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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, of fish that are discarded at sea, and of fish taken by recreational and customary fishers. This reconstruction accounts for unreported catch to provide a more comprehensive picture of total marine 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. We augment these baseline data 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. New Zealand's reconstructed catch totalled 38.1 million tonnes (t) over the 61 year period. This indicates the actual catch was about 2.7 times the 14 million t reported to the FAO on behalf of New Zealand for the same time period. New Zealand introduced a Quota Management System (QMS) in 1986, to ensure fisheries resource sustainability and improve reporting. The total catch since then is conservatively estimated to be 2.1 times greater than that reported to the FAO.

Unreported industrial catch and discards account for the vast majority of the discrepancy. Recreational and customary catch was 0.51 million t for the same period. From 1960 until 2010, 43% of all commercial catch was caught by foreign flagged vessels, which dominated the catching of hoki (*Macruronus novaezelandiae*), squid *(Nototodarus sloanii)*, jack mackerels (*Trachurus* spp.), barracouta (*Thyrsites atun*), and southern blue whiting (*Micromesistius australis*). These five species comprised 53% of reported landings from 1950-2010. These were also some of the most misreported and discarded species over the time period considered. Some estimates of unreported catches and discards are included in governmental stock assessment reports, but the lack of comprehensive and transparent reporting threatens the integrity of the QMS. Improving the transparency and reliability of fisheries data reporting is essential for fisheries management and sustainability. The future sustainability and certification of fisheries will depend on how the government addresses the under-reporting problems, which have long been a cause of concern.

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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.seaaroundus.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 (Palomares, Harper, Zeller, & Pauly, 2012), with the focus here being on the over 3 million km² of EEZ surrounding the main landmasses of New Zealand.

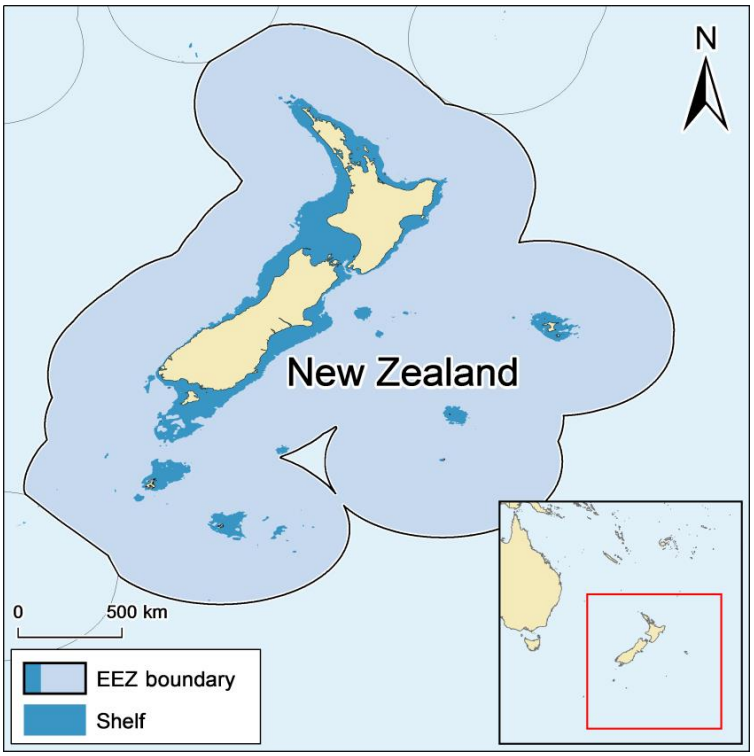

Figure 1: Map of New Zealand with its Exclusive Economic Zone (EEZ), excluding the Kermadec Islands, which are omitted from the picture.

1.1 Māori fishing

Māori, New Zealand's indigenous people, have fished since their arrival in New Zealand in ca. 1280. Fishing is foundational to their culture, as the sea had always been their 'garden' (Habib, 1987). From 1280 until ca. 1770 Māori primarily undertook fishing for subsistence (Smith, 2013). Due to their small population[1] they probably had little impact on marine stocks. By the time the first European explorers arrived, Māori fishing practices had become more regulated. Customs included respect for the ocean and the organisms living within it; embracing "not only the physical but also the spiritual, social and cultural dimensions" (Waitangi Tribunal, 1988, p. 7). Strict tribal rules and laws, developed over centuries, governed who could fish as well as where, how and when fish could be taken (Hohepa, 1976; Waitangi Tribunal, 1988). Tribal law defined fishing and ownership rights, with each inshore *hapū*[2] boundary often marked out by stakes (Nicholas, 1817; Heremaia, 2000). Habitats and breeding areas were protected to

[1] Pool (1991) determined that the founding Māori population was ca. 300-500 in 1280, growing to ca. 100,000 by 1769, with 90% of those living in the North Island.
[2] Subtribe group (Mutu, 2011).

conserve the life-force of ecosystems for future generations. Custom strictly prohibited disposal of fish offal, small fish, unused bait, food and rubbish at sea; and dragging nets, sacks and baskets over shellfish beds. To safeguard sustainability of fisheries "traditional customs and regulations were most strictly observed and rigidly enforced" (Mathews, 1910, p. 598). Breaches of a *rāhui*[3] 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 their *hapū* (Hohepa, 1976).

Pre-European Māori caught at least 182 different marine species (Smith, 2011; Smith, 2013).[4] They had in-depth knowledge of fishery habitats and "knew the proper seasons when, as well as how, to take them" (Waitangi Tribunal, 1988, S1.3). Māori travelled "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, p. 10). The first European explorers were amazed by the abundant fisheries, and the expertise and ingenuity of Māori fishers, particularly the high standard of their operations and the scale of their activities. Joseph Banks, a botanist on Captain James Cook's *Endeavour,* showed Bay of Islands Māori *Endeavour's* 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) (1768-1771, p. 104). Nets used in other areas were twice as long (Nicholas, 1817; Waitangi Tribunal, 1988). Banks was 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, p. 201). Captain Cook himself noted that Māori were better fishers than his crew and used nets far superior to European ones (Cook, 1893; Beaglehole, 1955). In a nutshell, fishing was the main 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, p. 104).

Māori were dependent on *kaimoana*[5] not only as a critical source of protein, but also for trade: "Few nations delight more in trading and bargaining than this people" (Polack, 1838, p. 111). Before the arrival of Europeans, Māori engaged in large scale commercial fishing, much of which was traded between iwi[6] (Taylor, 1855; Waitangi Tribunal, 1988). From the 1820s Māori, with their fishing monopoly, supplied European settlers, visiting ships and whaling stations. By 1830 they were shipping large quantities of seafood to Australia. Despite increased demand, Hohepa (1976) reported that fisheries were sustainably harvested. European settlers did not materially impact fisheries, as they primarily undertook subsistence activities for personal needs. From the late 1860s, these roles began to reverse after settlers obtained political control from Britain (Waitangi Tribunal, 1988). The settler-dominated government passed a series of laws that ultimately broke Māori sovereignty over New Zealand's fisheries (Heremaia, 2000). 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.

These statutes essentially restricted Māori to subsistence fishing. This was reinforced by Chief Justice Prendergast's 1877 judgment, in respect to the *Wi Parata* case.[7] He reasoned that "Māori customary law was merely the habit of an uncivilised people and did not constitute law as understood by the English legal system," and thus Māori "rights could not be recognised unless *specifically* incorporated into legislation." Yet, Section 8 of the Fish Protection Act 1877 provided: "Nothing in this Act…shall be deemed to repeal, alter, or affect any of the provisions of the Treaty of Waitangi, or to take away, annul, or abridge any of the rights of the aboriginal natives to any fishery secured to them thereunder." Following Prendergast's decision, Section 8 was replaced by the diluted S77 (2) of the Fisheries Act 1908, which

[3] Protection of an area or resource by forbidding access or harvesting (Mutu, 2011).
[4] Smith (2013) provides an excellent understanding of the magnitude of pre-European Māori marine catch on the northeast coast of the North Island, and along the southeast coast of the South Island.
[5] Seafood.
[6] An iwi is a tribe.
[7] *Wi Parata v The Bishop of Wellington* (1878), 3 New Zealand Jurist Report 72.

inter alia states "Nothing in this Part of this Act shall affect any existing Māori fishing rights." This section was subsequently incorporated into Section 88(2) of the Fisheries Act 1983. In essence, Māori fishing rights were reduced to only those that could be enforced (Waitangi Tribunal, 1983), meaning that a claim could not rest on the Treaty of Waitangi unless the Treaty had statutory recognition (RT Hon Sir Robin Cooke, 1994).

Despite this, Māori continued to assert and protect their fishing rights under Te Tiriti o Waitangi, the doctrine of native title, and legislation referencing Māori rights. Litigation was largely unsuccessful because of Prendergast's decision. However, in a landmark 1986 High Court decision Māori customary (or traditional) fishing rights were finally recognised in the *Te Weehi*[8] case. Justice Williamson found that customary rights were indeed protected by the doctrine of native title, as they had not been extinguished by statute. This was the turning point in how Māori exercised their fishing rights. The decision highlighted the Crown's obligations under the Treaty of Waitangi, in respect to Māori commercial and customary fisheries rights, which included access to and management of fisheries. The Crown's obligations underpinned the 1989 interim settlement of Māori fisheries claims, the Māori Fisheries Act 1989, the 1992 fisheries Deed of Settlement, and the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992 (Heremaia, 2000). Customary non-commercial fishing rights were subsequently provided for through regulations, under Section 186 of the Fisheries Act 1996. The Treaty of Waitangi (Fisheries Claims) Settlement Act 1992 and the Fisheries Act 1996 embody the Treaty relationship between the Crown and Māori, which guarantees Māori access to fisheries. These statutes together contain provision for Māori participation in the management and conservation of New Zealand's fisheries.

With the growth of non-Māori commercial fishing during the late 1880s the need to further regulate activities also grew. A range of laws were passed to encourage industry growth, and manage fishing activities and conservation. The Fisheries Act 1908, established the three mile territorial limit and set up the management regime used until the Act's repeal in 1983. Restricted licensing was introduced in 1937, and then removed in 1964 to encourage major expansion through open access (Waitangi Tribunal, 1988). Encouraged by concessionary loans and export incentives, the industry significantly expanded. By the mid-1970s overfishing had become a serious problem, with too many boats chasing too few fish. Innovations in fishing technology such as improved net design, fish-finding electronics and the introduction of pair trawling often resulted in catches greater 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 & 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 relied on "were largely fished out" (Waitangi Tribunal, 1988, S3.2). A moratorium was placed on new licences. Unused licences were cancelled. Part-time fishers (those who earnt <80% of their income from fishing) later had their licences cancelled. Others were compensated for exiting the industry.

1.2 New Zealand's quota management system

During the 1950s foreign fishing vessels began exploiting the waters off New Zealand (Francis, Griggs, & Baird, 2001). This created concern about who had rights to the ocean and its resources. In 1965, the territorial sea was extended to 12 nautical miles. In 1977, 400 foreign fishing vessels were reported to be fishing in waters near New Zealand (Johnson & Haworth, 2004). Later, the government learned that the foreign catch for that year was nearly 361,000 tonnes. In October 1977, New Zealand gained greater control over its fisheries after establishing a 200 mile EEZ. Foreign vessels could only fish within this EEZ through joint venture agreements with New Zealand entities licensed to use foreign vessels, rather than through intergovernmental agreements (Branson, 1997). Also in 1977, the government set the first Total Allowable Catch (TAC) at 262,000 tonne (t) for major fin fish stocks. They allocated New Zealand vessels 95,000 t and foreign vessels 167,000 t (Gibbs, 2008). An enterprise allocation system for deepwater fisheries followed in 1983 (Dewees, 1989). In 1986, a comprehensive quota management system (QMS)

[8] *Te Weehi v Regional Fisheries Officer* [1986] NZHC 149; (1986) 1 NZLR 680.

underpinned by individual transferable quotas (ITQs) replaced the deepwater allocation system and was introduced for inshore fisheries (Major, 1997). Government's overarching goal was to change the behaviour of fishers by implementing a competitive market-based system that encouraged the sustainable harvesting of maximum value from fisheries (Boyd & Dewees, 1992). The QMS aimed to "implement a fishery rationalization programme to address both biological and economic goals" (p. 183).

The QMS allocates a TAC for each fish stock in the system. Allowances for Māori customary, non-commercial, recreational and all other mortality to a particular stock caused by fishing (e.g. unreported or illegal catch), are then deducted from the TAC. The balance is the total allowable commercial catch (TACC).[9] Initially, the QMS included 26 fish stocks which represented 83% of the total commercial catch by weight (Boyd & Dewees, 1992). By 2014, the QMS included 638 fish stocks (Ministry for Primary Industries, 2015c). To permit fishers to deal with by-catch for which they did not have quota, a catch balancing system was established. This initially included mechanisms such as by-catch trade-off between species, surrender of over-quota fish to the government, and a 10% over and under catch allowance carried through to the next fishing year. The catch balancing system was designed to discourage illegal dumping and non-reporting of excess catch. However, it was criticised as complicated and biologically unsound (Lock & Leslie, 2007). In 2001, the catch balancing system was replaced with the simplified 'deemed value' system (Walker & Townsend, 2008). A deemed value is a financial penalty fishers must pay if they do not have quota for their catch. Deemed value fees are set for each species in each management area, at levels that theoretically discourage overfishing and encourage the landing of all catch. In practice, deemed value fees have acted as a fine that discourage fishers from reporting and landing all their catch (Kazmierow, Booth, & Mossman, 2010; Simmons, 2014).

Implementing the QMS system was not without other problems. The starting point was not solid; many TACs were viewed as arbitrary, due to a lack of comprehensive information about fish stocks (Sissenwine & Mace, 1992). The provisional allocation of quota was based on the best two out of three fishing years catch histories, for 1981-82,1982-83, and 1983-84, regardless of how successful or unsuccessful these years had been. This caught the majority of fishers by surprise, as they had previously under-reported catches in order to reduce income tax (Rees, 2005). "Of 1,800 individuals notified of their catch histories 1,400 lodged objections," and following the provisional allocation of quotas 1,100 appealed to the Quota Appeal Authority (Clark, Major, & Mollett, 1988, p. 327). Others recognised the system was coming, and increased their effort levels to increase their catch history (Sissenwine & Mace, 1992). This became known as "fishing for quota". For many stocks, the process resulted in final quota allocations being higher than the corresponding TACs. This forced Government to initiate two quota buy back schemes, and "as a result, the government may have spent much of the $42.4 million NZ to buy back quota which would not have been caught" (Sissenwine & Mace, 1992, p. 150).

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".[10] In other words, the bargain transacted in and represented in the Treaty, confirmed that at the time the Crown's representatives recognised that Māori had property rights, which included fisheries. In effect, ownership had been appropriated by the government without consultation and without considering prior Māori rights (Durie, 1998; Mutu, 2012). This created much controversy and litigation. Māori objected because ITQs were in fundamental conflict with the principles and terms of the Treaty and their customary rights. ITQs gave pākehā[11] "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, p. 148). The denial of quota to Māori fishers who did not earn at least 80% of their income from fishing exacerbated this appropriation.

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

[9] See Section 21 of the Fisheries Act 1996.
[10] The Treaty of Waitangi, Article 2.
[11] Non- Māori, European, or Caucasian.

Zealanders understood the extent of early Māori fishing activities. Māori did not oppose the concept of a QMS, as they supported 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 & Mutu, 2003). In 1989, Māori and the Crown reached an interim settlement. This recognised *tino rangatiratanga*[12] and established the Māori Fisheries Commission to administer Māori fishing rights, assets, and advance Māori involvement and management in fisheries. In 1992, a full and final settlement,[13] the Sealord deal, was reached for all Māori commercial fishing claims (Bess, 2001). Under this settlement, 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. Despite this, many within Māoridom were very dissatisfied with the settlement (Matiu & Mutu, 2003).

Fishing is also very important to recreational (amateur) fishers, with as much as one third of the population participating (Kearney, 2002; Ministry of Fisheries, 2008; Bess, 2010). Of these, 36% are subsistence fishers (Akroyd Walshe Ltd, 2002). Recreational fishing is deeply rooted in New Zealand culture and considered by many to be a birthright. It is managed on a per-person basis. 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). Apart from whitebait, no recreationally caught fish can be sold. Each TAC includes a recreational allowance, which translates into a daily per-person bag limit (Kearney, 2001). As the population increases and more people fish recreationally, either recreational allowances must increase or bag limits must decrease. If a recreational allowance increases the corresponding TACC must decrease. This is invariably opposed by affected quota holders. Conversely, recreational fishers strongly oppose decreases in bag limits. As the Government found in 1993 and again in 2002, it is politically untenable to regulate recreational fishing through the QMS (Borch, 2010).[14] For example, in 2013, the Ministry for Primary Industries (MPI) promoted a proportional approach to the allocation of the snapper (*Pagrus auratus)* TAC (Ministry for Primary Industries, 2013h). This was met with a fierce backlash from recreational fishers and resulted in the Minister increasing the recreational allowance, but not the commercial TACC (Guy, 2013). In short, it is challenging to accommodate recreational fishers in the TAC. In practice there is no settled pathway for granting future increases in recreational allowances 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 harvest (e.g. Teirney, Kilner, Millar, Bradford, & Bell, 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. Surveys since 2004, however, are considered more reliable (Wynne-Jones, Gray, Hill, & Heinemann, 2014), particularly the work led by Hartill (e.g. Hartill, Watson, & Bian, 2011; Hartill & Edwards, 2015) to estimate the annual recreational catch of snapper from New Zealand's largest recreational fishery. Catch and effort data was concurrently collected from boat ramp interviews while an aerial survey collected data on the total number of boats fishing on survey days. The most complete recreational estimates involved a nationwide panel of fishers in 2011-12 and regular survey-interviews. The methods used were "an advance over previous methods and [were] able to produce more accurate and defensible harvest estimates" (Wynne-Jones *et al.*, 2014, p. 1). The panel survey used the average weight from boat ramp interviews to estimate total harvest in tonnes, while the aerial survey used the proportion of catch by land based fishers to estimate the harvest by all fishing methods in the snapper fishery.

[12] The exercise of paramount authority and power derived from the gods, sovereignty, and autonomy (Mutu, 2011).
[13] Her Majesty the Queen and Māori, Deed of Settlement, 23 September 1992.
[14] Borch (2010) provides an excellent overview of the tension between the recreational and commercial sectors and the Ministry responsible for fisheries.

The poor quality of commercial catch data is of considerably more concern than the lack of recreational data. Commercial fishers were first required to report catches following the 1904 Sea Fisheries Amendment Act, but it was 28 years before any did so and a further 5 years before all fishers were completing catch returns, albeit poorly. Attempts were made at the 1906 and 1911 census to collect catch data, but "the information obtained was so unreliable and incomplete that no tabulation of the results was carried out" (Government Statistican, 1914). 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, p. 14). Parliament's 1937-1938[15] Sea Fisheries Investigation echoed this criticism. In 1969, the Fisheries Committee to the National Development Conference reported that there was virtually no statistical information on fish species; that every committee that had ever investigated fisheries had determined that critical data were missing, and there was insufficient expertise available to collate and analyse catch data. An inter-agency committee was formed to resolve the issues. Despite this, 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 with the collection and analysis of catch data continued. In 1980, the Commercial Fisheries Working Party of the National Research Advisory Council (1980) 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…" (p. 123).

In 1981, another review found the data from catch returns were entirely inadequate: "It is virtually impossible using present statistics to implement a proper scientific management of the fisheries" (Department of Statistics, 1981, p. 17). Up to 79% of the annual landed catches may not have been reported. Catch data from some individual fishers was only of use because scientists had themselves collected and recorded the data. Many fishers claimed they did not have time to complete returns, which they found unwieldy and confusing. The greatest fear for many was that the Inland Revenue Department would access their returns. Part-time fishers tended to be "tardy" in completing returns, and thus provided "data of dubious quality" (p. 19). To address the problems a Fisheries Statistics Unit (FSU) was established in 1982. The Unit developed a new reporting system and oversaw the collection and processing of catch-effort returns, but was disbanded in 1988, leaving some datasets incomplete (Fisher & Sanders, 2011). In 1990, the Controller and Auditor-General, and the Parliamentary Commissioner for the Environment found "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 & Hughes, 1990, p. 9). Problems they highlighted included inaccurate conversion factors for fish processed at sea, resulting in catches being under-reported by as much as 35%; non-reporting of bycatch; mislabelling of fish; unrecorded transhipments to foreign carrier vessels; and dumping of unwanted fish at sea.

Nine years later, 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, p. 82). In fact, "effective monitoring and compliance are virtually impossible for New Zealand's fisheries resources" (p. 50). 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" (p. 53). 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 acanthias)*. Commercial fishers first reported catch of this species in the 1980-81 fishing year, yet Māori caught it for food and trade over hundreds of years. Mathews (1910) personally witnessed the size of Māori catches in 1855, when 7,000 sharks and dogfish were caught during one fishing expedition. In contrast, commercial fishers habitually dumped spiny dogfish, regarding it as a nuisance species due to its abundance and low economic value (Ministry for Primary Industries, 2013b). For several other species, MPI Fisheries Assessment Plenary reports note an annual under-reporting rate of at least 20% before the QMS and 10%

[15] New Zealand House of Representatives (1937-1938). *Report of the Sea Fisheries Investigation Committee: Laid at the Table of the House of Representatives by Leave*. (H-44A). Wellington: Government Printer.

afterwards. A comprehensive 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, Johnstone, Bateson, & Clarke, 2009).

There is uncertainty about release mortality, undersized mortality, and illegal catch in recreational fisheries. As well, there has always been considerable uncertainty around the real commercial catch. The "all other mortality caused by fishing" (e.g. unreported or illegal catch) component of the TAC has often been criticised as unproven and inaccurate for key species. To these authors knowledge, no fisheries stock assessment has explicitly considered species other than the target species, nor any ecological or environmental considerations. In recent years there has been some moves to broaden the scope of fisheries management to include a wider range of affects and effects. The Ministry has sometimes acknowledged unreported catch: "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, 2013h, p. 43). In spite of these "concerns" MPI has withdrawn compliance resources previously allocated to commercial fisheries surveillance (Conf. Pers. Comm.). There is now very little effective surveillance by compliance officers of commercial fisheries, particularly in deep water fisheries.

1.4 Objectives

Given the reporting inadequacies described above, the data New Zealand has reported to the Food and Agriculture Organization of the United Nations (FAO) appears to be incomplete. Data collection processes have been ineffective; not all data was submitted, and data did not include all sectors (Garibaldi, 2012). Prior to 1981 there "has been the almost total lack of reliable fisheries statistics" (Department of Statistics, 1981, p. 8). Under the amateur fishing regulations, there is no requirement to report recreational catches. Customary fishing is either managed under the Amateur Fishing Regulations 1986, or the Kaimoana Customary Fishing Regulations 1995. While some details of customary permits are recorded, catches are not. The aim of this report is to estimate the total marine fisheries catches of New Zealand, including all sectors and catches not previously accounted for.

2. Methodology, Materials, and Methods

This catch reconstruction is one in a global series, and follows the methodology detailed in Pauly and Zeller's (2016) *Nature Communications* publication, with some fine-grained innovations to provide sub-categories and further detail, as outlined below. The basic methodology was also used in 247 catch reconstructions covering 273 different EEZs. There is an obvious difficulty in undertaking a catch reconstruction. For 25 of the 61 years covered by the New Zealand reconstruction, unreported landing or discarding of some species of fish has been a criminal offence. The Fisheries Act 1996, provides for penalties of up to 5 years imprisonment. Those engaged in these activities have naturally been reluctant to bring their actions to official and public notice. In consequence, to reconstruct the New Zealand catch the authors had to adopt an appropriate research method involving multiple data sources which are triangulated against each other (Yin, 2009, 2012). Data sources include interviews, observations, documentary, and archival data, following Castillo and Mendo (1987) in a similar catch reconstruction.

For the interviews, the critical realist approach associated with Bhaskar (1979, 2008) and Sayer (1992, 2004) was adopted. Bhaskar notes that not all reality is observable. Events occur independent of observation; their existence may be unknown or misunderstood. The absence of an event may also require explanation. Given that reality can only be partially observed by a single individual, a more complete understanding of reality can be gained by combining and analysing the knowledge and insights of different individuals who experienced the same event and related events (Healy & Perry, 2000), in this case reported (or unreported) catch. Together the methods associated with the critical realist perspective (i.e. interviews, observations, documentary and archival data) generate a real-world understanding of phenomena (Sayer, 1992). Importantly, interviews can potentially expose concealed, often unobservable real-world events to understand how and why phenomena occurred (Blundel, 2007). As Penrose (1959,

p. 198) explains, methods that do not take into account the complex heterogeneous nature of phenomena may "lead to an analysis which conceals more than it reveals."

The FAO reports that 14,028,000 t of marine species were caught by New Zealand within FAO area 81 during the period 1950 to 2010. To determine the accuracy 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 (Ministry for Primary Industries, 2013b, 2013e, 2013d, 2013c, 2013f). These reports did not cover all species, and most of the data series only went back to around 1990. We therefore compared other official reports to the FAO data, including Francis and Paul's (2013) 1931-1982 finfish and shellfish commercial landings report, as well as Marine Department (1950-1974) and Ministry of Agriculture and Fisheries reports (e.g. King, 1985). 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, for each year from 1950 to 2010, from which a baseline was constructed.

The Fisheries Assessment Plenary reports (i.e. Ministry for Primary Industries, 2013b, 2013e, 2013d, 2013c, 2013f) acknowledged that the catches of a number of species had been under-reported. To obtain data on the level of under-reported catch, the authors analysed a wide range of published and unpublished documents. These included several hundred submissions to two parliamentary fisheries investigations in 1956 and 1962, as well as their findings, and MPI reports and other information obtained pursuant to the Official Information Act. We also obtained and analysed a wide range of other material; including Fishing Industry Board documents and reports, 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), National Institute of Water and Atmospheric Research (NIWA), as well as industry reports, minutes of meetings, letters, and observer diaries.

In addition, and in keeping with the critical realist approach to qualitative research, the authors conducted 308 interviews between 2011 and 2015 with a range of expert stakeholders including those with first-hand knowledge and experience of fishing practices at sea, and the landing of catches. Interviewees included academics, fishing company executives, vessel officers and crew, former compliance officers, observers, and fisheries management officials, former industry representatives, licenced fish receiver and processing factory personnel, and fishery scientists. The vast majority were fishers themselves and included almost 200 foreign charter vessel (FCV) crew who had worked on 23 different FCVs between 1998 and 2013. Also included were at least 5 longstanding New Zealand fishers from each of the nine relevant Fisheries Management Areas[16] to avoid having to generalise from one geographical area, and to understand possible diversity of practices across New Zealand fisheries. Interviews followed the Appreciative Inquiry (AI) approach to guide the discovery of positive and also negative events in an appreciative way (Michael, 2005). AI establishes a dynamic in which people can speak freely about their experiences rather than defend or justify their bad experiences. Using AI ensured a standardised interview format that gave interviewees flexibility to respond to appreciative questions.

Individually and cumulatively, interviewees had a wealth of in-depth knowledge and first-hand experience of fishing, processing, and reporting practices across all fisheries areas and sectors. Some had been involved in the industry for up to 55 years. Collectively, their information was crucial to quantify the actual catches and achieve an in-depth understanding of fishing and reporting practices. As interviewees were assured of confidentiality, they provided detailed information about their own experiences, including the types and scale of unreported catches. Many interviewees also volunteered documents, photographs and video to corroborate their accounts, including their reported catches and their actual catch histories for 1981-82, 1982-83, and 1983-84, fishing years used to apply for quota, as well as other real catch records from New Zealand and foreign flagged vessels, which were subsequently analysed. As

[16] In 1977, 10 management zones were established upon declaration of the Exclusive Economic Zone (EEZ). The 10 zones were based on where major fish stocks were. When the QMS was introduced these zones became 10 Fisheries Management Areas (FMAs) (Straker, Kerr, & Hendy, 2002). FMA 10 is the Kermadec zone which is not included in this study.

previously noted, the different data collection methods (e.g. interviews, documentary and archival data) provides triangulation in order to construct as accurate a picture as possible (Bhaskar, 1989; Yin, 2011), resulting in stronger and more robust findings (Eisenhardt, 1991; Yin, 2012).

From the information collected coupled with expert consultations, two broad categories were identified: invisible landings and dumped or highgraded commercial catch at sea. We accounted for New Zealand flagged vessels from 1950, and foreign flagged vessels from 1960. Within each of the two categories, a number of sub-categories were identified, as outlined in Sections 2.1 and 2.2. Annual estimates for each subcategory (by sector, area, and species, where possible) were obtained from interviewees and compared to independent data gathered from the aforementioned documents. Estimates (anchor points)[17] for each subcategory were then compiled for each year from 1950 to 2013. When a range of values was evident for a particular anchor point, we used the mean. We used linear interpolation to calculate missing data between anchor points. Feedback was sought on the credibility of the estimates from a range of industry participants and experts who confirmed them, or in some cases commented that the figures were conservative. We opted, if anything, for a conservative approach.

This report reconstructs catch statistics for New Zealand's marine fisheries by adding unreported catches to reported catches for the period 1950-2010. We also report preliminary results for the extended reconstructed catch to 2013. We define 'reported catch' as that reported by the FAO on behalf of New Zealand. Here we focus on FAO statistical area 81. In accord with the *Sea Around Us* global database, reconstructed catches are assigned to the industrial (large-scale commercial), artisanal (small-scale commercial), subsistence, or recreational sectors. We consider charter operations utilizing foreign flagged vessels as 'foreign' catch by that flag country and not New Zealand catch. Therefore, although we consider the reported charter vessel catch in the FAO data as fish caught in New Zealand's EEZ, we have shown this separately in our figures. The following is a more detailed description of invisible landings, dumped and highgraded commercial catch, recreational and customary catch, sector allocation, and finally the composition of discarded catch.

2.1 Invisible landings

Invisible landings represent catch that is landed, rather than discarded at sea, by industrial and artisanal fishers and is either not reported/under-reported or is documented but not reported as part of the FAO statistics. Invisible landings are comprised of three broad categories: unreported commercial landings, under-reported and misidentified commercial landings, and black market landings. Under-reported and misidentified commercial landings include: misidentified commercial landings, under-reported fish weights, conversion factor error and fraud, commercial amateur landings, commercial catch consumed on-board, and under-reported fish to fishmeal. As outlined above estimates for each subcategory (by species and quantity where possible) were obtained from interviewees and compared to data gathered from the aforementioned documents, such as the Ministry for Primary Industries Operation Overdue.

In this reconstruction, commercial amateur landing is considered to be subsistence catch, i.e., defined as catch taken by a commercial fisher, for self and family private-consumption. We were able to determine the number of fishers in New Zealand for all years from 1950 to 1974, from Marine Department (1950-1974) data. This was supplemented by Census data provided by Statistics New Zealand on the number of fishers in 1976, 1981, 1986, 1991, 1996, 2001, 2006, and 2013. We calculated missing years using linear

[17] Anchor points are catch estimates usually pertaining to a single year and category, or subcategory, or sector, or area, and often to a single species. Missing data, such years from which no data are available, are estimated from anchor points using linear regression. Where anchor points are followed by several years of missing data, we assume that the underlying fishing activity continued in the intervening years. This 'continuity' assumption is the default proposition. Exceptions to such continuity assumptions are major events, such as the abolition of licensing in 1963, declaration of the EEZ in 1977, and the introduction of the QMS in 1986, which we explicitly considered with regards to the structure of time series estimates. Overall, our reconstruction assumes - when no information to the contrary is available - that commercial catches (that is, industrial and artisanal) can be linearly interpolated between anchor points. For subcategories such as commercial amateur landings and commercial catch consumed on-board we interpolated between anchor points using data based on the number of fishers in that fishery over time.

interpolation. Estimates of an individual's commercial amateur landings were determined from interviews or based on the maximum individual allowance where it applied. The total estimate was calculated by applying the average individual estimate to the total number of fishers for each year and summed.

2.2 Dumped or highgraded commercial catch

We classified unreported dumped or highgraded commercial catch[18] into fish smaller than the minimum legal size and nine other subcategories: 1) Characteristically unmarketable, valueless, or of low value; 2) Physically damaged; 3) Less than the minimum economic size; 4) Oversized; 5) Degraded; 6) Lack of hold/refrigeration space; 7) Incompatible with other catch species; 8) Uneconomic catch size, and; 9) Quota induced (see section 3.3 for details). As outlined above annual estimates for each subcategory (by species and quantity where possible) were obtained from interviewees and compared to data gathered from a range of documents (see for example, Vere-Jones, 1958; Enwright, 1962; Dewees, 1989; Macgillivray, 1990; Rowe, 2006; Burns & Kerr, 2008; Bremner *et al.*, 2009; Kazmierow *et al.*, 2010), and also Ministry for Primary Industries Operations such as Apate II, Hippocamp, and Achilles.

2.3 Recreational and customary catch

To estimate the total recreational catch we used snapper and kahawai (*Arripis trutta*) catch histories, as they were used in their respective stock assessments for Quota Management Area 1 (QMA1).[19] In the 2011-2012 national recreational survey, 50% of the total recreational catch was made up of snapper and kahawai from QMA1. We assume that this proportion of the total catch was consistent over time, and thus all other fish is the sum of SNA1 and KAH1.[20] Nonetheless, recreational fishing can be very important in local areas, at a smaller scale than fishery management zones. Recreational catch can be much greater and socio-economic factors can also influence the behaviour of recreational fishers. We estimate that discard rates and resultant discard mortality was a higher proportion of catches when abundance was high as only a few species were considered worth eating. Recent boat ramp survey-interviews determined the discard mortality rate of returned undersized fish, to be relatively low. They found catch of undersized snapper to be less than 5% by weight. The assumed survival rate of undersized snapper released by recreational fishers is 80% (Ministry of Fisheries, 1997, p. 145).

For the present study, customary catch estimates are based on the total customary allowances, which are set to reflect estimated customary catches. An estimated 95% of Māori customary fishers, fish as recreational fishers and take catches within their recreational allowance (Ministry of Fisheries 1997). We assume Māori catch taken under recreational regulations are included in recreational catch estimates, and not included in customary estimates. We estimate unreported customary catch from 1950 to 2010 at 4% of the recreational catch. Note that the *Sea Around Us* considers the unreported customary catches calculated here as subsistence catches.

2.4 Sector allocation

New Zealand marine fisheries statistics reported by the FAO consist of commercial catches only. In this reconstruction, we segregate commercial catches into the industrial and artisanal sectors. We define artisanal as small-scale commercial fishing and industrial as large-scale commercial fishing, in accord with the *Sea Around Us* global database. In 1950, New Zealand's marine fishing industry was small-scale and operated 100% inshore (Johnson & Haworth, 2004). Analysis of total catches by vessel and gear type from the 1970 Report on Fisheries (Marine Department, 1950-1974), indicate that an estimated 20% of fish by weight was caught by industrial vessels. This is consistent with Ministry for Primary Industries

[18] Dumping is the practice of disposing of fish at sea and not reporting it.
[19] Quota management areas (QMA) are defined for each species in the QMS, based on the geographical distribution of each species, with each QMA independently managed.
[20] We recognise that using QMA1 snapper and Kahawai to predict the national average, may not generalise well to locations where other species dominate, such as shellfish areas and blue cod in the Marlborough Sounds.

(2009) information. We therefore, allocated 80% of total domestic commercial catch in 1970 to the artisanal sector.

Reported domestic landings by fishing method were also available for 1983 (King, 1986). This report specifically differentiates between domestic, foreign charter vessel, and foreign licensed catch. 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, small-scale inshore trawling, others) then used the proportion of total catch caught by these gear-types as the anchor point for industrial and artisanal sector allocation in 1983 (see Table 1). In 2009, about 80% of New Zealand's fisheries catch was supplied by eight industrial fishing companies, with the remainder from inshore fishing operations (Ministry for Primary Industries, 2009). These numbers, however, include catches by foreign charter vessels operated by New Zealand companies. Therefore, since our previous anchor points are for catch by New Zealand vessels only, we calculated what 80% of National landings were in 2010 and subtracted the amount of foreign charter vessel catch in that year (see below) in order to obtain the domestic industrial catch. We then calculated what percentage that was from the total domestic commercial catch, giving us our final anchor point (Table 1). We calculated missing data between anchor points using linear interpolation.

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

	Artisanal	Industrial
1950	100.0	0.0
1970	80.0	20.0
1983	23.0	77.0
2010	32.5	67.5

Catch data from foreign flagged vessels were available for 1983 (King, 1986), 1984 (King, Jones, Fisher, & Sanders, 1987) 2005 to 2009,[21] and various years between 1960-1995. We filled gaps in data by linearly interpolating between years for which data were available. In 2010, 26 fishing vessels from South Korea, Japan, Ukraine, and Dominica fished in New Zealand's EEZ. Japanese, USSR, and Taiwanese vessels also fished within the EEZ-equivalent waters in the 1970s to mid-1980s.

2.5 Composition of discarded catch

Close to 400 species have been observed being discarded. The composition of the industrial discards were derived from multiple reports on discards. These covered the arrow squid trawl (Anderson, Clark, & Gilbert, 2000; Anderson, 2004; Anderson, 2013), hoki trawl (Clark, Anderson, & Gilbert, 2000; Anderson, Gilbert, & Clark, 2001; Anderson & Smith, 2005; Ballara, O'Driscoll, & Anderson, 2010; Ballara & O'Driscoll, 2015), jack mackerel trawl (Anderson *et al.*, 2000; Anderson, 2004, 2007), ling longline (Anderson *et al.*, 2000; Anderson, 2008, 2014), orange roughy trawl (Clark *et al.*, 2000; Anderson, 2009b, 2011), oreo trawl (Clark *et al.*, 2000; Anderson, 2011), southern blue whiting trawl (Clark *et al.*, 2000; Anderson, 2009a), scampi trawl (Anderson, 2004, 2012), and tuna longline (Griggs & Baird, 2013) fisheries. These reports provided information on the species and quantities of fish discarded at sea, based on data collected by government observers on vessels in key fisheries. For most of these fisheries it is straightforward to extrapolate to the level of the entire fleet on the basis of the relevant unit of effort (but see the caveats below).

Additional steps were taken with the tuna longline fishery information. Information for this fishery is only given in number of fish. Therefore, average weight per individual fish had to be estimated first. Common length and length-weight information from the FishBase website (www.fishbase.ca) was utilized. Information specific to New Zealand was used exclusively if available. If no New Zealand specific

[21] 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, 2012c).

information was available, all other information was utilized. Average weight was then combined with number of fish in order to calculate the weight of all discards.

In order to combine the information from each separate fishery together into one overall discard composition, the total contribution of each fishery (target landings, retained bycatch, and discards) was estimated. This was done using information on catch, vessels, tows and sets from the aforementioned reports. This information was then used to weight the individual discard compositions. Note that the same problem of tuna fishery catches being reported in number of fish presented a problem in estimating the contribution of this fishery. The contribution of the fishery in the late 2000s was estimated to be 7% (pers. obs.). This was held constant starting from 1994 when tuna longline effort peaked. The percentage was interpolated from zero in 1970 to 7% in 1994. The percentages of the other fisheries were normalized around the estimate of the tuna longline fishery, with each other fishery beginning when the target species first appears in the landings. From this, based on observer authorised discards, we derived an approximation of the taxonomic composition of fish discards (see Table 2). The proportion of major groups discarded was quantified as a proportion of total discards.

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

Merluccidae	21	Macrouridae	13
Squalidae	5	Carangidae	4
Gadidae	3	Carcharhinidae	3
Selachii	3	Trichiuridae	2
Others	22	Unidentified	24

This derived composition was adjusted to account for unreasonably high Squalidae discards. Therefore, only 5% of discards were assigned to spiny dogfish, the rest of which was relabelled, resulting in a total of 24% being assigned as 'unidentified'. "Others" consists of 161 minor taxa.

However, we have major reservations about these results for several reasons. Firstly, observer coverage in many fisheries has historically been low. Anderson and Smith (2005), caution that the ability of their methods to estimate bycatch and discard levels is highly dependent on the level and spread of observer coverage, and thus they have reservations about the accuracy of their estimates. Secondly, there has also been almost negligible observer coverage of the artisanal fishery during the period studied, and some other fisheries are not covered (e.g. the purse seine fishery). We therefore acknowledge that although we calculated discards on the entire commercial catch (industrial plus artisanal landings), they are more representative of industrial discards. Thirdly, generalizing these discard estimates to fleet level relies on the assumption that the presence of an observer on a vessel does not influence discarding behaviour. This assumption is known to be flawed (see for example, Burns & Kerr, 2008). Under Section 72 of the Fisheries Act 1996, quota species can only be discarded if an observer is present when it is caught, the observer authorises and supervises the discarding, and it is reported against quota. The incentive to discard quota species is therefore restricted when a vessel has an observer on board, while non-quota species and some other species are not subject to these restrictions. In consequence, the composition we derived is systematically biased in favour of non-quota species. We therefore had to correct the composition by reducing the high proportion of Squalidae discards we derived. The Squalidae proportion was reduced to 5% of the composition with the remaining amount relabelled as miscellaneous marine fishes (unidentified) (Table 2).

3. Results

New Zealand's reconstructed marine fisheries catch totalled 38.1 million tonnes (t) from 1950-2010 (and 40 million t from 1950-2013). This indicates that the actual catch was about 2.7 times the 14 million t reported to the FAO on behalf of New Zealand for 1950-2010. The reconstructed catch for all New Zealand and foreign flagged vessels averaged 130,000 t·year^{-1} in the 1950s, peaking at almost 1.3 million t in 1988, and were around 703,000 t·year^{-1} in the late 2000s. Of the total catch from foreign and New Zealand

flagged vessels, industrial landings amounted to 46.3%, artisanal landings 14.9%, recreational landings 1.3%, and subsistence (customary plus amateur) catches 0.1%, with commercial discards making up the remaining 37.4% (Figure 2). Unreported landings from the industrial, artisanal, recreational and subsistence sectors made up 18.3%, 6.1%, 1.1% and 0.1% of the total catch, respectively. Industrial catches including discards comprised nearly 84% of reconstructed total catch, 1950 to 2010, of which about 50% came from New Zealand flagged vessels and the remaining 50% from foreign flagged vessels. Artisanal sector catch was the other major component of reconstructed catch, at about 15%. The combined catch from recreational and subsistence (including customary Māori) fishing was 1.3% of the total reconstructed catch.

For the 1950-2010 period foreign flagged fishing vessels caught approximately 42% of the total New Zealand catch. From 1990, the FAO included an increasing proportion of catch from foreign flagged vessels that fished in New Zealand's EEZ (Figure 3). Thus, more recent FAO data may over-report the amount of catch of New Zealand flagged vessels. If the reconstructed total catch taken by New Zealand flagged vessels is compared to the FAO reported landings for New Zealand flagged vessels only (i.e. excluding that catch reported for foreign flagged vessels), it is 2.4 times that adjusted FAO baseline from 1950-2010. Only an estimated 42.5% of catch by New Zealand flagged vessels was reported. Unreported landings from the industrial, small-scale (artisanal plus subsistence), and recreational (including recreational discards) sectors amounted to 9.9%, 10.7%, and 2.2% of the total New Zealand catch respectively, with commercial discards estimated at 34.8% (see Figure 4).

Since 1980, a small number of commercially important species have made up a significant portion of New Zealand's marine fish catches. Hoki (i.e. *Merlucciidae* family) alone accounted for about 16% of the total reconstructed catch (Figure 5).

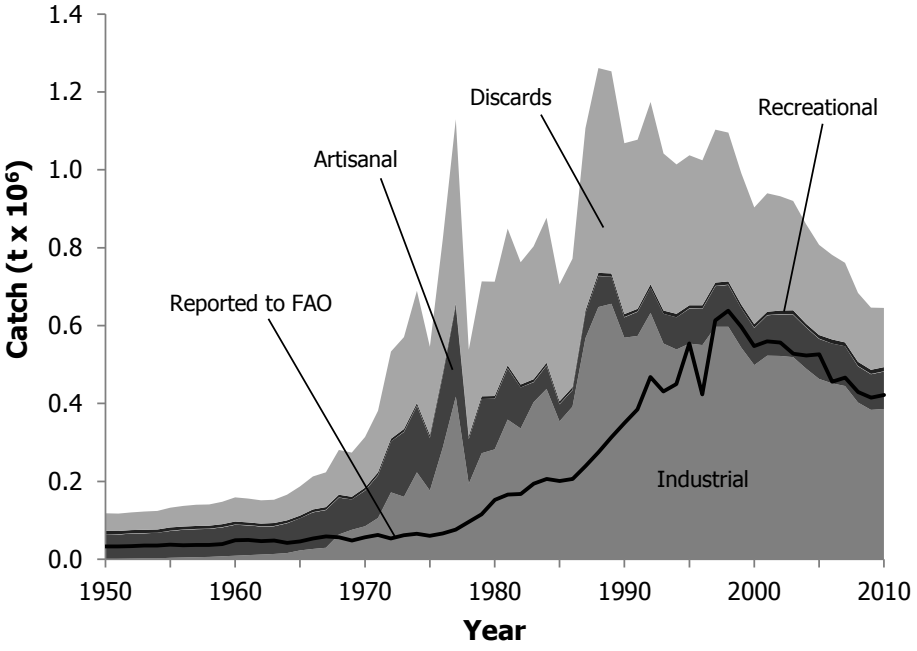

Figure 2. Total reconstructed catch (New Zealand and foreign flagged vessels) showing the contribution of each sector and fish discards. Subsistence sector catch is too small to appear on this chart. The solid line represents total landings reported by the FAO on behalf of New Zealand.

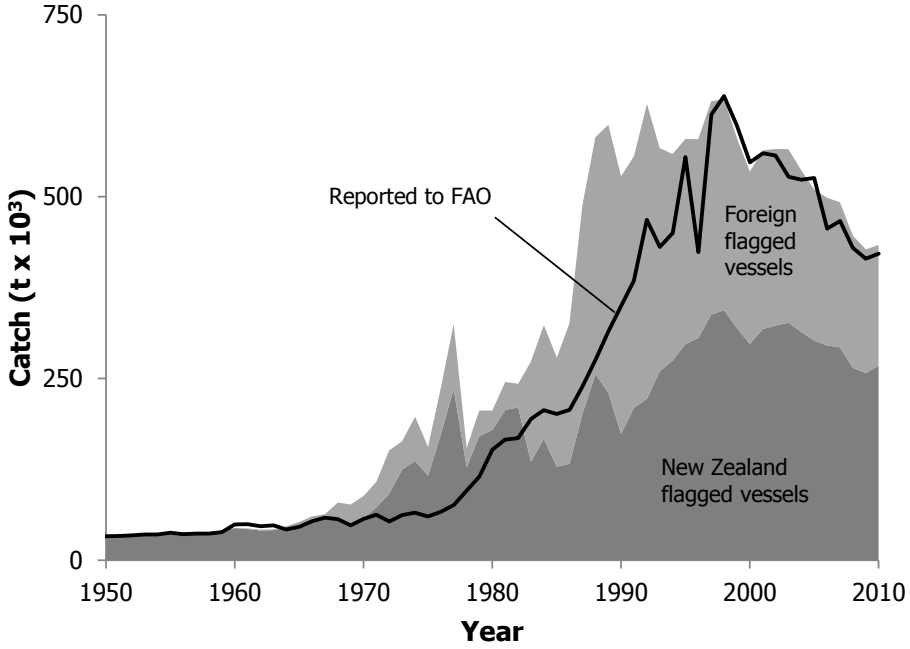

Figure 3. Reconstructed catch from official national data (only) for New Zealand and foreign flagged vessels. The solid line depicts the data reported by the FAO on behalf of New Zealand, which from 2000 onwards includes almost all the catch of foreign flagged vessels.

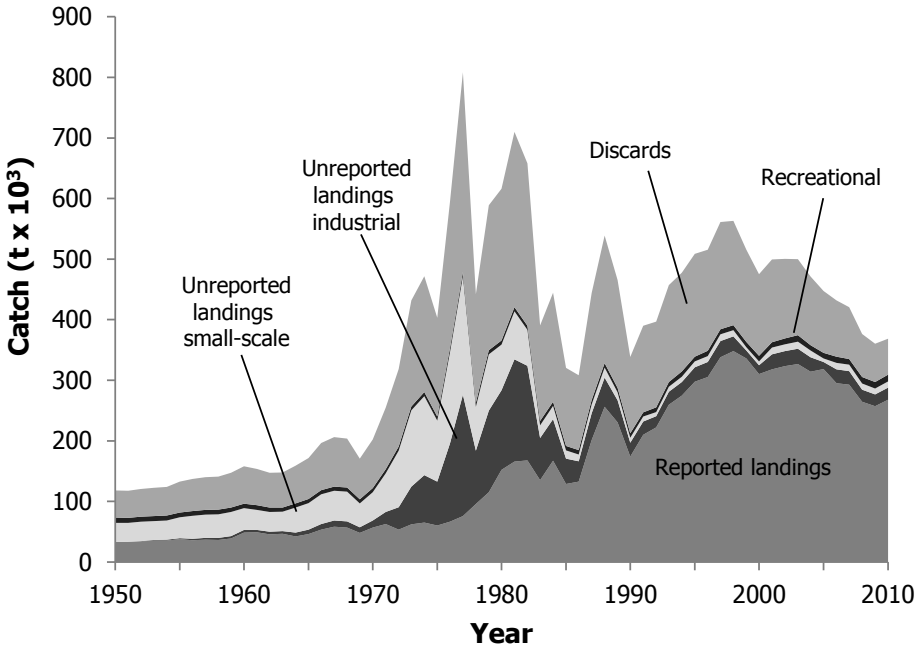

Figure 4. Total reconstructed catch of New Zealand flagged vessels only, showing unreported landings from industrial, small-scale (artisanal and subsistence), recreational, and discards, which are added to FAO reported landings for New Zealand flagged vessels only. The estimated catch by foreign flagged vessels is not included.

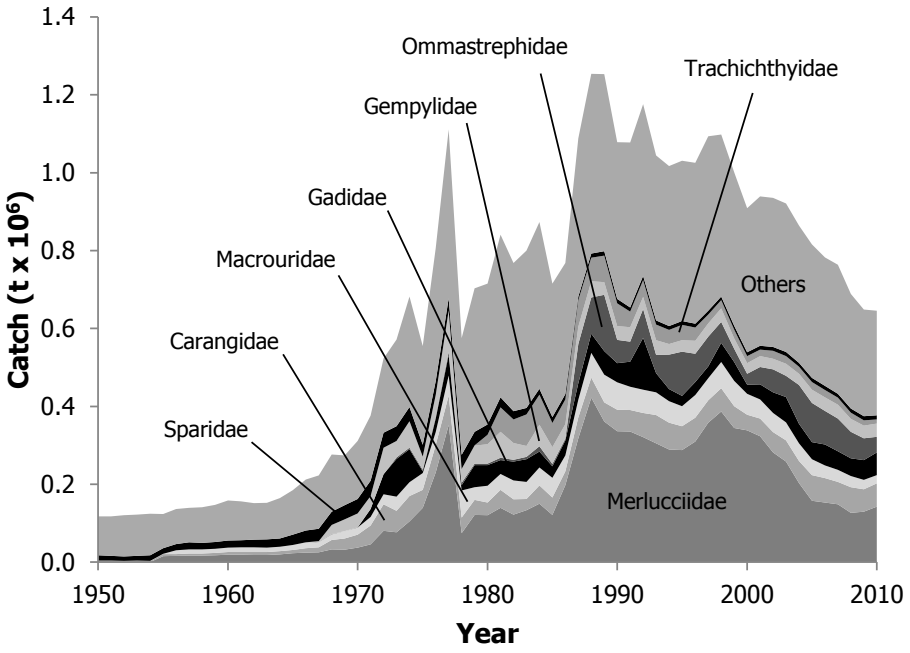

Figure 5. Total reconstructed catch (New Zealand and foreign flagged vessels) broken down by major families. 'Others' includes 193 additional families and higher taxonomic groupings.

3.1 Reconstructed official data

The total New Zealand catch of marine species from 1950 until 2010 reported in the FAO data – 14,028,000 t – is significantly lower than the total catch calculated from official national data – 17,672,000 t – for the same period. Since the early 1930s, Marine Department reports contained statistics about the reported catches for each species. From 1932 onwards, fishing vessel owners were required to report the quantities of fish landed each month through monthly returns. Before 1932, they were only required to provide annual reports. Until then "the data provided by the returns sent in [were] too heterogeneous to admit of any rational analysis" (Marine Department, 1931, p. 5). For 1950, the FAO data contains 24 species, while the 1950 Marine Department Report on Fisheries (1950-1974) lists 36 species. 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.

Table 3: Number of species reported

	~1400-1866	1950	1960	1970	1980	1990	2000	2010	2012
FAO data		24	22	39	50	60	117	146	133
Reconstructed official data	>182[22]	36	40	43	63	146	195	234	240
Bottom trawl surveys[23]			~60		~120	~165			
McMillan *et al.* (2011a, 2011b, 2011c)									397

Note: Some species in the FAO data and reconstructed official data are grouped under a single code, e.g. groper includes HPB, HAP, and BAS; while skate includes RSK and SSK. Differences also arise from the different reporting definitions between the FAO and New Zealand. There also appears to be a time lag between species first appearing in national catch statistics and when they appear in the data reported to FAO.

[22] See for example Smith (2011, 2013); estimating the magnitude of the pre-European Māori marine catch.
[23] Anderson, O. F., Bagley, N. W., Hurst, R. J., Francis, M. P., Clark, M. R., & McMillan, P. J. (1998). *Atlas of New Zealand fish and squid distributions from research bottoms trawls*. (NIWA Technical Report 42). Wellington: National Institute of Water & Atmosphere (NIWA).

From ca. 1400 to ca. 1866 Māori caught at least 182 species. It was not until the mid-1990s that commercial fishers reported as many species, despite exploitation of new fisheries in the EEZ from 1977 on (Johnson & Haworth, 2004). In fact, 1,008 marine fish species have been identified in New Zealand waters (Paulin, Stewart, Roberts, & McMillan, 1989). Between 1961 and 1997, 292 bottom trawl research surveys, conducted by 20 vessels, identified 270 of the most commonly caught fish and squid species or species groups (Anderson, Bagley *et al.*, 1998). In the early 1960s ~60 species were commonly caught in survey trawls. This increased to ~120 species in 1978, and ~165 in 1990 (see Appendix 1). The large increase in the number of species recorded per survey trawl from 1978 was attributed to the exploration of new fisheries in the EEZ that followed establishment of the 200 mile limit. Anderson *et al.* (1998) suggest misidentification as a reason for the difference in the number of species identified in trawl surveys, compared to those reported caught by fishers. Given that 120 different species at least were commonly known to Māori[24], an alternative explanation may be that many were not landed and reported. In 1994, for example, bottom survey trawls caught ~100 inshore species, but as the official reconstructed data revealed (see Table 3) only around 40 were reported during the 1950s, 1960s, and 1970s.

More recently, McMillan *et al.* (2011a) detailed 252 of the most commonly caught bottom and midwater species; McMillan *et al.* (2011b) listed 122 less commonly caught bottom and midwater species, and; McMillan *et al.* (2011c) listed 98 species commonly caught using surface fishing methods (i.e. surface longline, trolling, purse seine, lampara net). After removing double counted species, these reports together list 397 different species that are caught in New Zealand waters - those commercially sold and those that are not. All of these species should have been reported as caught, at least since the 1990s, but were not. One species, spiny dogfish, was missing from the FAO data until 1981, yet before then it was a significant part of total catches. Reporting anomalies were evident for other common bycatch species. Blue shark (*Prionace glauca*) was first reported in 1995 and ratfishes (*Hydrolagus* spp.) not until 1997. Carpet shark (*Cephaloscyllium isabellum*) was first officially reported caught in 1989, but was not included in FAO data until 2001. Black and smooth oreo (*Allocyttus niger, Pseudocyttus maculatus*) were only first reported in FAO data in 2001, yet were reported in domestic catches from 1973. By contrast, redbait (*Emmelicthys nitidus*) were first reported in FAO data in 1995 yet, oddly, even though national data is the source of FAO data, it was not reported in domestic data until 2002.

The differences between FAO data and New Zealand national catch data for each species was especially pronounced from the early 1970s to the late 1990s. These discrepancies may be due to different accounting of foreign flagged vessel catch. While the catch of these vessels are treated as part of total national fisheries landings in New Zealand data, they are allocated to the vessel's flag country (i.e., not New Zealand) in FAO landings data. From the mid-1980s, the FAO started to include foreign charter vessel catch as catch of the chartering nation in their reporting system, hence FAO and New Zealand's national catch data have become more aligned. In this reconstruction and the associated catch database, we differentiate between marine fish caught by New Zealand flagged vessels and those taken by foreign flagged vessels leased by New Zealand companies. This distinction is not made in national fisheries statistics, where all fish taken under QMS regulations are considered to be domestic catch[25] regardless of who caught the fish, although total catch quantity is subsequently segregated by vessel type i.e. New Zealand or foreign flagged.

When the data were 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 (*Thyrsites 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, show 143,394 t of hoki was landed in 1992, while national

[24] See Waitangi Tribunal (1988). Report of the Waitangi Tribunal on the Muriwhenua Fishing Claim. Wellington: Waitangi Tribunal.
[25] See for example the 'Background Paper on the Use of Foreign Charter Vessels' (Ministry for Primary Industries, 2011a).

statistics show landings of 215,000 t. Because of these discrepancies we do not accept the FAO data as representative of the total actual catch from 1950-2013.

Furthermore MPI's Fisheries Assessment Plenary reports (i.e. Ministry for Primary Industries, 2013b, 2013e, 2013d, 2013c, 2013f) acknowledged that the catches of a number of species had not been fully reported. This included hoki - New Zealand's most commercially important species. During the mid-1980s, large hoki catches caused nets to burst, but the amounts of fish lost were not determined. Hoki fishers adopted a Code of Practice to minimise these losses. For other species, such as hake (*Merluccius australis)*, plenary reports estimated the real catch to be as much as 78% higher than the reported total annual catch. Also, dumping and failure to report, up to 100% of catches, has historically been significant for certain species, e.g. barracouta (*Thyrsites atun*), black cardinal (*Epigonus telescopus*), ghost shark (*Hydrolagus spp.*), orange roughy (*Hoplostethus atlanticus*), oreos, school shark (*Galeorhinus galeus*), and sea perch (*Helicolenus percoides*). Discrepancies in tray weights and conversion factors resulted in under-reporting of some species, 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 fishing were also noted in the aforementioned plenary reports. In most cases the level of misreporting was either not credibly quantified or according to a number of interviewees, ignored. Few corrections were made to the official reported catches, although the plenary reports confirm that the misreporting of catches has long been a significant problem.

3.2 Invisible landings

New Zealand has always had an invisible commercial catch. Much of it has been landed on shore or used at sea and not reported. Invisible landings fall into a number of categories. In practice, a commercial vessel may land her catch without reporting it, thereby making an 'unreported commercial landing'. Historically, this was risky because failing to report commercial landings has been illegal throughout the period covered by this study. A less risky approach was to report the landing but understate the quantity or misreport the species of fish landed. As noted in section 2.1 the category of 'unreported commercial landings' can be further subdivided into misidentified commercial landings, under-reported weights, conversion factor error and fraud, commercial amateur landings, and commercial catch consumed on-board. Frequently, parts of the catch are used on board commercial vessels, either as food or as bait. This fish is deemed to have been landed, but often goes unreported. The final category of invisible landings is for the black market. If fish is sold through illegal channels after being caught by a vessel with or without a fishing permit, this constitutes a black market landing. The boundaries between the various categories of invisible landings are frequently blurred. However, the effect of each is the same. Invisible landings are not reported in the FAO statistics for New Zealand.

The reconstructed marine fish catches reveal that from 1950 to 1986 an estimated ~50% of all commercial landings were invisible i.e. not reported, primarily to avoid paying high levels of income tax. This rate decreased to ~10% by 1992 where it remained through to 2013. In total the invisible landings for the period 1950 to 2010 is conservatively estimated at 5.7 million t and for 1950 to 2013 at 5.8 million t. Interviewees explained that invisible landings dropped significantly in the years immediately after 1986, primarily because of the introduction of a Goods and Services Tax (GST) in October 1986, reductions to income tax, and new fisheries recordkeeping requirements from 1990.[26] Pre-1986 taxation was widely regarded as inequitable due to high marginal income tax rates (Muir, 1993). Post-1986 income tax rates fell significantly, while GST strengthened anti-avoidance measures. From 1985 to 1988 the top personal income tax rate fell from 66% to 33%, while the company tax rate fell from 45% to 33%. The introduction of on-board observers in 1986, and from 1989 strengthened compliance monitoring and enforcement of the QMS, also contributed to the decline in invisible catch. However, observer coverage was limited to 20 to 25% of the deepwater trawl fleet fishing the most important fisheries. Observers focused on scientific

[26] Fisheries (Recordkeeping) Regulations 1990.

information rather than compliance *per se* (Ministry of Fisheries, 2003). Observer coverage of the inshore fleet was negligible during the period considered by this study.

3.2.1 Unreported commercial landings

Prior to 1986 unreported landings by commercial fishers were very common. Until 1969 at least, in a number of areas "there was no record of fish caught which have no market for human consumption" (National Development Conference, 1969b, p. 82). Fishers complained that completing *"ridiculous fishing returns"* was onerous and that the returns were of no value to them (e.g. Interviewees 5, 60, 164, 181, and 194). Their accounts confirmed the findings of the review committee on New Zealand fisheries statistics (Department of Statistics, 1981), which had this to say about fishing returns:

> Many of the present returns in use are from everyone's point of view, unwieldy and confusing…the actual recording space is very cramped. There is nothing in the form re confidentiality. Instructions for completion are inadequate. Part 2 of the return (the effort section) is meant to be completed at sea. Fishermen very often claim that they do not have time to complete this section even while steaming home, which usually takes some hours. Most fishermen do not even attempt to complete Part 2 properly, saying that the amount of detail asked for is too great and that they cannot see what conceivable use all this information is put to (p. 17).

The committee found that where fishers had completed returns: "the landings information, is often completed unsatisfactorily, although it only requires that the fisherman copy the figures from his sales dockets" (p. 18). Part-time fishers provided particularly poor data. The industry saw no real benefit from completing returns. As a result there was "little effort within the industry to make the returns work" (p. 20). The committee did, however, achieve a good understanding of the scale of unreported commercial landings from 1975 to 1981. During those years there were about 12,000 permits to fish commercially using various types of gear. On average only 2,500 returns or 20.8% (plus nil returns) were completed each month. This suggests that a significant proportion of landings went unreported. A comparison of landing returns to export declarations showed that export species were 20-30% under-reported. The difficulty in interpreting the information on completed returns compounded issues due to the low rate of return completion. This problem was so bad that data entry staff were "instructed soon after the forms were introduced in 1975, not to punch Part 2", the effort section (p. 17). These findings followed the 1969 comprehensive review into fisheries statistics (National Development Conference, 1969a), which determined that until 1969 there were very few factual catch and fishing effort statistics. The cumulative effect of the problems described was that catch and effort data was extremely poor prior to the early 1980s. One interviewee (184) from that era *"was told by colleagues to under-report effort to make CPUE* [Catch Per Unit Effort] *look better"*, while another confirmed:

> *No-one filled fishing returns back then, no-one cared. I started in 1965 and never filled them out until catch histories [in the early 1980s] were wanted for quota. I just unloaded my fish and got thrown big bundles of cash. You could go anywhere in this country and unload in any port and be paid cash and never fill out a piece of paper. Back then Area 1 snapper was the biggest cash thing in town* (Interviewee 269).

Following a literature review and interviews with a number of fishers from that period we believe the non-reporting of landings was significant and common across almost the entire commercial fleet. Many did not report all of their landings and sales, as they feared the Inland Revenue Department would discover their real income. Some routinely sold all their catch of one species or other parts of their catch clandestinely, to private buyers. Others operated almost entirely on cash.

> *Our returns were bullshit! Back then, 25% of the catch minimum was cash in our back pocket. Fish dealers were at the wharf bidding for our fish, so never wrote it in our books for the taxman. So 25% of the catch was not recorded and often nothing was recorded* (Interviewee 266).

The magnitude of this cash trade became evident with the introduction of the QMS in the 1980s. Individual catch histories were used as the basis for issuing quota. Many fishers 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).

As catch histories used for quota allocation were based on two years only, 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 1977 when commercial fishing expanded due to the open access regime, coupled with more efficient harvesting technology. Catches increased sharply, for as long as fish stocks remained abundant. 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, or dumped in landfills. Unreported cash sales continued even after the QMS was introduced, although at lower levels.

> *In late 1986, we came into port with a deck-load of Trevalley and Kahawhai, and the company told us it needs to be gone before we start unloading [the hold] tomorrow morning. We had 10 tonne*[27] *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).

Foreign flagged vessels also did not report all of their landings. They were known to tranship up to 80% of their catch to carrier vessels at sea for direct export (Cameron & Hughes, 1990). It was not unusual for this to be done covertly: "MAF Fisheries seized four ships that were alleged to have mislabelled fish which had been transhipped as non-quota species in order to avoid using quota. Other suspected illegal activity included non-reporting of bycatch" (p. 34). New Zealand company vessels generally had fewer opportunities to tranship. 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 implemented more comprehensive recordkeeping requirements for licensed fish receivers (LFRs), fish dealers and fishers (Ministry of Fisheries, 2003). A mandatory tax invoice system was imposed that linked catch landing returns to the GST system. The Ministry[28] also established a team of forensic accountants. Failing to report landings supposedly became less feasible as reporting systems were progressively strengthened. Despite changes to the reporting systems, not all landings were reported, according to a number of interviewees.

> *Lots of people had two books, one for the fisheries inspector to see and one for them not to see. Guys ended up with a little bit of quota that wasn't enough and had to triple it, but we didn't write it down. Very easy to beat the system if you want to and doubt that will ever change. They thought they had us all at one time, but no. Just need a good relationship with the vessel. Every outfit [LFRs] that bought fish did it and probably still do. Well quota costs so much, so got to beat it. It's*

[27] The interviewee was adamant it was 10 tonne.
[28] Ministry of Agriculture and Fisheries.

> *the nature of fishing. So many people in this country will pay cash. I can take you now with a tonne of fish and drive to a place and get rid of it, no trouble at all* (Interviewee 268).

In 2011, a fisher forfeited two fishing vessels to the Crown after failing to report any catch for almost an entire year: "He simply ignored all the warnings and advice and then compounded his offending by continuing to fish when he no longer had a licence to do so" (Ministry for Primary Industries, 2011b).

Issues with completing catch returns have not been fully resolved. Many interviewees were critical of the post-1986 catch returns (e.g. CELR[29], TCER[30], TCEPR[31], TLCER[32]). In their opinion there were too many forms that they found *"complicated and unintelligible"*, particularly the effort section: *"I got asked once how long did I tow for, I never told them, we just didn't do it. Someone in the office did it, don't know what they put down"* (Interviewee 188). Some returns were designed to be completed after each fishing event rather than as a daily diary, but many fishers used the forms this way nevertheless. No check digit (as with bank accounts) is built into a fisher's client number, which caused mistakes in interpreting the number. This caused problems with reconciliations. Insufficient rows for recording the catch of each species caused some fishers to record additional species along the margins of the forms, or not record them at all. Others used additional pages despite viewing this as cumbersome and time-consuming.

> *It's ridiculous! The people who designed these returns, obviously have never been on a bloody fishing boat. It's a hassle, so don't always record everything. I had real problems, because they ask how many hooks we set and the time the hook was left in the water. I rang them and said you are not multiplying the time by the number of hooks to get effort. The guy said yeah and I said for fucks sake! They think if 1 hook is in the water for 1 hour, its 1 hook hour of effort but the bait is gone in minutes. They think if the hook is in the water for 2 hours it's twice as much effort as 1 bait for 1 hour, but it's not because it loses its effectiveness when the bait is gone. When he gave me that answer, I just told him you guys don't know what the hell you are doing and we have no faith in the system because of the way you are measuring effort. There are so many variables. How long you leave it [the hook] in, is not a measure of effort and its super dangerous if they treat it like a man hour of work* (Interviewee 180).

Several interviewees suggested that paper based returns should be replaced with real-time electronic forms. The Fisheries Act 1996 does provide for electronically completing and filing returns. At the time of writing the opportunities for this have not been well exploited.

3.2.2 Under-reported and misidentified commercial landings

Prior to the QMS there was an incentive to minimize income tax liability by understating the amount of income earned from landings. The introduction of the QMS in 1986 created incentives to understate the amount of fish landed, initially to minimize the amount of quota used to cover the catch, and from 2001 to also avoid deemed value penalties. More specifically, "the incentives are to misreport so that ACE[33] costs or deemed values costs are not incurred. These incentives result in incorrect data recording so that the information for fisheries management is wrong" (Kazmierow *et al.*, 2010, p. 89).[34] We discuss and quantify under-reporting catch via dumping and highgrading in a later section of this study.

Under the QMS it became profitable to under-report landings and misidentify the species landed. This became apparent during 'Operation Roundup', an investigation MAF conducted from late 1990 to mid-

[29] Catch, Effort and Landing Return.
[30] Trawl Catch Effort Return.
[31] Trawl Catch, Effort and Processing Return.
[32] Tuna Longlining Catch, Effort Return.
[33] "At the start of each fishing year, each quota owner receives an annual catch entitlement (ACE) equal to their share of the TACC. ACE is the right to harvest a quantity of a fish species in an area in that year. Once allocated, the use of ACE is solely at the discretion of the fisher concerned – they can fish it, sell it, or hold it. Trading ACE is theoretically equivalent to leasing quota for a year" (Straker *et al.*, 2002, p. 41).
[34] Released under the Official Information Act (OIA): Kazmierow, B., Booth, K., & Mossman, E. (2010). Commercial fishers' compliance decision making: perceptions, experiences and factors influencing regulatory compliance. (Prepared for the Ministry of Fisheries, 19th July 2010). Wellington, New Zealand: Lindis Consulting.

1991. Roundup investigated the false reporting of over 1,000 t of orange roughy. Twenty-one individuals and companies were charged with over 2,000 offences under the Fisheries Act 1983 and the Fisheries Reporting and Recordkeeping Regulations. The prosecution involved 80,000 documentary exhibits and resulted in the offenders incurring fines totalling $2.5 million and the forfeiture of quota, fishing vessels, and vehicles. The offending was described by the Parliamentary Commissioner for the Environment (Williams, 1999), as "a complex conspiracy over several years to misreport illegally caught orange roughy." It demonstrated how easily fishing operators and processors could "co-operate in falsifying documents in a consistent manner to circumvent the checks and balances in such a document intensive system" (Sullivan (1996) as cited in Williams, 1999).[35]

While Operation Roundup was the largest, it was only one of several similar serious QMS fraud investigations undertaken throughout New Zealand from 1990 to 1992 (Ministry of Fisheries, 2003). One interviewee participant (267) commented that *"we only scratched the surface of the offending."* Ultimately, the QMS relies on self-reporting and will always have a certain level of unreported commercial landings. As investigations found, the reporting cross-checks "could easily be avoided by collusion between the fisher, quota holder and receiver who, in many cases, are one in the same" (Ministry of Fisheries, 2003). Nielander and Sullivan (1999) claim that contrary to the assertions of ITQ proponents:

> The introduction of ITQs in New Zealand has clearly been accompanied by a significant increase in the level and scope of offending detected and prosecuted compared to pre ITQ. As was expected, the introduction of the ITQ in New Zealand created a range of economic incentives for some in the industry to cheat the system. What was not expected, perhaps, was the scale and extent of the "quota frauds" that has since been confronted. This is based on the writer's extensive personal experience in prosecuting and defending fisheries offences since 1984.

Roundup was arguably the largest investigation post 1986, but sophisticated offending continued. In 1996, the charterers of five Russian vessels (the FVs Om, Osha, Olenino, Orlovka and Ognevka, referred to as the "5-O vessels") had numerous charges laid against them for systematically falsifying fishing returns, under-declaring and misreporting quota species.[36] The relevant investigation demonstrated that damaged fish, up to 5% of the catch from each of the five vessels concerned, was routinely turned into fishmeal and under-reported as offal.

During Operation 'Purse' in 2004, the Ministry of Fisheries investigated five commercial fishing companies for misreporting approximately 170 tonne of fish, caught by two purse seiners (Ministry for Primary Industries, 2004a, 2004b). One of these vessels was estimated to have taken over 948 tonnes of fish illegally. Operation Webb a two year long operation investigated one of the most significant levels of misreporting under the QMS; "catching fish in one quota management area and misreporting it as coming from another" (Ministry for Primary Industries, 2010a). The operation ended in 2010, when a Japanese fishing company, its New Zealand partner and four Japanese nationals pleaded guilty to a total of 54 charges. They subsequently paid NZ$4.2 million in fines and deemed value penalties (Ministry for Primary Industries, 2011b; Radio New Zealand News, 2012). The misreporting involved 481 tonnes of ling and 112 tonnes of silver warehou caught in 2007 and 2008. The defendants also acknowledged that similar misreporting had occurred back to 2001.

In 2013, a fisher forfeited two vessels, following his conviction for "making false and misleading statements on fishing returns and documents relating to fishing trips made over a 17 month period from May 2010 to September 2011" (Ministry for Primary Industries, 2013a). MPI's Operation Portsmouth determined that the fisher misreported "his catch as being caught in another quota area, as well as failing to declare fish that had been landed and sold." Unreported catch was estimated at between 51-57 t of fish,

[35] Sullivan, M. S. (1996). The Evolution of New Zealand's Quota Management System: Success or Failure. Unpublished research paper, Spring 1996: Nelson.
[36] Ministry of Fisheries v Abel Fisheries Ltd, Unreported, District Court, Wellington, CRN 7085005665, 23 February 1998.

with a deemed value of $77,913. This case was described by the Ministry, as demonstrating "a total disregard for the QMS" that put the sustainability of fisheries at risk.

Despite utilising all available compliance resources "to detect and prosecute commercial operators who defraud the Quota Management System", interviewees described this type of offending as all too common: *"trucking* [reporting catch caught in another quota area] *is a fact of life"* (Interviewee 16). A number of interviewees (e.g. 60, 183, 195, 202, 227, 271) described how fishing returns were only partially completed while fishing and were not fully completed until the catch was actually landed. In some cases two sets of returns were maintained on board a vessel, one for the fisheries officer in the event they were seen and the other that they intended to submit if un-intercepted.

In 2014, a commercial fishing skipper was prosecuted for under-reporting catches. The skipper alleged he was a "foot soldier" in a wider misreporting operation (Stuff, 2015). Subsequently a seafood company, its directors and associated companies faced 380 charges (Sharpe, 2015b). MPI's Director of Compliance commented that the investigation was the largest "inshore fisheries" investigation of its type for many years (New Zealand Herald, 2015b). Offending occurred throughout the supply chain, including catching, landing, processing and exporting. There were "large discrepancies between catch records and export documents, with more fish being exported than was being reported as caught. Export documents showed the company had exported substantial quantities of fresh chilled product over an 18-month period, while catch records show the company has landed considerably less" (Sharpe, 2015a). The director of compliance expected the misreported figure to grow with the inclusion of domestic sales: It "looks like an example of a company side-stepping the regulations…in a very deliberate and calculated manner." The same company directors were convicted in 1994 for making false statements in quota reports and the illegal possession of fish (New Zealand Herald, 2015a). In 2010 one of the directors of the company pleaded guilty to "species misreporting" following the Ministry's long-term investigation Operation Blue (Ministry for Primary Industries, 2010b).

3.2.2.1 Misidentified commercial landings

Species misidentification is known to occur in commercial fisheries in other parts of the world (for a recent example, see Hentati-Sundberg, Hjelm, & Osterblom, 2014). Species misidentification is frequently perpetrated as a fraud on the consumer, whereby low value fish is sold as a higher value species. Under any form of QMS the incentive is reversed: the incentive becomes 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 false reporting of one species of fish as another. In a press release regarding a conviction in 2010 for "species misreporting - the false reporting of one type of fish as another", 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, 2010b). MPI does not collect data that would enable estimation of the quantity of fish misreported in this way. However, Smith and Benson (2001) found almost 42% of fillets from cartons labelled as lemon fish (*M. lenticulatus*) were from other species. Their study demonstrated that "shark landings recorded in New Zealand waters may be inaccurate, which will not only confound catch statistics but may compromise assessments upon which regulatory decisions are made" (p. 354). Bremner *et al's.* (2009) study of the West Coast hoki fishery, also found the quantities were substantial. 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 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 weights

The QMS saw the introduction of Licensed Fish Receivers (LFRs), as independent reporters of fish landings. Except for a few statutory exceptions, all commercially caught fish since 1990 had to be sold to an LFR. LFRs are responsible for determining and reporting the weight of all species they purchase each month. Fishers continue to estimate the greenweight of their catch at sea, but LFRs are required to actually weigh the landed catch. After weighing the fish, they must provide the fisher with a purchase docket listing the total weight of each species. A number of fishers claimed that the system was not foolproof as it merely shifted the problem of unreported commercial landings from them to the LFR. As one interviewee (223) explained:

> *Unless the fish is weighed from the boat, there is a gap in the paper trail that you can drive a truck through. I sprang my LFR. We have a pretty fair idea of how many kilos of fish we got. We were unloading each day and their weights were coming back at 10 kilos per iki-bin, but I was thinking it should be 13, so I got bloody feed-up with this. One day I weighed the fish myself, so knew how much fish exactly we had sent to the LFR. Sure enough they were stealing about 10% of our fish. I rang the manager and said you are stealing my fish. He said 'no that wouldn't happen and can't do anything about that'. So that shit happens all the time. Most of the other guys just say that's what we got, what can we do about it, we're running their boat, fishing their quota, we're just slaves. Yeah 10% off the top is a bloody lot of profits and bad news.*

Other interviewees (226 and 269 respectively) had this to say about the weighing of their fish:

> *We have to take it on good faith and that's something I've had disagreements about lots of times. I put down the estimated weights and then I get the weight from the LFR and it's different to mine, so then I get returns sent back asking why it's different, I think I have made the mistake, and put down the greenweight of the LFR even though I disagree with it, because it saves a big fucken argument - 10% easy. You have to take their word on the weight and conversion factor. It should be all done at the wharf in front of your eyes on certified scales, not taken half way around the bloody country and then weighed. You get dripage and some of it goes missing, so you don't know what the hell you will get.*

> *I bought some scales and weighed the fish, 77 kg total. After not getting paid I went in to get my money, and told him I had weighed the fish. After checking his records he wrote me a cheque for 50kg and then gave me cash for 27kg. He could not remember the total amount of fish I had given him. It wasn't in the book.*

Missing fish was a contentious issue for many fishers: *"We used to get dockets* [from the LFR] *and some fish would not be listed, so wrote down stolen for the weight on our returns. No one ever queried it"* (Interviewee 193). *"It's a given that LFRs will shortchange us. The most common and prolific is bycatch species when they are in small volumes. They don't even appear on your docket. They just vanish and we are having to adjust dockets that are a statutory declaration – 5-10% by weight"* (Interviewee 270). Many were of the opinion that it was futile challenging their LFR, as it could be detrimental to them: *"You can't complain, got to keep your trap shut, and if you don't do as you are told you won't get quota next year"* (Interviewee 253). In practice many landings are not actually weighed. Fish may be landed in bins, sacks or frozen in cartons. LFRs often only count the number of containers and multiply this number by a nominal per-container contents weight, which is almost always lower than the actual weight of the fish. Even if individual containers are weighed, excessive deductions may be made for ice and packaging, etc.

> *The classic is their scales, had the tare weight set at minus 5 to allow for a bit of ice but 80-90% of bins were always completely de-iced before putting them over the scales* (Interviewee 270).

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 (Ministry of Fisheries, 2003). This applies to most factory vessels and contract fishers. Interviewee 246 explained how this worked for him in practice.

> *I asked if he had any SPO quota? 'No'. Said, well can't fish up north cause running into too much of it. He said 'just whack the fillets off them, stack them in a bag, leave them onboard and after dark bring them around back and I'll will give you cash for them.*

Government observers routinely collect product-weight data when aboard factory trawlers, but these data are seldom 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*)*. In 2004, the Operation Overdue investigation found that:

> The staff in the factory [trawler] are indisputably packing packages of fish so that they contain more than the nominal net weight, and at least with respect to the shatterpacks of ling [Genypterus blacodes] and hake fillets, they are following company instructions to do so. Since the vessel processes a lot of fish the discrepancy will inevitably amount to several tonnes per landing.[37]

Comparison of the real processing records against reported landed carton weights from two foreign charter trawlers, for the years 2010-2012, revealed that carton weights were under-reported by between 5 and 11%. We have estimated the under-reporting of fish weights across the industry conservatively, as the degree of under-reporting varied between vessels, from species to species, and changed through time with increased observer coverage.

3.2.2.3 Conversion factor error and fraud

Because quotas are based on the greenweight of fish, catch must also be reported in greenweight, the weight of the whole, unprocessed fish. However, fish are often partially or wholly processed at sea. Official species-specific conversion factors are used to convert the processed weight 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 which 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 (e.g. ling) is cut to fit into a standard carton, application of the dressed conversion factor will inevitably underestimate 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 they are mainly dumped at sea or converted to fishmeal (Interviewee 7).

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 & Hughes, 1990, p. 24).

Currently, MPI does not collect data which would enable the estimation of under-reported greenweight via abuse of the conversion factor regime. 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. An egregious example involved under-reporting catch by over 40% (Interviewee 191). The proportion of catch processed at sea varies both by species and through time. 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.

3.2.2.4 Commercial amateur landings

Commercial fishers have always taken a portion of their catch home for consumption. Traditionally little if any of this was reported. When the QMS was introduced in 1986, the Ministry attempted to ban this

[37] Released under the Official Information Act (OIA): Operation Overdue (3rd February 2004).

practice. All fish had to be landed to an LFR, and if fishers 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 fishers had always taken home unreported fish for them and their pets to eat.

> *Years ago I met a trawler-man 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, the legislation controlling this type of activity was amended to require commercial fishers to report fish landed as amateur catch. In some circumstances commercial fishers are entitled to take home the amateur daily bag limit of seafood for their own use. Under section 111 of the Fisheries Act 1996, all commercial vessel catches are deemed to be for the purpose of sale, unless the Director General of MPI allows an exemption for amateur 'feeds'. The exemptions are routinely issued providing the fish are reported and meet the requirements of the amateur fishing regulations. Catches reported as amateur feeds are not deducted from the quota allocation and are not recorded by a LFR. It is unlikely 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 t. The quantity is proportional to the number of commercial fishers. However, it was a great deal higher in the 1970s and 1980s when there were many more part-time commercial fishers. Even if commercial amateur catches were reported to MPI via a vessel's catch and effort return, they were not included in the FAO data, and thus form another, albeit small, component of invisible catch. Although a very small quantity overall, commercial amateur catches can be big for some species e.g. blue cod (*Parapercis colias)*, dredge oysters *(Ostrea chilensis),* rock lobster, and snapper; and thus cannot be ignored.

3.2.2.5 Commercial catch consumed on-board

Commercial fishers often consume a small part of their catch at sea. They are required to report this fish and deduct it from their annual catch entitlement. This requirement was first introduced in 2001, so there are no data available for earlier years. Since 2001 the requirement has, often been ignored (Interviewee 251). The official figure for 2013 amounts to only 297 t for all species. However, before 2014, foreign charter vessel (FCV) crew were routinely required to eat fish, often three times a day, every day. It was an inexpensive source of food and minimized vessel operating costs. Stringer, Whittaker and Simmons (2015) confirmed from in-depth interviews, with 293 crew from 19 FCVs that crews ate significant quantities of fish. Food rationing was common:

> *[we were] forced to ration meat, none after 20 days … always 50 per cent less food than we ask for … when [we] run out of food, [we] have to eat fish* (interviewee 56).

On one FCV[38] when there was insufficient edible fish, the crew had no choice but to *"eat rotten fish bait to survive"* (Interviewee 17). The crew had previously caught the fish and bait. Crew from across the FCV fleet detailed that the amount of catch consumed on-board was substantial and seldom if ever 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). This was confirmed by observers, one of whom recounted:

> *They were pulling all sorts of things out of the net to feed the crew, and that went undeclared. They had rice, kimchi, and fish. Fish everyday! One morning I said to the chef don't want to eat*

[38] See Simmons, G. and Stringer, C. (2014) 'New Zealand's fisheries management system: Forced labour an ignored or overlooked dimension?' *Marine Policy*, 50, Part A: 70-84.

> *this for breakfast anymore, I was over it. So he cooked me up an egg, ham, jam and cabbage toasted sandwich and that's what I had for breakfast, for the next month. But the crew had to have fish every day* (Interviewee 250).

Total quantities consumed by foreign fishing crew during the past 2 decades were substantial. From July 1999 to June 2000, for example, almost 3,000 foreign fishing crew worked on foreign flagged vessels in New Zealand's EEZ. They ate an estimated 1,300 tonnes of fish. In the ten years from 2001 to 2010, 21,600 foreign fishing crew consumed an estimated 9,400 tonnes of fish or an average of 940 tonnes each year, little of which was reported. Fish consumed on-board vessels is not included in the FAO data and is an important part of the total invisible catch that cannot be ignored.

3.2.2.6 Under-reported fish to fishmeal

Some but not all of the large factory trawlers are equipped with compact rendering plants (meal plants). These convert unwanted fish and processing waste including offal into a dried and powdered fishmeal. A few vessels also separate and retain the oil from the oil rich liquid waste stream (known as stickwater) from this process. Large meal plants also operate at a few fishing ports. These process the waste and unwanted fish from processing factories. It is unusual for fishers to land unwanted bycatch to these onshore plants because the plants charge a fee for the fish they accept. Disposal of fish in landfill is usually cheaper, but dumping at sea is cheaper again.

> *You can't control what's going in the net, at what volume, and speed, so need some elastic system to deal with things. Hell no, we are not dumping anything! It all just went into meal. There was a whole lot that was done that was never to be spoken about. Anything that was too hard went to the meal plant. It's the great levelling machine on the boat, any headache we had the meal plant took care of it for us. All we had to do was navigate the observer and we were away laughing* (Interviewee 60).

Exports of fishmeal from New Zealand peaked in 1999 at approximately 74,000 metric tonnes, but subsequently declined to around 20,000 tonnes annually, with domestic consumption of about 15,000 tonnes per annum.[39] Assuming a processing yield of 20% the quantity of fishmeal produced in 2010 required 165,000 tonnes of whole fish and fish offal. The wet fish to fishmeal processing yield will vary slightly, depending on the species of fish processed. It is typically higher in land-based plants because these can employ evaporators and centrifuges to recover protein and solids from the stickwater stream (FAO, 1986). A yield of 22.5% is often used as a global average for shore based plants (Shepherd, 2005). Space constraints aboard vessels make at-sea recovery of solids from stickwater impracticable. The New Zealand Fisheries (Conversion Factors) Notice 2005 specifies a yield of just under 18%[40] for whole fish processed to meal at sea. New Zealand currently lacks methods to determine: (1) whether fishmeal has been derived from processing offal or whole fish, and; (2) to quantitatively determine the species composition of landed fishmeal. In consequence the mix of species and the proportion of whole fish going to the meal plant cannot be audited retrospectively. Unless an observer is present, the reporting of whole fish to the meal plant relies entirely on honesty. Observers expressed reservation about the veracity of the reporting, even when they were present: *"It's hit and miss the best of times…you can't be watching it the whole time, it's just not possible"* (Interviewee 250).

To report whole fish sent to the meal plant, vessels typically operate a timed-run sampling system, a hopper system, or some combination of both. For a typical timed-run sampling system a factory hand stands beside the waste conveyor for 10 minutes every hour and notes the number and identity of fish passing by. These data are then scaled by the total time the waste conveyor was operating. For a typical hopper system, small, damaged or otherwise unwanted fish were put into a calibrated hopper. When the hopper is full its contents are discharged onto the waste conveyor. Vessel crew record the number of times

[39] IndexMundi sourced from the United States Department of Agriculture: http://www.indexmundi.com/agriculture/?country=nz&commodity=fish-meal&graph=exports.
[40] Expressed as a conversion factor of 5.6.

the hopper tripped. In theory both systems could, with diligence, produce tolerably accurate data. In practice, the data from both is systematically biased downwards.

Multiple waste streams feed the waste conveyor. Catch is sorted as it comes from the pounds. Valueless species are generally put on the waste conveyor at this point. Heads, guts and tails are fed to the waste conveyor from the heading saw. Frames and trimmings are fed onto it further downstream. Target fish that were bruised, net damaged, too small or otherwise unsuitable for packing are also placed on the waste conveyor. If automated processing machinery is used it usually damages a proportion of the fish, or small fish simply fall out. Some vessels have a chute from the trawl deck to enable whole fish too damaged to process, to be fed directly to the waste conveyor. All of these waste streams fed the waste conveyor at different points. In consequence the composition of the waste changes as the conveyor moves towards the meal plant. The position at which the timed run sample is taken is therefore critical. It is often convenient to take the sample from a position very close to the pounds, since only whole fish is on the conveyor rather than whole fish mixed with and partially obscured by processing waste. This practice inevitably results in a biased estimate. The hopper system usually relies on factory hands remembering to cross the deck to mark a tally board each time a hopper is discharged. Two observers reported that it was commonplace to find that the gate of the hopper had been lashed open so that fish fell straight through the hopper onto the conveyor (Interviewees 8 and 11).

Because fishmeal is a low value commodity the return from a fish converted to meal is often far below the cost of the quota or annual catch entitlement required to cover the fish. Therefore there is no incentive to accurately report fish destined for the meal plant. The financial incentives are to either misreport high value species as another of little or no value; or to report that all the fishmeal produced is derived from processing offal. The former has certainly occurred (see Bremner *et al.,* 2009) although it did not affect the reported total catch. The latter practice also occurs. Operation 5-O resulted in the Ministry of Fisheries seizing five foreign charter factory trawlers which had been fishing for hoki. An observer aboard one of these trawlers intercepted a communication from the New Zealand charterer instructing the masters to report all damaged hoki sent to the meal plants as offal. The quantity of this damaged fish was believed to average approximately 5% of their catches. All five vessels were prosecuted. Systematic monitoring of processing returns to identify vessels producing impossibly large quantities of fishmeal from offal is possible. The Ministry has not done this routinely, and the data required are not publicly available. The prevalence of under-reporting whole fish to meal is therefore difficult to estimate, but is not insignificant.

> *On a single voyage in 2010 one FCV reported landing 891 tonnes of cartoned fish, produced from 1,390 tonnes of green weight fish. This meant there was about 500 tonnes of offal. Yet, somehow they produced 118.6 tonnes of fishmeal from the 500 tonnes. The efficiency of these fishmeal plants is <18% and even if it was 20% they could make only 100 tonnes of meal from the available offal. So where did the rest of the fishmeal come from?* (Interviewee 191).

3.2.3 Black market landings

For the purposes of this paper we refer to black market landings as catch which is not reported and subsequently sold through illegal, unlicensed and unregulated channels. We believe there is no black market catch from the deepwater commercial fisheries that dominate the FAO catch statistics. The current black market in New Zealand primarily exists for high value species such as paua (*Haliotis iris*), rock lobster, and snapper. Previously, there was a black market for toheroa (*Paphies ventricosa*) and mussels (Chisolm, 2005). Fish such as blue cod, elephant fish, and other finfish used by fish and chip shops and restaurants have also been traded through the black market (Ministry for Primary Industries, 2010c). "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). In 2011, one of New Zealand's longest and most comprehensive anti-poaching operations ended. Operation Paid targeted the organised poaching, sale and distribution of paua. A total of 53 offenders were subsequently convicted on 321 charges. Twenty-eight received prison sentences and 23 received community-based sentences. "The following year the ring leader of another major paua poaching ring was sentenced to five years" and three months imprisonment and banned from fishing for three years. His illegally-taken paua was sold to the

Auckland Asian community and restaurants. The offences were committed while the offender was on parole from prison for previous poaching offences.

In 2011, fisheries officers seized a commercial trawler and two refrigerated trucks after uncovering a large-scale black market operation that involved catching snapper and selling it in Tauranga, Hamilton and Auckland. The operation 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, 2011c). Several interviewees confirmed that sometimes fish caught by commercial fishers was sold on the black market.

> *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).

Rock lobster - another high value species - is also poached illegally and sold on the black market. In one operation during 2014, the Ministry 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 [unlicenced fishers selling catch] 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 recent years the black market trade has shifted online with the first cases detected in 2012 (Ministry for Primary Industries, 2015b). The number of cases since 2012 suggests the use of social media for black market sales is a growing trend. In 2015, MPI compliance officers terminated an online operation investigating four groups in Auckland who were selling black market seafood. The offenders with 400 followers were using Facebook to sell black-market seafood to the public. Compliance officers identified 10 suspects, who at one stage were offering super sacks of kina (thought to be wool fadges) for $500 each (Ministry for Primary Industries, 2015a). The total weight of black market catch is not high, but is significant for some species, such as paua, rock lobster, and snapper.

3.3 Dumped or highgraded commercial catch

Fishers using non-selective fishing methods are unable to control what they catch. A variety of species and a range of fish sizes will inhabit the area they are fishing, at any given time. Bycatch is common and unavoidable. Commercial fishers seek to maximize economic gain. It can be advantageous to dump unwanted fish, especially species that are unmarketable or bycatch species for which the fisher has no quota. The law may also require that certain sized individuals of a species must be returned to the sea. In this section, we define dumping as the practice of disposing of catch at sea and not reporting it. To increase the value of the catch, dumped fish may be replaced with a more valuable species or more valuable individuals of a species. This practice, where the most valuable fish are retained and the less valuable dumped, is known as 'highgrading'. For the purposes of this section we use the term 'dumping' to cover both practices except where 'highgrading' is used in a quote.

Historically species viewed as having little or no perceived economic value have been routinely dumped at sea and not reported (New Zealand House of Representatives, 1937-1938, 1956; Enwright, 1962; New Zealand House of Representatives, 1962). As a result New Zealand's total commercial catch has been under-reported. A range of reports have described dumping, some quantitatively (see for example, Vere-Jones, 1958; Enwright, 1962; Dewees, 1989; Macgillivray, 1990; Burns & Kerr, 2008; Bremner *et al.*, 2009; Kazmierow *et al.*, 2010).

In the case of New Zealand fishing vessels, we determined that dumping rates were higher before 1986 (~70% on average from 1950 to 1985), then declined to ~20% by 2013. The dumping rate for foreign flagged vessels from 1960 to 1985 was higher at ~80% on average, and subsequently dropped to ~50% by 2013. The reduced dumping from 1986 was due to the introduction of on board observers in 1986

(offshore vessels only), strengthened enforcement from 1989, and new recordkeeping requirements from 1990. Like Clark, Anderson, and Gilbert (2000) we found dumping is significantly influenced by vessel nationality, particularly in the hoki fisheries. Foreign flagged vessels (especially those that employed bulk harvesting methods) appear to have dumped higher proportions of their catch than New Zealand flagged vessels. For the period 1950 to 2010 we estimate unreported dumped catch at 14.3 million t and for the period 1950-2013 14.7 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. We are confident that the unreported dumped catch estimate is conservative for all years.

3.3.1 Landscape

Of the 1,008 marine fish species identified in New Zealand waters (Paulin *et al.*, 1989), 397 are commonly and less commonly caught using bottom, midwater and surface fishing methods (McMillan *et al.*, 2011a; McMillan *et al.*, 2011b; McMillan *et al.*, 2011c). Official data (refer Table 3) shows only around 65 species were reported caught in 1980, around 150 in 1990 and around 240 species in 2012. This indicates, notwithstanding some misidentification, that either many species were not caught, or were dumped and not reported. The 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 (*Chelidonicthys 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 (p. 21).

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" (p. 28). 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" (p. 6). 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, p. 21). 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, p. 4). Enwright's statement was significant, as he had in-depth knowledge of the fishing industry. He was first involved in the industry in 1910, and from 1930 managed Sanford Ltd 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 the reported catch in 1960 involved 44 species, but only half were of importance to the industry. Nine species (snapper, tarakihi (*Nemadactylus macropterusi)*, 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 fishers fished in mixed fisheries with high levels of bycatch. He noted: "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, p. 61).

Despite some species (squid and octopus) being regarded as of value overseas, in New Zealand they were used for bait or dumped. In Britain and Spain dogfish and skate were in demand and widely eaten. In New Zealand they were regularly dumped and not reported. Sutch's findings were also informed by a 1958 Department of Scientific and Industrial Research report, which highlighted the widespread practice of dumping unpopular varieties of fish into the sea. Vere-Jones's (1958, p. 6) 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. One witness to the Muriwhenua Fishing Claim recounted the "extensive fish dumping by those who profit from the sea" (Waitangi Tribunal, 1988, p. 193). 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, p. 42).

As part of Ngai Tahu's Sea Fisheries Claim, the Tribunal heard evidence that in the early years of the QMS, fish were lost at sea through nets bursting and from 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" (p. 374). 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, p. 21).

The observation that fishers were "dumping as much as they are selling" was confirmed by our interviewees. Interviewees recounted 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 described by one fisher:

> *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).

The level of dumping, particularly from the production of surimi in the West Coast hoki fishery, concerned many in the industry. Surimi is a deboned, washed and chemically stabilised fish mince. It is typically produced from low value white fish using automated machinery, and later used in the production of remanufactured fish products. A non-technical description of the process can be found in Kumar *et al.* (2015).

Surimi production is a high-volume, high-speed process that results in high levels of wastage. Under ideal conditions the yield might be as high as 27% of the initial weight of fish processed by the machinery, a yield obtained for blue whiting at the Stornoway Research Station (White Fish Authority, 1978). In practice, the Stornoway researchers discovered that yield was dependent on a steady supply of fish of the species and size for which the machinery was optimised and was typically rather lower, between 23 and 24%. Small whiting could not be processed at all. Good quality surimi could only be produced from very fresh or iced fish – protein degradation occurred even if the fish were stored in refrigerated seawater prior to processing. Hall and Ahmad (1997) note that in surimi production "the freshness of the raw fish is considered to be of paramount importance" and also that "a uniform size of fish is important for consistent yields". In a mixed species, mixed size class fishery targeting hoki, a species known to have poor keeping qualities, considerable wastage was inevitable and certainly occurred. According to one observer (6), surimi vessels dumped fish one way or another almost continuously.

One skipper described the prevailing attitude at the time, when he and other skippers complained to management about the wastage from their fishing practices: *"shut up and drive the boat, it's none of your business"* (Interviewee 199). By late 1986, it had become such a problem that fishers, including the National Executive of the NZ Share Fishermens' Association, were openly discussing how to "rectify the situation". The Association was sufficiently concerned that they complained to the Ministry of Agriculture and Fisheries (MAF), and the Fishing Industry Board (FIB). They also went public with 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.[41]

The official conversion factors for surimi in NZ range from 4.3 to 5.4 (equating to yields of 18.5 to 23.3%), and depending on the species and sea area concerned and are presumably based on process yields from the surimi machines, without taking associated dumping into account. Production of surimi by NZ vessels has not been constant in time, with a boom in the 1980s and a subsequent decline. By 2015, only one vessel was producing surimi.

Soon after, the Ministry raised the TAC for hoki to 250,000 t, which the National Executive of the NZ Share Fishermens' Association considered "was completely unrealistic".[42] A Ministry official from that time was also of the opinion that the TAC increase was unrealistic: *"We have never heard the full story of how that daft decision was arrived at"* (Interviewee 187). 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. Concerns were expressed about poor practices and wastage in other fisheries. One Fisheries Management veteran described orange roughy fisheries as being *"strip mined"* (Interviewee 182). Others also commented on the high level of wastage: *"The bloody dumping that's gone on is unbelievable! Shitloads of fish not reported"* (Interviewee 3). The Association decided to take up the issue "strongly with the Minister at the earliest possible opportunity".[43] At a subsequent meeting the Minister agreed to investigate the situation. 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"[44] in the Challenger area hoki fishery. Interviewees who attended this meeting said that, while the size of the problem was discussed, there was no agreement on a lasting solution.

Data collected included catch records for the entire fleet fishing hoki during the 1980s. Analysis of these data for 1986 show that 96,000 t of hoki was landed and reported. This compares to 99,623 t from the reconstructed data using official reports. A further 9,600 t was landed, but not reported – *"standard 10% under-reported"* rate at that time. Additionally, 2,460 t was lost on the surface from overfull nets, 105,000 t was lost from "nets bursting below the surface", and 70,000 t was dumped. In total this amounts to a total catch of 283,060 t of hoki for the 1986 fishing year, of which only 99,623 t was reported. There was no attempt to estimate discards from major New Zealand trawl fisheries until 2000 (Clark *et al.*, 2000). That study exclusively used observer authorised discard data. A number of similar studies followed (e.g. Anderson *et al.*, 2001; Anderson, 2004; Anderson & Smith, 2005; Anderson, 2007, 2009b; Ballara & Anderson, 2009; Ballara *et al.*, 2010; Anderson, 2014). However, these studies did not take account of the "observer effect", which means data from observed vessels cannot be generalised across the fleet (Cotter & Pilling, 2007). In this context, "observer effect" refers to the tendency for fishing and processing behaviour to change when an observer is on-board a vessel (Benoît & Allard, 2009). This phenomenon was confirmed by a number of fishers.

> *We behave very differently when there was an observer on board. We were very careful, jobs took longer to do. If there was no observer on board, the officers were happier as they could take as much fish as they like, and if what they caught didn't satisfy them, they could throw them away, and only keep the best quality. They will keep moving from one area to another quickly to get the best fish, but if there was an observer they would stay in one place and be careful about catching and throwing fish away* (Interviewee 261).

Anderson (2004) illustrates the observer effect. He used observer data to estimate the total annual bycatch in the New Zealand scampi fishery from 1990 to 2001. This was compared to catch records from

[41] 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.
[42] 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.
[43] 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.
[44] Ministry of Agriculture and Fisheries, Bulk Fishing Meeting, Nelson, 14th October 1986, Agenda.

commercial fishing returns. The commercial catch records amounted to only 12-25% of the totals calculated from observer data. The total annual bycatch estimates based on observer data ranged from about 3,200-6,800 t. This compared to 511-1,475 t from the commercial catch records. Anderson does not speculate on the reasons for the difference. Burns and Kerr's (2008) study also provides a good description of the observer effect in the context of bycatch in the ling (*Genypterus blacodes*) bottom longlining fishery. They found that high levels of unreported bycatch was common: "Observers reported non-ITQ bycatch on 98.5% of days ling was caught, but unobserved fishers reported non-ITQ bycatch on only 38.8% of fishing-days on which ling was caught. Spiny dogfish, skate, red cod, sea perch and ghost shark bycatch were significantly more frequent when an observer was present. There was sufficient ACE for each of these bycatch species and deemed values were low." Burns and Kerr estimated that the spiny dogfish catch should have been 13.7 times higher with 100% observer coverage, compared to no observer coverage. Even when an observer was on board, "fishers did not always report their catch accurately, particularly for non-ITQ species" (p. 27).

In 2007, 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, 2007a). Official data from 2004-2006 indicated that the problem was widespread, especially in the West Coast hoki fishery.

> Compelling evidence comes from the fact that vessels with government observers on board consistently land more small fish than those without. As an analyst suggested at a marine science conference in Nelson last week, it is unlikely that small fish are attracted to boats carrying observers. The conclusion must be that the other boats are cheating, and the Ministry of Fisheries believes that they dumped up to 71 percent of small hoki they caught in the West Coast fishery last year (Editor, 2006, p. 9).

Twenty six foreign charter vessels (FCVs) and 10 New Zealand owned vessels were selected for study. Observers were placed on all New Zealand vessels, but on few FCVs, because of health and safety risks.[45] This was despite evidence that FCVs had long been engaged in misreporting and illegal fish dumping. It was alleged FCVs were responsible for high levels of dumping in the hoki fisheries during the mid-1980s. In 2006, the Ministry of Fisheries had new data which indicated the widespread illegal dumping of fish by FCVs (Phillips, 2007b). Since then a number of FCV operators have been successfully prosecuted and vessels forfeited (Ministry for Primary Industries, 2001, 2002; The Press, 2008; Ministry for Primary Industries, 2012a; Ministry for Primary Industries v. Dae Jun Lee, 2014).

One 2011 prosecution, involving the FCV Oyang 75, was for the deliberate and systematic dumping of up to 1,000 tonnes of quota fish (Radio New Zealand News, 2012). Two deckhands gave evidence against their five Korean fishing officers. One testified that "approximately 30% of the total catch of fish was discarded, whole and processed. I had no choice but to do this; if I refused I would be reported to Korean officials and sent home. I was fearful of the [officers], they were very angry people." Another crew testified that "we knew that dumping fish like hoki, squid, barrcouta and many others was to be done in a manner in which the observers would not see it." Interviews with around 200 FCV crew who had worked on 23 FCVs fishing in New Zealand's EEZ between the early 1990s and 2013 confirmed the scale of the dumping. They had regularly participated in large-scale dumping of quota and non-quota species. Crew members confirmed that it was standard practice to dump part of or even all of the catch, due to a variety of factors.

> *Depends on the mix of the catch and ones that are undersized or oversized. Always dumped squid, hoki, and ling. During the squid season which is about 5 months, we dumped squid every day. Small squid is dumped straight away while sorting through the conveyor. During the hoki season dumped every tow, two times a day. Even though the fish that had been caught were of good quality, we dumped them because captain wanted to replace them with fresher fish. Even though there was plenty of fish on board they kept lowering the net to catch more fish. The amount that was dumped, usually was more than what was kept, and when we caught the non-targeted fish*

[45] Report dated 23rd May 2008, from National Manager Fisheries Operations to Chief Executive of Ministry of Fisheries, entitled 'Management measures to mitigate the risks from foreign charter vessels operating in New Zealand's EEZ'; details the problems with placing observers on board FCVs.

> *we throw them all back in the sea too, especially when there was no observer on board* (Interviewee 148).

> *When we targeted barracouta the catch varies from 3,000–4,000 pans [39-52 t], and the highest catch we had was 6,000 pans [78 t], but we couldn't pull them all in, so the rest was dumped, about 4,000 pans [52 t]. When we were catching silver warehou our catch varies from 1,500–2,000 pans [19.5-26 t]. We catch about 1,500 pans [19.5 t] but only 500 pans [6.5 t] were kept, and the rest dumped because most of them was other species not targeted* (Interviewee 139).

Since 2011, research into labour practices on board FCVs has found that crews were forced to engage in systematic dumping. If they did not they would be subjected to punishment, including beatings, denial of rest 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, Simmons, Whittaker, & Coulston, 2013; Simmons & Stringer, 2014; Stringer *et al*., 2015). When observers were on board, crew were ordered by their officers to restrict the dumping of fish to when the observers were sleeping, in the toilet, having their meal, or on the bridge. On occasions when an observer remained in the factory for a long period, crew would process the catch and then wait for the opportunity to remove the frozen blocks from the freezer to dump them.

> *When observer asleep we put a lookout on observer's 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* (Interviewees 147, 148, 149, and 150).

> *Another method for throwing fish away is from the kitchen, when there was an observer on board. The excuse the Koreans used was taking fish to the kitchen to feed us, but in reality we were told not to eat it and throw the fish away through a hole in the kitchen* (Interviewee 79).

Former observers, government and independent, who had worked on FCVs since the late 1980s, confirmed the practice of unreported dumping. They were critical of fishing and processing practices, particularly on Korean FCVs. A key theme from the interviews was observers did not feel they could speak openly about the problem, because of the trip by trip nature of their employment contracts which a number described as zero hour contracts. If they were too vocal they feared not getting another trip. A number described working under a culture of fear, fear of not getting any more work if they were too outspoken.

> *Everything goes over the side from Korean FCVs. Nothing good about Korean boats, and many turn a blind eye to it. No-one wants to rock the boat* (Interviewee 9). *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* (Interviewee 1*). 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).

By contrast, New Zealand vessels were associated with lower levels of dumping, although in some areas it was a common practice.

> *The level of offending on the inshore is just horrendous. Anything we don't want goes over the side. A lot of the inshore boats I have been on just don't even record what they throw over the side. I've worked on a lot of bottom long-liners and they have magic hooks, only ever catch snapper* (Interviewee 259).

Interviewees asserted that there were some chronic offenders among them. New Zealand fishers claimed that, at times, there was substantial dumping from their vessels.

> *It's obscene the wastage, but it's a rite of passage as far as many are concerned. They* [valueless fish] *are getting in the way, this is what we are here to catch, so we kill them and ditch them, and that's just the norm. It is seriously that bad. If you question it, I'm told 'what's your problem'. Landing small fish and complaining about dumping pisses the factories off* (Interviewee 270).

One interviewee detailed the dumping practices on his vessel, which he described as an everyday occurrence when fishing. He said dumping was significantly less when an observer was on board, as they minimised bycatch by being careful where and how they fished.

> *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).

3.3.2 Fish smaller than the minimum legal size

It is mandatory for fishers to return fish below the minimum legal size (MLS) to the sea, whether alive or dead. Possession of a fish or shellfish measuring less than the MLS is a criminal offence. Paradoxically, under the QMS, discarding fish less than the MLS reduced the notional loss to the fisher, since there is no requirement to count the sub-MLS fish against quota. This requirement, however, makes enforcement of the discard prohibition more challenging, since the size of any dumped fish becomes one of the key elements of the offence. Until 2014 there was no requirement or indeed procedure to report such legal discards. In 2014, the SNX code was introduced for the first time to enable fishers to report catches of undersized snapper in SNA1. This requirement was introduced after the 1950-2013 period this study covers. It only applies to a single stock. Compliance has not been universal, as illustrated by the following quote.

> *The ones that don't meet the quota size go directly down the discharge chute to the sea. We never record them. But when there was an observer we close the gate that goes to the chute, so we sort out all the fish first, and then the fish that doesn't meet the legal size is put together in a crate. This will be first checked by the observer and recorded and weighed, only then will that fish be thrown away* (Interviewee 233).

Legislation[46] sets out the MLS for seventeen species of finfish and six shellfish species. In theory, the MLS is intended to protect and enhance fish populations by allowing juvenile fish to live long enough for them to spawn. It is also designed to prevent the harvest of small fish and thus permit a greater number to survive to a more desirable size. Whether this occurred in practice depended on the species and the method used to catch it. Many shellfish survive the experience of being caught and then returned to the sea, while "generally, fish do not survive discarding processes well" (Suuronen, 2005, p. 19). In an open access fishery the rule is intended to remove the incentive to capture fish below their MLS, because they cannot be sold. The value of this rule in an ITQ managed fishery is more difficult to rationalize, as catches are constrained by quota. The regulations that first introduced MLS long predated the QMS, and now appear somewhat out-dated.

As described in section 3.3.3.3, the MLS for finfish is frequently less than the minimum economic size (MES), the size at which a fish is big enough economically to be worth landing. As MLS has a major effect on catch reporting, these legal discards form another important component of the unreported catch. It is mainly inshore species that have a MLS and the proportion of legal discards can vary by species, location and season. From 670 shots or tows in SNA1, Walshe, Akroyd, and Miller (1999, p. 10) found the number of sub-MLS snapper caught can be considerable:

[46] Part 3, Fisheries (Commercial Fishing) Regulations 2001.

> Seasonal variations in the proportion of the under size snapper catch ranged [by number] from 8.3 percent in the spring to 16.7 percent in autumn. Undersize catches in autumn were highest in the Hauraki GuIf, and reflected in both the trawl (36.4 percent) and Danish seine (31.4 percent) undersize proportions. These results may reflect the recruitment of juvenile snapper into the fishable length classes during the autumn and winter months. The survey results showed the proportion of undersize snapper decreased with increasing depth, particularly for the depth range less than and greater than 100 metres.

Fish smaller than the MLS are clearly part of New Zealand's overall catch, although they are seldom counted or reported. We make no attempt to quantify them in this study. The primary interest of our interviewees was in the MES (see 3.3.3.3) rather than the MLS, and where they were able to provide data quantifying the discard of "smalls" this would typically refer to fish less than the MES. Any attempt by us to quantify sub-MLS discards separately might result in double counting.

3.3.3 Nine types of dumping

During this study we identified nine main types of unreported dumping, most of which occurred simultaneously. These were: 1) Intrinsically unmarketable, valueless, or low value; 2) Physically damaged; 3) Less than the minimum economic size; 4) Oversized; 5) Degraded; 6) Lack of hold/refrigeration space; 7) Incompatible with other catch species; 8) Uneconomic catch size, and; 9) Quota induced. A species may be dumped for several reasons, for example spiny dogfish: "Because of processing problems due to their spines, sandpaper-like skin, and short shelf life, and their low economic value" (Ministry for Primary Industries, 2013b, p. 1190).

3.3.3.1 Intrinsically unmarketable, valueless, or low value

Fishers have always caught bycatch species that they could not sell, either because there was no demand or because of latent demand. Fishers commented that they had sometimes caught significant quantities of unmarketable bycatch, which were not worth landing. Even where a species was marketable, it might be dumped if of low value. Burns and Kerr's (2008, p. 28) study, for example, considered that the then values for spiny dogfish, skate, red cod, sea perch and ghost shark, between NZ $0.37kg and NZ $0.75kg, were too low to justify the effort of landing them. As one fisher explained:

> *Spiny dogfish, I never have one on the boat. I just put my knife through their guts, I open their guts up and put them to the bottom of the food chain that's how I look at it, because nobody wants to buy it from me, so absolutely pointless hanging onto it. Years ago before the quota management system, we used to catch many granddaddy hapuku but they only gave us 20 cents a kilo for them, whereas we were getting $2 a kilo for snapper. So they didn't get room in the fish hold and went back. Anything we couldn't sell just went back. They only wanted snapper, whereas now you can't make a living catching snapper cause the quota owner takes too much in lease. Its madness and those hapuku are worth more than snapper now, to the fishermen* (Interviewee 227).

3.3.3.2 Physically damaged

Fish can become damaged before being landed on deck. They can be damaged in the net, especially if a large catch which causes fish to be crushed at the cod end. The longer the trawl, the more damage to fish. On factory trawlers, damage can also occur when the net is hauled onto the deck and particularly when the catch cascades from the net down into the factory pound.

> *Often fish get crushed in the net so we have to throw them away and when we push them through the pound they get damaged. Just keep the best hoki* (Interviewee 131).

In line fisheries, hooked fish may be damaged by attack from other species such as sharks. Cumulatively, these events can produce large quantities of damaged fish. In 1996, for example, operation 5-O identified that up to 5% of the total catches from five chartered Russian fishing vessels (the Om, Osha, Olenino, Orlovka and Ognevka) was routinely damaged and processed into fish meal, and under-reported as

offal.[47] Interviewees confirmed this was not unusual, stating that they had always dumped damaged fish or turned it into fishmeal and not reported it, even when an observer was on board.

> *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* (Interviewees 79, 208, 209, 210, and 211).

Increased enforcement has resulted in the increased reporting of some damaged fish during the last 10 years. Recent prosecutions of officers from the Oyang 75, Oyang 77, Melilla 201, and Sur Este 707 highlight the ongoing practice of dumping large quantities of damaged fish and not reporting them (see: Ministry for Primary Industries v., Chong Pil Yun, Juncheol Lee, Wongeun Kang, & Minsu Park, 2012; Ministry for Primary Industries v., Kyung Ju Kim, & Gyeong Deog Gim, 2014; Ministry for Primary Industries v. Dae Jun Lee, 2014). Observers and particularly FCV crew interviewees explained that this type of dumping was very common because damaged fish, which they referred to as 'bulog', was worthless.

> *When we had large catches a lot of fish was squashed, especially hoki and southern blue whiting. We sometimes put this damaged fish into pans as bulog, and sometimes dump it all. The amount of damaged fish that was kept depends on the captain's instruction especially when there was no observer on board. The captain decided what sizes of damaged fish we keep* (Interviewee 159).

> *Quite often around 3% is damaged, from a bag. So when we see a boat recording, from the hoki trawl on the West Coast, 0.3% as damaged…that's bullshit. They were throwing away fish, simple as that, and that's what my figures show* (Interviewee 202).

3.3.3.3 Less than the minimum economic size

Commercial fishers have always recognised that there is a minimum economic size (MES) for fish. For many species, small fish under a certain size have historically been worth much less compared to larger ones, resulting in a financial loss if landed. Often they were dumped. This type of dumping was first highlighted by Parliament's 1937-1938 Sea Fisheries Investigation. In 1969, the Fisheries Committee to the National Development Conference (1969b, p. 82), found that "there is no minimum size regulation for red gurnard but there is a considerable market resistance to small fish, less than 10 in. [25 cm] in length, particularly in the North Island. The lack of market demand for fish less than a certain size may, result in the fish being dumped at sea." During the present study interviewees confirmed this was still the case, not only for red gurnard, but also for at least 45 other species.

> *LFR told me I won't be getting paid for fish under this size, between this size and what's minimum legal. Got told 'in my day we had a hole in the side that observers didn't know about. So you just have to think strategically, this is not a joke, you are in business to fucken make money and you can't afford to piss around. If you are out there and have half a ton of flounder and just landed 800kg of red cod, it's a no brainer you have to ditch your cod* (Interviewee 270).

Prior to the QMS the cost of landing sub-MES fish largely comprised the time and effort involved in handling them. The QMS added a financial component to this: fishers had to pay for quota to cover sub-MES quota fish. As well, *"companies only wanted premium fish* [greater than MES] *so they split fish into two prices. Got paid more than double for premium. Before it was all in one price"* (Interviewee 226). Following the introduction of the QMS there ought to have been an increase in the landings of fish less than the MES for many species. We do not know whether this has been the case, as official statistics do not include the sizes of fish landed. The MES for 12 common species is shown in Table 4. These were derived from commercial fishers. We consider the wider issue of quota induced dumping further in Section 3.3.3.9.

[47] Ministry of Fisheries v Abel Fisheries Ltd, Unreported, District Court, Wellington, CRN 7085005665, 23rd February 1998.

Table 4: Minimum economic size (MES).

NZ Code	Common Name	Latin Name	Minimum Economic Size (cm)	Minimum Legal Size (cm)
BAR	Barracouta	*Thyrsites atun*	50-70	33
BNS	Bluenose	*Hyperoglyphe antarctica*	45	35
GUR	Red gurnard	*Chelidonichthys kumu*	30	
HPB	Hapuku & Bass	*Polyprion spp.*	45	
JDO	John Dory	*Zeus faber*	30	
JMA	Jack Mackerel	*Trachurus spp.*	30	
KAH	Kahawai	*Arripis trutta*	35	
LIN	Ling	*Genypterus blacodes*	50-75	
RCO	Red Cod	*Pseudophycis bachus*	45	25
SNA	Snapper	*Pagrus auratus*	30	25
SQU	Squid		20	
TRU	Trumpeter	*Latris lineata*	40	

Although dumping fish subject to quota is prohibited, being required to land fish at a financial loss provides a strong incentive to dump small fish. A fisher who landed his sub-MES *"would get the weights back which were accurate but then there was 100kg of fish I wouldn't get paid for, because it didn't fit the economic size profile, he* [the LFR] *wanted"* (Interviewee 270). Other fishers took a different approach:

> *I'm fishing where there is 50% smalls. So we will catch 100kg of nice sized gurnard and 25-30 kg of small sized, but by number there as many individual smalls as large. Thrashed it last year and one of the crew complained how he had to stay up all night tipping smalls over the side once it was dark* (Interviewee 199).

For some fishers, the existence of a MES for particular species provides an incentive to improve gear selectivity and fishing practices. One fisher trialled a trawl net designed to reduce the catch of sub-MES fish.[48] From 18 trawls using a standard net, the catch of sub-MES fish caught amounted to 62.1%, by number for all species. When he used the modified net, bycatch was reduced by 54% and sub-MES catch by 28%. Few fishers have adopted this type of improved catching technology. Another fisher (interviewee 217) confirmed that it was not worth landing fish under the minimum economic size, given he could *"only get bait or fishmeal prices"* which would not cover the cost of quota nor provide a wage for his crew. Another (Interviewee 268) who fished an LFR's quota was warned not to land sub-MES fish.

FCV crew confirmed they also dumped fish on the basis of size:

> *As instructed by the factory manager or captain, only 15–20 pans were kept of small sized hoki. M, L and LL sized fish was all kept but S and smaller size were always dumped. Towards the end of the trip the M size would be thrown away and only the MM, L and LL were kept. The amount we dumped when we caught 3,000 pans [39 t], was 500 pans [6.5 t]. Dumping happened every tow, in August twice a day for hoki, but this happened only when there wasn't an observer on board. When observer on board it was less* (Interviewee 41).

> *The dumping of barracouta is a lot, because not very valuable. We only take the M size, and L when we still have a lot of fish to catch, but when we almost reach our quota limit only the L is kept and we throw away all M size, even from the holds. I see this frequently, and when I asked the captain and chief engineer why the M size is thrown away and only L is kept, they said 'well the M size is now too small, we only take the L size'* (Interviewee 211).

[48] Trials of the turned mesh trawl aboard the FV Nancy Glen II, prepared by Oliver Wade, 19th September, 2011.

What is the extent of this type of dumping? An interviewers' notes from the Ministry of Fisheries commissioned research into 'Commercial Fishers' Compliance Decision Making', sheds some light on this.

> He argues that the biggest compliance issue is that of small 'undersized' fish and the need for minimum sizes for quota fish species. Process of deemed values then requires those vessels to pay for fish they haven't landed and suffer and use up valuable quota. The solution is either put in place minimum sizes or double the Total Allowable Catches to acknowledge the discard component (part of historically recorded catch) (Kazmierow *et al.*, 2010, p. 43).

A 2012 official investigation into the extent of the problem found it to be significant. Operation Hippocamp (Ministry for Primary Industries, 2012b) was undertaken to determine the level of dumping and high-grading in one fishery. Information on catch composition and fish size was gathered on board vessels and compared to the reported landed catch at the wharf and/or in LFR premises. There were large discrepancies between the at sea and landed data. There were almost no small fish in the three landings. One LFR only paid for gurnard over 32 cms. Another only accepted gurnard above 28 cms. Apparently as a consequence, vessels only landed gurnard over 36 cms in length. Between one third and two thirds of gurnard by number were discarded at sea. Similarly, almost no elephant fish under 50 cms were landed. In short, Operation Hippocamp determined that the much lower port prices for fish under a certain size influenced whether fish were landed.

3.3.3.4 Oversized

Large fish can also have little value and hence be not worth landing. As is the case with minimum economic size, this type of dumping is driven by customers who only want fish of a certain size, or within a certain size range, not too small and not too big. One interviewee commented that, for certain species, if a fish was bigger than a plate customers did not want them. New Zealand interviewees described the process induced by minimum and maximum sizes as *"going fishing with a shopping list"*. FCV interviewees described it differently:

> *Always dumping ling especially the size of L or bigger or any size that can't fit into the pans. A pan takes 13 kilos and fish that are larger than 13 kilos would not be kept. Sometimes these big fish would be chopped up and thrown away, or thrown away whole. One ling weighs about 20 to 25 kilos. On each tow about 100 fish ling were dumped every day in June and July. That's every time we haul in, and sometimes we haul in 3 times a day or twice. I made a comment to the factory manager; 'Why we throw this fish away?' and he said 'this fish has no money value, it's very cheap.' When they tell us to dump, we dump, otherwise they will send us home and this creates much worry if they send us home before the contract finishes - our labor would have been in vain as no money. So when the Koreans order us to do something, we do it* (Interviewee 25).

3.3.3.5 Degraded

Dumping due to degradation is a result of fish not being processed before it spoils. We found the practice is primarily a consequence of large catches. Our findings agree with Clark, Anderson, and Gilbert's (2000) conclusion that dumping is significantly influenced by the size of the catch. With large catches there is "more likelihood of processing delays affecting the quality of fish on deck or in the pounds for long periods" (p. 26). FCV officers and crew stated that it was routine practice to catch much more fish than they could process. This particularly applied to catches of hoki, southern blue whiting, and squid. These are soft species and spoil quickly unless properly cooled. One FCV officer explained that was why *"when there are a lot of fishes, they* [migrant crew] *work for 24-36 hours and don't sleep"* (Interviewee 271). Due to the configuration of many FCVs, fish can only be cooled once they are processed and frozen down as blocks by plate freezers.

> *During hoki season the bags are always full, but we cannot process before fish go off, so always have to throw away and replace with new fish* (Interviewees 208, 209, 210, and 211). *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 can be half the catch* (Interviewee 131).
>
> *During squid season we dumped the squid that had swollen up or changed colour from grey or white, to reddish which means they are rotting. Dumping occurred when we caught a lot of squid while there is still squid left to be processed in the factory. We will dump this and replace with fresher squid. For undersized squid, smaller than S, always throw away. We only take the fresh squid if there was no observer on board. If there was observer we cannot dump so much - put more squid into bulog category* (Interviewee 209).

FCV crew are paid a fixed wage (ostensibly a minimum hourly wage), whether they are processing or not. Captains therefore strive to keep them productive. They also want good quality processed fish although some species deteriorate quickly. Both objectives can be achieved by landing large catches at regular intervals. In this way fish is always available to keep the crew processing. If the crew have not finished processing the trawl by the time the new catch was being hauled in, they are ordered to dump all the remaining catch remaining in the factory to make way for the new catch. In his findings concerning the sinking of the FCV Oyang 70, which sank near the Bounty Islands on 18 August 2010, the Coroner commented on this practice of taking large catches. The Coroner found that the main reason for the sinking was the captain's attempt to haul a 120 tonne bag of southern blue whiting onto a vessel with marginal stability. This led to a "catastrophic and sudden chain of events" that the captain and officers were unable to counter. "Factory personnel were bizarrely left processing fish until they were in water of a metre's depth, and left their work stations at their own initiative shortly before the ship's electricity failed and the vessel rolled over" (Coroner R G McElrea, 2012, p. 24). The captain was known for taking large catches.

Surviving crew (i.e. Interviewees 82-106) described southern blue whiting as a very soft oily fish which quickly spoils and, should be processed within 6 hours, at most 12 hours. While the 120 tonne catch was being hauled in, the crew were dumping fish from the previous catch to make room for the new catch. If the Oyang 70 had not sunk, crew could only have processed up to 20 t of the 120 tonne catch before the catch spoiled and they would have been ordered to dump the remaining 100 t. In other words, the real catch was 6 times what would have been reported. The crew pointed out that while this was a very large catch, they commonly dumped at least 50% of large catches, mainly due to degradation, as the capacity of the plate freezers limited the amount of fish that could be frozen down before it degraded.

3.3.3.6 Lack of hold/refrigeration space

We found that a shortage of hold/freezer space for higher-value species was often a reason to dump lower-value species. One fisher described how he *"let go 30 tonne once, no space and no one to give it to"* (Interviewee 236). Another interviewee who worked on a trawler in the orange roughy and hoki fisheries during the 1970s and 1980s commented that the lack of freezer space meant non-target species were dumped, in favour of higher-value target species. Similarly, freezer space aboard FCVs was often reserved for high-value species.

> *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).
>
> *If there was observer, then all undersized fish was put into bulog category, sometimes amounting to 2-3 shelves full or about 300 pans. One shelf takes about 120 pans, so if we have 2 shelves full then we have around 240 pans* [3.1 tonnes]. *But if no observer all these were thrown away, because they* [officers] *think it just wastes storage space in the freezer* (Interviewee 25).

3.3.3.7 Incompatible with target species

Species that are incompatible with target species are routinely dumped. Some species are incompatible with target species, as they can cause damage to them, for example spiny dogfish have rough skin and sharp spines which cause abrasions to other species. Black oreo also have abrasive skins and spines that

causes damage to other softer skinned species. Sharks may also be dumped to prevent ammonia leaching from them into target species, thus rendering them unmarketable. Species such as eels produce slime, making them problematic to handle and store. Some interviewees pointed out that, given the time required to process sharks, their time was better used resetting gear for higher-value target species.

> *Spiny dogfish we throw them all away. Twice the net was full of them, approx. 4,000 to 5,000 pans [52-65 tonnes]. They damage the fish and it's hard to get Spiny Dogfish out of the net, because they have rough skin, and the spine gets caught up in the net. So in the end we have to just tear the net up and throw everything back into the sea* (Interviewee 212).

3.3.3.8 Uneconomic catch quantity

Dumping of small catches occurs where the catch quantity is too small to process and pack economically. FCV crew explained that, if the catch was not large enough to fill one plate freezer, on occasions they would be instructed to dump the catch and wait for the next one. Often at the end of a processing run, some pans would only be partially filled. Once frozen these partial blocks were put aside in the hold. Sometimes they would be combined with other partial blocks to make up a carton. If not they were eventually dumped.

> *When we were approaching port to unload our catch we were often instructed to throw away some fish that had been frozen, especially the odd sized pans that didn't fill a carton, or pans that contain different types of fish. In each carton the fish must be the same size and the same species of fish. So the odd pan would be discarded regardless of what species they were* (Interviewee 158).
> *In our most recent voyage warehou, ling, sea perch, and squid was dumped because of insufficient quantities of those species for us to pack* (Interviewee 263).

3.3.3.9 Quota induced

Prior to the introduction of individual transferrable quotas (ITQs) the Ministry of Agriculture and Fisheries (MAF) recognised that "although ITQs provide controls on the landing of fish species, they do not effectively control catches. When catches are limited by ITQ allocation individual operators will probably want to high-grade the quality and size of fish so as to increase the economic returns from a fixed allowance of catch" (Ministry of Agriculture and Fisheries, 1985). Fishers confirmed that following the introduction of ITQs in 1986, lower-grade fish was indeed dumped at sea. Interviewees explained that quotas had been based on their historical recorded sales and not on what they actually caught. When quotas were set they did not incorporate an allowance for the discards of undersized uneconomic fish, which had always been dumped and not reported.[49]

> *Our biggest problem is discards and [mis]reporting. The whole thing needs to be resolved, I know we're breaking the law but we were never given our real catch histories in the first place. That's why I won't change my practice, because the moment I start bringing in smalls I have admitted defeat in my own mind* (Interviewee 268).

Fishers reasoned that "if their catches were to be limited, they needed to fetch top dollar for every fish landed against their ITQ" (Boyd & Dewees, 1992, p. 188). This became a major issue for MAF following complaints about the high-grading of snapper (Ministry of Agriculture and Fisheries, 1992). Fishers confirmed this continues to be the case: *"Not only fish to order but for grades as well, so if a certain grade of fish is wanted other fish will be discarded"* (Interviewee 246). The dumping of by-catch as a result of the ITQ system also became a significant problem (Rowe, 2006). Rowe's analysis "showed that a significant positive relationship exists between quota availability and by-catch reporting" (p. 48). He

[49] Kazmierow *et al.* (2010), provide a good understanding of this issue. One of their interviewee's explains: 'There should be a minimum legal size on all species set out at the minimum marketable size, below which discarding should be allowed. Having to land fish of a size or species for which there is no market is silly and unrealistic to have to count against quota, as quotas were originally set based on marketable fish, so by default discards have been allowed for as opposed to dumping of marketable fish (which must be avoided if at all possible). Having deemed values set above market prices is not helpful and only encourages dumping (p. 89).

found that "as much as 41% of elephantfish taken as a by-catch of one flatfish fishery may be dumped and under-reported" (p. iii).

Quota-induced dumping was a major problem on FCVs.

> *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* (Interviewee 61).

Quota induced dumping was also undertaken to avoid overfishing penalties. This was influenced by fishers' quota packages not being aligned to their particular fisheries. It was a particular problem for small inshore fishers.

> *Everybody seems to forget it's not a farm, they keep talking about it as if it's a farm, but it's not, its wild stock that you cannot see. We cannot get it all right like a farmer can. Fishing is not like that* (Interviewee 170).

When Dewees (1989) examined the list of provisional quota holders in the late 1980s, he noticed that many had sold part or all of their historical by-catch quota. A number of interviewees confirmed that this created a post-QMS situation that encouraged them to dump bycatch in spite of the catch balancing system. In 2001, the simplified 'deemed value' system replaced catch balancing. Deemed values were intended to discourage overfishing and encourage the landing of all fish caught (Walker & Townsend, 2008). Under this system fishers paid a deemed value fee when they are unable to acquire sufficient quota to cover their catch. According to a number of interviewees, in practice the deemed value system did not work as intended.

> *Was told no more [of a particular species], so steamed a long way away and shot the gear again and up it came again, same bloody madhouse. So chucked them over the side. If we'd put them in, we would have owed the government over $10,000 for a day's fishing* (Interviewee 244).

New Zealand fishers complained that one of their biggest constraints was the unavailability and price of quota for certain species. As a consequence some stopped targeting certain species. If they accidently caught these species as bycatch, they dumped the fish because they were unable to pay the deemed value penalties. *"If you have 2 tonne of snapper quota and get 10 tonne in one pull, which has happened, deeming it doesn't work. What are we supposed to do with it?"* (Interviewee 245).

Unsurprisingly, interviewees were highly critical of the deemed value system, which in their view encouraged them to dump quota species they did not have quota for.

> *We have best intentions to do certain things but then it goes all wrong, cause the wrong fish down there have taken my hook, and I'm not allowed to dump it, can't get quota to land it, and am expected to pay more than I can sell it for* (Interviewee 247).

> *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).

> *This deemed value is the biggest rort of all. The processor and distributor make their money on the fish, but the fisherman has to pay extra money to the government. Why would we pay a deemed, to sell the fish for less than what it cost us?* (Interviewee 178).

> *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).

> *If we landed it, it would be a disaster. It all goes over the side* (Interviewee 164).

Even tuna (*Thunnus spp.)* were dumped to avoid deemed value penalties. Some fishers described dumping tuna on every voyage. One interviewee described dumping 18 mature blue fin tuna on one day alone in 2013, while another dumped 4. One interviewee was furious about the unnecessary dumping that he has engaged in since 2001, because despite his best efforts he could not have avoided it:

> *It's a bloody embarrassment…take active measures to avoid it [a tuna species], 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).

Like Kazmierow *et al.* (2010) we found most New Zealand fishers do not set out to break the rules. In the main, they do their best to comply. However, the complexity and restrictive nature of regulations, coupled with unbalanced quota packages and the multi-species nature of fisheries meant bycatch, and consequently dumping, was unavoidable. Kazmierow *et al.* (2010, p. 42) emphasise:

> Most trawlers eventually find themselves "landing a net full of dogs" (i.e., spiny dog fish). Some skippers indicated that most would normally release the net load of such unwanted quota fish and not record the catch. This would ensure they did not incur a high deemed value bill, or use up quota that the fisher may or may not have. Technically such behaviour violates the regulations. Some believed that those skippers who opted to comply fully with the regulations would unfairly bear a high cost of complying with the rules, in terms of deemed value bills and loss of productive fishing time with unnecessarily processing and landing unwanted fish. From these interviewees' perspective, such fishers would risk going broke; while the skippers who opted otherwise would, while attempting to comply where practicable, break what they saw to be an impractical rule.

A number of official investigations and reports confirm that quota induced dumping/non-reporting is significant. Operation Achilles undertaken in 2012 (Ministry for Primary Industries, 2013g), provides an indication of the extent of the problem. Its findings are consistent with those of Operation Hippocamp, which found between one third and two thirds of fish may be dumped by inshore trawlers. Achilles found that 20-100% of some quota species from every haul were discarded. Other species were retained but not reported: e.g. hapuka (HAP), moki (MOK), kahawai (KAH), and king fish (KIN). Fishers failed to report any catch on some hauls and for one vessel only one of two Hector's dolphins (HDO) caught, was reported. Even in the presence of a Ministry Observer large quantities of QMS species were discarded. An extensive examination of the hauls made by one vessel between November 2012 and February 2013 "concluded that [name withheld] consistently and deliberately illegally discarded substantial quantities of quota fish, in particular he regularly discarded all small and damaged ELE [elephant fish], many small gurnard (GUR) and did not report rough skate (RSK) discards." The Achilles report further notes that:

> Following these findings the five other vessels involved in this project were also examined, which revealed that four of the five vessels openly discarded substantial quantities of quota fish and or did not report fish as they are required to under the Fisheries Act (p. 2). While this behaviour is alarming it is also not surprising as previous research and observations have indicated that the dumping/non reporting has been occurring in this fishery for many years (p.19).

3.4 Recreational and customary catch

From the 1950s until early-1970s near shore and harbour fisheries were very abundant, producing big catches for limited effort (Johnson & Haworth, 2004). The removal of licencing in 1963 and the 'think-big' policies of the 1970s led to a major expansion of industrial fishing inshore. Pair trawling was introduced and recreational catches peaked at the end of the 1970s. Rock lobster and several shellfish species were fished down by the early 1980s. Many large shellfish beds disappeared. Farmed green lip mussel (*Perna canaliculus*) replaced wild recreational shellfish in diets. Declining abundance caused recreational catches to decline, before an expanding recreational fishing population drove aggregate catches higher (Ministry for Primary Industries, 2013b). Population growth, coupled with constantly improving fishing technology and better access to fish stocks through more and better boats contributed to increased recreational fishing pressure (Hauraki Gulf Forum, 2014). Annual recreational catch estimates vary widely between 8,000 t (Hartill, Cryer *et al.*, 2012) and 25,000 t (Ministry of Fisheries,

2008). Traditionally there has been considerable inter-annual variation in recreational catches, but there is little reliable historical data that captures this variation, despite the range of methods used to estimate the total recreational catch during the past 30 years (Hartill *et al.*, 2012). In consequence, the approach taken in this study is a best estimate based on the most recent recreational catch estimates.

Snapper (*Pagrus auratus*) and kahawai (A*rripis trutta*) comprised about 40% of recreational catches, while other finfish like kingfish (*Seriola lalandi*) and blue cod (*Parapercis colias*) made up around 38%, and invertebrates about 24% of the total recreational catch (Hartill & Davey, 2014; Wynne-Jones *et al.*, 2014). 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). This area 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 under the rights conveyed by the Treaty of Waitangi, which is neither commercial, recreational, nor for pecuniary gain or trade (Ministry of Fisheries, 1997). This catch is not equivalent to sustenance fishing. It has a narrower application 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 Regulations.[50] Both must be authorised in advance by tribal elders known as Tangata Tiaki/kaitiaki (Ministry of Fisheries, 2008). Authorisation is typically for a specified number of individuals of each species, to be harvested for a ceremonial or traditional ceremony or function. Permits are copied to MPI, 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, there is very little information on the size of customary catches (Ministry for Primary Industries, 2013h). Often there is only a record of how much harvest a permit allows by species, but little information on the actual amount harvested. Nonetheless, "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, p. 10).

The total recreational and subsistence (customary plus amateur) catch for the years 1950 to 2010 was estimated at 512,000 t. Of this 33,700 t was subsistence catch and 479,000 t was recreational catch. For the period 1950 to 2013 the total recreational and subsistence catch was estimated at 549,000 t, comprising 35,100 t subsistence catch and 514,000 t recreational catch.

4. Discussion

Our findings show that the FAO data (14 million t) understate New Zealand catches in all years from 1950 to 2010, largely due to missing data. There are also large discrepancies between the FAO data and our reconstructed national data (17.7 million t). To the reconstructed national data is added invisible commercial landings (5.7 million t), unreported dumped commercial catch (14.3 million t), and recreational and customary catches (512,000 t). 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 38.1 million t. This indicates that actual catch was 2.7 times the 14 million t reported to the FAO on behalf of New Zealand for the same time period. The extended reconstructed estimate for 1950-2013 is 40 million t, comprised of 19 million t nationally reported, 5.8 million t of invisible landings, 14.7 million t of unreported dumped commercial catch, and 549,000 t of customary and recreational catches.

This is not entirely surprising, given that many reports and studies have described misreporting as a significant problem (e.g. New Zealand House of Representatives, 1937-1938, 1962; Macgillivray, 1990;

[50] The Fisheries (South Island Customary Fishing) Regulations 1998 or the Fisheries (Kaimoana Customary Fishing) Regulations 1998.

Williams, 1999; Ministry of Fisheries, 2001; Rowe, 2006; Burns & Kerr, 2008; Bremner *et al.*, 2009; Ministry for Primary Industries, 2012b, 2013g). Since 1986, when the QMS was introduced with the professed intention of improving sustainability, the economics of fishing, and reporting, the total catch is conservatively estimated at 2.1 times greater than the FAO data. The discrepancy between the reported and the reconstructed catches is due to inadequacies in reporting, but primarily due to widespread and systematic under-reporting of commercial catch. Before 1981, there was an "almost total lack of reliable fisheries statistics" (Department of Statistics, 1981, p. 8). Since 1981, under-reporting continued (Boyd & Dewees, 1992), but did decrease after 1986.

Despite efforts to collect reliable data during the past 110 years, New Zealand's catch reporting systems continue to be inadequate. Essential data are either lacking or missing from official statistics. Official documents have long highlighted the inadequacies of catch data, and acknowledged the significant levels of dumping and misreporting of catches. Even following the introduction of the QMS along with its supposedly better reporting systems, nefarious reporting practices persisted. Reliable catch data is a basic and essential requirement for the effective management of fisheries (Pitcher, Watson, Forrest, Valtýsson, & Guénette, 2002; McCluskey & Lewison, 2008). For most fisheries management purposes the essential data required is a reliable time series of catches of each managed species (Department of Statistics, 1981; Williams, 1999). Without this, fisheries management personnel cannot properly interpret trends, the effects of technology, or accurately evaluate the social and economic impact of actual or projected fisheries management measures (Cameron & Hughes, 1990). New Zealand's reporting system needs to account for all of the catch. This is vital to maintaining sustainable fisheries.

Addressing the issue of misreporting will not be easy: "Detecting and therefore deterring offending in New Zealand is inherently difficult due to the size of the EEZ, the length of the coastline and the number and geographical spread of fishing industry participants" (Ministry of Fisheries, 2003. Paragraph 26). Relying on criminal sanctions alone to deter misreporting is never likely to succeed. Despite an increase in the ratio of compliance staff to commercial fishers over the decades, misreporting continues. The ratio seems to have decreased since 2009. As one compliance officer lamented "if you don't look for problems, you won't find them. What's more, penalties are viewed by many in the industry, particularly the foreign charter sector, as merely a cost of business."

The most recent advances in information technology (e.g. e-log book technology and the development of smartphone apps for reporting catch and effort data) have made it relatively straightforward for commercial fishers to comply with catch reporting requirements in real time. However, the most serious obstacle to accurate reporting over the entire period covered in this study has not been that it was technically impossible for fishers to report accurately but that, for various reasons, the misreporting of catches has been profitable, while the chances of being detected and sanctioned have been very small.

A key theme that emerged from the interviews was the deliberate and systematic dumping of fish, particularly by FCVs. Dumping was found to be significant, principally during the 1980s and 1990s. The evidence indicates it continued to be a major problem until at least 2012. The dumping of fish and non-reporting of catches was also found to be significant in the inshore sector. While inshore stocks are much smaller, their fisheries, while less important economically, are much more important socially. Crucially, far less is known about what actually happens in the inshore. There has been virtually no inshore observer coverage during the period covered by this study and few stock surveys. While the perceived low economic value of some fish has always driven dumping, new drivers came into play following the introduction of the QMS and, later, the introduction of deemed values. If quota was unavailable to cover a catch and a fisher faced the alternative of a high deemed value bill or dumping catch it is perhaps not surprising they chose the latter option. It certainly is not desirable. It was recognized from the inception of the QMS that accurate reporting of catches was imperative for success (Pearse, 1981). That recognition seems to have been absent in some fisheries management decisions.

Given perfect information, the superior economic efficiency of a management system based on output rather than input controls is possible. However, if the catch information provided by fishers is sufficiently

unreliable there must come a point where input controls or other mechanisms are superior. In the most extreme case fishers provide no credible information whatsoever. In this circumstance a fishery can still be managed, but output controls based on self-reporting will clearly be ineffective. "We should be nondogmatic in our choice of management technique and we should select from the array of available fisheries management devices, the combination that is most beneficial and least deficient in any particular set of circumstances" (Copes, 1986, p. 290). The case for or against management by ITQ ought to be assessed on a fishery by fishery basis. The probability that fisheries managers can obtain accurate catch data has to be a critical part of any such assessment (Copes, 1986). It is important to systematically and regularly review the level of misreporting, as it is unlikely to remain static. There have been few serious attempts to assess the degree of misreporting in New Zealand fisheries since the inception of the QMS in 1986. Any such attempts have been uncoordinated and usually ignored by fisheries managers. To the best of these authors' knowledge no consideration has ever been given to removing a species from quota management in the event that catch information provided was simply too inaccurate. While more enforcement is an obvious answer, new approaches are also needed, as the same thinking that created and fostered the present unsatisfactory situation is unlikely to result in better reporting.

The levels of misreporting identified by this study "provides little confidence that fish are being harvested at a sustainable rate" (Cameron & Hughes, 1990, p. 41). Misreporting undermines the sustainability of fisheries, through its impact on Catch Per Unit Effort (CPUE), the key statistic that drives most New Zealand stock assessments. Undeniably, "catch data are a crucial part of any fisheries assessment — it is impossible to calculate the maximum weight of fish that could be harvested sustainably without knowing what is being caught each year" (Pauly, Hilborn, & Branch, 2013). Inevitably this results in flawed decisions about controlling fishing at sustainable levels. Flawed decisions can be costly to commercial operators through economic distortions such as over or under capitalisation, which engender undesirable economic outcomes. Successive fisheries Ministers may have been making suboptimal decisions on fisheries, because they have been given advice based on misleading information. This situation will not improve until the reliability and accuracy of New Zealand's catch data improve. We therefore repeat a key recommendation from the National Research Advisory Council Commercial Fisheries Working Party report (1980): That "the collection and analysis of [reliable] fisheries statistics be given priority". This must be undertaken to avoid the erosion of trust in New Zealand's fisheries management system. Ultimately, as Metuzals *et al.* (2006, p. 87) argue, "if misreporting is ignored, and catch data are worthless, what you have is an uncontrolled fishery."

The situation is exacerbated by official secrecy in respect to catch and effort data. All commercial landings and a high proportion of inshore catches have many witnesses, but whether or not catches have been reported at all, let alone reported accurately, is generally known only to the captain of the fishing vessel. The secrecy around catch and effort reporting has always been justified on the grounds that fishers would be reluctant to furnish accurate data if their competitors could monitor their catch rates and fishing locations. Yet the QMS was designed to halt 'the race for fish' through the provision of secure access to fisheries. Catch and effort data including approximate catch location ought to be publicly available. Making such data publicly available would promote better science by enabling all stakeholders to play a much greater role in management and protection of what is, after all, a public resource (Sullivan, Acheson *et al.*, 2006). Opening up catch reporting in this way would be consistent with the Declaration on Open and Transparent Government (Cabinet, 2011, p. Appendix 1), which states (*inter alia*) that it is important for all stakeholders to access high value public data "to grow the economy, strengthen our social and cultural fabric, and sustain our environment." A related problem is that government observers are effectively sworn to secrecy, and have been threatened with prosecution if they provide information to anyone outside strict official channels.

Greater transparency in the construction of fisheries management policy and official advice would also be valuable. This applies especially to the construction of estimates of other sources of fishing related mortality (OSFM). We agree with Mora *et al.* (2009, p. 1) that "the conversion of scientific advice into policy, through a participatory and transparent process, is at the core of achieving fisheries sustainability, regardless of other attributes of the fisheries". For most species the stock assessment plenary documents

simply state that no information is available on illegal and unreported catches, despite the existence of threat assessments and compliance risk profiles; the outcomes of multiple compliance operations; and many reports from observers and informants. The reason why such information is ignored, or the way in which it is used or not used in creating policy, has never been open to public or academic scrutiny.

It would also be helpful if Fisheries Management officials spent more time talking and listening to compliance officers, fishers and observers. During the last two decades much emphasis has been placed on consulting with quota owners and their representatives. There are now very few fisheries management staff located in significant fishing ports. Only three are now 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 land, what to discard, and what to report are carried out by those operating fishing vessels, whose captains have been almost entirely omitted from the discourse about fisheries management. If fisheries management officials do not include fishers, they risk alienating them, despite their participation being essential to the fisheries management process (Doom, 2001). The vast majority of fisher interviewees expressed disquiet at how disengaged they were from official discussions and decisions that directly affected them. Like Kazmierow *et al.* (2010, p. 49), we also suggest that the Ministry engage with the fishers themselves "as professionals". This lack of engagement has led to a growing knowledge deficit within officialdom, and an apparent blindness amongst fisheries management officials and scientists about the prevalence of catch misreporting. Torkington (2015) well highlights the gulf between officialdom's incoherent and conflicted policies and the actual realities faced by the fishers themselves. Catches in practice are unpredictable, variable, and inevitably multispecies in nature. Fisheries management in New Zealand continues to follow a single species approach.

Managing multi-species fisheries is challenging: "Part of the species mix is likely to be overfished, and excessive discards of fish catches above the allowable quota are likely" (Boyd & Dewees, 1992, p. 188). For so long as the fisheries management system provides incentives to misreport catches, the only way to ensure accurate reporting will be 100% observer coverage, draconian enforcement, use of more selective gear, combined with public access to all data (Gibbs, 2008). Full observer coverage may be impractical and 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. It is in the interests of the nation that all catches be reported and landed, and that incentives to take fish over quota be removed. The government sanctioned overfishing system i.e. the deemed value system imposes financial penalties on catch not covered by quota, and thus incentivizes both discarding at sea and misreporting. Indeed, "dumping and high-grading are in some ways an almost inevitable outcome of quota-managed fisheries" (Gibbs, 2008, p. 24). For too long "illegal catches [have been] a substantial proportion of the total in many New Zealand fisheries, particularly those for high-valued species" (Francis, Gilbert, & Annala, 1993, p. 65). Amendments to the system are needed now, to remove financial penalties for reporting over-quota catches and also to minimize incentive to take fish in excess of quota in the first place.

If the QMS cannot be refined this way, then the use of a tamperproof real-time Electronic Monitoring (EM) system incorporating on-board video, across the entire fleet, to collect location, and catch and effort data, would at least ensure that reporting was enforced. As EM is a two-step process, it is critical that data quality and the data recording conditions (i.e. meta-data), are effectively monitored independent of industry to ensure that fisheries data can be reliably determined. This could be reinforced by greenweight weighing at sea, or dockside weighing of landings by compliance officers or official observers. Misreporting and dumping can occur, where quotas and the science underpinning them are not respected by fishers and not effectively enforced (Beddington, Agnew, & Clark, 2007). Strong enforcement is therefore important, as inadequate enforcement can encourage dumping and misreporting resulting in poor scientific data, thereby undermining the integrity of the QMS (Pearse, 1991). Though, it is well recognized that the only successful method of obtaining reliable information at sea is from official observers (Benoît & Allard, 2009). In order to produce reliable catch data, 100% observer coverage on every vessel is required. Complete observer coverage would also enhance buy-in, trust and co-operation within industry and between industry, science, management and the public as it would remove the uncertainty in information and data. This has proven successful in Canada (Branch, 2006). In short, "all

vessels can be monitored, resulting in fully transparent utilization of public resources, enhancing compliance with rules, and even countering tax evasion" (Zeller, Rossing *et al.*, 2011).

To change the institutionally embedded misreporting behaviours a ban on all discards and the use of bycatch reduction devices should be made mandatory. Norway, Iceland and Namibia prohibit discards and bycatch reduction devices are mandatory in many Australian, European and Northwest Atlantic Fisheries Organization (NAFO) fisheries (Kelleher, 2005). A discard ban will encourage fishers to be more selective of fishing areas, fishing gear and behaviours to reduce unwanted by-catch (Branch, 2006). This can lead to the better utilisation of fish resources (Zeller *et al.*, 2011), and the landing of fish presently perceived as unmarketable could also drive innovation and market development in unforeseen directions. Much more ought to be done with the identified 397 species caught, not just with the 130 commercially valued species (Ministry of Economic Development, 2014). We also suggest that much of the fish currently regarded as unmarketable is not devoid of intrinsic value. In the final analysis, a 2013 Ministry for Primary Industries investigation report[51] into dumping and non-reporting highlights the potential damage of these practices to New Zealand, unless firm action is taken to resolve the problems once and for all:

> It is more than sustainability. It is more than the fact that we are relying on misleading and incorrect data to sustain our fisheries. The most pressing reason for urgent action is that we have compelling visual evidence of serious offending recorded on a media that could become available (for whatever reason) to outside persons and organizations. Some of these people and organizations could have strong vested interests in this information and make this material quickly available to the public via internet related media i.e. 'you-tube' etc.
>
> The resulting damage that could be caused not just to MPI but to the New Zealand fishing industry and economy as a whole could be extensive. The sight of large perfectly good fish being systematically discarded in such large quantities could have a huge negative effect, as it could easily stir up an emotive backlash from not only the New Zealand public, but from international quarters as well. These images could quickly negate the 'green sustainable' image that we as a country portray. This combined with the fact that we have known about these dumpings/discarding issues for many years, and would appear to have done little to combat it, would be very difficult to explain and be unpleasant at best.

5. Conclusion

This report provides, for the first time, a reconstruction of New Zealand's marine catches 1950-2010, which contributes to a better understanding of New Zealand's marine fisheries. While it is part of the wider *Sea Around Us* project to reconstruct the world's marine catches, this report also provides the foundation for a much-needed New Zealand specific discussion. This is necessary to ensure that the maximum value is sustainably harvested from fisheries, as the architects of New Zealand's fisheries management system envisaged over three decades ago. The QMS was an important step in halting the 'rape and pillage era', where regulatory regimes were displaced by an unsustainable focus on expansion and growth. That era produced the reduced stock levels New Zealand is endeavouring to now manage. While the current fisheries management system is far from perfect it has facilitated some positive change. However, it is in need of a robust critical review, along with consideration of alternatives to ensure the latest information, processes and technology are being utilized.

This paper demonstrates that misreporting and dumping in New Zealand fisheries have been and are of a significant magnitude and are deserving of much more attention and study. For the 1950-2013 period an estimated 24.7 million tonnes of catch was not reported, compared to the 15.3 million t reported (Appendix 2). Misreporting and dumping has been ignored for too long by the officials responsible for managing New Zealand's fisheries. 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"

[51] Ministry for Primary Industries. (2013). *Operation Achilles: Preliminary Investigation Report Dumping/Discarding* (26th July 2013). Ministry for Primary Industries.

(Department of Statistics, 1981, p. 14). Nearly ninety years on, catch statistics are still wanting. In order to sustainably manage fish stocks, fisheries managers need to account for all fish mortality, whether landed or not; commercial, customary and recreational (Sumaila, Alder, & Keith, 2006). Assuming the level of unreported catch to be zero when in fact it is considerably higher, may threaten the sustainability of the fishery concerned. If just a proportion, a variable proportion, of actual catches (including discards) are reported, stock assessments will be flawed. While some estimates of unreported catches and discards are included in stock assessment models and TACs, through an allowance for other sources of fishing related mortality (OSFM), the evidence indicates these are too low. According to one fisheries management official[52] "it is not set for every stock and is really just an educated guess as the observer monitoring of most fisheries is limited so discard and undersize catch levels are not really known."

Quantifying unreported catches is critical, yet this seems a mostly ignored component of OSFM. This is in spite of Section 10(d) of the Fisheries Act 1996: "the absence of, or any uncertainty in, any information should not be used as a reason for postponing or failing to take any measure to achieve the purpose of this Act." According to the Act the Minister "shall have regard to…all other mortality…caused by fishing."[53] Indeed, as Clark, Anderson, and Gilbert (2000, p. 6) point out, "successful stock assessment requires good data on the true catch and mortality of fish species. Estimates are needed of the total catch, and not just that which is landed or reported, so information on fish discards is important". Besides improving transparency and reliability of fisheries data, the future sustainability, traceability and certification of fisheries will depend on how government addresses the under-reporting problems, which have long been evident and which should be a cause of concern. Unreported catches and dumping not only undermine the sustainability of fisheries, but result in a suboptimal use of fishery resources and economic waste of valuable protein.

Finally, returning to where this report began; fishing is foundational to Māori culture and is a central part of Māori life, which includes respect for the seas and the organisms that live within them. Following colonisation, Māori lost sovereignty over their seas. Their fishing rights only began to be acknowledged and returned following the 1992 Māori fisheries settlement. It was not until 2004 that Māori re-established themselves in the commercial sector, first as absentee quota landlords and more recently as owners and operators of two major fishing businesses. Given the long standing misreporting identified in this study and Māori statutory "interest in the effects of fishing",[54] Māori ought to play a greater role in fisheries management. In fact, they have a critical role to play in terms of Kaitiakitanga, or guardianship over all New Zealand's fishing sectors – recreational, customary, and commercial. Bringing Māori customary values to bear on the commercial and recreational sectors would enhance governance, sustainability, and the integrity of New Zealand's fisheries management system. Continuing to turn a blind eye to the economic wastage diminishes the value of fisheries and does scant justice to the fisheries settlement, Kaitiakitanga, and Te Tiriti o Waitangi (Treaty of Waitangi). Ultimately, greater Māori participation in fisheries management and governance has to be good for the fisheries resource itself, the nation, and New Zealand's international image.

[52] Interviewee 222.
[53] Section 21(1)(b), Fisheries Act 1996.
[54] Section 12 of the Fisheries Act 1996.

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6. Appendix 1: Species recorded per survey trawl, 1961-1997

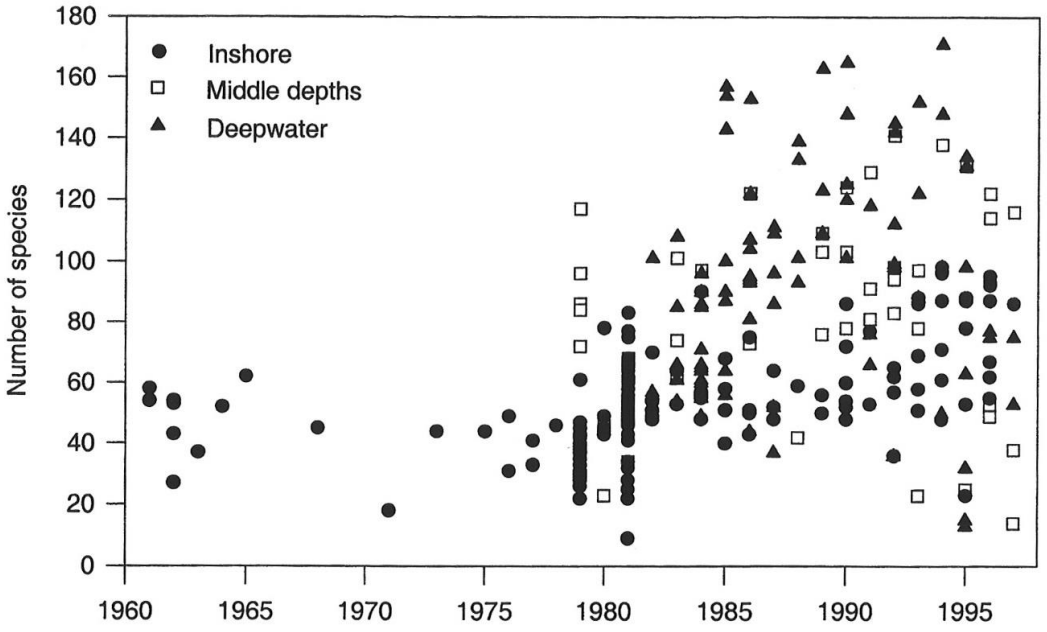

Figure 3: The number of fish and squid species recorded by survey, 1961–97. Survey types were classified by the following depth ranges: inshore, most stations shallower than 250 m depth; middle depths, most stations 250–800 m depth; deepwater, most stations deeper than 700 m depth.

Source: (Anderson *et al.*, 1998)

7. Appendix 2: Extended reconstructed marine catch 1950-2013

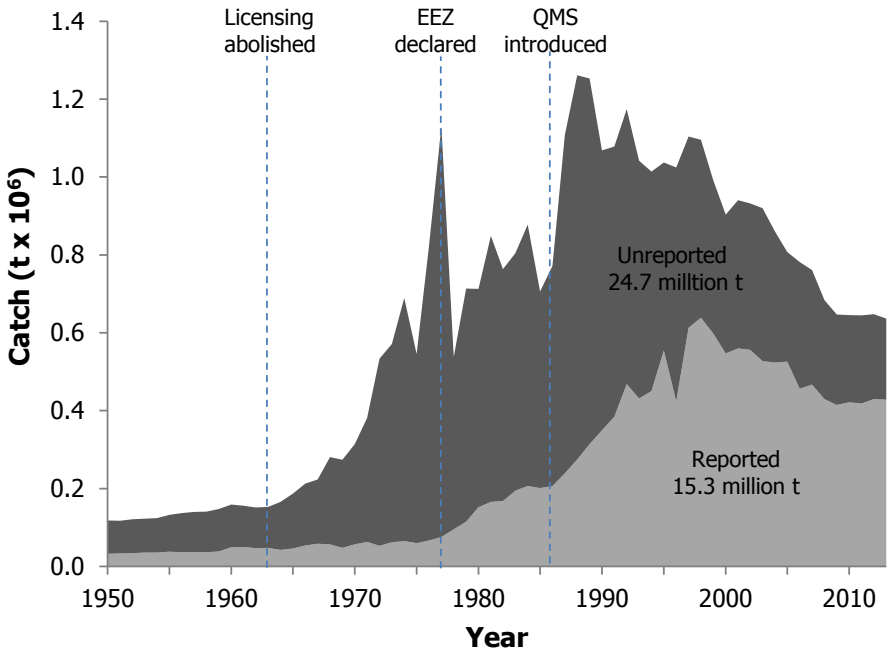

Figure 6. Extended reconstructed catch (New Zealand and foreign flagged vessels) showing reported and unreported catch.

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