2008/09	9	9	100.00	0	1	0.00
2009/10	4	5	80.00	0	1	0.00
Average	18	27	69.72	1	2	9.26

The above argument is supported by a great number of inconsistencies in trading data, which are shown by the percentage of so-called valid transactions[30] defined by Fish Serve. From Table 5.6, in terms of quota trading, the average rate of valid transactions was approximately 70% in SNA1. As a value and weight significant fishery whose quota market was argued to be relatively competitive (Batstone and Sharp, 2003), on average, only two of three transactions were considered to be reasonable. The rate was dismal in OYU5 (9%) and only 2002/03 fishing year had valid transactions.

Table 5.7 Percentage of valid ACE transactions, SNA1 and OYU5, 2002-2010.

Fishing Year	SNA1			OYU5		
	Number of valid transactions	Total number of transactions	Valid to total transactions (%)	Number of valid transactions	Total number of transactions	Valid to total transactions (%)
2001/02	1402	1495	93.78	8	50	16.00
2002/03	1544	1712	90.19	9	60	15.00
2003/04	193	1359	14.20	8	47	17.02
2004/05	176	1374	12.81	12	60	20.00
2005/06	315	1393	22.61	8	57	14.04
2006/07	233	1307	17.83	4	51	7.84
2007/08	299	1298	23.04	17	57	29.82
2008/09	487	1217	40.02	16	68	23.53
2009/10	500	1228	40.72	17	87	19.54
Average	18	27	39.47	11	60	18.09

Table 5.7 shows the same information for ACE trades. There were significantly more ACE transactions than quota transactions; there were ACE trades every fishing year for both fisheries. Only one in three ACE transactions was considered to be reliable for SNA1 and one in five for OYU5. The ACE trading data from MFish, which record all ACE transactions, agree with the data from Fish Serve (Table 5.7). If we exclude ACE prices below the 25th and

[30]Please see Appendix G The Fish Serve rules of calculation the average price for quota and ACE for detail.

above the 75th percentile, the percentage of 'valid' ACE transactions per year falls to 10% on average. What is more, the 'valid' transactions decrease to 6% if we exclude the transactions between two companies with the same registration address. Though the data from Fish Serve and MFish suggested that a significant number of transactions are invalid, there is also a reliability issue with those prices that were considered to be valid. For OYU5, according to Skeggs[31] (2009), there was virtually no quota market for the fishery. Although there were some quota and ACE transactions over the observed period, the prices were most likely driven by individual catch costs. The reason for a high percentage of invalid ACE transactions could be that companies frequently balance ACE, rather than quota, with catches. Furthermore, they can frequently pass ACE between their subsidiaries or barter with other fishers.

However, price dispersion can still be an indicator of market competitiveness if there is enough valid data. The argument is that if a market is competitive the differences amongst quota prices would be minimized because significant price differences leave participants opportunities to arbitrage. In reality, price discrepancies exist and persist because of the differences of transaction type – direct trading or through brokers. Differences in transaction costs, search costs and bargaining power also lead to price differences (Newell *et al.*, 2005).

Price dispersion can be measured in different ways. The Standard Deviation and Coefficient of Variation (CV) are the two most commonly used ways to measure sample variability. Standard deviation measures how widely spread each observation is from the mean. Newell *et al.* (2005, p. 447) used the "… annual average of the percent absolute deviation of each transaction price from the monthly mean price…" to measure the variability of a single transaction. Because there are no single transaction data available, only the monthly mean value, price dispersion in this study is the monthly average price deviation from its annual average. It was calculated by taking the square root of the sum of squared monthly average price, minus the annual average price for the fishing year.

However, because the yearly average prices (the basis on which standard deviations are compared) differ, CVs are used to compare the yearly changes of price dispersion and to show the trends. CV is the ratio between the standard deviation and its respective average price, and it scales the standard deviation on its respective mean for yearly comparison.

[31] David Skeggs is the Chairman of the BOMC and Director of Barnes Oyster Ltd, which fishes half of the quota in OYU5.

Table 5.8 Quota price dispersion, SNA1, 2002-2008.

Fishing Year	Number of monthly observations	Number of observations in the month	Annual Average Price/quota ($)	Standard deviation ($)	Coefficient of Variation (CV)
2001/02	6	28	2.53	0.08	0.03
2002/03	3	13	2.43	0.01	0.00
2003/04	1	5	2.22	NA	NA
2004/05	1	3	1.64	NA	NA
2005/06	2	8	1.69	0.10	0.06
2006/07	2	14	1.45	0.99	0.68
2007/08	2	7	1.96	0.10	0.05

SNA1 quota price dispersion from the 2001/2002 to the 2007/2008 fishing year is summarized in Table 5.8. Two things can be noticed. The price dispersions were reasonably small for most observed periods except for the 2006/2007 fishing year. The dispersions between 2001 and 2003 were trivial; most transactions in 2001/02 had a price within $0.084 of $2.53 and most quota prices in 2002/03 did not deviate from $2.43 by more than $.007. A similar case can be argued for the 2005/06 and 2007/08 fishing years. The only anomaly for the observed period is 2006/07; the price dispersion was almost $1 from the mean of $1.45. Because there was only one observation in the 2003/04 and 2004/05 fishing years, no data were available for calculating the dispersion.

Most price dispersions are acceptably small, which is a character of a competitive market. The CV values agree with the standard deviations; the CVs show that the discrepancies were close to zero except for the 2006/07 fishing year. However, the price dispersions in the last three fishing years were all calculated on two observations, which lowered the reliability. Further, given the number of monthly observations, seven fishing years/observations, in total, might not be long enough to show any pattern of price dispersion.

Table 5.9 Quota price dispersion, OYU5, 2002-2008.

Fishing Year	Number of monthly observations	Number of observations the month	Annual Average Price/quota ($)	Standard deviation ($)	Coefficient of Variation
2001/02	0	0	NA	NA	NA
2002/03	0	0	NA	NA	NA
2003/04	0	0	NA	NA	NA
2004/05	0	0	NA	NA	NA
2005/06	0	0	NA	NA	NA
2006/07	0	0	NA	NA	NA
2007/08	0	0	NA	NA	NA

It is obvious from Table 5.9 that there were not enough observations to support the price dispersion analysis for the OYU5 fishery. Fish Serve's Quota Monthly Report (QMR) showed a lack of quota trading in the fishery; between the 2001/2002 and 2007/2008 fishing year, there were16 quota trades, The number of transactions was not sufficient to generate any meaningful average quota price. In fact, there was no valid quota transaction considered by Fish Serve, which can be caused by in-house trading or recording for book-keeping purposes rather than real price registering.

Table 5.10 ACE price dispersion, SNA1, 2002-2008.

Fishing Year	Number of monthly observations	Number of observations in the month	Annual Average Price/ACE ($)	Standard deviation ($)	Coefficient of Variation
2001/02	12	1276	3.28	0.74	0.23
2002/03	12	1544	3.08	0.58	0.19
2003/04	12	244	4.51	0.21	0.05
2004/05	12	176	3.91	0.20	0.05
2005/06	12	340	3.19	0.18	0.06
2006/07	12	233	4.07	0.31	0.08
2007/08	12	277	4.43	0.54	0.12

The SNA1 ACE transactions and ACE price dispersions are given in Table 5.10. Compared with the quota sale price, lease prices show a better picture of price dispersion because there was valid ACE trade every month for seven consecutive fishing years. The standard deviation shows that the price dispersions were relatively small; on average, each ACE transaction was priced within $0.39 from the mean of $3.78. Similarly, CV shows the price discrepancy decreased in the snapper fishery, with a slight fluctuation, from 0.226 to 0.121.

Table 5.11 ACE price dispersion, OYU5, 2002-2008.

Fishing Year	Number of monthly observations	Number of observations in the month	Annual Average Price/ACE ($)	Standard deviation ($)	Coefficient of Variation
2001/02	1	4	0.30	NA	NA
2002/03	1	6	0.34	NA	NA
2003/04	1	4	0.44	NA	NA
2004/05	3	7	0.21	0.19	0.92
2005/06	1	5	0.11	NA	NA
2006/07	0	0	NA	NA	NA
2007/08	3	12	0.25	0.03	0.11

Comparing with SNA1, OYU5 was much less active; from Table 5.11, there were 66 valid exchanges in the seven years from 2001/02 to 2007/08 fishing year. There were only two computable standard deviations and CVs out of seven observations, of which only three monthly observations were available for computing each figure. Because of the lack of data, neither individual ACE price dispersion nor the trend of price variations can be analysed.

5.5 Results

After comparing the functionality of the quota markets between OYU5 and SNA1, it is obvious that the OYU5 fishing quota market is not competitive. Specifically, data from Fish Serve, MFish and local knowledge agree with one another that using all three criteria (the number of market participants, market activities and price dispersion) for OYU5 shows a lack ofcompetitive activity. However, the MIM theory assumes the competitiveness of quota markets and, therefore, there is no case to carry on further analysis along the line of MIMS (*i.e.*, analysing external factors that might affect asset price, or comparing the OYU quota price performance with a non-self-governed fishery).

If the Bluff oyster fishery had a competitive quota market, the next step would be to study the fishery and its operating environment to rule out the non-management external factors that might influence quota prices. That would be followed by selecting a comparable fishery (or the market) for comparison of its quota price performance. Conclusions could then be drawn as to whether self-governance adds value to the fisheries management.

If the OYU5 fishery did have a competitive quota market, a close look at the fishery would show that there is at least one confounding factor that can affect quota price significantly: the *Bonamia* disease. As the disease affects the oyster population significantly (the fishery was closed during 1992 and 1996), the quota price is more than likely to be affected in a negative way during the year if *Bonamia* is detected. Further, even if there is no *Bonamia* in a given year, the risk of disease infection will create uncertainty for fishers and investors and will impact the fishery’s quota price.

If the quota market of OY5 is competitive and there are no non-management factors that affect quota price, the next step is to find a comparable fishery for quota price performance comparison. However, the Bluff oyster fishery is a self-governed inshore shellfish fishery, with a small number of players who catch oysters by dredging. There is a lack of comparable fisheries that fit the criteria for comparison. For example, some paua fisheries are not self-governed, but use different fishing methods, *i.e.*, hand gathering. The Southland queen scallop fishery is not self-governed and only three vessels are operating in the fishery.

Table 5.12 The total asset price of all New Zealand QMS species, 1996-2007.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total asset value ($ million)	2740.15	2725.56	2285.27	2599.37	2641.44	3096.97	3184.76	3613.70	3865.72	3729.70	3793.52	3822.75
Percentage change from last year (%)		-0.53	-16.15	13.74	1.62	17.25	2.83	13.47	6.97	-3.52	1.71	0.77

Source: Statistics NZ (2008)

Therefore, it is necessary to compare the Bluff oyster quota price performance with the overall quota price behaviour of New Zealand QMS fisheries. Table 5.12 shows the total asset value of all QMS fisheries; it includes the average quota value, price and changes from 1996 to 2007. Though the total volume of catch, restricted by TACC, might change, the total share of quotas (100 million for each QMS fishery), hence price/share, does not. Therefore, the total quota price trend of all fisheries can be compared with the OYU5 quota price trend on price per share basis.

5.6 Conclusion

In this chapter, the Minimum Information Management System (MIMS) method was applied to evaluate the *ex-post* performance of self-governance on an integrated level. MIM theory implies that a single piece of information, the quota price, potentially contains most necessary knowledge (*e.g.*, biological, economic and market information) that fishery managers require to manage a fishery effectively (Arnason 1989, 1990). Therefore price can be a useful approximator of a fishery's status. However, for the theory to be valid, the fishing quota market has to be competitive.

There are both advantages and disadvantages of using asset price as the single approximator of fisheries management. On the up-side, it is relatively straightforward because only one set of data – ITQs prices – is required. However, it is not without its problems. There are some conditions that need to be met in this theory before ITQ prices can be used to approximate management quality. For example, the quality of quotas as property rights and the competitiveness of quota markets to generate fair priced assets are two major concerns, amongst others. Furthermore, the results generated from the MIMS can be ambiguous for interpretation. This is because ITQ prices can reflect a huge amount of information in the fishery and, therefore, it is difficult to determine whether it is the management or some other factor that caused a change in ITQ prices. For example, the premium return might be caused by the passage of a piece of legislation that favours the fishery or by the increase in demand for that fish product. This ambiguity in interpretation might lead to erroneous conclusions about the self-governance regime. However, by incorporating a procedure that investigates external factors carefully, the MIMS method might be able to identify and rule out major 'noise' from other aspects of the fishery that cause asset prices to change.

Despite the potential relevance of the theory to evaluate fisheries management, the application of this theory is limited. Only two research papers were found that attempted to apply the theory to real-world fisheries. Gudmundsson (2002) assumed MIM theory to be valid and applied it to an Icelandic fishery. Batstone and Sharp (2003) found evidence to support the theory in one New Zealand fishery. In contrast to these two papers, this chapter sought to develop the MIMS discussion further by first invesitigating the validity of the theory in New Zealand, then usingthe theory to evaluate the ITQ-based self-governance regime.

Because the fish quota market in the Bluff oyster fishery is not competitive, the quota sale and lease prices are not likely to be able to reveal the fishery's condition. Hence, we cannot determine if the quota asset price behaviour can signal the underlying biological, economic and institutional performance. That is, fisheries managers cannot rely on quota price behaviour to monitor the management (mismanagement) of self-governance.

Even if the quota market were competitive, the reliability of quota price behaviour to reflect the underlying fisheries condition needs to be examined carefully. In the Bluff oyster fishery, there is at least one non-management factor, the *Bonamia* disease, which would affect the price of quota. It is likely that there will be other external dynamics that can affect quota prices, yet difficult to discover. The more commercially significant the fishery is, the more likely its quota price would be affected by other factors (*e.g.*, such as change of fish demand due to change in consumers taste or due to the discovery of cheaper substitutes).

Even if the quota market was competitive and there were no other external factors that would have affected the quota price, it is difficult to detect which information is contained in the quota price and how this information is reflected by the quota price. Because all those elements are lumped into one piece of information, it is difficult to separate the main contribution of self-governance from other contributions or even mismanagement. Therefore, a method that disaggregatedly evaluates the self-governance regime is necessary.

The MIMS, however, can still be a good tool for assessing fisheries management. When only quota price data are available or other information is too costly or time-consuming to obtain, quota price behaviour can be used as a quick approximator for the condition of the underlying fishery. In addition, where the MIMS is applicable, quota prices can capture the benefit of self-governance into measurable monetary term. That is, the management (mismanagement) of self-governance is shown by the gain or loss in the asset price.

Chapter 6
Indicator System (IS)

6.1 Introduction

Chapter 5 used quota price behaviour to evaluate ITQ-based self-governance regimes integrally. It was found that the quota market of the Bluff oyster fishery is uncompetitive and, therefore, the MIMS is inappropriate to apply. Even if the quota price did reveal the management quality of self-governance, it cannot identify the aspects (*e.g.*, institutional effectiveness and environmental stewardship) to which self-governance adds value. Therefore, in order to gain a more complete and insightful picture whether and how self-governance improves fisheries management on ITQ programmes, a different method is needed.

An indicator System (IS) can be applied to further evaluate particular aspects of self-governance. The IS approach can investigate multiple dimensions. First, the IS can verify the findings observed with the MIMS. Specifically, the ITQ prices should contain information of profit-rated variables (*e.g.*, population dynamics, profitability and institutional change) (Batstone and Sharp, 2003, 2008). Therefore, if there is a positive return on the asset price, it could be expected that there might be improvements in various aspects of the fishery that co-determine its profitability. Secondly, indicators will be able to provide the required inclusive and discerning assessment because the IS can include as many aspects of fisheries management as required and assess specific merits with measurable variables. Moreover, unlike the modelling or MIMS approach, no rigorous assumptions are needed in the IS and, therefore, the results have few ambiguities attached.

The remainder of this chapter is arranged as follows: Section 6.2 provides a literature review that applies indicators in various ways with a particular focus on fisheries management. This literature review also provides the basis on which indicators were selected for application in this study. Section 6.3 is the methods section, which develops the IS for studying self-governance. This section will show the process by which the indicators in this study were selected. Section 6.4 applies the IS to the Bluff oyster fishery to study if the promises of self-governance can be fulfilled, as well as examining the practicality of the IS method. This is then followed by Section 6.5, which provides the conclusion from the findings in the case study.

6.2 Literature review

Using indicators to examine the performance of underlying events is not new with regard to economic phenomena. Because the target socio-economic system is often complex, indicators are used to "summarise complex information of value" and "…condense … complexity to a manageable amount of meaningful information" (Bossel, 1999, p. 8). For example, the production of a nation is influenced by numerous items, but the single indicator – the Gross Domestic Product (GDP) – can sum and capture many important items into a single piece of information.

Fishing is one sector where indicators have been used to assist with management. Hilborn and Walters (1992, Chapter 2) discussed the objectives in four fishery management areas: biological, economic, recreational and social. They provided indicators in each area to assess if each management objective is met. For example, annual weight/number of catches and average size/age in the catch are used as two indicators to capture or assess the biological status of fisheries. A more complete Indicator System (IS) approach to fisheries management can be found in publications by some major Non-Government Organisations (NGOs), including the United Nation (UN, 1987, 2001), the Food and Agriculture Organisation of the UN (FAO, 1999) and the Organisation for Economic Co-operation and Development (OECD, 1993, 2001, 2008, 2010).

Although indicators have been used extensively in various socio-economic studies, there are no readily available indicators to evaluate ITQ-based self-governance. The existing work, nevertheless, can provide a set of candidate indicators. This section will review four research literature categories that are relevant to fisheries management to provide a starting point to develop the set of indicators for self-governance evaluation. The four groups of research include: reports of NGOs, journal papers from a special collection, more recent studies of indicators' application and papers on self-governance studies.

6.2.1 Non-Government Organisations

The United Nation's (1987) *the Report of the World Commission on Environment and Development: Our Common Future* promotes indicators as part of the monitoring mechanisms for sustainable development. Following that lead, a series of indicator frameworks were developed by the leading international NGOs, namely the UN, the FAO and the OECD. These organisations have published a number of comprehensive guidelines for using indicators to assist sustainable development. Some works focus mainly on the environment (with fisheries being a component of it) and economic and social development, whereas others focus solely on the specifics of fisheries management.

Publications from the OECD emphasise environmental sustainability. OECD (1993), a paper in response to the UN's Agenda 21, opened up a series of discussions on indicators for assessing environmental performance. OECD (2004) followed the previous works to provide the core environmental indicators for areas such as climate change, freshwater quality, forest resources and fish resources. For each area, the paper identified pressures, conditions and responses. For example, for fish resources: the pressure comes from fishing activities; the conditions presented are changes of spawning stock size, which is indicated by overfished areas; responses to the pressure is the introduction of fishing quotas, which is indicated by the number of stocks regulated by quotas and the cost of fisheries management. The OECD report of the core set of indicators is updated every year according to changing conditions. However, the core set of indicators for fish resources have not changed since 2004.

Similar to the OECD's work, the UN has developed indicator guidelines for sustainable development. However, the UN's studies are more comprehensive; they cover not only environmental but also economic, social and institutional issues. Since the UN's reports try to cover almost all aspects of human life, their focus is diverted and, therefore, only one indicator is discussed for fisheries resources. The UN (2001) used annual catch by major species to show the status of the world's fisheries. Though the trend of catch rate shows, to a certain extent, changes of fisheries' productivity, the report also acknowledges its limitations. For example, the catches in some areas are difficult to assess and they might be influenced by various other non-management factors such as climatic conditions. Further, decreasing annual catch rate does not necessarily mean the fisheries' status deteriorates and may be caused by catch limits imposed by some nations.

Recognising the limitations of catch rate as the core indicator, the UN (2007) recommended using a portion of fish stocks within safe biological limits to indicate world's fisheries' condition. This indicator appears to be more reliable than annual catch because it shows the condition of the fishery itself and has fewer external influences. For example, an underexploited stock shows it is relatively healthy, but a depleted stock means the fishery is under its maximum biological capacity and productivity. However, there is still a problem with this indicator, *i.e.*, determining the status of the fishery. Specifically, in order to conclude that a fishery is underexploited or overexploited, research is needed. This can be problematic because some developing countries might not have the resources or expertise to accommodate these studies.

Perhaps the most comprehensive set of indicators developed for fisheries management are the FAO's (1999) indicators for sustainable development of marine fisheries. It is a guideline created to implement the Code of Conduct for Responsible Fisheries in order to achieve sustainable development of fisheries. Like the UN reports, all aspects of fisheries sustainability – environmental, economic, social and institutional – are included. Further, not only has the report provided the set of indicators, but also the procedures in its development (*e.g.,* the set of criteria required for indicator selection and the corresponding reference points for interpretation).

6.2.2 The special edition of Marine & Freshwater Research

In responding to the UN's Agenda 21, the special issue of Marine & Freshwater Research (Volume 51, 2000) was dedicated to sustainability indicators in marine capture fisheries. All papers in the edition are scientific but some are more technical than others. Some papers emphasise the structure of indicator systems, whereas some emphasise the development and testing of indicators for a specific area (*e.g.,* social or economic) of fisheries management. Therefore, they can provide the basis for selecting a set of potential indicators to be used in this study.

In this special issue, Garcia and Staples (2000) discussed five frameworks (the FAO Responsible Fisheries Code of Conduct; the FAO definition of sustainability; the general framework for sustainability; the Pressure–State–Response (PSR) model; and the Ecologically Sustainable Development (ESD)) for organising indicators. However, because they are suggested in the context of sustainability, not all of them are readily applicable to a self-governance study. For example, the first two frameworks strictly follow FAO's Code of Conduct that pinpoints the sustainable development of fisheries resources. The last two frameworks, the PSR model and the ESD framework, are mostly seen in management literature, especially the PSR model. Because the PSR model helps identify the problem, the severity of the problem and the solution to the problem, it has been used extensively in environmental and sustainability reports (*e.g.,* Hughey, Cullen and Kerr, 2010; OECD, 2004).

However, this study focuses mainly on the Response part: if self-governance is one of the solutions for fisheries management. Therefore, the PSR framework does not fit this context.

The framework that has some relevance to self-governance is the general framework for sustainability. In this framework, Garcia and Staples (2000) identified the environmental and human dimensions with the management of fisheries. These two dimensions can be further broken down into categories that are related to self-governance. For example, with regard to the environmental dimension, self-governance promises the same, if not better, management of the fishing environment. From the human perspective, self-governance promises possible increases in economic rent.

Ward (2000) provided potential indicators for assessing an ecosystem from the perspective of Australia. The 61 indicators were grouped by the components of an ecosystem such as protected species and water and sediment qualities. Some of the indicators are relevant to the self-governance studies in New Zealand (*e.g.,* fish population and marine protected areas), whereas others (*e.g.,* water nutrients (nitrogen) and seabird eggs) are too technical and might not be applicable to this study.

Gilbert, Annala and Johnston (2000) provided fish stock status indicators in the context of New Zealand using the PSR model. The authors discussed a set of readily usable indicators for stock status assessment such as the MSY and the Total Allowable Catch (TAC) level. They pointed out that the heavy data orientation of these indicators limited their use. Therefore, these indicators are reliable for fisheries where extensive research has been carried out. The paper further develops a set of proxy indicators, which are variations of current stock biomass to the virgin stock biomass. Proxy indicators are useful when original data are missing. However, neither original nor proxy data can be obtained. This chapter will suggest the use of other alternative indicators (*e.g.,* Catch-Per-Unit-Effort (CPUE) or survey based relative stock biomass index) to indicate stock status.

Seijo and Caddy (2000) presented a set of indicators that cover the basics of bio-economics of fisheries management. The indicators are simple and do not require specialised knowledge to understand. For example, seasonal recruitment and total mortality are used as indicators for fish resource and fishing days is used for fishing effort. However, one indicator on its own might be misleading so needs justification in order to be used in this study. For example, fishing days is driven by fishing power. Hence, only when fishing power stays constant can fishing days indicate changes in effort.

Hundloe (2000) discussed economic indicators for fisheries management. The indicators are, as Garcia and Staples (2000) described, for non-specialists. In fact, the author suggested that the profit of the fishing industry is the sole indicator of importance for the assessment of a fishery's economic performance. Other indicators, such as price of fish, cost of catch, are merely components that make up profits. Although the concept is simple, it is also practical and useful when profit data are available. However, when data are not available, some components that make up profit might be used to examine the fishery's performance.

Chong (2000) focused on the social side of fisheries management. By using indicators to study the fisheries in India, he concluded that the involvement of users of the fishery in management can lead to favourable outcomes for sustainable development. In the study, some indicators used were area specific, such as the relationship of the fishers with money-lenders and market intermediaries, which has little application in New Zealand. On the other hand, some indicators, such as the attitude of the users (and the participation of the community), can be used in fisheries management in New Zealand.

6.2.3 Recent development of indicator literature since 2000

Since UN's Agenda 21, there have been more indicator applications in fisheries management. Not only have there been more indicator studies in ecosystems and the environment[32], indicator applications in economic and social aspects have become more structured and specific. Ithindi (2003) reviewed rent capturing in the catch sector. His study provided a further theoretical framework for using profit and its components (*e.g.*, total revenue and total fishing cost) as indicators for assessing the economic aspects of fisheries management. In terms of social indicators' development, Allen and Gough (2006) considered the longline swordfish fishery in California to show the social impact of a fishery on a fishing community. The paper showed that the estimated result of shutting down a fishery can be quite different depending on the data input used.

New dimensions are being added to the literature. Indicators are applied in areas such as compliance monitoring. King, Porter and Price (2009) looked at compliance indicators in the U.S. and found conflicts between the observed data from the U.S. Coast Guard and survey data from other sources. The authors concluded that enforcement rules might become obsolete as situations change regarding whether the benefit of rule-breaking exceeds the unchanged punishment.

[32]See for example, Caddy (2004), Fogarty and Gendron (2004), Raakjær *et al.* (2007) and Powers and Monk (2010).

Their findings are relevant to New Zealand self-governance studies. In New Zealand, the main legislation that oversees fisheries management is the Fisheries Act 1996. Although the Act was amended in 1999 (Fisheries Amendment Act 1999), some articles have not been changed since then. Therefore, if either catch restrictions or enforcement rules become out of date, self-governance might be able to adjust the gap before introducing new legislation. Further, as much as the Fisheries Act covers all aspects of fisheries management, there is still a need for specified fishing rules for the individual fishery, because fisheries are different in terms of their catch methods, fishing seasons and main markets. Hence, self-governance might be able to complement fisheries legislation by establishing regulations that are relevant to the individual fishery.

6.2.4 Case studies of self-governance

The discussed body of literature above applied indicators explicitly to evaluate the management of fisheries. Case studies of self-governance also use certain variables as indicators of fisheries performance. Townsend, Shotton and Uchida (2008) collected self-governance fisheries studies from around the world, most of which contain detailed performance analysis using indicators. For example, Eggert and Ulmestrand (2008) studied the co-management of the Swedish shrimp fishery in a marine reserve, using landed value and fishing effort (fishing days) to evaluate the fishery's performance improvement. Mincher (2008) investigated the New Zealand Challenger scallop fishery and applied four indicators: the level of agreement amongst stakeholders, recruited stock biomass indicators, pre-recruited stock biomass indicators and the implicit discount rates (ACE price divided by ITQ price) in the fishery.

In summary, indicators have been used as a tool for evaluating fisheries and fishery management, explicitly stated or otherwise. Generally, the indicators were applied to environment, ecological and biological studies, but there have been extensions of their application to social and economic aspects. Further, as well as the comprehensive and structured reports produced by the NGOs (*e.g.* FAO, 1999; OECD 2004, 2008) from the world perspective, a lot of work has been undertaken at regional or individual fishery scale.

However, not all previous research and the indicators are readily usable for evaluating self-governance in New Zealand. The existing research has a different purpose. The theme of the UN Agenda 21 and its associated studies was ecosystem-based resource management, whose main focus is environmental performance. The numerous indicators in those studies were designed to measure sustainability. Other literature and most self-governance case studies in Townsend *et al.* (2008) have their own background, purpose and application. Therefore, a selection is needed to choose the appropriate indicators for self-governance evaluation in New Zealand.

6.3 Method

Fisheries management is multi-disciplinary and the capacity of indicators to assess fisheries' status appears almost unlimited. A system is needed to develop a set of indicators to study the potential benefits of self-governance in New Zealand. The IS in this chapter adopts the FAO (1999) and Rice and Rochet's (2005) indicator selection method, with some alterations to fit the purpose of this study. These steps are shown in Figure 6.1 and will be elaborated in detail in this section.

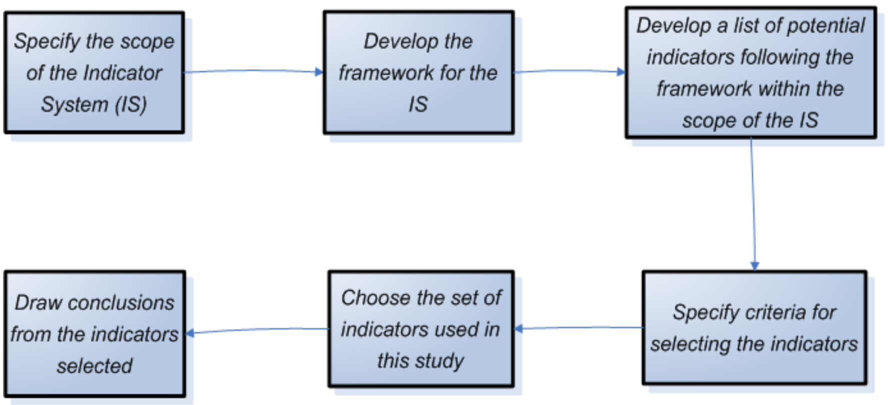

Figure 6.1 Indicator development procedure for New Zealand fisheries self-governance studies.

The figure shows that there are six steps in developing the indicator system for studying self-governance. This procedure, with some variations, is common practice for building an indicator system for other studies. The steps include, clockwise, specifying the scope of the Indicator System (IS), developing the framework for the IS, developing a list of possible indicators following the framework within the scope of the IS, specifying criteria, objectives, potential indicators, choosing the set of indicators and drawing conclusions from the indicators selected.

6.3.1 Specifying the scope of the IS

The scope and emphasis of the IS depends on the purpose and potential audience of the study. First, the purpose of the system means that this set of indicators is limited to examining whether the potential benefits of self-governance have been realised in New Zealand fisheries.

For example, the selected indicators should cover areas that are wider than fish stock alone, but narrower than studying the impact of fishing. Further, the intended user of the IS determines the emphases of the study. This IS is designed to assist managers and users of fisheries with their decision-making. Therefore, the indicators should be rigorous, yet understandable to untrained public.

6.3.2 Developing the framework for the IS

After setting the scope and emphasis of the IS, a framework is needed to organise the indicator selection process. A framework can be priority oriented. For example, if the healthiness of fish stock is judged to be more important than economic performance, fish stock indicators would be listed above economic ones. However, different users have different priorities; commercial users of the IS will rank the economic set of indicators the highest, but the general public might put fish stock abundance as highest priority. Therefore, the framework that uses priorities as the ranking mechanism is not suitable in a thesis. Alternatively, a framework can follow ways that "reflect(s) the pressures of human activities, the state of human and natural systems and the responses of society to the changes in those systems (pressure-state-response)" (FAO, 1999 p. 15). However, the focus of this study is not sustainable development, which calls for identifying the pressure, state and response. Hence, the framework of this IS approach follows the arrangement of the three dimensions of self-governance (*i.e.*, economic, institutional, and resource and environmental). Not only is this framework easy to follow, it also serves the purpose of examining fisheries management by self-governance in New Zealand.

6.3.3 Developing a list of candidate indicators

The candidate indicators were selected using a matrix that combined two screening points; research scope is discussed in step 1 and the IS framework determined in step 2, as shown in Table 6.1.

Table 6.1 The framework and scope of indicator selection for New Zealand fisheries self-governance studies.

		Scope		
		...	Self-governance in NZ	...
Framework	...	x	x	x
	Economic	x	o	x
	Institutional	x	o	x
	Resource and environmental	x	o	x
	...	x	x	x

Table 6.1 shows that only indicators that fit the purpose of this study were considered. The relevant indicators to the scope and framework receive a circle (o) in the figure, whereas the irrelevant indicators receive a cross (x). First, the **scope** narrows indicators down to examining self-governance in New Zealand. The dots in the two cells besides '*Self-governance in New Zealand*' represent other topics of fisheries management (*e.g.*, sustainability or self-governance in Canada). Based on this screening process, some indicators fitted all topics. For example, landed values and enforcement of catch rules can be used to show sustainability and performance of a self-governed fishery in either New Zealand or Canada. In contrast, some indicators are more topic-specific. For example, the number of processing facilities in a fishery cannot show sustainability of fish stock. Similarly, the amount of subsidy granted to the fishery is not a suitable indicator for self-governance in NZ because NZ fisheries are not subsidised.

Additionally, the **framework** shows the dimensions of this study. It is difficult to cover all dimensions of fisheries management in any single research. This is because fisheries management is multi-disciplinary; it embraces, amongst others, aquatic ecology, fisheries biology and social science. There are many indicators that are represented in each discipline. Therefore, for the purpose of evaluating self-governance on its merits, only three areas (economic, institutional, resource and environmental) are considered. The dots above and below the three categories represent the other areas of fisheries management, which are not discussed in this study. Social welfare and the recreational value of fisheries management are two examples of this. Consequently, indicators for those two areas, such as income level for social welfare and recreational accessibility for recreational value, are excluded from this study.

After setting the scope and framework, it is necessary to identify the appropriate literature in order to find the indicators that potentially can reveal the quality of self-governance in New Zealand. Based on the literature review in this chapter, the following literature was used as sources for candidate indicators. As shown in Table 6.2, the source literature, as in the literature review section, is grouped into four categories: NGO reports, papers in the special edition of Marine & Freshwater Research (2000), recent literature since 2000 and the case studies of New Zealand self-governance fisheries in Townsend *et al.* (2008).

Table 6.2 Source literature of indicators for New Zealand fisheries self-governance studies.

Source	Purpose	Target	Area 1	Area 2	Area 3	Area 4
NGOs						
FAO (1999)	Sustainable development of fisheries	International, national, regional	Environmental	Economic	Social	Institutional
OECD (2004, 2008)	Sustainable development of environment	International, national, regional	Environmental			
UN (2001, 2007)	Sustainable global development	International, national, regional	Environmental	Economic	Social	Institutional
Marine & Freshwater Research (2000)	*Fisheries resource management*					
Ward	Marine ecosystem sustainability	Australia	Ecological			
Gilbert *et al*.	Fish stock management	New Zealand	Biological			
Seijo and Caddy	Indicators application	Generic	Biological	Economic		
Hundloe	Economic sustainability	Generic		Economic		
Bonzon	Fisheries sustainability	Mediterranean		Economic	Social	
Chong	Fisheries sustainability	Bay of Bengal, India			Social	
Recent literature (2000 onwards)						
Ithindi (2003)	Fisheries economics	Namibia		Economic		
Allen (2006)	Fisheries environmental impact	California, U.S.A.			Social	
King et al. (2007)	Fisheries regulation enforcement	U.S.A.			Social	
Townsend et al. (2008)	*Self-governance*	*New Zealand*				
Clement *et al*.		Orange Roughy fishery	Biological	Economic		Institutional
Soboil and Craig		Deep-sea Crabs fisheries	Biological	Economic		Institutional
Mincher		Challenger scallop fishery		Economic		Institutional
Yandle		Rock lobster fishery				Institutional

Table 6.2 provides the literature sources from which the candidate indicators were chosen. The first column shows the article's authors. This is followed, in the second column, by the main purpose of the literature. This column states the scope of the study, for example, whether it is an environmental study or study of fisheries alone. The third column provides the scale of the study, for example international, national, or regional. The last four columns show the areas that the article studied: biological, economic, social, institutional or ecological.

From the literature in Table 6.2, Table 6.3 lists the candidate indicators for this study. According to the IS framework, the candidate indicators were grouped into three areas of fisheries management: economic, institutional, and resource and environmental. Within each area (*i.e.*, economic, institutional, or resource and environmental), the first column lists the indicators alphabetically and the second column provides the source(s) of the indicator.

Table 6.3 Candidate indicatorsfor New Zealand fisheries self-governance studies.

Economic	Source	Institution	Source	Resource and environmental	Source
Capital costs/Fixed costs	Bonzon (2000); Hundloe (2000)	Capacity to elicit, receive, and use information from all stakeholders/Management leadership	FAO (1999)	Areas of critical habitat (marine reserves)	FAO (1999); Pelletier *et al*. (2008)
Exporting earnings	Clement *et al*.(2008)	Caring and protective attitude and behaviour of users	Chong (2000)	Biodiversity	FAO (1999); Raakjær *et al*. (2007)
Gross value added	Bonzon (2000)	Effecitve communication between stakeholders	FAO (1999); Yandle (2008)	Biomass/targeted biomass	FAO (1999); Seijo and Caddy (2000)
Implicit discount rates	Mincher (2008)	Enforcement of catch	Seijo and Caddy (2000); Mincher (2008)	CPUE	Gilbert *et at*. (2000); Raakjær et al. (2007)
Indirect fishing costs (No. of vessel, crew, processing facilities etc.)	FAO (1999); Bonzon (2000); Hundloe (2000)	Existence of outstanding disagreements	FAO (1999)	Exploitation rate/ target exploitation rate	FAO (1999)
Landed prices	FAO (1999); Hundloe (2000); Ithindi (2003)	Higher level authorities facilitaing lower levels of management	FAO (1999); Clement (2008); Yandle (2008)	Fish population	Seijo and Caddy (2000); Ward (2000); Mincher (2008)
Landing value	FAO (1999); Bonzon, (2000); Hundloe (2000); Clement *et al*. (2008); Soboil and Craig (2008)	Involvment of major stakeholders in making and applying rules of the game	FAO (1999); Seijo and Caddy (2000); Clement et al. (2008); Mincher (2008); Soboil and Craig (2008); Yandle (2008)	Pre-recruited stock biomass	Mincher (2008)
Management cost/Government Charges (Research, enforcement etc.)	Hundloe, 2000;Seijo and Caddy (2000); Clement *et al*.(2008)	Level of agreement amongst stakeholders	Mincher (2008)	Protected species populations (protective species mortality)/By-catch	Ward (2000)
Net return on investment	FAO (1999); Bonzon (2000); Seijo and Caddy (2000)	Lowered pollution level	Chong (2000)	Recruited stock biomass	Mincher (2008)
Net value added	Bonzon (2000)	Management Leadership	Clement *et al*. (2008); Mincher (2008); Soboil and Craig (2008); Yandle (2008)	Size of spawning stocks	OECD (2004, 2008); Seijo and Caddy (2000); Raakjær *et al*. (2007); Mincher (2008)
Operational costs/Variable costs	Bonzon (2000); Hundloe (2000)			TACC	Clement *et al*. (2008); Mincher (2008); Soboil and Craig (2008)
Productivity of capital	Bonzon (2000)			Total catches	FAO, 1999; UN (2001)
Productivity of labour	Bonzon (2000)				
Profits	FAO (1999); Bonzon (2000); Hundloe (2000); Ithindi (2003)				
Quality of fish products	Clement *et al*.(2008)				
Subsidies	FAO (1999)				

The source literature and candidate indicators used in this study are by no means exhaustive. In fact, there are other aspects to the literature on fisheries management that include many potentially useful indicators. However, the literature listed in Table 6.2 and their indicators in Table 6.3 are an adequate representation (*i.e.,* NGOs research; the special edition of Marine & Freshwater Research (2000)), up to date (*i.e.,* the recent literature since 2000) and specific (*i.e.,* Townsend *et al.,* 2008)). Moreover, the majority of the candidate indicators were used in one or more sources, which suggests their wider acceptance. For example, profit as an economic indicator of fisheries management is recommended by four different studies, which range from NGO reports (*e.g.,* FAO, 1999) to independent studies (*e.g.,* Ithindi, 2003). For the indicators that are discussed in only one paper, or one set of similar papers, their application is either unique to New Zealand and/or to fisheries self-governance. For example, TACC as fish stock indicator (*e.g.,* Clement *et al.,* 2000; Mincher, 2008; Soboil and Craig,

2008) is unique to New Zealand's quota management system. Level of agreement amongst stakeholders as an institution indicator (*e.g.,* Mincher, 2008) can demonstrate the unity of the fisher community to management decisions within a self-governed fishery.

6.3.4 Setting criteria for selecting best indicators

Different studies require different indicators. Stemberger, Larsen and Kincaid (2001, p. 2222) suggested that an ecological indicator should "... integrate complex ecosystem processes and the magnitude and direction of response should be interpretable within some theoretical or empirical framework. Ideally, indicators should be simple to measure and to construct, and effective in the context of the goals of the monitoring programme. Common objective include status estimation and trend detection". On the other hand, Garcia (1997) required that indicators have a cost-effective collection system, have the ability to monitor conditions and trends, provide information for fisheries managers and be able to signal early warnings.

Table 6.4 Fisheries indicator selection criteria for New Zealand fisheries self-governance studies.

Indicators	Explanatory notes	Sources
Understandable	Indicators are able to communicate infomation relatively easy to reades and users; and is readily understood by a broad audience (eg. Non-scientists), non-economists.	FAO (1999); UN (2007); State of the environment reporting: framework for Australia, (1994 cited in Ward, 2000)
Specific/relevant	Indicators are relatively tightly linked to the relevant activity - high responsive to fishing activity, low responsive to other influences; adequately reflects the management effects of self-governance that they are intended to measure.	FAO (1999); OECD (2008)
Concrete/Scientifically validity/Conceptually sound/Adequate documentation	Indicators are ideally grounded in theory, methodologically sound. They are better to be based on existing studies and/or time series data to allow a realistic reflection of underlying reason of change. The influence of self-governance and facts of different management region are awared by users.	State of the environment reporting: framework for Australia, (1994 cited in Ward, 2000); UN (2007)
Data available/ measurable	Indicators need to be relatively easily to be obtained. They are ideally to be observable, and/or existed as commercial and managerial indicators. Indicators should be able to be measured regularly and consistently over time, and across fisheries, to reflect improvement or deterioration and enable comparison. Indicators are ideally to be readily available or can be collected within economic resources for research on a sustained basis	FAO (1999); State of the environment reporting: framework for Australia, (1994 cited in Ward, 2000); UN (2007); OECD (2008)
Sensitive/Responsive	Indicators vary with changes in fisheries management region. Ideally the respond to change would be relatively quick and noticeable, but not show false movements.	FAO (1999); UN (2007)
Timely	Indicators should report current rather than historical information. However, it could be either leading to provide an early warning of potential problems; or lagging to show the effect of self-management.	FAO (1999); State of the environment reporting: framework for Australia, (1994 cited in Ward, 2000); UN (2007)

Table 6.4 shows the indicator selection criteria sourced from some major studies and reports. The first column shows the criterion, followed by the explanation in the second column and the last column provides the sources from which the criterion is drawn. Although there are other selection criteria available, these ones are chosen for this study. Specifically, as well as

fitting the research purpose and research target, the indicators in this study fulfil six criteria, or display as many of the following attributes as possible. That is, indicators need to be understood by the audience, be specific to the purpose, conceptually sound, available and measurable, and sensitive to changing conditions.

First, the indicators in this study were required to be understandable, plain and straightforward to communicate to the audience. Fisheries managers and stakeholders, amongst others, should be able to use the IS to evaluate the performance of self-governance for their own purposes. Indicators that are highly technical, have monitoring difficulties, or are vague in interpretation would be excluded from the candidate list. For example, fish stock assessment and ecological status indicators are often difficult to gather and interpret. Ward (2000) noted that chlorophyll concentration is one of the indicators for habitat quality. Although it is scientifically valid, it does not meet the criteria of this study because of the monitoring and interpretation complications.

Secondly, indicators should be specific and relevant to the area of concern. In other words, they should be highly responsive to management regimes but not external factors. For example, compliance rate as an indicator is more relevant and specific than management structure. Higher compliance rates of catch regulations after a fishery is managed by its users show the effectiveness of stakeholder involvement. In contrast, the management structure of a fishery, even if it has a co-management component, does not indicate the effects of self-governance.

However, in many cases, linkages amongst indicators might cause potential conflicts. For example, profit changes can be management driven but could also be a result of fish product demand change, which is external to management. Similarly, change in direct fishing costs can be a result of efficient management or simply caused by technology advancement. Although those conflicts are sometimes unavoidable, a combination of indicators that point in the same direction should add confidence in drawing conclusions. Further, according to UN (2007, p. 30), ambiguity of the signal reinforces the need to interpret results in a balanced and integrated manner.

Thirdly, indicators need to be conceptually sound and grounded in theory. Ideally, they should either be applied to a number of studies or be shown to be able to reflect the effect of a fisheries management regime. If the indicator is not frequently used, there at least should be awareness of its use in the field. For example, biomass is an indicator to show fish stock condition, which has been used in a number of studies such as Seijo and Caddy (2000), Ward (2000) and Mincher (2008). On the other hand, Catch Per Unit of Effort (CPUE), is also argued to be able to show the abundance of a fish stock (Gilbert *et al*., 2000; Raakjær, Manh, Stæhr, Hovgård, Dieu *et al.,* 2007), but is applicable when only certain conditions (*e.g.,* a positive relationship between fish stock and catch) are met.

Furthermore, data availability and measurability form the fourth criterion for selecting appropriate indicators. The information needed should be able to be gathered or calculated for most fisheries in New Zealand. Data for those indicators should either be readily available from various sources, or could be made available within reasonable time and cost limits. Further, indicators should be able to be measured regularly and consistently over time and across fisheries, to reflect improvement or deterioration and enable comparison.

The last selection criterion is the indicator's responsiveness or sensitivity. It is important that indicators chosen are responsive to the management of self-governance. According to Statistics New Zealand (2005), ideally the response to change should be relatively quick and noticeable, but not show false signals. Further, this criterion is set to bind the indicators to be as directly related to a fisheries management regime as possible. For example, catch compliance rate is a better indicator than safer fishing conditions. This is because the former is mostly driven by fishers' attitudes towards regulations, whereas the latter could be a result of both fishing activity and natural forces. Further, compliance rate is more responsive to management actions within a short time.

6.3.5 Choosing the set of indicators

Based on the selection criteria, this section determines the indicators that will be used for analysis. This set of indicators provides the basic information about a self-governed fishery and evaluates self-governance for New Zealand fisheries. Further, it is necessary to limit the number of indicators because too many indicators confuse the result and make interpretation difficult (UN, 2007).

Tables 6.5 – 6.7 show the process of selecting indicators for the three studied areas, economic, institutional, and resource and environmental. The general procedure is that, from the list of candidates, indicators were rated against the selection criteria. For each criterion, the indicator gets a tick if it meets the requirement, a question mark if it meets the requirement conditionally, or a cross if it does not meet the condition of the criterion. For example, the economic indicator '*subsidies*' gets three crosses in terms of relevancy, data availability and responsiveness. This is because New Zealand fisheries do not get funding from the government, thus subsidies are irrelevant to this study. Productivity of capital and productivity of labour get two question marks for specificity and responsiveness. They are not specific to the study of a fisheries management region and might respond more to technological changes.

Table 6.5 Analysis of the selection of economic indicatorsfor New Zealand fisheries self-governance studies.

Indicator	Understandable	Relevant/Specific	Conceptually sound	Data available/ measurable	Responsive/Sensitive
Capital costs/Fixed costs	√	√	√	?	√
Exporting earnings	√	?	√	√	?
Gross value added	?	?	√	?	?
Implicity discount rates	√	√	√	?	?
Indirect fishing costs (No. of vessel and processors)	√	√	√	√	√
Landed prices	√	√	√	√	?
Landing value	√	√	√	√	?
Management costs (actual management, Research, and enforcement)	√	√	√	√	√
Net return on investment	√	√	√	?	?
Net value added	?	?	√	?	?
Operational costs/Variable costs	√	√	√	√	?
Productivity of capital	√	?	√	?	?
Productivity of labour	√	?	√	?	?
Profits	√	√	√	?	√
Quality of fish products	√	√	√	?	?
Subsidies	√	x	√	x	x

Table 6.6 Analysis of the selection of institutional indicatorsfor New Zealand fisheries self-governance studies.

Indicator	Understandable	Relevant/Specific	Conceptually sound	Data available/ measurable	Responsive/Sensitive
Capacity to elicit, receive, and use information from all stakeholders (Management leadership)	√	√	√	√	√
Caring and protective attitude and behaviour of users	√	?	√	√	?
Effecitve communication between stakeholders	√	√	√	√	√
Enforcement of catch	√	√	√	√	√
Existence of outstanding disagreements	√	√	√	√	√
Higher level authorities facilitaing lower levels of management	√	√	√	√	√
Involvment of major stakeholders in making and applying rules of the game	√	√	√	√	√
Level of agreement amongst stakeholders	√	√	√	√	√
Lowered pollution level	√	√	?	?	x
Management leadership	√	√	√	√	√

Table 6.7 Analysis of the selection of resource and environment indicators for New Zealand fisheries self-governance studies.

Indicator	Understandable	Relevant/Specific	Conceptually sound	Data available/ measurable	Responsive/Sensitive
Areas of critical habitat (Marine reserves)	√	√	√	√	?
Biodiversity	?	?	√	?	?
Biomass/targeted biomass	√	√	√	√	?
CPUE	√	√	?	√	?
Exploitation rate/ target exploitation rate	√	√	?	√	?
Fish population	√	√	√	√	?
Pre-recruited stock biomass	√	√	√	√	?
Protected species populations (protective species mortality)/By-catch	√	√	√	√	√
Recruited stock biomass	√	√	√	√	?
Size of spawning stocks	√	√	√	?	?
TACC	√	√	?	√	?
Total catches	√	√	?	√	?

The indicator selection rule applied is that any indicator that gets one or more crosses or two or more question marks is excluded. Since each criterion covers a vital aspect of this study, any indicator that gets one or more crosses compromises one aspect of the requirement; one that gets two or more question marks makes the interpretation ambiguous hence lowers the quality of the indicator system. The indicators that are bolded in Tables 6.5, 6.6 and 6.7 are the ones that fit the selection criteria.

Table 6.8 A summary of selected indicatorsfor New Zealand fisheries self-governance studies.

	Indicators
Economic	Profit
	Indirect fishing costs - No. of vessel
	Indirect fishing costs - No. of associated facilities
	Management costs - Actual management cost
	Management costs - Research cost
	Management costs - Compliance cost
Institutional	Existence of users leading group in managing the fishery
	Level of communication
	Catch compliance rate
Resource and environmental	Fish biomass
	Total non-fish areas (including marine reserves and non-take zone)
	By-catch rates

Following the selection rules, a summary of the specific indicators is provided in Table 6.8. Some are generalised and combined into one indicator because they measure similar aspects of fisheries management. For example, '*the involvement of major stakeholders in making and applying rules of the game'* and '*capacity to elicit, receive and use information from all stakeholders'* are similar and are measured by a single indicator called '*level of communication'*. Similarly, biomass, targeted biomass, recruited biomass and pre-recruited biomass are all indicators of fish population. They do not need to be distinguished specifically for studying self-governance, as opposed to fish biology studies.

In the second column of Table 6.8, there are three key indicators showing the economic effect of self-governance: profitability, indirect fishing costs and management costs. Any single indicator might not be sufficient to fully support or refute the argument whether self-governance adds value to fisheries management economically, but the results are more convincing if the indicators agree with each other.

Profit is one of the most used economic performance indicators (Hundloe, 2000; Lindner *et al.*, 1992). As discussed before, self-governance is argued to have positive effects on economic rent generation. However, an upward trend of profitability does not necessarily directly link to good management. For example, a surge in fish demand and therefore price, can lead to an increase in profit. Or, a decrease in fuel price could have the same effect on profit, if other factors remain constant. Having considered these factors, the profit performance of a self-governed fishery should at least be better than one without the self-governance.

Indirect fishing costs in this study mainly refer to the number of vessels/boats and number of fishing related facilities (*e.g.*, processing plant). Self-governance is argued to improve fishing efficiency and thus lower fishing costs. Direct fishing costs – the cost of running a vessel – instead of the number of vessels and operating cost of processing instead of the number of processing facilities – are more in line with economic performance of a fishery. However, direct costs are often absent because of business confidentiality concerns. Additionally, direct costs are often affected by non-management factors, as well as management factors. For example, besides co-operation induced vessel number decreases, the operating cost of the vessels is also related to the cost of maintaining and insuring vessels, which is driven by general market conditions. Further, because variable costs in dollar term are often associated with catch volume, they might not show signs of decreasing levels even when the fishery is more efficiently managed (James, 2008).

Management cost is the last economic indicator. Compared with profit or indirect fishing costs, management costs are more specific and responsive to management methods because they are less affected by external influences. Wallis and Flaaten (2003) noted that fisheries management activity included research services, actual management services and enforcement services. Self-governance is argued to be able to lower total management costs in all three elements and shift part of the cost from general taxpayers to fisheries stakeholders.

Institutional evaluation of self-governance also comprises three key indicators. The first indicator is the existence of the users group leading in managing the fishery. Although self-governance means the coalition of all user groups, it is important to have leadership to co-ordinate and carry out the management responsibility. Without a management leader, the transactions cost of negotiation amongst users would consume part of the benefit created by self-governance, or become too high for self-governance to be mutually beneficial (Clement *et al.*, 2008; Townsend, 2008, 2010).

The level of communication and agreement amongst stakeholders and between users and fisheries managers is another indicator of the institutional performance of self-governance. It refers to the soundness of the management structure that involves fisheries users in the management system. It includes horizontal integration amongst users and vertical integration between users and fisheries policy makers.

Lastly, compliance rates also indicate the institutional performance of self-governance. Chong (2000) argued that compliance with regulations showed users' caring and protective attitude towards a fishery. Self-governance argues that users would be more compliant to fisheries management rules and regulations if they were involved in the management (Townsend, 2008).

The third aspect of self-management promises relates to its contribution to the resource and the environment. As discussed previously, this advantage is more debatable than the other two promises. There are three main indicators, one for fish stock and two for fishing environment. Fish biomass level is the most direct indicator of fish stock status. Because it is impossible to count the number of fish in a fishery, fish biomass from a stock assessment survey is often used as a proxy, which is applied here.

Other variables (Table 6.7) can also be used to indicate the stock level but were not selected in this study. For example, Catch Per Unit Effort (CPUE) can also indicate the stock level. Using CPUE as a fish stock biomass indicator is not new (Gilbert *et al.*, 2000), but remains somewhat debatable whether it can capture changes of fish abundance. First, it is difficult to keep the unit of effort constant. For example, using fishing days as unit of effort ignores technological improvement over time. Further, a decrease in CPUE could either be a result of a real decrease of fish abundance or simply a change of fish abundance location. Therefore, the specific nature of the fishery needs to be studied first before CPUE can be used as an indicator of stock abundance.

In terms of fishing environment, total non-fish area is used as an indication of biodiversity in fisheries. It is expected that areas of no-take or restricted-take zone, namely marine reserves, Taiapures and Mātaitai, in a single fishing area would not change greatly. However, the appearance or increase in non-fishing area is positive to fish stock conservation and fishing environment protection. Increase of non-fishing area is evidence for self-governance's assistance to address environmental problems. This indicator is expected to perform better when there are environmental or customary groups involved in the self-governance management circle.

By-catch is another indicator of self-governance's fishing environmental management. Decrease in by-catch rates can be an indication of conservation. However, the decrease of QMS species by-catch can be a result of deemed value[33] charges by MFish. Further, one would expect by-catch of a protected species and non-QMS species to be less responsive to self-governance if no environmental groups were to be directly involved in the management.

6.3.6 Drawing conclusions from the indicators selected

For a set of indicators to be meaningful, there must be some reference point (FAO, 1999; Rice and Rochet, 2005). Reference points or standards are needed for indicators so that they can be measured or compared. For example, non-compliance rate and by-catch rate are preferred to be zero, or as low as possible. On the other hand, not all indicators have a standard. Profitability does not have a reference point and, therefore, it is hard to tell if the fishery is performing well from a single profit number.

[33] Deemed value is the amount fishers pay for any fish caught that exceeds their ACE holdings. Deemed value is often set above the ACE price to encourage fishers to balance catch through the purchase of ACE.

Conventional reference points used in indicator systems are not appropriate in this study. Mostly, reference points are used to check the performance of a fishery against a certain standard, sustainability, for example. In contrast, the purpose of this study is to examine if self-governance adds additional value to fisheries management. Points of reference for each indicator do not serve this purpose.

Therefore, a three-step double-reference point system was developed to measure self-governance performance as shown in Figure 6.2.

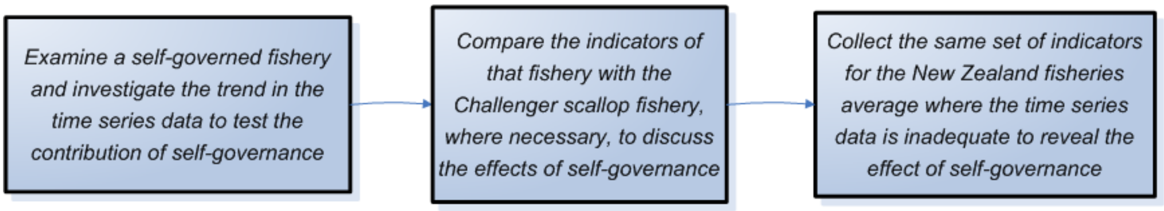

Figure 6.2 The three-step double-reference point system for New Zealand fisheries self-governance studies.

Figure 6.2 demonstrates the unique reference system that will be used in the thesis to evaluate self-governance. The first step (Figure 6.2, box 1) involves studying a self-governed fishery, monitoring the time series data of selected indicators. In the examination process, for each indicator, the previous year's figures were used as a reference for the following year. Any general improvement of the figure over time following implementation of self-governance provides evidence for realisation of the promises.

In the second step (Figure 6.2, box 2), the same set of indicators from the Challenger scallop fishery were collected in order to add confidence in drawing conclusions. The Challenger scallop fishery is the most successful case of self-governance in New Zealand (Townsend, 2010) and will be used as a comparison for the Bluff oyster fishery. If the indicators from the two fisheries, Bluff and the Challenger, agree with each other, it provides evidence for or against self-governance. Further, it is expected that given Challenger's leading position in self-governance, the indicators will provide evidence of the merits of self-governance even if the other fishery does not.

The third step (Figure 6.2, box 3) is to collect the same set of indicators from all QMS fisheries[34]. It is necessary to evaluate the self-governed fishery based on the overall fisheries

[34] It is better to compare the indicators with a non-self-governance fishery with a similar nature; collecting the same set of indicators from that fishery as reference points. However, not only is there no fishery similar enough to base the comparison on, for small fisheries like the Bluff oyster fishery, economic statistics are not to be released in order to protect the confidentiality of the players.

performance in New Zealand, which serves as the second reference. This second reference is needed because the improvement in one aspect in the management could be the result of the implementation of the QMS. It is therefore not appropriate to conclude that self-governance alone contributes to the improvement in that area without looking at its operating environment – the QMS. Despite the internal trends of the indicators in the fishery, one would expect indicators of self-governance fisheries to outperform the overall fisheries statistics when other factors, such as the general economic and management background are the same.

6.4 Case study

This section studies if self-governance's promises have been realised by applying the IS to the Bluff oyster fishery. The three-step double-reference structure discussed in the methods section was used throughout this case study to monitor each indicator. Specifically, the first step was to collect and examine the time series data of each indicator for the Bluff oyster fishery. When examining the data trend, the variable in the previous year serves as a reference point for the following year. Therefore, the improvement of time series data provides evidence for self-governance's ability of achieving better management and *vice versa*.

The second step involves collecting the same set of indicators data for the Challenger scallop fishery (SCA7). The purpose of comparing OYU5 and SCA7 is to verify the possible generalisation of the findings. That is, if the data trends in the two fisheries are both in favour or disfavour of self-governance, it provides greater confidence in drawing the inference that self-governance has/has not delivered its promises. On the other hand, if the two fisheries data trends conflict with each other, it is evidence that self-governance works selectively. In this case, further investigation is required as to why that is the case.

The last step requires collecting the same set of data for all QMS fisheries, where applicable and necessary. It will serve as general reference point for the performance of the two self-governed fisheries, the Bluff oyster fishery and the Challenger scallop fishery. For example, an improvement of one indicator in the OYU5 fishery and/or the SCA7 fishery, but no improvement for the overall QMS fisheries, shows the extra benefit of the self-governance management regime.

6.4.1 Economic indicators

There are three indicators/indicator groups in this section that analyse the economic aspect of self-governance. The first indicator is conventional profitability. It is the simplest yet most effective measurement of economic performance (Hundloe, 2000). The second indicator group examines the three indirect fishing costs, boat numbers, crew numbers and processor numbers. Those indicators also suggest the economic outlook of a fishing industry. The last group of indicators includes fishing management costs, namely, actual management costs, compliance costs and research costs. As self-governance literature proposes that it is possible to shift major fisheries management expenses from the government to industry, this third group of indicators will reveal the merits of such a claim.

6.4.1.1 ***Profitability***

There is a lack of consistent data to show the historic trend of profitability in the Bluff oyster fishery (OYU5). Profitability is commercially sensitive, especially in a small industry like Bluff oysters, where there are a mere 16 companies (as at 2008) in the fishery and fishers are familiar with each other. Companies also hesitate to release profit related data (*e.g.*, wholesale prices and costs of catch). The main reason for caution is their concern for business confidentiality. In addition, they also worry that the figures might be misinterpreted. Further, some small companies simply do not keep records of this data and bigger companies' records do not go as far back as the mid-1990s when the fishery was first formally self-governed.

Nevertheless, the simulation in Chapter 4 suggests that the profitability of the Bluff oyster industry is higher when self-governed than without self-governance. In fact, the difference that self-governance makes can be substantial; $1.43 million more is earned per year, on average, with self-governance. Given there were 16 quota holders in the fishery in 2008, each holder is better off, on average, by $90,000 per year. However, this finding might be case specific to the Bluff oyster fishery because the Bluff oysters are price inelastic and the price effect of decreased supply overweighs the quantity effect.

There is also evidence of increasing economic benefit being obtained in the Challenger scallop fishery. It is shown by the convergence of the discount rate to the risk free interest rate (Mincher, 2008). In a competitive market, the quota lease price (ACE price) represents the expected annual income of the fishery. Quota price reflects the present value of the future profit for that fishery (Newell *et al.*, 2005). The discount rate is calculated by dividing the one-year quota lease price (ACE price) by the quota asset price. Akroyd *et al.* (1999, as cited in Arbuckle, 2000) compared the discount rate of the Challenger scallop fishery to the risk free interest rate to show the rationalisation of harvest and stock biomass level. Compared with discount rate discrepancies in other scallop fisheries, the Challenger scallop fishery was managed effectively under self-governance (Mincher, 2008).

In contrast, the profit level of New Zealand fisheries as a whole decreased. According to the Annual Enterprise Survey (StatsNZ, 2009), between 1998 and 2007, fisheries profit, in 2007 dollars, dropped from 107 million to 98 million. There was a consistent decrease of income from 1998 (107 million) to 2004 (81 million), but a slight recovery in 2007 (98 million). The decrease might be a result of a decrease in exports due to the strong New Zealand dollar then. However, it is also possible that there is a diminishing marginal benefit from the ITQs 10 years after the implementation of the QMS.

The comparison among the Bluff oyster fishery, the Challenger scallop fishery and the overall fishing industry performance provides support for the economic benefit of self-governance. There is evidence of economic performance improvement in both the Bluff oyster fishery and the Challenger scallop fishery. In contrast, the overall profit for the fishing industry fell during the same time.

6.4.1.2 *Indirect fishing costs*

Fishing costs can be divided into direct and indirect costs. Direct fishing costs are the expenses items that are directly related to catch. Some examples are, sacks/gear costs, wharfage charges and ACE costs. On the other hand, there are costs that are indirectly related to fishing such as vessel maintenance and crew wages. There are two main drivers of indirect fishing costs: the number of fishing boats and the number of processing facilities.

In the OYU5 fishery, vessel insurance, depreciation and maintenance, and administration are the three main boat-related indirect fishing costs (Riley, 1980). Given that catches are capped by TACC, the more fishing boats share the fixed amount of fish the higher the operating costs become. Further, efficiency increases as the remaining boats operate at a higher capacity, if they were not already fully utilised.

The vessel numbers changed with management regimes in Bluff. The changes are shown in Table 6.9 along with the management regimes and disease condition.

Table 6.9 The oyster vessel numbers in Bluff, 1880-date.

Period	1880s -	1962 -	1963 -	1969 -	1970 -	1986 -	1993 -	1995 -	1996 -	1998 -	2000-	2003-	2006
Management type	Limited entry		De-licensing		Declared licensed industry					QMS			
No. of Vessels	5-12		up to 30		23 (0nly)				15				11
Catch limit			121 - 132 mil		85-89 mil				14.95 mil			7.5 mil	
Notes						*Bonamia*	beds closed		reopen		*Bonamia*		

Table 6.9 shows that boat numbers were capped at a maximum of 12 when the commercial fishery was managed under a limited entry regime from 1937 to 1963. It then increased dramatically after the fishery was opened up (1963) to 30 by the end of 1969. Following the introduction of a licensed regime in the 1970s, the boat numbers dropped to 23. The oyster fishery entered the Quota Management System in 1998. The number of vessels in the fishery dropped from 23 to 15 in 1996 and kept dropping to reach 11 in 2002 (Fu and Dunn, 2009) and has remained at that number since then. Furthermore, there are 16 quota owners in the fishery but 11 boats, which indicates catch co-operation amongst the quota owners.

The drop in boat numbers coincided with the BOMC's self-governance effort. It is unlikely that the decrease in boat numbers was driven solely by the oyster population decrease. This is because the number of boats remained at 23 after the first round of the disease between 1986 and 1992, when the oyster population declined dramatically. On the other hand, the management of the BOMC (formally started in 1992 as discussed in Chapter 3) along with the second *Bonamia* outbreak saw the boat numbers fall gradually from 23 to 11 between 1996 and 2004. Furthermore, the introduction of the QMS is less likely to be another reason for the drop of boat numbers because the biggest boat number drop started in 1996, two years before the fishery was introduced to the QMS.

Similarly, the same effect has been shown in the Challenger scallop fishery. Since the introduction of QMS and the management of the Challenger Scallops Enhancement Company (CSEC) in 1994, the boat number has declined from 60 to 31 in 2006 (Mincher, 2008). The decrease is less likely a result of fish stock reduction, since the TACC remained at around 750 tonnes during that period.

The number of vessels in New Zealand did not decrease as much as the two self-governed fisheries above. In fact, boat numbers increased 17% between 1987 and 1995 (Batstone and Sharp, 1999). However, the number of vessels decreased between 1996 (2458 vessels)and 2006 (1335 vessels) (New Zealand Official Yearbook, 2008). The decrease in vessel number happened 10 years after the implementation of the QMS; the intensification of the QMS in New Zealand might be a reason for a consolidation of quota and vessels. However, Henderson (2011) maintained that the drop in vessel numbers was caused mainly by the employment of foreign charter vessels in the deepwater fisheries (*e.g.*, hoki, ling and orange roughy). More research might be needed in order to identify the reason for vessel number decrease in New

Zealand fisheries. In contrast, the drop in boat numbers in Bluff and Challenger was more rapid with the implementation of self-governance.

Besides the number of boats, cost of processing also affects the indirect cost of a fishery. Under the QMS, fish must be processed by Licensed Fish Receivers (LFRs). The number of LFRs acts as a proxy for the number of associated processing facilities. One thing to be noted is that a number of LFRs have sub-facilities for further processing and some might share one facility.

In Bluff, there were 11 LFRs in 2002, which increased to 13 in 2004, then gradually decreased to 5 in 2007. The decrease of the number of LFRs might have been induced by quota owner co-operation because all processing facilities are owned by quota owners (Wright, pers. comm., 2009). If they co-operate on catch, as discussed before, they might also co-operate on processing. As there was ACE shelving in 2002, but the number of LFRs decreased in 2004, it is less likely that decrease in catch caused the decrease in LFRs.

In the Challenger scallop fishery, the numbers of LFRs remained at 6 between 2001and 2007. This shows that self-governance was not able to consolidate processing activity in that fishery. However, without 1994 data, which is when the fishery first initiated self-governance, it is not certain if the numbers have gone down since then to 6. However, it is certain that there is co-operation in processing in the Challenger fishery since there were 32 quota holders in Challenger as at 2008, but only 6 LFRs owned by quota owners.

For the rest of the QMS fisheries, there were 260 LFRs in 2001 and the number dropped to 221 in 2010. However, there is no direct comparison between the two self-governed fisheries and the rest. This is because some large LFRs might be processing a number fish species but are registered as one entity.

The number of processing facilities for all ITQ fisheries is not recorded. However, the literature suggests that ITQs are more likely to support a more vibrant processing industry (Townsend, 2006). The reason is that ITQs grant the freedom of fishing, which can lengthen fishing seasons because more fish are processed all year round rather than concentrated only at the beginning of the fishing season. Therefore, ITQs might sustain more processing facilities. In contrast, the decrease of processing plants in Bluff suggests that there is some consolidation of such facilities.

From the above analysis, there is an argument to support the idea that self-governance made indirect fishing cost-savings possible. The number of fishing boats decreased in Bluff under self-governance though the overall vessel numbers increased under the QMS for all ITQ fisheries. In addition, the number of processors fell in Bluff. It is likely that co-operation amongst ITQ-holders facilitated such collaboration of fishing effort and of processing.

6.4.1.3 ***Management costs***

The literature argues that self-governance might be able to redirect management costs from the public sector to the fishing industry (*e.g.*, Arnason, 2007c; Scott, 2000a). However, in New Zealand, most management costs are already recovered from the fishing industry (the rest of the cost is funded by the public sector, which covers the amount used for non-commercial fishing). Nevertheless, self-governance can potentially save management costs, which were discussed in Chapter 2. Briefly, if the service is provided by, or through, the government, part of the funding will be spent on administration. Furthermore, the type of research determined by the government might not fit the needs of the fishing industry. On the other hand, if the fishing industry provides services, not only are the fishers able to prioritise services that fit with their perspective, they might also achieve cost-savings by dealing directly with research providers.

In New Zealand, based on the main functions, management costs can be attributed to actual management, research and compliance (Wallis and Flaaten, 2003). Actual management includes services such as new legislation, policy advice and registry. Registry is provided by a private company, Fish Serve. Research services cover stock assessment and evaluation. Compliance includes actual offence detection and observer service.

Figure 6.3 shows the actual management costs levied by MFish to the OYU5 fishery and the trend over time. The horizontal axis is the fishing years observed and the vertical axis is the amount levied in 2007 dollars. The green line in the figure shows the actual costs for registry and other miscellaneous services[35].

[35]In the 2003/2004 fishing year, there was a lump sum paid to the fishing industry as credit settlements, which led to a negative actual management amount in that fishing year. However, in order to avoid disturbing the real trend, the average cost of all other years was used for 2003/2004.

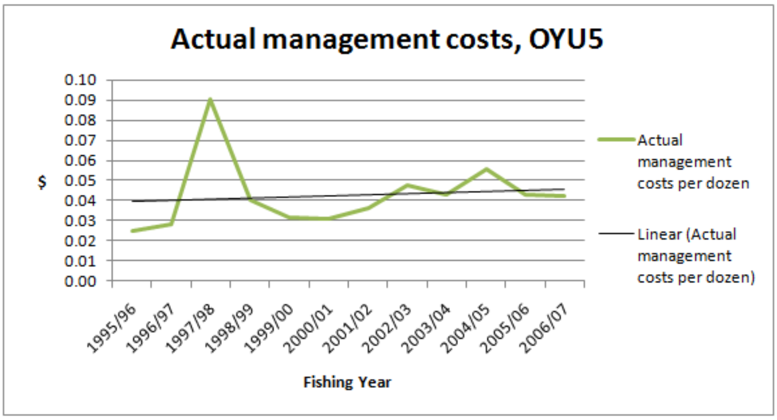

Figure 6.3 Actual management costs, OYU5, 1996-2007.

As shown in Figure 6.3, the total amount spent on actual management in the OYU5 fishery fluctuated over time and shows no clear reduction trend. This lack of reduction might be related to the nature of the cost. That is, the actual management includes registry and other basic services attached to the QMS, which are not removed since the fishery is still a QMS fishery. A linear trend-line is added to the figure; it shows a very slight increase of actual management cost in the fishery.

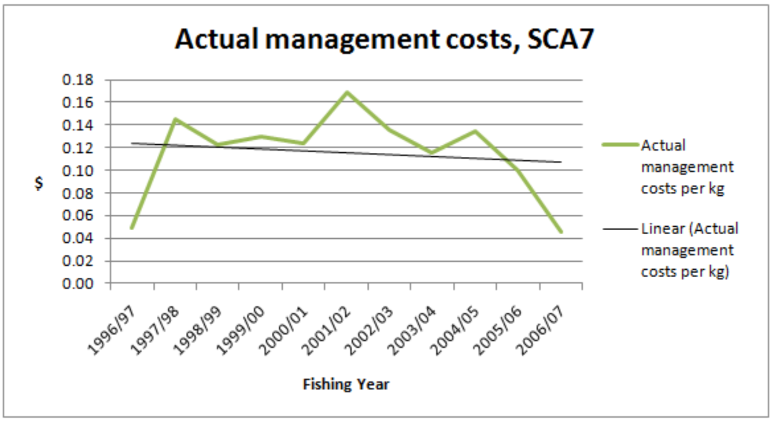

Figure 6.4 Actual management costs, SCA7, 1997-2007.

However, the Challenger scallop fishery provides evidence of cost-saving, as shown in Figure 6.4. The actual management costs, as shown by the green line, fell from 15 cents to 5 cents per kilogram between 1998 and 2007. The general trend-line suggests a gradual decrease of the amount spent on registry and other services[36]. This steady decrease provides some evidence that the more sophisticated self-governance mode might create cost-saving opportunities. This cost-saving is not simply shifting cost from the government to the

[36]Because of the credit settlements to the fishing industry as the industry in 2003/04 that led to a negative figure, the average cost of all other years is used for 2003/2004.

industry, but eliminating some management tasks that might not be necessary. For example, there might be less legislative modification for the fishery.

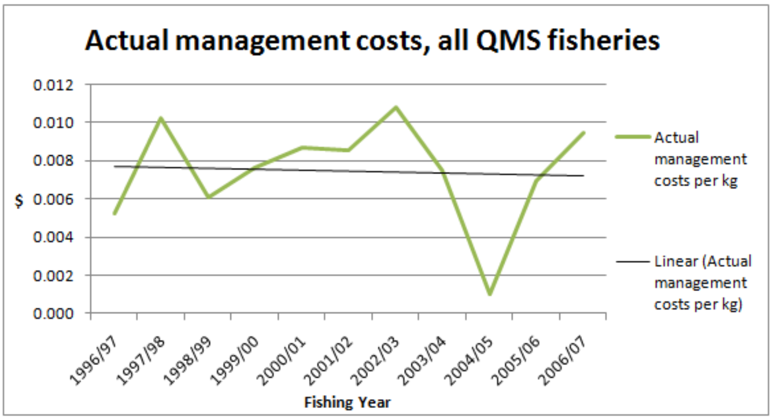

Figure 6.5 Actual management costs, QMS fisheries average, 1997-2007.

In comparison, Figure 6.5above shows the overall actual management cost for all QMS fisheries between 1997 and 2007. From the figure, the actual management costs per kilogram for all QMS fisheries fluctuated around 0.8 cents for the 11 fishing years[37]. Although the trend-line shows a slight decrease of actual management costs, the discrepancy is less than 0.1 cents over 11 years. Given the overall actual management costs remained stable, as they did the OYU5 fishery, the claim of self-governance providing cost-saving on the administration side of fisheries management is not fulfilled in the Bluff case. However, the actual management cost in the Challenger fishery did decrease. This might be evidence that as the self-governance mechanism becomes more established, it becomes more efficient to run.

One thing to be noted about the ITQ programme is that there was a decrease in registry service in the more recent years (2007-date). If just focusing on the registry service, excluding conservation service or new policy development, the total cost has fallen down. Townsend (2010) noted that the services provided by Fish Serve have been satisfactory and the registry cost per ACE has fallen from NZ $16.65 in 2001 to $11.25 in 2009. Further, because the cost for registry service has decreased but not the overall actual management costs, other components of actual management costs must have increased. Those costs are mainly driven by new policy development and conservation conducted by the Department of Conservation (DOC). Although the QMS in New Zealand could become more mature and the traditional ITQ related management cost is decreasing, there might be more new functions and

[37]The average of all other years is used for 2003/04 due to the credit settlements paid to the fisheries

management responsibilities (*e.g.*, environmental conservation) added under the QMS to keep the overall management cost up.

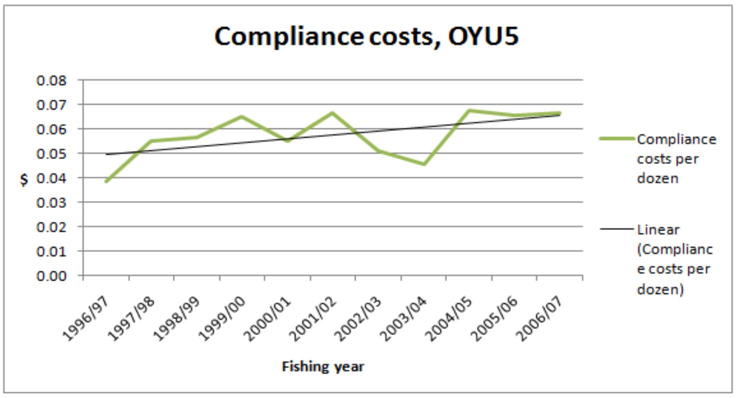

Figure 6.6 Compliance costs, OYU5, 1996-2007.

Compliance costs in the Bluff oyster fishery, as shown in Figure 6.6, show an increasing trend. They increased from an average of 5 cents per dozen oysters in the 2002/2003 fishing year to 7 cents in the three most recent years (2004 – 2007). The upward slope of the trend-line shows that more attention and cost were applied to detect non-compliance behaviour over the years regardless of the self-governance of BOMC.

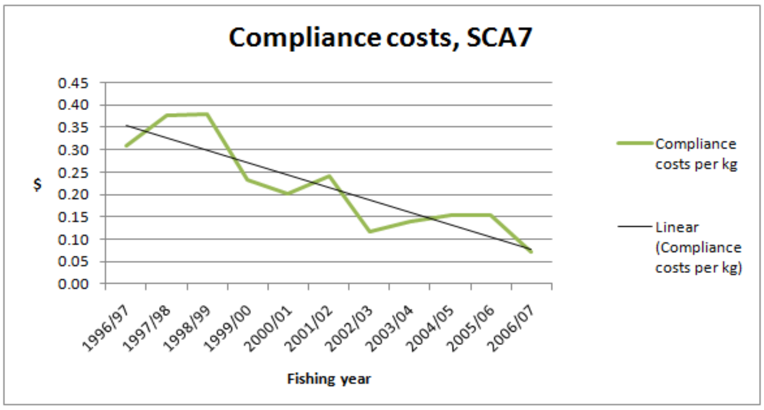

Figure 6.7 Compliance costs, SCA7, 1997-2007.

However, the Challenger scallop fishery showed evidence of declining compliance costs, as shown in Figure 6.7. In Figure 6.7, the green line indicates that the average cost per kilogram decreased from approximately 40 cents, in the first three years, to around 20 cents in the following three years, to around 10 cents in the most recent years. The trend-line is clearly downward sloping. These declines may be the result of two factors. The first is that the self-governance of the CSEC has established rules that are more practical and realistic for fishers to follow, which means that there would be fewer fishing offences. A second related cause of the compliance cost reduction might be that as non-compliance incidents dropped, the budget and spending on compliance matters dropped accordingly. However, the 7 cents per kilogram in 2007 might not be sustainable. Data from the following years are required in order to conclude if the drop is permanent.

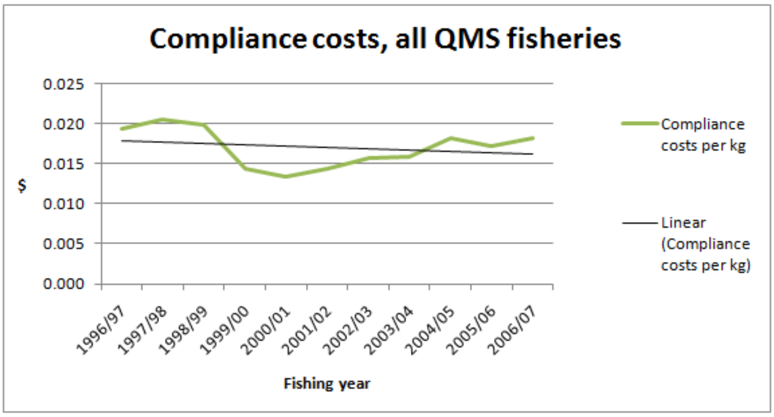

Figure 6.8 Compliance costs, QMS fisheries average, 1997-2007.

The average compliance costs for all New Zealand QMS fisheries did not increase as in the OYU5 fishery but did not decrease as in the SCA7 fishery. Figure 6.8 shows the average compliance cost fluctuated between 1.5 and 2 cents in the past 11 years. In the most recent five years, the costs remained at 2 cents per kilogram. The trend-line shows a slight decrease. However, the compliance expense, on average, increased to 1.8 cents for the most recent years from the low of 1.3 cents in the early 2000s.

Given that the cost behaviour for OYU5 does not out-perform the average compliance costs for all QMS fisheries, no evidence was found in terms of cost-savings for compliance in this self-governed fishery. The steadiness of compliance cost in the oyster fishery is to be expected. Although self-governance literature predicts a possible cost-saving on compliance, the status of the BOMC restricts its ability to carry out compliance duties. Under the Fisheries Act 1996, fisheries officers from the Ministry of Fisheries are the main entity for compliance matters. The self-governance entity does not have the legal status for offence detection and punishment. Since the compliance service is budgeted according to the previous record of a fishery and the rate of compliance remained roughly constant over the years, the amount spent (budgeted) for OYU5 remained similar. The informal status of a self-governance entity remains as a big obstacle for cost-saving on catch rule enforcement.

Although there is no evidence to support the cost-saving argument in Bluff, there is such evidence in the Challenger fishery. Besides the actual management cost-savings discussed in the previous section, there were compliance cost-savings in the fishery. The savings might be achieved by successful co-operation between commercial and non-commercial groups, especially recreational fishers. Furthermore, it provides evidence that the more mature the self-governance regime the more likely it will achieve cost-savings.

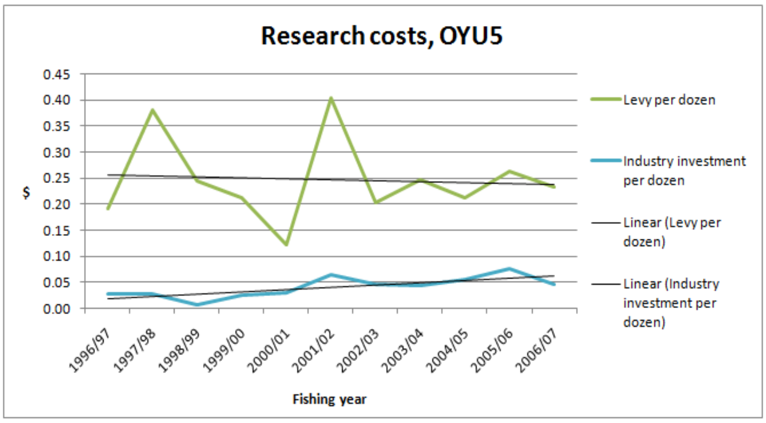

Figure 6.9 Research costs, OYU5, 1996-2007.

Figure 6.9 shows both the cost of research conducted by the government (the green line) and by the industry (the blue line). The cost of research conducted by the government fluctuated with no sign of decreasing as predicted by self-governance advocates. The amount of research spent on oysters per dozen reached was highest in 2001/2002 and increased again in the two years from 2005[38]. The research cost in OYU5 is most likely to be driven by *Bonamia* studies.

However, there were industry initiated research projects as predicted by the self-governance literature. The blue line in the figure indicates that, recently, the industry investment stayed at 5 to 6 cents per dozen oysters and the trend-line also suggests a steady increase of industry investment since the reopening of the fishery in 1996. The research includes research and development tasks on biotoxin and sanitation, experiments on returning of shells to the marine habitat, stock enhancement experiments, logbook programme and facilitating fisheries plans. Since 2007, BOMC and SeaFIC have jointly undertaken an innovative research programme. BOMC assumes 40% of the cost ($250,000) through a commodity levy to SeaFIC. The three-year research project has been carried out mainly for commercial purposes. Some of the main tasks of the programme involve developing new dredge designs and fishing procedures to maximise dredge efficiency, and developing and evaluating strategies to increase oyster production and minimise the effects of disease (Wright pers. comm., 2009).

[38]To avoid a negative anomaly, the average cost of all other years is used for 2003/2004.Because of the credit settlements paid to the fishing industry at the time.

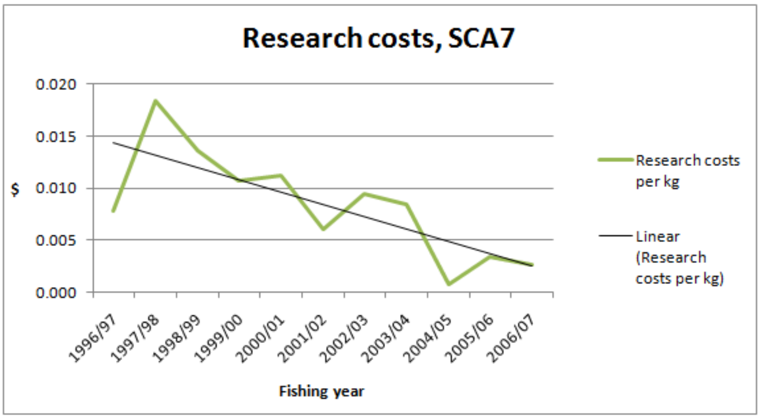

Figure 6.10 Research costs, SCA7, 1997-2007.

In contrast to the Bluff oyster fishery, the Challenger scallop fishery provided evidence of cost-savings in research. According to Figure 6.10, the cost of government research per kilogram in the Challenger scallop fishery decreased from around 1.8 cents in 1997/98 and 1998/99 to about 1 cent in the following four years, to less than 1 cent in the most recent fishing years[39]. Mincher (2008) noted that there has been industry-initiated research for the fishery with a significant amount of investment. It is because of the maturity of the self-governance structure that research and the cost of research have shifted from government to the industry. For example, the CSEC employs independent researchers on several tasks (Harte, 2008) in conjunction with the standard management research that the government initiates.

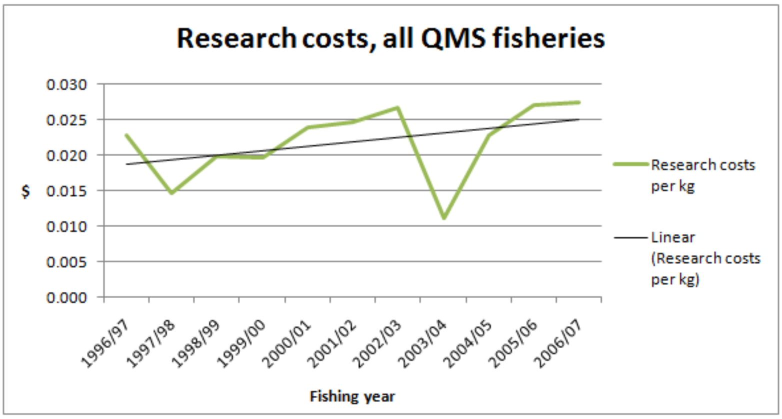

Figure 6.11 Research costs, QMS fisheries average, 1997-2007.

The average research costs for all QMS fisheries present an increasing trend. As shown in Figure 6.11, the total research investment remained at 2 cents per kilogram in the late 1990s and early 2000, but fluctuated with an increasing trend to 3 cents in 2005/06 and 2006/07.

[39]The average cost of all other years is used for 2003/2004 to avoid a negative number due to the credit settlements.

One reason for such an increase might be that as new species are introduced into the QMS, more research is required for these fisheries.

A similar conclusion can also be drawn for research costs, as for actual management and compliance costs. The costs of research conducted by the government varied, but did not decrease, for the OYU5 fishery, which does not provide evidence for cost-saving. In other words, there was no shift in research from government to the industry as far as the Bluff oyster fishery is concerned. However, there was industry-initiated research that would not be carried out otherwise. This extra management effort put into place is due solely to self-governance. Furthermore, the research costs in the Challenger scallop fishery did decrease, while the average research costs for QMS fisheries had an increasing trend. Overall, it appears from the results that self-governance in its mature form can contribute to cost-savings in management and redirect management costs from the public to the private sector.

6.4.2 Institution indicators

The direct effects of self-governance, such as the analysed economic outcomes above, can be hard to identify. The reason is that self-governance is not a separate management tool, but one that is embodied in the QMS, along with ITQs and other input controls (*e.g.*, gear restriction) and output controls (*e.g.*, size restriction). Therefore, it is not convincing to relate performance improvements to self-governance solely based on direct outcomes. However, "[t]he effect that devolved governance had on the process of management is more directly observable" (Yandle, 2008, p. 303). Chapter 2 discussed the benefits of having a user-led management group in fisheries management. In general, a devolved management regime is beneficial because user participation could contribute to the overall robustness of the management regime (Ostrom, 1990; Ostrom *et al*., 1994).The three institution indicators in this section analyse management devolvement. The first two indicators, *i.e.*, the existence of a user leading group and the level of communication amongst fisheries stakeholders, examines the level of user participation. The last indicator, compliance rate, looks at the effectiveness of user participation.

6.4.2.1 *The existence of a user leading group in managing the fishery*

Though the Minister and the Ministry of Fisheries are the official management entity of the New Zealand fisheries, a number of fisheries have their own users association. Those associations are called the Commercial Stakeholders' Organisations (CSOs) by MFish or the Quota Owners Associations (QOAs), in general. However, not all QOAs are the same; they differ hugely in terms of representative authority. Specifically, although a small number of QOAs do take non-commercial interests into consideration, the majority of the QOAs represent only commercial fishers. Furthermore, some QOAs are more similar to a fishing union; some are designed only as a cost centre to meet the fisheries statutory needs (*e.g.*, quota registry) and some QOAs take on broader management roles from stock enhancement to research.

The QOA in the OYU5 fishery is the Bluff Oyster Management Company. Its development as the management entity of the oyster fishery and functionality was discussed in Chapter 2. In brief, the company represents all the quota holders in the fishery, which stands for 100% of quota (BOMC, 2005). It is a cost centre for the fishery in that it collects levies from the fishers for MFish and SeaFIC for management purposes. Further, it is also active in the fishery's daily management. For example, it provides funding for an oyster enhancement trial and the logbook programme. The detailed management tasks carried out by BOMC are given in Appendix A.

The Challenger Scallop Enhancement company (CSEC) is argued to be one of the most sophisticated self-governance modes and has been praised for its success in self-governing the fishery (Arbuckle, 2000; Harte, 2000a; Mincher, 2008). It was formed in 1994 to take on the stock enhancement task (Arbuckle, 2000). The general role of the CSEC is to collect levies and payments to fund management activities, and report back to the government and the stakeholders (Arbuckle, 2000). This function of the company is authorised by the Southern Scallop Fishery Enhancement Plan that was officially approved under Fisheries Act 1996 (Arbuckle, 2000). As well as carrying out those regular administration roles, CSEC has been continuously developed to incorporate complete management responsibilities, from enhancement to enforcement (Mincher, 2008).

There have been self-governance developments in New Zealand, but there is a limited numbers of QOAs that are self-governing or initiating management of their fisheries. Based on the level of involvement, Townsend (2010) grouped New Zealand self-governance into four different categories. The most sophisticated case[40] is the Challenger scallop fishery. It is followed closely by two well-established self-management arrangements: the rock lobster fishery and the deepwater fisheries (hoki, orange roughy and squid). The third category comprises a small number of shellfish fisheries (*e.g.,* the Bluff oyster fishery), which are

[40]The Commercial Fisheries Services (Fish Serve) is also described as a successful model of self-governance in Townsend (2010). However, the entity is not is not a QOA but a private service provider.

attempting to achieve better self-governance. The fourth group comprises the rest, the majority of fisheries, which have little or no self-governance experience. In fact, there are 97 QMS species or species complexes (MFish, 2010b) in New Zealand, but only 28 QOAs (SeaFIC, 2009). Moreover, a number of the QOAs are general associations (*e.g.*, Fishing Vessel Owners' Association, New Zealand Federation of Commercial Fishermen, NZ Fishing Industry Association Inc, NZ Fishing Industry Guild and New Zealand Seafood Retailers and Wholesalers Association Inc.) rather than QOAs for specific fisheries' management.

Therefore, compared with the overall slow self-governance development in New Zealand, the Bluff and Challenger cases show more complex user involvement in managing their own fishery. The management tasks the Challenger QOA, the CSEC, takes on contain some basic functions that only MFish would normally take. The BOMC does not assume management functions that are as wide as the Challenger ones, but it, nevertheless, complements the MFish administration and adds value to fisheries management.

6.4.2.2 ***Level of communication***

Communication effectiveness in a self-governed fishery indicates the level of co-operation in a fishery. The level of communication is three-fold in the Bluff oyster fishery: agreements with quota holders, negotiation amongst all parties (*i.e.*, commercial users, non-commercial users and external associated parties) and agreements between quota owners and harvesters. The BOMC represents 100% of the quota shares in the commercial fishery and agreement amongst quota holders can be achieved relatively easily because of the common profit-seeking objective. According to Skeggs (pers. comm., 2009), there has been no significant dispute amongst stakeholders of the company. There was some disagreement on the amount of ACE the fishery shelves for stock recovery purposes. However, the disagreement was resolved within the company, with the outcome that all quota holders agreed to have half of ACE being shelved between the 2002/03 and 2007/08 fishing years.

There has been interaction and negotiation amongst commercial and non-commercial users. The decision-making process within the Foveaux Strait Dredge Oyster Fisheries Plan invites all stakeholders into the management circle. Figure 6.12 shows the current decision-making process in the fishery.

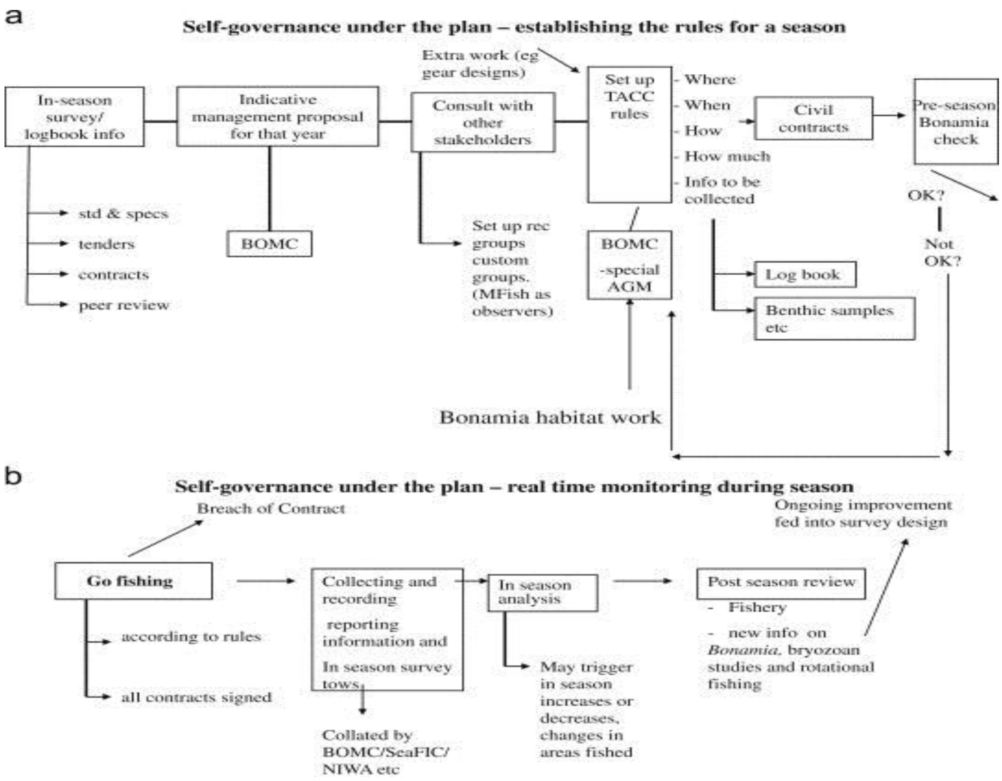

Figure 6.12 BOMC fishing management flow chart.

Source: Foveaux Strait Dredge Oyster Fisheries Plan, 2009

First hand information is gathered from the logbooks, which the BOMC collects and bases management proposals on Figure 6.12a steps 1 and 2. Then the BOMC consults with non-commercial groups over management decisions and this consultation and ongoing engagement is guaranteed by MFish's monitoring position, steps 3 and 4.

The development and approval of the Plan shows also that there has been understanding amongst the wild fishery's users. According to Skeggs (pers. comm., 2009), no dispute has taken place in the process of developing the plan. Further, he suggested that the relationships between the BOMC and the fisheries associated parties, such as MFish and Sea Food Industry Council (SeaFIC), have been pleasant. MFish had also contributed in developing the Plan; SeaFIC partnered with the BOMC in joint research programmes.

The last level of communication within this self-governed fishery is the agreement between quota owners and skippers. First, contracts or agreements have been reached between the company quota holders and harvesters before going fishing (step 5) to make sure certain protocols such as logbook registration, are followed. Skippers are encouraged and paid to fill in the logbook. Further, there is follow up data collection, analysis and protocol adjustment processes for ongoing management of commercial fishing (Fig 6.12b steps 2-4). Additionally, Skeggs (pers. comm., 2009) suggested that, recently, the manager of the BOMC, Mr Graeme Wright, served as a mediator between the owners and their crew, and brought requirements from the owners and the company to the fishers and gathered feedback information from skippers. Because Mr. Wright has been involved in and understood the fishery and fishing, his involvement has increased the efficiency of communication.

There are similar management arrangements in the Challenger scallop fishery but with one significant difference. In the OYU5 fishery, although established on paper, the agreements amongst stakeholders are not binding. For example, the logbook programme is incentivised by monetary reward; the skipper gets an extra bonus by filling in and handing in the paper. On the other hand, the CSEC has several binding agreements that are authorised by the government. Arbuckle (2000) noted that the Challenger Scallop Fishery Management Plan, including a compliance plan, is annually approved by the Ministry of Fisheries. Further, there is a Memorandum of Understanding (MoU) between the industry and the Ministry, which is supported by the necessary consents and permits (Arbuckle, 2000). As well as the use of written agreements, the CSEC's negotiation with non-commercial stakeholders has proven to be effective and one recreational representative has been agreed to be involved in the directorship of the company (Mincher, 2008).

6.4.2.3 ***Catch compliance rate***

Catch compliance rates in a fishery show, to a certain extent, the effectiveness of a management regime. Self-governance literature argues that user initiated catch regulations are more specific and reasonable to the catch condition of their fishery and, therefore, might lower catch non-compliance rate in the fishery. Further, commercial and non-commercial user collaboration in a self-governed fishery might lead to better understanding, which in turn leads to higher compliance.

This section uses data from the Ministry of Fisheries to compare the trends of non-compliance rates in OYU5, SCA7 and the overall QMS fisheries. The Ministry of Fisheries is the only legislated authority of the New Zealand Government responsible for enforcing the fisheries regulations. Non-compliance data from MFish cover both commercial and noncommercial catch offences. However, those data do not capture all offences because compliance and enforcement services are delivered based on the Ministry management decisions and budget. Therefore, the analysis from those data would be biased towards the priorities set by MFish.

For example, if the commercial sector was the compliance priority, it would be monitored more often than the recreational or customary sectors, thus more offences might be detected.

Table 6.10 Catch offences, OYU5, 1997-2007.

Fishing Year	Commercial	Customary	Recreational	Grand Total
1999/2000	2		6	8
2000/01	2			2
2001/02	7			7
2002/03	6	1	1	8
2003/04	3			3
2004/05	2	1	3	6
2005/06	1		1	2
2006/07	8			8
Grand Total	31	2	11	44

Table 6.10 illustrates the number of catch offences by sector in the Bluff oyster fishery. There were a small number of non-commercial offences. In contrast, there were 31 commercial offences, which accounted for most catch violations in the fishery. However, the number of commercial offences has decreased since 2001/02, except for the 2006/07 fishing year.

Table 6.11 The number of commercial offence types, OYU5, 1999-2007.

Fishing Year	Permit/Licence/ Registration	Possession	Record keeping
1999/2000		2	
2000/01	1		1
2001/02	5	2	
2002/03	1	3	2
2003/04	1	1	1
2004/05		2	
2005/06		1	
2006/07	1	1	6
Grand Total	9	12	10

Although there appeared to be an increase in commercial offences in 2006/07, most offences were record keeping related, that is, failing to file or delaying of filing certain documents. Table 6.11 shows the count of the non-compliances by breach type. In Table 6.11, the category '*Record keeping*' means knowingly making false a statement, or failing to provide a CELR (Catch Effort Landing Return, which is an official document fishers are required to file). '*Permit /Licence /Registration*' refers to activities such as fishing without minimum holding of ACE or use of an unregistered vessel to take fish. There were five '*Permit/Licence/Registration*' type offences in the first year of the study period but this occurred infrequently since 2001/2003. '*Possession*' can refer to activities such as possessing undersize shellfish or knowingly receiving fish unlawfully. There were one or two incidences in each offence class, except for record keeping, in the 2006/07 year.

Further to the decrease in recorded commercial offences, one of the objectives of the stakeholder-led fishery's Plan is to develop a compliance strategy. According to the Plan (MFish, 2009a), taking under sized oysters and illegal sales are the two main offences that concern all sectors and taking excess oysters above the bag limit is another non-compliance by recreational sector. The strategy on non-compliance from the Plan is to "… hold a workshop between sectors and MFish…" (MFish, 2009a, p. 13).

Table 6.12 Catch offences, SCA7, 1997-2007.

Fishing Year	Commercial	Customary	Recreational	Grand Total
1997/98			6	6
1998/99	1			1
1999/2000			13	13
2000/01	6		38	44
2001/02	2		68	70
2002/03	12		96	108
2003/04	4		80	84
2004/05	5	1	74	80
2005/06	4		40	44
2006/07			41	41
Grand Total	34	1	456	491

Table 6.12 shows the number of catch offences in the Challenger scallop fishery (SCA7). Unlike OYU5, amateur fishing appears to be the major non-compliance sector because there were significantly more recreational non-compliances than commercial ones. There was an increase in non-compliance pre-2002 in the recreational sector, but the numbers have gradually decreased since then.

The decrease in recreational non-compliance between 2002 and 2007 might be caused by co-operation between the commercial and recreational sectors. Around 2002, an agreement negotiated between commercial and recreational catchers allowed amateur fishers to access areas where commercial fishing is prohibited (Mincher, 2008). In 2005, a recreational representative was invited and joined the CSEC board of directors. By 2006/07, recreational offences had halved since the co-operation between commercial and recreational groups.

Table 6.13 Catch offences, all New Zeland QMS fisheries, 1997-2007.

Fishing Year	Commercial	Customary	Recreational	International	Grand Total
1996/97	492		1,696	2	2,190
1997/98	397		1,925		2,322
1998/99	428		2,095		2,523
1999/2000	686		2,159		2,845
2000/01	1,271	1	3,323	3	4,598
2001/02	3,119	22	3,267	2	6,410
2002/03	2,870	27	3,453	11	6,361
2003/04	2,029	26	3,187	11	5,253
2004/05	1,779	13	3,844	1	5,637
2005/06	1,626	113	2,863	72	4,674
2006/07	2,300	44	3,769	5	6,118
Grand Total	16,997	246	31,581	107	48,931

The catch non-compliance rate for the all QMS fisheries showed a completely different picture. Table 6.13 indicates that the overall non-compliance rate for all QMS fisheries showed an increasing trend from 1996/97 to 2006/07. Although all sectors' (commercial, customary, recreational and international) non-compliance rates grew over time, commercial offences increased the most. Though there were 2.2 times more recreational offences in 2007 than in 1997, there were 4.7 times more commercial offences recently than 10 years ago.

The comparison between the performance of the two self-governed fisheries and the overall QMS fisheries supports the argument that self-governance helps catch regulation enforcement. On the one hand, there was a rapid increase of non-compliance in all QMS fisheries. On the other hand, there was a decreasing trend of catch regulation violation in OYU5 and SCA7 fishery. Although it is possible that the increasing trend for all QMS fisheries was brought about by increasing time and budget in detecting violations rather than a real increase in offending, this argument would also apply to the self-governed fisheries.

6.4.3 Resource and environment indicators

Besides economic and institutional outcomes, the literature also argues that self-governance helps resource and environmental management. There are three indicators in this section. The first indicator, fish biomass, examines the targeted fish stock abundance. The last two indicators, total fished area to non-fished areas and by-catch rates, inspect management regimes on non-fishing habitat and non-targeted species.

6.4.3.1 *Fish biomass*

In the Bluff oyster fishery, oyster stock condition appears to be influenced less by management than by *Bonamia* (Dunn, 2005, 2007; Fu and Dunn, 2009, Chapter 4 of this thesis). However, the preliminary results in Chapter 3 found that, if the impact of *Bonamia* is factored out, the fish stock recovers faster under the management of self-governance. The modelling method in Chapter 4 found that self-governance preserved approximately 13.5 to 32.5 million oysters per year for the 10 years between 2008 and 2010, assuming the disease mortality will repeat its historic pattern. The results in Chapter 3 and 4 are consistent and the fish stock is in better condition when self-governance is incorporated into this ITQ fishery.

There was also evidence from the Challenger scallop fishery that self-governance helps protect and rebuild fish stocks. In the fishery, the stock enhancement programme conducted by the government and continued by the CSEC has supported the sustainable development of the fishery. The programme, along with other self-management measures such as ACE shelving, rotational catch and daily catch limit, has brought about an additional catch of 160 tonnes since the self-governance of the CSEC (Mincher, 2008).

Table 6.14 Historical estimates recruited biomass, SCA7, 1997 - 2007.

Year	Total green weight (tonnes)
1996/97	620
1997/98	1,247
1998/99	1,557
1999/00	2,096
2000/01	2,606
2001/02	2,702
2002/03	1,758
2003/04	1,178
2004/05	961
2005/06	618
2006/07	1,168

However, the stock condition evaluated by NIWA in the stock assessment (MFish, 2009d) showed that the Challenger scallop fishery sustained major stock fluctuations. As shown in Table 6.14,the annual scallop biomass was highly variable and the reasons for the large fluctuations in abundance are unknown (MFish, 2009d). However, the biomass decline was more likely caused by indirect fishing and environmental factors than fishing activity (MFish, 2009d). It is also argued that in the stock assessment report that the current fishing strategy of 'rotational' fishing (fish at one spot, then move to another for the previous one to recover) alone is not sufficient explanation (MFish, 2009d).

The fish stock status in all QMS fisheries improved. In 1993, 179 stocks were managed by the QMS and 73 stocks were found to be sustainable (Annala, 1996). That gives an overall pass-rate of 41%. In comparison, as at 2009, 628 stocks were managed by the QMS and 337 stocks were found to be in favourable condition (MFish, 2009e). That gives a total pass-rate of 54%.

Therefore, it appears that stock conservation is more effective in OYU5 than in SCA7. The conclusion that self-governance leads to stock conservation in the Bluff oyster fishery is based on the simulation in Chapter 4. This stock conservation is contributed directly by the self-governing practice of catch reduction. In the scallop fishery, there are stock enhancement activities conducted directly by the CSEC (Mincher, 2008). However, the results of stock enhancement have not been reflected directly in the stock abundance as shown in Table 6.15. There is conflict in views of the industry and the Ministry of Fisheries' scientific research, as discussed above (*i.e.*, Mincher, 2008 versus MFish, 2009d).

6.4.3.2 ***Total fished area to non-fished area***

In New Zealand, there are three main forms of fishing-related marine reserves, the marine reserves, mātaitai[41] and taiapure[42]. The Fisheries Act 1996 sets out that, in a marine reserve, there can be total fisheries closure or partial fisheries closure (restrictions of fishing methods and/or seasons). Similarly, although mātaitai and taiapure reserves are essentially for Maori customary use and management, rather than marine protection, they provide ecosystem reservation if a no-take or restricted-take zone is included (New Zealand's Marine Reserves, 2010).

In Bluff, there is only one no-take zone, on the north-east of Stewart Island along the shore of the north-east edge of Steward Island, which has not changed with any management regime. There is no intention of establishing more non-fishing zones in the fishery by either commercial or non-commercial groups. In Challenger, the CSEC has proposed catch strategies that include areas closed to commercial fishing and closed commercial fishing areas for recreational fishing (Mincher, 2008). However, there is no actual area of a no-fish zone.

Compared with the slow and no development of marine protected areas in OYU5 or SCA7, the situation is different in New Zealand as a whole, where environmental based measurements have becoming a significant part of the fisheries management. There are over 30 marine reserves, which protect 7% of New Zealand’s territorial sea (DOC, 2010). In addition, since the introduction of mātaitai and taiapure in the late 1990s to the early 2000s, there have been 16 mātaitai and 8 taiapure approved by the Ministry of Fisheries. The area covered by these two customary marine reserves expanded from 0 to 600 square kilometres (NABIS, 2010).

6.4.3.3 ***By-catch rate, protected species, QMS species and non-QMS species***

The by-catch of protected species is largely related to the fishing methods of the fishery. Classified by DOC, protected species include “almost all New Zealand seabirds, all marine mammals, some marine reptiles, black and some red corals, black-spotted groper and white pointer sharks”(DOC, 2010). Because dredging at the bottom of the sea is the primary fishing method in OYU5, there are no protected species such as seabirds and marine mammals being accidentally caught in the fishery (Wright, pers. comm.,2009).

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[41]Mātaitai is “(a) identified traditional fishing ground which has special status under the Fisheries Act 1996 to protect customary fishing values. Restrictions may be placed on taking fish, aquatic life or seaweed in the reserve. A Maori Committee or kaitiaki can be empowered to make by-laws over the reserve”(New Zealand's Marine Reserves, 2010).

[42]Taiapure are “area(s) that are given special status to recognise rangatiratanga (as Taiapure-Local fisheries); management arrangements can be established (under the Fisheries Act 1996) for Taiapure that recognise the customary special significance of the area to iwi or hapu as a food source or for spiritual or cultural reasons” (New Zealand's Marine Reserves, 2010).

Table 6.15 By-catch, OYU5, 2002-2008.

Fishing year	Total By-catch (Kg)
2001/02	2,686
2002/03	316
2003/04	30
2004/05	74
2005/06	585
2006/07	195
2007/08	197

The by-catch in the Bluff oyster fishery is shown in Table 6.15. According to MFish (2009a), the by-catch of QMS species in OYU5 is very small. On average, since 2000, 630 kg of octopus, 300 kg of kina and less than 30 kg of blue cod and spiny dogfish had been caught per year in the fishery. Table 6.17 provides the detail of the QMS by-catch in the fishery. Although there are only seven years of data available, two things can be seen from the table. The total by-catch in weight (tonnes) has decreased dramatically since the 2001/2002 fishing year. This can be explained by the voluntary catch shelving in 2003 (2002/03 fishing year), which led to a dramatic fall of targeted catch. Interestingly, when the targeted catch halved, the by-catch more than halved. In addition, the by-catch rate has decreased again since the 2005/06 fishing year when the logbook programme took effect. However, Burns (2005) found that when observers were on board, more by-catch was reported. The decrease in by-catch in the Bluff oyster fishery might be caused by the logbook requirements, whereby fishers are more cautious and may misreport their by-catch rate. Therefore, there is no evidence that it is self-governance that caused fisher to be more environmentally conscious.

Non-QMS by-catch species in the fishery include bottom-sea species such as bryozoans, octopus, sponges, molluscs, starfish, tunicates and seaweed (MFish, 2009a). Because there is no statutory reporting requirement, non-QMS by-catch is not well-recorded. However, because most by-catch species are alive when caught they are thrown back into the sea when the crew sort oysters on the deck (Wright, pers. comm., 2009).

There is by-catch and fishing environment related management activities in the OYU5 fishery. The BOMC oriented logbook programme assists with non-QMS by-catch recording. The fishers' logbooks have recorded fishing data such as catch and effort since 2006. In addition, the BOMC is cooperating with SeaFIC in innovation research. This three year programme, started in 2007, aims at not only increasing dredge efficiency but also minimising the footprints of dredges on the sea bottom.

Table 6.16 By-catch, SCA7, 2002-2007.

Year	Catch (Tonnes)	By-catch (Tonnes)	By-catch/catch ratio
2001/02	697	25	0.04
2002/03	469	76	0.16
2003/04	199	277	1.39
2004/05	117	194	1.65
2005/06	158	12	0.08
2006/07	67	4	0.07

By-catch in the Challenger scallop fishery shows no obvious change in the observed period. As shown in third column of Table 6.16, its total by-catch rate varies significantly. It varied from as little as 4.38 tonnes in the 2006/07 fishing year to as much as 277 tonnes in 2007. However, if investigated further, the by-catch rate is positively related to the normal catch rate in the fishery, as shown by the positive by-catch to catch ratio in the fourth column. However, self-governance did not appear to have affected the by-catch rate because the by-catch/catch ratio showed no pattern. It was more likely to have been driven by the changeable nature.

According to the data from the two fisheries, OYU5 and SCA7, self-governance does not automatically contribute to a decrease in the by-catch of commercial fishing. In the OYU5 fishery, the decrease in by-catch in Bluff oyster fishery was brought about by protecting the targeted species *i.e.*, oysters, by reducing the yearly catch. There is management effort in environmental protection but it also is designed for more efficient oyster catch than active environmental management. In the CSA7 fishery, the decrease in by-catch is also related to targeted-catch decrease rather than active avoidance of environmental damage.

6.5 Conclusion

In this chapter, the Indicator System (IS) was used to evaluate the *ex-post* effect of a self-governance regime to manage the Bluff oyster fishery. Indicators have been used extensively in evaluating the sustainability of fisheries (*e.g.*, FAO, 1999; OECD, 2004, 2008), but there has been no IS designed specifically for evaluating self-governance. However, evaluating sustainability and self-governance are different and, therefore, require a different research framework. Specifically, sustainability studies focus on various areas of fisheries management especially the sustainable use of fishery resources. In contrast, self-governance evaluation should be focussed on the proposed merits of this management regime. Hence, the indicators were grouped into three categories: economic, institutional, and resource and environmental. Furthermore, one reference point might be sufficient for sustainability studies, where the indicators are compared with a single standard to show the condition of the fishery. In contrast, in order to analyse the effect of the self-governance component in an ITQ fishery, two reference points might be needed. The first reference point examines the trend of each indicator to observe whether there is improvement with the functioning of self-governance. The second reference point compares the trend of each indicator between the self-governed fishery and the comparable non-self-governed fishery (or the rest of the QMS fisheries if such a comparable fishery is not available).

Table 6.17 A summary of the trends of all indicators.

Indicators		Bluff	Challenger	Other QMS fisheries
Economic	Profit	$ 1.43 million more with self-governance than without self-governance	Convergence of the discount rate	Decreased between 1998 and 2007
	No. of boats	Decreased from 15 to 11 between 1996 and 2006	Decreased from 60 to 31 between 1994 and 2006	Increased by 17% between 1987 and 1995 then decreased by 46% between 1996 and 2006
	No. of processing facilities	Decreased from 11 to 5 between 2002 and 2007	Remained at 6 between 2001 and 2007	Decreased from 260 to 221 between 2001 and 2010
	Actual management costs	Increased by 50% between 1996 and 2007	Fluctuated with a decreasing trend between 1996 and 2007	Remained stable between 1996 and 2007
	Compliance costs	Increased by 30% between 1996 and 2007	Decreased by threefold between 1996 and 2007	Mainly stable between 1996 and 2007
	Research costs	Mainly stable between 1996 and 2007	Decreased by more than a half between 1996 and 2007	Increased by 30% between 1996 and 2007
Institutional	Existence of users leading group in managing the fishery	Yes	Yes	28 QOAs out of 97 QMS fisheries
	Users' communication	Mutual agreement	Contracted	NA
	Catch non-compliance rate	Showed a decreasing trend between 1996 and 2007	Showed an increasing then a decreasing trend between 1996 and 2007	Increased by threefold between 1996 and 2007
Fish stock and fishing environment	Fish stock abundance	13 million to 32 million oysters will be conserved between 2008 and 2017 by self-governance	Fluctuated between 1996 and 2007 because of the nature of the fishery	For QMS fisheries, the portion of sustainable fisheries increased from 41% to 54% between 1996 and 2007
	Total fished area to non-fished areas	Unchanged, no non-fished areas	Unchanged, no non-fished areas	30 marine reserves, 16 mātaitai and 8 taiapure
	By-catch rate	Fluctuated with no clear trend	Fluctuated with no clear trend	NA

The result found in this chapter is mixed in terms of the contribution of self-governance to fisheries management. First, self-governance has different effects on fisheries. The IS found that not all the theoretical merits are realised in the Bluff oyster fishery, but the result from the Challenger fishery is more encouraging. Furthermore, self-governance has different effects on different areas of fisheries management. By dividing the indicators into the three main areas of fisheries management (economic, institutional and resource and environmental), the results show that self-governance improves the fishery's economic and institutional performance more than resource and environmental management performance.

Table 6.17 summarises the findings from the indicators for the two self-governed fisheries (*i.e.*, Bluff and Challenger) and the rest of the QMS fishery. According to the time series data, there is evidence that self-governance adds value to fisheries management. This appears most likely to be true for the economic performance, which comes from cost-savings from indirect fishing costs and management costs. In terms of indirect fishing costs, boat numbers decreased faster in the two self-governed fisheries compared with the delayed and slow decline for the rest of the QMS fisheries. The other indicator of indirect fishing costs is the number of processing plants. The numbers in both self-governed fisheries show a certain level of co-operation in processing. The management costs also indicate economic performance. In the Bluff oyster fishery, there is no evidence of shifting management cost from the public to the users, but there was extra investment on research. However, in Challenger, there is evidence for cost-savings in all three areas (actual management, compliance and research). There is not enough evidence for profitability improvement. In order to confirm the exact benefits from self-governance, especially for the Bluff oyster fishery, further investigation is needed. The next chapter will address this issue.

In addition, investigation of institutional effectiveness showed that self-governance in both Bluff and Challenger helped users' communication and increased compliance rates. Although the degrees of self-governance differ between Bluff and Challenger, BOMC and CSEC carry a number of management functions, which facilitates the communication amongst fisheries users. As a result, the number of non-compliance cases decreased with the co-operation in both fisheries. In contrast, the number of non-compliance incidents increased for the rest of the QMS fisheries.

The last group of indicators show the effectiveness of self-governance on resource and environment management. In Bluff, self-governance contributed to stock rebuilding by organising ACE shelving. Challenger engaged in scallop enhancement programmes. On the other hand, fishing habitat management is perhaps the area where self-governance contributed the least. No non-fish zone was added to either Bluff or Challenger though those areas have been increasing in New Zealand waters. Similarly, the by-catch rates in the two self-governed fisheries show that self-governance did not contribute to extra habitat protection awareness.

Chapter 7
Conclusions

In the economics of fisheries management, ITQ-based self-governance has received more praise than analytical critique. This management regime for the most part, is hypothesised to add value to the management of ITQ programmes and benefit almost every aspect of fisheries management, including economic, institutional, resource and environmental performance. Despite the theoretical promotion of ITQ-based self-governance, there are only unstructured case studies that describe the 'benefit' of self-governance in practice, and only New Zealand officially endorses this management regime on a great scale.

Seeing there is a lack of rigorous research on ITQ-based self-governance, this thesis aimed at providing a systematic evaluation of this research literature-promoted management regime. Addressing this objective requires appropriate theory-based methods and supporting empirical studies. Therefore, the following two research questions were asked: (1) *What methods can be used to more effectively measure the merits of the ITQ-based self-governance regime?* (2) *Have these merits attributed to ITQ-based self-governance been realised?*

With regard to the first research question, until now, there has been a lack of rigorous methods to evaluate ITQ-based self-governance in ITQ fisheries. Specifically, the existing studies have uniformly used the unstructured case study approach. However, unstructured case studies are inadequate because of the problem of indeterminacy. That is, unstructured case studies cannot separate the value of self-governance from the benefits gained by ITQ management and, thus, cannot determine if self-governance is a means of improving fisheries management. For example, in the case study of the New Zealand rock lobster fishery, Yandle (2008, p. 303) suggested that "QMS and the devolved governance are so intertwined … that it is difficult to separate their relative contributions". This statement is true when analysing ITQ-based self-governance without a structured analytical method. However, the self-governance contribution can be separated from ITQs by careful selection of quantitative methods, as applied in Chapters 4 to 6.

In addition to the indeterminacy problem, the unstructured case study approach alone is insufficient to enable generalisations about the self-governance regime. This is because unstructured case studies tend to describe the impact of self-governance in some areas of significance to the specific fishery (*e.g.*, economic or social), but not evaluate all merits that have been hypothesised. Furthermore, the specific focus of each unstructured case study prevents comparison and contrast across similar research and, thus, makes synthesising of findings difficult (Poteete *et al.*, 2010).

In order to rigorously evaluate self-governance in fisheries management, this thesis deployed an array of methodical approaches. Three methods: a bio-economic model using Bayesian inference and system dynamics, the Minimum Information Management System (MIMS) and the Indicator System (IS), were developed and applied to address the research objective of assessing the merits of self-governance within ITQ fisheries. These three methods allow us to evaluate self-governance from different viewpoints using different data sets, yet they are interrelated and complement each other. Therefore, the results generated from the three methods can provide relatively confident and complete generalisations about ITQ-based self-governance.

In order to answer the second research question, the three methods were applied to the New Zealand Bluff oyster fishery, a self-governed ITQ fishery, to verify the hypothesised merits attributed to this management regime. The performance of the Bluff oyster fishery may be a useful indicator of the management contribution of self-governance to other New Zealand ITQ fisheries. This is because the Bluff oyster fishery is not the most sophisticated mode of self-governance (Townsend, 2010) and if the merits of self-governance have been realised in the Bluff oyster fishery, it is likely that the merits can be realised in other fisheries. In addition, the performance of the Challenger scallop fishery (the most sophisticated self-governance regime in New Zealand) and the average performance of other non-self-governed ITQ fisheries were also evaluated using the IS system. The comparison and contrasts amongst the Bluff oyster fishery, the Challenger scallop fishery and the non-self-governed ITQ fisheries provided a comprehensive picture of the performance of self-governance in New Zealand.

7.1 General findings with regard to the three methods

In contrast to the unstructured case study research that is usually applied to evaluate self-governance, the indeterminacy problem is minimised in the three methods applied herein.

By evaluating the self-governance effects independently from ITQ management through a comparison procedure incorporated in each of the three methods, this thesis evaluated self-governance analytically and enabled more valid generalisations about this regime's merits. Specifically, the bio-economic model compared the possible stock and profit outcomes of a fishery 'with' and 'without' self-governance. The MIMS compared the quota price behaviour of a self-governed fishery with a comparable non-self-governed fishery (or the average performance of all ITQ fisheries if such a similar fishery is unavailable). The IS examined the trend of each indicator in a self-governed fishery and compared the behaviour of all indicators with a comparable non-self-governed fishery (or the average performance of all other ITQ fisheries if a similar fishery is not available). Furthermore, it would be possible to synthesise the findings from research that applies the three methods that standardised the analytical approach.

In terms of the method used in Chapter 4, developing a bio-economic model to evaluate a self-governance regime, there are three key findings. First, with an appropriate bio-economic model, an ITQ-based self-governance regime can be readily analysed. That is, the model can readily separate the contribution of self-governance from an ITQ programme by identifying the difference in management measures between the 'with' and 'without' self-governance regimes. Furthermore, the model can be adjusted to adapt to different situations. Therefore, though the dynamics of fish stock and management structure will differ amongst individual fisheries, the model can be adjusted, where needed, to fit different fisheries.

Secondly, the biological sub-model incorporates Bayesian inferences, which are often widely applied in fish biology research, but noting fisheries economics research. The use of Bayesian inference allows the biological sub-model to make use of all relevant information (*e.g.*, scientific stock assessment and survey and commercial CPUEs), which helps to minimise uncertainty in estimation. As a result, the biological sub-model in this thesis can better capture stock dynamics. This contrasts with conventional economic discussions in fisheries management, where non-stock information that might have a significant influence on stock dynamics is usually ignored.

Finally, the economic sub-model adapted the simulation of system dynamics, which provides for more flexible and realistic outcomes. The flexibility of simulation provides a way of projecting profit levels when there are no 'hard' data available or when the quality of the data is poor. In the case of the Bluff oyster fishery, a time series of catch cost data is unavailable; data are available only for 2007. Simulation helped project profitability without requiring consecutive profit-related data. In addition, the system dynamics approach allowed the interaction of all factors that might have impacted on profitability (*e.g.,* interactions between fish stock and fishing activity and management decisions). In the Bluff oyster fishery, only population dynamics were included in the model as an external factor, but it can also incorporate ecological and/or management elements (*e.g.,* the impact of climate change or input restrictions) into the model if deemed necessary.

Besides being flexible, simulation allows realistic variable inputs into the economic model. For example, in a conventional mathematical bio-economic model, price of output and cost of catch are often assumed to be constant, such as is observed in the widely-applied Gordon-Schaefer model. However, in reality, the input and output prices are often non-constant, which in turn causes profit estimation to be erroneous. The price of the Bluff oysters, according to the OLS regression analysis, varies with the quantity available in the market. It would be challenging to incorporate such endogenous variables into a model without simulation. On the other hand, system dynamics simulation allows the non-linear application of variables, which makes estimation more reliable.

In terms of the method used in Chapter 5, applying the MIMS to evaluate the ITQ-based self-governance regime, there were two findings. First, the MIMS provided a means to evaluate ITQ-based self-governance integrally, which is a more straightforward approach than the bio-economic model or the IS. That is, using the MIMS to evaluate ITQ-based self-governance is less costly and more user-friendly. This is because the quota price is market information that is readily available and the change of quota price can be observed and explored by both fisheries managers and fishers.

Secondly, even though the application of MIMS method relies on a number of assumptions, some can be relaxed and some are already realised in New Zealand. Therefore, despite the application of MIMS being limited until now, it has the potential to be used more extensively to evaluate fisheries management in New Zealand.

In terms of the method used in Chapter 6, developing a new IS to evaluate a self-governance regime, there were two key findings. First, the IS were able to evaluate the merits of self-governance at a disaggregated level. The evaluation was undertaken by selecting the most suitable indicators from the literature according to the perceived merits of self-governance in fisheries management, which include economic, institutional, and resource and environment factors. Thus, the IS provided a more complete understanding of the effects of self-governance for fisheries management.

Secondly, the IS is effective in separating the contribution of self-governance from the ITQ programme. This is achieved by the two reference-point system developed in the IS. The first reference point compares the performance of the fishery over the course of the establishment of the self-governance regime; the second reference point compares the performance of the fishery with a compatible non-self-governed fishery (or the average performance of the ITQ fisheries if such a fishery is unavailable).

7.2 General findings with regard to ITQ-based self-governance regimes

Providing an answer to the second research question "*Have these merits attributed to ITQ-based self-governance been realised?*" is not straightforward even after the extensive analysis undertaken herein. There are areas where self-governance makes a valuable contribution for the improvement of fisheries management. For example, ITQ-based self-governance improves the fishery's economic performance. However, this result is hardly surprising. The economic gain might be the very reason ITQ-holders are able to co-operate. On the other hand, there are areas where self-governance does not add value to an ITQ programme, especially with regard to environmental stewardship. Moreover, there are areas that self-governance can contribute to fisheries management, but the realisation of the merits depends on the nature of the self-governance entity. For instance, savings in management costs are related to the structure of the QOA in the fishery. That is, a mature and legitimate QOA is more likely to assume more management responsibilities and, therefore, internalise management expenses.

In Chapter 4, the bio-economic model evaluated the *ex-ante* effects of self-governance on fish stock size and profitability. It was found that self-governance in the Bluff oyster fishery contributes to both stock conservation and profitability improvement. In other words, the results from the simulation projected that there can be 'win win' situations where profit-maximisation accompanies higher stock biomass level. This finding, in turn, can be viewed in a wider debate in fisheries management on whether profit-maximisation is likely to lead to stock extinction (Clark, 1973; Clark and Munro, 1975) or it does not necessarily lead to stock degradation (Grafton *et al.*, 2007; Grafton *et al.*, 2010). In terms of the New Zealand Bluff oyster fishery, the profit-seeking behaviour of the fishers actually leads to stock conservation.

Specifically, as discussed in Chapter 3, Clark (1973) suggested that if the unit price of fish product is greater than the unit cost of catch the fish ($p > c(0)$) and the discount rate is more than double the stock maximum intrinsic growth rate ($\delta > 2r$), the level of biomass that supports MSY is always greater than the level of biomass that supports MEY ($B_{MSY} > B_{MEY}$). However, Grafton *et al*. (2007) found empirical evidence in four fish stocks over a range of prices, costs and discount rates, that the level of biomass that supported MEY was greater than that for MSY. One of these four stocks was orange roughy, the famous slow growing fish stock ($r = 0.025$).

Compared with orange roughy, the intrinsic growth rate of oysters is higher, the average positive growth rate (r) estimated for Maryland oysters is 0.2744 (Wieland and Kasperski, 2008). However, this estimation excludes negative growth caused by diseases. If disease mortality is incorporated, the real intrinsic growth rate is much lower for the Bluff oysters. Based on historical survey data (MFish, 2009f, p. 177), the average real intrinsic value, between 1992 and 2007, was $r = 0.05$. The average one-year government bond rate in New Zealand, for the same time period, was $\delta = 0.07$ (RBNZ, 2009). Although the social discount rate is greater than the intrinsic growth rate, the BOMC did not harvest the full ACE but has shelved half of the harvest since 2003. Therefore, even though the social discount rate (δ) is greater than the intrinsic growth rate of the oysters (r) in Bluff, private profit-maximisation leads to stock conservation. At present, from the simulation (Table 4.5), the average intrinsic growth rate of Bluff oysters is $r = 0.07$, which is approximately equal to the one-year government bond rate (the risk free rate) in New Zealand for the year 2007 (RBNZ, 2009). This situation, $\delta = r$, should further incentivise private owners to preserve the resource. In other words, the Bluff oyster fishery shows that private ownership should not be banned based on their profit-seeking motives. Rather, the decision on management regime (*e.g.*, state, community versus private) should be based on the nature of the individual fishery.

In Chapter 5 the MIMS was applied to evaluate effects of self-governance on the performance of a fishery integrally. With regard to answering the question whether the benefits attributed to self-governance have been realised, the application of MIMS to the Bluff oyster fishery did not reach a conclusion due to OYU5's uncompetitive quota market. However, although MIMS cannot be successfully applied to the Bluff oyster fishery, there is evidence that it can be applied successfully to commercially significant fisheries such as the snapper fishery (*i.e.*, Batstone and Sharp, 2003), which is currently not self-governed. Meanwhile, there has been the development of QOAs in New Zealand since the implementation of the QMS (Yandle, 2003). In fact, there are QOAs in fisheries such as rock lobster, salmon, orange roughy and paua. It is also expected that some form of QOAs will develop in the near future for some other major species[43] and, therefore, could provide adequate data for MIMS application if warranted.

In Chapter 6, the IS was applied to evaluate the *ex-post* effects of the self-governance regime on the economic, institutional, resource and environmental performance of the Bluff oyster fishery. There were two main findings with regard to determining whether the merits attributed to self-governance have been realised. First, the IS found that self-governance can contribute to economic efficiency and institutional effectiveness. However, the value of having self-governance in the management of a fishery depends on the maturity of the QOA. This argument is supported by comparing the performance of the Bluff oyster fishery (a relatively young self-governance regime) with the Challenger scallop fishery (a mature self-governance model). Almost every indicator, especially the ones for fisheries management cost-saving, indicated that the merits of self-governance were presented in the Challenger scallop fishery. One aspect that must be noted is the maturity of a co-operative is not measured by the establishment period of the self-governance entity, but rather by the legitimate status of the QOA (*i.e.*, the amount of support from the government). The CSEC is younger than the BOMC in terms of existence: the CSEC was established in 1994 and the BOMC in 1992. The difference between the two self-governance regimes is that the CSEC's management is supported by legislation (Arbuckle 2000), is bound by legal agreements and is overseen by government. In contrast, the BOMC's self-governance is sustained by mutual agreements amongst its users, which do not have binding power authorised by government.

The second finding, apart from the importance of the legitimacy of the QOAs, is that there were mixed results presented on resource and environmental stewardship in a self-governance regime. Specifically, in both the Bluff oyster fishery and the Challenger

[43]According to New Zealand Seafood Council, the top ten species by export values are mussels, rock lobster, hoki, squid, salmon, orange roughy, paua, jack mackerel, ling and snapper.

scallop fishery, though there was evidence of fish stock conservation and enhancement, no significant measures were taken to manage by-catch or establish no-fish zones. This result adds empirical knowledge to the conventional understanding about resource stewardship in rights-based regimes. As discussed in Chapter 3, there are two different views regarding fish stock and habitat conservation in a self-governance regime. On the one hand, because fisher co-operatives have more exclusivity to the resource, they have more incentive to safeguard their resources and the environment (Arnason, 2007c; Hughey *et al.,* 2000; Scott, 2000a, b). On the other hand, Townsend (2006) noted that when the private costs of protecting fishing resource and habitat outweigh the benefits, fisher co-operatives will fail to address public good problems. This result provides evidence for the conclusions drawn by Townsend (2006) that both by-catch and environmental management are external to commercial self-governance and that self-governance will not internalise all externalities.

7.3 Policy implications

The findings from Chapter 4, the bio-economic model, provide one policy implication regarding how we should view user self-governance. In the Bluff oyster fishery, users' profit-maximisation behaviour led to a 'win win' situation. Therefore, self-governance should not be dismissed simply based on the optimal extinction theory (Clark, 1973) or the misperception that profit-maximisation leads to stock degradation. Despite that, profit-maximisation and catch-maximisation appear to complement each other; fishers' long-term interest in the fishery can provide them with the incentive to look after the resource.

There is one policy implication to be drawn from the findings in the MIMS chapter. Following the discussion in Chapter 5, a competitive quota market can provide management insights about the status of fisheries. However, even in a competitive market, quota price information can be false or misleading because of the lack of a legal requirement to record the true quota exchange price (Lindner *et al.*, 1992). By studying nine fisheries and 29 fish quota markets between 1986 and 1988, Lindner *et al.* (1992) found that some quota transactions can be in-house trading between companies under the same ownership. Although the situation might have improved more recently, Fish Serve records still show reoccurrences of similar misreporting behaviours and in-house trading activity. Further, some transactions may be barters in the form of exchange of quota holdings between two companies and the price registered is only for administrative purposes. Although not all price records are unreliable, fishers might have the incentive to report trading price strategically out of the fear of fisheries officials using the information against them. Therefore, the lack of data or lack of high quality data might hinder the application of MIMS in New Zealand.

Hence, in order to fully utilise market information to support the data needs for fisheries management, it is recommended that law-makers formalise rules regarding quota/ACE exchange. This might include requiring the participating fishers to register accurate information for both quantity and price traded. Formalising quota/ACE exchange information can then provide reliable data for fisheries management in an inexpensive way. Furthermore, the market might become more competitive due to price accessibility and comparability.

The findings from Chapter 6, the IS, provides two policy implications. First, the maturity of a QOA plays an important role in realising the potential benefits of self-governance. Therefore, the government's legal support of the self-governance entity is crucial in order to fully realise those benefits. This implication aligns with the literature that has emphasised the role of the government in a co-management regime. Specifically, Grafton (2000) examined three different management regimes (private rights-based, community rights-based and state rights-based) and concluded that the success of any management regime calls for government facilitation and co-ordination. Townsend (2006, 2008, 2010) also stressed the role of government for self-governance regimes. However, he identified that the role of government should be more than just facilitation. In fact, the legitimacy of stakeholder entities helps deliver the potential benefits of self-governance. Therefore, in order to realise the full potential of self-governance, the government has to be willing and prepared to grant such legal status to the stakeholders.

Secondly, the findings in Chapter 6 indicate that self-governance does little to manage fishing habitat. Therefore, government should pay close attention to environmental management. If generalised further, the implication is that government should be in charge of aspects of self-governance where there is a value mismatch between the ITQ-holders and society as a whole. That is why 'ITQ and self-governance' literature often recommended that the government should retain a supervisory role to protect the interests of the public (*e.g.*, McCay, 1995; Scott, 2000b).

However, the above view regarding the government's involvement might be impractical. This is because the need for government supervision varies for different fisheries. McCay (1995, p. 11) believed that the ability of the ITQ regime to address resource conservation issues hinged on "the time horizon for planning, the nature of future rewards for present sacrifices and the extent to which ITQs affect the capacity for collective action". All of these traits vary with fisheries because of the heterogeneity of fisheries and their self-governance structures. For example, the nature of future rewards for present sacrifices will be different between fish stocks. For stocks that decrease catch at present (sacrifice) can yield greater future catch (reward) (*e.g.,* the Bluff oyster fishery), less supervision might be needed. Similarly, for a capable self-governance structure (*e.g.,* the Challenger scallop fishery), less supervision is required. Therefore, there might be a mis-match between the requirements for supervision and the level of supervision.

The consequence of such a mismatch can be significant. Excessive amounts of supervision create wastage and tension between managers and users, but inadequate supervision might lead to fishery collapse. In addition, government supervision cannot cover every aspect of fisheries management. In this regard, the issue of supervision in a self-governance regime is similar to the input control regulations a government imposes on fishers. Often, fishers can find ways to get around the control if they have an incentive to do so. For example, a deemed value system might be able to address part of the by-catch dumping problem, but dumping is always an option if unsupervised.

It might not be enough to recommend government supervision for problems that self-governance cannot address properly. The finding from using the IS, for the Bluff oyster fishery and the Challenger scallop fishery, is that self-governance is not a panacea for all problems in fisheries management. There will be areas that this management regime cannot address. Furthermore, not all of these problematic areas can be addressed by government supervision. This is because, in terms of resource and environmental stewardship, "[f]ar less is known about what the conditions are, or can be, that lead to individual or collective behaviour to reduce such behaviour, including ways the systems can be designed for that purpose" (McCay, 1995, pp. 17-18). What is important is to realise the priorities in fisheries management. Generally, the goal of fisheries management in modern capitalist economies is to utilise the resource efficiently with the provision that the resource conservation goal is met. In this regard, ITQ-based self-governance, according to the findings in this thesis, out-performs an ITQ regime alone.

7.4 Limitations and future research opportunities

The thesis has two limitations in terms of evaluating the performance of self-governance regime with ITQ fisheries. The first limitation is with regard to its scope. Because only the Bluff oyster fishery and, in some areas, the Challenger scallop fishery were studied, generalisation of the findings about the relationship between self-governance and fisheries performance remains to be fully concluded. However, since the Bluff oyster fishery is not the most sophisticated self-governance model in New Zealand, it is likely that the performance of other self-governed fisheries will confirm the findings observed in the Bluff case. However, further analysis is still required for a more reliable generalisation on the contribution of self-governance to fisheries management in New Zealand.

Therefore, follow-up research is needed to enable further generalisation. This future research could take two possible forms. The first type of research could be a large-N comparative study that includes all self-governed ITQ fisheries in New Zealand. This approach supports Poteete *et al.* (2010), who argued that the validity of generalisation is based on the breadth of comparison and sample size. For evaluating the contribution of self-governance to New Zealand fisheries, the breadth of comparison is limited to New Zealand ITQ-fisheries that have a self-governance component, which is also the population of the study. Therefore, a comparative study that covers all fisheries would presumably provide a valid generalisation of the relationship between self-governance and fisheries performance.

The reason that this thesis did not cover the whole population is because it is beyond the scope of this study. In fact, it would have been challenging for a single piece of research to have examined all ITQ-based self-governance fisheries in New Zealand. This is especially so given that, before this thesis, the means to evaluate self-governance had not been developed. In addition, the extensive research of ITQ-based self-governance will require a substantial amount of financial resource and time to collect the required data and obtain the necessary local knowledge about the resource. However, the study of the complete population is feasible for large organisations such as MFish or SeaFIC. Furthermore, as discussed in Chapter 3, the application of the three methods developed in this thesis provides a foundation for further comparison across fisheries.

Besides a complete large-N comparative study of all ITQ-based self-governance fisheries, the second possible approach for future research would be an econometric analysis. A case study approach might be appropriate when cross-case data are unavailable (Poteete *et al.*, 2010), but econometric methods might be a better approach if there is sufficient data input available. Newell *et al.* (2005) found that for 150 New Zealand fisheries, the quota prices are related to their lease (ACE) price, input and output price, and other underlying factors such as quota demand and ecological uncertainties. Therefore, it might be possible to compare the general performance of self-governed fisheries with non-self-governance fisheries using a dummy variable to identify the difference between the two groups of fisheries. Specifically, based on Newell *et al.* (2005), the regression might be expressed as follows:

$$\begin{aligned}\ln\lambda_{ijmy} = {} & \beta_1 \ln p_{imy} + \beta_2(\ln p_{imy})^2 + \beta_3 \ln c_{my} + \beta_4 \frac{H_{ijy-1}}{Q_{ijy-1}} + \beta_5 \left(\frac{H_{ijy-1}}{Q_{ijy-1}}\right)^2 \\ & + \beta_6 \left(\frac{\sum_{n=1}^{m-1} h_{ijny}}{Q_{ijy}} - \frac{\sum_{n=1}^{m-1} h_{ijny-1}}{Q_{ijy-1}}\right) + \beta_7 \left(\frac{\sum_{n=1}^{m-1} h_{ijny}}{Q_{ijy}} - \frac{\sum_{n=1}^{m-1} h_{ijny-1}}{Q_{ijy-1}}\right)^2 \\ & + \beta_8 \ln p_{imy} \left(\frac{H_{ijy-1}}{Q_{ijy-1}}\right) + \beta_9 \ln s_{my} + \beta_{10} g_{my} + \beta_{11} SG + \varepsilon_{ijt}\end{aligned}$$

Where λ is the quarterly average lease price,

p is the export price,

C is fishing costs index,

H is the actual annual catch,

Q is the annual TAC,

h is the actual quarterly catch,

s is the southern oscillation index – an index for ecological uncertainties,

g is the New Zealand real GDP growth rate,

t is an annual time index,

SG is the dummy variable, SG = 1 when the fishery self-governs and SG = 0 otherwise, and

ε is the error term.

Two points of consideration need to be checked to indicate the validity of the above econometric equation. First, generally speaking, if the regression is statistically significant, that is, if the F test shows a significant explanatory power in all independent variables, the relationship established by the equation is valid. More importantly, the power of the equation in identifying management functions between self-governance and 'without' self-governance falls on β_{11}. Specifically, if self-governance fisheries quota prices out-perform ITQ-only fisheries, β_{11} is expected to be statistically significant from zero in a t-test.

The reason that this thesis did not use regression analysis is because the market price for self-governance fisheries, such as the Bluff oyster fishery, is usually unavailable. The simulation method used in Chapter 4 overcame this data issue, but the conventional econometrics approach requires extensive amounts of reliable data. Furthermore, the degree of self-governance differs amongst self-governed fisheries and, therefore, the regression results might not be able to reflect the difference between self-governance and otherwise. However, regression analysis can be an appropriate approach for identifying the value of self-governance in the future, when the necessary data might become available, if self-governance regimes and quota markets grow in maturity.

Another limitation of the thesis is its limited focus. The economic efficiency evaluation of a self-governance regime was solely focused on the profitability of producers. However, the economic rent improvement for producers may come at a cost to consumers. Therefore, future research is needed to investigate the impact of self-governance on the total net economic benefits. A preliminary discussion in terms of future research direction is presented as follows.

The net economic benefit issue has its root in the two original papers considering the economics of fisheries management, Gordon (1954) and Scott (1955). In these two papers, sole-ownership was promoted under the 'nil price effects' assumption, where the sole-owner has control over output quantity, but where price remains unaffected. This can happen when there are a few close substitutes in the market, or where the sole-owner only dominates locally, but not nationally or internationally. Following this assumption, fisheries that are domestically oriented (*e.g.,* the Bluff oyster fishery) are more prone to lower net economic gains if consumer losses are taken into account. This possible total rent loss indicates self-governance regimes may take on a cartel-like arrangement.

There is, therefore, a legal issue to consider concerning the QOAs' quota holdings. In New Zealand, formal explicit collusive agreements, especially cartels that fix prices, are illegal under the Commerce Act 1986 Part II and III[44]. The reason for this legislation is that cartels prevent competition. Similarly, there is a prohibition of maximum quota holdings under the Fisheries Act 1996 section 59. This Act limits, in general, the maximum quota holding to be 20% of the total quota for any single species[45]. The aggregate quota holding limit was introduced to prevent monopolistic behaviour (Lock and Leslie, 2007) and to enhance ownership diversification (Hansard, 1996, as cited in Lock and Leslie, 2007).

The antitrust law in New Zealand and the regulation of fisheries are both in place to ensure adequate competition in the industry. However, this situation is a concern in ITQ-based self-governance fisheries. Yandle (2003) noted that when a QOA comprises large quota holders, the co-operative might act like a cartel, which fixes output prices rather than only co-ordinating harvest. After surveying most QOAs in New Zealand, Yandle found that approximately 94% of the organisations represent 60% to 100% of the commercial interest in those fisheries.

A recent case in the scampi fisheries shed some light on this issue of competition. Sanford Limited, one of New Zealand's largest fishing companies, was seeking to acquire the scampi quotas of Simunovich Fisheries Limited. Before the acquisition, Sanford held 24.11% of the total quotas in the scampi fisheries and Simunovich held 11.78%. However, with the acquisition Sanford would have over one third of the totally quota holdings if the acquisition were to be approved by the Commerce Commission. The Commission ruled in favour of the acquisition and granted clearance for the acquisition by Sanford. The supporting evidence of the decision, in considering both the scampi market and scampi fishing rights market, is two-fold. First, the acquisition is likely to

[44] "*Part II of the Act prohibits certain restrictive trade practices. The main practices that are prohibited include: section 27, which prohibits contracts, arrangements or understandings substantially lessening competition; section 29, which prohibits contracts, arrangements or understandings containing exclusionary provisions; section 30, which prohibits arrangements that lead to prices being fixed by competitors; section 36, which prohibits a person that has a substantial degree of market power in a market from taking advantage of that power for exclusionary purposes; and sections 37 and 38, which prohibit suppliers fixing the prices at which goods may be sold by other businesses. Part III of the Act prohibits business acquisitions that have, or would be likely to have, the effect of substantially lessening competition in a market".*

[45] "*…no person shall entitled to own – (a) A number of quota shares for any one species the total quota weight equivalent of which is more than 45 percent of the combined totally allowable commercial catches for every stock of that species … (b) More than 10,000,000 quota shares (10 percent of the total allowable commercial catch) for spiny rock lobster in any one quota management area. (c) In the case of bluenose (Hyperoglyphe Antarctica), a number of quota shares for that species the quota weight equivalent of which is more than 20 percent of the combined total allowable commercial catches for very stock of that species. (d) In any other case a number of quota shares fo5 any one species the total quota weight equivalent of which is more than 35 percent of the combined total allowable commercial catches for every stock of that species"*– Fisheries Act 1996

bring more competition in the domestic market. Secondly, other new entry and by-catch fishers would also constrain the combined entity's market power.

The impact of fisheries co-operatives, therefore, depends on their level of market power. The high concentration ratio can be alarming if, as mentioned at some length above, the QOA does have control over the market. In this case, new entrants might be blocked and the consumers might be worse off if a higher price is fixed by the QOA. Nevertheless, this issue would be trivial for fisheries where the fishers are merely price takers or have close substitutes.

7.5 Concluding remarks

The empirical evaluation of self-governance in the thesis was based on the documented merits in the prevailing literature. Therefore, the focus was limited to the three aspects of fisheries management, namely economic, institutional, and resource and environmental. Although these three areas provide adequate knowledge of management quality, there are other areas (*e.g.*, employment opportunities and recreational fishing support) that are important to fisheries management. Hence, the study might have provided sufficient information for evaluating an ITQ-based self-governance regime from an economic viewpoint, but future research will be needed to provide a wider-ranging evaluation.

Based on the findings in this thesis, self-governance is recommended for New Zealand fisheries management. In New Zealand, the goal of management is to balance the use and the conservation of fish stock, amongst other concerns (Fisheries Act 1996). According to the analysis of the Bluff oyster fishery, as well as the Challenger scallop fishery, self-governance contributes to fisheries management by improving fisheries' performance beyond the results from ITQ programmes alone. The essence of this recommendation is based on the capitalist nature of New Zealand's fishing activity, where resource utilisation is a focal point. This differs from the situation for many developing nations where fisheries often provide a livelihood for coastal fishing communities. In those fisheries, a more 'balanced' approach that focuses on job and income security as well as on productivity might be more appropriate.

The recommendation of ITQ-based self-governance also rests on the long-term viability of a nation's fishing industry. This thesis found that the further economic gain brought about by a self-governance regime in an ITQ programme is evident. Therefore, this management regime can increase the viability and competitiveness of a fishing industry domestically and internationally. On the other hand, CBM might delay the technological improvement and decrease the competitiveness of a fishery because of its fish stock conservation and job security focus. Domestically, fisheries managed by CBM might be out-competed by more efficient fisheries managed under some market-based management instruments. Internationally, given the imminent approach of globalisation in every aspect of human lives, in the long run, fisheries competitiveness might be a valid concern for commercially significant fishing nations.

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Appendix A

MCMC process

In essence, the MCMC is a process of convergence towards the target posterior distribution p(H|E) from a sequence of random points (H^1, H^2, H^3,…) (Hilborn, 1999). The process includes seven steps:

1. *Selecting starting estimates from the parameter vector,*

2. *For each parameter of the model,*

3. *Sample a new point from a "jumping distribution",*

4. *Calculate posterior density at new point,*

5. *If posterior of new point is greater than old point, accept new point,*

6. *If posterior of new point is less than posterior of old point, accept new point with a probability equal to the ratio of the new posterior to the old posterior, and*

7. *Repeat from "for each parameter of the model" thousands or millions of times.*

Appendix B

Population file

……

@initial 1907

@current 2007

@final 2017

……

@recruitment

n_rinitial 79

YCS_years 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006

YCS 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00

SR BH

steepness 0.9

initial_size_mean 15.5

initial_size_cv 0.40

first_free 1985

last_free 2004

year_range 1985 2004

……

@growth

type basic

l 30 55

```
g 11.91 3.61

cv 0.31

minsigma 4.45

......

@disease_mortality

years 1907 1908 1909 … 2005 2006 2007

index 0.00 0.00 0.00 … 0.30 0.20 0.10

……

@fishery SummerFishery

years    1907  1908  1909  …  2005  2006  2007

catches  0.00  0.00  0.00  …  0.00  0.00  0.00  0.00

selectivity FishingSel

U_max 0.5

@fishery WinterFishery

years    1907  1908  1909  … 2005  2006  2007

catches 18.83 17.34 19.19 … 7.57  7.44  7.50 # 2007 value assumed

future_constant_catches 15

selectivity FishingSel

U_max 0.5

……
```

Appendix C

Estimation file

……

@estimator Bayes

@max_iters 1000

@max_evals 4000

@grad_tol 0.0002 #The default is 0.002

@MCMC

start 0

length 1500000

keep 1000

adaptive_stepsize True

adapt_at 100000 200000 400000

burn_in 500

proposal_t True

df 4

stepsize 0.01

OBSERVATIONS: Biomass CPUE (catch per hour)

@relative_abundance CPUE-A

years 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968

step 2

proportion_mortality 0.5

q CPUE-Aq

biomass True

……

@relative_abundance CPUE-B

years 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984

……

OBSERVATIONS: Biomass Dredge survey (Pre-recruits)

@relative_abundance OctSurveyPreRecruit

years 1993 1995 1997 1999 2001 2002

step 2

proportion_mortality 1.0

q DredgeSurveyq

biomass True

ogive DredgeSurveySelPreRecruit

1993 383

1995 380

1997 727

1999 896

2001 872

2002 520

cvs_1993 0.11

cvs_1995 0.10

cvs_1997 0.14

cvs_1999 0.12

cvs_2001 0.12

cvs_2002 0.11

dist lognormal

cv_process_error 0.0001

OBSERVATIONS: Commercial catch-at-length

@catch_at CommercialCatchLength

years 2002 2003 2005 2006

fishery WinterFishery

sexed false

plus_group true

sum_to_one true

min_class 5

max_class 45

class   10   12   14   …   86   88   90

class nos. 5   6   7   …   43   44   45

2002   0.0000 0.0000 0.0000 … 0.0010 0.0005 0.0000

2003   0.0000 0.0000 0.0000 … 0.0005 0.0001 0.0002

2005   0.0000 0.0000 0.0000 …1 0.0010 0.0017 0.0015

2006   0.0000 0.0000 0.0000 … 0.0010 0.0001 0.0014

……

Appendix D

Output file

……

@print

parameters False

unused_parameters True

population_section True

……

@quantities

……

B0 True

R0 True

SSBs True

YCS True

actual_catches False

……

Appendix E

List of BOMC tasks

Year	Project	Associated Parties	Expense BOMC	Expense Other Party
1996	Biotoxin and saitisation	BOMC / NZFSA	100%	
1997	**Stock Assessment Survey** and Bonamia survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
1998	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
1999	**Stock Assessment Survey** and Bonamia survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
2000	Bonamia Survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
2001	**Stock Assessment Survey** and Bonamia survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
2002	**Stock Assessment Survey** and Bonamia survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
	Develop Fisheries Plan - Industry facilitaed process	BOMC	100%	
2003	Bonamia Survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
	Develop Fisheries Plan - Industry facilitaed process	BOMC	100%	
2004	Bonamia Survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
	Develop Fisheries Plan - Industry facilitaed process	BOMC	100%	
2005	**Stock Assessment Survey** and Bonamia survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
	Enhancement / return of shell experiment	BOMC / NIWA /ES	100%	
2006	Bonamia Survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	BOMC Logbook programme	BOMC / NIWA	100%	
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
	Development of Bluff Oyster Fisheries Plan -Mfish facilitated process	BOMC / NIWA/ MFISH		
		Recreational & Customary stakeholders		
	Enhancement / return of shell experiment	BOMC / NIWA /ES	100%	
	Foveaus Strait ecosystem & effects if fishing report	Mfish /NIWA/ BOMC		100%
2007	**Stock Assessment** & Bonamia Survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	BOMC Logbook programme	BOMC / NIWA	100%	
	BOMC / Seafood Innovations Research	BOMC / SIL's	40%	60%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
	Development of Bluff Oyster Fisheries Plan -Mfish facilitated process	BOMC / NIWA/ MFISH		
		Recreational & Customary stakeholders		
2008	Bonamia Survey - cost recovered	BOMC / Mfish / NIWA	74%	26%
	BOMC Logbook programme	BOMC / NIWA	100%	
	BOMC / Seafood Innovations Research	BOMC / SIL's	40%	60%
	Biotoxin and saitisation	BOMC / NZFSA	100%	
	Oyster Enhancement trials/ development -(Southern Shellfish Ltd)	BOMC / SSL	100%	
	Development of Bluff Oyster Fisheries Plan -Mfish facilitated process	BOMC / NIWA/ MFISH		
		Recreational & Customary stakeholders		

Appendix F

Sample of logbook page

Foveaux Strait Oyster Fishery Logbook

2009 Season. Sample only

8869 ✓

LANDED DATE: VESSEL: SKIPPER.

AREA GRID:		J15				
Commercial Tow or Prospecting Tow ("C" or "P") (Do not include Customary Tows)		C				
		hr:min	hr:min	hr:min	hr:min	TOTALS
TIME TOWING AT EACH GRID (hrs/mins): (Eg. 5 hours 30 minutes not 5.5 hours)		5:00	:	:	:	5:00
NUMBER TOWS: (For each dredge)		44				44
NUMBER OF SACKS		16½				16½
NUMBER OF BINS		0				0
SEABED TYPE:	A: Empty Dredge	0				
record dredge contents as % (10% or more) of each category. Total of all catagories to equal 100%	B: Red Weed	0				
	C: Kaeos	0				
	D: Shell	80				
	E: Sand	20				
	F: Gravel	0				
	G: Sponges	0				
	H: Mullock (Corals)	0				
BONAMIA estimated % of new clocks (each size group) to the total of Live Oysters plus new clocks	A: % New Clocks - Legal Size	1%				
	B: % New Clocks Spat & Wings	1%				
CATCH SIZE (estimated % of all live oysters. Total 3 groups=100%)	A: % Legal 58mm +	30				
	B: % Sub Legal 50-57mm	60				
	C: % Spat & Wings	10				
% Catch with Wings Estimated % of all live Oysters with Wings & Spat (i.e 10%, 20%, 30% etc etc)		25				
Skippers assessment of dredge performance due to weather, tides and bottom type. G or A or P Good (G) Average (A) Poor (P)		A				

Skippers Signature:

At the end of each week, please place the completed forms in the envelope provided and place in the "mail box" attached to the Toiler shed

Appendix G

The Fish Serve rules of calculation

The Fish Serve rules of calculating the average price for quota and ACE are as follows: "*Any transactions involving the Treaty of Waitangi Fisheries Commission will be removed from the calculation. Where a stock has no differential deemed value, all transactions that have a total price that equates to 20 per cent or less of the annual deemed value or 100 per cent or more of the annual deemed value will be removed from the calculation. Where a stock has a differential deemed value, but was less than 90 per cent caught in the preceding two fishing years, all transactions that have a total price that equates to 20 per cent or less of the annual deemed value or 100 per cent or more of the annual deemed value will be removed from the calculation. Where a stock has a differential deemed value and was more than 105 per cent caught in the preceding two fishing years, all transactions that have a total price that equates to 30 per cent or less of the annual deemed value or 140 per cent or more of the annual deemed value will be removed from the calculation. Where a stock has a differential deemed value and was between 90 per cent and 105 per cent caught in the preceding two fishing years, all transactions that have a total price that equates to 20 per cent or less of the annual deemed value or 120 per cent or more of the annual deemed value will be removed from the calculation. Exceptions: SQU1T, SQU6T. Due to analysis of past trading prices on these stocks, all transactions that have a total price that equates to 10 per cent or less of the annual deemed value or 100 per cent or more of the annual deemed value will be removed from the calculation. Average prices will only be displayed if there are three or more valid transactions for the period*".