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Catch-Quota Balancing in Multispecies Individual Fishing Quotas

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Abstract

Individual fishery quotas (IFQs) are an increasingly prevalent form of fishery management around the world, with more than 170 species currently managed with IFQs. Yet, because of the difficulties in matching quota holdings with catches, many argue that IFQs are not appropriate for multispecies fisheries. Using on-the-ground-experience with multispecies IFQ fisheries in Iceland, New Zealand, Australia, and Canada, we assess the design and use of catch-quota balancing mechanisms. Our methodology includes a mix of interviews with fishery managers, industry representatives, and brokers, literature review, and data analysis. We find that a combination of incentives and limits on use rates for the mechanisms provide sufficient flexibility to the quota owner without the fishery manager incurring excessive levels of overexploitation risk. Contrary to some opinions, these programs are evidence that it is possible to implement IFQ programs for multispecies fisheries and that they can be profitable and sustainable.

Key Words: Natural resources, created markets, tradable permits

JEL Classification Numbers: Q22, Q28, D40, L10

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Catch-Quota Balancing in Multispecies Individual Fishing Quotas

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Introduction

Individual fishery quotas (IFQs) provide individuals or companies with rights to a share of the total allowable catch (TAC) from a fish stock.[1] They are an increasingly prevalent form of fishery management, with more than 170 species in Iceland, New Zealand, Canada, and Australia currently operating under an IFQ. More importantly, research has shown that they can be effective in improving the profitability and sustainability of fisheries (OECD 1997; Arnason 2004; Newell et al. 2005; Dupont and Grafton 2001; Grafton, Nelson, and Turris 2004).

Multispecies fisheries, however, can present particular difficulties for IFQ management because it is very difficult to know ex ante the catch composition (Squires et al. 1998). While fishers have some ability to alter the species composition of their catch either by location choices, timing of trips, or alteration of fishing methods, it is almost inevitable that individual fishers' species mix of catch will not exactly match their ex ante portfolio of catch rights. Critics of multispecies IFQ systems often cite "catch-quota balancing" as an insurmountable problem (Copes 1986).

Fishery managers have addressed this difficulty by allowing market transactions, such as permanent and temporary transfers of quota. Management systems permit "retrospective balancing" or trades after landings are made to allow a fisherman to cover overharvest of quota. Mangers also have used non-trading mechanisms to aid in balancing catches with quota holdings. These include rollover provisions, such as carrying forward or back of quota, "deemed value payments," under which fishers are charged a fee for each unit of catch they land above their quota, or permitting fishers to surrender or discard catch they cannot match with quota. Some

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[1] We use IFQ interchangeably with individual transferable quota (ITQ), the term used in the New Zealand and Australia fisheries, and individual vessel quota (IVQ), the term commonly used in Canada.

programs also permit "cross-species" exchanges where quota of one species can be used to cover catches of another species at a prescribed trading ratio.

All of these mechanisms introduce flexibility into the system for the benefit of the individual quota owner. The costs of this additional flexibility, however, can be a loss of precision in TAC management, potential effects on the performance of the lease market, and a greater administrative burden. If two species in a multispecies complex have TACs that are out of balance with average catch ratios, the non-trading instruments might enable fishers to more fully utilize the TAC of the species that would otherwise have been constrained by the TAC of the jointly caught species. Flexibility mechanisms can, therefore, increase the value generated by the multispecies complex, but they also can increase the risk of overexploitation. Achieving the right balance between flexibility, overexploitation risk, and administrative simplicity is critical for the profitability and sustainability of multispecies fisheries.

Over the years, fishery scientists, policy analysts, academics, managers, and fishermen have debated whether IFQs are appropriate for multispecies fisheries (e.g., Copes 1986; Buck 1995; Squires et al. 1998). During this time, fishery managers and governments around the world have gained considerable on-the-ground-experience with multispecies IFQ programs. The objective of this paper is to document, assess, and compare the experiences with catch-quota balancing mechanisms in Iceland, New Zealand, Australia, and Canada. Analysis of the flexibility mechanisms is timely and relevant for managers currently designing multispecies IFQ programs, including those in the Gulf of Alaska, Gulf of Mexico, and along the West Coast of the United States (Washington, Oregon, and California).

While other papers provide qualitative discussions of catch-quota balancing mechanisms used in specific multispecies IFQ fisheries (Annala 1996; Annala, Sullivan, and Hore 1991; Arnasson 1993; Dupont and Grafton 2001; Sissenwine and Mace 1992; Squires et al. 1995; Turris 1999) or of general issues with multispecies IFQ systems (Squires et al. 1998), we evaluate the effectiveness of the methods for balancing catches against quotas using qualitative and quantitative data. We also pay particular attention to how and why these policies might have changed over time in response to experiences in the fisheries or changing conditions and needs. Data on the use of these mechanisms (up to now absent in the literature) helps to put the use of each mechanism into perspective. Quantitative analysis also reveals the preferences of the quota owners for the different types of mechanisms, as all of the programs have multiple options.

Our methodology consists of reviews of available literature; interviews with fishery managers, industry representatives, and quota brokers; and compilation and analysis of data on the use of catch-quota balancing mechanisms. In particular, we analyze information on retrospective balancing arrangements, quota markets, cross-species exchanges, rates of quota rollover, catch surrender and discarding provisions, and deemed value payments. Because the types of policies used and the information available to assess them differ greatly across the systems, our assessment includes a mixture of quantitative indicators, such as how actively various balancing mechanisms are used, potential for TACs being exceeded, and more subjective criteria, such as perceptions of fishery stakeholders and managers.

We find that a combination of incentives to match catches with leasing quota and limits on the level each mechanism can be used provides sufficient flexibility to the quota owner without fishery managers incurring excessive levels of overexploitation risk. In most circumstances, flexibility mechanisms are used at the margin and represent a small percent of the TAC. There are designs where abuses are more likely, especially if managers do not take into account the incentives provided by the entire suite of options available to the quota owner. Contrary to some opinions, we believe that the performance of these programs is evidence that it is possible to implement IFQ programs for multispecies fisheries and that they can be profitable and sustainable.

The paper is organized as follows. Next, we provide background information on the multispecies IFQ systems in New Zealand, Australia, Iceland, and Canada. We then define and analyze the catch-quota balancing mechanisms used in the different systems. A discussion on our findings follows, with a focus on how each of the mechanisms fits into the design of each system, potential issues that arise when instruments are used simultaneously, and the balance between providing incentives and limiting the use of the mechanisms. We conclude by highlighting issues that arise in the design of catch-quota balancing mechanisms.

Background

For each of the five programs, we provide selective background information on the overall structure of the management program, such as species and gear included, the setting of the total allowable catches, and the systems put in place to monitor catches. This discussion is not meant to be comprehensive; rather, we focus on the information relevant to understanding the performance of the catch-balancing mechanisms. Readers interested in more information on the programs should consult the review articles listed in the reference list.

Since their inception, each of the programs has evolved and adapted to new information on the ecology, economics, and social implications of the program, but the goal to create a profitable and sustainable fishing industry remains the same.

New Zealand QMS

The New Zealand Quota Management System (QMS) had its origins in the enterprise allocation system, which created company-held quotas for nine companies for seven deepwater stocks in 1983.[2] In 1986, the QMS was implemented, creating allocations for 17 inshore species and the 9 offshore species. The majority of the quota was allocated free of charge and based on catch histories. An expansion of the QMS began in 1998 and, as of 2004, there were 93 species included, with a goal of including all living marine resources (including invertebrates and some seaweeds but not marine mammals) that are commercially valuable or where sustainability concerns could arise as a result of fishing (Bess 2005).[3]

For each fish species managed under the QMS, New Zealand's exclusive economic zone is divided up into a number of quota management areas, creating a total of 550 fishing quota markets as of 2004. The TAC is set annually for each species in each management area.[4] Fisheries legislation requires individual fish stocks to be maintained at or above a level capable of producing maximum sustainable yield (MSY).[5]

Most TACs are not changed in response to overcatch or undercatch situations, and many remain constant from year to year. In some cases, this has lead to TAC overruns persisting for many years. If overcatch results in a depletion of the stock, it could result in a reduction of the TAC, but this stems from management advice that a reduction is appropriate rather than an

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[2] For further history and institutional detail on New Zealand fisheries management, see Annala (1996), Dewees (1998), and Yandle (2001).

[3] The QMS primarily relies on output controls to manage fisheries, but a variety of other regulations are used, including closed areas, gear restrictions, and minimum size limits. There is relatively little use of input controls and no direct restriction of the number of fishing vessels or effort.

[4] An allowance is made within the TAC for non-commercial use—customary recreational fishing and other sources of fishing-related mortality—with the remaining portion allocated as the total allowable commercial catch. For consistency, in this paper we will refer to the total allowable commercial catch as the total allowable catch.

[5] Although Section 14 of the Fisheries Act of 1996 provides some flexibility, allowing the Minister of Fisheries to deliberately set a total allowable catch that may result in the stock size falling below B_{msy} in the interest of increasing the value generated by a multispecies complex as long as viability is not threatened, the requirements for applying this exception are substantial and the minister has never exercised authority under it.

automatic adjustment. Many fish stocks (especially those of low value) do not have formal stock assessments (Annala 1996), but TACs must be set for allocated species to administer the QMS.

Quota shares originally were issued as fixed annual tonnages, which required the Crown to operate in the market to change the TAC. This proved too costly, and in 1990, quota shares were redefined as a share of the TAC. In 2001, managers began issuing annual catch entitlements (ACE), which is a right to harvest a specific quantity of fish in a given year that is separate from long-term quota and is determined by multiplying a share and the TAC as a means to simplify leasing or temporary trades. A regularly updated registry of quota and ACE holdings facilitates transfers that can be made online.

Species aggregation limits on quota ownership, which cap the amount of quota an entity may own of a combined TAC of a species across all management areas, have changed over time. Current caps range from 45 percent for hake, hoki, and orange roughy to 20 percent for paua and bluenose. Spiny lobster is the only species subject to a limit on the ownership of quota stock (a limit in each management area at 10 percent). Maori (aboriginals) own more than 40 percent of the total quota (levels vary by fish stock) through companies they own collectively and quota owned by individual iwi (tribes). Much of this quota ownership resulted from companies and quota purchased by the government and transferred to Maori as a settlement of Maori claims to fishery resources. Maori are allocated 20 percent of quota for all fish stocks introduced to the QMS after 1992.

Monitoring of catches and quota holdings occurs through a dual reporting system that requires fishers and fish purchasers to fill out forms matching catches to fishers' permits. For most small vessels and fish purchasers, catch-effort-landing returns are due the 15th day of the month following the catch. For large trawl vessels, the trawl-catch-effort-processing-return must be submitted within seven days after the end of a trip. FishServe, a private company, processes all of these forms under contract for the New Zealand Ministry of Fisheries. Observers and vessel monitoring systems are not comprehensive but are required in some cases, particularly in fisheries with marine mammal interactions and on vessels participating in international fisheries, such as Patagonian toothfish. When observers are required, costs are distributed across the fleet through cost recovery levies.

Iceland IFQ System

More than in most other countries, the Icelandic fishing industry is a major direct and indirect contributor to the country's gross domestic product, with estimates of its contribution as high as 45 percent (Arnason 1995). Furthermore, the industry is important for trade and employment, and in many remote communities it is single largest employer. As such, fishery issues and policies have far-ranging implications; therefore, it comes as no surprise that Iceland has been at the forefront of rationalizing its fisheries. The impetus for rationalization, as in other settings, came out of crises, first in the herring fisheries in the early 1970s, followed by the demersal fisheries (i.e., cod, haddock, saithe, redfish, Greenland halibut, plaice, catfish, and witch) in the mid-1980s. In 1990, the Fisheries Management Act made permanent the demersal IFQ systems that had existed in some form since the early 1980s.[6]

Most of the major commercial stocks (25 species) now are under IFQ management, and together they account for more than 97 percent of the commercial value. TAC levels, at least for the most important species, are determined each year by the Ministry of Fisheries based on recommendations from the Marine Research Institute.[7] Recently, the ministry has followed the institute's recommendations fairly closely (Runolfsson and Arnason 2000). Since 1995, the ministry has adhered to a catch control rule that generally sets cod TACs at 25 percent of the fishable biomass, which naturally changes over time.[8] Setting the TAC as a fixed percent of biomass has focused discussions on the estimate of fishable biomass, removing the TAC rule from controversy. Managers believe the rule automatically incorporates overages and underages into the annual TAC setting process.

As with other IFQ systems, each vessel was allocated gratis a permanent share of the TAC based on past catch histories. Each year, the tonnage available to a quota holder is their ACE. Current limits on quota ownership are 12 percent for cod; 20 percent for haddock, saithe and Greenland halibut; and 35 percent for redfish. An additional cap prohibits any entity from holding more than 12 percent of the value of the combined quota shares for all IFQ stocks.

Multiple government agencies monitor and enforce the IFQ regime. The Fisheries Directorate issues commercial fishing permits, allocates catch quotas to Icelandic fishing vessels, tracks quota transfers between vessels, and checks that vessels do not fish in excess of their

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[6] Originally, vessels under 10GRT where not included, but they were brought into the IFQ system under the 1990 legislation. Vessels under 6 GRT have only recently been included in the IFQ program.

[7] The Marine Research Institute uses logbooks to estimate catch per unit of effort by vessel classes and landing reports to help with stock assessments, where data are gathered on age, length, height, maturity, and sex.

[8] The rule also states that the resulting TAC cannot be below 155 thousand tons. In 2000, a further clause was added to the catch rule for cod that states that the total TAC should not vary by more than 30,000 MT from one fishing year to the next.

quotas. Licensed operators, hired by port authorities, weigh and record catch, transmitting catch data to the directorate twice daily by computer.[9] While at sea, vessels can be boarded by the Coast Guard to monitor catches and fishing gear.[10] With due cause, the Directorate of Fisheries can place inspectors aboard vessels who monitor catch composition, handling methods, and equipment.

The Icelandic IFQ system places significant emphasis on balancing economic efficiency, ecological sustainability, and social objectives. Trade-offs across these dimensions have likely constrained efficiency gains. At the same time, these rules have been attempts to preserve employment, particularly in areas where the fishing industry is the largest employer. Any type of assessment of the Icelandic system cannot ignore these often competing interests.[11]

Australia Southeast Trawl Fishery

Established in 1915, the South East Trawl Fishery (SETF) is one of Australia's oldest commercial fisheries.[12] Participants in the fishery target 20 quota species (or species groups) using otter trawl and Danish seine. The estimated gross value of production of the SETF for 2003-2004 was $54 million (AFMA 2005), making it Australia's third most valuable commonwealth fishery.

The use of IFQs for the SETF was adopted gradually beginning with the introduction of IFQs for gemfish and then orange roughy between 1988 and 1990. In 1992, a number of other scalefish species were brought under IFQ management, bringing the total to 16 species (AFMA 2003). A large number of other "bycatch" species caught in the SETF remain outside of the system, with catch constrained primarily by input controls.[13] In response to increased targeting,

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[9] If Icelandic fishing vessels sail directly from the fisheries to markets in Europe, the catches are monitored through sales records that are transmitted from the importing country to the Directorate of Fisheries (http://www.fisheries.is/managem/enforcem.htm).

[10] In addition to the IFQ system, fisheries continue to be subject to other management measures, such as closed nursery and spawning areas, gear-area restrictions, and minimum-size requirements imposed via mesh size regulations.

[11] For more information on the Icelandic Fishery management system, see Eythorsson (1996), Runolfsson and Arnason (2000), Arnason (2004), and Danielsson (2005).

[12] For more information on the history and management system for the SETF, see AFMA (2003), Connor and Alden (2001), Smith and Wayte (2004).

[13] There is a limit on the number of boats that operate in each sector, as well as limits on mesh size and the amount of fishing gear that can be used.

some new species are being introduced into the quota management system (e.g., deepwater sharks and a basket quota for a number of species, including smooth dory, ribaldo, oreos, and alfonsino), with others likely to be added in the future (Towers 2005).

Most of the SETF IFQ species are managed as one stock, but gemfish are managed as two separate stocks and orange roughy as four. Each stock has a separate TAC and quota shares to reconcile against catch. Quota shares always have provided a perpetual right[14] to a share of the total allowable catch rather than as a fixed quantity. IFQs are associated with particular permits that specify the vessel and gear. Quotas are transferable both through sale and leasing, but the Australian Fishery Management Authority (AFMA) must approve transfers, and only licensed vessels can fish the quota. Leasing across sectors/gears has been allowed for most species since 1998.

The 1991 Fishery Management Act is the primary fishery legislation, and it sets forth an objective of "maximizing economic efficiency in the exploitation of fisheries resources." At the same time, the act dictates that the exploitation of fisheries be "conducted in a manner consistent with the principles of ecologically sustainable development and the exercise of the precautionary principle." To date, TACs for primary target stocks have been set using single-species assessments, while TACs for some stocks that are primarily taken as incidental catch are generally set at levels that accommodate historical catch levels.[15]

Monitoring requirements in the SETF vary by fishery and state. Logbooks have been mandatory for trawl and Danish seine fishermen since 1985. Prior to the introduction of the trawl IFQ system in 1992, data analyses and targeted validation studies indicated most (more than 80 percent) logbook data to be of good quality (Smith and Wayte 2004). Since that time, logbook data quality is thought to have declined due to underreporting of catches and misreporting of catch location (Smith and Wayte 2002).[16]

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[14] The legal nature of quota rights has changed over time. Quota rights in the SEFT have been issued annually as annual renewable permits since 1998 and law does not ensure the perpetuity of the right. This will change when statutory fishing rights are issued under the new plans in 2005.

[15] A project currently underway is exploring ecosystem-based management strategies for setting TACs, including a system of companion TACs that would set a group of individual TACs based on the relative sustainable harvest of the most-at-risk species and a system of multi-year TACs (and quotas) intended to accommodate uncertainty by allowing increased retention in years of high abundance and reduce effort in years of low abundance.

[16] Among other things, these logbook inaccuracies have led to the introduction of compulsory satellite transponders for the orange roughy fleet operating off of New South Wales.

When the catch is landed, the fisher is required to complete a form detailing the weight of each species caught—a copy of which is forwarded to AFMA.[17] Historically, observer coverage in the SETF is relatively low, but the SETF Integrated Scientific Monitoring Program, which began in 2001, has resulted in increases (Knuckey et al. 2002). AFMA funds the program, with 80 percent cost-recovery from industry. The principal objectives of the program are to collect information on the composition of the retained and discarded catches and the size and age composition of the quota species landed (including those of the non-trawl sector). These data are used to monitor the fisheries and for stock assessments.

British Columbia Trawl Individual Vessel Quota System

The commercial groundfish trawl fishery on the Pacific coast of Canada originated in the 1940s. Beginning in 1976, a series of limitations were implemented, including a limited entry license system, the establishment of TACs, and a collection of other input and output controls. After a closure of the fishery in 1995, due to concerns regarding TAC overages, discards, and stock management, a consultation process resulted in the implementation in 1997 of the Individual Vessel Quota (IVQ) system for the groundfish trawl fishery.[18] An IVQ is a privilege to a share of the TAC for a period of one to nine years that is revocable at any time at the discretion of the Minister of Fisheries and Oceans.[19]

Currently, 31 species across 8 species management areas, identified according to stock distribution, are included in the IVQ, resulting in 56 area-specific stocks. Approximately 50 other species are caught in conjunction with the IVQ species and are not subject to TAC management. An "other rockfish" category is, however, managed through bycatch limits. Certain IVQ species and areas can be closed to bottom trawlers due to concerns that arise with regard to

[17] For some areas and gears, fishing operators are required to call-in to AFMA one to four hours before arriving in port with information on catch and port destination. In addition, AFMA is working cooperatively with state/territory fisheries compliance organizations to implement a system to require records at all points in the marketing chain. The system will enable product movements to be tracked beyond the first receiver and auditing of products at all stages of the market.

[18] In addition to the IVQ allocations, fishing in the IVQ fishery is regulated by gear and vessel-length restrictions, prohibited species regulations, species and area closures, area-specific quotas, species-specific caps on individual and vessel holdings of quota, and license limitation.

[19] For more information on the British Columbia groundfish fishery, see Grafton et al. (2004), Branch et al. (in press), and Sporer (2001).

non-IVQ species. IVQ species are a large share of the harvest and total value from West Coast Canadian fisheries.

The Minister of Fisheries and Oceans sets TACs based on scientific advice from the public and government officials. This body bases its recommendations on stock assessments from the Department of Fisheries and Oceans (DFO) and includes a precautionary buffer that is based on the life history traits of the species.[20] The groundfish trawl TAC is divided into three different quotas: vessel owner quota (80 percent), groundfish development quota (10 percent), and code of conduct quota (10 percent). The initial allocation of quota to vessels was based 70 percent on catch history and 30 percent on vessel length. Groundfish development quota is allocated to vessels based on social objectives achieved through joint proposals from vessel owners and processors. The code of conduct quota is intended to encourage the fair and equitable treatment of crewmembers. Both of these special programs are allocated at the minister's discretion based on recommendations of a group of industry, community, and provincial government representatives.

Monitoring and enforcement in the IFQ system is facilitated by 100 percent at-sea observer coverage and dockside monitoring.[21] The DFO contracts this work to a private company (Archipelago Marine Research Limited) that is responsible for transmitting catch information to DFO within 24 hours after it is landed. At-sea observers record towing location and time, record discards and estimate mortality based on towing duration and species-specific mortality rates, examine and measure fishing gear, verify the weight and species of fish caught and retained, and conduct biological sampling. Industry pays for two-thirds of the cost of observers (~CA$300 per day for an at-sea observer) (Mc Elderry, personal communication, May 11, 2004) and the entire cost of the port monitoring.

Nova Scotia Mobile Gear Groundfish IFQ

In the 1970s and 1980s, the inshore mobile gear groundfish fishery in the Scotia-Fundy region of Canada was regulated by fleet quotas, limited entry, area closures, and various input restrictions (including vessel length and gear restrictions). Overcapacity concerns and stock

[20] Overages and underages are not explicitly incorporated into the annual TACs but are indirectly accounted for through stock assessments. Only sablefish stock assessments are carried out each year; other IVQ species are assessed every third or fourth year.

[21] Complete observer coverage was instituted before the IVQ program in response to the crisis in 1995.

declines led to early closures of some areas in 1989 and to the development of the IFQ program.[22] Since 1991, the IFQ program has governed directed harvests of cod, haddock, pollock, various flatfish, and redfish.[23]

An aggregation limit prohibits any quota holder from holding more than 2 percent of the TAC of any species for a specific area. Processors were not allowed to own vessels or quota at the time of the initial allocation. Soon thereafter, vessel owners bought processing facilities and were allowed to keep the quota they were allocated initially.

Under the current management, TACs are set for fish stocks, which are species–area combinations. The Minister of Fisheries and Oceans sets TACs based on recommendations from the Department of Fisheries and Oceans and the regional advisory panel. Unlike in the British Columbia fishery, TACs are set to achieve a biomass that yields 10 percent less than MSY. Four stock assessments are carried out each year, with the goal that each stock is assessed every two to four years. Overruns are subtracted from the following year's TAC and the fleet's allocation. For example, if the mobile fleet goes over its allocation in any fish stock, then its allocation will go down next year.

Portions of the various TACs are allocated to the inshore mobile gear fleet as fleet quotas, which are in turn allocated as IFQ among the 327 licenses in the program. Most fleet quotas are for fish stocks. If the fleet quota is reached for fish stock, the area is closed to the fleet. In this way, any quota species for which the fleet quota has been fully caught constrains the catch of other species.

The DFO introduced a Dockside Monitoring Program in 1991 to verify and report landings on a timely basis. Recent discrepancies between monitored and unmonitored landings data led to a goal of increasing dockside monitoring to 100 percent. Observer coverage requirements vary by gear. For example, mobile gear vessels 65–100 feet are required to carry industry-funded observers at a rate of 10–20 percent in some areas and 10 percent in other areas. In other sectors, observers are required when using certain gear combinations. In the generalist

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[22] For more information on the Scotia-Fundy inshore mobile gear groundfish fishery, see Dupont and Grafton (2001) and Liew (2001).

[23] In some areas, quota are allocated for a single species, with no directed fishing for other species. Directed fishing of some other species harvested by this fleet are governed by a competitive, limited entry management. These fisheries that are not managed with multispecies IFQs are beyond the scope of this paper.

fleet, industry-funded observer coverage is required at a rate based on a minimum of one sea day per 100 ton of quota

Catch-Quota Balancing Mechanisms

Across the five programs, solutions to balancing catches with quota focus on introducing flexibility at the individual level. How much flexibility is needed depends on how closely initial allocations match catch histories, how aligned the TACs are with species catch rates, and how much control operators have in modifying their fishing to match catches with quota/ACE holdings. What is clear, however, is that each of the programs has introduced a suite of mechanisms for fishermen—all with the goal of helping address the problem of catch balancing. In designing mechanisms, managers try to encourage selective fishing and discourage fishing for species without adequate quota as well as ensure that fishermen land and report catch that exceed their holdings.

In Table 1, we list the flexibility mechanisms encountered in our survey of the different programs. In the analysis that follows, we describe each of the mechanisms, the scope and limitations on their usage, changes in the mechanisms over time, and insights into their performance from industry and government representatives. Where data are available, we illustrate the use of the mechanisms in terms of the volume of quota covered, which is measured as percent of the TAC, percent of vessels using the instrument, and relative cost measured as percent of the annual profits for the industry.[24]

Use rates provide information on each quota owner's preferences for a particular instrument.[25] Measuring volume in terms of percentage of the TAC also provides insights into the potential aggregate TAC overage or underage in that year due to use of the instrument. It is important to point out, however, that there is not necessarily a one-to-one mapping between the volume of use and ratio of the aggregate catch to the TAC. Suppose, for example, that there are 100 quota owners, each of which has the same 10-ton allocation of ACE. If half the quota

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[24] Limited data are available for some of the fisheries assessed by this paper. In each case, data are presented to the extent available.

[25] One caveat in mapping use rates onto preferences of quota owners is lack of information on why fishermen use a mechanism. An interesting research project would be to collect the necessary data to better understand the behavioral factors that drive quota owners to utilize certain mechanisms over the course of the year, such as the reasons why leasing occurs (see footnote 43).

owners' carry-forward 10 percent of their allocation and half use deemed values to cover overages of 10 percent, then the TAC is not exceeded.[26] Obviously, other examples can be constructed where there is a one-to-one mapping.

Quota Markets

When quota owners have portfolios of annual quota (or ACE) that, on average, balance with expected catch composition, then trading of ACE between fishermen should enable reallocations over the year such that ACE balances against catch in the aggregate. Markets for ACE are, therefore, an important mechanism for accommodating imbalances between fishermen's catches and their annual quota.

Each of the programs allows the sale of the permanent rights and lease of annual quota or sale of the ACE, but most do so under certain conditions. In Iceland, the sale of quota was tied to the vessel before 1991 (Danielsson 2005), and currently there are restrictions on the amount of ACE each owner can sell each year and use-it-or-lose-it restrictions. Use-it-or-lose-it restrictions are intended to prevent "armchair" fishermen that own and only lease out their quota. There are often ways to work around these restrictions, however, such as fishing-on-behalf-of arrangements or contractual arrangements for a multiple-year lease of permanent share. British Columbia, which recently amended its program to allow leasing (it had unofficially existed before), plans to reduce gradually the amount that can be leased each year to maintain an owner–operator fleet. New Zealand, Nova Scotia, and Australia, on the other hand, do not restrict quota ownership to active vessel operators.[27]

Other common restrictions are allowing trades only within a pre-specified market (area–species combinations), limits on the share of quota ownership, and requirements that trading partners must be members of the same fleet (i.e., gear and vessel type). For example, in Nova Scotia in-season transfers are restricted to members of the same gear sector, while transfers in the

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[26] This example illustrates our point, but a natural question to ask is why wouldn't the quota owners carrying forward quota sell to those using the deemed value system. If the deemed value rates were set optimally, transaction costs are zero, and fishermen were risk neutral, then we would expect these trades to occur. In real world IFQ markets, none of these conditions hold. In many cases, fishermen might prefer to carry-forward quota rather than sell it because they want to make sure that next year they will have enough quota or they might think the price of fish will be higher next year. The former reason is more likely when there are stiff penalities for going over your holdings.

[27] In addition to leasing, Iceland and New Zealand also permit "fishing on behalf of other" relationships, under which one person can fish the quota of another without engaging in a formal transfer.

off-season to balance holdings and catches are permitted more broadly. In Iceland, regional trades must be pre-approved to limit concentration of the quota in certain areas of the country.

Each fishery examined has an active market for the temporary transfer and sale of the permanent right (or privilege to catch fish out into the foreseeable future). In almost all systems, quota brokers facilitate trades, taking commissions of three to six percent. Large quota owners in New Zealand employ quota managers. Fishery associations also facilitate trades. Newell et al. (2005) found that quota market participation rates increased over time, with more than 75 percent of the quota owners either buying or selling in the market by 1998. Conner and Alden (2001) also report high quota market participation rates for the Australian SETF.

Iceland and New Zealand both have established central trading exchanges. New Zealand managers have experimented with two centralized quota-trading exchanges over time. The first, created by the New Zealand Legislature alongside the QMS (Clark et al. 1989), included fish brokers and a trading information exchange but never materialized and was closed down shortly after the QMS system was implemented. In 2004, an online auction system for annual quota (or ACE) (www.acetrader.maori.nz) was created. The system has achieved limited success to date.

The primary purpose of Iceland's trading exchange was to convey timely information on the value of fishing quota to be used by crew and non-quota owners to negotiate contracts and payments. The exchange was abolished after two years because it was partly redundant with a separate system that monitors the compensation of crew.

Figure 1 illustrates the annual volume of temporary transfers as a percentage of the TAC for the median fish stock in each system.[28] We find that in a typical year, between 30 and 50 percent of shares of the median stock are transferred temporarily. There also is substantial variation from year to year, and this likely is due to changing economic, ecological, and oceanographic conditions from one year to the next. In Iceland, managers attribute the dramatic drop in leasing in 2000 to a rule requiring all leases to be registered on the central exchange. The recent increase is then explained by the abolishment of that exchange. This example illustrates

[28] Data on the volume of leases for the SETF was reported in Kompus and Che (2003), and TAC data is from Smith and Wayte (2004). The Icelandic Fisheries Directorate provided data for Iceland. We utilize the multispecies subset of the lease transaction data compiled by Newell et al. (2005). The New Zealand Ministry of Fisheries provided data on the deemed value use rates and revenues and the bycatch trade-off scheme. In SETF, the TAC used in the calculations is the actual TAC, which differs from the agreed TAC due to netting-out overages and underages from the previous year (see Conner and Alden [2001] for a discussion of the different TACs).

the potential effects that administrative rules can have on market performance. Overall, the large volume of temporary transfers illustrates that leasing is an important tool for quota owners.[29]

We focus on temporary transfers rather than permanent ones because temporary transfers are the preferred means of meeting short-term mismatches between catches and holdings. Of course, over the long-term, firms will learn and acquire a portfolio of quota that better matches their expected catches. Therefore, permanent transfers are an important part of the solution. Overall, the volume of permanent transfers is much lower than leases; for New Zealand, the median stock has seen about six percent sales volume between 1986–2000 (Newell et al. 2005).

An expert on the SETF, Richey (personal communication, November 29, 2004), suggests that the South East Trawl quota market, though primarily an informal one, is effective at facilitating trading. Nevertheless, there are indications that quota is not always getting to those who can use it. Other experts note that for some species, the availability of quota becomes constrained when the catch gets up around 80 percent of the TAC (Knuckey, personal communication, December 9, 2004). The relatively tight market at the end of the season as catches get close to the cap, which is normal in a rationed market, suggests that fishermen may not solely be using leasing to resolve catch-matching issues. The ability of participants to discard overages and to carry-forward as much as 20 percent of their allocation for use in the following year also may limit the need for temporary transfers to cover overages in the fishery.

In the other fisheries, managers reported that the markets are liquid, with varying amounts of average annual transactions. For instance, in Nova Scotia there are approximately 1,100 temporary transfers between the 300 licensed vessel owners each year. Quota transactions are facilitated by participation in the Mobile Gear Fishing Association and/or the Fixed Gear Fishing Association (McMaster, personal communication, April 20, 2005). According to British Columbia groundfish trawl managers, there are approximately 2,500 transfers of quota each year

[29] According to brokers in British Columbia, the first quarter of the fishing year is the most active time for trading, as vessels are getting their portfolios of quota ready. Newell et al. (2005) report a similar result for New Zealand.

among its 142 owners, with seasonal fluctuations in trade volume within each of those years (Ackerman, personal communication, April 20, 2005).[30]

Consolidated holdings, which may be objectionable to some for distributional reasons, can facilitate catch-quota matching. For example, some New Zealand processors hold large allocations that are leased out to fishing fleets, with fishermen leasing out exactly what they need to cover their landings. If distributional concerns are an issue, coordinated quota management (through entities such as fishermen cooperatives) is another possible means to address catch-quota matching issues. Quota-owner cooperatives also developed under IFQ management in New Zealand with very little government intervention.

In theory, rules such as caps on ownership, annual limits on leasing, use-it-or-lose-it restrictions, and limiting transfers by region or fleet can constrain individual flexibility in balancing catches with quota holdings. However, the fishery managers surveyed in our study do not seem to think that this is a problem, at least not in the aggregate.

Rollover Allowances

Rollover allowances permit operators either to carry-forward unused quota for use in the following year or carry-back or deduct from the next year's allocation an overharvest of the current quota. Each of the programs allow some form of rollover, but none allow the quota to be carried over multiple years, which would permit the accumulation of banked quota for use in future periods.

Carry-forward allowances vary across programs. Iceland and the SETF[31] both allow persons to carry-forward 20 percent of their annual quota. For SETF, the carry-forward amount permitted increased from 10 percent in 1994. New Zealand allows 10 percent carry-forward.

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[30] These transfers are categorized as permanent transfers, but most are likely for short-term leasing purposes since, until recently, leasing was not officially allowed in British Columbia. Some of the short-term leasing that takes place at the end of the season in British Columbia is not to cover overages but instead to ensure that quota left at the end of the year is carried forward. For example, if an individual has 35 percent of his quota for a particular species left at the end of the year, 30 percent of that will automatically be rolled over to next year. To avoid the loss of the remaining 5 percent, a fisherman may sell it to someone who has not yet maximized his rollover allowance and can roll over his 5 percent. The fisherman will then sell the amount back to the original quota holder the following year.

[31] In 2003, fishers in the SETF were not allowed to be in an over-quota situation at any time (i.e., to land catch for which they don't own quota) for some species, and the same is true for other species in 2004. However, this is a temporary measure related to a legal change in the catch entitlement and presumably carry-backs will be allowed in future.

Generally, British Columbia allows up to 30 percent of a person's quota to be carried forward, but British Columbia managers can reduce the percentage of, or even eliminate, the carry-forward for conservation reasons on an annual basis. Since 2001, New Zealand operators have borne the risk that all quota carried forward will be forfeited if the TAC is reduced the following year. British Columbia also is reducing its carry-forward allowance to reduce the possibility of TAC overruns

British Columbia and SETF have symmetrical carry-forward and carry-back percentages, while Iceland limits its carry-back to five percent over the annual quota (or ACE). Nova Scotia had an overage schedule that was graduated by the amount of total overage, until a recent court decision declared the system punitive. In particular, overages up to 10 tons (after an allowed 1 ton overage was accounted for) were counted at a one-to-one rate against the next year's allocation. Overages of between 10 and 20 tons were counted at a rate of two-to-one, and overages in excess of 20 tons were accounted for at a rate of three-to-one. After the court decision, the 1-ton allowed overage was removed and all overages are charged at a rate of one-to-one against the following year's quota.[32] In 2001, New Zealand eliminated its 10 percent overage rule that was in place since 1986, requiring overages to be covered by acquiring ACE or paying a deemed value.

A common pattern across the systems is that the volume and use of carry-forward provisions is greater than carry-back provisions. Figure 2 illustrates the median percentage of quota owners using the mechanism across the ITQ fisheries and the volume measured as a percentage of the TAC for the median fish stock across all Icelandic ITQ fish stocks. We find that about 60 percent of the vessels carry-forward quota in the median fishery, corresponding to about 10 percent of the median TAC. While the percentage of vessels carrying back to cover overages is around 10 percent, the tonnage carried back is a very small percentage of the TAC. In Iceland, Atlantic cod had the greatest percentage of quota owners carrying back quota, and in one year, there was little difference between the percentage carrying back and carrying forward. The temporal variation in Figure 2 likely is driven by changes in stock abundance due to environmental factors (changes in water temperatures, etc.), world markets for fish, and prices of inputs.

[32] Overages that are deemed excessive also can be prosecuted.

Likewise, Connor and Alden (2001) found that the use of carry-forward provisions tended to decline in general as the SETF IFQ system matured, particularly for stocks such as ling where catches generally were close to the TAC. However, for a number of stocks, aggregate catches are chronically well below the TAC and many fishermen continue to carry-forward unused quota from one year to the next. There appears to be much less use of carry-back provisions.

While there is not much hard evidence, it appears that the same patterns found in the Icelandic and South East Trawl fisheries hold for the British Columbia fishery and New Zealand. In New Zealand, the lack of resistance to canceling the allowed overage amounts in 2001 is evidence that this mechanism was not considered critical to catch balancing. One reason for this might be the potential redundancy with New Zealand's deemed value system, which is described below.

One potential reason for lower usage rates of the overage provisions both in terms of the number of vessels and the volume is that quota owners face penalties if they exceed their overage amounts. For example, in the SETF, mangers can deduct from next year's quota at a penalty of 2:1 the weight of fish caught in excess of the overage provisions. Similarly, over-compliance is also found in pollution control settings where firms face pollution control standards and stiff penalties (Oates et al. 1989).

Deemed Value Payments

New Zealand is unique in its use of deemed value payments, under which quota owners are charged for landing fish for which they do not have sufficient annual quota (or ACE). Deemed value rates generally are set to discourage discarding at sea but at the same time to not encourage targeting of fish for which the fisherman does not have quota.[33] The deemed value system creates a dual price–quantity management regime under which both the TAC for allocated quota and deemed value prices for individual overharvests manage total catch. Theoretically, a fisherman in New Zealand could fish throughout the year without balancing any

[33] For example, deemed values are set for each QMS fish stock, with 2004–2005 per kilogram values ranging from as low as NZ$0.01 per kilogram for frostfish in area 2 to a high of NZ$105 per kilo for spiny rock lobster in area 8. The law requires the minister to set deemed values with the primary objective of providing incentives for fishers to cover catch with ACE. In practice, annual deemed values are adjusted as some percentage of ex-vessel prices. However, deemed values sometimes are set above ex-vessel prices for some high-value target species and for overcaught stocks in response to TACs being exceeded.

of his catch with ACE as long as he pays the deemed value.[34] Obviously, the deemed value rate (per unit of fish landed) is an important potential deterrent for such actions.

Figure 3 illustrates the percentage of the fish stock's TAC that was covered by deemed value payments for the 25th, median, and 75th quartile stocks. While the percent of the median fish stock's TAC covered by deemed value payments remained steady at approximately one percent, the upper quartile averaged more than five percent in most years. Between 1990 and 2004, the total annual deemed value outlays by the industry ranged from approximately $5–10 million in New Zealand 2000 dollars. These outlays are a small percentage of the annual profits in each fish stock, where the median percentage is about two percent.[35] The revenues from the deemed value system go to the New Zealand Treasury's general fund.[36]

Figure 3 also shows that the variation in the volume of usage across stocks has increased since 1999. One reason for increase is that additional fish stocks were introduced into the system in 1999, and for many of these stocks, very little information is available for setting the TAC. Also in 2001, the 10 percent carry-back allowance to cover overages and the bycatch tradeoff scheme that allows use of quota of one species to cover catch of another in 2001 were eliminated and this reduced the mechanisms available to match quota to catch.

The large variation in usage of deemed value payments across stocks and perception of the negative effects on certain stocks because of consistent use of the deemed value compelled managers to revise the payment rate schedule in 2001. Under the revised system, an owner's payments increase with use of the system.[37] Table 2 illustrates the schedule, under which payments increase in 20-percent increments for each 20 percent by which a person's catch

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[34] This holds only so long as no overfishing threshold has been imposed for any species found in the area the person is fishing. If an overfishing threshold is imposed on a QMS stock, no fishery can continue to fish where it is feasible to catch that species/stock if the catch they have landed exceeds their ACE holdings by a given percentage. If they have no ACE for that species in that QMA, they cannot fish in that QMA. However, overfishing thresholds have rarely been imposed.

[35] Annual profits were estimated by multiplying the annual lease price of quota in New Zealand and the total allowable catch.

[36]When employing a system of deemed values, careful consideration should be given to the recipient of the funds to ensure that there is no potential conflict of interest.

[37] In New Zealand, a joint working group that included members of the Ministry of Fisheries, Treasury, and the industry completed a comprehensive review of the deemed value system in 2005. Among the issues considered were whether responses, in terms of raising deemed values, should be stronger to eliminate chronic TAC overruns, whether differential deemed values should be applied as a default policy, and whether a portion of the revenue from the deemed values should be returned to quota owners in some form.

exceeds ACE holdings. Differential deemed values are not charged on some low-value stocks for which there is inadequate stock assessment for regulators to have confidence that the TAC has been set appropriately. The differential deemed value system is designed to provide stronger incentives to the individuals who are most responsible for TAC overruns. For certain stocks, the differential deemed value system increased the level of the outlays by the industry.

In 2003, a new ACE trading service was created by a private company (FishTech Ltd.) with the specific aim of matching individuals paying different deemed value rates with those that still had quota remaining. The gains from trade are split evenly between the parties after FishTech takes a percentage. This system attracted 12 participants in 2003 and reduced total deemed value payments by around $400,000. In 2004, 40 participants signed up, of which 20 ended up making ACE trades, resulting in a total net reduction of deemed values around $600,000 (Howard 2005).

Deemed values have been particularly useful in providing flexibility for some bycatch stocks for which there is relatively little information on biological status but for which there are no sustainability concerns.[38] Deemed values for these stocks are set at 60 percent of port price and in some cases much lower. There is some evidence that even in cases where deemed values have been set near or above ex-vessel prices, they have been used to balance incidental catch. In these rare cases, fishermen have found it worthwhile to pay the deemed value because the alternative would be to forgo use of the quota for the associated target species or undertake costly bycatch avoidance actions.[39]

Iceland has an instrument that resembles deemed value payments, but it differs in that it only applies to catches in excess of the five percent carry-back provision. In Iceland, boats that land fish in excess of the five percent carry-back provision must supply their catch to the local auction house, where the proceeds are split between the government (80 percent) and vessel owner (20 percent). The 20 percent that the vessel owner gets is to pay for the variable costs of fishing, mainly crew wages. Government revenues go to a special development fund run by the Minister of Fisheries. The amount of quota surrendered to the auction house cannot exceed 10

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[38] An interesting research question is to adapt the single species analysis investigating the use of quantity or price instruments for fisheries (Weitzman 2002, Hannesson and Kennedy 2004) to the mutlti-species context with target and bycatch stocks with multiple types of uncertainties.

[39] This example also illustrates the need to consider joint production when setting deemed values. A fisherman can be expected to pay deemed values for constraining low-value stocks to allow targeting of a high-valued target stock.

percent of an owner's total holdings. According to industry sources, there are ongoing discussions to remove this provision, because the perception is that it is mainly used for cod. We find that between 2002–2004, cod was the primary species subject to this auction; however, the amount of cod landed under this provision was less than one percent of the cod TAC.

Similar to Iceland, catch in excess of the overage allowance in British Columbia may be retained, but revenues from that catch must be relinquished to the Canadian Groundfish Research and Conservation Society, a non-profit organization that conducts research for the benefit of the fishery. In addition, the pounds of fish caught in excess of the overage allowance are deducted from the vessel's allocation the following year. In a seven-year span, this overage forfeiture has been applied only twice (Ackerman, personal communication, November 22, 2004).

Species Quota Exchanges

Species quota exchanges permit fishermen to cover catch of one species with quota of another at a pre-specified trading ratio. For example, consider a fisherman that lands 10 tons of haddock over and above the amount of quota owned, who also holds 5 tons of uncaught cod quota. If the quota program allows an exchange of cod quota for haddock catch at a rate of 1 ton of cod quota to cover 2 tons of haddock catch, the fishermen could use the 5 tons of cod quota to cover the haddock overage.

A disadvantage of species exchanges (similar to deemed value payments) is that the aggregate catch of each species is uncertain. The possibility that TACs will be exceeded depends on the relationship of relative catches and TACs of exchangeable species. In some instances, these could arise from rates of exchange that create incentives for fishermen to convert quota of less valuable stocks into ones for more valuable stocks. Limits on the amount that can be converted from one species to another can inhibit such abuses.

Iceland is the leader in using species exchanges. Under its system, quota shares are put into cod equivalents or a cod currency. [40] Limits, however, constrain the conversion of ACE among species. Specifically, quota owners can convert cod to other demersal species and make conversions among the other demersal species, but demersal species other than cod cannot be

[40] "Cod equivalent" refers to weight and implies the relative value of different fish species on the market and is set by a regulation every year. For each vessel having a quota for several species, the total quota may be calculated in kilograms as cod equivalents. Quota transfer between vessels, even if the same non-cod species (e.g., saithe) is traded in the market, often is measured in cod equivalents.

converted into cod. In addition, owners cannot convert more than five percent of their total ACE in "cod equivalent" units, and no more than two percent of their ACE can be converted into any one species. These restrictions attempt to reduce the possibility for large overruns of TACs in any given year. Very sophisticated web-based catch-balancing data collection and real-time updating of catches has helped to reduce the administration costs of the species trade-off system in Iceland.

Panel A in Figure 4 shows the annual net volume of quota converted through cod equivalents from 1991 to 2004 for four species. Negative levels indicate that cod equivalent conversions decreased quota for the species, and positive levels indicate that on net the species quota was increased by cod equivalent conversions. None of the species consistently had positive (or negative) conversion over the period. Most of the annual conversions are less than 20 percent of the TAC, but there are some anomalies with saithe and plaice.[41] While the figure represents net aggregate conversions, individual quota-owner conversions likely are offsetting to some degree, as one quota owners use of halibut quota to cover haddock catch will be offset by another's use of haddock quota to cover catch of halibut.

Similar to the deemed value system, where the use depends on the deemed value charged for quota, the use of the "species exchanges" greatly depends on the exchange rates between species quota. Cod equivalence rates have changed over time and are calculated based on the relative value of the different species.[42] While Icelandic fishery managers do not dismiss the potential for abuse of their system of cod equivalents, their oversight has disclosed no evidence of systematic abuse. A more comprehensive method of setting exchange rates, which considers factors such as economic rents and ecological risks, could reduce the potential for abuses, but the additional complexities of such a system could pose analytical challenges and could have difficulty obtaining public acceptance.

Panel B of Figure 4 illustrates the time series of the cod equivalence rates in Iceland. Considering the quota exchange rates together with the net transfers across species shows that the system has provided incentives for fishermen to reduce the catch of a species. The increase in the halibut exchange rate in the mid-1990s corresponds with lower net conversions for that

[41] In reviewing conversions, it should be noted that halibut TACs disproportionately are lower than the other TACs due to natural differences in the population sizes.

[42] Value is defined as gross revenues, which is the product of the expected average price of fish times the TAC.

species. For example, by setting a rate greater than one for halibut, the Icelandic government could make it unprofitable to convert other species to halibut and profitable to convert halibut to other species. Such a pattern is observed when comparing the two panels, where the increase in halibut rates corresponds with lower conversion volumes.

Between 1990 and 2001, New Zealand included a system similar to Iceland's cod equivalents. The bycatch trade-off scheme allowed limited trading of quota of certain species against quota of other species. Each year the program was in operation, specific bycatch and target stocks would be listed with the rates at which they could be traded. The scheme allowed a fisherman who landed the bycatch stock for which he had insufficient quota to trade off quota for the target stock at a specified rate on the condition that the bycatch was taken while fishing for that target species. The trading ratios were specific to each bycatch and target species. That is, elephant fish (area 3) could be traded at one ratio with red cod (area 3) and at another with flatfish (area 3). Over the course of the program, 30 fish stocks were denoted target species, 46 were denoted bycatch, and 6 were denoted both bycatch and target. Unlike in Iceland, where quota could not be converted into cod, often a species would be classified as bycatch in one quota management area and as a target species in another quota management area.

Panel C of Figure 4 shows the aggregate percent of the TAC converted at the 25th quartile, median, and 75th quartile from 1991 to 2001. Although overall conversion of quota under the bycatch trade-off scheme was relatively small, converted quota was a large portion of the TACs of some stocks. The annual quota conversions for a select group of fish stocks are shown in Figure 5 to illustrate some of the variability across various stocks. An upward trend in conversion is also evident, at least for some of the stocks for which conversion was most widely used.

While Iceland limits the amount of quota that a fisherman can convert and protects cod, its most valuable stock, by not allowing conversions to cod quota, conversions by New Zealand fishermen were constrained only by their target species holdings. The absence of additional limits increased the potential for abuse and the risk of overfishing bycatch stocks. At the extreme, net conversion of target quota into both bluenose quota and elephant fish quota in area 3 exceeded 60 percent of their TACs in at least one year. As Peacey (2002) notes when discussing the trade-off scheme, "the method was biologically unsound and some fishers used the system to target species which they had little or no IFQ for." The former manager of the trade-off system, McGregor, believes that the system was ended primarily because of the administrative complexity of the annual process of setting exchange ratios, but abuses also contributed to its demise (McGregor, personal communication, October 11, 2004).

Nova Scotia's quota program initially included a species exchange system similar to Iceland's. Conversion rates among the three species (cod, haddock, and pollock) included in the program were predetermined based on the market prices. In the first year, conversions balanced the catch of the different species without any substantial fleet quota overruns. In the second year, however, conversions led to an overharvest of haddock and an underharvest of cod and pollock, leading managers to discontinue the program (Hansen, DFO manager, personal communication, November 19, 2004). Similar to concerns in New Zealand, some commentators in Nova Scotia believe overruns occurred because some participants fished for species for which they held no quota (Barbara, Brander, and Liew 1995, referenced by Dupont and Grafton 2001).

Although the Nova Scotia system was eliminated, some current participants in the quota program think it could be resurrected. Supporters of this view believe that better market information could improve the setting of exchange rates, which in conjunction with limiting the use of quota exchanges to unintended incidental catch that cannot reasonably be covered with quota acquisition, would prevent abuses (Giroux, personal communication, January 11, 2005).

British Columbia also has a species exchange system similar in some ways to Iceland's. According to Bruce Turris (personal communication, November. 18, 2005), BC's program allows fishermen to convert their quota to groundfish equivalents where pacific ocean perch is the base. Under the rules, fishermen are able to exchange pounds of one species for another in terms of groundfish equivalents. To date, this is a rarely used (if at all) flexibility mechanism in the BC system.

Retrospective Balancing

Beyond simply permitting transfers, catch-quota matching in many programs is facilitated by permitting a quota holder to balance their catches and quota holdings retrospectively.

The Nova Scotia program initially allowed 30 days for post-landing quota acquisitions. To allow greater flexibility, the period for purchases has been extended to 45 days. In addition, a two-month period is allowed at the end of the fishing season during which people have the opportunity to cover their overages with temporary transfers. During this period, limitations that restrict trading within gear types are lifted. Limiting these transfers to the post-season is thought generally to preserve the distribution of the fisheries between the gear types, while facilitating the coverage of quota overages to prevent TAC overruns and decreasing the potential incentive to discard that might arise if few shares are available for the gear type.[43]

In New Zealand, catch must be balanced with ACE by the 15th day of the following month in which the fish were caught. If the fisherman does not do so, he must pay a deemed value, which is refunded if the fisherman acquires ACE to balance the catch within 15 days of the end of the fishing year. British Columbia quota owners must balance catch and quota within 30 days of the landing date, and SETF owners have until the end of the fishing year.

In Iceland, the Fishery Directorate immediately notifies vessels that have catches over their holdings. After three days, if the vessel does not have quota to match its catches, its fishing permit is suspended. This immediate response is possible because of the real-time data monitoring and an online catch-balancing program. All the ports of landing electronically transmit catch information to the Fisheries Directorate twice a day. Many in Iceland argue that such rapid catch reporting and real-time monitoring avoids surprises that might arise if fishermen have a longer period to balance their catch and quota.

Discarding

Most programs have general prohibitions on discards of quota species. Nova Scotia allows no discards of groundfish by licensed groundfish trawlers. New Zealand generally does not allow discards except for certain species, such as lobster, where survival rates are high. Iceland permits discarding for live young haddock and cod caught on a handline.[44] In British Columbia, discarding of quota species is permitted, but discards are counted against annual quota based on mortality estimates.

Few estimates of discards are available, but Iceland has produced estimates for cod and haddock in recent years. Between 2001 and 2003, cod discards were estimated to be between 0.4 and 1.8 percent of total landings, with a downward trend, and haddock varied between 3 and 5.8 percent of total landings, with an upward trend.[45] According to fisheries biologists in Iceland, the

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[43] Allowing for balancing after the season can get very confusing, however, as this period will overlap with the start of the new fishing season and can introduce additional administrative and accounting costs.

[44] This catch typically is counted against annual quota at a 50 percent discount, but the total amount cannot exceed 10 percent of the vessel's total catch.

[45] Sources of this information are Pálsson (2004a, 2004b), Pálsson et al. (2002), Pálsson et al.(2003) as translated to us by Ólafur K. Pálsson.

different trends in discards most likely are connected to recruitment trends. Cod recruitment in recent years has been near or below average, whereas haddock recruitment has been exceptionally strong.

A key characteristic of the SETF system that differs from the others is allowing discards that do not count against your quota. Discarding occurs for a range of reasons, including lack of quota, highgrading, damage to fish, and weak markets for landings (Towers 2005). While regulators and the industry are attempting to decrease discards, most currently accept it as an unavoidable part of multispecies IFQ management. The ability to discard effectively eliminates the possibility that catch of any one species will be constrained by the TAC of another.

In the SETF, managers believe that discarding accounts for a large, though highly variable, percentage of catch for certain low-value species and is significant for some higher value species as well. Estimated discard rates in all zones increased slightly in 2001 and were highest for redfish off New South Wales (65 percent); mirror dory in New South Wales, Victoria, and eastern Tasmania (54, 84 and 89 percent, respectively); and inshore ocean perch off New South Wales and eastern Victoria (70 and 77 percent). Discards of mirror dory, redfish, ocean perch, and eastern gemfish are considered to be a major issue in the fishery (Smith and Wayte 2004).

As part of the accreditation for authorizing exports of fishery products, regulators are required to quantify discarding in the fishery and then reduce it by 40 percent. Managers have informed the industry that reporting of discards is not an offence and that any discards of quota species reported will not be taken off the individual's quota holdings. Managers intend to use these data to reduce the level of discards through spatial and temporal closures or gear restrictions, such as increased minimum cod-end mesh size. Managers are hopeful that these measures will achieve the 40 percent reduction goal, particularly for species that are limited by low TACs.

Additional flexibility mechanisms

While we have covered the most utilized mechanisms, there are some additional ones that are or were in use. Between 1986–2001, fishers in New Zealand could surrender their catch to the government. Fishing on behalf of other relationships is permitted in Iceland and was permitted in New Zealand until 2001. In this case, quota-owner 10 can upon agreement with quota-owner 11 use some of quota-owner 11's quota to cover his catch without formally making a transfer.

Another design mechanism that simplifies catch-quota matching is the grouping of multiple species into an aggregate for which a single quota is issued. For species in the aggregation, the catch of each is allowed to vary, but the quota for the aggregation limits the total catch of all species. Nova Scotia uses a species aggregation for a group of flatfish and SETF aggregates warehou. New Zealand relies on numerous aggregations. For example, it has a flatfish aggregation that includes six species (black flounder, brill, New Zealand sole, greenback flounder, lemon sole, sand flounder, and turbot), a hapuku and bass aggregation, and a jack mackerel aggregation that also includes slender and horse mackerel.

New Zealand adopted aggregations for species with little differentiation in data reporting before the introduction to the QMS and for species with little market differentiation (Banks 2004). In these cases, managers considered the benefits of introducing individual species as separate quota stocks insufficient to offset the complications that would result from separate reporting and setting individual TACs. Undoubtedly, the likelihood of any individual component species constraining catches of other species and problems of balancing catches with quota are reduced.

Discussion

The multispecies IFQ systems surveyed all provide flexibility mechanisms for balancing catches and holdings. We summarize the use of the different mechanisms in Table 3. In the table, a Y indicates that the instrument currently is used as a catch-balancing mechanism, and the box is shaded to represent changes over time in the limit, availability, or both. Two observations are worth emphasizing. First, programs employ multiple instruments to provide more dimensions over which the quota owner can balance catches and holdings. Second, the systems and rules regarding catch balancing are dynamic, with many programs trying and then canceling different options or changing the parameters. Both observations imply that no one design is optimal and that participants involved in multispecies IFQ systems are responding to changing conditions and information.

Our survey also found, not surprisingly, that the design of the systems follows directly from the characteristics of the fisheries and the goals of fishery management. An implication of this is that it is difficult to compare the relative performance of a flexibility mechanism across the programs. For example, under the Australian management system, discards are permitted without deduction of quota. The importance of other mechanisms to catch matching is diminished severely given the liberal discard rule. Similarly, the importance of the cod fishery in

Iceland is reflected in their system of "cod equivalents," under which exchange of shares across species is measured against cod and cannot be used to create cod shares.

While rankings are not possible, there are some strong patterns that we observe across the systems. First, the amount of leasing of quota or sale of ACE is significant across the programs.[46] Quota leasing and ACE sales are the primary mechanism to match ex ante quota holdings with expected catches or to reconcile discrepancies after landing the catch. Other mechanisms in Table 3 are utilized, for the most part, to match catch and holdings at the margin. For example, the median fish stock's volume of carry-forward, carry-back, bycatch trade-off (BCTO), deemed value, and cod equivalence conversions basically are within 10 percent of the TAC. The median volume of carry-back in Iceland and BCTO in New Zealand is much closer to one percent of the TAC. However, we do observe exceptions to this pattern. For example, certain stocks in the BCTO system had usage totals at 50 percent their TAC.

In designing multispecies IFQ systems, managers need to consider that the potential risks of overexploitation vary across the mechanisms, everything else being equal. Lease or ACE market transactions with retrospective balancing simply reshuffle quota amongst the participants in a given year and therefore have negligible risk. Rollover provisions allow shuffling of quota over time, and because the programs do not allow owners to accumulate banked quota, a TAC overage will be temporary, leading to little additional risk to the viability of fish stocks. Species exchanges allow reshuffling of quota between species within a given year, and if there are large differences in TACs levels, overexploitation is possible, especially if conversions into the species persist over many years. Deemed values differ from the other mechanisms because their use is akin to creating quota as opposed to a shuffling of existing or future quota, either within or across species. Therefore, continued non-marginal use of deemed values has the greatest potential risk of overexploitation.

Managers can reduce the risks associated with the use of each of the mechanisms in a number of ways. First, instituting limits on the level of use could reduce overages. Iceland has implemented upper limits on the use of their mechanisms, with the goal of preventing abuses.[47]

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[46] Given the information collected by fishery managers, it is difficult to discern the reasons for quota leasing or ACE sales. For instance, leases could be due to contractual arrangements between owners who own but do not fish quota (e.g., processors or investors) and/or trades between harvesters to balance portfolios with either expected catches or after the fact.

[47] In addition, vessels in Iceland are not allowed to commence a fishing trip unless they have sufficient catch quota for their probable catches.

Another option is to set incentives such that quota owners find it in their interest to not over use the mechanisms; for example, by using differential deemed values or graduated penalties for overages. Managers also can address TAC overruns explicitly in the TAC-setting process, either by reducing the TAC of the jointly caught stock or, if appropriate, increasing the TAC of the overcaught stock. Relatively little attempt has been made to coordinate TAC setting in multispecies fisheries. New Zealand and Australia are moving in that direction, but it remains to be seen whether they will be successful.

Setting permissible limits or incentives for each mechanism imposes varying degrees of informational requirements over and above those needed to set TACs and varying levels of regulatory oversight. On this dimension, leases, time limits for retrospective balancing, and limits on rollover provisions likely are on the low end of the spectrum. Species exchanges and deemed values, on the other hand, require additional information when setting the exchange rates or levels and could have knock-on effects in the lease market. In both cases, for example, managers need to gauge the potential incentive for targeting behavior (or bycatch avoidance) against the potential harm to the stock caused by the allowed overage and the incentives to land catches rather than discard at sea. While setting an optimal level is a very complex problem, in practice the exchange rates in Iceland are based on ratios of expected total revenues in the coming year, and deemed value rates are set as some fraction of average ex-vessel price over the season.[48]

When contemplating the set of instruments and their design, managers need to consider the possibility for interaction effects between the options. For example, we find that more than 30 fish stocks in New Zealand had occurrences, sometimes over many years, where the aggregate catch of a species was covered with deemed value payments at the same time that the species was used in the BCTO scheme to cover the catch of a bycatch species. This implies that quota owners covered their catch of the target species by paying the deemed value while simultaneously converting their target species quota into bycatch quota. We also find cases

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[48] Because lease prices are measures of profitability per unit of catch (prices minus marginal costs of fishing), it follows that in a well-functioning lease market, lease prices should be a fraction of ex-vessel prices. Therefore, the Icelandic and New Zealand systems are likely to have a smaller effect on the performance of the lease market than if the limits were set lower, everything else being equal. Iceland also limits the potential knock-on effects in the market by limiting the amount of quota that can be converted across species. Theoretically, all flexibility mechanisms can affect market performance, and this is especially true with species exchange programs and deemed value systems, as both systems represent an additional level of information and government participation.

where species catches were converted into in BCTO and deemed values were used to cover catch. This latter case can lead to higher TAC overruns.

Another factor contributing to overexploitation risk is whether the set and level of each flexibility mechanism causes unreported discards at sea to increase or decrease. All things being equal, it is preferable to have information on overages via reported use of the mechanisms than to not have the information. To eliminate the potential for unreported discards, the British Columbia program employs 100 percent observer coverage.[49] In Nova Scotia, New Zealand, and Iceland, partial observer coverage, along with catch profiling, accommodating flexibility mechanisms, and stiff penalties for violations apparently has been sufficient to inhibit extensive discarding. The permitting of unreported discarding of IFQ and non-IFQ species in Australia is an anomaly in our study.[50]

Another issue in the design of the programs is the administrative burden associated with the mechanisms. Each of the programs has faced problems with the additional complexity in recordkeeping that accompanies flexibility mechanisms. Nova Scotia and New Zealand abandoned the use of species exchange rates partly for this reason. Given that these programs installed these approaches prior to the information technology revolution, it is not surprising that these tasks were costly and that data delays were frequent. The real-time, web-based catch recording and quota balancing in Iceland is a notable exception, and many managers believe that it is the linchpin for their success. With fisheries such an important commodity in Iceland's economy, the costs of implementing such a system are more tenable. For some fisheries with lower value, it is not clear that such costs are practical; however, the costs of developing web-based data programs are coming down.

[49] Branch et al. (2005) have found that the at-sea observer coverage has resulted in changes in target behavior and consequent changes in species catches so that they aligned more closely with TACs. For example, fishermen are making a short, sample tow to assess the suitability of the mix of species when entering a new area and are investing in gear that allows for selective harvesting (Jones 2003).

[50] Although incentive to balance catches with quota remain since handling bycatch is costly and fishermen generally do not want to discard fish, legal discarding greatly reduces incentives to avoid species for which the individual does not hold sufficient quota. Nevertheless, the large volume of ACE transfers in the SETF indicates that individuals do attempt to acquire quota portfolios to balance catch. The flexibility allowed by discarding may increase short-term profits from the multispecies complex, but the effects on the fish stocks over time would likely reduce the profits in the long run, especially if the costs of fishing are dependent on the size of the fish stock.

Conclusion

Managing fisheries where a number of species are caught jointly is a difficult task, regardless of the type of management system used. Differences between the ratios of catch rates and desired total catch levels across species can constrict total catches of some species below desired levels or allows catches of other species to exceed them. IFQ management helps address this problem by providing individuals with economic incentives to match catches with quota holdings and, as a consequence, total catches with total quota. As demonstrated most clearly in the British Columbia groundfish fishery, the combination of the incentives provided by the market and the monitoring and enforcement program can lead to substantial changes in fishermen's behavior and therefore in relative catch rates (Jones 2003, Branch et al. 2005).

While all of the IFQ programs reviewed include multiple species that are caught jointly, the complexity of the fisheries varies, and this has implications for the need and use of catch-quota balancing mechanisms. For example, in a large system like New Zealand's, with more than 93 species and 550 stocks (and more being added), the probability is higher that ex ante holdings do not match catches and that the catches of some species are likely to be constrained by quota of others. This is particularly true if there is little information to set the TACs for stocks that are primarily taken as bycatch or if species in the multispecies complex have very different life history traits that can lead to greater variability in stock levels across years and/or variability in the level of the mixing of the stocks. For systems with these traits, more flexibility in catch-quota balancing may be necessary to avoid constraining the profitability of the complex. Too much flexibility, on the other hand, can lead to persistent overruns in TACs and lower the incentives for quota owners to change their targeting behavior to limit the catch of incidental species or to align their portfolios of catch rights with their expected catch of species.

In designing multispecies IFQ programs, managers will need to find the "right" balance between risks of overexploitation, economic benefits of the fishery, preserving the social structure, and administrative costs. One approach to this problem is to cautiously experiment with different flexibility mechanisms and TAC levels, with the goal of mitigating, where possible, large discrepancies between TACs and catch rates. Such an experimentation process, where managers set levels for the mechanisms, TACs, record use rates, TAC overages, and iterate until a socially acceptable design is found, is consistent with the adaptive management system put forth by Walters and Hilborn (1976). A learning process is present in the systems we surveyed, but the process to date is ad hoc rather than adaptive. It also should be noted, however, that such a process can have distributional consequences. For example, removing a flexibility mechanism could increase the value of bycatch species quota at the expense of the target species, whose catch is more constrained. Depending on the set of owners in the system, this can result in a redistribution of wealth from the quota owners of the target species to those owning bycatch quota.

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Tables

Table 1: Flexibility Mechanisms for Catch-Quota Balancing

Instrument	*Definition*
Permanent transfer	Transfer of a share of the TAC in perpetuity.
Temporary transfer	Transfer of a annual catch entitlement (ACE). Similar to leasing.
Carry-forward	Ability to "bank" any unused ACE to be used in the next fishing year.
Carry-backward	Ability to borrow a portion of next year's expected allocation of ACE to use in this fishing year.
Discarding	Fish that are not retained for market; usually discarded at sea.
Deemed-value	A fee that is charged to fishermen who land catch in excess of holdings. Set at a level such that the fish are landed but without creating incentives for fishermen to exceed their ACE or fish without any intention of acquiring ACE.
Species-equivalence	Ability to covert ACE of one species into ACE of another at a pre-specified conversion ratio.
Retrospective balancing	Period of time allotted fishermen to match catches with quota holdings.
Quota-baskets	Grouping species into one aggregate quota bundle where the TAC is for all the species combined.
Fishing-on-behalf-of arrangements	A fishermen can agree to cover his catch with the ACE of another.
Surrender	Provision allowing fishermen to land fish that do not count against their ACE by surrendering it to the government.

Table 2. Differential Annual Deemed Values in New Zealand IFQ Fisheries

Individual Catch as a Percentage of ACE Held	*Differential Annual Deemed Value*
100 percent < x ≤ 120 percent of ACE	Basic annual deemed value
120 percent < x ≤ 140 percent of ACE	120 percent of basic annual deemed value
140 percent < x ≤ 160 percent of ACE	140 percent of basic annual deemed value
160 percent < x ≤ 180 percent of ACE	160 percent of basic annual deemed value
180 percent < x ≤ 200 percent of ACE	180 percent of basic annual deemed value
x > 200 percent of ACE	200 percent of basic annual deemed value

ACE: annual catch entitlement

Table 3: Use of Flexibility Mechanisms in Multi-species IFQ programs

	Permanent Transfer	*Temporary Transfer*	*Carry-forward*	*Carry-backward*	*Discarding (without use of ACE)*	*Deemed Values*	*Species Equivalence*	*Retrospective Balancing*
British Columbia	Y	Y	30 %	30 %			Y	30 days after landed
Nova Scotia	Y	Y	0 %	1:1 reduction (no limit)				45 days after landed, plus 2 months at end of year
Iceland	Y	Y	20 %	5 %			Y	3 days after landed
New Zealand	Y	Y	10 %			Y		15 days after last day of month landed
Australia	Y	Y	20 %	20 %	Y			End of fishing year

Note: Y and specific rule indicate that yes the instrument is employed; shaded box indicates that the system employed the instrument at one time; shaded box with a Y or rule implies that the rules regarding the use of the instrument have changed over the course of the program.

ACE: annual catch entitlement

Figures

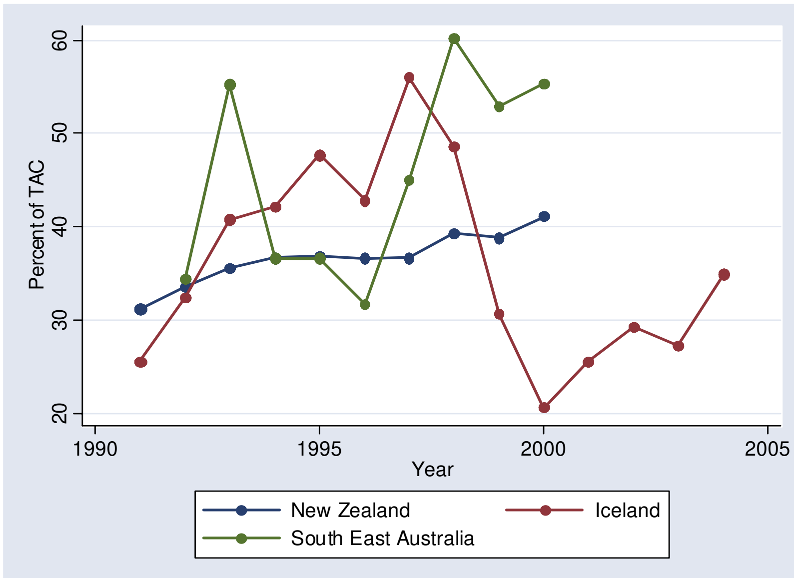
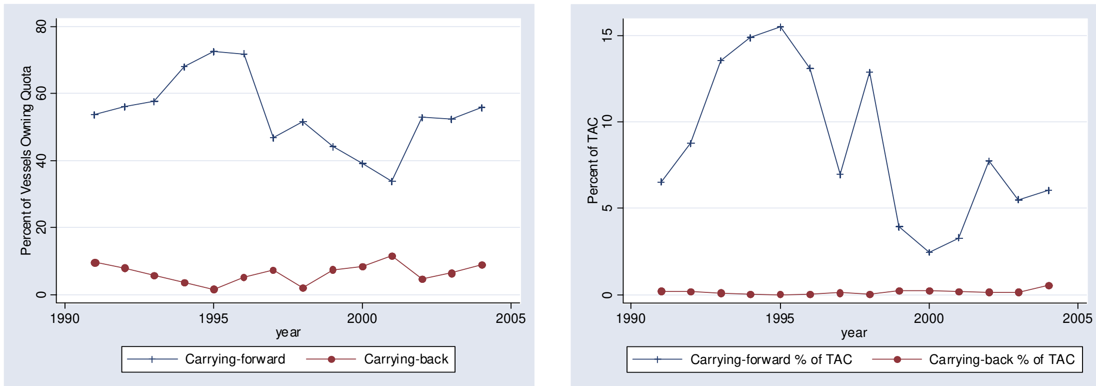


Figure 1: Median Percent of the TAC Leased Each Year

Note: New Zealand lease transaction data are from Newell et al. (2005). Our results differ slightly from those presented in Newell et al. (2005) because we focus specifically on multispecies fisheries (shellfish fisheries are not included). The New Zealand data also represent market transactions between different economic entities (e.g., trading between subsidiaries of one company or family members are omitted). Neither the data from Iceland nor Southeast Australia has been subject to the same data-filtering process. This would imply that relative to the other systems, we would expect New Zealand to be lower, everything else being equal.

TAC: total allowable catch

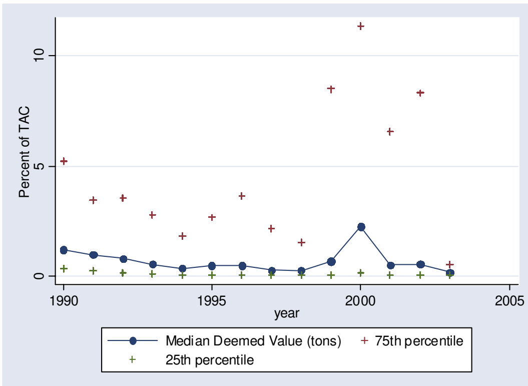


Panel A: Median Percent of Quota Owners **Panel B: Median Volume of TAC**

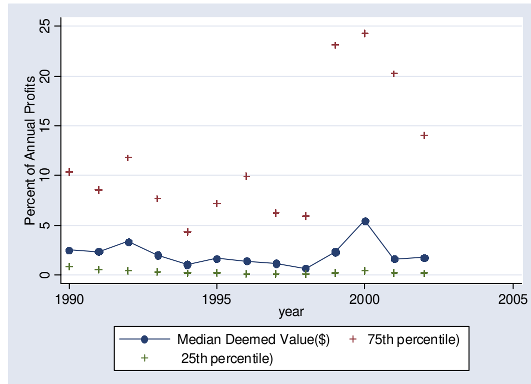
Figure 2: Rollover Provisions in Iceland's Demersal Fisheries

Note: Panel A is the median percent of quota owners using the rollover mechanisms. Panel B is the volume of carry-forward and carry-back for the median stock measured as a percent of the individual stock's TAC.

TAC: total allowable catch



Panel A: Volume as Percent of TAC

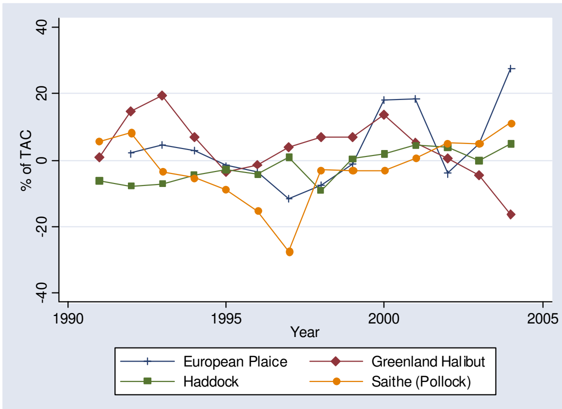


Panel B: Percent of Annual Profits

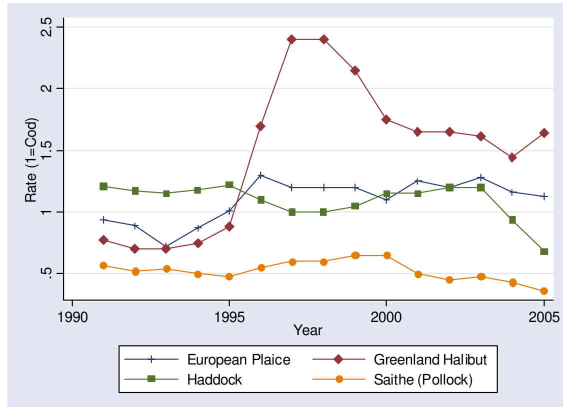
Figure 3: Usage of Deemed Value as Percent of TAC and Annual Profits in New Zealand

Note: Panel A is the volume of deemed values measured as a percent of the TAC, and panel B is the dollar amounts measured as a percent of the annual average profits in the fish stock (annual profits are approximated by the annual average of the lease or ACE price).

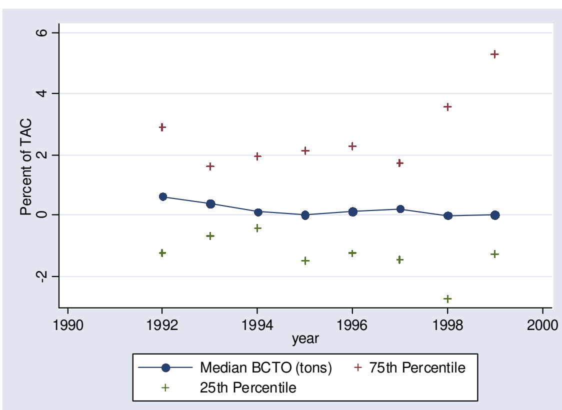
TAC: total allowable catch
ACE: annual catch entitlement



Panel A: Species Exchange in Iceland



Panel B: Cod Equivalence Rates in Iceland



Panel C: Species Exchange in New Zealand

Figure 4: Species Conversions in Iceland and New Zealand

Note: Panel A is the conversion of species as percent of TAC in Iceland's species exchange system. Negative percent means the species was converted out of and into another in the aggregate, and positive means that the species was converted into on net. Panel B is the exchange rates, or "cod-equivalence" rates, which are the gross revenues of the fishery measured by cod. Rates below one imply that 1 ton of cod can be converted into more than 1 ton of another species. Panel C is the conversion of species in the New Zealand BCTO scheme measured as a percent of the TAC. Negative levels imply that the species are being converted out of their quota into another species' quota. Since the BCTO scheme developed exchange rates between species, we shouldn't expect to see a one-to-one relationship between negative and positive levels. TAC: total allowable catch; BCTO: bycatch trade-off

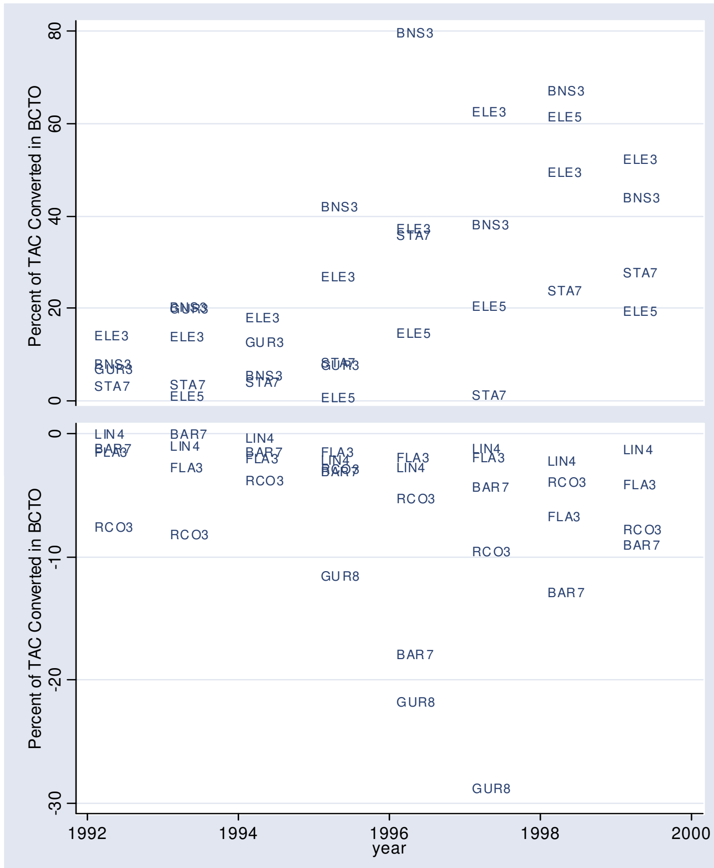


Figure 5: Percent of TAC of the BCTO Usage For Selected Fish Stocks from New Zealand

Note: Positive values imply that quota was converted into the fish stock and negative values imply that quota was converted out of the fish stock. The labels correspond to fish stock (BNS=bluenose, BAR=barracuda, ELE=Elephant fish, FLA=flatfish, GUR=gurnard, LIN=ling, RCO=red cod, STA=stargazer), which are species–region combinations (represented by the numbers).

TAC: total allowable catch
BCTO: bycatch trade-off