

Fisheries Centre

The University of British Columbia



Working Paper Series

Working Paper #2015 - 87

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Year: 2015

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PRELIMINARY RECONSTRUCTION OF MARINE FISHERIES CATCHES FOR NEW ZEALAND (1950-2010)

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ABSTRACT

New Zealand's reported marine fisheries catch statistics are incomplete due to the omission of significant amounts of 'invisible' (i.e., unreported) landings in industrial fisheries, fish that are discarded, and fish taken by recreational and customary fishers. This reconstruction accounts for unreported catch to provide a more comprehensive picture of total fisheries catches taken from New Zealand's waters from 1950 to 2010. We use publically available official catch data from the Ministry for Primary Industries to reconstruct a baseline. This baseline is then improved upon using stock assessment reports, peer-reviewed literature, grey literature, data obtained under the Official Information Act, and data from a wide range of industry experts and personnel. Reconstructed total catch in New Zealand totalled 40.4 million t in the 61 year period, suggesting that actual catch was about 2.9 times the 14 million t reported to the FAO on behalf of New Zealand for the same time period. Since 1986 - when the quota management system was introduced to ensure resource sustainability and improve reporting - the total catch is conservatively estimated at 2.2 times greater than the FAO data.

Unreported industrial catch and discards account for the vast majority of the difference. Recreational and customary catch at 0.55 million t for the same period are insignificant. Overall, 44% of industrial catch from 1960-2010 was caught by foreign flagged vessels, which dominated the catching of hoki (*Macruronus novaezelandiae*), squid, jack mackerels (*Trachurus* spp.), barracouta (*Thyristes atun*), and southern blue whiting (*Micromesistius australis*), the largest amount of reported landings from 1950-2010. These five species are also some of the most misreported and discarded over the time series considered. While some estimates of unreported catches and discards are included in stock assessment reports, the lack of comprehensive and transparent reporting has implications for the quota management system. Besides improving transparency and reliability in fisheries data reporting, the future sustainability of the fishing sector will also depend on how the government addresses poor fishing practices and particularly labour practices aboard foreign flagged vessels, which have long been a cause of concern and controversy in the fishing sector.

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1. Background

New Zealand, an island nation in the South Pacific Ocean, consists of two main landmasses (North and South Islands), as well as several smaller groups of islands (including the Antipodes, Auckland, Bounty, Campbell, Chatham, Kings, Kermadec and Stewart Islands). Together these outlying islands create a very large Exclusive Economic Zone (EEZ) covering over 4 million km² (www.searounds.org; Figure 1). The Kermadec Islands, which are the most segregated, have their own EEZ, of nearly 700,000 km². For the purposes of this paper, the Kermadec Islands and the EEZ surrounding them are treated separately (in Palomares *et al.* 2012; Zyllich *et al.* 2012), with the focus here being on the over 3 million km² of EEZ surrounding the main landmasses of New Zealand.

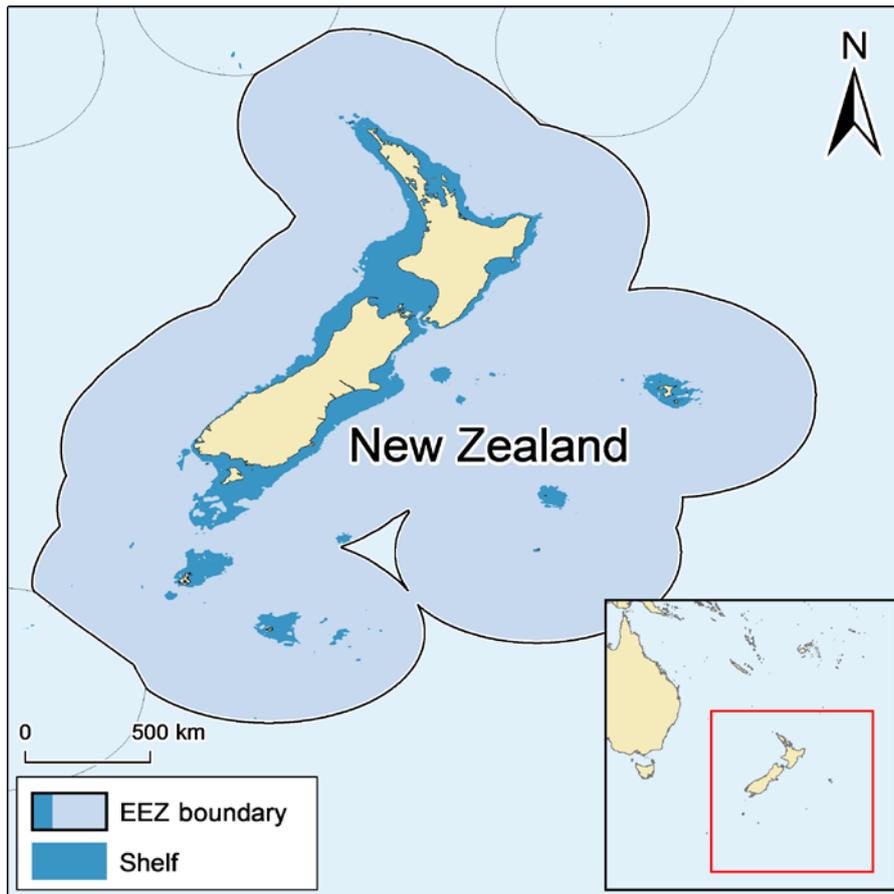


Figure 1: Map of New Zealand with its Exclusive Economic Zone (EEZ).

1.1 Māori fishing

Fishing is foundational to the culture of Māori, New Zealand's indigenous people (Habib 1987). Māori fishing customs include respect for the ocean and the organisms living within it; embracing 'not only the physical but also the spiritual, social and cultural dimensions' (Banks 1768-1771). Strict rules and laws, developed over several centuries, governed who could fish as well as where, how and when fish could be taken (Hohepa 1976; Waitangi Tribunal 1988). This included sharply defined fishing rights with each *hapū*¹ boundary often marked out by stakes (Nicholas 1817). Habitats and breeding areas were protected so that the life-force of the ecosystem would be conserved for future generations. Disposal of fish offal, small and dead fish, unused bait, food and rubbish at sea was strictly prohibited. Nets, sacks and baskets were not permitted to be dragged over shellfish beds. To ensure the sustainability of fisheries 'traditional

¹ Subtribe group (Mutu 2011).

customs and regulations were most strictly observed and rigidly enforced' (Mathews 1910). Breaches of a *rāhu*² within a *hapū* resulted in the confiscation of an offender's property, including the destruction of their canoe. Breaches by outsiders generally had fatal consequences for the offender as well as for their *hapū* (Hohepa 1976).

Māori caught at least 120 different species, had an in-depth understanding of fishery habitats and 'knew the proper seasons when, as well as best manner how, to take them' (Waitangi Tribunal 1988, S1.3). They would travel 'in large canoes to the deep sea-fishing, five to ten miles from the shore...sometimes they use very large drag nets, and enclose great numbers of grey mullet, dog-fish, mackerel, and other fish which swim in shoals' (Colenso 1868). The first European explorers were amazed by the expertise and ingenuity of Māori fishermen, particularly the high standard of their operations and the scale of their activities. Joseph Banks (1768-1771), a botanist on the *Endeavour's* first voyage, showed the Bay of Islands Māori their fishing net: 'After a little laugh at our seine, which was a common kings seine'...they 'showed us one of theirs which was 5 fathom deep and its length not less than 4 or 500 fathoms' (730-910 meters). Nets used in other areas were up to twice as long (Nicholas 1817; Waitangi Tribunal 1988). Banks was particularly struck by one type of innovative net, used to catch 'vast numbers of fish and indeed it is a most general way of fishing all over the coast' (Banks 1768-1771). Captain Cook himself noted that Māori were better fisherman than his crew and used nets far superior to European ones (Cook 1893; Beaglehole 1955). In short, fishing was the primary business of Māori: 'About all their towns are abundance of nets laid upon small heaps like hay cocks and thatched over and almost every house you go into has nets in the making' (Banks 1768-1771).

Māori were dependent on *kaimoana*³ not only as a critical source of protein, but importantly for trade which was commonplace: 'Few nations delight more in trading and bargaining than this people' (Polack 1838). Before the arrival of Europeans, Māori engaged in large scale commercial fishing, much of which was traded between *iwi*⁴ (Taylor 1855; Waitangi Tribunal 1988). From the 1820s Māori, with their fishing monopoly, supplied European settlers, visiting ships and whaling stations. By 1830 Māori were shipping large quantities of seafood to Australia. Despite increased demand, fisheries were sustainably harvested (Hohepa 1976). Europeans settlers did not materially impact fisheries, as they primarily undertook subsistence activities for personal needs. However, from the late 1860s these roles began to reverse after settlers gained political control from Britain (Waitangi Tribunal 1988). A series of laws were passed that ultimately overrode Māori governance over New Zealand's fisheries. The first was the 1866 Oyster Fisheries Act, New Zealand's first fisheries management legislation. It effectively prohibited Māori from continuing with the commercial exploitation of their oysters, and provided for the leasing of Māori oyster beds to non-Māori (Waitangi Tribunal 1988). In 1867 inland fisheries were brought under statutory regulation and the comprehensive Fish Protection Act followed in 1877. Together these statutes essentially restricted Māori activities to subsistence fishing.

With the growth of non-Māori commercial fishing the need to further regulate activities also grew. Over the next thirty years a range of laws were passed to encourage industry growth, and manage fishing activities and conservation. In particular, the Fisheries Act, 1908, established the three mile territorial limit and set up the management framework that was used until it was repealed in 1983. Restricted licensing was introduced in 1937 and then removed in 1963 to encourage major expansion through open access (Waitangi Tribunal 1988). Encouraged by concessionary loans and export incentives, the industry significantly expanded, but by the mid-1970s overfishing had become a serious problem with too many boats chasing too few fish. This was exacerbated by the introduction of pair trawling which caught more fish than markets could absorb. Despite restrictions being reintroduced, by the early 1980s coastal fisheries were in a state of crisis from depleted fisheries and poor economic performance (Johnson and Haworth 2004). Drastic action was urgently needed to reduce fishing effort - in some fisheries by as much as 77% (National Fisheries Management Advisory Committee 1983). The fishing grounds Māori

² Protection of an area or resource by forbidding access or harvesting (Mutu 2011).

³ Seafood.

⁴ An *iwi* is a tribe.

had 'nurtured for centuries were largely fished out' (Waitangi Tribunal 1988, S3.2). A moratorium was placed on new licences, those that were not used were cancelled and later, part-time fishermen had their licences cancelled while others were compensated to exit the industry.

1.2 New Zealand's quota management system

During the 1950s foreign fishing vessels began exploiting the waters off New Zealand (Francis *et al.* 2001). This created concern about who had rights to the ocean and its resources, and thus in 1965 the territorial sea was extended to 12 nautical miles. Nonetheless, by 1976 over 400 foreign fishing vessels were operating off the coast of New Zealand (Johnson and Haworth 2004). In 1977 New Zealand gained greater control over its fisheries, when it established the 200 mile EEZ. Foreign vessels could only fish within the EEZ through contractual agreements with those licenced to use foreign vessels, as opposed to intergovernmental agreements (Branson 1997). An output-based management system was introduced in 1982, which 'was effectively a trial period for the QMS' (Massey 2005). This system managed 9 deepwater species specific to 12 commercial operators. In 1986 another, more elaborate, quota management system (QMS) underpinned by individual transferable quotas (ITQs) was introduced for the inshore fisheries and merged with the original deepwater system (Major 1997). The QMS provided the vehicle 'to implement a fishery rationalization programme to address both biological and economic goals' (Boyd and Dewees 1992). Government's overarching objective was to change the behaviour of fishermen, by implementing a competitive market-based system that encouraged the maximum value to be sustainably harvested from fisheries.

The QMS sets a Total Allowable Catch (TAC) for each fish stock subject to quota. Allowances for Customary Māori and Recreational catch, and an allowance to cover unreported or illegal catch are then deducted from the TAC with the balance being the Total Allowable Commercial Catch (TACC). Initially 26 fish stocks were included in the QMS, representing 83% of the total commercial catch (Boyd and Dewees 1992). By 2012 the QMS covered 636 fish stocks. For deep water fisheries, TACCs were established at or above pre-QMS levels, while inshore TACCs were set at below pre-QMS levels (Massey 2005). A catch balancing system (by-catch trade-off between species, surrender of over-quota fish to the government, and 10% over and under carried through to the next fishing year) was also established, to permit fishermen to deal with by-catch for which they did not have quota. It was designed to discourage illegal dumping and non-reporting of excess catch. However, it was criticised as complicated and biologically unsound, and thus in 2001 catch balancing was replaced with the simplified 'deemed value' system (Walker and Townsend 2008). A deemed value is a financial penalty that fishermen must pay, if they do not have quota for a catch. Deemed value fees are set for each species in each management area, at a level that theoretically discourages overfishing and encourages the landing of species. In practice, however, the deemed value fees have acted as a fine and proven detrimental to fishers reporting and landing all of their catch (Simmons 2014).

The implementation of the QMS system was not without problems. The provisional allocation of quota was based on catch histories between 1982 and 1984, regardless of how successful (or not) these seasons had been. This caught many fishers by surprise as they had previously underreported catches in order to reduce income tax (Rees 2005). Thus, many appealed their allocations. TACs were also viewed as arbitrary, due to a lack of comprehensive information about fishery stocks (Massey 2005). In the end quota allocations were higher than the TAC, which forced Government to engage in two quota buy back schemes at a cost of \$45 million, as well as enforce cuts to quota holders. Moreover, Māori did not receive any quota, despite Te Tiriti o Waitangi (and particularly the English Treaty of Waitangi) guaranteeing Māori the 'full exclusive and undisturbed possession of their Lands and Estates Forests Fisheries and other properties'.⁵ In short, ITQ rights had been appropriated by the government without consulting and considering prior Māori rights (Durie 1998; Mutu 2012). Hence, this created much controversy and litigation. Māori objected because ITQs were in fundamental conflict with the principles and terms of the

⁵ The Treaty of Waitangi, Article 2.

Treaty. ITQs gave pākehā⁶ ‘the full exclusive and undisturbed possession of the property right in fishing that the Crown had already guaranteed to Māori’ in 1840 (Waitangi Tribunal 1988). Māori fishers were also denied quota unless they earned at least 80% of their income from fishing.

In a series of Waitangi Tribunal hearings and Court cases seeking relief, iwi successfully challenged the government, and refuted widespread views that Māori had only ever been subsistence fishers. Few New Zealanders understood the extent of early Māori fishing activities. Māori did not oppose the concept of a QMS, as they related to the sustainability objectives of the system. The Court of Appeal held that the rights of Māori had not been properly considered and consequently the QMS could be in breach of their rights. It ordered the Crown to settle with Māori (Matiu and Mutu 2003). This led to negotiations with Government, and in 1989 an interim settlement was reached. This recognised *tino rangatiratanga*⁷ and established the Māori Fisheries Commission to administer Māori fishing rights assets and advance Māori involvement in fisheries. In 1992 a full and final settlement (the Sealord deal) was reached for all Māori commercial fishing claims (Bess 2001). In short, 10% of the total commercial quota and a half share of Sealord Products Ltd were transferred to the Māori Fisheries Commission. Additionally, 20% of the quota for all new species introduced into the QMS would be allocated to Māori. This led to Māori collectively becoming the largest owners of quota and fisheries assets in New Zealand. Yet ‘Māoridom in general were, and still are, very angry with the settlement’ (Matiu and Mutu 2003).

Fishing is also very important to recreational (amateur) fishers, with around one third of the population participating (Kearney 2002; Ministry of Fisheries 2008; Bess 2010). It is deeply rooted in New Zealand culture and considered to be a birthright. No permit is required to fish recreationally in the sea, but there are limits, including gear restrictions, closed seasons, minimum size and bag limits (Ministry of Fisheries 2008). Recreational caught fish cannot be sold, except whitebait. A recreational allowance is provided for in the TAC, which translates into daily per person bag limits (Kearney 2001). The sector is managed on a per person basis. As the population increases and more people fish recreationally, either the total recreational allowance must increase or bag limits must decrease. If the allowance increases the TACC must decrease (with much opposition from the commercial sector); equally a decrease in bag limits will be strongly opposed by recreational fishers. As the Government found in 1993 and again in 2002, it is politically untenable to regulate recreational fishing through the QMS (Borch 2010).⁸ In 2013 the Ministry for Primary Industries promoted a proportional approach to the allocation of the snapper (*Pagrus auratus*) TAC (Ministry for Primary Industries 2013f). This was met with a fierce recreational backlash and resulted in the Minister for Primary Industries increasing the recreational allowance, but not the TACC (Guy 2013). Thus, it is challenging to accommodate recreational fishers in the TAC, and in practice there is no settled pathway for granting future increases in Allowance or reducing daily bag limits.

1.3 Catch data

Various regional and national studies have been undertaken during the past 30 years to estimate recreational catches (e.g. Teirney *et al.* 1997; Bradford 1998; Reilly 2002), but they are not considered reliable. In a review of the 1996 and 2000 recreational surveys, Kearney (2002) cautioned against accepting the results, including those from regional surveys. However, surveys since 2004 are considered broadly reliable. The most recent surveys in 2011-12, 2012-13, and 2013-14 involved a nationwide panel survey undertaken concurrently with an onsite boat ramp survey to collect fish weight data and an aerial survey to estimate the number of recreational fishers. The 2011-2012 panel survey ‘appeared to be an advance over previous methods and [was] able to produce more accurate and defensible harvest estimates’ (Wynne-Jones *et al.* 2014). However, while the report provides estimates of the total number

⁶ Non- Māori, European, or Caucasian.

⁷ The exercise of paramount authority and power derived from the gods, sovereignty, and autonomy (Mutu 2011).

⁸ Borch (2010) provides an excellent overview of the tension between the recreational and commercial sectors and the Ministry responsible for fisheries.

of fish caught, it did not provide their total weight. Moreover, the results for 2012-13 and 2013-14 have yet to be released.

Compounding the lack of recreational catch data is the poor quality of commercial catch data. Commercial fishermen were first required to complete catch returns following the passage of the 1903 Sea Fisheries Amendment Act. Yet it was 28 years before any did so and a further 5 years before all fishermen were completing catch returns, albeit poorly. Unsurprisingly, in 1926 the Chief Inspector of Fisheries and Director of Fisheries Research noted that the catch statistics 'throw little or no light upon the condition of the fisheries' (Department of Statistics 1981). This criticism was echoed by the Fisheries Committee to the National Development Conference in 1969. The Committee highlighted that every committee that had ever investigated fisheries had determined that critical data was missing, as was the expertise necessary to collate and analyse catch data. An inter-agency committee was formed to resolve these issues, yet in 1974 the Inter-department Advisory Committee on Statistical Needs and Priorities stressed that the accuracy of catch data still needed to be drastically improved (Harris 1974). Problems continued and in 1980 the Commercial Fisheries Working Party of the National Research Advisory Council reported that they were 'most disturbed to discover that New Zealand has no straightforward and workable system to obtain catch statistics for fisheries nor teams of analysts able to sort out and assess trends and values' (National Research Advisory Council 1980).

In 1981 another review committee found the data from catch returns was completely inadequate: 'It is virtually impossible using present statistics to implement a proper scientific management of the fisheries' (Department of Statistics 1981). Only catch data from some individual fishermen was of any use, because scientists themselves had collected and recorded the data. Many fishermen claimed they did not have time to complete the returns which they found unwieldy and confusing. They did not see that the catch data would provide a benefit to them. The greatest fear for many was that the Inland Revenue Department might access their returns. Part-time fisherman, of which there were many, tended to be 'tardy' in completing their returns, and thus provided 'data of dubious quality' (Department of Statistics 1981). The committee found that catches were 20 to 30% under reported compared to figures from other sources (e.g. export declarations). To improve the veracity of data a Fisheries Statistics Unit (FSU) was established in 1982. The Unit developed a new fisheries statistics system and oversaw the collection and processing of catch-effort returns, but it was disbanded in 1988, leaving some datasets incomplete (Fisher and Sanders 2011). In 1990 the Controller and Auditor-General, and the Parliamentary Commissioner for the Environment found in their review of the QMS, 'a system struggling to provide the necessary information for management decisions which can control fishing at sustainable levels and ensure the sustainability of the fishery resource' (Cameron and Hughes 1990). Problems they highlighted included inaccurate conversion factors for processed fish resulting in catches being under-reported by as much as 35%, non-reporting of bycatch, mislabelling of fish, unrecorded transshipments to foreign carrier vessels, and dumping of unwanted fish at sea.

Nine years on, the Parliamentary Commissioner for the Environment reported: 'There is still insufficient information on the fish stocks managed under the QMS...ineffective use of information; and, there are still problems ensuring compliance' (Williams 1999). Indeed, 'effective monitoring and compliance are virtually impossible for New Zealand's fisheries resources' (Williams 1999). The Commissioner was critical of large discrepancies in catch data, particularly of fishers who 'strategically compiled' their catch returns. He further noted that 'there is a high degree of error in the data returns received by the Ministry' (Williams 1999). Unsurprisingly, the total catch of many species have historically been under-reported, particularly prior to the introduction of the QMS. One example is spiny dogfish (*Squalus acanthius*), which was first reported commercially caught in the 1980-81 fishing year, yet Māori had, been catching it for food and trade for hundreds of years. Mathews (1910) himself, witnessed the size of Māori catches in 1855, when 7,000 sharks and dogfish were caught during one fishing expedition. Commercial fishers typically dumped spiny dogfish, regarding them as a nuisance species due to their abundance and low economic value (Ministry for Primary Industries 2013c). For several other species anecdotal evidence suggests an annual under-reporting of at least 20% before the QMS and 10% afterwards. A 2005 study of

New Zealand's largest fishery - hoki (*Macruronus novaezelandiae*) - found that 'the catches reported by unobserved vessels contain large elements of fiction' (Bremner *et al.* 2009).

In sum, there has always been considerable uncertainty around the actual total annual commercial catch. Furthermore the 'Other Sources of Fishing Mortality' (OSFM) allowance estimated for key species has often been criticised as unproven and inaccurate, which the Ministry acknowledges. This particularly includes high grading and unreported dumping, as 'there are concerns about the level of commercial discarding driven by mostly economic factors, and thus reported landings do not reflect actual catches' (Ministry for Primary Industries 2013f). In the recreational sector, there is uncertainty about recreational release mortality, recreational undersized mortality, and recreational illegal catch.

1.4 Objectives

Against this backdrop, therefore, it is known that the data New Zealand reports to the Food and Agriculture Organization of the United Nations (FAO) may not be complete due to inadequacies in reporting. Data may not have been submitted, the process for collecting data may be ineffective to accurately record total catches, and/or not all sectors may be accounted for in the data (Garibaldi 2012). In fact, prior to 1981 there 'has been the almost total lack of reliable fisheries statistics' (Department of Statistics 1981). Moreover, under the amateur fishing regulations recreation catches are not required to be reported. Customary fishing also falls outside the QMS system, and is either managed under the Amateur Fishing Regulations 1986, or the Kaimoana Customary Fishing Regulations 1995. While details of customary permits are recorded, the catches themselves are not. The purpose of this report therefore, is to estimate the total marine fisheries catches of New Zealand and to address all of the sectors and catches which have not been accounted for in the past.

2. Materials and Methods

The catch reconstruction approach used broadly follows that outlined by Pauly (1998) and described by Zeller *et al.* (2007). New Zealand fishing vessels fish New Zealand's territorial sea, its EEZ and on the high seas including: Lord Howe Rise, West Norfolk Ridge, Northwest Challenger Plateau, and the Louisville Ridge. The fishing grounds all fall within FAO area 81 (Penney *et al.* 2007). The FAO reports 13,960,000 tonnes of marine species were caught by New Zealand within FAO area 81 for the period 1950 to 2010. To determine the veracity of this figure, we first compared the FAO data (FAO Capture Production dataset obtained from the FishStatJ statistics database) to official reported data detailed in New Zealand's 'Fisheries Assessment Plenary' reports (e.g. Ministry for Primary Industries 2013c, 2013a, 2013b, 2013e, 2013d). Not all species were covered in these reports and in the main the data only went back to around 1990. Thus, other official reports, particularly Francis and Paul's (2013) 1931-1982 finfish and shellfish commercial landings report, complemented by Marine Department (1950-1974) and Ministry of Agriculture and Fisheries reports (e.g. King 1985) were also compared to the FAO data. To construct a complete picture, these reports were supplemented with data from Licenced Fish Receiver Returns (LFRR). Together this enabled a detailed comparison for each species annually from 1950 to 2010.

The plenary reports (Ministry for Primary Industries 2013c, 2013a, 2013b, 2013e, 2013d) highlighted that the catches of a number of species had not been fully reported, including hoki New Zealand's most important species. During the mid-1980s, large hoki catches caused nets to burst, but the amount of fish lost was not determined. It was, however, of a sufficient level that a Code of Practice was introduced in order to minimise the losses. For other species, such as hake (*Merluccius australis*), the real catch was estimated to be as much as 78% higher than the reported total annual catch. Dumping and non-reporting (up to 100% of the total catches) had historically also been significant for certain species (e.g. barracouta (*Thyristes atun*), black cardinal (*Epigonus telescopus*), ghost shark (*Hydrolagus spp*), orange roughy (*Hoplostethus atlanticus*), oreos, school shark (*Galeorhinus galeus*), and sea perch (*Helicolenus percoides*), as well as discrepancies in tray weights and conversion factors (e.g. groper (*Polyprion spp*), hoki, orange roughy and skates). For other species, such as grey mullet (*Mugil cephalus*) and snapper

under-reporting was estimated at 10-20% prior to the introduction of the QMS in 1986 and 10% thereafter. Low value, damaged and under-size fish had also traditionally been dumped and not reported. Some instances of illegal catches were also noted in the plenary reports.

As the level of misreporting could not be properly determined, few corrections if any were made to the official reported catch. The plenary reports note that the level of dumping may have declined as species were introduced into the QMS. In short, these reports suggest that the misreporting of catches has long been a significant problem, due to poor reporting or deliberate non-reporting of catches, resulting in the reported total catch for many species being understated. To obtain data on the level of under reporting, an examination of a wide range of relevant published and unpublished documents was undertaken. This included several hundred submissions to two parliamentary fisheries investigations in 1956 and 1962, as well as their findings, Ministry for Primary Industries reports and Ministerial correspondence obtained pursuant to the Official Information Act. We also obtained and analysed Fishing Industry Board reports, as well as a wide range of reports and publications from: the Department of Statistics, Department of Scientific and Industrial Research (DSIR), Department of Trade and Industry, Ministry of Agriculture and Fisheries (MAF), Ministry of Fisheries (MFish), and the National Institute of Water and Atmospheric Research (NIWA). Industry reports, minutes of meetings, letters, observer diaries, and other confidential letters and reports were also obtained and analysed.

In addition, 271 semi-structured interviews were carried out between 2010 and 2013. Interviewees included fishing company executives, vessel officers and crew, former observers and government officials, as well as former industry representatives. Interviewees had in-depth knowledge of fishing practices, particularly those deployed on foreign flagged vessels. Together, interviewees had a wealth of knowledge and first-hand experience. Many had been involved in the industry for up to 55 years. Their information collectively was crucial to gain an in-depth understanding of actual catches. Interviewees also volunteered documentation to corroborate their accounts, including real catch records from New Zealand and foreign flagged vessels. These were also analysed.

This report reconstructs New Zealand's marine fisheries catch statistics by adding unreported catches to reported catches for the period 1950-2010. Preliminary results for extended reconstructed catch to 2013 are also reported. We define 'reported catch' as that reported by the FAO, i.e., marine fishes that are caught in New Zealand's waters by New Zealand flagged fishing vessels and foreign charter vessels. Reconstructed catches are assigned to the industrial (large-scale commercial), artisanal (small-scale commercial), subsistence, or recreational sectors. Note that we consider charter operations utilizing foreign flagged vessels as 'foreign' catch by that flag country (i.e., not New Zealand catch). Therefore, although we do consider the amount of reported charter vessel catch which is included in the FAO data as New Zealand catches, we have re-assigned this catch from New Zealand to the respective flag countries.

2.1 Invisible landings

Invisible landings, i.e., unreported commercial catch landed by industrial and artisanal fishers (as opposed to discards at sea), was estimated as a percentage of reported total commercial landings. From 1950 to 1986 we applied a 50% non-reporting rate, which was then linearly decreased to 10% in 1992 and subsequently maintained until 2010 (see section 3.2 for details).

2.1.1 Commercial amateur landings

Commercial fishers have always taken a portion of their catch home for consumption, and this 'commercial amateur landing' amount was not reported. Commercial amateur landing is considered as part of subsistence catch (i.e., defined as use for self and family-consumption) in this reconstruction, and was estimated as a proportion of the number of fishermen. We were only able to access data on the number of full-time fishermen in New Zealand from 2005 to 2010 (OECD 2013). We obtained statistics on the percentage of New Zealand's workforce that is employed in agriculture, within which fishery sector jobs are aggregated, from 1986-2010 (World Bank 2014). We assumed that fisheries employment

fluctuated annually in line with that of the agriculture sector as a whole, and extended fisheries employment from the 2005 anchor point back to 1986 according to the annual change in agricultural employment. Due to a lack of data, the gap in fisheries employment from 1950 to 1985 was filled by assuming that the change in the number of fishermen was at the minimum of the observed change from 1985 to 2010, when fisheries employment dropped by 40%. The number of fishermen in 1950 was thus calculated by multiplying the 1986 fishermen population by 1.6, and using linear interpolation to fill in data gaps from 1951 to 1985. We then used a 10:1 catch to fisherman ratio to derive the total commercial amateur catch from 1950 to 2010.

2.2 Dumped or highgraded commercial catch

The amount of discarded fish was estimated as a percentage of total reconstructed reported landed catch from domestic fishing vessels and foreign flagged vessels. In the case of domestic fishing vessel discards, we determined that the dumping rate was higher prior to the implementation of the quota management system in 1986 (~70% total catch from New Zealand flagged vessels), then declined after that to around 20% by 2010 due to anti-dumping regulations and the use of observers under the new management system. We started accounting for discards by foreign flagged vessels in 1960, which was determined at a higher rate of 80% of total catch in the period 1960 to 1986, and subsequently dropped to about 50% by 2010. High grading, where only high quality fish are landed and the remainder consisting of low quality quota catch are discarded, is a common practice aboard foreign flagged vessels fishing under contract for New Zealand companies (Morrah 2012).

2.3 Recreational and customary catch

To estimate the total recreational catch we used snapper and kahawai (*Arripis trutta*) catch histories, as used in their respective stock assessments for QMA1. In the 2011-2012 national recreational survey 50% of the total catch was made up of snapper and kahawai from QMA1. We assume that this proportion of the total catch was consistent over time, so all other fish is the sum of SNA1 and KAH1. We estimate that discard rates and resultant discard mortality was a higher proportion of overall catch when abundance was high as only a few species were considered worth eating. More recently the discard mortality rate from returned undersized fish is considered to be low.

Catch of undersized snapper is known that less than 5% as measured at boat ramps, and assumed survival of undersized snapper released by recreational fishers is assumed at 80% (Ministry of Fisheries 1997).

A wider range of species have been harvested and utilized in recent years and methods are more selective. Rock lobster and a number of shellfish species were fished down by the 1980s, causing many large shellfish beds to disappear. The farmed green lip mussel (*Perna canaliculus*) has replaced wild recreational shellfish harvests. While there has traditionally been considerable inter annual variation in recreational catches, there is little reliable historical data that captures this despite a range of methods used to estimate the total recreational catch during the past 30 years (Hartill *et al.* 2012). Moreover, recreational catch estimates vary widely between 8,000 tonnes (Hartill *et al.* 2012) and 25,000 tonnes (Ministry of Fisheries 2008). The approach taken is a best estimate based on the most recent recreational catch estimates.

For this paper customary catches are based on the total customary allowances, as these are set at a level to reflect what customary catches were likely to be. Moreover, an estimated 95% of Māori undertake customary fishing as recreational fishers - taking catches within the recreational allowance (Ministry of Fisheries 1997). Māori catch taken under recreational regulations are most likely enumerated in recreational catch estimates, and thus are not accounted for here. Unreported customary catch is here estimated as 4% of the recreational catch from 1950 to 2010.

2.4 Sector allocation

New Zealand marine fisheries statistics reported by the FAO consist of catches from the commercial sector only. In this reconstruction, we segregate commercial landings into the industrial and artisanal sectors, where artisanal is defined to be small-scale commercial fishing and industrial is large-scale commercial fishing (thus adhering to the *Sea Around Us* global database structure). Nowadays, about 80% of New Zealand's fisheries catch is supplied by eight fishing companies, with the remainder from inshore fishing operations (Ministry for Primary Industries 2009). This is in contrast to the 1970s, when the fishing industry was largely inshore. We took the qualitative description of 'largely inshore' to mean that about 80% of the fishery was inshore based in 1970. Given that historically fisheries development in New Zealand progressed slowly, we further assume that 100% of the fishery was operating inshore in 1950. We allocated 80% of total commercial catch in 1970 to the artisanal sector, then linearly decreased the artisanal component to 20% by 2010. Industrial sector catch increased from being 20% of commercial catch in 1970 to 80% by 2010 (see Table 1). Reported landings by fishing method were available for 1983 (King 1986). We classified gear types as being 'industrial' (single trawl, pair trawl, purse seine, Danish seine, squid jigging, dredge) or 'artisanal' (longlines, handlines, set nets, beach seine, trolling/polling, hand gathering, rock lobster pots, crab, fish pots, others) then used the proportion of total catch caught by those gears as the anchor point for industrial and artisanal sector allocation in 1983. Missing data between anchor points were calculated using linear interpolation.

Table 1: Allocation of commercial catch (%) to artisanal and industrial sectors.

	Artisanal	Industrial
1950	100	0
1970	80	20
1983	77	23
2010	20	80

Industrial catches were further segregated by the flag country of the fishing vessel's origin starting in 1960. Data on fish catch quantity from foreign flagged vessels was available from 1983 (King 1986), 2005 to 2009,⁹ and various years between 1960-1995. Gaps in data were filled by linearly interpolating between years for which data were available. In 2010, 26 fishing vessels from South Korea, Japan, Ukraine, and Dominica operated in New Zealand's EEZ,⁹ while USSR vessels also fished within the EEZ-equivalent waters in the 1970s to mid-1980s. Foreign flagged catches were proportioned to their countries of origin based on anchor points in 2010 and 1983 (King 1986).

2.5 Species composition

Industrial and artisanal sector catches were broken down according to the taxonomic composition of FAO commercial landings. Species that are commonly discarded are fish that are perceived as being of low value, non-quota fish, or fish for which quota limits have been reached. Close to 400 species have been observed discarded, of which commercial and QMS species make up about a third with the remainder being non-commercial and non-QMS species (Ballara *et al.* 2010). We synthesized data from multiple reports (e.g., Anderson 2004; Ballara *et al.* 2010) to derive a rough approximation of the taxonomic composition of fish discards in New Zealand's fisheries (see Table 2).¹⁰ The proportion of major discarded fish species was determined by qualitatively assessing the relative abundance of those

⁹ Catch quantity taken in nine key fisheries (~67% of total fisheries catch) by FCVs from 2005 to 2010. Report of the Ministerial Inquiry into the use and operation of Foreign Charter Vessels (Ministry for Primary Industries 2012b).

¹⁰ FCVs dominate the catching of five major targeted species - hoki (*Macruronus novaezelandiae*), squid, jack mackerels (*Trachurus spp.*), barracouta (*Thyristes atun*), and southern blue whiting (*Micromesistius australis*). Through continuous highgrading by FCVs, these species also tend to be highly discarded and misreported.

species in discards. The figures reported in Table 2 are derived from the discards authorised by government observers. However, observer coverage in many of the fisheries has historically been very low. Anderson and Smith (2005) caution that the ability of their methods to estimate by-catch and discard levels is highly dependent on the level and spread of observer coverage achieved, and express reservations about the precision of their own estimates. But the extrapolation to fleet level also depends on the assumption that the presence of an observer on a vessel does not influence discarding behaviour. This assumption is known to be deeply flawed. If an observer is present, discards of QMS species must be both reported and counted against quota. The incentive to discard QMS species is therefore removed when the vessel has observers on board, though species outside the quota management system can be discarded as normal. In consequence the species composition reported in Table 2 is dominated by species such as spiny dogfish, which was a late entrant to the QMS and can still be discarded without financial implications, if the fisherman believes the discarded fish are likely to survive return to the water. Therefore, until such time that a more comprehensive and reliable discard composition for all gear types can be compiled, we have temporarily adjusted the breakdown derived from Anderson (2004) and Ballara *et al.* (2010) to reduce the unreasonably high amount of discarded spiny dogfish (from 25% to 5%).

Table 2: Species composition of discarded fish (%), 1950-2010.

Spiny dogfish ¹	25	Macrouridae	15
Hoki	9	Sea perch	3
Hake	9	Redbait	3
Ling	9	Arrow squid	3
Snoek	9	Silver warehou	3
Others ¹	9	Jack mackerel	3

¹This derived composition was adjusted to account for unreasonably high spiny dogfish discards. Therefore, only 5% of discards were assigned to spiny dogfish and 29% was assigned as 'others'.

The composition of recreational finfish catch was derived from the findings of reports on a recent national survey on recreational fishing (i.e. Hartill *et al.* 2012; Hartill and Davey 2014; Heinemann *et al.* 2014; Wynne-Jones *et al.* 2014). Snapper (*Pagrus auratus*) and kahawail (*Arripis trutta*) comprised close to 40% of recreational catches, while other finfish like kingfish (*Seriola lalandi*) and blue cod (*Parapercis colias*) made up on average another 38%, and invertebrates were about 24% of total recreational catch.

3. Results

Reconstructed catch in New Zealand's EEZ totalled 40.4 million tonnes from 1950-2010 (and 43.3 million t from 1950-2012), of which approximately 34% was from foreign flagged fishing vessels. The reconstructed total catch taken by New Zealand flagged vessels was 1.9 times that reported by the FAO on behalf of New Zealand for the same time period. It should be noted that from 1990 an increasing proportion of catch from foreign flagged vessels are included in New Zealand landings data reported by FAO (see Figure 2), thus more recent FAO data may in fact be over-reporting the amount of fish caught in New Zealand's EEZ by New Zealand flagged vessels. If estimated catch from foreign flagged vessels are taken out from FAO reported landings, then reconstructed total catch taken by New Zealand flagged vessels was 2.6 times that reported by the FAO from 1950-2010 (Figure 3). Fish discards made up 57% of total unreported catches from foreign and New Zealand flagged vessels, with contributions from unreported landings of the recreational, industrial, artisanal and subsistence sectors making up 2%, 25%, 16% and 0.1%, respectively (Figure 4). In comparison, if New Zealand flagged catches were considered only, fish discards were lower at approximately 50% of unreported total catch, while recreational fishing and small-scale sector contributions were higher at 3% and 26% (25.5% artisanal and 0.2% subsistence), respectively (see Figure 3).

Reconstructed marine fish catches from all New Zealand and foreign flagged vessels averaged 139,000 t·year⁻¹ in the 1950s, peaked at almost 1.6 million t in 1988, and were around 713,000 t·year⁻¹ in the late 2000s (Figure 4). Industrial catches including discards comprised almost 80% of reconstructed total catch, of which about 56% came from New Zealand flagged vessels and the remaining 44% from foreign flagged vessels. Artisanal sector catch was the other major component of reconstructed catch at 20%, while the combined contribution of catch from recreational and subsistence (including customary Māori catch) fishing amounted to 1.4% of total reconstructed catch. Since 1980, commercially important fish have made up a significant portion of New Zealand's marine fish catches, of which hoki (blue grenadier) alone accounted for about 15% of total catch (Figure 5).

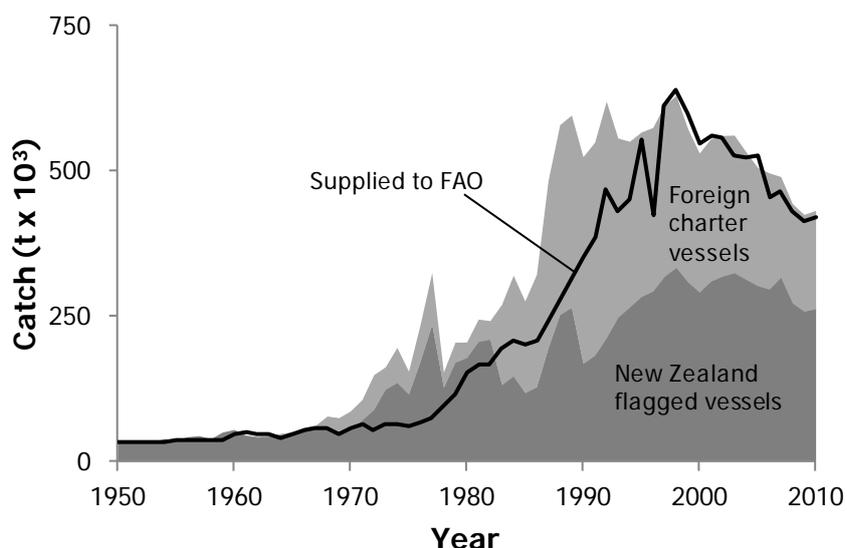


Figure 2. Breakdown of national catch statistics of New Zealand and foreign flagged fishing vessels. The solid line is the data reported by FAO on behalf of New Zealand, which, from 2000 onwards includes almost all the catch of foreign flagged vessels.

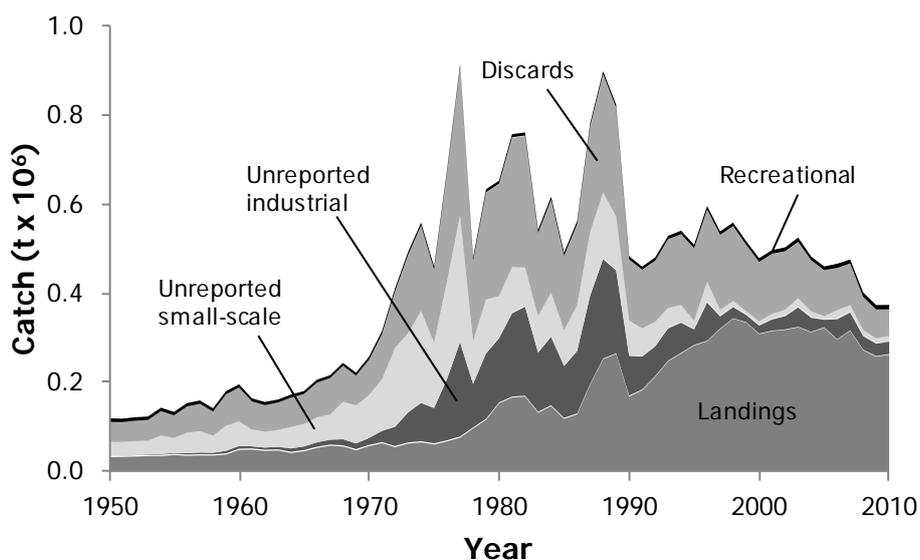


Figure 3. Total catches from New Zealand flagged vessels from 1950-2010, showing unreported catches from industrial, small-scale (artisanal and subsistence combined as subsistence is not visible individually) and recreational.

recreational fishing and discards added to FAO reported landings for New Zealand. Note that estimated catch from foreign flagged fishing vessels that were included in total landings for New Zealand as reported to the FAO (see Figure 2) have been removed.

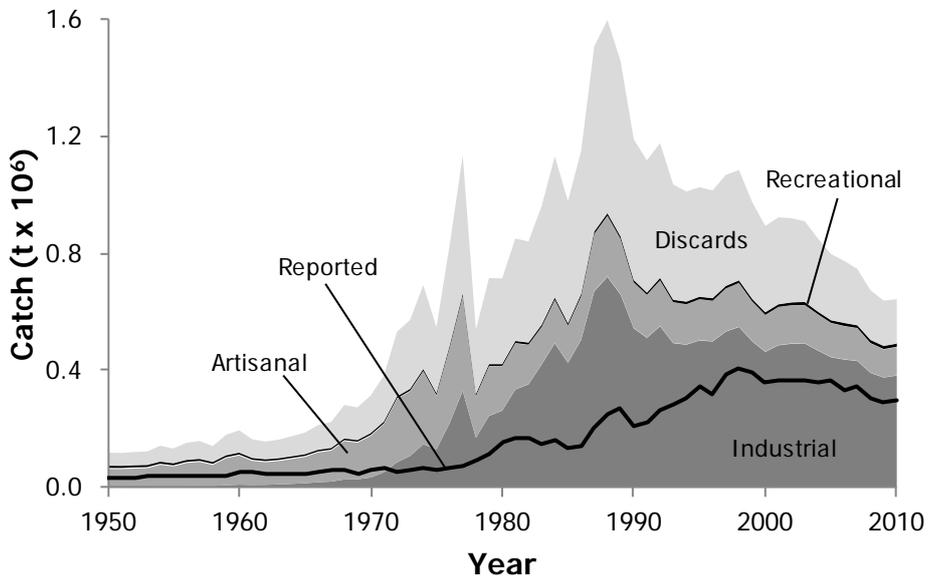


Figure 4. Reconstructed catches of New Zealand flagged and foreign charter fishing vessels showing the contribution of different sectors and fish discards. Subsistence sector catches are too small to appear on this graph. The solid line represents total landings reported by the FAO on behalf of New Zealand (i.e., including reported foreign charter vessel landings).

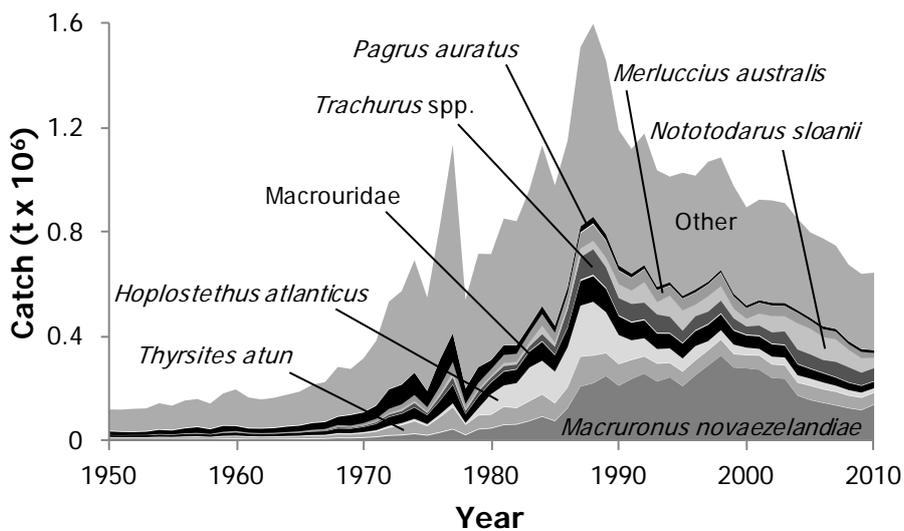


Figure 5. Total reconstructed catch (from New Zealand and foreign flagged vessels) broken down by major taxon groups. 'Others' includes 165 additional taxa.

3.1 Reconstructed official data

The total catch of marine species reported in the FAO data (13,960,000 tonnes) is significantly lower than the official national data (17,670,000 tonnes), taken from official reports to reconstruct a baseline, for the period 1950 to 2010. This was unexpected, as since the early 1930s official reports have contained detailed statistics about the reported catches for each species. From 1932 onwards fishing vessel owners were required to submit monthly returns (instead of annual returns) on the quantities of fish landed, because up until then ‘the data provided by the returns sent in [was] too heterogeneous to admit of any rational analysis’ (Marine Department 1931). For 1950 the FAO data contains 24 species, yet the Marine Department (1950-1974) Report on Fisheries for 1950 lists 36 species caught. On the other hand, this is not entirely unexpected, given frequent acknowledgement of problems with catch data. Table 3 compares the number of species reported in the FAO data with the reconstructed number of species from official reports, for certain years. This highlights that the FAO data understates the total catches. One species – spiny dogfish - is excluded from the FAO data until 1981, but before then it was a significant part of total catches.

Table 3: Number of species reported

	1800-1866	1950	1960	1970	1980	1990	2000	2010	2012
FAO data	-	24	22	39	50	60	117	146	133
Reconstructed official data	120	36	40	43	63	146	195	234	240

The difference between FAO and New Zealand national catch statistics was especially pronounced from the early 1970s to the late 1990s. This discrepancy may be due to different accounting of catch from the foreign flagged vessels. While the fish catch of these vessels are treated as part of total national marine fisheries landings in New Zealand fisheries statistics, they are correctly allocated to the flag country of the fishing vessel (i.e., not New Zealand) in FAO landings statistics. From the mid-1980s onwards the FAO apparently started to include parts of foreign charter vessel catch in their reporting system, hence FAO and New Zealand’s national statistics have become more aligned. In this reconstruction and the accompanying catch database, we differentiate between marine fish catches from New Zealand’s EEZ that are caught by New Zealand flagged fishing vessels and those taken by foreign flagged fishing vessels leased by New Zealand companies as a capacity expansion strategy. This distinction is apparently not made in national fisheries statistics, where fish taken under QMS regulations are considered to be domestic catch¹¹ regardless of who caught the fish, although total catch quantity is subsequently segregated by vessel type (New Zealand or foreign flag).

When the data was compared by species, little of the FAO data matched the reconstructed data taken from official reports. There were large discrepancies that could not be explained for many species (e.g. barracouta, snoek (*Thyristes atun*), hoki (*Macruronus novaezelandiae*), snapper (*Pagrus auratus*), orange roughy (*Hoplostethus atlanticus*), southern blue whiting (*Micromesistius australis*), and silver warehou (*Seriolella punctata*). FAO data, for example, shows 143,394 tonnes of hoki was landed in 1992, while national statistics show landings of 215,000 tonnes. Thus, based on this we do not accept the FAO data as representative of the officially recorded data.

3.2 Invisible landings

New Zealand has always had an invisible catch, most of which was landed on shore. By ‘invisible catch’ we mean catch which is either not reported or is systematically under-reported; or (in the context of this paper) catch which is documented but not reported as part of the FAO statistics. Invisible catch is

¹¹See for example the ‘Background Paper on the Use of Foreign Charter Vessels’ (Ministry for Primary Industries 2011a).

comprised of three broad categories: unreported commercial landings, under-reported and misidentified commercial catch, and black market catch. Under-reported and misidentified commercial catch include: misidentified commercial catch, under-reported fish weights, conversion factor fraud, commercial amateur catch, and commercial catch consumed on-board. On average 50% of all commercial catch was invisible and thus not reported prior to 1986. This declined to around 10% by 1992 and remained static through to 2012. The total invisible catch for the years 1950 to 2010 is estimated at 5.7 million t and for 1950 to 2012 at 5.8 million t.

3.2.1 Unreported commercial landings

Prior to the introduction of the QMS, unreported landings by commercial fishermen were common. Often a part of or the entire catch was traded without an audit trail in order to avoid income tax. The magnitude of this trade became evident when the QMS was introduced in the 1980s. Individual catch histories were used as the basis for issuing quota. Many fishermen appealed their allocation on the basis that unreported cash sales (known as 'cashies') had been an important part of their business. Those able to produce supporting evidence were allocated additional quota. Those unable to produce evidence often received unbalanced and uneconomic quota allocations. The following complaint made in 1987 to the Ministry of Agriculture and Fisheries was typical:

Traditionally line fishermen here sold their bycatch on the wharf to fish shops and the public and this has invariably not been recorded. So most of us haven't got any quota for blue cod and grey shark which is caught each day with groper...we can't afford to buy quota at the price the big companies pay for it. I just wonder how you expect us to survive on lining for groper for five months of the year when we have been reduced to 62% of our income. I can catch my quota in five days: what the hell do I do after that – go on the dole? (Anonymous respondent to 1987 questionnaire on how inshore fishermen were faring in the first year of the QMS).

The catch histories used for quota allocation were based on only two years. Thus, there was no incentive to confess to the true extent of this trade, which had been going on for decades. This included the period between 1968 and 1980 when commercial fishing rapidly industrialized and experienced a sharp increase in fishing efficiency, due to abundant fish stocks. During this period, vessels routinely came into port with full holds and sometimes with excess fish on the deck. Sales were often concluded with a cash buyer at a low price, or the fish sold for rendering to fish meal.

In late 1986, we came into port with a deck-load of Trelvalley and Kahawai, and the company told us it needs to be gone before we start unloading tomorrow morning. We had 10 tonne to get rid of, so went to the pub and when the locals came down we loaded up the boots of their cars until the springs were groaning. It was flogged off for cash or given away until it was all gone (Interviewee, 57).

How large was this unreported trade? Following interviews with a number of fishermen from this era we believe the non-reporting of landings and tax avoidance was significant and common across almost all of the commercial fleet. Some owner-operators would routinely sell some species or part of their catch clandestinely to private buyers, whilst others would operate almost entirely for cash. Foreign flagged vessels clandestinely transhipped fish to carrier vessels at sea. New Zealand company vessels generally had fewer opportunities to engage in misreporting. However, a number of interviewees recalled transferring catch at sea to other vessels, or midnight unloads at a rural wharf to a fish dealer with the crew sharing the proceeds. Sometimes catch would be bartered for goods and services as one interviewee explained: 'We used to swap strings of fish for sex at [name withheld] wharf which led some very irate parents to set fire to the wharf in order to keep us away' (Interviewee, 253).

The introduction of the QMS in 1986 was followed by a number of regulatory changes, including the licensing of fish receivers; the introduction of recordkeeping requirements for fish receivers, fish dealers

and the fishermen themselves; and development of a mandatory purchase tax invoice system which linked the fishing records and returns to the newly introduced Goods and Services Tax (GST) regime. The Ministry of Agriculture and Fisheries also established a team of forensic accountants. Failing to report landings became progressively less attractive as reporting systems were improved and enforced.

3.2.2 Under-reported and misidentified commercial catch

The introduction of the QMS in 1986 brought a different set of incentives. Prior to the QMS the incentive had been to minimize income tax liability by understating the amount of income earned from landings. The QMS provided an incentive to understate the amount of fish landed in order to minimize the amount of quota used to cover the catch, and since 2001 to avoid deemed value penalties. Dumping and highgrading as a means of under-reporting catch is discussed and quantified in a later section. But under the QMS it became profitable to under-report landings and to misidentify the species landed.

3.2.2.1 Misidentified commercial catch

Species misidentification is known to occur in commercial fisheries in other parts of the world (for a recent example see Hentati-Sundberg *et al.* 2014), and is frequently perpetrated as a fraud on the consumer, wherein low value fish is sold as a higher value species. But under any form of a QMS the incentive is reversed: the incentive is to pass off high value quota fish as a species of low value, or preferably as a species not subject to quota whatsoever. According to the Commission of the European Communities (2007) this may be a worldwide phenomenon:

Unfortunately, the restricted number of species managed by TACs has encouraged the misreporting of the species in the catches to avoid counting them against the quotas.

New Zealand is clearly not immune to the deliberate false reporting of one species of fish, as another. In a press release regarding a conviction in 2010 for species misreporting, the Acting Deputy Chief Executive Field Operations of the Ministry noted; 'it is very disappointing that we're having to keep prosecuting this type of offending' (Ministry for Primary Industries 2010). The Ministry for Primary Industries does not collect data that would enable estimation of the quantity of fish misreported in this way. However, Bremner *et al.*, (2009) studied just one fishery, and found the quantities to be substantial. For example, vessels without government observers reported 5.4 times more scabbard fish per tow than observed vessels, but rather less frostfish (FAO common name: silver scabbardfish; *Lepidopus caudatus*). The species are superficially similar, but the latter is managed under the QMS and the former is not. Misreporting of species in this way does not affect the total national catch statistic, but does make interpretation of the species specific FAO data problematic.

3.2.2.2 Under-reported fish weights

Licensed fish receivers are responsible for the accurate determination of landed weights. In practice many landings are not actually weighed. The fish is landed in bins, sacks or frozen in cartons, and licensed fish receivers often, only count the number of containers and multiply the result by a nominal weight, which is almost always lower than the actual weight of the fish itself. Even if the containers are weighed excessive deductions may be made for ice, etc. The incentive to under-report weights is especially strong in situations where the licensed fish receiver, the fish processor and the fishing vessel operator are related parties. Most factory freezer vessels are in this situation, but government observers routinely collect product weight data when aboard these vessels. However, these data are not normally analyzed. Investigation of carton weight reporting on several vessels between 1998 and 2006 demonstrated that the wet weight of the landed catch had been systematically under-reported by more than 5% (Interviewee, 252). One investigation determined that 'the staff in the trawler's factory were indisputably packing packages of fish so that they contained more than the nominal net weight, and at least with respect to ling [*Genypterus blacodes*] and hake fillets, they are following company instructions

to do so' (Anonymous, pers. comm., 2011).¹² Moreover, comparison of the real processing records against declared landed carton weights aboard two foreign charter vessels, for the years 2010-2012 revealed that carton weights were under-reported by an average of 5 to 11%.

Therefore, we use 5% as an average, but conservative estimate of the under-reporting of fish weights across the industry, but recognize that the degree of under-reporting will vary between operators and from species to species and may have changed through time with increased observer coverage.

3.2.2.3 Conversion factor fraud

As quotas are based on the greenweight of fish, catch data must be reported in greenweight, which is the weight of the whole fish. However, fish are often partially or wholly processed at sea. Official species specific conversion factors are used to convert the landed weight of processed fish back to greenweight. A hierarchy of processed states is defined in legislation, with different conversion factors applicable to each. Misreporting of processed states allows use of a more favourable conversion factor and results in under-reporting of greenweight. The definition of the 'dressed' processed state, for example, requires that the head cut be made immediately behind the insertion of the pectoral fin, and the tail cut be made behind the anal fin. If an anguilliform fish is cut to fit into a standard carton, application of the dressed conversion factor will inevitably fail to recreate the original weight of the fish. Part of the 'dressed' body will be missing. The same issue arises if the head cut is made further toward the tail. In this instance the heads or 'collars' with the missing flesh attached may be a valuable byproduct in their own right, yet in the main they are either dumped at sea or converted to fishmeal. The degree of under-reporting from using incorrect conversion factors was highlighted during a 1990 Ministry of Agriculture and Fisheries investigation. The conversion factors for processed orange roughy and hoki were lower than what the industry actually achieved, which resulted in these catches being under-reported. Following this 'the hoki factor was increased almost 35% and the orange roughy by 4%. In terms of 1988/89 catch under-reported this represents 63,729 tonnes of hoki and 2,118 tonnes of orange roughy' (Cameron and Hughes 1990).

The Ministry for Primary Industries does not routinely collect data which would enable the estimation of under-reported greenweight from abuse of the conversion factor regime. However, a systematic attempt to evaluate the quantity of fish under-reported in this way by factory trawlers was conducted in 2004 and uncovered widespread misreporting of processed states. A most egregious example was the under-reporting of catch by over 40% (Interviewee 191). The proportion of fish which are processed at sea varies both by species and through time, and the statutory conversion factor regime is gradually evolving to take account of changes in industry practice. It is unlikely that the degree of conversion factor fraud is static. We have insufficient data to make estimates for every year, but based on analysis of a number of documents, interview data and photographs, we conservatively estimate conversion factor misreporting at a minimum average of 3% across the industry for all years.

3.2.2.4 Commercial amateur catch

Commercial fishermen have always taken part of their catch home, which traditionally was not reported. In 1986 when the QMS was introduced, the Ministry attempted to ban this practice - all fish had to be landed to a licenced fish receiver (LFR), and if fishermen wanted to take some fish home they had to come to an arrangement with the LFR to get it back. However, this policy lasted only a few months. 'There was 100% non-compliance and the legislation did not change, so we started turning a blind eye to the practice' (Interviewee, 251). Many interviewees confirmed that commercial fishermen had always taken home unreported fish for them and their pets to eat.

¹² The source of this information wishes to remain anonymous.

Years ago I met a trawlerman who fed his cat almost exclusively on witches [Arnoglossus scapha], he said they had a really good flavour and the cat didn't mind all the bones, so the cat ate his entire annual bycatch. I've also been treated to sumptuous seafood dinners at the houses of fishermen I have visited in out of the way places, and I know they didn't drive 100 km to a fish shop to get the ingredients (Interviewee, 189).

In 1996, legislation was strengthened to control this type of activity, so that fish landed in this way was reported. In some circumstances commercial fishermen, were entitled to take home an amateur daily bag limit of seafood for their own use. Section 111 of the Fisheries Act 1996, provides that all commercial vessel catches are deemed to be for the purpose of sale, unless the Director General of the Ministry for Primary Industries provides an exemption for amateur 'feeds', provided that they are reported and meet the requirements of the amateur fishing regulations. However, catches reported as amateur feeds are not deducted from the quota allocation and hence are not recorded by a licenced fish receiver. Moreover, it is unlikely that such catches have been picked up by recreational fishing surveys, as commercial vessels would not feature in recreational boat ramp and aerial studies. The total amount of commercial amateur catch for 2013 was estimated at between 100 and 200 tonnes. The quantity is roughly proportional to the number of commercial fishermen. However, it would have been a great deal higher in the 1970s and 1980s when there were many more part-time commercial fishermen and higher again during the 1950s and 1960s before the era of the supermarket, when subsistence fishing was an important part of New Zealand life. Although commercial amateur catches are reported to the Ministry for Primary Industries via a vessel's TCER, they are not included in the FAO data, and thus form another, although small, component of invisible catch. We have included the reported commercial amateur catch in our own calculations of the total invisible catch. Although insignificant overall, at well under 0.1% of the total reconstructed commercial catch, commercial amateur catches can be significant for some species (e.g. blue cod (*Parapercis colias*), dredge oysters (*Ostrea chilensis*), rock lobster, snapper) and thus cannot be ignored.

3.2.2.5 Commercial catch consumed on-board

Commercial fishermen often consume a small part of their catch at sea. This is required to be reported and deducted from the annual catch entitlement. This requirement was first introduced in 2001, hence there are no figures available for earlier years; however, this requirement was often not observed (Interviewee, 251). The official figure for 2013 amounts to only 297 tonnes for all species. However, foreign charter vessel (FCV) crews are routinely fed fish every day as an inexpensive source of food. Crew from across the FCV fleet confirmed that catch consumed on-board was seldom properly recorded: '*we ate fish from the factory every day, but we only weigh it and record it when the observer was on board, but when they weren't we didn't weigh it and only record some*' (Interviewee, 254). While fish consumed on-board vessels is not included in the FAO data, we estimate it to be less than 0.3% of the total reconstructed commercial catch and thus the overall effect is negligible.

3.2.3 Black market catch

For the purposes of this paper we refer to black market catch as catch which is not reported and subsequently sold through 'black market' channels. We believe there is no black market catch in the bulk commercial fisheries that dominate the FAO catch statistics. The black market in New Zealand currently exists for high value species such as paua (*Haliotis iris*), rock lobster, and snapper, and once existed for toheroa (*Paphies ventricosa*) and mussels (Chisolm 2005). 'The most serious 'black market' offending, involving large numbers of paua, had remained fairly stable over the years, with about 80 prosecutions a year' (Sharpe 2014). Rock lobster - another high value species - is also poached illegally and sold on the black market. In one operation during 2014, authorities shut down a major illegal rock lobster ring involving 43 people. An undercover officer had bought 1,200 lobsters from the ring during a 12-month operation. 'Recreational fishers had been fishing in a pseudo-commercial way and selling their catch to

supply a large black market including locals, tourists, hotels and restaurants and businesses further afield' (Ministry for Primary Industries 2014).

In 2011 fisheries officers seized a commercial trawler and two refrigerated trucks after uncovering a large-scale black market operation that caught and sold snapper in Tauranga, Hamilton and Auckland. The operation had identified offenders at each stage of the black market chain: commercial fishers, transporters, and traders. 'More than 12 tonnes of the trawler's catch had not been reported as required...much of this illegal activity happened at night or in the early hours of the morning. Those buying the black market fish appear to be a combination of takeaway outlets and businesses that are not Licensed Fish Receivers' (Ministry for Primary Industries 2011b). Black market catch is not high as it is estimated at 0.1% of the total reconstructed commercial catch, but it is significant for some species, such as paua, rock lobster, and snapper and thus cannot be ignored.

3.3 Dumped or highgraded commercial catch

Fish-dumping is the illegal practice of disposing of less valuable or valueless fish, including small and damaged fish or bycatch at sea and not reporting it. Often more valuable fish is caught to replace the dumped fish. This practice is also referred to as 'highgrading', where only the highest grade fish are retained. For the purposes of this section we use the term 'dumped' except where highgrading is used in a quote. Historically in New Zealand, fish species viewed as having little or no economic value have been routinely dumped at sea, which has resulted in the total commercial catch being under-reported. This has been highlighted in a range of reports, some with estimates (See for example, Vere-Jones 1958; Dewees 1989; Macgillivray 1990; Anderson and Smith 2005; Bremner *et al.* 2009; Kazmierow *et al.* 2010). The widespread practice of fish-dumping was first highlighted in the large number of submissions to Parliament's (1937-1938) Sea Fisheries Investigation. The committee found that small fish and particularly excess catches of gurnard (*Chelidonichthys kumu*), red cod (*Pseudophycis bachus*), and skate among others were regularly dumped at sea and not reported. They noted:

The small fish left on deck, which have been out of the water for some considerable time and have been roughly handled, are [also] then shovelled over the side. We cannot see how any great proportion of such fish are likely to survive this treatment (New Zealand House of Representatives 1937-1938).

The investigation found that fish-dumping was a systematic and widespread problem, with fish often dumped because they were unsalable or 'the market could not absorb them'. A second Parliamentary investigation in 1956 also highlighted the dumping of large quantities of unpopular species at sea (New Zealand House of Representatives 1956). A key recommendation of this Committee was 'that consideration be given to finding a use for the species of fish which are at present unpopular and much of which is dumped' (New Zealand House of Representatives 1956). A third major Parliamentary investigation in 1962 found 'there is still considerable dumping of good edible fish for which it was claimed there was limited sale' (New Zealand House of Representatives 1962). The Committee heard evidence about the large quantities of undersize and uneconomic fish, which although landed dead, by law were dumped back into the sea. One industry veteran gave evidence that dumping practices had changed little from the 1930s: 'The position hasn't changed so much in some parts of N.Z. today [1962] where there is more fish dumped at sea than is brought into ports' (Enwright 1962). This statement is significant, as Enwright had in-depth knowledge of the fishing industry - he was first involved in the industry in 1910 and from 1930 ran a major fishing company for 12 years. He personally owned the two largest fishing vessels in Auckland, as well as two smaller ones.

Prior to the third Parliamentary investigation the Secretary for Industries and Commerce, W B Sutch, undertook his own investigation into the fishing industry. He found that the commercial sector, resistant to change had always sought to maintain the status quo. The reported catch in 1960 involved 44 species, but only half were of importance to the industry. Nine species (snapper, tarakihi (*Nemadactylus macropterus*), tarakihi, gurnard, trevally (*Pseudocaranx dentex*), blue cod, groper, elephant fish

(*Callorhinchus milii*), sole and flounder (*Rhombosolea spp*) accounted for 90% of the reported catch, yet Sutch determined that fishermen fished in mixed fisheries with high levels of bycatch. Sutch commented that:

One of the most abundant of New Zealand demersal fish [in 1961-1962] is red cod. This fish is widespread throughout New Zealand waters but at present has little commercial value and is dumped at sea' (Sutch 1962).

Despite some species (squid and octopus) being regarded as rare delicacies overseas, in New Zealand they were used for bait or dumped. In Britain and Spain dogfish and skate were in demand and widely eaten, but in New Zealand they were regularly dumped and not reported. Sutch's findings were also informed by a 1958 scientific research report, which highlighted the widespread practice of dumping unpopular varieties of fish into the sea. Vere-Jones's (1958) empirical investigation determined that 'over the whole country perhaps 20% or more of the total trawler catch of edible fish is thrown back into the sea to foul the fishing ground'. During the 1980s and 1990s the Waitangi Tribunal heard extensive evidence on the dumping of fish. During the Muriwhenua Fishing Claim, one witness recounted the 'extensive fish dumping by those who profit from the sea' (Waitangi Tribunal 1988). The Tribunal noted in its findings that:

Many were the complaints against the larger operators and the trawlers in particular. Several reported on trawlers operating close inshore, on massive dumping at sea (with claims that beaches have been littered with dead fish (1988).

For Ngai Tahu's Sea Fisheries Claim, the Tribunal heard that in the early years of the QMS, fish were lost at sea through nets bursting and from deliberate dumping (Waitangi Tribunal 1992). More particularly 'fishermen have discarded species that they have no authority to catch, or catches in excess of their quota, or lower grade fish that do not give the highest return' (Waitangi Tribunal 1992). One witness described these contemporary commercial fishing practices:

Nets and trawls take everything [sic] and you have a crazy situation in that fishermen are dumping as much as they are selling... I have personal experience of a fisherman dumping 20 tonnes strictly on the grounds of economics... (Waitangi Tribunal 1992).

Several interviewees confirmed this, particularly in respect to their own experiences in the orange roughy and hoki fisheries during the 1980s (e.g. Interviewees; 6, 57, 181, 182, 188, 196, 221, and 253). The magnitude of the loss of catches and dumping by trawlers in the deep-sea fisheries is illustrated by one veteran:

In the 1970s we kept the good species and threw hoki away, couldn't sell it so wouldn't land it. During the 1970s and 1980s couldn't see the water for all the fish lost - driven by inexperience and gear failure. We took what we wanted and threw the rest away. 1979-83 big bags habitually dumped, only kept 30% of over 100 tonnes bags. We were also bursting bags and losing everything. We were trucking from the Challenger and Chathams Rise, but the biggest thing was, at least as much fish was lost, as was landed. It was insane. That always went on until the late 1990s and even into the 2000s. Much less now, maybe 10% (Interviewee 181, 2013).

This was confirmed by another interviewee who worked on a different vessel at that time.

It was horrific that we only kept 20% and chucked 80% away. Most juvenile bycatch was hoki but also ling and others. The big breeders - groper, bass, ling etc - were also dumped because we needed to make room for higher value catch (Interviewee, 265).

The level of dumping, particularly in the West Coast hoki fishery, was very concerning to many in the industry. By late 1986 it had become such a problem that fishermen, including the National Executive of the NZ Share Fishermens' Association, were openly discussing it to 'rectify the situation'. So concerned

was the Association that they complained to the Ministry of Agriculture and Fisheries (MAF), and the Fishing Industry Board (FIB). They also went public through press releases:

*Only 30% of the fish caught was being processed and that 70% was being dumped, that the position was serious and that the attention of the appropriate authorities should be drawn to this to prevent the fishery being wiped out in a very short time.*¹³

The following month the Ministry raised the TAC for hoki to 250,000 tonnes, which the Association considered 'was completely unrealistic'.¹⁴ The Association did not favour an increase in quota and re-affirmed their opposition to dumping and were concerned that hake and ling fisheries would also be sacrificed. The Association decided to take up the issue 'strongly with the Minister at the earliest possible opportunity'.¹⁵ At the meeting the Minister agreed to investigate the situation. The MAF immediately launched an investigation and held a meeting in Nelson on 14 October 1986, the objective being to find solutions to 'disposal of waste, discarding of whole fish, and bycatches'¹⁶ in the Challenger area hoki fishery. Several interviewees who had attended this meeting said while the size of the problem was discussed, no lasting solutions were agreed upon. Two interviewees had kept records across the entire fleet of the total catch from hoki fisheries during the 1980s. Analysis of these records for 1986 show that 96,000 tonnes of hoki was landed and reported. This compares to 99,623 tonnes from the reconstructed data using official reports. A further 9,600 tonnes was landed, but not reported – standard '10% under-reported' rate at that time. Additionally, 2,460 tonnes was lost on the surface from overfull nets, 105,000 tonnes was lost from 'nets bursting below the surface', and 70,000 tonnes was dumped. In total this amounts to a total catch of 283,060 tonnes of hoki for the 1986 fishing year, of which only 99,623 tonnes was reported.

Little was done to address the problem until 2007, when the Ministry of Fisheries launched a major investigation to determine the amount of quota and non-quota fish being illegally dumped at sea by commercial fishing vessels (Phillips 2007). Official data from 2004-2006 suggested that the problem was widespread, especially in the West Coast hoki fishery. Often it involved highgrading, where only the more valuable fish was kept and the rest dumped. Twenty six foreign charter vessels (FCVs) and 10 New Zealand owned vessels were singled out for attention. Observers were placed on New Zealand vessels, but not on all FCVs due to health and safety reasons.

FCVs have long been associated with illegal fish dumping. It was alleged that they were responsible for high levels of dumping in the hoki fisheries during the mid-1980s. Since then a number of FCV operators have been prosecuted with vessels forfeit (e.g. Ministry for Primary Industries 2001, 2002; The Press 2008; Ministry for Primary Industries 2012a; Clarkson 2014). More recently, in sentencing the captain of the FCV Oyang 77 for dumping quota fish (squid, hoki and barracouta) at sea and misreporting the catch, Judge Callaghan said 'the offending was clandestine and difficult to discover and prosecute' (Clarkson 2014). The fish was dumped because it was uneconomic to process because of its small size, or was damaged. The prosecutor echoed that there was an inherent difficulty in prosecuting this type of case and presenting accurate evidence at the hearing. This may explain why dumping and under-reporting has gone on for so long, because it relies on the honesty of the fishermen themselves and is hard to detect. Also, previous research into forced labour practices on-board FCVs, found that crew were forced to engage in dumping, and if they did not they would be subject to severe punishment, including beatings, denial of rest periods and sleep, confinement to a freezer without protective clothing or being forced to stand on the open deck without food or water for up to 6 hours (See for example, Stringer *et al.* 2013; Simmons and Stringer 2014; Stringer *et al.* 2015).

¹³ Minutes of National Executive Meeting of the NZ Share Fishermen's Association (Inc.), held at Gateway Lodge, Kirkbridge Road, Mangere, on Wednesday 13th August 1986, at 9.30am.

¹⁴ Minutes of National Executive Meeting of the NZ Share Fishermen's Association (Inc.), held at the Nelson Fishermens Co-op, 124 Vickerman St, Nelson, on 25th September 1986, at 1pm.

¹⁵ Minutes of National Executive Meeting of the NZ Share Fishermen's Association (Inc.), held at the Nelson Fishermens Co-op, 124 Vickerman St, Nelson, on 25th September 1986, at 1pm.

¹⁶ Ministry of Agriculture and Fisheries, Bulk Fishing Meeting, Nelson, 14 October 1986, Agenda.

As FCVs have traditionally caught the majority of New Zealand's deep sea species, we interviewed nearly 200 FCV crew to understand the issue. These interviewees had worked on 19 different vessels fishing in New Zealand waters over a period from 1998 to 2013. All crew confirmed it was standard practice on all the vessels they worked on to dump fish. All had participated in dumping under the orders and direction of their officers, dumping on a daily basis when fishing. In particular, the fish they did not have quota for was dumped. The following quotes are representative of their comments and come from different crew from different FCVs:

During hoki season bags always full, 4-5,000 pans. Hake and ling always dumped, one bag of 4,000 pans [52 tonnes] dumped as too much fish, in 2011. When no observer, captain always tell us to keep 20 sample bycatch baskets and dump the rest (Interviewee, 12).

If the fish are too big or too small we will throw them back, depending on the area. If in the small fish area we dump about 70% and if in the other area we throw back about 10–15% of the catch (Interviewee, 17).

For non-target fish we would dump all and if not processed within 24 hours we would dump that too. Highgrading is common, especially when fishing squid, at least 20% dumped this way (Interviewee, 58).

One tactic when observer on board is to give them alcohol to distract them from their job, so they don't see us dumping fish. If observer doesn't drink, then we wait until he is asleep and then throw away the old fish. When two observers on board it's no problem to dump as they both sleep at the same time (Interviewee, 117).

When no observer on board we throw anything away as the sea belongs to the Koreans. If second catch comes in and still processing the first catch, then we keep the fresh fish and throw the old fish away - normally between a quarter and one third of the catch, but sometimes it can be half the catch. We dump fish that are too small, too big, crushed and damaged fish. Often fish get crushed in the net so have to throw them away and when we push them through the pound they get damaged. Just keep the best hoki. Dump all big ling, ghost shark, spiny dogfish, but keep some bycatch and small fish to show observers (Interviewee, 131).

We dump every trip, 30 tonne average because we are over quota and only record if observer is on board. The old captain would dump more, up to 50 tonnes each trip (Interviewee, 132).

When observer asleep we put a lookout on observers door to watch if he comes out. Then told by the officers to dump fish. If observer comes out we yell "he's up" and stop dumping. If no observer we will dump anytime, day and night. We dump because too much bycatch, so have to. We keep some bycatch for show, keep some small ling and throw the rest, especially big ling, gem fish [Rexea solandri], blue warehou [Seriolella brama], red cod, jack mackerel [Trachurus spp.], school shark, and barracouta. Hoki we dump those are too big, too small, and crushed. When the catch is too big we must dump whatever we cannot process in 12 hours because the fish is too old (Interviewees, 147, 148, 149, and 150).

During hoki season we had much damaged hoki. We told observer we would take to kitchen to cook for us, but instead we dump it from the kitchen. We always did this. When no observer, captain will tell us to keep 20 basket samples of bycatch and dump the rest. During hoki season the bags are always full, but cannot process before fish go off, so always have to throw away and replace with new fish (Interviewees, 208, 209, 210, and 211).

Former observers, who had crewed on most of the FCVs, also confirmed the level of dumping across the FCV fleet.

I witnessed major illegal dumping and told the observer manager. He said, if under 15 tonnes not much we can do about it. It just went into a black hole...you don't stick your head up above the parapet, definitely not. We're told what happens at sea stays at sea. We're told if we ever say anything we will never work in this country again (Interviewee, 1).

Everything goes over the side from Korean FCVs as no fishmeal plants. Nothing good about Korean boats, and many turn a blind eye to it. No-one wants to rock the boat (Interviewee, 9).

Huge potential, but chronically mismanaged particularly in terms of dumping of quota species and misreporting of quota species to fishmeal. Koreans are illegally dumping and the Ukrainians misreporting what goes to fishmeal. Observers have detected huge discrepancies of misreporting of quota species to meal and unauthorised and authorised discards. Huge discards of hoki on one trip and Korean captain refused to sign forms. If this is happening on the few times we are on board, what is happening when we are not (Interviewee, 11).

Misreporting goes in our diaries and reports. We are often interviewed by compliance officers which resulted in prosecutions, but they have barely scratched the surface of what really goes on across the industry (Interviewee, 59).

I was on many Korean and Ukrainians FCVs during the 2000s. The dumping was out of control and despite warning the officers they did not alter their practice. The fish should have been kept aside as damaged or small, and packed down as block for turning into fishmeal on shore. Obviously it comes off quota, which is why they dumped it and did not bring it in (Interviewee, 61).

On the Chatham Rise fishing for orange roughy, after 10 minutes of towing we had caught about 70 tonnes, but not good to catch this much as by the time they got to the end of the bag, the fish had decomposed. Captain offered me money to look the other way. He said how much do you want, name your price? Wanted me to agree to changing the catch records (Interviewee, 202).

Highgrading on FCVs driven by the need to maximise production, 24/7 every day. These practices have never changed until recently, from increased observer coverage (Interviewee, 203).

FCVs are not the only vessels involved in dumping, however. In 2001, the catch balancing system was replaced with the simplified 'deemed value' system, which is designed to discourage overfishing and encourage the landing of all caught fish (Walker and Townsend 2008). Fishers must pay a deemed value fee when they are unable to cover a catch with quota. Yet, New Zealand fishermen highlighted that one of the biggest constraints on their business has been and continues to be the availability of quota for certain species. Subsequently, they no longer target certain species, but if caught as bycatch, they are forced to dump the fish because they cannot afford the deemed value penalties. Dumping tuna (*Thunnus spp*) was also a common practice with some dumping tuna on every voyage. For example, on one day in 2013 an interviewee dumped 18 mature blue fin within the EEZ, while another dumped 4. One interviewee was furious about the high levels of unnecessary dumping that he has been forced to engage in since 2001, because despite best efforts he could not have avoided it:

Have to dump as no quota. Can be half a tonne a day, that's crazy! If we landed it, it would be a disaster. We are dumping a lot, cause so much snapper out there. Catching a lot of small stuff. It all goes over the side. Big snapper put into a fish case and dumped at night so no one sees. The annoying part is the time it takes to knife the swim bladder so they don't float (Interviewee, 164).

Others commented:

Dumping is very bad, it's done under the radar, especially on trawlers. Ninety % of the time we dumped (Interviewee, 193).

It's a bloody embarrassment...take active measures to avoid it, but can't avoid catching it...can be 100% of the catch, can't get quota so got to dump it. If we land it we're bankrupt. The Japanese take everything and we have to dump it. It's not our fault, why is it so hard for people to understand. The whole thing is nonsense! (Interviewee, 194).

It's hard to balance your portfolio of ACE, because we're fishing in mixed fisheries. For snapper, we can get a bill from the government for three times what we can sell it for. Is that an incentive to bring the fish in or an incentive to dump it? We dump it (Interviewee, 195).

We landed a big bag of snapper and didn't know what to do with it as no quota. So got a relative to take it to sell it through the black market. Better than dumping it (Interviewee, 218).

The way the QMS operates we are criminals, even though we are just trying to make an honest living. There's a lot of dumping going on but what do they expect (Interviewee, 221).

The fishing industry is constantly dumping some of its catch. I worked on a bottom trawler, fishing for squid south of NZ. We regularly dumped fish that weren't squid out of the side of the boat. There was a belt that carried them out of the side along with any coral and sediment we dredged up. We would pack barracouta, monk fish [Kathetostoma giganteum], and a few other fish occasionally to pretend that we were packing everything that we caught, but since these were less lucrative fish, they mostly went back in the sea dead. Once we caught an 8-10 foot shark (maybe a Mako) that accidentally ended up in the hold and was killed and dragged out (Interviewee, 241).

In sum, for the years 1950 to 2010 the unreported dumped catch, is estimated at 17.2 million t and for 1950-2012 17.7 million t. Due to high levels of unreported dumping during the 1980s and 1990s the estimated result was much higher, but we have taken a conservative approach to the estimates. Hence, we are confident that the unreported dumped catch estimate is conservative for all years estimated.

3.4 Recreational and customary catch

Historically most recreational catch has been taken off the northeast coast of the North Island (East Northland, the Hauraki Gulf, and the Bay of Plenty) (Hartill *et al.* 2012; Wynne-Jones *et al.* 2014), which falls within Quota Management Area 1 (QMA1). Since 1950 recreational catch has amounted to only a small percentage of the total reported New Zealand catch, but has amounted to a significant proportion of the total catch of particular inshore species, such as rock lobster, blue cod, kahawai, paua, and snapper.

Customary catch is seafood caught by Māori in places of customary food gathering importance, which is neither commercial, recreational or for pecuniary gain or trade (Ministry of Fisheries 1997). This catch does not equate to sustenance fishing. It has a narrower use and is conducted in two ways: either through a permit under the Fisheries (Amateur Fishing) Regulations 1986, or through an authorisation under the Customary Fishing Regulation. Both must be authorised in advance by tribal elders known as Tangata Tiakia / kaitiaki (Ministry of Fisheries 2008). Authorisation is typically for a number of each species to be harvested for a ceremonial or traditional ceremony or function. Permits are copied to the Ministry for Primary Industries, who collect and use the data to allow for customary catch within the TAC. However, historically customary authorities have not maintained effective records on customary catches. While customary regulations were strengthened following the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992, reporting processes have not been effective with only partial compliance. Thus, there is very little information on the size of customary catches (Ministry for Primary Industries 2013f), although 'an allowance is made for customary fishing within the TAC for each stock, which in total equates to less than 5,000 tonnes' (Ministry of Fisheries 2008).

In terms of the extent of the error between estimated customary catch and actual customary catch this category is not significant. Thus, the total recreational and customary catch together for the years 1950 to 2013 was estimated at 572,922 tonnes. Of this 17,578 tonnes was customary catch and 555,344 was recreational catch.

4. Discussion and Conclusion

The findings show that the FAO data understates both catches and landings for all years from 1950 to 2010, largely due to missing data. There are also large unexplained discrepancies between the FAO data and our reconstructed official data, which are driven by the addition of estimated 'invisible' (unreported commercial landings), recreational and customary catches, as well as dumped catch. For the years 1950 to 2010, the reconstructed total marine catch of New Zealand (by New Zealand and foreign flagged vessels) is estimated to be 40.4 million t, with the extended reconstructed time series for 1950-2012 estimated at 43.3 million t. This suggests that actual catch was about 2.9 times the 14 million t reported to the FAO on behalf of New Zealand for the same time period. Since 1986 - when the quota management system was introduced to ensure resource sustainability and improve reporting - the total catch is conservatively estimated at 2.2 times greater than the FAO data. The difference between reported and reconstructed catch statistics is due to inadequacies in reporting, primarily the deliberate, widespread and systematic under-reporting of commercial catch. Before 1981, there 'has been the almost total lack of reliable fisheries statistics' (Department of Statistics 1981). This is not surprising, given what this research found. Indeed, since 1981, under-reporting has continued (Boyd and Dewees 1992), although it has diminished during the past few years - somewhat. Ultimately, 'the risk factor, created by this information lack, provides little confidence that fish are being harvested at a sustainable rate' (Cameron and Hughes 1990).

Furthermore, the findings bring into question the credibility of current fisheries data to set TACs. Reliable catch data is a basic and essential requirement for the effective management of New Zealand's fisheries. It is fundamental to the assessment of fisheries stocks and for setting of TACs. For most purposes the catch data required is a reliable time series. Yet, essential data is either lacking or missing from official New Zealand catch data and in turn from the FAO data. Without reliable data, scientists, practitioners, and policy advisors cannot properly interpret fisheries trends, the effects of technology, or accurately evaluate the social and economic impact of actual or projected fisheries management measures. This inevitably leads to flawed decisions to control fishing at sustainable levels, which ultimately can be costly not just to commercial operators themselves through over (or under) capitalisation - resulting in undesirable economic outcomes - but also to the nation. Most concerning is successive fisheries ministers appear to have been making flawed decisions about fisheries. This will continue until New Zealand's catch data are corrected to improve their reliability. Hence, we echo a key recommendation from the National Research Advisory Council Commercial Fisheries Working Party report (1980), insofar as 'the collection and analysis of [reliable] fisheries statistics be given priority over all other scientific and administration areas'. This matters greatly, if New Zealand wishes to claim that it has a world leading quota management system.

Despite efforts to improve data collection spanning nearly eighty years, New Zealand's reporting system has underperformed. Official documents have long highlighted the inadequacies of catch data, including the significant levels of dumping and under-reporting of catches. Despite the introduction of the QMS, increased use of technology, and better reporting systems, nefarious reporting practices continue. A key theme that emerged from the interviews was the deliberate and systematic dumping of fish, which has long been normalised. Dumping was found to be significant, particularly during the 1980s and 1990s. While the perceived low economic value of a fish still drives dumping, new drivers came into play following the introduction of the QMS. If quota is unavailable to cover the catch and fishermen are faced with the prospect of a high deemed value fee, fish are dumped. Ultimately, as Metuzals *et al.* (2006) argue 'if misreporting is ignored, and catch data are worthless, what you have is an uncontrolled fishery.' While more compliance is an obvious answer, new approaches are also needed. The same thinking that

has created and fostered this situation will not result in better reporting. An effective system that accounts for all of the catch is central to maintaining sustainable fisheries ecosystems.

Addressing the issues of misreporting will not be easy. The most recent advances in information technology (e.g., the development of smartphone applications for collecting catch and effort data) have made it very straightforward for commercial fishermen to comply with catch reporting requirements in real time. However, the most serious obstacle over the entire period covered in this paper has been that misreporting catches has been profitable. Relying on criminal sanctions alone to deter misreporting of catches was never likely to succeed, and despite an enormous increase in the ratio of compliance staff to commercial fishermen over the decades misreporting is still rife.

The situation is exacerbated by official secrecy surrounding catch and effort reporting. Catch and effort returns have never been open to the scrutiny of competitors and other users of the marine environment. Every commercial landing and a high proportion of inshore catches have many witnesses, but whether or not the landing or catch has been reported at all, let alone reported accurately, is known only to the senior crew of the vessel. The secrecy around catch and effort reporting has always been justified on the grounds that fishermen would be reluctant to furnish accurate data if their competitors could monitor their catch rates and fishing locations. Fishing is a competitive business and knowledge of the best locations is of course an important part of every fisherman's intellectual property. Yet it would be possible to make all catch effort data publicly available with the catch locations rounded to (say) the nearest half degree of latitude and longitude. Making such data publicly available would enable the public to play a much greater role in protection of what is, after all, a public resource.

We also believe it would also be helpful if Fisheries Management staff spent more time talking to fishermen. Over the past two decades much emphasis has been placed on consulting with quota owners, and this has been coupled with a deliberate policy of centralization. There are now very few fisheries management staff located in significant fishing ports: in fact only three are located in the whole of the South Island, the island in which the bulk of the national catch is landed. Yet the decisions on what to report, what to land and what to discard are made by those crewing fishing vessels, whose captains are now almost entirely omitted from discussions. A key interview theme was how disengaged fishermen were from official discussions that directly affected them. This has resulted in a growing knowledge deficit within officialdom about the prevalence of catch misreporting.

In the final analysis, however, for so long as the fisheries management system provides powerful incentives to misreport catches, the only way to ensure accurate reporting will be 100% observer coverage, combined with public access to all data. Nonetheless, criminal sanctions are inevitably limited in what they can achieve (Packer 1968). It may be time for a fundamental rethink of the fisheries management system. Indeed, it is in the interests of society as a whole that all catches be reported and landed, and that incentives to take fish over quota be removed. The present system imposes financial penalties on over quota landings, and this incentivizes both misreporting and discarding at sea. It should be possible to refine the QMS to remove any financial penalty for reporting over-quota catches, whilst also minimizing the financial incentive to take fish in excess of quota in the first place.

If it is not possible to refine the QMS in this way, then proscription of any discarding of fish at sea, coupled with installation of on-board video monitoring systems across the fleet, would at least ensure that reporting is enforced, by dockside monitoring of landings if necessary - as by Iceland. This would result in the landing of a good deal of currently perceived unmarketable fish, though we note that if such fish were routinely landed this would probably drive innovation and market development in unforeseen directions. We also note that much of the fish currently regarded as unmarketable is not devoid of intrinsic value – it is unmarketable simply because the price that it would fetch is lower than the current cost of quota. But quota prices currently factor in the ease of highgrading and under-reporting catches.

It was recognized from the inception of the QMS that accurate reporting of catches was imperative for success. Given perfect information, the superior economic efficiency of a management system based on output rather than input controls is indisputable. Yet information is never perfect, and if the catch

information supplied by fishermen is sufficiently unreliable there must come a point where input controls or other mechanisms are superior. In the most extreme case fishermen supply no credible information at all. In this circumstance a fishery can still be managed, but output controls based on self-reporting will clearly be completely ineffective. The case for or against management by ITQ needs to be assessed on a fishery by fishery basis, and the probability that accurate catch data can be obtained has to be an important part of this assessment. It is also important to review the level of misreporting from time to time as this is unlikely to remain static. However, there have been few serious attempts to assess the degree of misreporting in New Zealand fisheries since the inception of the QMS in 1986, and to the best of these authors' knowledge no consideration has ever been given to removing a species from quota management in the event that the information supplied was simply too inaccurate.

This paper demonstrates that catch misreporting in New Zealand fisheries is of a noteworthy magnitude. It is a topic which has been ignored for too long in official circles and is deserving of much more study and attention. In order to sustainably manage fish stocks, fisheries managers need to account for all catch (Wynne-Jones *et al.* 2014). While some estimates of unreported catches and discards are included in stock assessment reports, the lack of comprehensive and transparent reporting has implications for the quota management system. Besides improving transparency and reliability in fisheries data reporting, the future sustainability of the fishing sector will also depend on how the government addresses poor fishing practices and particularly labour practices aboard foreign flagged vessels, which have long been a cause of concern and controversy in the fishing sector.

Acknowledgements

We are indebted to the participants who went out of their way to so generously share their knowledge, experiences and insights. We assured you all confidentiality, and thus are unable to name you, but your contributions go to the heart of this research. Special acknowledgement goes to the industry reviewers who so freely gave their time. We value your feedback and support greatly. The co-authors who are members of the *Sea Around Us* acknowledge support from The Pew Charitable Trusts and the Paul G. Allen Family Foundation.

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