Maximising Value in Multi-species Fisheries

Prepared by

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EXECUTIVE SUMMARY

This report explores how the application of economic principles and bio-economic frameworks might further the Ministry of Fisheries' overarching objective to "Maximise the value New Zealanders obtain through the sustainable use of fisheries resources and protection of the aquatic environment." In order to maximise the value of fisheries, I put forward the principle that fish stocks should be managed at a level where the incremental value of catching fish is equal to the incremental value of leaving fish in the stock. As an unregulated fishery will tend to focus on the value of catch, and not the value of the stock, it becomes the specific role of public policy to provide the incentives for private actors to recognise the stock value part of this equation.

While the New Zealand Quota Management System (QMS) takes a big step in this direction by allocating the Total Allowable Commercial Catch (TACC) to individual fishers, the principle for setting the TACC itself has been almost exclusively biologically-based. Incorporation of economic information, in combination with the biological characteristics of different fish stock complexes, could provide the basis for significantly increasing the value of New Zealand fisheries by tailoring stock targets and catch targets to specific bio-economic conditions. In some cases such analysis may indicate that managing stocks at B_{MSY} (so that they produce the maximum sustainable yield) is a value-maximising strategy. In other cases, it may be valuable to manage stocks well above B_{MSY}, and in limited cases below B_{MSY}. While some such adjustments have no doubt already implicitly occurred through the Total Allowable Catch (TAC)-setting and implementation processes, more systematic application of bio-economic frameworks would be beneficial in guiding these decisions.

I also highlight the point that landing fees on catch can be an alternative to quota as a means to controlling catch, and that New Zealand in fact employs a hybrid "quantity-price" system through its use of deemed values in combination with quotas. In cases where deemed values are paid and the catch exceeds the TACC, the deemed value (not the quota) in effect becomes the instrument controlling the level of catch. This recognition clarifies that the same principle that should apply to the setting of the target stock and TACC—that of representing the value of leaving fish in the stock—should also apply to the setting of deemed values, as these are just two different instruments for achieving the same end. While the concept of value has entered into the implementation of the deemed-value regime, its application to specific species and fish stocks could be improved through refinement and tailoring to the specific characteristics of individual fishery complexes.

I also find that the deemed value system has consequences for the redistribution of value in the fishery from quota owners to catchers and the Government, and raises the question of how associated revenues should be used. Deemed-value revenues are related to, but not equal to, the value lost by owners of quota for the stock on which deemed values are paid.

I raise the prospect that the policy instruments of individual quotas and deemed values could be used in tandem in managing multiple-species fisheries, to improve value and

potentially alleviate some of the rigidity and tension that are otherwise inevitable in an inflexible Individual Transferable Quota (ITQ) system. This recognition is already implicit in the manner in which some TACs are set, and in the implementation of the deemed value system, but systematising this process would increase both value and transparency. Finally, I point out that these different instruments will tend to behave differently when one considers uncertainty in stock size, year-to-year stock recruitment, and other biological and economic variables. How to best employ quotas and deemed values to maximise value in the face of these uncertainties is an important area requiring further research and practical experimentation.

New Zealand has embraced the difficult task of managing a much larger number of species through tradeable quotas than any other country – soon to be over 70 species and 300 individual fish stocks and corresponding quota markets. Rather than leaving lower-value species outside the system, New Zealand has sought to bring all commercial species into the system. While this strategy appears to have been successful overall, it has created increasing tension in the system as catch limits for lower-value species in some cases become binding on higher-value target fisheries. As the target for establishing the TACs for individual fish stocks has been predominantly the biologically-determined Maximum Sustainable Yield (MSY), such tensions are inevitable under the current system.

In summary, the Fisheries Act and broad fisheries policies that implement it contain most of the basic tools necessary for increasing the value received from fisheries, although some modifications will probably be necessary. Many of these tools are, however, not being fully used, or are being used in a manner that is not individually tuned to the specific biological and economic characteristics of fish stocks or fishery complexes. Fish-stock strategies and fishery plans are two new approaches under development to respond to this need. Guiding principles for redesigning the use of available policy tools still need to be fully developed.

I conclude by offering the following recommendations:

- Incorporate into decision-making the principle that fish stocks should be managed at a level where the incremental value of catching fish is equal to the incremental value of leaving fish in the stock, incorporating both commercial and non-commercial values. It becomes the specific role of public policy to provide the incentives for private actors to recognise the stock-value part of this equation, that is the value of leaving fish in the sea.
- Set the ends (stock and catch targets) and design the means of policy (e.g. deemed values) in order to maximise value, not catch.
- Incorporate into stock strategies and fish plans an overall system of bio-economic indicators for categorising and managing stocks.
- Target TACCs differentially for each fish stock based on the biological and economic characteristics of each fishery.
- Set TACCs roughly where you want to go, and use the ITQ system and deemed values to get you there with an appropriate degree of flexibility.

- Select a series of case studies, possibly in the context of stock strategies, to do more thorough bio-economic analysis and follow up with pilot projects to implement stock-tailored management approaches.

- In order to implement many of these recommendations, the Ministry will need to incorporate both biological and economic information and analysis into decision-making processes in a more systematic fashion. Important information components that require tracking include data on: costs, value, stock levels, growth rates, relationships between stock size and costs, and measures of economic and biological uncertainty. A lack of biological and economic information, and an inadequate use of existing information, are hindering better fishery outcomes. Collecting and using such information in a cost-effective manner present a significant challenge.

- Evaluate existing TACCs with an eye toward reducing TACCs that are not currently binding. Non-binding TACCs are an indication of low profitability and conditions approaching open access.

- Reassess the TACCs for fish stocks that are taken primarily as incidental catch and acting as a constraint on target fisheries. In setting new TACCs for these stocks, have regard for achieving the value-maximising yield from the fishery, including the value of related target stocks, and recreational and customary fishing rights, subject to the constraint that TACCs not be set above a level that would compromise the long-term viability of the stock.

- Base deemed values should be set to approximate the unit stock value (and unit profit) corresponding to the target catch. In cases where the target catch is equal to the TACC, the deemed value should therefore be set to approximate the price of Annual Catch Entitlement (ACE), when catch is about equal to the TACC.

- TACCs should be set to reflect the value-maximising (or other desired) target catch, and deemed values should be set on an iterative basis to achieve that target on average. Repeated catches above the TACC are either a signal that the TACC is inappropriately set, or that the deemed value is too low. Likewise, TACCs that are not binding on catch are probably set too high.

- The increments of the differential deemed-value schedule should be based on the biological and economic characteristics of individual fish stocks—in terms of both the catch increments and value increments—in principle to reflect the increasing value of leaving fish in the stock.

- Redefine the basis for applying differential deemed values by transitioning from deemed-value brackets based on individual catch-to-ACE ratios to brackets based on aggregate catch-to-TACC ratios. Rates would apply equally to all fishermen based on end-of-year values, possibly updated throughout the fishing year. This would ensure that all fishers faced the same price for taking fish from the stock.

- Move the end-of-year ACE true-up date from October 15th to November 15th, to allow more time for end-of-year balancing of catch with ACE. Transaction costs in quota markets can also be reduced through measures such as promotion of on-line trading and use of public auctions.

- It should be investigated whether deemed values can be recycled to make deemed values a more distributionally-neutral instrument, without undermining the incentives deemed values are designed to create.

- Where appropriate, reinvest deemed-value payments in research and other efforts that lead to improved knowledge and increased value of associated stocks. This acknowledges that deemed-value payments are related to the value of catch in excess of TACC for a particular stock, and returns that value to the stock.

- The current degree of uncertainty about many stocks, and the importance of knowledge about stock size in determining appropriate TACCs and deemed-value levels, indicate that there is a high value in increased monitoring of stock abundance and environmental and economic conditions.

- Increase non-compliance penalties and enforcement in tandem with deemed values and rates of overcatch.

- Require reporting of ACE and quota prices to reflect true prices, so that this important source of information becomes a more accurate measure of commercial value.

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1 INTRODUCTION

Economists Gordon (1954) and Scott (1955) identified the “common pool” problem of fisheries 50 years ago, predicting that open access would lead to excess fishing effort, dissipation of economic profit from fishing, and inefficient depletion of fish populations.[1] Unfortunately, this prediction has been borne out. Throughout the world approximately 25% of the major fish stocks are currently in jeopardy of collapsing (FAO 2001).

Until the early 1980s, most fisheries were either completely unmanaged or managed under command-and-control regulations that governed the size of vessels, types of net, season length, and which areas were open to fishing. Such regulations fail to effectively limit the number of vessels or the level of fishing effort, and they encourage fishermen to work around equipment constraints. Under these regulations, a fisherman has no sense of ownership over the fish until they are caught. This creates a race to fish, and the historical record shows that the race will continue until fish stocks are depleted and the numbers and types of vessel in a fishery exceed its viable capacity.

Individual transferable quota (ITQ) systems are a promising means to correct this market failure.[2] They limit fishing operations by setting a total allowable catch (TAC), which is typically allocated in perpetuity to fishing participants based on historical catch. Because the aggregate catch is capped and fishermen have access to a guaranteed share of the TAC, this approach significantly reduces the likelihood that fish stocks are overfished and the incentives to engage in a race to fish.[3] In addition, when transferability of the shares is permitted, the least efficient vessels will find it more profitable to sell their quotas rather than fish them. Over time, this should both reduce excess capacity and increase the efficiency of vessels operating in the fishery.

Since the late 1970s and early 1980s, when countries began establishing exclusive economic zones in the oceans off their coasts, more than 15 countries have followed New Zealand’s and Iceland’s lead in establishing ITQ systems. To date, ITQs are used to manage over 80 species, including four in the United States. New Zealand alone now has over 70 species within its ITQ system. Although assessments of these programmes are generally positive, their future is unclear.[4] For example, until

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[1] Material for this introduction and background on the New Zealand QMS is drawn in part from Newell, Sanchirico, and Kerr (2004).

[2] As discussed further in Section 3, landing fees or other price-based policies represent an alternative to quantity-based policies such as tradeable quota.

[3] Several benefits arise from allocating shares of the TAC to individual fishermen, including relaxing of controls on season length and the ability of fishermen to shift to quality from maximising quantity. For example, since the introduction in 1994 of an ITQ system in the Alaskan halibut fishery, the season length has grown from two 24-hour openings to more than 200 days. The flexibility to time fishing trips when port prices are higher, and the elimination of large supply gluts of fresh product, have resulted in increases in price per pound of more than 40% (Casey et al. 1995). The focus on quality is also evident in New Zealand, where fishermen have changed catching methods in the red snapper fishery in order to sell their catch on the highly profitable Japanese live fish market (Dewees 1998).

[4] The existing literature on ITQ programmes, although extensive, is dominated by description and anecdotal evidence of their effects (NRC 1999). There are, however, a few notable exceptions. Recent work by Grafton et al. (2000) uses firm-level data from the British Columbia halibut fishery spanning pre- and post-ITQ periods to estimate a stochastic production frontier. They find evidence of

recently a moratorium on implementing new ITQ systems has been in place in the U.S. since 1996, while policymakers have debated various design elements, including whether quota should be transferable.[5]

In previous research, using a 15-year panel dataset from New Zealand that covers 33 species and more than 150 markets for fishing quotas, Newell et al. (2004) assessed trends in market activity, price dispersion, and the fundamentals determining quota prices. They found that market activity appeared sufficiently high to support a reasonably competitive market for most of the major quota species and that price dispersion had decreased over time. They also found evidence of economically rational behaviour through the relationship between quota lease and sale prices and fishing output and input prices, ecological variability, and market interest rates. Controlling for these factors, their results showed an increase in quota prices, consistent with increased profitability. Overall, the results suggest these markets are operating reasonably well, implying that ITQs can be effective instruments for efficient fisheries management.

This report examines how New Zealand has managed the complex task of implementing an ITQ system, not just for a handful of high value species, but also for literally dozens of interrelated species managed as hundreds of individual fish stocks. The New Zealand QMS has thus developed in practice what many fishery economists believe is impracticable.[6] I explore the tools the New Zealand QMS employs to implement this multi-species ITQ system, consider how this approach achieves the goal of value maximisation in fisheries, and offer recommendations for how the system might be further improved to better achieve this goal.

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substantial gains in revenues and producer surplus and predict that the gains in producer surplus could be five times higher if restrictions on transferability were not in place. Other studies quantitatively assess ITQs using relationships estimated on either pre- or post-ITQ catch-effort data to predict changes in fleet restructuring, costs, and revenues (Squires et al. 1994; Wang 1995; Weninger 1998). Such predictions are based on the assumption that the market for fishing rights is operating efficiently. Newell, et al (2004) actually test that assumption, finding that the New Zealand lease and quota sale markets reflect a reasonable degree of economic rationality.

[5] In addition to the transferability question, other contentious issues include whether shares should have limited duration, whether shareholders must remain active in the fishery, and whether processors should be allowed to hold quota.

[6] See, for example, Copes (1986), Squires et al. (1998), Squires and Kirkley (1991, 1996), and Boyce (1996) for discussions of the complexity of multi-species ITQ management and its application in particular contexts, and Annala et al. (1991) and Peacey (2002) for how this complexity has been managed in New Zealand.

2 THE NEW ZEALAND QUOTA MANAGEMENT SYSTEM

Although the New Zealand fishing industry accounts for less than 1% of the world's fishing output, it contributes NZ$1.7 billion annually to the New Zealand gross domestic product. Seafood is the fourth largest export earner, and more than 90% of fishing industry revenue is derived from exports. New Zealand is currently considered a world leader in fisheries management, in both environmental and economic terms. This was not the case, however, prior to the implementation of its ITQ system.[7]

Before 1976, New Zealand fishery policy focused primarily on the development of inshore fisheries, leaving offshore fisheries to Japanese, Soviet, and Korean factory trawlers. This focus began to shift, however, after New Zealand extended its exclusive economic zone (EEZ) to 200 miles in 1978, which had the effect of "nationalising" the waters where the offshore fisheries reside. Subsidised loans, duty-free imports of large fishing vessels, and price supports were all used by the Government to promote domestic production in the offshore fishery.

In 1983, after a series of joint-venture programmes with foreign and domestic fishing interests, the New Zealand Government established a quota-based system (known as the enterprise allocation system) for nine companies fishing seven offshore species. Quotas were allocated to each company for a ten-year period based on investment in catch and processing capital although, as described below, this programme was absorbed three years later by a more comprehensive ITQ system. Trading and leasing of shares are reported to have occurred (Sissenwine and Mace 1992), but the system did not provide an adequate mechanism for the transfer of quotas.

While the Government was encouraging the development of offshore fisheries, inshore fisheries were beginning to exhibit signs of overfishing (Crothers 1988). The catch of red snapper, for instance—a commercially important inshore species—had peaked in 1978 and fallen by 43% by 1983. As far back as the early 1960s, the Government had instituted programmes to encourage the growth of the inshore fishing industry, which resulted in increases in fishing effort. These subsidies for an industry in a regulated open-access setting are cited as the main reason for excess capacity and depleted fish populations in the inshore fisheries in the early 1980s (Crothers 1988).

Inshore fisheries depletion, the development of the quota-based programme for offshore fisheries, and the general orientation of the Government in the 1980s toward deregulation, combined to create an atmosphere conducive to fundamental change in New Zealand fisheries management. After several years of consultation with industry, the Fisheries Amendment Act of 1986 was passed, creating New Zealand's ITQ system. Modifying legislation has been passed several times since, but the basic structure of the system has remained intact.

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[7] For further history and institutional detail, see the many descriptive assessments of New Zealand fisheries management: Crothers (1988), Clark et al. (1988), Pearse (1991), Sissenwine and Mace (1992), Boyd and Dewees (1992), Annala (1996), Dewees (1998), Batstone and Sharpe (1999), Yandle (2001), Clement & Associates (1997), Bess and Harte (2000), New Zealand Official Yearbook (2001), SeaFic (2001), and Bess (2004).

The ITQ system initially covered 17 inshore species and 9 offshore species, and expanded to a total of 33 species by 1998. Under the system, the New Zealand EEZ was geographically delineated into quota management regions for each species, based on the location of major fish populations and to protect against localised depletion. Rights for catching fish were defined in terms of fish stocks that corresponded to a specific species taken from a particular quota management region. Figure 1 shows the basic fishery management regions. The fish stocks for specific species correspond to combinations or, in some cases subdivisions and/or alterations of, the ten fishery management regions.

As of early 1998, the total number of fishing quota markets stood at 157, ranging from one for hoki *(Macruronus novaezelandiae)* to 10 for abalone.[8] As of 1996, the species managed under the ITQ system accounted for more than 85% of the total commercial catch taken from New Zealand's EEZ. A significant number of new species were brought into the QMS in 1998, and again after 2001, so that as at the end of 2003 there were 61 species and over 320 fish stocks in the QMS. The species in the QMS as of 2003 are given in Table 1.

There is considerable heterogeneity in the characteristics of New Zealand fish stocks, along both economic and ecological dimensions. For example, average life spans range from one year for squid *(Nototodarus gouldi)* to over 145 years for orange roughy *(Hoplostethus atlanticus).* Some species occupy inshore and shallow habitat, such as red snapper *(Pagrus auratus),* and are targeted with trawl gear, set netting, and long lining. Others, such as orange roughy, are found offshore in depths over 1000m and require large vessels and very specialised trawling gear. The quota markets also include shellfish and crustacean fisheries (e.g. abalone, rock lobster, *Jasus edwardsii*) where potting, diving and dredging are the most common harvesting techniques.

The export value of these species currently ranges from about NZ$630 per tonne for barracouta to about NZ$57,300 per tonne for rock lobster. ACE prices currently range from about NZ$130/tonne for barracouta to NZ$16,600 for rock lobster. Quota share prices currently range from about NZ$290/tonne for jack mackerel to NZ$330,300 for paua. Figures 2, 3 and 4 demonstrate the interrelationships between ACE prices, quota share prices, and export prices received for fish. Note that the term "quota ACE" is occasionally used herein to mean simply the annual catch entitlement.

Fishing quotas are generally tradeable only within the same fish stock, and not across regions or species or years, although there have been some minor exceptions in the past.[9] The quota rights can be broken up and sold in smaller quantities and any

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[8] I exclude region 10 because this region was set up for administrative reasons (Yandle 2001) and is rarely fished for any species.

[9] Given the uncertainty around quantity and composition of catch, quota holdings represent a mix of ex-ante and ex-post leases, purchases, and sales to cover actual catch. Before 2001, prior to leaving the dock, fishermen were required by law to hold quotas for their intended target fish stocks. After returning from their trips, fishermen had a number of ways to balance their quota holdings and catches (Clement & Associates 1997). First, fishermen had 30 days after landing their catch to arrange the quota to cover the various species caught. Second, a "bycatch trade-off exemption" allowed fishermen who incidentally took non-target fish to offset the catch by using quota from a predetermined list of target species. Third, quota owners could carry forward to, or borrow from, the next year up to 10% of their quota. A fourth option was to enter into a non-monetary agreement to fish against another's

amount may be leased and subleased. There is no restriction on the number of times quotas can be leased, subleased, or sold. Note that, since 2001, annual quota leases have been supplanted by sales of "Annual Catch Entitlements" or ACEs, which are issued annually by the Government equal to each quota owner's annual quota allocation. Thus the ACE market has now supplanted the previous lease market.

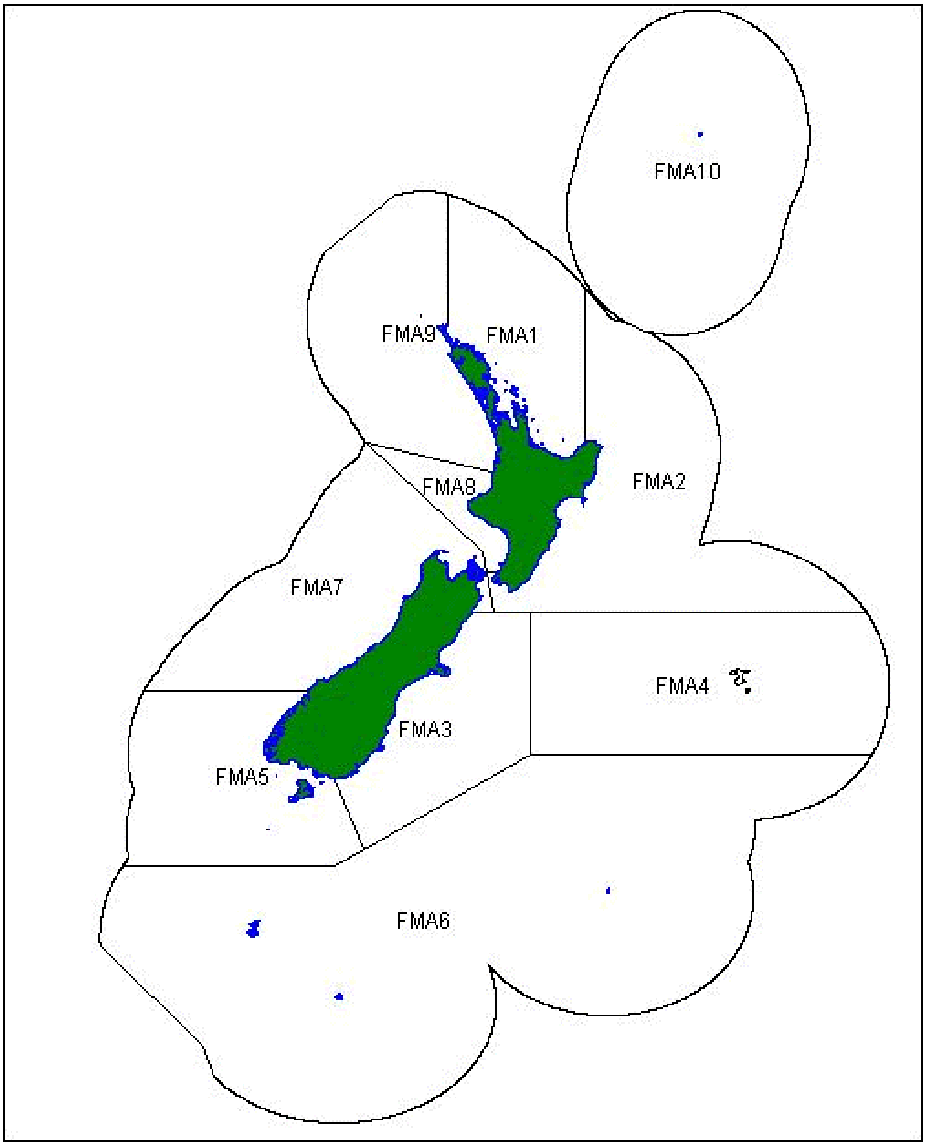

Figure 1. Primary Fishery Management Areas of the Quota Management System

Note: The actual geographical boundaries for individual fish stocks in the QMS do not always correspond to the fishery management areas defined above. In many cases the areas are combined, or occasionally subdivided, according to individual species' characteristics.

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quota. Or a fisherman could surrender the catch to the Government or pay a "deemed value," which was set based on the port price to discourage discarding of catch at sea and targeting stocks without sufficient quota (Annala 1996). As discussed further below, this catch-balancing regime has been considerably simplified since 2001, and the deemed value is the only element that remains in addition to the use of quota.

Table 1. Species in the New Zealand Quota Management System as of 2003

Species	Species code	Entry date	Fish stocks	Species type
Anchovy	ANC	2002	6	Pelagic
Freshwater eels	ANG	2000	4	Freshwater
Barracouta	BAR	1986	4	Mid-depth
Blue cod	BCO	1986	7	Inshore
Bluenose	BNS	1986	5	Inshore
Butterfish	BUT	2002	7	Inshore
Alfonsino	BYX	1986	5	Inshore
Cardinal fish	CDL	1998/99	9	Mid-depth
Cockles	COC	2002/03	4	Shellfish
Rock lobster	CRA	1990	9	Shellfish
Elephant fish	ELE	1986	5	Inshore
Blue (English) mackerel	EMA	2002	4	Pelagic
Flatfish	FLA	1986	4	Inshore
Frostfish	FRO	1998	9	Mid-depth
Garfish	GAR	2002	6	Pelagic
Grey mullet	GMU	1986	4	Inshore
Ghost shark, dark	GSH	1998	9	Inshore
Ghost shark, pale	GSP	1999	3	Inshore
Red gurnard	GUR	1986	5	Inshore
Hake	HAK	1986	3	Mid-depth
Hoki	HOK	1986	1	Mid-depth
Hapuku, bass (Grouper)	HPB	1986	7	Inshore
John Dory	JDO	1986	4	Inshore
Jack mackerel	JMA	1987	3	Pelagic
Kingfish	KIN	2003	6	Pelagic
Leatherjacket	LEA	2003	4	Inshore
Long-finned eels	LFE	2003	1	Freshwater
Ling	LIN	1986	7	Mid-depth
Blue moki	MOK	1986	4	Inshore
Oreo	OEO	1986	4	Deep
Orange roughy	ORH	1986	7	Deep
Oyster	OYS	1996	2	Shellfish
Paddlecrab	PAD	2002	9	Shellfish
Paua (abalone)	PAU	1987	10	Shellfish
Packhorse rock lobster	PHC	1990	1	Shellfish
Pilchard	PIL	2002	6	Pelagic
Queen scallop	QSC	2002	1	Shellfish
Red cod	RCO	1986	4	Inshore
Rubyfish	RBY	1998	9	Mid-depth

Table 1. Species in the New Zealand Quota Management System as of 2003

Species	Species code	Entry date	Fish stocks	Species type
Ribaldo	RIB	1998	9	Inshore
Rough skate	RSK	2003	4	Inshore
Southern blue whiting	SBW	1999, 2000	5	Mid-depth
Scallops	SCA	1992/97, 2002/03	4	Shellfish
School shark	SCH	1986	7	Inshore
Short-finned eel	SFE	2003	1	Freshwater
Gemfish	SKI	1986	4	Mid-depth
Snapper	SNA	1986	5	Inshore
Sea perch	SPE	1998	9	Inshore
Rig	SPO	1986	5	Inshore
Sprat	SPR	2002	4	Pelagic
Squid	SQU	1987	3	Mid-depth
Smooth skate	SSK	2003	4	Inshore
Stargazer (Monkfish)	STA	1986	7	Inshore
Kina	SUR	2002/03	5	Shellfish
Silver warehou	SWA	1986	3	Mid-depth
Tarakihi	TAR	1986	7	Inshore
Trevally	TRE	1986	4	Inshore
Trumpeter	TRU	1998	9	Mid-depth
Blue warehou	WAR	1986	5	Mid-depth
White warehou	WWA	1998	9	Mid-depth
Yellow-eyed mullet	YEM	1998	9	Inshore

Note: There were 61 species in the QMS as at the end of 2003. At least 12 more species entered it in 2004. The number of fish stocks does not include those for region 10.

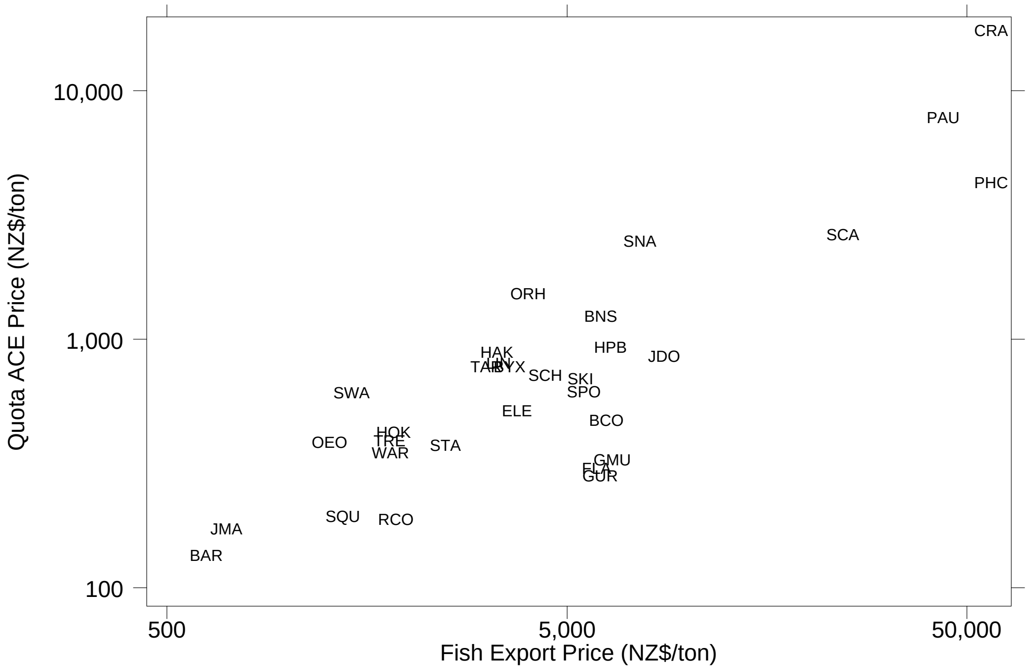

Figure 2. Quota ACE Prices Versus Fish Export Prices

Note: Logarithmic scale. Averages by species for the 2002/2003 fishing year. Year 2003 NZ$. Data symbols are species abbreviations. The relationship indicates that quota ACE prices are approximately proportional to the price of the fish, at a ratio of about 20%. Only species for which export price (per greenweight tonne) data have been compiled are included. Tons are metric tonnes.

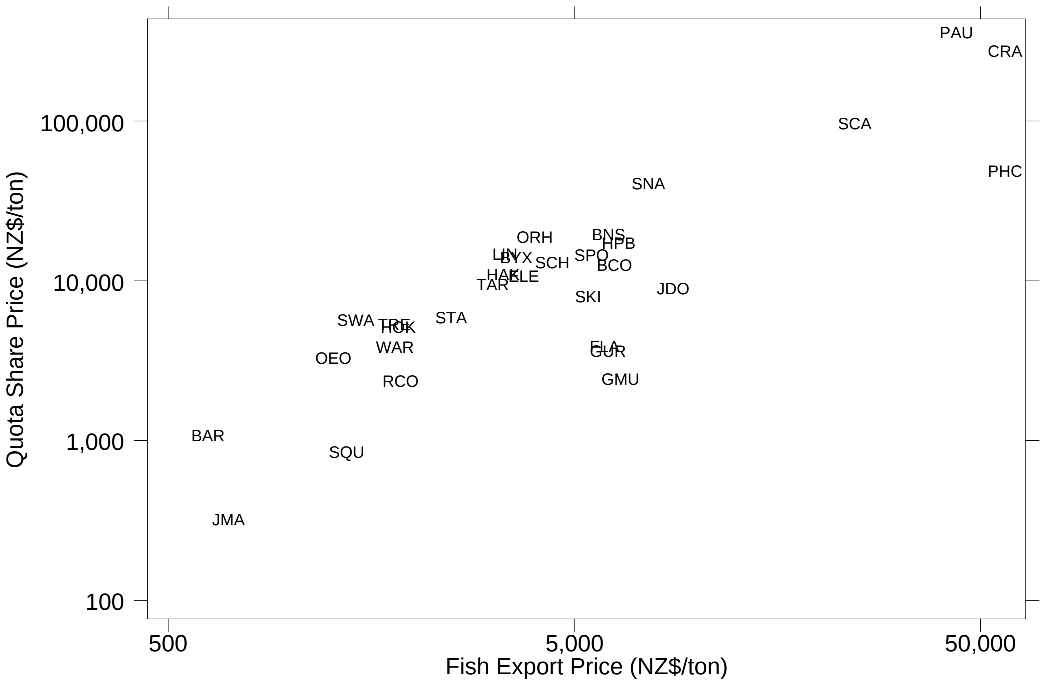

Figure 3. Quota Share Prices Versus Fish Export Prices

Note: Logarithmic scale. Averages by species for the 2002/2003 fishing year. Year 2003 NZ$. Data symbols are species' abbreviations. Only species for which export price (per greenweight ton) data have been compiled are included.

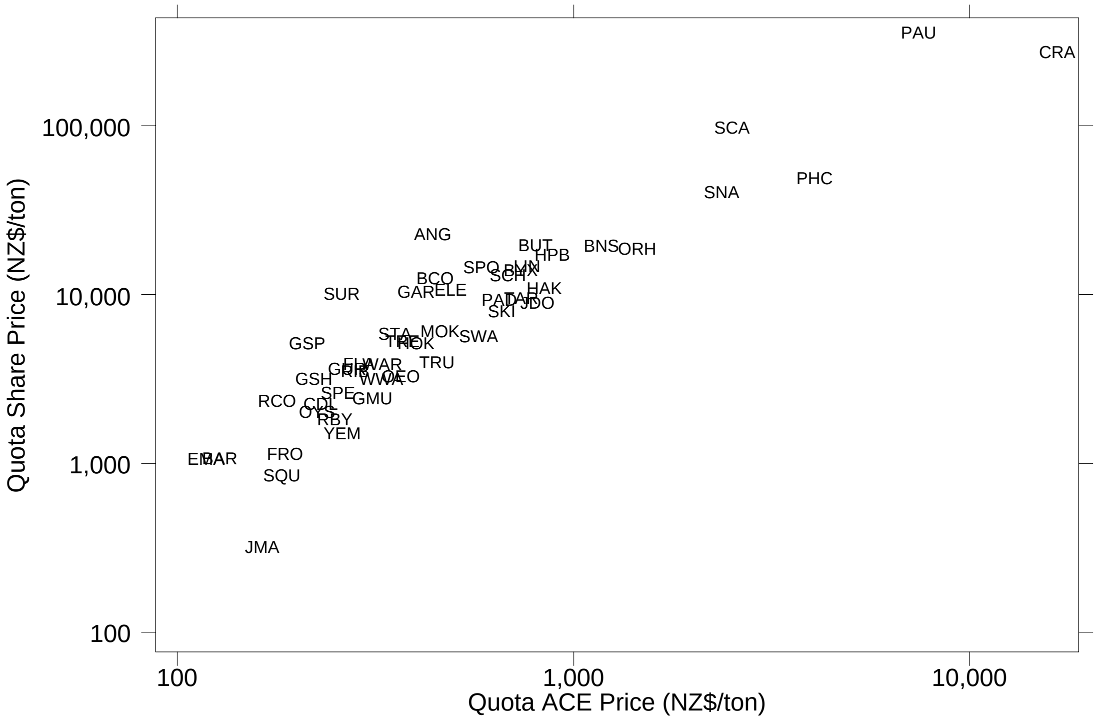

Figure 4. Quota Share Prices Versus Quota ACE Prices

Note: Logarithmic scale. Averages by species for the 2002/2003 fishing year. Year 2003 NZ$. Data symbols are species' abbreviations. The relationship indicates that quota share prices were about 15 times quota ACE prices on average, which is consistent with the present value of a perpetuity of (constant value) ACE at about a 6-7% real discount rate.

As described further below in Section 4, the New Zealand Ministry of Fisheries sets an annual total allowable catch for each fish stock based on a biological assessment as well as other relevant environmental, social, and economic factors. The TACs are set with a goal of moving the fish population toward a level that will support the largest possible annual catch (i.e. maximum sustainable yield). The total allowable commercial catch (TACC) is determined after an allowance for recreational and other non-commercial fishing. Consequently, the TAC (and TACC) will differ from the economically efficient level that takes into account the intertemporal stock externalities inherent in common pool resource extraction.[10] There are also legislative limits on aggregation for particular stocks and regions, and limitations on foreign quota holdings.[11]

Compliance and enforcement are undertaken through a detailed set of reporting procedures that track the flow of fish from a vessel to a licensed fish receiver (on land) to export records, along with an at-sea surveillance programme including on-board observers (Boyd and Dewees 1992).[12]

[10] For many species (e.g. offshore fish stocks) there is no interest from recreational anglers and almost the entire TAC is allocated to the commercial sector, typically with an allowance for other mortality associated, for example, with underreporting and/or discards.

[11] Initially, the aggregation limits were on holding quota. Substantial changes were written into the 1996 Fisheries Act, one of which was changing the limits on holdings to ownership levels. The 1996 legislation also relaxed the aggregation limits for particular species and region combinations.

[12] In a survey of inshore fishermen based out of Auckland in 1987, Dewees (1998) found that 40% thought enforcement and 66% thought "highgrading" were potential problems with the ITQ

Individual quotas were initially allocated to fishermen as fixed annual tonnages in perpetuity, based on their average catch level over two of the years spanning 1982-1984 (Yandle 2001). To increase industry support for the plan, the Government allocated the quotas free of charge and allowed fishers to petition for a change in their initial allocation. The main reasons for introducing the system, however, were to rebuild the inshore fisheries and improve the economic condition of the industry. By denominating quotas as fixed tonnages, the Government was counting on its ability to purchase quotas on the open market if it wanted to reduce the total catch from a fishery.

Because the initial allocations—which were based on past catch histories—exceeded the maximum sustainable yield in some fisheries, the Government bought back quota on two occasions prior to the implementation of the programme. Purchasing these quotas turned out to be expensive, however, as the Government paid NZ$45 million for 15,000 tonnes of quotas from the inshore fisheries (Clark et al. 1988).

Faced with the prospect of spending another NZ$100 million when it became clear that additional TAC reductions would be necessary for certain stocks (Sissenwine and Mace 1992), and after prolonged negotiations with industry, the Government switched from quota rights based on fixed tonnages to denominating the quotas as a share of the TAC beginning with the 1990 fishing year.[13] In doing so, the burden of risk associated with uncertainty over future TAC levels was moved from the Government to the industry. At the same time, the industry received compensation payments over the period to 1994 for TAC reductions (Annala 1996).

During the development phase and first years of the QMS system, the Maori tribes, or Iwi, contested whether the New Zealand Government had the legal authority to claim ownership of the fish resources and, therefore, allocate individual quota.[14] Their claims stemmed from the Treaty of Waitangi that was signed in 1840 between the Maori Chiefs and the representatives of the Queen of England, and set out the relationship between the colonial power and the Maori (Clark et al., 1988). In the second article of the Treaty, the Queen of England granted the Tribes of New Zealand the exclusive rights to their possessions, which included land and fishery resources (Yandle, 2001).

With the Treaty in hand, Maori were granted an injunction against the Government commencing a round of negotiations (Yandle, 2001). These negotiations culminated in the Maori Fisheries Act 1989 and the 1992 Treaty of Waitangi Settlement, which provided Maori with 10 percent of the existing quota, and a guaranteed 20 percent of any new stocks that were to be brought in under the QMS system. In addition, the

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management system. Highgrading is the practice of maximising the quality of the catch to be counted against one's quota by dumping less valuable fish overboard. These numbers dropped to 21% and 25%, respectively, by 1995. In any event, all regulations based on landings, whether market-based or not, are susceptible to issues associated with reporting, which could stem from fishers throwing less valuable fish back or transferring their catch to vessels at sea.

[13] The details of the "Accord'" that resulted from these negotiations can be found in Annala (1996). Some of the other important features are the freezing of the resource rentals at 1990 levels for four years, compensation packages were developed for quota holders who were greatly impacted by the reductions, and the industry agreed to large reductions in the orange roughy TAC levels.

[14] In 1988, Maori comprised 10 percent of the 3.25 million population of New Zealand.

Government purchased for Maori half of Sealord Products, which is the largest seafood company in NZ, at a price of NZ$150 million. To manage these resources, the Treaty of Waitangi Fishing Commission was established.

In conjunction with the Treaty of Waitangi Settlement, the Government switched from collecting resource rentals to cost-recovery fees. The resource rentals were initially set up to collect some of the windfall gains the initial quota holders would experience, and to keep the rents in the fishery from being capitalised into the quota price.[15]

Early on the Government thought that revenues raised from the resource rentals would outweigh the administrative costs associated with the QMS. However, this never materialised, for two reasons. First, the resource rentals were initially set at low levels to increase industry buy in. Second, the Government considerably underestimated the costs of rationalising the fishery. Having already frozen them at low levels for four years as part of the compensation package in the 'Accord', the Government abolished the resource rentals in 1992 and created cost-recovery fees.[16]

The next major piece of legislation was the Fishery Amendment Act of 1996. Unlike the previous legislation, it focused on more detailed refinements to the system. Prior to 1996, lenders were reluctant to accept quota as security, as there was no official quota registry that provided the support needed to use the quota as collateral (Pearse, 1991). This was addressed in 1996 when a quota registry was created. Other additions and changes were included but, due to industry opposition, many have only slowly been implemented, if at all. Further details on other refinements in the Fisheries Act 1996 are described in Sections 4 and 5 below. Peacey (2002) provides an overview of the past and present implementation of the catch-balancing regime in New Zealand.

The New Zealand quota-management system is a dynamic entity that has had multiple refinements since its beginnings about 18 years ago. The system's characteristics evolved from fixed tonnage to proportional quota, and from resource rentals to cost-recovery fees, but the basic tenets of the system—the setting of a total allowable catch and leaving the market to determine the least-cost harvesting methods—have remained intact, as have the goals to manage the fish stocks in a sustainable manner and to improve the economic conditions of the fishing industry.

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[15] The allocation of quota can be viewed as a transfer of a public resource to private parties, and to stop some of the rents from being capitalised into the asset price, and therefore transferred from the Government to the initial owners, the resource rental was to be levied.

[16] These two types of fee are more than just semantically different. Resource rentals imply that the Government owns the fish resources, which was then being contested by the Maori. In addition, cost-recovery fees are to be used solely for the purpose of off-setting the costs associated with administering the QMS system. Symbolically, the semantic switch also empowered the industry to begin requesting more input into the management of the system as many argued that, if they were going to pay for it, they would like a say in how the money was used.

3 MAXIMISING THE VALUE OF FISHERIES

The Goal of Value Maximisation as Expressed in NZ Fisheries Policy

The Public Finance Act 1989 provides the legislative basis for improving the quality and transparency of public management in New Zealand. The driving principle behind the Public Finance Act is a shift in focus from what departments consume to what they produce. Among other things, this reform requires budgeting and reporting to be done on an output basis, and requires a "Statement of Intent" and statements of service provision that clearly set out the outcomes to which the Ministry aspires and the supporting outputs it intends to produce.

Within this context, the New Zealand Ministry of Fisheries has articulated a single overarching goal or outcome:

Fishery Outcome (*Strategic Plan 2003–2008,* p. 8)

Maximise the value New Zealanders obtain through the sustainable use of fisheries resources and protection of the aquatic environment.

While the Ministry has begun laying out some of the components of value and the means of its achievement, the process of developing an outcomes-based framework that more fully conceptualises this goal and operationalises its attainment is still very much a work in progress. For example, the *Strategic Plan 2003–2008* (NZ Ministry of Fisheries 2003b) and the *Statement of Intent 2003/08* (NZ Ministry of Fisheries 2003a) identify the following components of value:

- Value of preserving the aquatic environment;
- Value to Maori of sustainable aquatic resources;
- Value gained from pleasure of recreational fishing;
- Value of a thriving seafood industry; and
- Value of flourishing communities with a fisheries sector at their heart.

The *Statement of Intent* (p. 4) and *Strategic Plan* also set forth three strategies for attaining the key elements of this value-based outcome:

- Protect the health of the aquatic environment;
- Enable people to get the best value from sustainable and efficient use of fisheries; and
- Ensure the Crown delivers on its obligations to Maori with respect to fisheries.

A focus on maximising value through sustainable utilisation can be traced in part to the fundamental guiding purpose of the Fisheries Act of 1996:

Fisheries Act 1996, Section 8. Purpose –

(1) The purpose of this Act is to provide for the utilisation of fisheries resources while ensuring sustainability.
(2) In this Act –
'Ensuring sustainability' means –
(a) Maintaining the potential of fisheries resources to meet the reasonably foreseeable needs of future generations; and
(b) Avoiding, remedying, or mitigating any adverse effects of fishing on the aquatic environment:
'Utilisation' means conserving, using, enhancing, and developing fisheries resources to enable people to provide for their social, economic, and cultural wellbeing.

A Bio-Economic Framework for Guiding Value Maximisation

The field of economics studies how, when faced with scarce resources, individuals and society can make choices to achieve maximum value. Given this focus, it is not surprising that economics might provide useful frameworks for guiding fisheries policy and management in the quest for value maximisation. Since economists Gordon (1954) and Scott (1955) identified the "common pool" problem of fisheries 50 years ago, and especially since the 1970s,[17] economists have been engaged in clarifying why unregulated fisheries tend to destroy value, and in setting out possible policy goals and tools that might be used to maximise the value that is obtained from fishery resources.

The standard approach to economic analysis of policy begins with the identification of the "market failure" to which the policy is being directed. The basis for this approach lies in the principle that, *if* the unfettered market is employing resources in a manner that maximises value, then there is no need for policy intervention from the perspective of economic efficiency.[18] It is well known, however, that unregulated "common property" or "open access" resources will tend to be overexploited, that there will be excess effort, and that value will be diminished.

In the case of unregulated fisheries, the most basic market failure takes the form of a "negative externality", which is a cost that is imposed by one economic actor on another, for which no compensation is paid. The negative externality or "external cost" emanates from conditions where the individual fisherman does not take account of the value of leaving fish in the sea, where they can reproduce and create more fish in the future. If he were to leave the fish in the sea, under competitive open-access conditions another fisherman would have an incentive to simply catch the fish, which the first fisherman cannot stop him from doing as he has no property right. Thus, the economic profit or "rent" associated with the natural growth of fish tends to be dissipated in an unregulated fishery. In this sense, fish are like an asset. If left in the sea they generate a return in the form of more fish. But, unlike a financial asset, if the

[17] It was in 1973, for example, that Francis Christy put forth the idea of individual fishing quotas (Christy 1973).
[18] There may of course be non-efficiency rationales for policy, including concerns over the distribution of costs and benefits, as well as non-economic policy criteria.

individual fisherman has no claim on that return he will not have any incentive to save the fish.

In addition to the common property externality we have focused on thus far, there may be other non-financial externalities that are relevant to fisheries management. These additional externalities could be associated with the polluting effects of vessels, broader ecosystem effects, damage to the aquatic environment, loss of species, and other external costs that reduce the value individuals and firms receive from the marine environment, without compensation.

To understand how these external costs influence the value received from fisheries, and to begin moving toward a framework for identifying solutions, one can make use of Figure 5. This is analogous to industry supply and demand curves used in standard economic analysis of everyday markets, but adapted to the case of fisheries. The horizontal axis represents the aggregate level of catch (in tonnes) of a particular fish stock that is taken on a recurring annual basis. The vertical axis represents the per-unit value associated with catching that amount of fish from the stock each year (in $/tonne). It is a highly simplified representation of a complex, dynamic problem, but simplification is often most useful precisely in such cases.

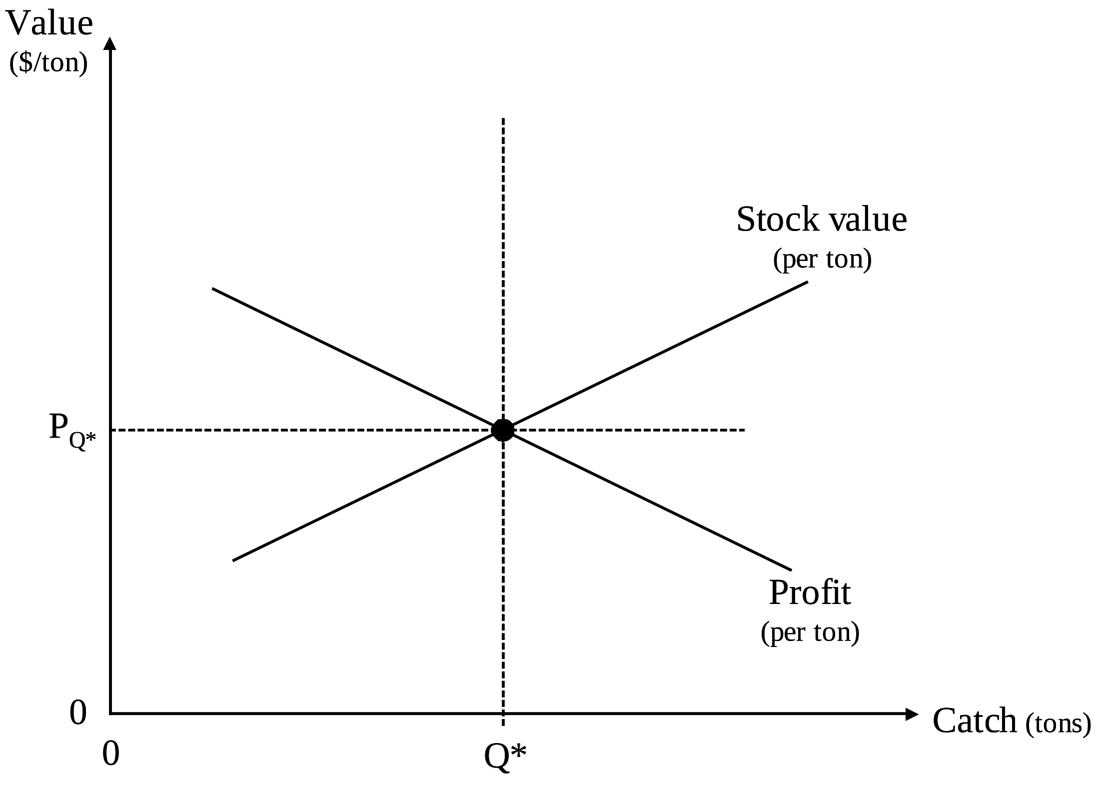

Figure 5. Optimal Catch Levels Through Quotas or Fees

Note: Q^* represents the optimal catch level, where the unit profit from the catch equals the value of leaving fish in the stock (i.e. the external cost of fishing).

The downward-sloping line in Figure 5 represents the incremental (or marginal) per-unit profit obtained from fishing, equal to the price per tonne of fish minus the cost of catching it. It is downward sloping to represent the typical situation where the profits per tonne from catching additional fish tend to decline as more fish are caught, the stock is depleted, and the incremental effort expended to catch additional fish rises.[19] It is analogous to a demand or marginal benefit curve in standard economic analysis, and in the presence of a quota regime for fisheries management can be taken to represent the aggregate demand function for quota (as it would represent the marginal willingness to pay for quota). Note that at some point the unit-profit function reaches zero, which corresponds to the catch that would be expected in an open-access fishery, where profits are fully dissipated. For non-commercial uses, the unit-profit function would simply represent the incremental value of catching fish.

The upward-sloping line in Figure 5 represents the external cost of fishing or, conversely, the (marginal) value of leaving the fish in the stock. As described above, this represents the loss of value from not leaving the fish in the sea so that it might reproduce and generate future fishing returns. The value of leaving the fish in the stock should also include any value associated with non-consumptive uses, such as recreational value or values associated with species preservation. It is upward sloping to represent the typical case where the incremental value of leaving fish in the sea tends to increase as catch increases and stocks are depleted. This is due, both to the biological character of fisheries, which tend to exhibit higher reproductive rates at smaller stock sizes, and to the other external costs of fishing, which it is reasonable to assume increase at an increasing rate as catch levels expand and stocks decline. In the fisheries economics literature, this is referred to as the "marginal stock effect" or "marginal user cost". At an intuitive level, this stock value function captures the idea that the societal value of leaving more fish in the sea becomes increasingly high as the stock of fish becomes more depleted.

In an unregulated fishery, the fisher tends to care only about the profits from catching fish, not the external cost function or value of leaving the fish in the stock. It is the role of public policy to design instruments that "internalise" these external costs to the fisher so that total social value is maximised. In other words, the role of policy is to represent the stock value function, as this is the value that tends to be ignored when the private market is left in a "laissez faire" state.

Value-Maximising Stocks and Catch

Putting these two marginal-value functions together in typical economic fashion, one finds the catch level that maximises total value at the point where the two lines intersect. This corresponds to optimal catch level Q*, where the marginal profit from fishing just equals the marginal external cost of that fishing. If catch were to expand beyond Q*, the marginal external cost would be higher than the marginal private benefit (profit), thereby reducing total value. If catch were to contract below Q*, on the other hand, there would be "value left on the table", because the incremental value of increasing catch would more than offset the external cost of doing so.

[19] In this sense, the declining profit function is a manifestation of the link between stock size and catch per unit effort. Just as the catch per unit effort tends to decline as stock size declines (and is thus often used for stock assessment purposes), the unit profit function declines as catch increases.

One can also think of this value maximisation decision as consisting of a trade-off between catching more fish or leaving it in the sea. Again, the value of fishing resources is maximised when the value of catching additional fish just equals the value of leaving that fish in the sea. Note that the marginal value at this point is given by P_{Q*}, as it corresponds to the value at the optimal catch level Q*.

The quantity Q* is often called the Maximum Economic Yield (MEY)[20], in contrast to the Maximum Sustainable Yield (MSY), which corresponds to the maximum *catch* level that can be continually sustained rather than the maximum *value of catch* that can be continually sustained. It is always the case that, in the long term (or steady-state), MEY is no greater than MSY, and is typically less than MSY. MEY cannot be greater than MSY simply because MSY is a *biological maximum* and any catch consistently above MSY will inevitably deplete the stock, and thus is by definition not sustainable. This is shown by the stylised representation of the relationship between the stock biomass and the annual natural fish production level shown in Figure 6.

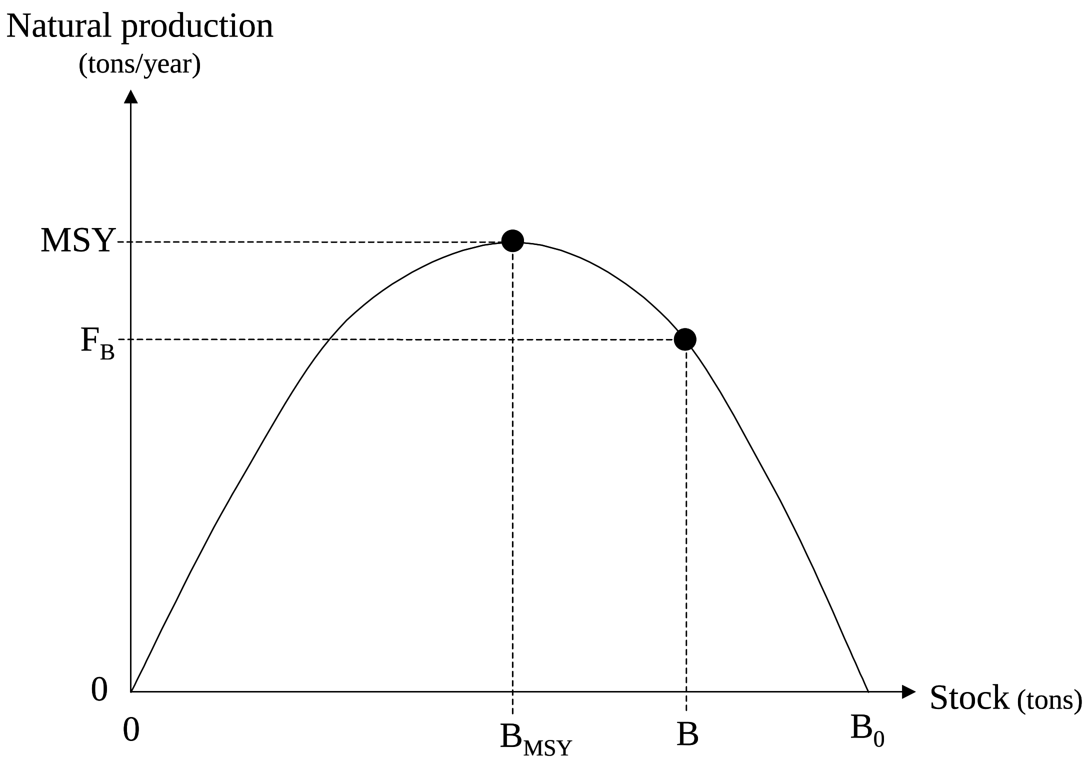

Figure 6. Relationship Between Fish Stock Biomass and Natural Production

Note: F_B represents an arbitrary point on the function that relates the annual amount of natural fish production possible with stock biomass B. B_{MSY} is the stock that can support the maximum annual production of fish on a sustained basis, also known as the maximum sustainable yield (MSY). B_0 represents the virgin biomass level, also known as the carrying capacity because it is the natural maximum stock to which the stock evolves when left in its natural virgin state.

[20] Note that MEY is sometimes taken to mean the economic optimum assuming a zero discount rate.

While the determination of MSY can be based solely on biological modelling, determining MEY requires economic information in addition, combined with bio-economic modelling. The standard bio-economic model used for determining MEY is detailed further in the Appendix and in many fisheries economics texts (see e.g. Clark 1990). The following relationship describes, in words, the fundamental equation determining the stock that supports MEY. That is, the following condition will hold when the stock is managed at a level that maximises the value of the fishery:

Relationship governing stock that supports MEY

$$V = \frac{\text{(change in } F \text{ with unit increase in } B\text{) x } V}{\text{discount rate}} - \frac{\text{(change in } c \text{ with unit increase in } B\text{) x } F}{\text{discount rate}}$$

where:

V = unit profit from catch ($/tonne)
F = annual natural fish production from stock (tonnes/year)
B = biomass of stock (tonnes)
c = unit cost of catch ($/tonne)

The left-hand side of this relationship is the downward-sloping unit profit function in Figure 5, while the right-hand side is the upward-sloping stock value function in the same figure. The point at which these two values are equal gives the stock size that corresponds to the catch level at the intersection of the two lines in Figure 5. The intuition for this relationship is that, at the value-maximising stock level, the incremental value of catching fish should equal the incremental value of leaving fish in the sea.

It is clear that the unit profit from catch (on the left-hand side of the equation) represents the value of catching the fish. The value of leaving the fish in the sea (the right-hand side of the equation) has two components. The first represents the value associated with future natural production from the fish left in the stock. It is multiplied by unit profit V to convert tonnes into value, and is discounted to reflect the present value of a future stream of growth. Let's call this the *growth value*.

The second component represents the value associated with reduced fishing costs that comes from a larger stock. It is also discounted to reflect the present value of a future stream of cost savings. Since c actually decreases when the fish stock increases, the second component is also positive. Let's call this the *cost-stock effect*. The growth value and the cost-stock effect together comprise the commercial value of leaving the fish in the stock. In addition to these values, if there is additional non-commercial value associated with leaving additional fish in the sea, then this value would be added to the right-hand side of the equation in similar fashion.

This relationship for MEY can be compared to the condition describing MSY:

Relationship governing stock that supports MSY

$$\text{change in } F \text{ with unit increase in } B \quad = \quad 0$$

This target coincides with the maximum of the fish production function in Figure 6, because changing the *stock in either direction* from B_{MSY} will lower annual production. In mathematical terms, the left-hand side of the MSY equation equals the slope of the production function, which is equal to zero (i.e. is flat) at the maximum.

The difference in the MEY and MSY targets can perhaps best be seen by rearranging the MEY relationship as follows:

Relationship governing stock that supports MEY (rearranged)

$$\begin{array}{c}\text{change in } F \text{ with unit}\\ \text{increase in } B\end{array} = \frac{(\text{change in } c \text{ with unit increase in } B) \times F}{V} + \begin{array}{c}\text{discount}\\ \text{rate}\end{array}$$

Comparing these two equations makes it clear that MSY will equal MEY only if both the stock-cost effect and the discount rate are zero or if, by some coincidence, the two terms on the right-hand side cancel one another out. Referring back to Figure 6, the change in natural fish production (*F*) with unit increase in the stock (*B*) (i.e. the slope of the production function) will be positive when the stock is below $B_{MSY,}$ and will be negative when the stock is above B_{MSY}.

With this in mind, one can see that B_{MEY} will be greater than (and to the right of) B_{MSY} when the right-hand side of the rearranged MEY equation is negative. And B_{MEY} will be less than (and to the left of) B_{MSY} when the right-hand side is positive. Recalling that the first term on the right-hand side is negative (because costs tend to fall with higher stocks), the entire right-hand side of the expression will be negative if the first term is bigger than the second term; that is the cost effect dominates the discounting effect. If the discounting effect dominates the cost effect above, then B_{MEY} will be less than B_{MSY}.

Whether the stock size corresponding to MEY is greater or less than the stock size corresponding to MSY therefore depends on the specific biological and economic characteristics of each individual fishery. As is summarised in the Appendix, standard bio-economic models of fisheries suggest the following variables are key determinants of the MSY and MEY relationships identified above: natural growth rate of fish; virgin biomass of fish stock; price of fish; unit cost of fishing; relationship between costs and the stock size; and the discount rate. At least the first two biological variables are necessary to determine MSY, while the remaining variables are also needed to determine MEY.

By evaluating the above expression governing MEY, and by exploring specific functional forms for the natural production function and the cost function, one can establish some basic principles regarding the size of the MEY stock, and for targeting stocks for more detailed analysis if MEY is likely to deviate significantly from MSY.

Under standard assumptions, the stock size corresponding to MEY will tend to be greater when:

- (i) the growth rate of the fish stock is greater;
- (ii) the price of fish is smaller;
- (iii) the unit cost of fishing is greater;
- (iv) the unit profit from fishing is smaller;
- (v) the sensitivity of costs to the stock size is greater; and
- (vi) the discount rate is lower.

In other words, low fish prices, high cost effects, low profit per tonne, high fish growth rates, and low discount rates all tend to increase the value of leaving the fish in the stock relative to catching the fish now. I explore each of these bio-economic characteristics of species somewhat further below.

One important biological variable, the natural or "intrinsic" growth rate of fish species, is closely related to the natural mortality rate, which is one of the more readily available pieces of biological information. The mortality rates for most of the species in the New Zealand QMS are listed in Table 2. As the mortality rate rises from about 0.05 to one, the intrinsic growth rate rises from about 0.05 to about 2.5. They are quite close when they are low, but the growth rate is always higher and can be greater than one. The natural mortality rate is also used as an indicator of natural variability in fish stocks, because the population of fast-growing species with few age cohorts can vary widely from year to year. Other things being equal, for species higher in the table with low growth and mortality rates, the stock that supports MEY will tend to be lower relative to MSY than fast-growing species farther down in the table. This is not to say that B_{MEY} will be below B_{MSY} for slow-growing species, but rather that slow growth pushes the value-maximising stock in that direction.

Figure 4 shows the ACE and quota prices for most fish stocks in the QMS as of 2003. The species with high prices and high average unit values are in the upper right of the figure, while species in the lower left tend to have relatively low commercial value per tonne. Other things being equal, therefore, the higher-value species illustrated there would tend to have MEY near to MSY, whereas the low-value species are more likely to have a stock size supporting MEY that is higher than B_{MSY} (unless the species is a low-value bycatch stock that constrains a higher-value target species, as discussed further below).

Although the choice of discount rate is always a contentious issue in policy analysis, around 5% (real) is a reasonable discount rate to use for this type of analysis. The implicit discount rate inherent in the relative value of ACE and quota share prices, for example, indicates about a 5% real discount rate (see Figure 4).[21] Sensitivity analysis using rates ranging from 2%-7% is desirable. At such levels of the discount rate, under standard modelling assumptions, the stock that supports MEY tends to be near or above the stock that supports MSY, at least for single-species fisheries. The stock that supports MEY might be below B_{MSY} for slow-growing, high-value species with little effect of stock size on fishing costs. As discussed further below, it may also be

[21] Note that, if ACE prices are biased downward relative to quota share prices (e.g. due to a reporting bias), the implicit discount rate found by dividing the ACE price by the share price might be too low.

value-maximising to manage low-value bycatch stocks that constrain catch of target species at levels below B_{MSY}.

Table 2: Mortality Rates of Species in Quota Management System

Mortality (growth) rate	Species	Species Code	Mortality rate (M)
Very low ($M< 0.05$)	Cardinal fish	CDL	0.034
	Orange roughy	ORH	0.045
	Oreo	OEO	0.044-0.063
	Oysters	OYS	0.02-0.10
Low ($0.05<M<0.15$)	Rubyfish	RBY	0.03-0.1
	Sea perch	SPE	0.07-0.13
	Snapper	SNA	0.075
	Grouper	HPB	0.10
	Scallops	SCA	0.10
	School shark	SCH	0.10
	Tarakihi	TAR	0.10
	Trevally	TRE	0.10
	Rock lobster	CRA/PHC	0.12
	Paua	PAU	0.10-0.15
	Blue moki	MOK	0.14
	Bluenose	BNS	0.14
Medium $0.16<M< 0.25$	Hake	HAK	0.18
	Jack mackerel	JMA	0.18
	Ling	LIN	0.18
	Southern blue whiting	SBW	0.20
	Stargazer	STA	0.20
	Flatfish	FLA	0.20-0.25
	Scampi	SCA	0.20-0.25
	Alfonsino	BYX	0.23
	Blue warehou	WAR	0.24
	Rig	SPO	0.20-0.30
	Hoki	HOK	0.25
	Gemfish	SKI	0.25
	Silver warehou	SWA	0.25
High ($0.26<M<0.35$	Blue cod	BCO	0.26
	White warehou	WWA	0.27
	Barracouta	BAR	0.30
	Red gurnard	GUR	0.30
	Grey mullet	GMU	0.33
	Elephant fish	ELE	0.35
Very high $M>0.35$	John dory	JDO	0.38
	Blue (English) mackerel*	EMA	0.40
	Garfish*	GAR	0.44
	Pilchard	PIL	0.46-0.66
	Anchovy*	ANC	0.55
	Frostfish	FRO	0.58
	Yellow-eyed mullet	YEM	0.66
	Red cod	RCO	0.76
	Squid	SQU	1.0
M Unavailable	Butterfish, Kina, Paddlecrab, Ghost shark-dark, Ghost shark-pale, Ribaldo, Smooth Skate, Rough Skate, Sprat, Trumpeter	BUT, SUR, PAD, GSH, GSP, RIB, SSK, RSK, SPR, TRU	

Note: From Annala et al. (2003), except estimates with an asterisk which are based on an estimate for the intrinsic growth rate (K) from Froese and Pauly (2004): Anchovy (K=0.39 for *Engraulis australis*), Blue mackerel (K=0.24 for *Scomber australasicus*, Garfish (K=0.6 for *Hyporhamphus melanochir*), and Spiny dogfish (K=0.07 for *Squalus Acanthias*).

To make things a bit more concrete with respect to the stock-cost effect, it is worthwhile to say something more about what can influence the degree to which stock size affects costs. While this relationship would depend on the complex interaction of species behaviour and fishing methods, an important variable that has an important influence is the aggregation or dispersal behaviour of different fish species.[22] This behaviour influences the relationship between the stock size and the concentration of fish. The concentration of fish in turn has an effect on the cost of fishing because unit costs are typically lower when fish are in greater concentrations. This is the reason that catch-per-unit-effort data are often, but not always, a good indicator of stock size.

The standard starting assumption in bio-economic models is that fish quickly diffuse through a given area, so that the concentration of fish is proportional to the stock size. This is represented by the linear relationship between concentration and stock size in the upper right of Figure 7, labelled "fast diffusing." Under these conditions there tends to be an inversely-proportional relationship between fishing costs and the stock size. Slower-diffusing (sedentary) stocks, represented by the curve in the upper left of Figure 7, tend to have a greater-than-proportional effect of stock size on fish concentrations, and therefore on costs. This category might include certain demersal species and shellfish.

On the opposite extreme are highly-aggregating species, represented by an almost constant concentration of fish regardless of the stock size (see "Highly aggregating" panel in lower right of Figure 7). Pelagic schooling species may fit into this category, as they still tend to pool together in dense schools as a stock is depleted. Once the school of fish is located, the concentration of fish in the school is still high, so that costs are not greatly affected by the stock size. This category might include pelagic species such as Anchovy, English (Blue) mackerel, Garfish, Jack mackerel, Kingfish, Pilchard, and Sprat (see Table 1). Other schooling species might include Barracouta, Grey mullet, Hoki, Blue moki, Orange roughy, Rig, School shark, Silver warehou, and Trevally. This list is suggestive only, and highly tentative; further species-specific analysis would need to be conducted to apply these concepts in practice.

Finally, the intermediate aggregating case is represented in the lower left of Figure 7, where the relationship between concentration, costs, and stock size is less than proportional. That is, stock size does have an effect on costs, but not as great as that for the other fish categories in the top half of the figure.

In summary, the stock-cost effect will tend to be bigger for species exhibiting greater effects of stock size on fish concentration, which will tend to make it more desirable to have a higher stock for these species, other things being equal. The opposite would hold for highly-aggregating species. This is not to say that aggregating stocks should necessarily be managed at lower stock levels, only that cost considerations would not be a dominant reason *for* managing them at high stock levels. This discussion has also glossed over the many different types of aggregation that might occur, including spawning aggregations, juvenile aggregations, loose aggregations, and schooling behaviour more generally. The general concepts still apply, but how these concepts might influence management of specific fish stocks must be the subject of more

[22] See Clark (1985, pp. 42–56) for a very useful discussion of how the "concentration profiles" of different species influence the bio-economic properties of fisheries and management principles.

detailed analysis. These relationships could be estimated, for example, by combining catch-effort data with independent data on stock abundance.

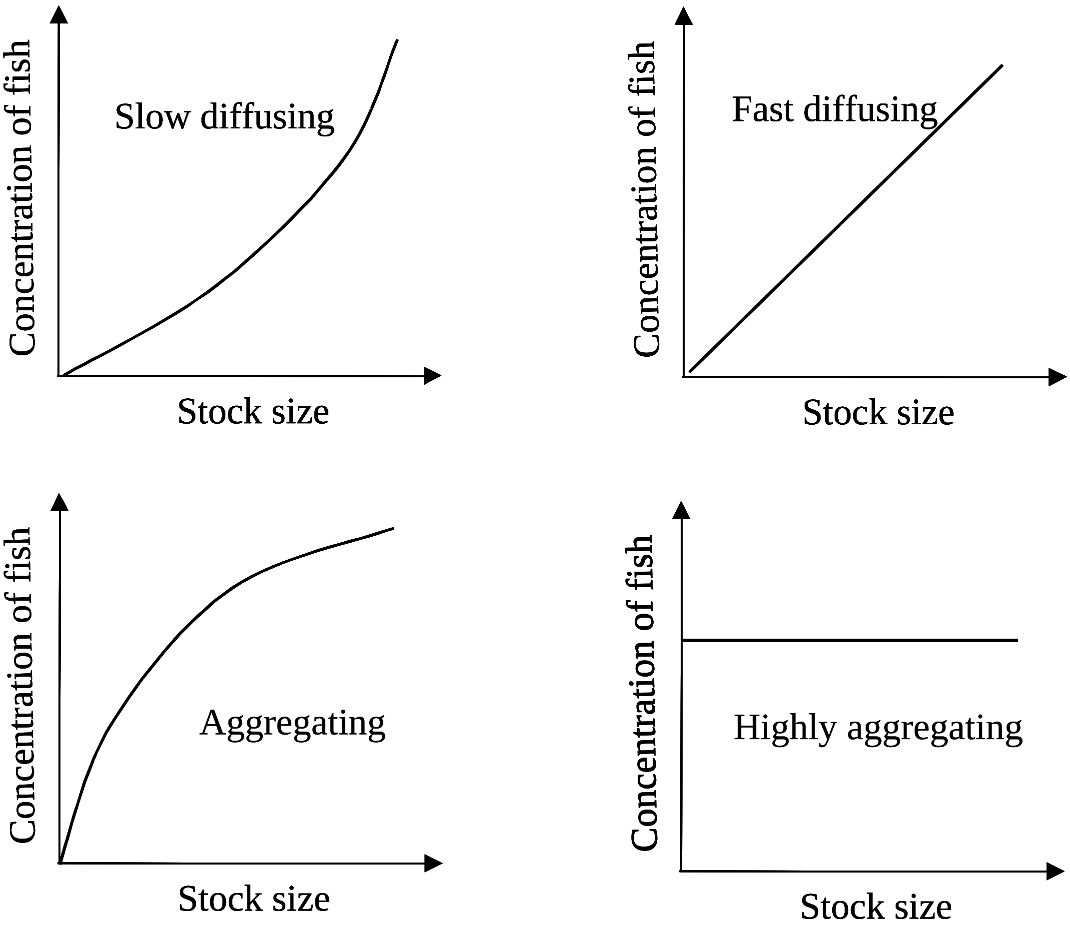

Figure 7. Relationship Between Stock Size and Concentration of Fish

When is the Stock Supporting MEY Likely to be Close to (or Far away from) the Stock Supporting MSY?

A natural question is: what might lead B_{MEY} to be very close to or far from $B_{MSY?}$ If, for example, the economic and biological characteristics of a given fishery are such that MEY is likely to be very close to MSY, there may be little value lost in using MSY as a convenient, and simpler, proxy for the value-maximising MEY.

Based on the discussion above, as long as the discount rate is not high, MEY will tend to be close to MSY for single-species fisheries with high prices relative to costs, high profit levels, and thus high quota prices. The intuition for this result is that, when prices are high relative to costs, costs do not matter very much in the calculation of value, and so the approach that maximises catch, MSY, also tends to maximise value. This is illustrated in Figure 8 for a representation of the Rock lobster stock in region 8 (CRA8). The numerical model underlying the figure assumes a standard bio-economic model (see Appendix) and uses data specifically for CRA8 based on the relevant stock assessment report and data on ACE prices and port prices.

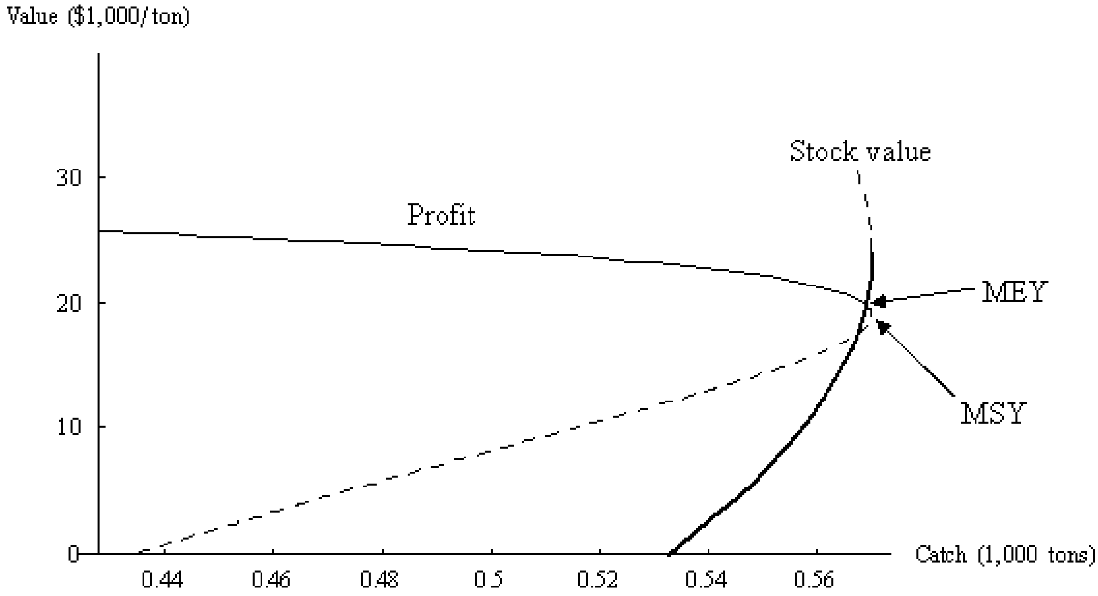

Figure 8. MEY v. MSY for Rock Lobster Region 8 (CRA8)

Note: MEY is at the point where the two solid curves intersect, while MSY is at the tip of the profit curve, where catch is maximised; in this case the two are very close. In the numerical model, MEY=0.998MSY, B_{MEY}=1.04B_{MSY}, and the unit profit at MEY is about 4% higher than for MSY.

Figure 8 is a specific example of the stylised representation given in Figure 5. The dotted portion of the profit and stock-value curves represents catch and value levels associated with stock levels below B_{MSY}. At stock levels below B_{MSY} profit levels continue to decrease at the same time as sustainable catch levels also decrease. Eventually profits go to zero, which corresponds to a stock and catch level that would be associated with open access. At the same time, the stock-value function is quite steep in this case, approximately doubling for about a 4% change in catch level. Steep stock-value functions will tend to exist in cases where the MEY is near the MSY.

Finally, note that the stock-value function goes to zero at the point where the component of the stock value due to growth equals the part of the stock value due to the cost effect. That is, for levels of the stock above B_{MSY}, further reductions in catch actually reduce the productivity of the stock. This is valuable for a time, because the higher stocks imply lower costs, but eventually the loss in productivity outweighs the cost savings, driving the stock value to zero. At that point there is no additional value from leaving additional fish in the stock. Due to the influence of the fish growth rate on the stock-value function, the stock value tends to be steeper for faster-growing species.

MEY will tend to be quite different from MSY in many cases, however. At lower fish prices, for example, harvest costs are relatively more important. Because the cost of fishing depends on the stock of fish, it is desirable in the case of low prices to operate where the stock is higher than B_{MSY}, the amount of catch is lower than MSY, and costs are thereby kept relatively low and profitability relatively high. The value of having a higher stock and lower costs offsets the value of a higher catch. This cost effect has a bigger impact on the fishery, the lower the price of fish. This case is illustrated in Figure 9 for a hypothetical fish stock where the profit per tonne goes negative even before catch levels reach MSY. In this case even an open-access fishery would catch below MSY, similar to the many QMS stocks that have catch levels below the TACC. The value-maximising stock is over 40% above B_{MSY} in this case, and the MEY is 20% lower than the MSY. The stock-value function is much less steep than in the case above, which tends to be more the case when the MEY is well below the MSY and stock levels are well above B_{MSY}.

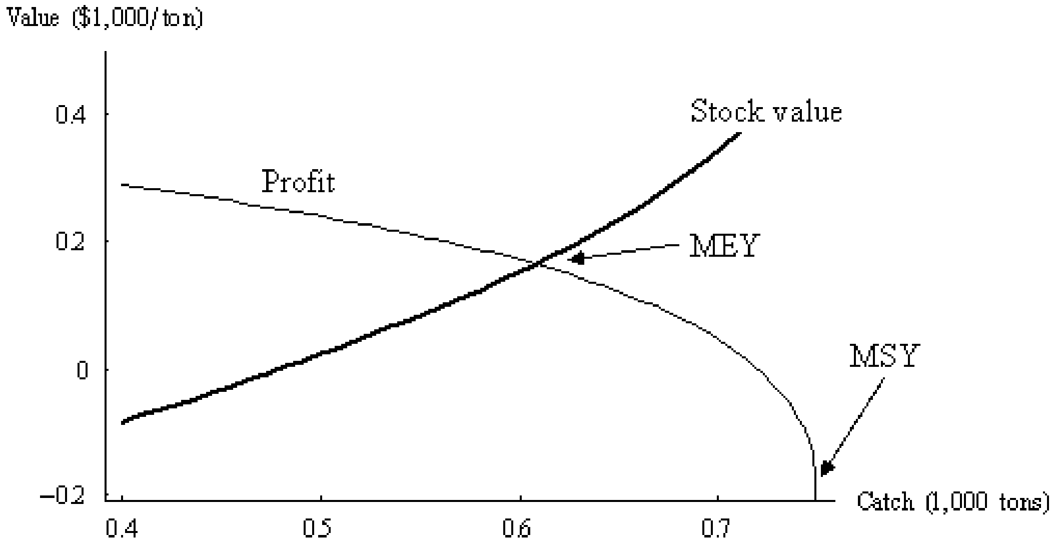

Figure 9. MEY v. MSY for Hypothetical Low-value Fish Stock

Note: MEY is at the point where the two curves intersect, while MSY is at the tip of the curve, where catch is maximised. In the numerical model, MEY=0.8MSY, B_{MEY}=1.44B_{MSY}, and the unit profit at MSY is negative.

The above discussion has not directly addressed the issue of how joint catch of species, including target-bycatch relationships, would influence the analysis. This is one of the most complex problems in fisheries economics, and even the theoretical literature on optimal management of interrelated species is surprisingly thin. At a practical level, to the extent quota systems have been employed, most countries have included only major target species. New Zealand, on the other hand, has progressively included species of lesser commercial importance in the QMS.

At a conceptual level, the existence of joint production or bycatch relationships implies that the value-maximising stock level and catch level for species will depend not only on each individual species' economic and biological characteristics, but also on those of co-caught species. One implication is that the value-maximising catch and stock levels for low-value species will tend to be driven by the characteristics of the higher-value species together with which they are caught.

To take one example, imagine a very low-value species that, if it were caught in an isolated fashion, would make sense to catch at a low level, *X*, with a high corresponding stock size. Now, imagine that in reality the species is caught together with a relatively higher-value species, and that the value-maximising catch level for the high-value species is *Y*, if it is treated as if it is caught alone. If the ratio in which they tend to be caught is less than *X*/*Y* then, once joint maximisation of value is considered, it will tend to be the case that the value-maximising approach is to catch about *Y* of the high-value species, while catching no more than *X* of the low-value species. The low-value species is not a binding constraint on catching the high-value species, so little tension arises in the maximisation of joint value.

If, on the other hand, the two species tend to be caught in a ratio that is greater than *X*/*Y* then, once joint maximisation of value is considered, it will tend to be the case that the value-maximising approach is still to catch about *Y* of the high-value species, while catching greater than *X* of the low-value species.[23] To take an extreme example, imagine a species that has zero value on its own. For this species, there is no value of leaving the fish in the sea and therefore a value-maximising strategy would be not to place any constraint on catch of the low-value species. Referring back to the primary motivation of policy being the representation of stock value, if there is no stock value then there is no motivation for policy.

To be clear, however, there is no example of a fish stock that has so little value. Furthermore, from a policy perspective, value should incorporate not only commercial value but also non-commercial value associated with recreation, species preservation, and health of the aquatic ecosystem. In practice, for species of low commercial value, an important management decision will involve incorporating these non-commercial values into the process of establishing catch targets. Setting TACs primarily based on the individual biological characteristics of interrelated stocks, however, is likely to place a significant constraint on value maximisation unless, by chance, it turns out that catch ratios are not binding. Given this, it is perhaps surprising that bycatch relationships have not caused more serious tension for the New Zealand ITQ system than they have. One very likely reason is that, while TACs for major stocks have been set based on independent stock assessments, the TACs for many "bycatch" species have been set based on actual historical catch.

Policy Instruments: Individual Quotas and Landing Fees

So far we have seen that an unregulated fishery will tend to dissipate value, and that value can be maximised by constraining catch levels to the point where the value of leaving a bit more fish in the sea is just about equal to the value of catching it. The obvious question then is: what policy instruments does the Government have for achieving this beneficial outcome? The two primary instruments suggested by economists correspond to a "quantity instrument" in the form of individual quotas for catch, or a "price instrument" in the form of landing fees for catch.

Before exploring these instruments further, it is useful to pause and point out that, if there were a sole owner of fisheries, then much of the above market failure could, in

[23] Recognising that the ratio of *X* to *Y* is a function of the relative stock sizes, it may also be optimal from a purely commercial perspective to drive down the stock size of the low-value species over time so that the catch ratio is not as high.

principle, be avoided. At least with regard to the optimal management over time of the commercial value of fisheries, a sole owner would have an incentive to take into account the value of leaving fish in the stock, because that owner would in effect *own* the stock and would not face the problem of some other fisher catching the saved fish. The sole owner would, in principle, consider the stock an asset and would have full rights over the dividends from that asset. In effect, the stock externality identified above would be internalised.

Note, however, that in the absence of policy intervention a sole owner would still not have any incentive to account for any non-commercial value of the fishery (e.g. environmental, cultural, or recreational values). In addition, there are other problems associated with industrial concentration, such as market power and anti-competitive behaviour, which may offset other gains. Finally, while sole ownership may conceptually solve the stock externality problem, sole ownership as a practical policy solution would likely face significant resistance. Nonetheless, the potential advantages of sole ownership, including greater co-ordination of effort, more efficient use of capital, and greater stewardship of resources, are useful to keep in mind when designing policies to improve the utilisation of fisheries. Another way of achieving some of these same goals is through mechanisms to encourage co-operative behaviour, such as might in principle be achievable through Fisheries Plans, quota-management companies and co-operatives, and other forms of co-management.

Individual Quotas

The quota-based approach is called a quantity instrument because it directly allocates a right to catch a specific quantity or tonnage of fish, termed the total allowable catch (TAC). By setting the TAC equal to catch level Q*, policy can constrain aggregate catch to the value-maximising level. Constraining *aggregate* catch to Q* is not enough, however. Unless quotas are allocated at an individual level there will still tend to be a race to fish, and excess fishing effort, because the individual fisherman has no claim over a particular amount of fish until it is caught. Note also that, while the target catch we have focused on is Q*, the TAC can be set at any level desired by policymakers and the ITQ system used to attain that target TAC. The target will not be value maximising, however, unless it is set at Q*.

Furthermore, allowing trading of quota will further enhance the value of fisheries by providing an incentive for relatively inefficient fishers to sell their quota to more efficient ones. Trading also permits a degree of flexibility in the system, which is valuable given the need to balance quota with catch when the magnitude and composition of catch is uncertain. Individual tradeable quotas are the primary policy instrument used in the New Zealand QMS.

In a competitive quota market, each fishing enterprise has an incentive to trade quotas until it attains just enough quotas to cover a catch level that maximises its expected profits. The price of a one-year right to catch one tonne of fish should therefore equal the marginal flow of profit or rent from that enterprise; that is, the price of fish (marginal revenues) minus the marginal cost of fishing. In the New Zealand QMS this should correspond approximately to the price of ACE, or Annual Catch Entitlements. In Figure 5, the price of quotas associated with TAC and catch level Q* is P_{Q*}, corresponding to the vertical level of the marginal profit function when catch is constrained to Q*.

In turn, the value of holding the ACE right in perpetuity (that is, the quota share price) should equal the discounted expected rent from fishing or, equivalently, the discounted flow of future expected ACE prices. If ACE prices are expected to remain relatively constant, then the quota share price would simply equal the ACE price divided by the relevant market rate of interest.[24] This relationship is demonstrated in Figure 4 and in further analysis by Newell et al. (2004).

Landing Fees

An alternative instrument for attaining catch level Q* is a landing fee that charges fishermen P_{Q*} for each tonne of fish caught. Faced with a charge of P_{Q*} per tonne, it will be profitable to catch only up to the point where catch is equal to Q*. When catch is less than Q*, the marginal profit from catch is greater than the landing fee, so it pays to catch the fish, pay the fee, and pocket the difference. When catch exceeds Q*, the marginal profit is less than the fee, so a fisherman would suffer a net loss from catching beyond Q*. As with quotas, landing fees can be adjusted to achieve any desired level of catch, not just Q*.

The landing fee approach is called a price instrument because it directly controls the price a fisherman must pay for the right to catch a tonne of catch, and thereby indirectly controls the quantity of catch. In fact, the landing fee that achieves catch level Q* is equal to the annual quota (ACE) price that would result within a tradeable quota market with the TAC set at Q*, that is P_{Q*}. It is in this sense that a landing fee of P_{Q*} and a quota of Q* are said by economists to be "equivalent" instruments, because a quota of Q* leads to a price of P_{Q*}, while a landing fee of P_{Q*} leads to a catch of Q*.

This "equivalence" no longer holds, however, when there is ecological and economic uncertainty in the functions describing profits and external costs. Depending on the policy goal, the instruments are also not equivalent in terms of the information required for implementation. For any particular target catch, a quota system can be employed to achieve that target simply by setting the amount of quota equal to the target catch. To achieve that catch through landing fees, however, one also requires information about the shape of the marginal profit function depicted in Figure 5, as the catch level is determined by the intersection of the landing fee with the profit function. If the goal is not a particular catch level per se, but is rather value maximisation, then information about the profit function is required in the setting of both instruments. Alternatively, each instrument could be adjusted iteratively over time to achieve a given catch level or value target.

[24] If lease prices are expected to move up or down over time, however, because of changing export prices or costs, the relationship between ACE and share prices would be more complex, since it would depend on expectations of changing future conditions. For example, if rents (and ACE prices) were expected to increase at a constant rate, then the ACE price divided by the sale price would equal the discount rate *minus* the expected ACE growth rate.

Distributional Implications of Quotas and Fees

These instruments are also not equivalent in terms of the implications for who captures the additional value created when the fishery is controlled. Under the purist landing fee approach described above, the Government collects the value of the rectangle $Q^*P_{Q^*}$, while under a quota system this value typically accrues to quota owners. This has obvious implications for the distribution of wealth, the financial profits of the fishing industry, and the relative political feasibility of each of these instruments.

Thus, while economists have long recognised the theoretical possibility of controlling catch through landing fees, these distributional differences help explain why quota systems with allocation based on historic catch have been used around the world, but there are no examples in practice where fisheries management has been based primarily on landing fees of the form economists typically describe. Nonetheless, it is of course possible to alter the distributional character of these two instruments by either charging for quota or by not charging, or refunding, a portion of landing fees.

New Zealand has in fact experimented with both of these distributional modifications. While New Zealand has typically allocated commercial quota based on historic catch, in the initial period of the QMS the Government charged resource rentals to capture at least part of the value created by quota. In 1992, however, in conjunction with the Treaty of Waitangi Settlement, the Government switched from collecting resource rentals to cost-recovery fees (see Section 2 for more detail on this transition). The Government has also tendered quota at times.

Around the same time, in 1990, the Government began charging "deemed values" on catch that was not covered by quota. Deemed values are a form of landing fee but, rather than charging the fee for all catch, the fee is only levied on the additional units of catch above what is covered by quota. This is roughly analogous to a landing fee system where the fees are not charged on the units of catch below the target TAC. I explore this integrated use of quotas and fees further below.

ITQs and Deemed Values: A Hybrid System

While the New Zealand QMS controls catch primarily through the use of ITQs, it does employ elements of a landing-fee approach in the form of the deemed-value system. In effect, the New Zealand QMS has evolved into a hybrid system that employs both quantity and price instruments in controlling catch.[25] Since modifications to the catch-balancing regime in 2001, it is now legal to catch fish managed under the QMS while holding no ACE, except for a modest minimum holding for a few species.[26] That is, as long as a fisherman pays deemed values for

[25] This aspect of the New Zealand system is both practically and intellectually interesting, as such hybrid systems have been proposed in the past for addressing natural resource and environmental problems (Roberts and Spence 1976), but rarely if ever employed in practice. The principles for designing such a hybrid system optimally are undeveloped for the case of fisheries, but of potentially high value.

[26] As listed in the Eighth Schedule to the Act (9/9/99), there are minimum ACE-holding requirements of 1–4 tonnes for Freshwater eels, Oysters, Paua (Abalone), Rock lobster, and Scallops.

any catch not covered by ACE, he can continue to do so indefinitely, except again for those same species with minimum holdings.[27]

Thus, the key feature that maintains the ITQ system, rather than the deemed-value system, as the primary means of controlling catch is that ACE prices are typically lower than deemed-value rates. Fishers therefore have an incentive to cover their catch with ACE, rather than pay deemed values, simply because ACE prices are typically lower than deemed values. In the following sections I explore the specifics of the New Zealand TAC-setting process and the deemed-value system, as well as the possibilities for improving the design and integration of these policy tools in order to better achieve the goal of maximising value.

[27] The exception is if "overfishing thresholds" have been applied to the relevant stock, in which case the fisher's permit could eventually be revoked. At this point in time, however, overfishing thresholds (of 5%) have only been established for Freshwater eels, Oysters, Paua (Abalone), Rock lobster, and Scallops.

4 SETTING TOTAL ALLOWABLE CATCH LEVELS

A main ingredient in implementing an ITQ system is the setting of a Total Allowable Catch (TAC) level for each fish stock within the system. Once the TAC is set, it can be allocated in any number of ways among fishing interests—some efficient and some not—but, if it is set at the wrong level, then no amount of reallocation through trading is going to correct this error.

Legislative Basis for Setting TACs

The Fisheries Act 1996 sets out the primary principle for setting TACs in the New Zealand QMS in Section 13:

> **Fisheries Act 1996, Section 13. Total Allowable Catch –** (emphasis added)
>
> (2) The Minister shall set a total allowable catch that -
> (a) Maintains the stock ***at or above a level that can produce the maximum sustainable yield***, having regard to the interdependence of stocks;

Where, according to the definition in the Fisheries Act 1996, Section 2:

> **Fisheries Act 1996, Section 2. Interpretation –**
>
> **'Maximum sustainable yield'**, in relation to any stock, means the greatest yield that can be achieved over time while maintaining the stock's productive capacity, having regard to the population dynamics of the stock and any environmental factors that influence the stock.

Maximum sustainable yield (MSY) (as described earlier and in Figure 6) is a pervasive concept in fisheries biology and management, and often serves as a focal point for the setting of TACs. Because there is natural variability over time in both the level and growth of fish stocks, MSY will ideally not be a constant number. In practice, however, uncertainties in the size of existing stocks of fish, annual recruitment (or growth) in stocks, and the biological characteristics of individual species, along with the practical difficulties of updating TACs regularly, have meant that constant proxies for a variable MSY are often used.

In the "Guide to Annual Reference Points for the 2002-2003 Fisheries Assessment Meetings" (Annala et al. 2003), for example, the New Zealand TAC-setting process identifies the Current Annual Yield (CAY) as a time-varying basis for MSY, whereas Maximum Constant Yield[28] (MCY) is identified as the constant proxy for MSY in

[28] Annala et al. (2003, p. 14) define MCY as "The maximum *constant* catch that is estimated to be sustainable, with an acceptable level of risk, at all probable future levels of biomass." CAY, in contrast, is "The *one-year catch* calculated by applying a reference fishing mortality, F_{ref}, to an estimate of the fishable biomass present during the next fishing year. F_{ref} is the level of (instantaneous)

(most) cases where the TAC is not likely to be adjusted regularly. In any event, an important feature to remember about MSY is that it is a *biological maximum*. If it has been identified accurately, levels of catch greater than MSY will lead to inevitable depletion of the stock.

While there is often a focus amongst those involved in fisheries on TACs and the annual catch, note that the Fisheries Act appropriately identifies maintenance of the *stock* of fish at a desired level as the ultimate objective to consider in setting annual TACs. This ultimate focus on the stock is consistent with our identification above of the role of public policy in fisheries management, which is to find means to reflect the value of leaving fish in the stock rather than catching it.

It is thus also consistent with the identification in the fisheries economics literature of optimal management rules based on the *escapement level* (i.e. how much stock is left after the catch is complete) rather than the *catch* per se (see Reed (1979), Clark and Kirkwood (1986), Koenig (1984, 1985), Weitzman (2002), and Sethi et al. (2003)). This distinction becomes particularly important given uncertainties in the initial stock level and recruitment to the stock in each year; uncertainties that lead to optimal management rules that target the end-of-year stock level rather than a constant annual catch.

Legislative Flexibility in Setting TACs

While the setting of TACs based on the stock associated with MSY (B_{MSY}) may seem to be a restrictive principle, if the ultimate goal is maximising the value (rather than catch) from fisheries, the Fisheries Act actually gives considerable latitude to set TACs at levels other than those corresponding exactly to the MSY stock. First, the relevant portions of the Fisheries Act refer to setting TACs to achieve a stock that is "at or above" the stock that would support MSY. So the flexibility immediately seems to exist to move towards TACs that come closer to achieving MEY, as long as this corresponds to a stock size that is greater than the MSY stock size, which it will in many cases. We will see below that the flexibility also exists to set the TAC for some bycatch stocks at a level *below* that which would support MSY.

Section 13 of the Fisheries Act 1996 also gives the Ministry considerable flexibility in adjusting TACs on an annual basis, or even within the fishing year in certain cases, as well as adjusting the rate at which the desired stock level is achieved based on social, cultural, and economic factors:

Fisheries Act 1996, Section 13. Total Allowable Catch – (emphasis added)

(2) The Minister shall set a total allowable catch that -
…
(b) Enables the level of any stock whose current level is below that which can produce the maximum sustainable yield to be altered -
(i) In a way and at a rate that will result in the stock being restored to or

---

fishing mortality that, if applied every year, would, within an acceptable level of risk, maximise the average catch from the fishery." Emphasis added.

above a level that can produce the maximum sustainable yield, having regard to the interdependence of stocks; and

(ii) Within a period appropriate to the stock, having regard to the biological characteristics of the stock and any environmental conditions affecting the stock; or

(c) Enables the level of any stock whose current level is above that which can produce the maximum sustainable yield to be altered in a way and at a rate that will result in the stock moving towards or above a level that can produce the maximum sustainable yield, having regard to the interdependence of stocks.

(3) ***In considering the way in which and rate at which a stock is moved towards or above a level that can produce maximum sustainable*** yield under paragraph (b) or paragraph (c) of subsection (2) of this section, ***the Minister shall have regard to such social, cultural, and economic factors as he or she considers relevant***.

(4) ***The Minister may from time to time,*** by notice in the Gazette, ***vary any total allowable catch*** set for any quota management stock under this section by increasing or reducing the total allowable catch. When considering any variation, the Minister is to have regard to the matters specified in subsections (2) and (3).

(4) Without limiting subsection (1) or subsection (4) of this section, the Minister may set or vary any total allowable catch at, or to, zero.

(5) Except as provided in subsection (7) of this section, every setting or variation of a total allowable catch shall have effect on and from the first day of the next fishing year for the stock concerned.

(6) After ***considering information about the abundance during the current fishing year of any stock listed in the Second Schedule*** to this Act, and after having regard to the matters specified in subsections (2) and (3), ***the Minister may***, by notice in the Gazette, ***increase the total allowable catch for the stock with effect from such date in the fishing year*** in which the notice is published as may be stated in the notice.

(7) If a total allowable catch for any stock has been increased during any fishing year under [subsection (7)] of this section, the total allowable catch for that stock shall, at the close of that fishing year, revert to the total allowable catch that applied to that stock at the beginning of that fishing year; but this subsection does not prevent a variation under subsection (4) of this section of the total allowable catch that applied at the beginning of that fishing year.

(8) The Governor-General may from time to time, by Order in Council, omit the name of any stock from the ***Second Schedule*** to this Act or ***add to that Schedule the name of any stock whose abundance is highly variable from year to year***.

The last part of this section refers to flexibility to increase the TAC *within* a given fishing year based on stock abundance for highly-variable stocks. As of 2004, the Second Schedule lists the following stocks as being highly variable: Flatfishes, Freshwater Eel and Red Cod. In Section 14 of the Fisheries Act, similar within-year flexibility is given to particular stocks listed in the Third Schedule:

Fisheries Act 1996, Section 14. Alternative total allowable catch for stock specified in Third Schedule – (emphasis added)

(1) Notwithstanding anything in section 13 of this Act, if satisfied, in the case of any quota management stock listed in the Third Schedule to this Act, that the purpose of this Act would be better achieved by setting a total allowable catch otherwise than in accordance with subsection (2) of that section, the Minister may at any time, by notice in the Gazette, set in respect of the quota management area relating to the quota management stock a ***total allowable catch for that stock that he or she considers appropriate to achieve the purpose of this Act***.

…

(6) After ***considering information about the abundance during the current fishing year*** of any stock listed in the Third Schedule to this Act***, the Minister may,*** by notice in the Gazette, ***increase the total allowable catch for the stock with effect from such date in the fishing year*** in which the notice is published as may be stated in the notice.

…

(8) The Governor-General may from time to time, by Order in Council, -

(a) Omit the name of any stock from the Third Schedule to this Act:

(b) Add to that Schedule the name of any stock if -

- (i) It is ***not possible, because of the biological characteristics of the species, to estimate maximum sustainable yield***; or
- (ii) A catch limit for New Zealand has been determined as part of an ***international agreement***; or
- (iii) The stock is ***managed on a rotational or enhanced basis***.

The Third Schedule can include species having biological characteristics that make it impossible to estimate maximum sustainable yield; stocks which are managed on a rotational or enhanced basis; and stocks that are part of an international agreement. Thus, the Third Schedule also provides flexibility to set TACs based on something other than MSY for certain species. As of 2004, the Third Schedule includes: Freshwater Eel, Southern Scallops and Squid.

The Fisheries Act was amended in 1999 to include Sections 14A-B, which allow flexibility, under certain restrictive conditions, in the setting of TACs for stocks that are taken primarily as incidental catch. Figure 10 illustrates many (but not all) of the target-bycatch relationships that exist among QMS species. Specifically, Sections 14A-B allow the TAC to be set at a level that "maintains the stock above a level that ensures its long-term viability", which implies that the TAC could be set at a level that would be associated with a stock level below that which would be associated with MSY. The relevant sections are:

Fisheries Act 1996, Section 14A. Alternative total allowable catch for stocks specified by Order in Council –
(As of September 9, 1999)

(1) The Governor-General may from time to time, by Order in Council made on the recommendation of the Minister with the concurrence of the Minister responsible for the administration of the Environment Act 1986, apply **section 14B** to the quota management stock or stocks specified in the order.
(2) No recommendation relating to any stock may be made under subsection (1) unless quota owners ('proposers') who hold in the aggregate at least 95 000 000 quota shares in that stock propose to the Minister that he or she recommend the making of an Order in Council under subsection (1).
(3) A proposal made under subsection (2) must –
(a) Specify the concerns (if any) of the quota owners who do not support the proposal; and
(b) Specify what arrangements are in place to address those concerns; and
(c) Address the matters specified in subsection (4).
(4) In considering making a recommendation under subsection (1), the Minister must have regard to the following:
(a) The need to commission appropriate research to assess the impact of the order on the stock; and
(b) The need to implement measures to improve the quality of information about the stock; and
(c) Whether it is appropriate to close areas to commercial fishing to reduce any sustainability risk to that stock; and
(d) The need to avoid any significant adverse effects on the aquatic environment of which the stock is a component.
(5) No recommendation may be made under subsection (1) in relation to a proposal made under subsection (2) unless the Minister is satisfied that –
(a) The ***stock is taken primarily as an incidental catch*** during the taking of 1 or more other stocks ***and is only a small proportion of the combined catch*** of the stock and other stock or stocks; and
(b) The ***total benefits*** of managing the stock at a level other than that permitted under section 13 ***outweigh the total costs***; and
(c) Managing the stock at a level other than that permitted under section 13 will have no detrimental effects on non-commercial fishing interests in that stock; and
(d) The stock is able to be maintained above a level that ensures its long-term viability; and
The purpose of the Act would be better achieved by setting a total allowable catch otherwise than in accordance with section 13.

Fisheries Act 1996, Section 14B. Alternative total allowable catch for certain stocks – (As of September 9, 1999)

(1) Despite section 13, in the case of any quota management stock to which this section applies, the Minister must, by notice in the *Gazette*, set a total allowable catch

for that stock in accordance with this section.
(5) Subject to subsection (3), the Minister ***must set a total allowable catch under subsection (1) that is no greater than a level that will allow the taking of another stock*** or stocks in accordance with the total allowable catch and the total allowable commercial catch set for that other stock or stocks.
(2) The Minister must ***set a total allowable catch that maintains the stock above a level that ensures its long-term viability***.
(3) When setting a total allowable catch under subsection (1), the Minister must be satisfied that quota owners have taken, and will continue to take, all reasonable steps (including, but not limited to, modifying fishing methods, fishing areas, and times of fishing) to minimise take of the stock.
(6) Every total allowable catch set under subsection (1) for any stock continues to apply in each fishing year for the stock unless varied under subsection (6).
(4) The Minister may from time to time, by notice in the *Gazette*, vary any total allowable catch set under subsection (1) for any stock by increasing or reducing the total allowable catch.
(5) Without limiting subsection (1) or subsection (6), the Minister may set or vary any total allowable catch at, or to, zero.
(6) The setting or variation of a total allowable catch under this section has effect on and from the first day of the next fishing year for the stock concerned.

Where, according to the definition in the Fisheries Act 1996, Section 2:

Fisheries Act 1996, Section 2. Interpretation –

'Long-term viability', in relation to a biomass level of a stock or species, means there is a low risk of collapse of the stock or species, and the stock or species has the potential to recover to a higher biomass level.

There are several things of interest to note about Sections 14A-B. One is that the requirements for actually applying them in practice appear to be quite restrictive. For example, the approval of quota owners representing 95% of the stock is required, among other things listed in Section 14A. This may explain in part why Sections 14A-B have to date not been applied. It is also interesting to note that this is the only place in the Act where explicit mention is given to setting TACs based on net benefit criteria; that is, at a level where the total benefits outweigh the total costs. In fact, the only other place in the Fisheries Act that makes reference to benefit-cost-based assessment is in the decision to introduce new stocks into the QMS (see Section 19). One of the necessary ingredients to applying Sections 14A-B would be to identify those stocks that can be considered to be "taken primarily as incidental catch" and that are "only a small proportion of the combined catch."

Target	Bycatch: Alfonsino	Barracoutta	Bluenose	Gemfish	Hake	Hapuku/ Bass	Hoki	Jack Mackerel	Ling	Orange Roughy	Oreo Dories	Scampi	Southern Blue Whiting	Squid	Warehou, Blue	Warehou, silver
Alfonsino			■	✔		✔			✔	■						
Barracoutta			✔	■	✔	✔	■	✔	✔					■	✔	■
Bluenose	✔			✔		■	✔		✔						✔	
Gemfish	✔	■	■			✔	✔		✔						✔	✔
Hake		✔		✔			✔		✔						✔	■
Hapuku/ Bass	✔		✔	✔	✔				✔						✔	✔
Hoki		✔	✔	✔	■	✔		✔	■					✔	✔	■
Jack Mackerel		■		■			✔		✔					✔		✔
Ling			✔	✔	■	■	■								✔	✔
Orange Roughy	■										■					
Oreo Dories	■									■						
Scampi		✔	✔	✔	✔	✔	✔		■					✔		✔
Southern Blue Whiting		✔			■		■		■					✔		✔
Squid				✔		✔	✔	✔	✔						✔	✔
Warehou, Blue		✔		✔		✔	■		■							■
Warehou, silver		✔		■	✔		■	✔						✔	■	

■ Typically caught together ✔ Sometimes caught together

Figure 10. Bycatch Relationships for Major QMS Species

Summary of TAC-Setting Criteria

Table 3 summarises the categorization of fish stocks for the purposes of setting TACs. As is clear from this table, while the Ministry of Fisheries seems to have considerable flexibility in principle in the setting of TACs, in practice it has relied predominantly on the target of maintaining the stock at a level that would achieve MSY. This is also clear from reviewing stock assessment reports, which inform the setting of TACs. In addition, while the Act clearly allows for the setting of TACs (at a level lower than MSY), that would maintain the stock at a level *above* that which would support MSY, in practice it appears that the target stock is seldom above that which would support MSY. And, if such a target was chosen, it would be based on biological rather than economic considerations under the current system.

Table 3: Summary of Basis for Setting TACs in the Fisheries Act

Category	Basis for setting TAC	Stocks in category
All other (most) stocks	Maintains the stock at or above a level that can produce the MSY	All others
Highly variable species (Second Schedule)	Maintains the stock at or above a level that can produce the MSY. Plus, within-year flexibility.	Flatfishes, Freshwater Eels, and Red Cod
Predominantly taken as bycatch (Section 14A-B)	Maintains the stock above a level that ensures its long-term viability	None currently
MSY is impossible to determine biologically (Third Schedule)	Appropriate to achieve the purpose of this Act. Plus, within-year flexibility.	Freshwater eels, Southern scallops, Squid

Setting the Total Allowable Commercial Catch (TACC)

Whereas the discussion of total catch level has thus far focused on the TAC, I now turn briefly to describing how the commercial portion or Total Allowable Commercial Catch (TACC) is determined. It is the TACC that determines the total tonnage managed under the QMS and ultimately allocated to individual quota owners, either free, based on historic catch, or through tendering. As laid out in Sections 20-21 of the Fisheries Act, the TACC is simply the residual after subtracting from the TAC an allowance for non-commercial Maori customary and recreational fishing interests, as well as other fishing mortality such as illegal catch and underreporting. The Act states:

Fisheries Act 1996, Section 20. Setting and variation of total allowable commercial catch –In force on 1/10/01

(5) A total allowable commercial catch for any quota management stock shall not -
(b) Be greater than the total allowable catch set for that stock.

Fisheries Act 1996, Section 21. Matters to be taken into account in setting or varying any total allowable commercial catch -
In force on 1/10/01

(1) In setting or varying any total allowable commercial catch for any quota management stock, the Minister shall have regard to the total allowable catch for that stock and shall allow for -
(a) The following non-commercial fishing interests in that stock, namely-
  (i) Maori customary non-commercial fishing interests; and
  (ii) Recreational interests; and
(b) All other mortality to that stock caused by fishing.
(2) Before setting or varying a total allowable commercial catch for any quota management stock, the Minister shall consult such persons and organisations as the Minister considers are representative of those classes of persons having an interest in this section, including Maori, environmental, commercial, and recreational interests.

As most stocks have little, if any, customary or recreational catch, most TACCs are simply equal to the TAC, with an allowance for other mortality due, for example, to underreporting, discards or illegal catch. This is not true in all cases, however. For example, the TACCs for Snapper in regions 1 and 7 (SNA1 and SNA7) are only 60% and 65%, respectively, of the TAC, and the TACC for Rock Lobster in region 2 (CRA2) is about 50% of the TAC.

For any new species coming into the QMS, commercial fishers are allocated a portion of the TACC, typically based on their catch history in the 1990-1991 fishing year, and after a 20% allowance for Maori (see Sections 32-35 of the Act). For stocks where the TACC is greater than the aggregate catch history for that stock, the “overhanging” quotas are tendered by the Government through an intermittent auction. Historically the tendering process has moved from a uniform-price auction to the current “pay-your-own-bid” approach or discriminatory price auction. Consideration is currently being given to whether it makes sense to move back to a uniform-price auction.

Another issue currently facing the Ministry is what provisions to make, if any, for stocks entering the QMS for which the TACC is much greater than the catch histories, because the fishery has grown significantly since 1990, or due to historic under-reporting of catch. This is of particular concern in the context of tendering species caught primarily as bycatch. Because the value of some of these bycatch species is associated primarily with the target species with which they are caught, the worry exists that the value of the target-species quota will be “captured” by the tendering of the bycatch quota. Both of these issues are under active consideration by the Ministry and the fishing industry.

Setting TACCs to Maximise Value Rather than Catch

Section 3 introduced a conceptual basis for targeting catch and stock levels, suggesting that they be targeted to maximise value by equalising the unit value of catch and the value of leaving the fish in the sea. This can be contrasted with the New Zealand TAC-setting process which has, in principle, focused primarily on MSY. This reflects an approach which focuses on maximising catch, rather than value. To the extent that the MSY catch target has been adjusted to incorporate economic considerations, this appears to have been done in a non-systematic fashion.

As we saw in the earlier discussion, in many cases it may make sense to manage stocks at a level above B_{MSY}. In those cases—such as for relatively isolated species with low value and high growth rates—value can be increased at the same time as stocks are increased. In other cases, managing stocks at MSY levels may be a reasonable approximation, such as for high-value single-species fisheries. Managing stocks at levels below that which supports MSY is likely to be a value-maximising strategy only for low-value stocks that are co-caught in ratios that would represent a significant constraint on catching higher-value species. The determination of the best strategy for individual fish stock complexes is a matter for much more detailed analysis than is possible here. Possible venues for such analysis include both the Stock Strategies and Fishery Plans approaches currently under development by the Ministry of Fisheries.

The basic legislative flexibility to accommodate the variety of situations seems to be in place, except perhaps with respect to managing low-value bycatch stocks. While there are provisions for management of such stocks at levels below B_{MSY}, Sections 14A-B of the Fisheries Act have yet to be applied. It is unclear at this point whether this is due to some inherent weakness or inflexibility in this part of the Act, or is simply an evolutionary process whereby certain elements of the system are just waiting to be tested.

As a preliminary suggestive step in classifying species along the above mentioned dimensions, Figure 11, 12 and 13 show plots of species value against species mortality rates using different measures of species value. Based on the discussion above and in Section 3, the TAC for high-value species might be reasonably approximated by the MSY, while lower-value stocks may be candidates for management at a stock level above B_{MSY}, particularly if they are fast growing. One such measure of value is the ACE price, which is employed in Figure 11 and can be taken to approximate the unit profit from catch. An exception to this is very low-value species with binding TACCs, where the ACE price reflects more the value of co-caught species.

Another way of representing value is as a “Percent Profit”, whereby the unit profit is viewed as a percentage of the price of the fish (by dividing ACE by the price of the fish). This variation is used in Figure 12 and13, the difference being that Figure 12 uses 2002 port prices from the port price survey, while Figure 13 employs a measure based on the export price (per greenweight tonne). These two Figures show the same pattern as the port price tends to be proportional to the export price, as shown in Figure 14, with the typical port price being about 60% of the export price, when calculated on a species basis. Within species, the port prices for individual stocks show a surprising degree of variation. Note that in Figure 12 certain low-value species rise considerably relative to Figure 11, which could indicate that their ACE price is also reflecting the value of co-caught species (e.g. Silver warehou (SWA)).

As mentioned above, it is also the case that fast-growing species tend to have more volatile stock size, raising the value of regularly updating the TACC to incorporate the latest information on stock recruitment. As discussed below in section 5, faster-growing species also tend to have stock-value functions (as described in Figure 5) that are quite steep around the value-maximising catch level. This is attributable to the fact that, while these species grow quickly, they also do not live very long, so that beyond a certain point the value of leaving these species in the stock quickly goes to zero.

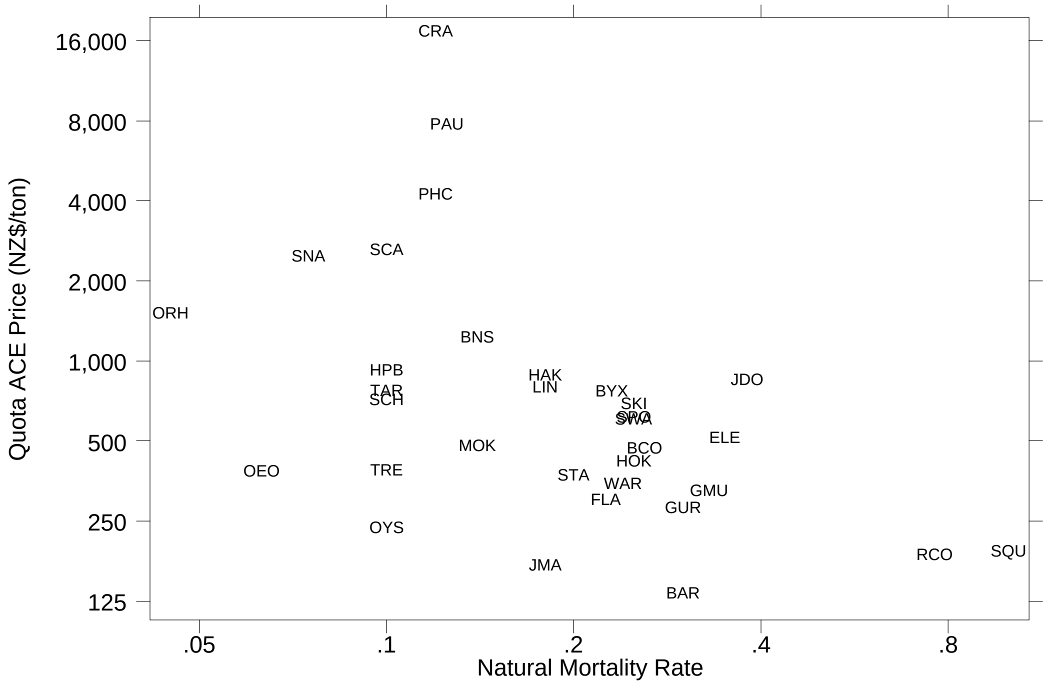

Figure 11. Species ACE Prices and Natural Mortality Rates (2002 Fishing Year)

Note: Scales are logarithmic. ACE price is an average for each species.

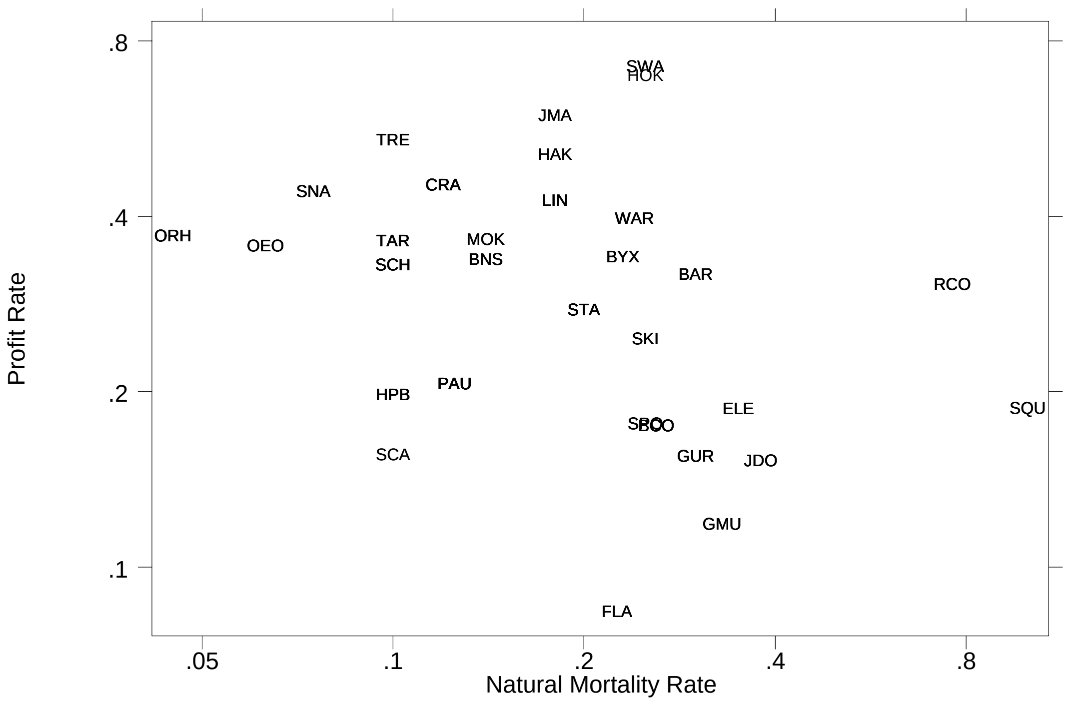

Figure 12. Profit Rate (Using Port Price) and Mortality Rates (2002 Fishing Year)

Note: Scales are logarithmic. Profit rate equals average ACE price divided by average port price for each species.

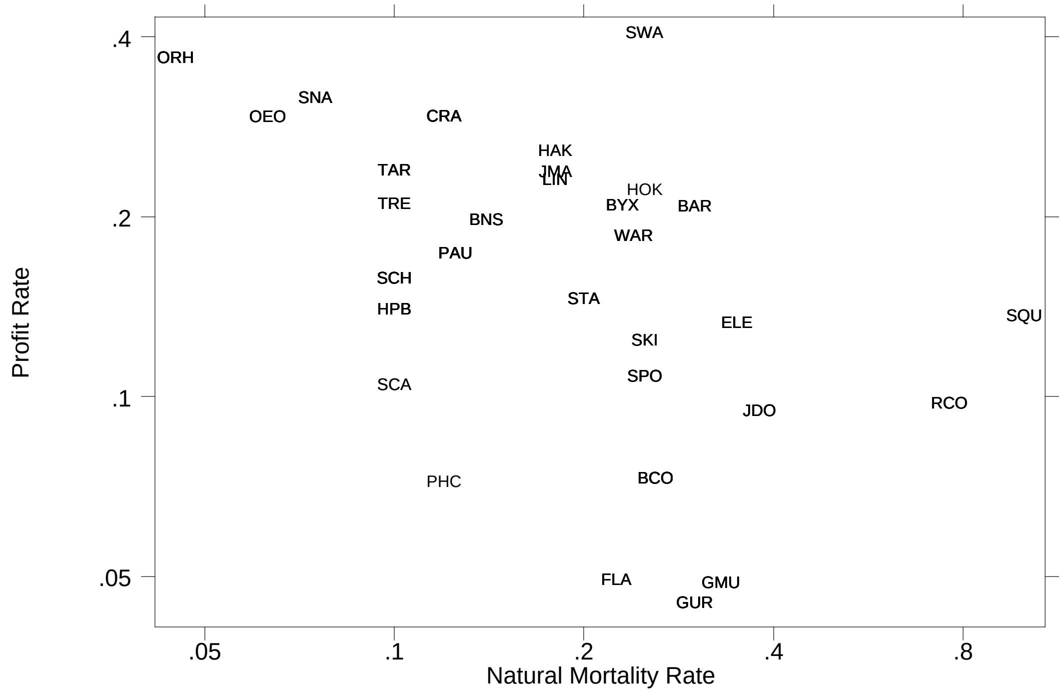

Figure 13. Profit Rate (Using Export Price) and Mortality Rate (2002 Fishing Year)

Note: Scales are logarithmic. Profit rate equals average ACE price divided by average export price for each species.

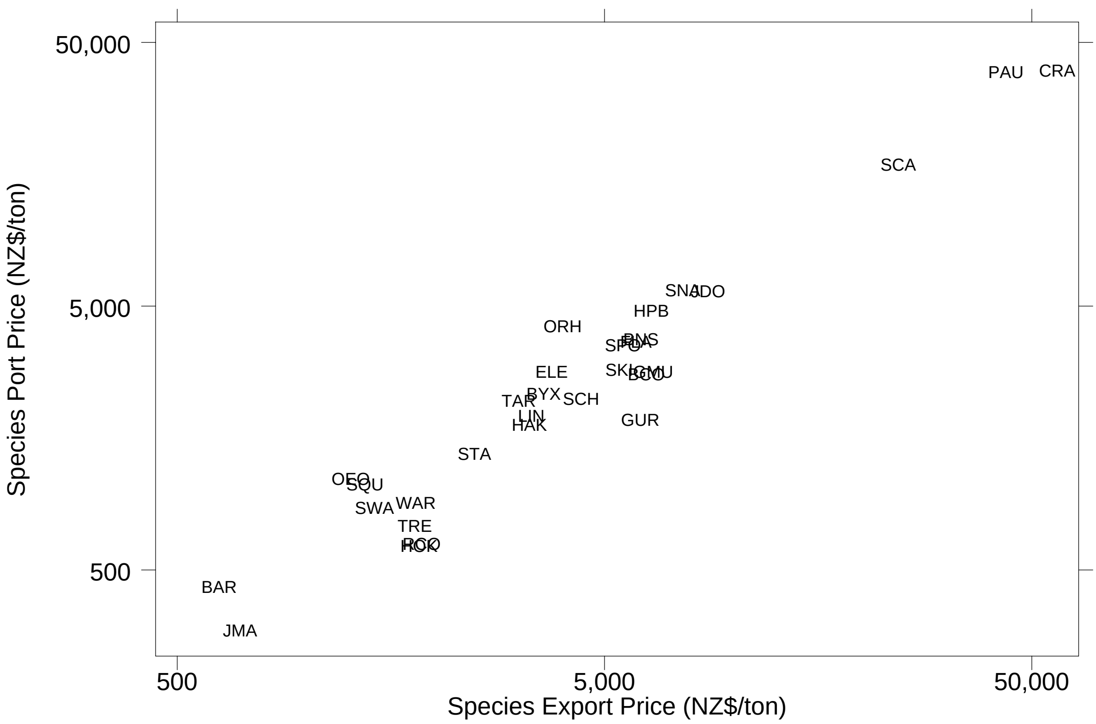

Figure 14. Port Prices v. Export Prices (2002 Fishing Year)

Note: Scales are logarithmic. Port prices are from the Ministry of Fisheries' port price survey while export prices were calculated using Statistics New Zealand export data, converted to greenweight tonnes using product-specific conversion factors.

5 SETTING DEEMED VALUES

Since modifications to the catch-balancing regime in 2001, it is now legal to catch fish managed under the QMS while holding no quota, except for modest minimum holding requirements for a few species.[29] That is, as long as a fisherman pays deemed values for any catch not covered by ACE, he can continue to do so indefinitely, except again for those same species with minimum holdings.[30] Failure to pay deemed values can result in suspension of the fishing permit. This approach represents a significant change from the prior system, where it was illegal to target QMS species without holding quota for them, and the ultimate penalties for catching without quota were criminal in nature. Peacey (2002) provides an overview of the past and present implementation of the catch-balancing regime in New Zealand.

The impetus for this change is described in an Advice Paper to the Minister that sets out the new catch-balancing regime (Ministry of Fisheries 2001, p. 2):

> "The balancing regime in the Fisheries Act 1996 (as amended by the Fisheries Amendment Act 1999) is very different from the regime that was initially introduced by the Fisheries Amendment Act 1990. In the new balancing regime graduated administrative disincentives play a pivotal role in controlling overfishing.
>
> Under the Fisheries Act 1983, fishing in excess of quota is a criminal offence. Deemed values are provided as part of a limited defence to overfishing. The deemed value rate is required to be set at a level that removes the economic benefit of taking the stock without authority, while ensuring there is an incentive for fishers to land such fish. In practice, criminal prosecutions have been rarely used to deter overfishing and deemed values have proved to be the primary deterrent to fishing in excess of quota. However, due to the very different nature of various fishing operations harvesting the same stock, it has proved impossible to set deemed values that simultaneously discourage targeting of a fish stock by fishers without relevant quota and encourage fishers to land fish taken in excess of quota.
>
> In the catch balancing regime to be implemented on 1 October 2001 it is no longer a criminal offence to take fish without adequate Annual Catch Entitlement (ACE—the harvest element of quota in the new regime) to cover the catch (except for those stocks where a minimum ACE holding applies). Deemed values are now established as the primary deterrent to fishing in excess of ACE. The deemed value provisions are now structured so that the only matter the Minister must take into account when setting a deemed value is the need to provide an incentive for fishers to cover all catch by ACE. The desirability of fishers landing catch for which they do not hold ACE is now

[29] As listed in the Eighth Schedule to the Act (9/9/99), there are minimum ACE holding requirements of 1-4 tonnes for Freshwater eels, Oysters, Paua (Abalone), Rock lobster, and Scallops.

[30] The exception is if "overfishing thresholds" have been applied to the relevant stock, in which case the fisher's permit could eventually be revoked. At this point in time, however, overfishing thresholds (of 5%) have only been established for Freshwater eels, Oysters, Paua (Abalone), Rock lobster, and Scallops.

only one of a number of matters that the Minister may have regard to when setting a deemed value."

I describe the legislative basis for the current deemed-value regime further below.

Legislative Basis for Deemed Values

The legislative basis for the deemed-value system is set out in Sections 75 and 76 of the Fisheries Act:

Fisheries Act 1996, Section 75. Minister to set deemed value rates –
(As of May 1, 2001) (emphasis added)

(1) For each quota management stock, the Minister must, by notice in the *Gazette*, set an interim deemed value rate and an annual deemed value rate for that stock, and those rates continue to apply in each fishing year for that stock until varied under this section.
(2) In setting an interim deemed value rate or an annual deemed value rate, the Minister –
(a) ***Must take into account the need to provide an incentive for every commercial fisher to acquire or maintain sufficient annual catch entitlement*** in respect of each fishing year that is not less than the total catch of that stock taken by that commercial fisher; and
(b) ***May have regard to –***
   (i) The ***desirability of commercial fishers landing catch*** for which they do not have annual catch entitlement; and
   (ii) The ***market value of the annual catch entitlement*** for the stock; and
   (iii) The ***market value of the stock***; and
   (iv) The economic benefits obtained by the most efficient commercial fisher, licensed fish receiver, retailer, or any other person from the taking, processing or sale of the fish, aquatic life, or seaweed, or of any other fish, aquatic life, or seaweed that is commonly taken in association with the fish, aquatic life, or seaweed; and
   (v) The ***extent to which catch of that stock has exceeded or is likely to exceed the total allowable commercial catch*** for the stock in any year; and
   (vi) Any other matters that the Minister considers relevant.
(3) The Minister must set annual deemed value rates for a stock that are greater than interim deemed value rates set for that stock.
(4) The ***Minister may set different annual deemed value rates in respect of the same stock which apply to different levels of catch in excess of annual catch entitlement***.

The main components of Section 75 can be summarised as:

- Deemed-value levels *must* take account of providing an incentive to cover catch with ACE;
- Deemed-value levels *may* have regard to the desirability of landing fish caught without ACE;

- Deemed-value levels *may* have regard to the likelihood of catch exceeding the TACC; and
- Differential deemed values *may* be set to take account of the degree to which catch exceeds ACE.

Thus, the most important element of the legislative framework is the need to provide an incentive to cover catch with ACE, as indicated by use of the word "must" rather than "may", as with the other elements. This focus is deliberate, as there was an intention to make sustainability the dominant concern in the setting of deemed values, once deemed values became the primary compliance mechanism for the QMS regime. It also deliberately contrasts with the previous catch-balancing regime where the desirability of landing fish was given greater weight. As I discuss further below, the structure of the policy for implementing the deemed-value "catch-balancing regime" incorporates these main elements.

Section 76 of the Fisheries Act spells out that there must be a monthly accounting at the close of the 15th of each month, whereby each fisher is charged an interim deemed value based on the amount of catch in excess of that covered by ACE. The interim deemed value is a "reminder" for fishers to cover catch with ACE during the fishing year. At the 15th day after the end of the fishing year, a similar accounting is conducted for each fisher's annual aggregate catch compared to total ACE holdings for each stock. Credit is given for interim deemed values paid, any ACE purchased since the interim monthly reports, and a bill is sent to the fisher based on annual deemed-value rates, which are in practice typically about twice as high as interim deemed-value rates.

Under Section 79, a fisher's permit is suspended if a deemed-value debt of more than $1,000 is not paid within 20 days of the demand. Fishing with a suspended permit is a criminal offence. The only other important element of the catch-balancing regime is the possible application of "overfishing thresholds" (see Sections 77 and 78), which prevent a fisher from fishing in a QMA where his or her catch has exceeded a certain threshold.

Implementation of Deemed Values (the Catch-Balancing Regime)

Since June 21st 2001, the deemed-value system has been implemented according to the Ministry of Fisheries Advice Paper to the Minister "Fisheries Act 1996—Catch Balancing Regime", with some modifications as of September 5th 2003, based on the Final Advice Paper to the Minister "Review of Sustainability Measures and Other Management Controls for the 2003-04 Fishing Year". I will refer to these collectively as the "balancing-regime guidelines".

The primary means by which the balancing-regime guidelines provide an incentive to cover catch with available ACE[31] is by setting deemed values based initially on the market value of a stock, and then in most cases updating deemed values if catch levels exceed ACE or port prices rise. Deemed values are set initially as a proportion of the

[31] Note that total available ACE may be more than the TACC when uncaught ACE has been carried-forward from the previous fishing year. Up to 10% carry-forward is allowed for all stocks except for the following shellfish and eel species: ANG, CRA, OYS, OYU, PHC, PAU, SCA (see Schedule 5A).

value of the stock. The Ministry typically uses port prices as the primary indicator of market value, and a port-price survey is now conducted annually by the Ministry of Fisheries to support this information need. The system is then designed to iteratively adjust these deemed values over time in order to keep catch within ACE. This is accomplished by raising deemed-value rates if catch exceeds ACE by more than a certain percentage, or if port prices change. Differential deemed values may also increase as the degree to which catch exceeds ACE increases. Finally, overfishing thresholds may apply, after which point further catch is typically not permitted.

Thus, there are five basic elements to the structure of the balancing regime:

- The base deemed value rate;
- Whether and how the deemed value is automatically increased in response to catch in excess of ACE in prior years;
- Whether and how deemed values change in response to port price changes;
- Whether and how differential deemed values apply; and
- Whether overfishing thresholds apply.

To help ensure the balancing regime accounts for the substantial differences in the characteristics of species currently managed in the QMS, the application of each of these five elements within the balancing-regime guidelines differentiates between four categories of stocks: "High Value, Single Species Fisheries Fish Stocks", "Low Knowledge Fish Stocks", "Low/Medium Value Bycatch Fish Stocks," and "All Other Fish Stocks". These categories are summarised in Table 4.

The 2001 Advice paper describes the rationale for the relatively stringent application of the balancing regime to high-value, single-species stocks such as shellfish and eels (Ministry of Fisheries 2001, p. 6):

> The high value of these stocks means there is potential for large profits to be made from taking catch in excess of ACE. Representatives of fishers in high value, single species fisheries have requested the strongest possible deterrent to continued taking of catch in excess of ACE. They note that, due to the targeted nature of these fisheries, there is little, if any, excuse for catches to exceed ACE at any stage during the fishing year. They are concerned that the move from criminal to administrative disincentives as the primary deterrent could potentially undermine the value of their quota property right by allowing overfishing.

Table 4. Categorization of Fish Stocks for the Purpose of Setting Deemed Values

Category	Definition	Stocks included
High-value, single-species fisheries stocks	High value (port price and ACE value); taken primarily with little, if any, bycatch	All stocks of: Paua; Rock lobster; Scallops; Oysters; Eels
Low-knowledge stocks	Stocks with relatively little information on the fishery status; no sustainability concerns	All stocks of: Cardinal fish; Frost fish; Ghost shark (pale and dark); Ribaldo; Ruby fish; Sea Perch; Trumpeter; White Warehou; Yellow-eyed mullet
Low/medium-value bycatch stocks	Low/medium value; majority of catch taken as bycatch; TAC to be reviewed in next few years; no sustainability concerns	Silver warehou 3 and 4; Stargazer 1 and 2; Rig 2; School shark 2; Trevally 2; John dory 7
All other (most) stocks	Stocks that do not necessarily have a high unit value and for which there is adequate information for MFish to have confidence in the TACC	All remaining stocks

Regarding low-knowledge stocks, the 2001 Advice paper states (Ministry of Fisheries 2001, p. 6):

> These are fish stocks for which there is relatively little information on the fishery status and about which there are believed to be no sustainability concerns. Catches of these stocks prior to their introduction to the QMS were typically poorly recorded and, as a result, small TACCs were set when the fishery came into the QMS. In some cases this has led to a significant shortage of available ACE to cover catch, and in some cases considerable over-catch of the TACC.
>
> For these stocks, it is appropriate to set balancing regime variables that encourage fishers to land any catch taken in excess of ACE, for a period, in order to improve the available information on the fishery. This additional information should allow a TACC to be set with greater confidence. It is proposed that stocks would be moved from the Low Knowledge category to the All Other category once MFish has more confidence in the TACC or after 5 years catch data has been collected—whichever is sooner. Once a stock is reclassified, the balancing regime variables would be adjusted to more strictly restrain catches within the available ACE.

The primary change brought about by the 2003 Advice Paper was the addition of the "Low/Medium Value Bycatch" category, as explained in that paper (Ministry of Fisheries 2003, p. 310):

> The new balancing regime has placed increased emphasis on the appropriateness of TACs because in a number of cases fishers will face increased disincentives associated with the level of over-catch in some

fisheries. MFish has therefore developed a framework on the setting of TACs for low/medium value stocks where the majority of catch is taken as bycatch. It is proposed that the stocks of this type, and for which TACCs are to be reviewed, should be classified into a new category under the Balancing Regime Guidelines. For stocks in this category, the deemed value will not be increased and, if appropriate, the differential deemed value will not apply.

The "all other" category is self-explanatory, and includes all stocks that do not necessarily have a high value and for which the Ministry has confidence in the TACC. The guidelines do not currently impose overfishing thresholds on these other stocks, and there are plans to do so only if "deemed values prove inadequate to prevent persistent, significant overfishing and there are risks to ensuring sustainability" (Ministry of Fisheries 2001, p. 8). The Advice paper continues: "If, in future, overfishing thresholds and tolerance levels are set for finfish stocks, the thresholds and the tolerance levels will likely be greater than those proposed for shellfish stocks. This is to account for the nature of the fisheries in which these stocks are taken—especially where stocks are taken in mixed species fisheries."

Table 5 summarises how the different elements of the deemed-value system vary across the different fish stock categories.

Table 5: Application of Balancing Regime Elements in Each Fish Stock Category

Stock category	Initial base deemed value rate	Increase in response to overcatch?	Change with port price?	Differential deemed values apply?	Overfishing thresholds apply?
High-value, single-species fisheries	200% of highest port price	20% increase if total catch exceeds ACE by >2% in 1 year or >1% in 2 consec. years	Yes	Yes, see Table 6	Yes 5%
Low knowledge	Incentive to land fish & cover catch w/ ACE (~10% of port price)	No	No	No	No
Low/medium value bycatch	Portion of avg. port price (~75% of port price)	No	No	No	No
All other	Portion of avg. port price (~75% of port price)	20% increase if total catch exceeds ACE by >10% in 1 year or >5% in 2 consec. years	Yes	Yes, see Table 6	None currently

Differential deemed values for all stocks other than low-knowledge and low/medium-value bycatch stocks currently apply according to the schedule given in Table 6 (see Ministry of Fisheries 2001). The schedule is based on each individual fisher's catch in proportion to his end-of-year ACE holdings, and increases deemed-value rates in a linear step function of 20% increments up to a maximum of two times the base deemed-value rate. Each deemed-value rate applies only to the tonnage within the applicable bracket, like a progressive income tax system with marginal brackets. That is, the first 20% of catch above ACE is charged the basic rate, the next 20% of catch above ACE is charged 120% of the basic rate, and so on. While the flexibility exists for this schedule to be adjusted according to the particular characteristics of individual fisheries, such flexibility has not yet been used.

Table 6. Differential Annual Deemed Values

Individual catch as a percentage of ACE held	Differential annual deemed value
100% < x ≤ 120% of ACE	Basic annual deemed value
120% < x ≤ 140% of ACE	120% of basic annual deemed value
140% < x ≤ 160 % of ACE	140% of basic annual deemed value
160% < x ≤ 180% of ACE	160% of basic annual deemed value
180% < x ≤ 200% of ACE	180% of basic annual deemed value
200% < x of ACE	200% of basic annual deemed value

Effect of Deemed Values on Catch Levels and Quota Values

Paying the deemed value on a tonne of catch in effect represents a substitute to purchasing a tonne of ACE. One would therefore expect there to be a close relationship between the level of catch relative to the TACC, and the deemed-value rate relative to the ACE price. This relationship is shown in Figure 15, where the horizontal axis represents total catch (in tonnes) and the vertical axis represents unit value (in $/tonne).

As in Figure 5, the downward-sloping line in Figure 15 represents the profit per tonne of catch where, as explained above profits per tonne tend to decline as catch levels increase. The vertical line at Catch = TACC represents a constraint on catch at the TACC.[32] A profit-maximising fisher would therefore be willing to pay up to an ACE price of P_{TACC}, where the TACC constraint intersects with the unit profit function. It is in this sense that the downward-sloping function is also an ACE demand function, because it represents the willingness to pay for ACE at different levels of catch.

As long as the deemed value is equal to or greater than P_{TACC} per tonne, fishers will not have an incentive to catch beyond the TACC, because the profits from this additional catch would be lower than the deemed-value payment they would need to make to cover the catch. Therefore, the basic principle to apply if the target is to constrain catch to be at or below the level of available ACE, is to set deemed value rates at or above P_{TACC}, which is the ACE price that would exist if catch levels were equal to the TACC.

[32] One could equally think of the TACC level as the level of available ACE, which could be as much as 10% higher than the TACC if there are carryovers from the prior fishing year.

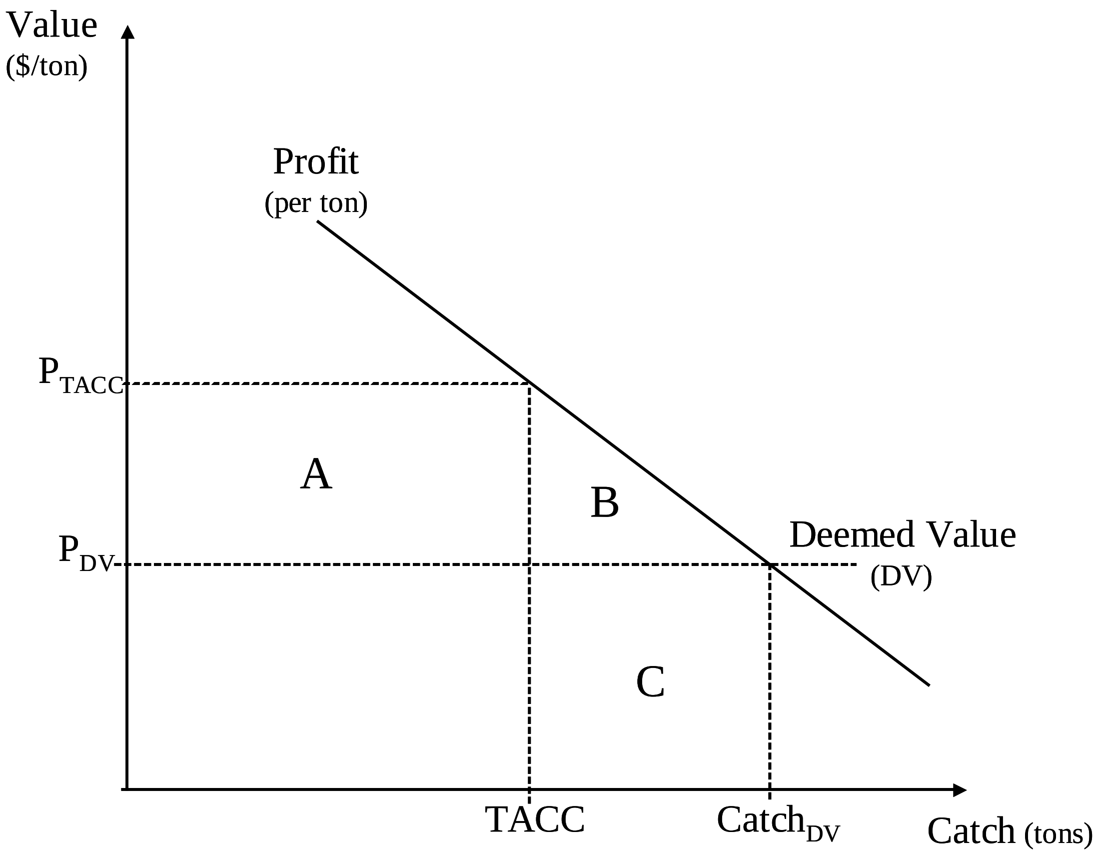

Figure 15. Effect of Deemed Value on Catch Levels and Quota Values

Now, assume for the moment that *differential* deemed values do not apply,[33] and consider the consequences of setting a deemed value at a level below P_{TACC} (i.e. the ACE price that would exist if catch levels were equal to the TACC). This is shown in Figure 15 by the horizontal line labelled "Deemed Value", where the deemed-value rate is P_{DV} per tonne. Given the opportunity to cover catch with deemed-value payments at a cost of P_{DV} per tonne, fishers will now have an incentive to catch up to a level of $Catch_{DV}$, given by the intersection of the deemed-value rate with the profit function. This will also bring ACE prices down to the level of the deemed-value rate, P_{DV}, because no fisher would be willing to pay an ACE price greater than the deemed value, which is a perfect substitute for ACE.

Note therefore that it is not correct that deemed values will constrain catch levels to available ACE so long as the deemed value is at or above the ACE price. The correct point of comparison, as discussed above, is the ACE price *that would exist* if catch was constrained to available ACE (i.e. P_{TACC}). As is clear from the example, with a deemed value below P_{TACC}, the ACE price and the deemed value will tend to be equal for catch levels that exceed the TACC. Thus, deemed values act like a ceiling or cap on ACE prices, because fishers will revert to deemed-value payments as soon as ACE

[33] Allowing for differential deemed values would not change the basic analysis, but would complicate the figure.

prices start to rise above the deemed-value rate.[34] Therefore, any time that catch levels exceed available ACE, the ACE price is no longer an appropriate reference point for setting deemed-value rates, except as an indicator that the deemed value should be *higher* than the ACE price if it is desired to keep catch within the TACC.

Effect of Deemed Values on the Distribution of Profits

Deemed values also have consequences for which parties receive the value associated with a given level of catch: quota owners, catchers, or the Government. "Quota owners" here refers to the owners of the quota in question, who can differ from those who are catching the fish. The Government currently receives the value associated with deemed-value payments. These distributional effects are depicted in Figure 15 by the areas labelled A, B, and C.

Rectangle A is equal to the TACC multiplied by the difference in the ACE price, with and without a deemed value, set at level P_{DV} below P_{TACC}. Area A represents a loss in value to quota owners of the fish stock in question. The deemed value puts a ceiling on the price quota owners can get for ACE, lowering the ACE price from P_{TACC} to P_{DV}, and thus lowering the total value received by quota owners. One might ask: where does this value totalling A go? It is captured by catchers who now pay lower prices for their ACE. Economists refer to this type of redistribution of value as a "transfer" because it has no direct consequence for the total value received from the fishery, just for who receives that value. As discussed further below, in addition to area A, quota owners also lose the value of leaving the fish in the stock, where it will grow and have a future payoff in terms of both more fish and lower costs.

The total of areas B and C in Figure 15, in contrast, represents the increase in profits from the additional catch in excess of the TACC. In the figure, profits are still positive at catch levels beyond the TACC, so increasing catch beyond the TACC increases current profits. The distinction between the two subcomponents, B and C, is who captures this value. Rectangle C is equal to the amount of catch in excess of the TACC (or available ACE), multiplied by the deemed-value rate. It is therefore equal to total deemed-value payments, and thus represents the portion of additional profits captured by the Government. Triangle B, on the other hand, is the portion of additional profits captured by catchers, as it represents the amount of profit gained from catch above the TACC that is above the level of deemed-value payments on that catch.

In summary, the current distributional effects of deemed values are that quota owners lose area A (plus the stock value—see below), catchers gain areas A and B, and the Government (or "public") gains area C. The net gain in current profits is B plus C, with the fishing industry gaining B and the Government gaining C. The relative magnitude of these gains and losses depends on the shape (e.g. steepness) of the incremental profit function, the level of the deemed value (P_{DV}), and the ACE price that would obtain if catch were constrained to available ACE (P_{TACC}). For instance, as the deemed value gets closer to zero, the net gain in current profits to industry becomes larger relative to the deemed-value payments to Government. A steeper

[34] Unless overfishing thresholds apply, in which case the deemed value is no longer a substitute for ACE.

profit function implies that the size of the transfer (A) is larger relative to the magnitude of the current profit gain (B+C).

This analysis has implications for ongoing fishery policy discussions in New Zealand, particularly those regarding the disposition of deemed-value payments, which currently flow to the Treasury along with other government revenues. The extent to which catchers coincide with quota owners is of obvious importance for assessing these distributional impacts, particularly in the context of multi-species fisheries. Most deemed value payments are made on species, such as Ling, Hake, and Silver warehou, that are taken as bycatch with other target species, such as Hoki.[35] In this case, a significant part of the profit function is likely to be associated with the value of the target species rather than that of the bycatch species on which deemed value is being paid.

To the extent that the owners of the bycatch stock on which deemed values are being paid are the same as the fishers who catch beyond the TACC, the effect of deemed value on lowering ACE prices has a net beneficial effect on profits. But for those who own the bycatch ACE, but do not benefit from the catch in excess of the TACC, there is a net loss. This could be the case, for example, for fishers who target species (e.g. Ling) that are bycatch to those who target other species (e.g. Hoki).

At least two questions arise when considering the disposition of deemed-value payments. T he first question is: who is the legitimate claimant on deemed value payments—owners of quota for the fish stock on which deemed values have been paid; quota owners more generally; those who paid the deemed values; the Government; or some other party? The second question is whether deemed values could be recycled in a manner that did not eviscerate the very incentives it was designed to provide, if such recycling was desired. In addition to these questions, there is also the issue of whether the Treasury would have additional considerations regarding changes in this revenue stream.

With respect to the first question, one perspective is that the deemed-value revenues should accrue to whoever is the legitimate claimant on catch in excess of the TACC. If there are no non-commercial interests in the relevant fish stock, then one could argue that the legitimate claimant is the owners of quota for the fish stock on which deemed values have been paid. In this point of view, commercial fishers are the residual claimants on catch once non-commercial fishing is subtracted from the TAC. That is, the TACC (and the quota that goes with it) is equal to the TAC minus non-commercial catch. If the Government permits fishing in excess of the TAC, then one could argue that the value of this catch should also accrue to the quota owners for that fish stock. As I discuss further below, fishing above the TAC also degrades the stock of fish and thus lowers the future profitability of the fish stock and the value of quota. In this sense there is both a direct and indirect loss to quota owners: the direct loss is the lower ACE prices in the current period (as discussed above); the indirect loss is lower future profitability of the fish stock, which should be reflected in lower quota share prices.

[35] One recent estimate suggests that at least two-thirds of deemed-value payments in the 2001–2002 fishing year were made on these three species, which are virtually always caught together with Hoki.

But this loss suffered by owners of quota in stocks where deemed values have been paid can be greater than, or less than, the amount of deemed values paid, and would be equal to it only by coincidence. This is clear from the fact that very low deemed-value rates would result in very few deemed-value payments, but would in fact maximise the loss to quota owners. In terms of Figure 15, area A (which represents a lower bound on this loss because it does not include the loss in stock value), can be greater or less than the deemed-value payment (area C). The loss in stock value would in principle be measurable through an analysis like that underlying Figure 5. But then this raises the issue of whether the current TACC is the value-maximising TACC (i.e. TACC = MEY). On the other hand, if the catch corresponding to the deemed value ($Catch_{DV}$) is viewed as the "right" catch level, then the amount of deemed-value payments (area C) does in fact represent the value to which quota owners are probably entitled. If, for example, it was envisioned that the TACC would eventually be raised to $Catch_{DV}$, then under the new TACC = $Catch_{DV}$ the revenue to quota owners would actually be what quota owners currently get (P_{DV} x TACC), plus area C.

This has assumed, however, that the only value of relevance is commercial value. If there are recreational and customary interests in the fish stock that have been harmed by commercial catch beyond the TACC, then one could reasonably argue that deemed-value payments should go to those parties as compensation. In that case keeping the revenues (or at least part of them), with the Government as the representative of non-commercial interests, seems legitimate. There may also be other non-commercial values at stake, such as the value associated with the health of the aquatic ecosystem. If it is this "environmental sustainability value" that policy is seeking to protect in setting a particular TACC, then the deemed-value payments represent compensation for diminution of that value. The Government would seem to be the appropriate recipient of such compensation.

In practice it would be difficult to disentangle and estimate the magnitude of these various losses if one envisioned recycling deemed-value payments to proportionally compensate harmed parties. With respect to commercial interests, a useful and feasible analysis would be to assess the degree to which the quota owners who are harmed by deemed values are the same entities as the catchers who are exceeding the TACC. If, for example, quota holdings tended to be in direct proportion to the amount of deemed values paid, then there is a net gain to the quota owners from the flexibility allowed by deemed values. In this case it would only make sense to pay compensation to commercial interests if one thought that commercial interests had some right to the catch in excess of the TACC (and if such compensation did not erode the desired incentives).

From a pragmatic standpoint, there is legitimacy to the claim that deemed values capture commercial value from catch, that government policy has typically taken the approach of leaving such value with the commercial sector, and that there are valuable fishery-specific purposes to which the deemed-value revenues could be put. There are also ways in which deemed-value revenues could be recycled without diminishing the incentive to cover catch with ACE. The incentive would only be fully diminished if deemed values were simply returned to those who paid them, which would obviously negate the whole system.

One possibility is to recycle deemed-value revenues (or a portion thereof) to offset or augment cost-recovery fees for the same or related stocks, particularly for supporting fishery-specific biological and economic research. Funds for such research are in short supply and could greatly benefit the process of setting TACs and adding value to the fishery. In the event that deemed values ended up offsetting cost recovery fees, each fisher who paid deemed values would in effect get back a portion of these payments equal to his quota share. This could present an incentive problem for those fish stocks where the quotas are highly aggregated. In situations where there is a concern that recycling deemed-value revenues would create incentive problems, the breadth of the use to which the deemed values are being put could simply be broadened.

Deemed Values and Maximising the Value of Fisheries

With the focus on current profits in the previous section it might seem that, as long as the profits from additional catch are positive, then lowering deemed values to allow that catch would increase the value from fisheries. But the analysis embodied in Figure 15 did not take full account of the value of leaving fish in the stock, as was discussed earlier in Section 3 in the context of maximising the value of fisheries (see Figure 5). That is, unless the additional profits gained from the expansion of catch beyond the TACC through deemed values are greater than the value of leaving this fish in the stock (as indicated by Figure 5), then the net value of such expansion is negative.

To be specific, if the stock that supports MEY is at or above the stock that supports the TACC, then allowing expansion of catch beyond the TACC will decrease rather than increase the value of fisheries. On the other hand, if the TACC is "too low" relative to achieving the stock that supports MEY, then allowing expansion of catch through deemed values will increase the total value from fisheries.

One could in fact view the degree of satisfaction of different fishers with the current deemed-value system as an expression of the degree to which the TACCs they are designed to enforce do indeed coincide with the MEY. On the one hand, as discussed earlier in Section 3, it is likely that, for high-value single-species fisheries (e.g. Rock lobster, Paua (Abalone), Scallops) the MEY is quite close to MSY (which is the standard basis for setting the TAC). These are also the very fishers who have requested the most stringent application of deemed values (200% of highest port price), and the only stocks for which overfishing thresholds apply. For many low-value fish stocks primarily caught as bycatch, on the other hand, there has been disgruntlement and a desire to keep deemed-value rates low, and allow greater catch. Low-value bycatch stocks whose TACCs have been set on biological criteria without regard to maximising value, are not likely to be near MEY.

This discussion makes particularly clear the tension that is created in multi-species ITQ fisheries management when TACCs are set independently for interrelated stocks based predominantly on MSY. This tension arises because MSY for a particular fish stock reflects only its own biology, and does not reflect the economic production relationships that might exist with other jointly-caught species. Thus MSY is more likely to be a poor proxy for MEY in a multi-species context, particularly with respect to bycatch fish stocks that have low direct value. In cases where a fish stock has low direct value but is inevitably caught as bycatch with another more valuable species, it becomes more likely that the value-maximising stock level is below that which would support MSY.

But this cannot imply that catch levels above MSY are sustainable or even possible in the long run, simply because catch levels above MSY cannot, by definition, be sustained. A more likely scenario is that catch levels above MSY would eventually drive the bycatch stock down to a level where the bycatch species is no longer caught in as high a ratio to the target species. If this was a deliberate goal, one could envision two strategies for accomplishing it. One approach is to set the TACC to correspond to where you eventually want the stock (and catch) to be, but to set deemed values at a level that allows higher catch until that stock is achieved. Another approach is to dynamically adjust the TACC over time to correspond to the catch pattern one wants to achieve.

These two approaches differ in at least two respects, one pragmatic the other distributional. From a pragmatic point of view it is easier for the Ministry of Fisheries to adjust deemed values over time than it is to adjust TACCs, due to different standards for consultation and scientific assessment, and due to the implications for quota allocation when the TACC is changed. From a distributional perspective, the difference depends in part on whether deemed-value payments remain with the Government or are recycled. Under the current system, ACE can be viewed simply as a credit against paying deemed value.

Given that these two instruments can therefore be viewed as simply two different means to the same end (controlling the catch), one could argue that overall policy coherence and consistency would be advanced by designing the system so that the distributional consequences of each instrument were comparable. This brings us back to the discussion in the previous section. It could thereby alleviate a potential bias against more advanced use of deemed values, as they would be seen less as a loss to industry and a gain to government revenue, and more as another available instrument in the fishery policy toolbox.

In addition, the recognition that the setting of both TACCs and deemed values has implications for the catch suggests that the standards for consultation and analysis underlying these two closely-related aspects of the system should be similar and should be closely co-ordinated.

What Should the Role of Deemed Values be in Order to Maximise Value?

Section 3 introduced the basic structure of a framework for maximising value in fisheries. There we found that the primary role of policy is to represent the value of leaving fish in the stock so that there is an incentive to constrain catch to the maximum economic yield Q*. I also discussed in Section 3 the possibility of attaining a particular target catch through either catch quotas or landing fees, and that deemed values can be viewed as a particular form of landing fee. In that discussion, the goal was framed in terms of achieving target catch Q*, and we saw that in principle this target could be achieved with either instrument *if we knew these functions exactly and if there was no uncertainty*. Furthermore, in that scenario, once the target is known, the best policy is a simple constant fee (of P_{Q*}) or a rigid quota of

Q*. Once the quota or fee is determined the value functions themselves become irrelevant and do not play a further role in designing the policy.

But once one acknowledges that there is considerable uncertainty in many aspects of fisheries—including stock levels, optimal TACC levels, the specific composition of catch, and fish prices—the value-maximising target Q* will vary over time depending on conditions. Given this reality, a fixed quota or fee will not be a value-maximising strategy. Instead, a value-maximising policy will replicate the upward-sloping stock-value function represented in a stylised fashion in Figure 5. The primary purpose of the policy has not changed, but there is additional value in designing the policy to take account of a wide range of conditions. In this manner, the policy adjusts to send varying signals about the stock value depending on particular circumstances. In terms of Figure 5, the optimal catch level varies over time because the profit and stock-value functions are moving around, and thus their intersection moves around.

Faced with uncertainty and the goal of replicating the stock-value function, one might ask how each instrument—a quota or fee—fares in achieving that goal. There is a sizeable economics literature on the general issue of policy choice under uncertainty, but a rather modest one specifically pertaining to fisheries.[36] Nonetheless, the basic intuition of the matter is most easily found through reference to Figure 5.

In that figure one can see that, despite all its practical advantages, a quota instrument by itself is quite blunt. The quota is a vertical line, implicitly indicating that up to the quota level there is zero value to catching more or less. At and beyond the quota level, however, the value of leaving the fish in the stock becomes infinite. In contrast to the upward-sloping stock-value function, therefore, the quota provides little if any conservation incentive when catch is below the quota, and provides "too much" incentive allowing no flexibility for catch beyond the quota.

A fixed landing fee of P_{Q*} levied on all catch, on the other hand, has the opposite problem, in that it indicates the value of leaving fish in the stock is the same regardless of how much is caught. In comparison to the stock-value function which it is attempting to represent, the fixed fee provides "too much" incentive for desired catch levels below Q* and "too little" incentive for catch levels beyond Q*.

The ideal solution is to implement a graduated landing fee schedule that exactly replicates the stock-value function. How well each of the two simple instruments does in approximating this ideal depends on how steep the value function is relative to the profit function. If the value function is very steeply sloped in the relevant range of catch, then a stringently-enforced quota will tend to do better because a quota is very steep. If, on the other hand, the stock-value function is very flat in the relevant range of catch, a landing fee will do better because it is perfectly flat. How exactly each of these instruments performs under different types of uncertainty is an important question requiring further analysis.

It is important at this point to also note that, in order to make the analysis more readily translatable to practical policy, we have been thinking of the stock value as a function

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[36] See Reed (1979), Koenig (1984, 1985), Clark and Kirkwood (1986), Weitzman (2002), and Sethi et al. (2003).

of the catch level (as in Figure 5). It is, however, more appropriate to think of the stock value as a function of the remaining stock, or level of escapement. Although the two are clearly linked, there may be year-to-year fluctuations in the stock that make a variable catch level appropriate in order to attain a relatively constant escapement level. This implies that the catch level at which different levels of the deemed values apply, should vary based on the status of the stock. If the TACC is adjusted to reflect these changes, then the principles underlying the "optimal" deemed-value schedule described above would hold. But, if the TACC is not adjusted, it may make sense to "flatten" the deemed-value schedule as a function of catch, so that the deemed value becomes the mechanism by which flexibility is allowed in annual catch.

Setting the Deemed-Value Schedule

One might ask: "What does this all have to do with deemed values?" As discussed earlier, New Zealand has a hybrid quota-fee system, and deemed values are a particular form of landing fee that does not apply on catch covered with ACE, and is not necessarily constant. This is depicted in Figure 16, which shows how deemed values begin at the point of the TACC, and for most stocks increase in 20% increments up to a maximum of two times the base rate.[37] Where overfishing thresholds apply, they would be represented as a point where the deemed-value schedule goes vertical. As is clear from comparing Figure 5 and Figure 16, the differential deemed value system thus has most of the basic design elements to give it the capacity to represent the stock-value function. A value-maximising deemed value system would set each of these elements based on the biological and economic characteristics of each fishery. I discuss some further design principles for the base deemed value and differential deemed-value increments below.

Based on the discussion in Section 3, it is probably now clear that the base deemed-value rate should ideally be set to approximate the value of leaving the fish in the stock, when the stock and the catch are at their desired levels.[38] If the TACC is considered to be a good approximation of the desired catch level, then the base deemed value should approximate the price of ACE when catch is about equal to the TACC. If the current TACC is not considered to be a good approximation of the value-maximising catch, then setting the deemed value to achieve a target catch other than the TACC can be desirable.

[37] The figure shows an example where the profit function is such that it makes sense to pay deemed values and catch about 50% over the TACC.

[38] If there is better information about the desired level of catch, then the deemed value can be adjusted to achieve this level.

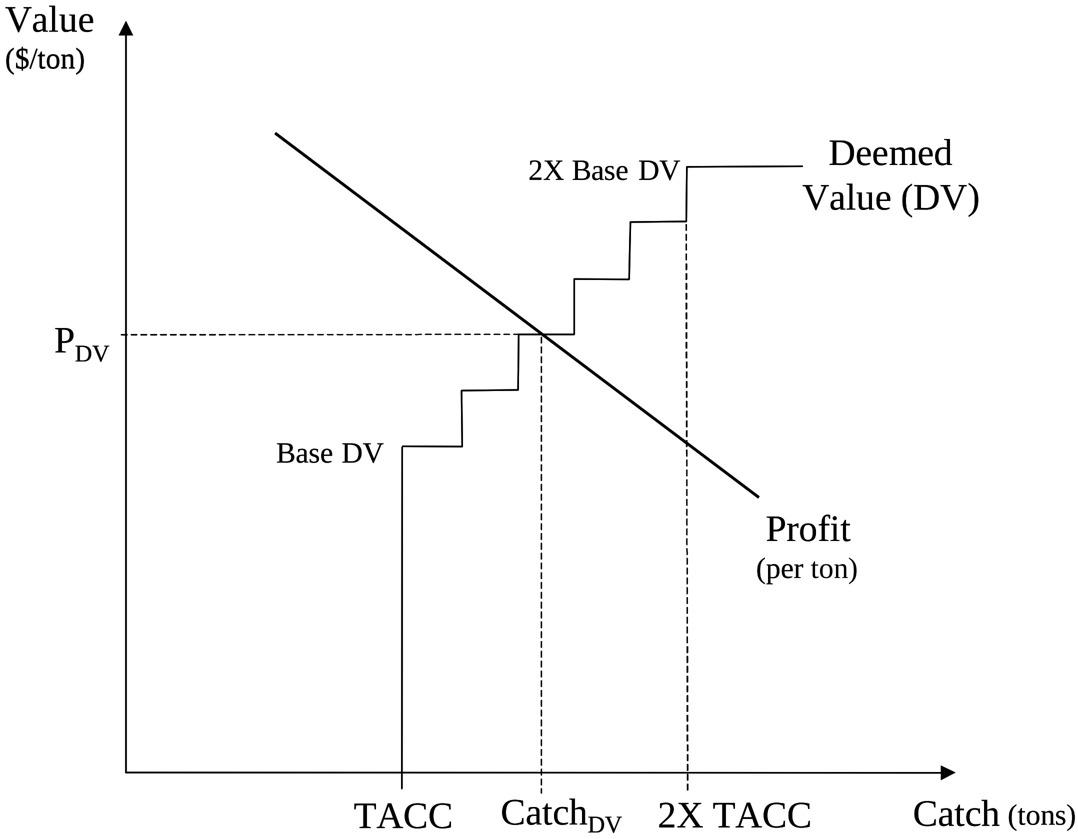

Figure 16. Differential Deemed Values

In the long term, however, if the average catch level desired in the future is very different from the current TACC, it would be desirable to change the TACC level. This is true for two reasons. First, having the TACC set at about the "right" level makes it clear what the target is, and makes it easier to iteratively adjust deemed values to aim for that target. Second, it avoids large continuous flows of revenue from the fishing industry to the Government, as the TACC is effectively a credit against having to pay deemed value. Whenever feasible, it is also valuable to adjust TACCs on a regular basis to reflect the current status of the stock, particularly for species exhibiting a large degree of variation in stock abundance.

One additional issue confronting the Ministry is the use of different bases for setting deemed values, including the use of port prices, ACE prices, and other information. Setting deemed values for incidental catch based on a percentage of port price is flawed, because the ACE price is a function not just of the TACC and the value of that stock, but of the target fishery as well. To provide the necessary incentive to limit the catch of the bycatch species it may be necessary to have deemed values well in excess of the port price. This raises the additional need for adequate monitoring and compliance enforcement. At a minimum, it would be useful for the Ministry to consider other information such as estimates of profitability (based in part on ACE prices) in setting initial deemed values. The iterative process through which deemed values are adjusted to keep catch in line with the TACC is probably the best tool, as long as the TACC is set at the "right" level.

Regarding the application of differential deemed values, one issue is what the basis of any increases in the deemed value should be. Under the current structure, the deemed value increases as a function of the percentage each individual fisher catches above his ACE holdings. This gives rise to a situation where different fishers assign different values to additional catch, even though that additional catch has the same effect on the stock. From the perspective of representing the value of the stock, it makes more sense to base the steps of the deemed-value schedule on aggregate catch relative to the TACC, rather than on individual catch relative to ACE.

In addition, many large players have effectively circumvented the existing individual-based differential deemed-value system anyway, by trading quota at the end of the fishing year from those facing low differential deemed values to those facing high ones. But this type of trading does not lead to any increase in value, simply a redistribution of revenue from the Government back to the fishing industry. Plus there is a loss in value due to the transaction costs involved. Finally, the existing system imposes a competitive disadvantage on a small-scale fisher who pays 20% more if he overcatches by 2 tonnes (for example), while a large-scale fisher can overcatch by 200 tonnes before he pays a higher deemed value. Unless there are important overriding considerations, a basic principle of efficient economic design of policy is for different actors to face the same prices. Under the current system, different fishers can face a different price for taking fish from the stock.

For all these reasons, it makes sense to redefine the basis for applying differential deemed values by transitioning from deemed-value brackets based on individual catch-to-ACE ratios to brackets based on aggregate catch-to-TACC ratios. Rates would apply equally to all fishermen based on end-of-year values of overcatch. This would ensure that all fishers faced the same price for taking fish from the stock. At the same time, it would make sense to raise the interim deemed-value rate throughout the fishing year, to provide an up-to-date reflection of the current state of overcatch.

At the same time, it is probably sensible to move the end-of-year ACE true-up date from October 15th to November 15th, to allow more time for end-of-year balancing of catch with ACE. Currently there are only two weeks at the end of the fishing year for fishers to balance catch with ACE and sort out deemed-value payments. Basing individual deemed-value payments on aggregate end-of-year catch-to-TACC ratios provides an additional reason to allow more time at the end of the fishing year for this complex balancing process.

The existence in some cases of unused ACE at the end of the fishing year, at the same time that individuals are paying deemed values, is another indication that there is probably value in efforts that make ACE transactions easier. In addition to more end-of-year balancing time, transaction costs in quota and ACE markets can be reduced through measures such as promotion of on-line trading (such as ACE Trader) and greater use of public auctions.

A more difficult question is what the logic should be for the rate at which differential deemed values increase as a function of catch above the TACC. As already mentioned, this should ideally reflect the rate at which the stock value increases as a function of catch. The examples set out in Section 3 illustrated that, depending on the biological and economic characteristics of individual fish stocks, the rate at which the stock-value function increases can differ dramatically. In those not implausible examples, the stock-value function in one case approximately doubled over about a 4% increase in catch, while in the other case it doubled over about a 15% increase in catch, starting from a much lower level. More detailed analysis would be required to set the schedule in particular fisheries.

As a starting point, one important determinant of the steepness of the deemed-value schedule should undoubtedly be the ratio of the TACC to the stock of fish. For stocks managed at a high level, where the annual catch is only a small portion of the stock, it is less likely that the stock value increases dramatically as catch increases. Put differently, if the catch is a small fraction of the stock, then overcatching (as long as it is not persistent) is unlikely to have large incremental consequences. For other stocks, where the annual catch is a large portion of the stock, overcatching by something of the order of 100% might have much more serious consequences.

One important determinant of the ratio of desired catch to the stock size is likely to be the growth rate of the species. In the standard logistic growth model, for example, $MSY = rB_0/4$, and the stock corresponding to MSY is $B_{MSY} = B_0/2$, where r is the intrinsic growth rate of the species, a number ranging from about 0.05-2.5. In this case, if the target catch is MSY, then the catch is equal to fraction $r/2$ of the stock. If $r = .1$, for example, a stock managed in this way would have an annual catch that is 5% of the stock, a fairly small portion. If $r = .5$, on the other hand, a stock managed in this way would have an annual catch that is 25% of the stock, a fairly sizeable portion. An overcatch of 100% in the first case would represent taking 10% of the stock, while in the second case it represents taking 50% of the stock.

While the consequences of these levels of overcatch would depend on other characteristics of the specific species, at first blush the latter case might present a more serious problem, other things being equal. One factor that would mitigate this problem is that faster-growing stocks would typically be able to recover more quickly. How these various considerations would combine to influence an overall deemed-value schedule needs to be the subject of further analysis. Absent other information on the stock size, one initial suggestion might therefore be to base the deemed-value schedule in part on the growth rate of the species. But, as we saw earlier, the value-maximising stock size may also be high for low-value species, as in the example in Figure 9. This illustrates another principle. It may make sense in some cases to manage the stock at a relatively high level, but to allow substantial year-to-year flexibility in catch through a relatively flat deemed-value schedule, so long as the *average* catch is not above the target level.

6 CONCLUSION AND RECOMMENDATIONS

This report has explored how the application of economic principles and bio-economic frameworks might further the Ministry of Fisheries' overarching objective to "Maximise the value New Zealanders obtain through the sustainable use of fisheries resources and protection of the aquatic environment." In order to maximise the value of fisheries, I put forward the principle that fish stocks should be managed at a level where the incremental value of catching fish is equal to the incremental value of leaving fish in the stock. As an unregulated fishery will tend to focus on the value of catch, and not the value of the stock, it becomes the specific role of public policy to provide the incentives for private actors to recognise the stock value part of this equation.

While the New Zealand QMS takes a big step in this direction by allocating the TACC to individual fishers, the principle for setting the TACC itself has been almost exclusively biologically-based. Incorporation of economic information in combination with the biological characteristics of different fish stock complexes could provide the basis for significantly increasing the value of New Zealand fisheries by tailoring stock targets and catch targets to specific bio-economic conditions. In some cases such analysis may indicate that managing stocks at B_{MSY} (so that they produce the maximum sustainable yield) is a value-maximising strategy. In other cases, it may be valuable to manage stocks well above B_{MSY}, and in limited cases below B_{MSY}. While some such adjustments have no doubt already implicitly occurred through the TAC-setting and implementation processes, more systematic application of bio-economic frameworks would be beneficial in guiding these decisions.

I also highlighted the point that landing fees on catch can be an alternative to quota as a means to controlling catch, and that New Zealand in fact employs a hybrid "quantity-price" system through its use of deemed values in combination with quotas. In cases where deemed values are paid and the catch exceeds the TACC, the deemed value (not the quota) in effect becomes the instrument controlling the level of catch. This recognition clarifies that the same principle that should apply to the setting of the target stock and TACC—that of representing the value of leaving fish in the stock—should also apply to the setting of deemed values, as these are just two different instruments for achieving the same end. While the concept of value has entered into the implementation of the deemed-value regime, its application to specific species and fish stocks could be improved through refinement and tailoring to the specific characteristics of individual fishery complexes.

I also found that the deemed-value system has consequences for the redistribution of value in the fishery from quota owners to catchers and the Government, and raises the question of how associated revenues should be used. Deemed-value revenues are related to, but not equal to, the value lost by owners of quota for the stock on which deemed values are paid.

I thus raised the prospect that the policy instruments of individual quotas and deemed values could be used in tandem in managing multiple-species fisheries, to improve value and potentially alleviate some of the rigidity and tension that are otherwise inevitable in an inflexible ITQ system. This recognition is already implicit in the manner in which some TACs are set, and in the implementation of the deemed-value system, but systematising this process would increase both value and transparency. Finally, I pointed out that these different instruments will tend to behave differently when one considers uncertainty in stock size, year-to-year stock recruitment, and other biological and economic variables. How to best employ quotas and deemed values to maximise value in the face of these uncertainties is an important area requiring further research and practical experimentation.

New Zealand has embraced the difficult task of managing a much larger number of species through tradeable quota than any other country; soon to be over 70 species and 300 individual fish stocks and corresponding quota markets. Rather than leaving lower-value species outside the system, New Zealand has sought to bring all commercial species into the system. While this strategy appears to have been successful overall, it has created increasing tension in the system as catch limits for lower-value species in some cases become binding on higher-value target fisheries. As the target for establishing the TACs for individual fish stocks has been predominantly the biologically-determined MSY, such tensions are inevitable under the current system.

In summary, the Fisheries Act and broad fisheries policies that implement it, contain most of the basic tools necessary for increasing the value received from fisheries, although some modifications will probably be necessary. Many of these tools are, however, not being fully used, or are being used in a manner that is not individually tuned to the specific biological and economic characteristics of fish stocks or fishery complexes. Fish-stock strategies and fishery plans are two new approaches under development to respond to this need. Guiding principles for redesigning the use of available policy tools still need to be fully developed.

I conclude with the following recommendations:

- Incorporate into decision-making the principle that fish stocks should be managed at a level where the incremental value of catching fish is equal to the incremental value of leaving fish in the stock, incorporating both commercial and non-commercial values. It becomes the specific role of public policy to provide the incentives for private actors to recognise the stock value part of this equation, that is the value of leaving fish in the sea.

- Set the ends (stock and catch targets) and design the means of policy (e.g. deemed values) in order to maximise value, not catch.

- Incorporate into stock strategies and fishery plans an overall system of bio-economic indicators for categorising and managing stocks.

- Target TACCs differentially for each fish stock, based on the biological and economic characteristics of each fishery.

- Set TACCs roughly where you want to go, and use the ITQ system and deemed values to get you there with an appropriate degree of flexibility.

- Select a series of case studies, possibly in the context of stock strategies, to do more thorough bio-economic analysis and follow up with pilot projects to implement stock-tailored management approaches.

- In order to implement many of these recommendations, the Ministry will need to incorporate both biological and economic information and analysis into decision-making processes in a more systematic fashion. Important information components that require tracking include data on: costs, value, stock levels, growth rates, relationships between stock size and costs, and measures of economic and biological uncertainty. A lack of biological and economic information, and an inadequate use of existing information, are hindering better fishery outcomes. Collecting and using such information in a cost-effective manner presents a significant challenge.

- Evaluate existing TACCs with an eye toward reducing TACCs that are not currently binding. Non-binding TACCs are an indication of low profitability and conditions approaching open access.

- Reassess the TACCs for fish stocks that are taken primarily as incidental catch and acting as a constraint on target fisheries. In setting new TACCs for these stocks, have regard for achieving the value-maximising yield from the fishery, including the value of related target stocks, and recreational and customary fishing rights, subject to the constraint that TACCs not be set above a level that would compromise the long-term viability of the stock.

- Base deemed values should be set to approximate the unit stock value (and unit profit) corresponding to the target catch. In cases where the target catch is equal to the TACC, the deemed value should therefore be set to approximate the price of ACE when catch is about equal to the TACC.

- TACCs should be set to reflect the value-maximising (or other desired) target catch, and deemed values should be set on an iterative basis to achieve that target on average. Repeated catches above the TACC are either a signal that the TACC is inappropriately set, or that the deemed value is too low. Likewise, TACCs that are not binding on catch are probably set too high.

- The increments of the differential deemed-value schedule should be based on the biological and economic characteristics of individual fish stocks—in terms of both the catch increments and value increments—in principle to reflect the increasing value of leaving fish in the stock.

- Redefine the basis for applying differential deemed values by transitioning from deemed-value brackets based on individual catch-to-ACE ratios, to brackets based on aggregate catch-to-TACC ratios. Rates would apply equally to all fishermen based on end-of-year values, possibly updated throughout the fishing year. This would ensure that all fishers faced the same price for taking fish from the stock.

- Move the end-of-year ACE true-up date from October 15th to November 15th, to allow more time for end-of-year balancing of catch with ACE. Transaction costs in quota markets can also be reduced through measures such as promotion of on-line trading and use of public auctions.

- It should be investigated whether deemed values can be recycled to make them a more distributionally-neutral instrument, without undermining the incentives deemed values are designed to create.

- Where appropriate, reinvest deemed-value payments in research and other efforts that lead to improved knowledge and increased value of associated stocks. This acknowledges that deemed-value payments are related to the value of catch in excess of TACC for a particular stock, and returns that value to the stock.

- The current degree of uncertainty in many stocks, and the importance of knowledge about stock size in determining appropriate TACCs and deemed-value levels, indicate that there is a high value in increased monitoring of stock abundance and environmental and economic conditions.

- Increase non-compliance penalties and enforcement in tandem with deemed values and rates of overcatch.

- Require reporting of ACE and quota prices to reflect true prices so that this important source of information becomes a more accurate measure of commercial value.

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APPENDIX

Bio-Economic Model of Single-Species Fishery

Definitions

Variable	Definition	Example units
B	biomass or size of fish stock	tonnes
B_0	natural carrying capacity biomass of fish stock	tonnes
$F(B)$	annual growth of a fish stock as a function of its size B	tonnes/year
$F'(B)$	derivative of $F(B)$ with respect to B, or how growth differs when stock B is increased by 1 unit	1/year
H	annual catch (harvest)	tonnes/year
r	intrinsic growth rate of a fish stock as the stock size approaches zero	1/year
p	unit price of fish, assumed to be fixed	\$/tonne
$c(B)$	unit cost to catch from a fish stock as a function of its size B	\$/tonne
$c'(B)$	derivative of $c(B)$ with respect to B, or how costs differ when stock B is increased by 1 unit	\$/tonnene^2
E	fishing effort	SFU (standardised fishing unit)
V	unit profit	\$/tonne
w	cost per unit of effort	\$/(SFU·year)
m	catchability coefficient	1/(SFU·year)
ρ	discount rate	1/year

Condition for Maximum Economic Yield

$$p - c(B_{MEY}) = V_{MEY} = \frac{F(B_{MEY})V_{MEY}}{\rho} + \frac{-c'(B_{MEY})F(B_{MEY})}{\rho}$$

which is equal to:

$$p - c(B_{MEY}) = V_{MEY} = \frac{c'(B_{MEY})F(B_{MEY})}{F'(B_{MEY}) - \rho}$$

Condition for Maximum Sustainable Yield

$$F'(B_{MSY}) = 0$$

Condition for Open Access

$p - c(B_{OA}) = V_{OA} = 0$

Solutions with Specific Functional Forms

Schaefer (Logistic) growth function: $F(B) = rB\left(1 - \frac{B}{B_0}\right)$

Schaefer growth function implies: $B_{MSY} = \frac{B_0}{2}$; $H_{MSY} = \frac{rB_0}{4}$

General catch-effort function: $H = q(B)EB = mB^{\theta}E$

General catch-effort function implies unit cost function: $c(B) = \frac{w}{mB^{\theta}}$

Schaefer catch-effort function (c.p.u.e. proportional to biomass; $\theta = 1$): $H = mEB$

Schaefer catch-effort function implies unit cost function: $c(B) = \frac{w}{mB}$