

The evolution of New Zealand's fisheries science and management systems under ITQs[†]

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New Zealand implemented a comprehensive management system using individual transferable quotas in 1986 that has been instrumental in guiding the roles, responsibilities, and accountabilities of fisheries science, fisheries management, and the fishing industry ever since. However, at the time of the initial design, a number of issues were not adequately considered. These relate mainly to the dynamic nature of fish stocks, multispecies considerations, and environmental and other externalities. Subsequent efforts to address these issues have been challenging and many are not yet fully resolved. The outcomes for fisheries science, stock status, multispecies management, ecosystem effects, and fishing industry accountability have been mixed, although mostly positive. Fisheries science, fisheries management, and the fishing industry have all become much more professionalized and their activities have been increasingly streamlined. New initiatives to further improve the system continue to be researched and implemented. Overall, we believe that the positives considerably outweigh the negatives. The initial design has proved to be a system that can be built upon. Comparing New Zealand with most of the rest of the world, key positive outcomes for preventing overfishing are the current lack of significant overcapacity in most fisheries, the development of biological reference points and a harvest strategy standard, the favourable stock status for the majority of stocks with known status, and the development and implementation of comprehensive risk assessments and management plans to protect seabirds and marine mammals.

Keywords: fisheries management, ITQs, maximum sustainable yield, New Zealand, overfishing.

Introduction

In 1986, New Zealand was one of the first countries to adopt individual transferable quotas (ITQs) as a primary means of managing its fisheries. Although others have subsequently adopted ITQs for an increasing number of fisheries, New Zealand has applied ITQs more comprehensively than any other country. ITQs in New Zealand represent shares of Total Allowable Commercial Catches (TACCs), which make up most of the overall Total Allowable Catches (TACs) that also include allowances for recreational fisheries, customary fisheries, and other fishing-related mortality. These latter sources of fishing mortality are not governed by ITQs and are not considered further here. ITQs by themselves are just one part of the overall commercial fisheries management system, though an important part. The system as a whole is called the Quota Management System (QMS).

There have been many papers and books published about the initial rationale for New Zealand's QMS and aspects of its evolution since. Most of these have been written from an economic, social,

policy, or fisheries management perspective (Clark and Duncan, 1986; Clark *et al.*, 1988; Annala *et al.*, 1991; Sissenwine and Mace, 1992; Annala, 1996; Bess, 2001, 2005; Connor, 2001; Hersoug, 2002; Yandle, 2008; Connor and Shallard, 2010). To date, there has been little analysis of the role of the QMS in preventing overfishing either in a single species or ecosystem context. In this paper, we briefly outline the initial rationale and design of the QMS, then discuss several of the oversights in the initial design and subsequent remedial efforts, the outcomes to date, and new developments on the horizon. Throughout, the emphasis is on those areas where the supporting science has played a critical role.

Initial rationale and design of the QMS

Before the declaration of its 200-mile Exclusive Economic Zone (EEZ) in 1978, New Zealand's fisheries were mostly small and mostly restricted to inshore domestic fleets operating to a depth

of ~200 m. Foreign fleets from Japan, Korea, and the Soviet Union operated beyond the 12-mile Territorial Sea.

Until 1983, New Zealand fisheries were governed by the Fisheries Act of 1908, with many amendments over the intervening years. Amendments included periods of restrictive licensing, periods of deregulated open entry with investment incentives, and latterly moratoria on fishing permits in several fisheries—all peppered with various gear and area controls. Further details are provided in Clark *et al.* (1988), who termed these controls “regulatory interventionist policies aimed at biological protection”. While biological conservation was certainly an objective at times, it would seem that limited entry, investment incentives, and permit moratoria also had an economic element, though imperfect. Regardless of the intent, the ultimate result was overcapacity of the inshore fishing fleet—although this was perhaps modest by world standards (~20%; Connor, 2001). In the 1980s, some officials and industry members felt that it was time that economic objectives gained prominence. In 1982, the government introduced a system of “enterprise allocations” in deepwater fisheries that awarded transferable quotas to individual fishing companies. The main impetus was to provide the security of future access to companies that had developed the substantial infrastructure required to expand into deepwater fisheries. A new Fisheries Act in 1983 recognized both biological objectives and the goal of maximizing economic returns from fisheries. This Act was amended in 1986 to provide for the introduction of an ITQ system in inshore commercial fisheries and to solidify its implementation in deepwater fisheries.

ITQs were initially based on catch histories with fixed amounts of quota designated in terms of absolute tonnages of fish issued in perpetuity. The New Zealand government intended to explicitly enter the market to buy or sell quota should there be a need for a decrease or an increase in the TACC. It was believed that this would provide a more certain environment for the industry, that there was scope for further increases in TACCs in deepwater fisheries, and that the latter would provide revenues to the government. However, for various reasons, including over-optimism about the potential for quota increases in deepwater fisheries, and an urgent need to buy back quota to reduce the TACCs for orange roughy, the QMS was changed from fixed to proportional shares of the TACC in 1990 (Sissenwine and Mace, 1992).

Another key aspect of the initial design was the principle of resource rentals. Economists believed that an important consequence of the QMS would be the generation of economic rent (or, in colloquial terms, “super-profits”). These could either be returned to the New Zealand public—the actual “owners” of the resource—or capitalized into the value of the ITQ, which could encourage speculation and make it financially difficult for new entrants. The approach adopted was that, as the economic rent was generated by restricting access to a public resource, it would be reasonable for the public owners to expect compensation. As Clark *et al.* (1988) stated, “the government held the view that unearned income from quota ownership should not become a windfall gain to the quota holder, nor should it be capitalized into the value of quota”. Initially, token resource rentals were set on most species to establish the principle, with the government signalling its intention to ultimately move towards capturing most if not all the economic rent. For various reasons, some of which are covered below, this did not happen and much of the economic rent has become capitalized into the value of quota.

Oversights in the initial design

Overall, the introduction of ITQs in New Zealand's fisheries has been an extremely positive development in terms of achieving the

fine balance between utilization and sustainability to ensure biologically and economically viable fisheries that can endure for both current and future generations. The QMS was, however, implemented rapidly and there were a number of oversights. Some of these have subsequently been fully or partially rectified, but the legacy of others remains. In this section, we focus on those elements that relate to biological conservation and overfishing that were arguably not given sufficient consideration at the time—although we recognize that many of them were not topical in that era. It must also be noted that several important aspects of the initial design were well-formulated from the start and are still working well. These include: a “paper trail” system that tracks fish from their capture to the retailer or exporter, with responsibilities and accountabilities at each step; convincing the courts to take fisheries infringements seriously and impose heavy penalties, including jail sentences and forfeiture of vessels and other gear involved in the offense; and a sophisticated compliance system. Such initiatives are covered elsewhere (Aranda and Christensen, 2009).

When New Zealand's QMS was introduced, the Law of the Sea Convention (UNCLOS) was yet to come into effect. Even so, both signatories and non-signatories had already declared 200-mile EEZs and were in the process of rapidly expanding—and subsidizing—national fishing fleet capacity to take advantage of the perceived economic opportunities afforded by expelling foreign fleets from their waters. The possibility that these waters had already been overexploited by foreign fleets was generally not considered. Fisheries were widely perceived to offer a development opportunity, particularly for coastal communities.

Another characteristic of this era was the lack of attention paid to the environmental effects of fishing, including effects on associated fish species, seabirds and marine mammals, and the effects on habitat of bottom-impacting gears. With a few notable exceptions, such issues did not enter the public consciousness until about the mid-1990s.

Bearing the above in mind, we briefly examine four issues that in hindsight may not have received adequate exploration in the initial design of New Zealand's QMS:

- (i) natural variation in the abundance of fish stocks,
- (ii) application of a single-species approach in multispecies fisheries,
- (iii) environmental externalities, and
- (iv) conflicting objectives of alternative users of the marine environment.

Natural variation in the abundance of fish stocks

Several fisheries scientists, including the authors of the current paper, were concerned that specifying quotas as absolute tonnages ignored the dynamic nature of fish stocks, which can vary substantially even in the absence of fishing, and that it might be difficult to use the mechanism of government intervention in the markets to modify quotas, essentially resulting in a constant catch system. At the time, there were a number of scientific papers outlining the drawbacks of constant catch controls compared with other approaches such as constant fishing mortalities or constant escapement policies and variations on these themes (Doubleday, 1976; Beddington and May, 1977; Kirkwood, 1981). As was even then well known, constant catch policies are inherently risky and can lead to stock collapse.

New Zealand fisheries scientists attempted to emphasize this point by developing two alternative interpretations of the maximum sustainable yield (MSY) requirement of the 1983 Fisheries Act: a maximum constant yield (MCY) interpretation based on constant catch and a current annual yield interpretation based on a constant fishing mortality (F_{MSY}) strategy that results in a maximum average yield (MAY) akin to a stochastic interpretation of MSY (Mace and Sissenwine, 1989; Mace, 2012). These two strategies were embedded in the context of risk criteria, primarily a criterion that the probability of a stock declining below 20% of the unfished level should be no greater than 10% (Francis, 1992). To meet such a criterion under an MCY strategy, it is necessary that catches be kept relatively low while biomass is kept relatively high (Francis, 1992; Francis and Mace, 2005). Unfortunately, this has resulted in the false, but widely held impression that “MCY strategies are conservative” with the result that TACCs have generally been set above the calculated MCY level. This fails to recognize that if it is desirable to maintain TACCs at constant levels over long periods (e.g. because ITQs are denoted as absolute tonnages, because the fishing industry requires stability in catches, or because there is insufficient research or monitoring to change TACs very often), it is essential to consider the trade-off between long-term average catches (MCY vs. MAY) and the risk to stock sustainability.

For many New Zealand fish stocks, the quota has remained unchanged since their entry into the QMS over the period 1986–2010. Of the 636 fish stocks (spread among 100 species or species complexes) currently in the system, 288 are considered to be “nominal” or “administrative” stocks (species-area combinations for which the TAC is 0–20 t, or where a significant commercial or non-commercial potential has not been demonstrated). For the remaining 348 stocks, 77% of which have been in the QMS for 10–27 years, TACs for 57% have never been altered and there have been two or fewer changes for 89% of stocks. Only 16 of the 348 stocks have experienced five or more changes in TAC. The main reason for this inertia is the paucity of research and assessment information to inform quota changes, particularly for small stocks. Therefore, implicit constant catch scenarios are actually the norm and the legacy of the initial design of the system prevails.

For some key species, alternative approaches have been taken, including setting TACs based on projections of stock size under alternative TAC scenarios (e.g. hoki) or developing management strategy evaluations (e.g. rock lobster; Haist *et al.*, 2011). In both of these cases, alternative scenarios are scientifically evaluated using performance measures related to the probability of stocks attaining management targets or falling below biomass limits. New Zealand’s Harvest Strategy Standard (Ministry of Fisheries, 2008; Mace, 2012) defines MSY-based management targets and biomass limits that take account of variations in stock size. For example, management targets can be based on B_{MSY} or F_{MSY} or proxies thereof, but these targets are explicitly defined as levels around which stocks or fisheries are expected to fluctuate.

ITQs based on a single-species approach

There are two essential elements required to ensure that overfishing does not occur in an ITQ system: first, the TAC and TACC must be set appropriately and, second, they must be adhered to. The supporting science is primarily responsible for underpinning the first of these and the management and compliance systems are primarily responsible for the second. Both elements are problematic in multi-species fisheries.

The QMS is essentially a single-species management system where for most stocks the TACC and ITQ shares of the TACC are set independently of other stocks. However, the nature of many fisheries is that fishing gear also catches non-target species. In particular, in inshore trawl fisheries, a wide range of quota and non-quota species is taken. Over a long period following the introduction of the QMS in 1986, fisheries managers adopted a number of mechanisms to accommodate the bycatch of non-target species. Peacey (2002) outlined the main methods available to fishers from 1986 to 2001 to balance catch against quota holdings:

- (i) carry-over up to 10% of ITQ holdings from the previous year (for uncaught ITQ),
- (ii) bring forward up to 10% of ITQ holdings from the following year,
- (iii) surrender catch to the government,
- (iv) buy or lease uncaught ITQ by the end of the fishing year,
- (v) use a bycatch trade-off scheme, or
- (vi) pay a deemed value for overcaught quota.

The bycatch trade-off scheme allowed fishers to trade off quota of more valuable stocks against the catch of less valuable species for which not enough ITQ was held. The trade-off ratio was based on the relative value (port price) of the fish species. Deemed values were a fee paid for any overcatch above the ITQ holdings of the fisher.

In October 2001, a new approach was introduced. It was believed that the catch balancing regime had become too complex and was being applied inconsistently in different fisheries management regions. The new system was based on annual catch entitlements (ACE). ACE is a harvest right giving the holder the right to take a certain weight of a fish stock during the fishing year. Essentially, ITQ shares are the long-term asset—a quasi-property right—whereas ACE is the annual harvest right spawned off ITQ holdings and the TACC. ACE can only be obtained by owning quota shares (ITQ) at the beginning of the fishing year or at the time of an in-season TAC increase or by purchasing ACE from another ACE owner.

At the end of each month, the ACE holdings of each fish stock are checked against each fisher’s cumulative catch for that year. If catch exceeds the ACE holdings an interim deemed value payment is required. Interim deemed values are charged for the first 11 months of the fishing year. At the end of the year, the final catch balancing is determined and a higher annual deemed value is payable if catch is still not matched with ACE holdings. However, it is not necessary to own ACE for a fish stock before fishing occurs. This represented a substantive change from the previous regulations where fishers had to own or lease ITQ of the species being targeted before fishing commenced.

One of the original tenets of the QMS was that it would promote wise stewardship of fisheries resources through quota owners wanting to maximize the asset value of their quota holdings. This was somewhat undermined by the changes in 2001. Soon after the introduction of ACE, some operators used the more relaxed provisions to overcatch fish stocks for which they did not hold sufficient ACE. In particular, they exploited the changes to overcatch a number of stocks where the deemed values were set at low levels. Rather than buy ACE, these fishers landed catch for a number of stocks well over the annual TACCs and paid annual deemed

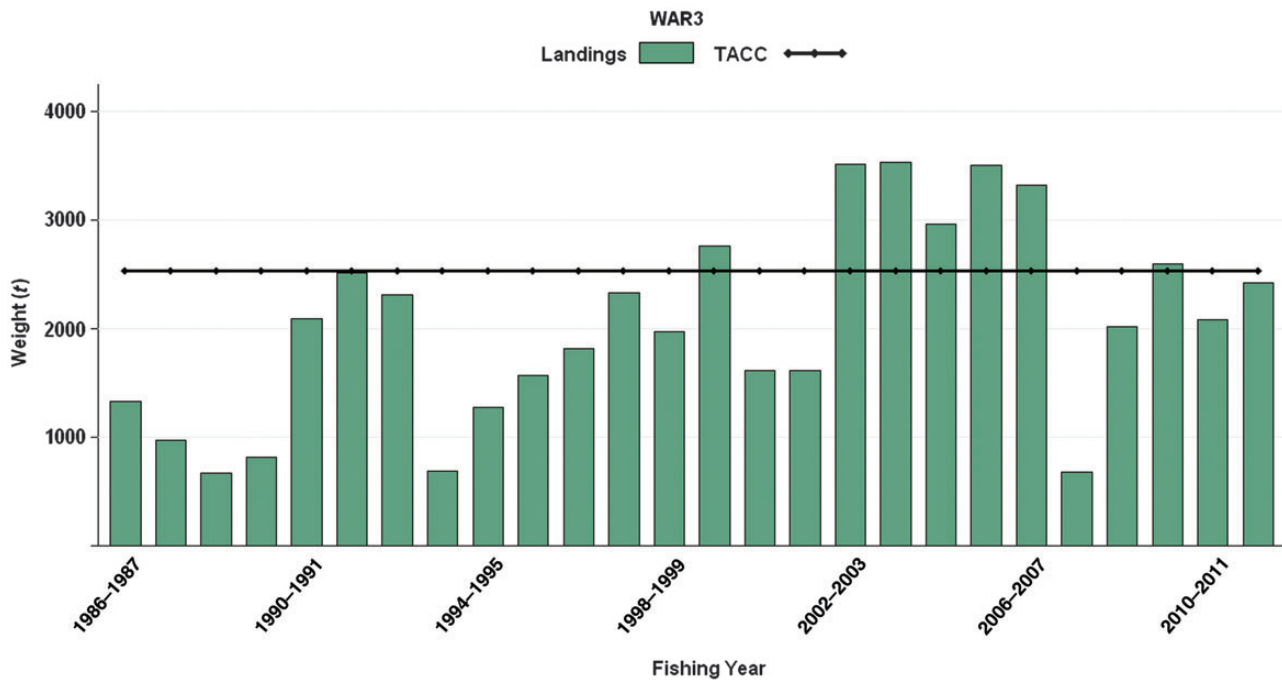


Figure 1. Landings compared with the TACC for blue warehou in area 3 (WAR3).

Table 1. Deemed value (DV) payments for blue warehou in area 3 (WAR3)

Fishing year	Interim DV (\$/kg)	Annual DV (\$/kg)	Differential DV (\$/kg)	ACE price (\$/kg)	Total DV payments
2002-03	0.13	0.25	Standard	0.18	\$360 380
2003-04	0.13	0.25	Standard	0.17	\$410 540
2004-05	0.13	0.25	Standard	0.17	\$208 755
2005-06	0.13	0.25	Standard	0.22	\$415 961
2006-07	0.13	0.25	Standard	0.19	\$372 019
2007-08	0.45	0.90	Unique increments	0.46	\$270
2008-09	0.45	0.90	Unique increments	0.34	\$48

Standard differential DVs increase by 20% increments for each 20% over the ACE holdings of the individual. Unique increments mean that the annual DV applies up to 110% of holdings then the cost/kg rises to 200% of the annual DV.

values that were less than the cost of ACE for the catch not balanced with ACE holdings.

Starting around 2007, a concerted effort was made to set deemed values at levels that would accomplish the aim of encouraging fishers to land rather than discard catch that could not be covered by ACE while also discouraging them from targeting such species. The effect was dramatic as the following example illustrates.

From 2002-03 to 2006-07, (in New Zealand, fishing years run from 1 October of one year to 30 September of the next year, so that 2002-03 represents 01/10/2002 to 30/09/2003) landings of blue warehou in area 3 (WAR3) were well above the TACC as fishers landed catches over their ACE holdings and paid deemed values for the overcatch (Figure 1). From October 2007, the deemed values were increased to \$0.90/kg and differential rates were applied to all landings over 110% of ACE holdings at which point the deemed value rate increased to \$2.00/kg. The effect of these measures was immediately obvious in 2007-08 as fishing without ACE was reduced and the landings fell well below the TACC (Figure 1). From 2007-08 on, total deemed value payments for WAR3 declined to trivial amounts (Table 1). It would appear that the change in deemed value settings resulted in reduced

intentional targeting of stocks in excess of the available ACE because this became unprofitable under the new settings.

Differential deemed values were progressively applied across other fish stocks in the QMS. They were set at increasing rates depending on the individual fisher's overrun of landings against ACE. For example, for most stocks the annual deemed value increased to twice the annual rate when landings were twice the ACE owned. The aim of these changes was to remove any profit from the overcatch as a disincentive for fishers who did not hold ACE. Deemed values are reviewed annually to reflect changes in port prices and adjusted as appropriate. The system relies on regular review and adjustments to deemed value rates to the level that encourages fishers to balance landings with ACE. However, the effect of these changes on the amount of discarding is unknown.

The current situation in 2013 is that the two mechanisms, the TACC (with ITQ and ACE) and the deemed value regime, now jointly act to minimize overcatch of the TACC. However, the use of discarding to avoid deemed value fees is common in some fisheries. The solution to this problem is not clear, as many fisheries (especially inshore fisheries) have historically had very low observer

coverage and the government has little quantitative information on levels of discarding. For the deepwater fleet, some success has been made with profiling the catches using the observed catch history as a benchmark. Obvious misreporting can be detected by such means and successful prosecutions have been taken against some offenders. Work is underway to improve information on inshore fisheries, including through increased observer coverage.

Deemed values are theoretically elegant. All that is required is to determine a fee that fishers must pay that is low enough to provide an incentive to land fish that have already been caught but are not covered by ACE holdings, but high enough to provide a disincentive to target fish for which a fisher has no ACE. The problem is that the correct level that balances these conflicting incentives will vary by fishing operation, area, and time, possibly on a weekly or daily basis as market demand and market prices fluctuate. Additionally, it has provided an incentive for the fishing industry to underreport port prices.

Environmental externalities

A consequence of changing from input controls to catch-based management is that the control of the regulating authority may be reduced, which may affect the outcomes for ecosystem management (Emery *et al.*, 2012). The designers of the initial QMS not only believed that output controls were far superior to input controls, they also believed that many if not most of the then-existing input controls could be abolished. However, by themselves, ITQs provide little if any incentive to take account of ecosystem considerations such as bycatch of unmarketable species, particularly protected species such as seabirds and marine mammals, or habitat impacts.

Protected species bycatch

Before the arrival of humans, the absence of mammalian predators in New Zealand made it a relatively safe breeding ground for seabirds and marine mammals, important for ~95 seabird taxa (more than a third of them endemic, Miskelly *et al.*, 2008), two species of pinniped, and several cetaceans. Seabirds and marine mammals are incidentally caught in trawl, longline, set-net and, occasionally, other fisheries. This fishing-related mortality has been recognized as a serious, worldwide issue for only a little over 20 years (Bartle, 1991; Croxall, 2008) and so was not a major factor when New Zealand introduced its QMS.

New Zealand took steps to reduce incidental captures of seabirds starting around 1990 and mitigation efforts have developed markedly since (ACAP, 2011). A National Plan of Action (NPOA-seabirds) covering all New Zealand fisheries was published in 2004 (Ministry of Fisheries and Department of Conservation, 2004) and recently revised (Ministry for Primary Industries, 2013b). New Zealand is also Party to the Agreement on the Conservation of Albatrosses and Petrels (ACAP), which requires that signatory Parties achieve and maintain a favourable conservation status for seabird taxa. Similarly, sea lion exclusion devices have been in use in trawl fisheries for squid to reduce captures of New Zealand sea lions since ~2000 (Thompson and Abraham, 2009), and various area closures have been introduced to reduce captures of Hector's and Maui's dolphins in coastal trawl and set-net fisheries (Currey *et al.*, 2012).

Protected species bycatch generates substantial controversy which is exacerbated by a lack of quantitative information. To balance the demand for information against the high cost of relevant data and research, New Zealand has developed increasingly

comprehensive semi-quantitative risk assessments (sometimes called Level-2 assessments, Hobday *et al.*, 2007). New Zealand's current risk assessment for seabirds (Richard and Abraham, 2013) covers all commercial trawl, longline, and set-net fishing within New Zealand's EEZ. For each of 70 taxa, risk has been assessed as the estimated potential annual fatalities relative to potential biological removals (PBR, after Wade, 1998), considering direct effects of commercial fishing within New Zealand waters but not other anthropogenic fatalities. Conversely, a semi-quantitative risk assessment including all anthropogenic threats (relative to PBR) was conducted for the critically endangered Maui's dolphin (Currey *et al.*, 2012). A risk assessment across all New Zealand marine mammal species is underway. Fully quantitative population modelling to assess risks posed by fishing is expensive and data-hungry and has been conducted for only about six seabird species and two marine mammals. All assessments have been complicated by uncertainties about productivity and fishing-related fatalities.

Other effects of fishing

Discarding of unwanted parts of the catch has been identified as a significant issue in many fisheries worldwide (Kelleher, 2005), and few fisheries are without bycatch. When the QMS was introduced in 1986, it was presumed that fish bycatch would be dealt with through the need to have access to quota for all species of commercial importance, which is one reason most are now included in the QMS. Total bycatch and discards are monitored for key offshore trawl and longline fisheries using observer and fisher-reported catch-effort information, but inshore fisheries have had low observer coverage and it has not been possible to assess levels of bycatch and discarding quantitatively in these fisheries. It has also been difficult to estimate unrecorded fishing-related mortality of non-QMS fish at a species level.

Bottom trawls and dredges are used to catch a relatively large proportion of commercial landings in New Zealand and can represent the only effective way of catching some species. Seabed disturbance has consequences for biodiversity and ecosystem services, including fisheries production (Rice, 2006; Thrush and Dayton, 2010) but little thought was given to such effects in the initial design of the QMS. It was assumed that quota holders would focus on the methods that gave the highest economic return, but potential longer-term ecosystem repercussions were not considered. In recognition of the effects on biodiversity and fish nursery areas, certain coastal areas with particularly dense emergent invertebrates (known to be particularly susceptible to fishing disturbance) were closed to bottom trawling and dredging in the 1990s. Outside the Territorial Sea, 18 seamount closures were established in 2000 to protect 25 representative features covering 81 000 km² of the EEZ from all bottom trawling and dredging (Brodie and Clark, 2003). In 2007, Benthic Protection Areas covering ~1.1 million km² (30%) of New Zealand's EEZ were closed to trawling on or close to the bottom following an initiative by the New Zealand fishing industry (Helson *et al.*, 2010; Rieser *et al.*, 2013). Fine-scale reporting by most trawlers using the EEZ since 1989 and by almost all trawlers since 2007 allows the footprint of bottom trawling to be monitored and compared with broad-scale habitat classifications (Baird and Wood, 2012; Leathwick *et al.*, 2012).

Broader aspects of ecosystem form and function, insofar as they support fisheries production, were never part of the initial rationale for the QMS which was designed simply to constrain catches at a single-species level. Notwithstanding, the nature of the productive system is important if fishing affects overall productivity.

Conflicting objectives of alternative users of the marine environment

The designers of the QMS believed that the system would give fishers more flexibility in determining where, when, and how to fish, thereby reducing government intervention. As quota owners would have an incentive to maximize the asset value of their quota holdings, they would also have the incentive to put in place voluntary arrangements to ensure the long-term sustainability of the species for which they held quota. This would largely negate the need for many if not most regulations relating to input controls, such as vessel and gear restrictions and seasonal and area closures. However, conflicts soon arose between different sectors of the commercial industry, recreational fishers, customary fishers, and biodiversity conservation considerations. As a result, few input controls have been removed. Rather, many more have been added, including areas where some or all commercial fishing is excluded, customary fishing areas, marine protected areas, marine reserves, marine mammal sanctuaries, and areas set aside for aquaculture. Some of these have been legislated, but others have resulted from voluntary actions by the fishing industry.

An early example of such conflicts occurred when ITQ fishers inadvertently intercepted salmon returning to rivers that had been stocked for recreational fishing purposes. This necessitated closing off several river mouths to commercial fishing activities during the annual return. Ever since, attempts to set aside areas for other purposes, such as marine reserves, have been perceived by quota holders to be an erosion of the original ITQ right granted to them.

Most recently, the interests of fishers have come into conflict with alternative uses of the marine environment including expanding aquaculture ventures and ocean mining.

Outcomes for conservation and stewardship Outcomes for fisheries science and research

Before the introduction of ITQs in 1986, fisheries research was for the most part not directly linked to fisheries management objectives—which themselves were not well-defined—but rather to studies of fish biology and ecology, many of which are still used in stock assessments today. In the lead-up to implementation of ITQs, the Fisheries Research Division of the then-Ministry of Agriculture and Fisheries rapidly stepped up to the mark by assembling and analyzing all existing research information that could be used to underpin TAC setting. Subsequently, fisheries research has continued to play an integral role in providing the scientific basis for setting TACs and other management measures.

The science has evolved to include trawl and acoustic fisheries-independent surveys, state-of-the-art stock assessment models (Bull *et al.*, 2012), management strategy evaluations (Haist *et al.*, 2011), research on the environmental effects of fishing and biodiversity, comprehensive risk assessments (Currey *et al.*, 2012; Richard and Abraham, 2013), adoption of a Harvest Strategy Standard (Ministry of Fisheries, 2008; Mace, 2012), and the adoption of a Research and Science Information Standard that sets out the role of science working groups and other forms of peer review to ensure the quality of the science (Ministry of Fisheries, 2011). While fisheries science in New Zealand has evolved in line with that in much of the rest of the developed world, the perceived value of scientific research has varied considerably across fisheries due, at least in part, to the way in which it is funded. Originally, resource rentals designed to capture economic rent were imposed as a levy on quota holders that was returned to the public owners

via the government who then provided research, management, and compliance services. However, the levy system was eventually changed to a cost-recovery system in 1994, due primarily to challenges from New Zealand's Māori citizens, who perceived the implementation of the QMS as a violation of the rights promised to them under the 1840 Treaty of Waitangi and saw resource rentals as a levy on rights to which they were already entitled (Bess, 2001; Connor and Shallard, 2010).

Under cost-recovery, the costs of research, compliance, and a few other government-provided services are explicitly billed to quota holders. Initially, a set amount was recovered for the overall research programme, with individual quota holders being invoiced in proportion to the value of their quota holdings. However, some members of the fishing industry protested that quota holders in larger fisheries were subsidizing research for quota holders in smaller fisheries. A system of cost-recovery at the level of individual research projects (on QMS species as well as bycatch and protected species) was therefore implemented in 2001 with costs being recovered only from those quota holders who might be affected by, or benefit from, the research, or who cause environmental risks requiring research. This has worked well for some high-valued species—such as hoki and rock lobster—but has been disadvantageous to research on low productivity or low abundance species, particularly mixed-species inshore finfish fisheries.

A further complication has been the introduction of contestability for research. In 1995, most fisheries and related research was moved out of government to the National Institute for Water and Atmospheric Research (NIWA), a Crown Research Institute (CRI) established in 1992. CRIs were formed under an Act of Parliament and are classified as “quasi-government” and expected to not only be self-sufficient but also to return a reasonable rate of return (i.e. a profit) to government. For the first two years, a contract for fisheries research was set up exclusively with NIWA. Thereafter, a fully-contestable system was implemented. The aim was to create a competitive regime that would drive down what were perceived to be the unnecessarily high costs of science. However, the small population size of New Zealand and the limited funding for fisheries research has meant that only a few small, “niche providers” have entered the research market, and a large proportion of fisheries research is still conducted by NIWA. The combination of cost-recovery and contestability has also made it difficult to ensure the financial viability of the country's dedicated deepwater and inshore research vessels.

Fishers and fishing companies, of course, aim to maintain or increase profits. There are essentially two ways of doing this: to increase revenues or to decrease costs. Given the overall lack of scope for increasing revenues through sustainable increases in catches, cost-recovered research has frequently been perceived as a target for decreasing costs. Industry members often contend that the research is not needed or that it is unaffordable. As a result, most species have received little if any research attention for many years, and the overall fisheries research budget has decreased considerably—to ~50% of the level of the early 1990s in real terms. Concomitantly, the number of species and stocks in the QMS has increased 3.5-fold, and the need for research on recreational fisheries, the environmental effects of fishing, and an ever-increasing number of international fisheries research obligations has escalated from minimal to substantial.

This has resulted in higher priority being afforded to stock monitoring and stock assessment modelling on high-valued species and considerably less priority being given to basic biological research on

either high- or low-valued species. Some basic biological information on stock structure, growth, and recruitment dynamics has not been updated since the 1960s or 1970s. It has also been difficult to fund innovation as the cost-recovery system is not expected to provide for research that is not perceived to be of immediate relevance and, until recently, New Zealand's public good funding sources have contributed relatively little to marine research in general. A major impediment has been the belief that, if fisheries did not exist, there would be little need for marine research at all. However, fish and shellfish provide significant benefits in terms of high-quality food and livelihoods to many. In addition, there are other aspects of the marine environment such as oil and gas and minerals that are currently being explored. Public expectations about the required baseline knowledge of the marine environment have as a result changed profoundly over the last 2–3 decades.

The decrease in government research funding has been partially compensated by industry-initiated research and collaborative government–industry research surveys. However, this has occurred mostly in larger deepwater fisheries and represents only a small proportion of the shortfall.

Outcomes for stock status

New Zealand fisheries are currently governed by the Fisheries Act 1996, as subsequently amended. In terms of TAC setting, it requires that TACs are set so as to maintain stocks at or above a level that can produce MSY. However, it provides little detail on how this is to be accomplished.

The Harvest Strategy Standard (HSS) for New Zealand Fisheries (Ministry of Fisheries, 2008; Mace, 2012) was developed to provide technical guidance on how best to achieve this goal. The HSS is a policy statement of best practice in relation to the setting of fishery and stock targets, overfishing thresholds, and biomass limits for fish stocks in the QMS. It requires, at the minimum, the specification of an MSY-compatible target based on either a biomass or a fishing mortality rate, a soft limit set at $1/2 B_{MSY}$ or 20% of the unfished level (B_0), whichever is higher, and a hard limit set at $1/4 B_{MSY}$ or 10% B_0 , whichever is higher. Stocks that have fallen below the soft limit are defined as “overfished” or “depleted” and a formal, time-constrained rebuilding plan is required to rebuild the stock back to the target level. Stocks that have fallen below the hard limit are defined to be “collapsed” and closure of target fisheries should be considered. When fishing mortality exceeds F_{MSY} , “overfishing” is deemed to be occurring.

Since it was adopted in 2008, progressively more stocks have been assessed against the HSS using a range of approaches (Ministry for Primary Industries, 2013a). Of the 348 significant stocks currently in the QMS, in 2012, there was sufficient information to assess 125 relative to the soft limit, 163 relative to the hard limit, 104 relative to the overfishing threshold, and 119 relative to the management target. The lower number of stocks for which the status relative to overfishing can be determined reflects the legacy of a fisheries management system and legislation that is based more on biomass targets rather than fishing mortality targets.

Over the last 4–5 years, the percentage of stocks of known status above the soft limit (not overfished) has averaged ~84%, those above the hard limit have been near-constant at just under 94%, those where overfishing is not occurring have increased from 75 to 82%, and those above the management target have been relatively steady at ~70% (Figure 2; Ministry for Primary Industries, 2012a). It should be noted that the management target is a level that stocks are expected to fluctuate around and as such any outcome greater

than 50% is noteworthy. Stocks of favourable status in 2012 accounted for 96.6, 99.5, 95.9, and 92.4% of the landings of known status, respectively, for the four metrics.

Overall, for stocks of known status, New Zealand is already well on the way to achieving the goal of the Johannesburg Declaration of 2002 of recovering fish stocks to levels that can produce MSY by 2015. However, while the results in Figure 2 compare well with global statistics, there is concern about the relatively large number of stocks of unknown status. In 2012, stocks of known status relative to the management target accounted for only 63.4% of the total landings by weight and value (excluding squid where MSY-based management targets are not considered appropriate). There is particular concern for inshore finfish fisheries where the percentage of stocks of unknown status has been increasing in recent years.

This issue is not unique to New Zealand. In most parts of the world, a relatively small number of fish stocks or species make up a disproportionately large percentage of the landings. Even the richest countries cannot afford to adequately research and manage all stocks or species captured as target or bycatch in their fisheries.

Outcomes for multispecies management issues

As the QMS is a single-species management system, concerns have been expressed about its utility for managing multispecies fisheries or assemblages with complex interactions among stocks (i.e. it is not immediately obvious how it can be reconciled with an ecosystem approach). The 1996 Fisheries Act is not entirely single-species focused, however, and includes: environmental principles about associated or dependent species, biological diversity, and habitats of particular significance for fisheries management; a requirement to consider any effects of fishing on any stock and the aquatic environment before setting or varying sustainability measures; and a requirement to set TACs that maintain stocks at or above a level that can produce MSY, having regard to the interdependence of stocks. Together, these provisions give some latitude to set controls, including TACCs, to take account of species interactions and externalities.

As stocks have been progressively introduced into the QMS, TACs and TACCs have most frequently been set to achieve single-species MSY-related objectives. However, pilchards (*Sardinops sagax*) were introduced in 2002 with TACCs that were considered conservative in recognition of its role as a forage species. Bladder kelp (*Macrocystis pyrifera*) was introduced in 2010 to provide a mechanism to limit the harvest of attached weed in recognition of the functional importance of kelps in coastal systems.

In many mixed-species fisheries, the landings of lower value bycatch species are often well below the TACC, while the prime species is fully caught or even overcaught each year. For example, the area-specific landings of John dory (JDO1) and red gurnard (GUR1) have been far below their respective TACCs, while snapper (SNA1 and SNA8) landings have matched or exceeded the TACC every year. John dory and red gurnard are both taken as bycatch of trawling operations in northern New Zealand and it is difficult to catch these species and avoid the more abundant, higher-valued snapper. The status of many of these bycatch species is unknown as research effort has been concentrated on the highest value fisheries.

Outcomes for protected species

The current status of protected species populations can be assessed using threat classifications (see Molloy et al., 2002 for New Zealand's Department of Conservation system). Baker et al. (2010) classified

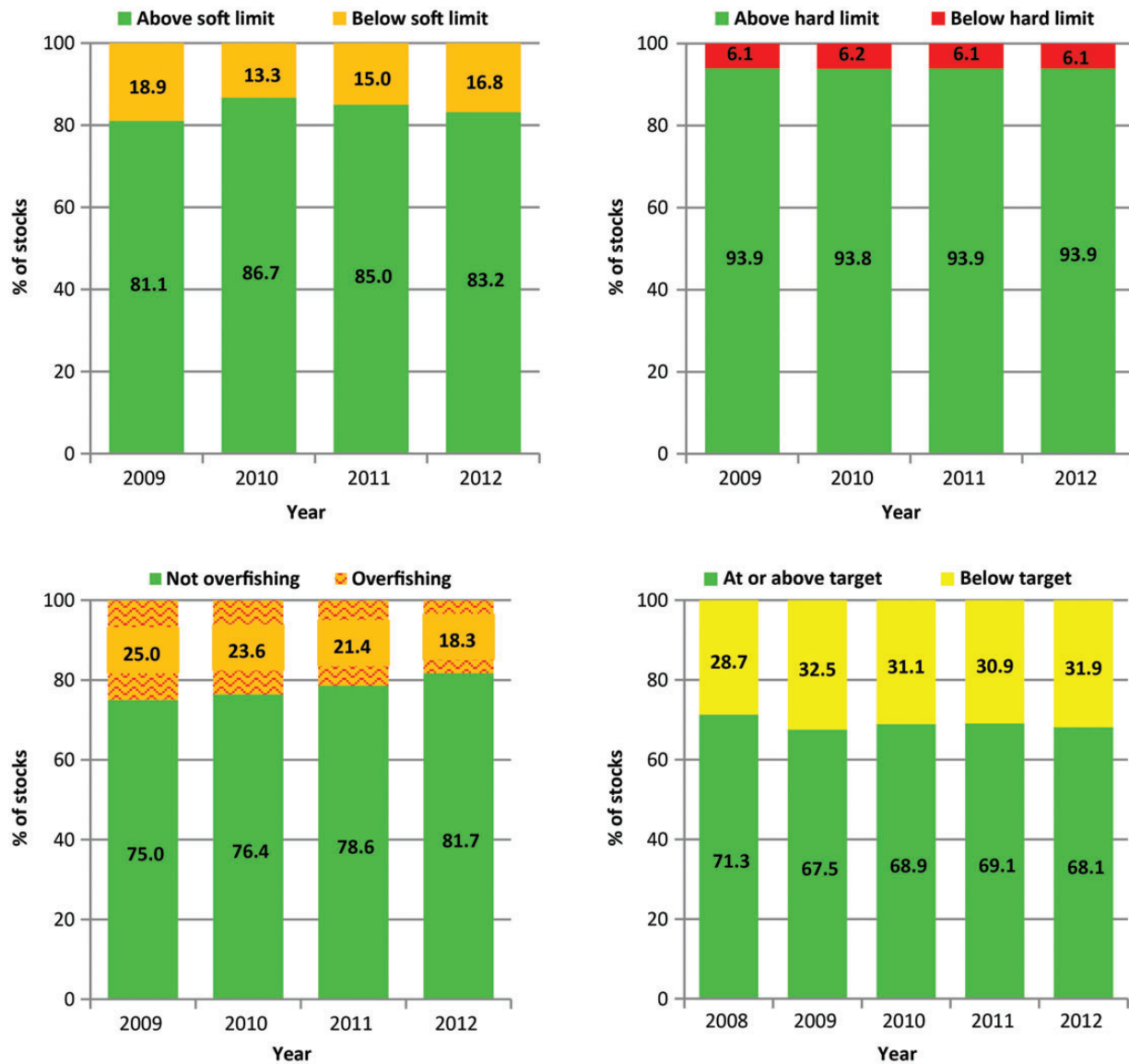


Figure 2. The status of New Zealand's fish stocks of known status relative to the soft limit, the hard limit, the overfishing threshold, and the management target over the period 2009–2012 (or 2008–2012 for the management target).

eight marine mammal taxa as threatened with extinction, nine taxa not so threatened, and 13 taxa as data deficient (a total of 30 taxa) in 2009. This compares with six taxa threatened, one at risk, five not threatened, and 12 data-deficient (total 24) in 2002 (Hitchmough, 2002). Overall, this suggests a decline in status for marine mammals through the 2000s (not necessarily as a result of fishing-related mortality), although comparisons over time are complicated by changes to the number of taxa assessed. The Ornithological Society of New Zealand (OSNZ, 2010) lists 111 seabird taxa for New Zealand, of which 33 are threatened and a further 49 are at risk. This shows a larger proportion of threatened species among seabirds than among mammals. Indeed, at a global level, seabirds are ranked as the most threatened bird grouping (Croxall *et al.*, 2012).

The recent average rate of fishing-related mortality for protected species populations can be assessed against PBR using risk assessments. A risk assessment for seabirds breeding in New Zealand

(Richard and Abraham, 2013) classified 10 of 70 seabird taxa (including seven albatrosses) at high or very high risk from commercial fishing in New Zealand waters. There are no comprehensive historical assessments to allow robust assessments over time, but estimated captures of albatrosses (especially white-capped albatross) have declined markedly in New Zealand's offshore fisheries since 2002-03 due to improved operational procedures informed by scientific experiments, whereas estimated captures of diving seabirds have remained steady (e.g. sooty shearwater) or increased (e.g. white-chinned petrel) (Ministry for Primary Industries, 2012b). The performance of inshore fisheries remains poorly understood due to low observer coverage but is nevertheless included in the risk assessment. Fisheries outside New Zealand's waters also catch large numbers of some New Zealand-breeding seabird species.

There is no analogous comprehensive risk assessment for marine mammals, but specific assessments that have been conducted suggest that fishing-related mortality is a major contributor to

overall risk for Maui's dolphin (Currey *et al.*, 2012) although not for New Zealand sea lions (Abraham, 2012; Breen *et al.*, 2012).

Outcomes for habitats

Bottom trawling and dredging effort increased after the introduction of the QMS to a peak in ~1998, but has decreased substantially since, following substantial decreases to allowable catches for several finfish and shellfish species. In combination, there were ~300 000 trawl or dredge tows each year in the first half of the 1990s, but this has decreased to ~120 000 tows annually since 2010. The outcome of this trawl fishing effort on bottom habitat is not known, but varies substantially by habitat type. Almost no trawling or dredging occurs in some habitat types, whereas others are overlapped almost entirely over much of their geographical distribution (Figure 3).

The cumulative size of the trawl footprint and its overlap with most, possibly all, habitat classes has undoubtedly increased in recent decades. However, the intensity of the disturbance has probably decreased in most broad-scale habitat classes since 1998, and some particularly vulnerable coastal areas and a large proportion of very deep areas have been closed to bottom-impacting gears (Ministry for Primary Industries, 2012b).

Outcomes for fishing industry accountability

The introduction of ITQs and other aspects of the QMS paved the way for increased responsibility and accountability from the fishing industry. This has been a process of evolution and, even today, the record varies between fishing sectors. The designers of the initial QMS hypothesized that bestowing ITQs would lead to an enhanced stewardship ethic in the fishing industry and that this would in turn result in a reduced need for government intervention. This hypothesis has been challenged by factors such as a lack of consideration of natural variation in fish stocks, the complexity of managing multispecies fisheries, environmental externalities, a limited and diminishing research budget that cannot address the full range of species and issues, potential conflicts with alternative users of the marine space, and the various mechanisms by which quota ownership has become divorced from fishing activity. A key role of fisheries science, fisheries management, and the fishing industry itself since the inception of ITQs has been to address these challenges.

Scientists, managers, the fishing industry, and other stakeholders need to work collaboratively to maintain and enhance the integrity of the QMS in the face of increased complexity in the problems that need to be addressed and reduced research funding for an increasingly large number of QMS fish stocks and ecosystem considerations. Equally importantly, it is essential to continue to explore economic incentives to improve profitability in the commercial fishery and reduce wastage. Over the years, many fishers who previously owned ITQ have sold their quota but have continued fishing by purchasing ACE each year. New entrants to the industry usually fish using ACE because the high value of ITQ is beyond their means. This change in the industry means that many fishers no longer own a (quasi-) property right and have reduced incentive to follow the rules and report bycatch for which they have no ACE. Anecdotal reports are that an increasing volume of fish is being discarded illegally, because the fish are too small for market or fishers have insufficient ACE to cover the bycatch.

Nevertheless, professionalization of the fishing industry has occurred in all sectors, to varying degrees. Professionalization implies both responsibility and accountability. The most successful

examples have occurred for fisheries on highly productive, high-value, or high-volume species where fishing industry organizations have not only abided by government rules but have also implemented additional voluntary arrangements to further ensure the sustainability of their fisheries. The best such examples include rock lobsters, hoki, and several other deepwater species.

Developments on the horizon

In the last 2–3 years, New Zealand has begun to formulate Fisheries Plans including for the first time explicit fisheries management objectives, which were previously simply inferred from the broad mandates in the Fisheries Act and agency policy. Fisheries Plans will ultimately streamline fisheries management activities, foster closer links between fisheries research and fisheries management, and better align fisheries observer services and compliance activities. Related initiatives on the horizon that will further contribute to preventing overfishing include: an electronic monitoring/discards project that aims to quantify the amount of discarding in inshore finfish fisheries; finer-scale reporting to facilitate resolution of spatial conflicts; increased consideration of ecosystem issues, particularly as they relate to eco-certification requirements; more widespread application of ecological risk analysis to inform research priorities and management actions; increased use of management strategy evaluations; implementation of updated national plans of action for seabirds and sharks and threat management plans for Hector's and Maui's dolphins; and closer scrutiny of the activities of foreign charter vessels fishing in New Zealand waters.

Conclusions

The QMS was put in place over a relatively short period, given its revolutionary nature. Compared with the first author's experience with US fisheries management systems, New Zealand's initial system for 26 species and 153 management units (fish stocks) was implemented extremely rapidly and it is not surprising that the issues we discuss were not fully considered. However, one could also argue that there was a window of opportunity to implement such a radically different system. New Zealand governments of the time were putting in place sweeping reforms using market-based economic theories (Bess, 2005). Extensive discussion of the wider issues omitted in the initial QMS may have even thwarted it ever coming into existence.

Since 1986, New Zealand's QMS has evolved from one that denominated quota shares in terms of absolute tonnages valid in perpetuity, to one that reconfigured quota shares as a specified proportion of a potentially variable TAC in recognition of the dynamic nature of fish stocks. More recently, MSY-related targets are being considered in an ecosystem context with consideration given to forage species, bycatch species, discards, protected species, and habitat impacts. There has also been thought given to the benefits of managing more conservatively (e.g. setting higher biomass targets) to gain potential additional economic benefits along with concomitant reductions in the risk to the stock and other components of the ecosystem. The system in its current state can be considered to constitute a first-level ecosystem approach to fisheries management (*sensu* Holliday and Gautam, 2005), similar to that achieved by many other developed countries.

Overall, we believe that the positives considerably outweigh the negatives. The initial design has proved to be a system that can be built upon, although some design changes have been challenging. Comparing New Zealand with most of the rest of the world, one key positive outcome for preventing overfishing is the current lack

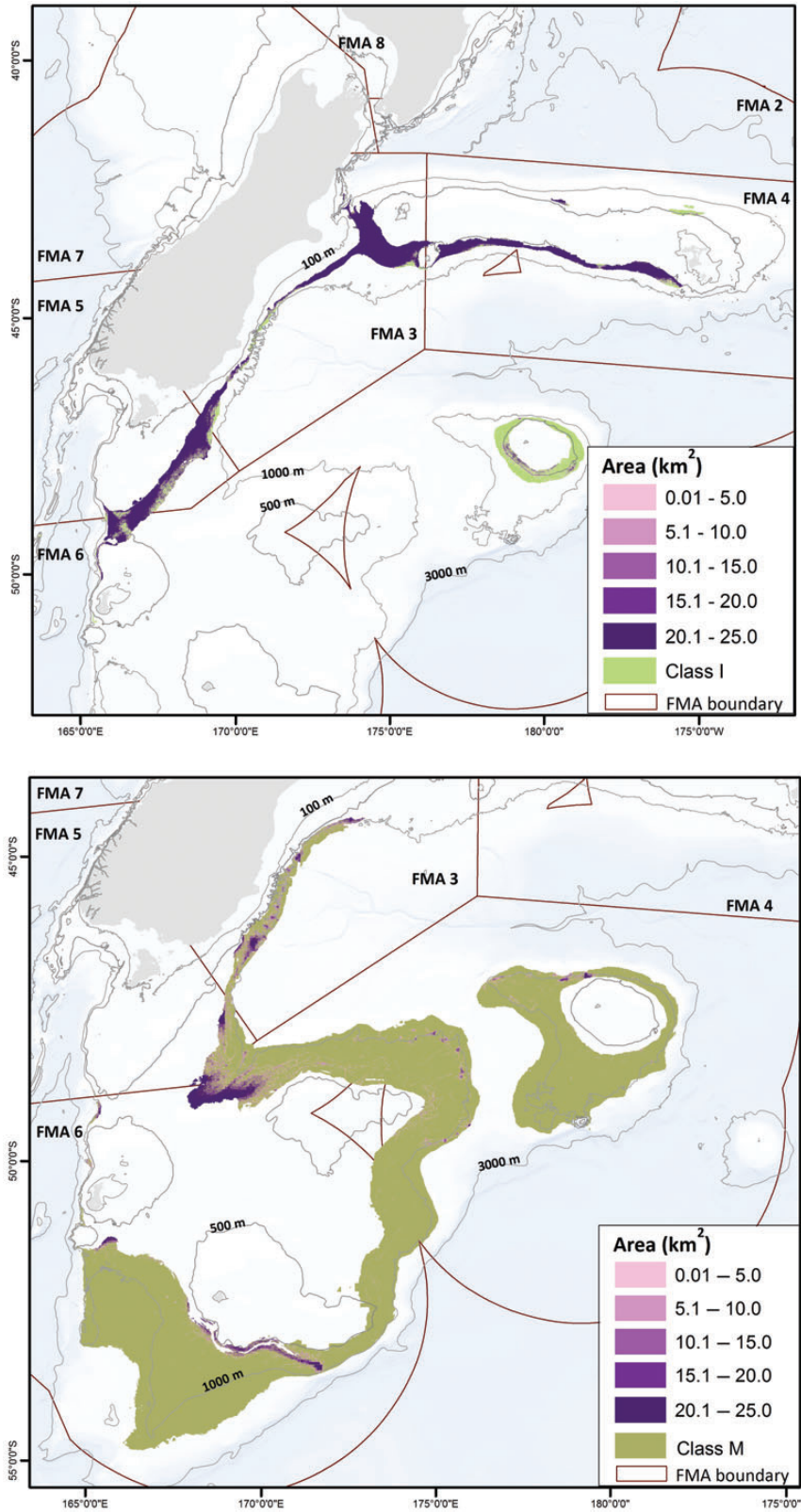


Figure 3. The habitat classes (in two shades of green) that are the most (top) and the least (bottom) overlapped by offshore trawling in New Zealand's EEZ. Relevant portions of the trawl footprint (in shades of purple related to the cumulative trawl footprint in each 25 km² cell) are superimposed on the areas occupied by these two habitat classes, which they overlay and therefore obscure. EEZ and fishery management area boundaries are shown in red, and depth contours in grey. After Baird and Wood (2012).

of significant overcapacity in most fisheries, given that overcapacity almost inevitably leads to overfishing with associated impacts on other components of the ecosystem (Mace, 1997). It could be argued that New Zealand's small size and relative isolation have made this and some other aspects of fisheries management relatively less complex compared with other jurisdictions, such as the EU. However, attempts to prevent overfishing in multispecies systems have been less successful and are still being grappled with today. The application of cost-recovery and contestability to research has led to a substantial reduction in the overall research budget and a continuing reduction in research on small stocks, resulting in a concomitant reduction in the number of stocks of known status.

Innovative science has proceeded nevertheless. Examples since the early 1990s include the development of deepwater acoustic methods, state-of-the-art stock assessment models, the formulation and adoption of an HSS and a Research and Science Information Standard, the development of management strategy evaluations and implementation of the resulting management procedures, and the generation of formal risk assessments. It has also led to a drive for efficiency in the overall research effort with, for example, New Zealand scientists leveraging research opportunities from other research programmes. A key remaining challenge is how to increase the information base and management approaches for the large number of relatively small or low-information stocks and non-QMS components of ecosystems given the constraints imposed by cost-recovery and other factors.

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