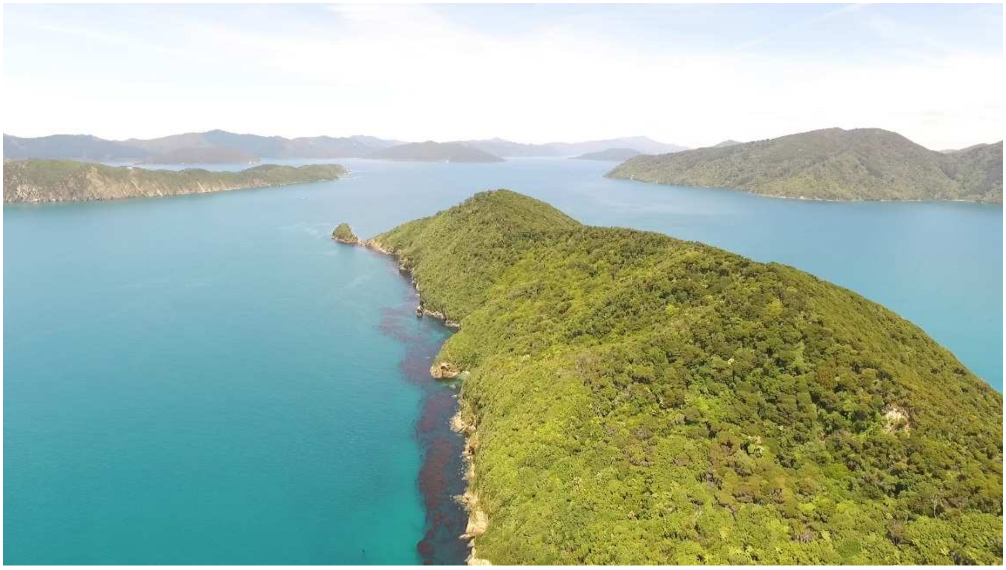
History of benthic change in Queen Charlotte Sound/Totaranui, Marlborough

Prepared for Marlborough District Council

March 2016



Motuara Island, Peter Hamill, MDC 2016

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Executive summary

This report reviews historical changes to benthic habitats in Queen Charlotte Sound (QCS)/Totaranui from published research, interviews with some long-term residents, and searches of historical newspapers and literature. Significant changes appear to have occurred to benthic habitats and connected fisheries resources in the Marlborough Sounds marine food-web.

The seabed of the QCS has been subjected to accelerated sediment and nutrient discharge relating to land clearance (deforestation, agriculture, farming, forestry, urbanisation, industry), disturbance from contact fishing gear (finfish trawling, shellfish and kina dredging), and modification on coastal fringes by land development and reclamations. The presence of a wide variety of dead shells from mollusc species not represented by live specimens in the earliest 1967 soft sediment benthic surveys potentially indicates that prior anthropogenic disturbance factors had altered benthic faunal diversity before the first scientific surveys were carried out.

Anecdotal evidence from newspaper reports, interviews and scant published information show the Marlborough Sounds ecosystem has undergone dramatic declines in: kelp beds, migratory biomass of pilchard 'feed-fish', whale stocks, rock lobster (reef keystone species to control grazers), predatory blue cod, kahawai, groper, snapper and likely reductions in large sharks. The lack of recovery of fisheries resources and biogenic habitats and their continued decline in QCS indicates that the Marlborough Sounds benthic habitats remain under threat and have undergone a regime shift. This shift in species composition and distribution is likely to have many causative factors with complex interactions including multiple stressors, bottlenecks created by the lack of suitable settlement substrata (e.g., for shellfish larvae), and the ongoing disturbance from fishing and sediment discharge from land. As some of these changes may have occurred over decades to centuries it is proposed a shifting baseline has occurred resulting from gradual but sometimes rapid changes to seafloor habitats, species composition and biomass. In the dominant low flow sites of QCS, where fine sediments accumulate, these habitats are now dominated by silty sediment such that what exists today is unlikely to resemble historic benthic communities and sediment composition that are hypothesised to have been more biogenic and diverse.

At Long Island – Kokomohua marine reserve, the dramatic recovery since cessation of commercial and recreational fishing in 1992 of: predatory blue cod (3x increase); blue moki (1.4x increase); rock lobster (11.5x increase); grazing black foot paua (1.4x increase), and reductions in the number of grazing kina (-3x decrease), especially small (<45 mm) kina demonstrate cause and effect from commercial and recreational fishing. The recovery of these conspicuous species inside the reserve demonstrate the resilience of the ecosystem and the potential for restoration outside the reserve.

Successful restoration efforts overseas demonstrate benefits such as: reversal of 'shifting baselines'; more sustainable fisheries management; diversification of local economies and fisheries; community building; increased local pride; enhanced ecosystem services and recreational opportunities. The protection of remaining benthic species and habitats and restoration of lost species/grounds in Totaranui is therefore encouraged. Restoration of ecosystems and fisheries can provide positive feedback between economic and social benefits that enhance community engagement and provide motivation for further restoration. A failure to protect and restore species and habitats will reduce resilience under a future of climate change, accelerating and exacerbating further degradation of QCS.

1 Introduction

Marlborough District Council (MDC) has requested a review of available information relating to historical changes to organisms living on/in the seabed (benthos) of Queen Charlotte Sound (QCS)/Totaranui. Anecdotal information has arisen following a 2011 report (Davidson et al. 2011) identifying significant marine sites where widespread dredging and overfishing have fundamentally altered ecosystem processes and resulted in serious declines in biodiversity. However, these changes are not well understood which makes it difficult to identify realistic restoration goals.

At the same time there is a process underway within the Marlborough community to better integrate coastal marine management. The 'Marlborough Marine Futures' process aims to create a rich, abundant future.

To more effectively engage in, and inform that process, there is a need to establish whether 'shifting-baselines' have occurred in the Sound. That is, has gradual change to seafloor habitats occurred over decades, such that what exists today does not represent historical benthic communities and sediment composition? The answer to this question could affect management and restoration decisions relating to the seabed and the maintenance of indigenous biodiversity.

Other key questions include:

- What were the seafloor habitats in the Queen Charlotte Sound (QCS) prior to major human-induced impacts?
- How ecologically important and widespread would biogenic[1] habitats have been?
- What ecological functions and roles would biogenic habitats have had?
- Where and how were these habitats impacted over time?
- What factors prevent them from widespread re-establishment?
- How are contemporary activities, including land uses influencing the health and functioning of the seabed ecosystem?
- What are the future risks associated with 'business as usual' approach? E.g. risks associated with climate change.

2 Methods

The approach for this report was to undertake a wide ranging search for historical information relating to marine and land-use changes in QCS. To achieve this, search engines; Papers Past (http://paperspast.natlib.govt.nz), Google and NIWA's library catalogue were used, along with information previously collected for similar exercises in the Nelson and Pelorus Sound (e.g., Handley and Brown, 2012; Handley, 2006; Handley 2015). To address knowledge gaps, interviews were conducted with iwi and long-term QCS residents and fishers. Historic maps of shellfish beds and biogenic habitats were scanned and geo-rectified in GIS using ArcMap (10.2.1), before digitizing locations or their extent.

[1] "Biogenic" is defined as 'produced or brought about by living organisms'.

3 History of Queen Charlotte Sound

3.1 Geology and soils

The Marlborough Sounds consist of a series of narrow river valleys that have been submerged by the sea due to sea-level rising some 140 metres higher than during the peak of the last ice age 14,000 years ago, and the subsidence of the Marlborough Sounds area north of the Wairau Fault (Davidson and Wilson, 2011). The rock substrata of the Sounds is composed of metasedimentary rocks that vary in texture, with the lowest being most metamorphosed (Lauder, 1987). The rock type has been described as the Haast or Marlborough Schist Group which are aligned in bands to the northeast. Weathering of weaker mineral bands in the schist produces planes of weakness prone to deep and surficial slippage with sediment detritus of characteristically flat (platy) form. Overlying the schist is a layer of hardened sandstones and siltstones as greywacke and argillite atop the Pelorus Group (Lauder, 1987). Sediments derived from the Pelorus Group are more blocky than platy.

The soils formed from these greywacke and schist rocks are primarily silt and silty-clay loams with up to approximately 45% clay, formed by weathering of the parent material and some loessal deposition (Laffan & Daly 1985). Soils between the shoreline and 200 m elevation in the Sounds are generally clay-rich, highly weathered, and therefore prone to erosion (Laffan & Daly 1985; Urlich 2015). Soil mantles are generally thicker at these lower altitudes and likely to yield more fine sediment than less weathered and thinner soils at altitudes above 200 m.

3.2 Human habitation and land-use change

3.2.1 Māori

Māori and European historians recount early occupation of the Marlborough Sounds with modification of the land for dwellings and for agriculture. Pit dwellings, later excavated by Europeans, show changes to the landscape (Figure 3-1). Pa and kainga scattered the top of the South Island-Te Tau Ihu o Waka (Mitchell & Mitchell 2008). During early European settlement, Māori communities were present in nearly every bay of Tory Channel, at various sites on Arapaoa [Arapawa] Island, Waitohi (Picton) (Challis 1991; Figure 3-3, Figure 3-4), and many bays throughout Totaranui (QCS) from Anakiwa to Port Gore (Figure 3-2).

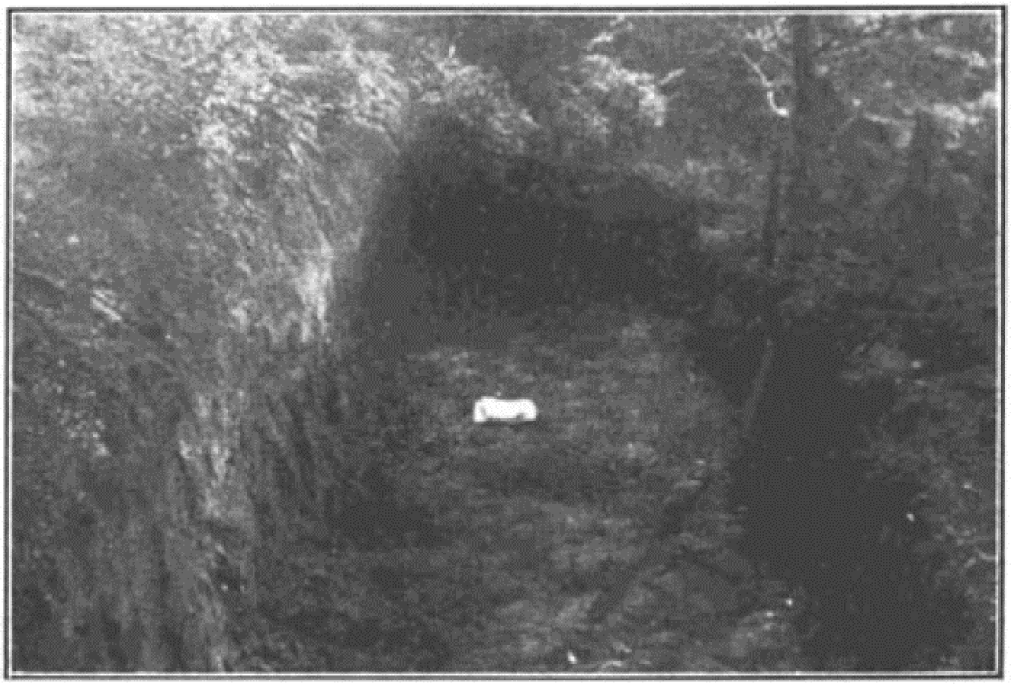


Figure 3-1: An old pit dwelling (top) from McIntosh et al. (1940), and (below) another from Elvy (1926).

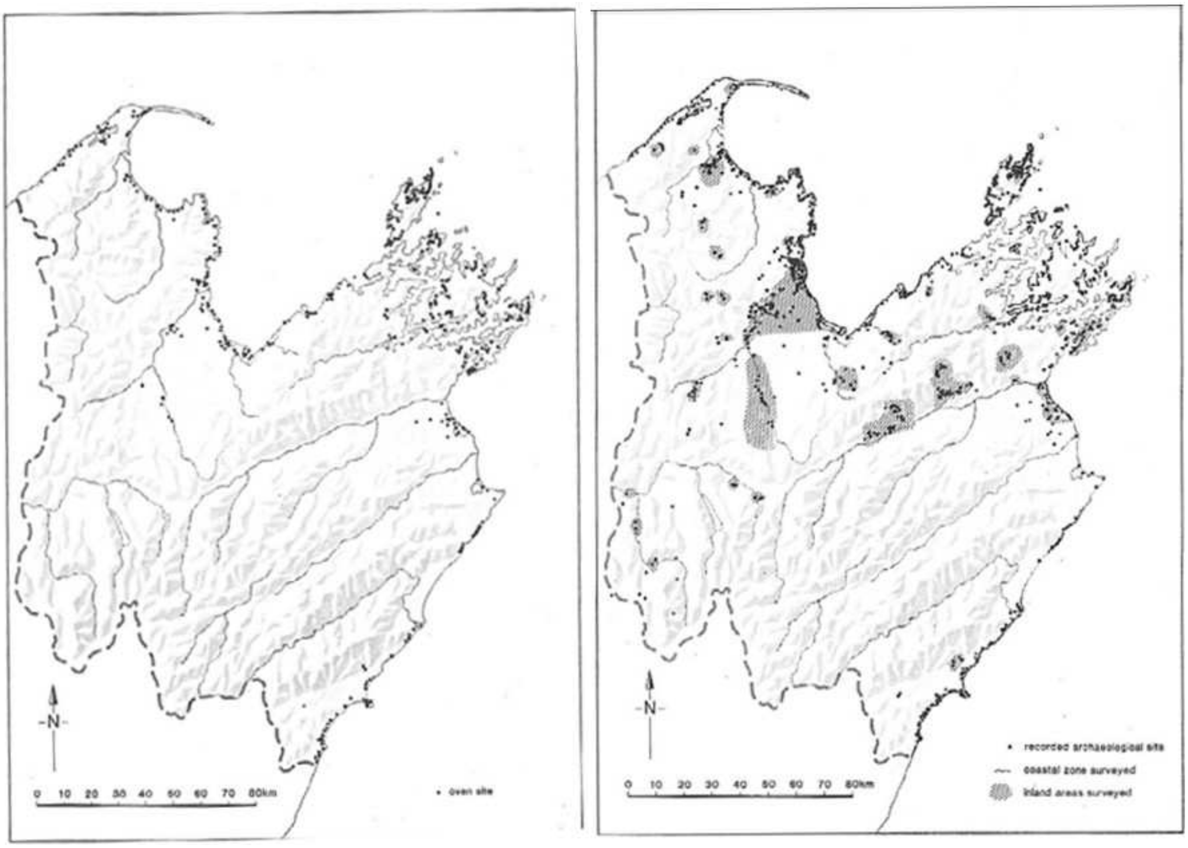


Figure 3-2: Distribution of oven sites (left) and recorded archaeological sites from Challis (1991).

Figure 3-3: Water colour by Sir William Fox (1848). Bird's eye view of Waitoi. showing a Māori kainga, Alexander Turnbull Library, C-013-001 .

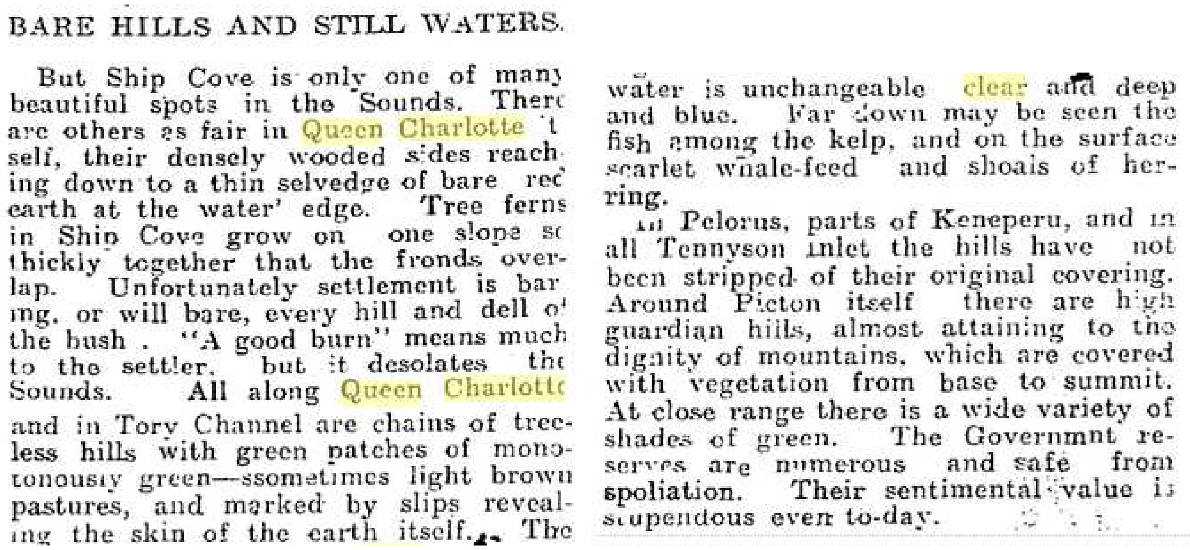
Figure 3-4: This painting shows the interior of a pā located in Queen Charlotte Sound. John Webber 1784. Alexander Turnbull Library, B-098-011.

3.2.2 Europeans

Accounts by James Cook from 1770 noted that the land was sparsely occupied and "they [Māori] cultivate no parts of the land". The history of the area told by Ponder (1986) recounts the inner areas of the Sounds having been temporarily displaced by early Māori inhabitants during conquest raids of north island iwi led by Te Rauparaha from Kāwhia in the north in 1828.

With arrival of settlers, in the mid to late 1800's the water was "unchangeable clear and deep and blue", but much of the hills of QCS were laid bare of vegetation with a "good burn" resulting in the inevitable slips and presumably sediment entering the sea as reported in 1911[2]:

[2] LOCH AND FELL. Nelson Evening Mail, Volume XLVI, 11 January 1911, Page 3

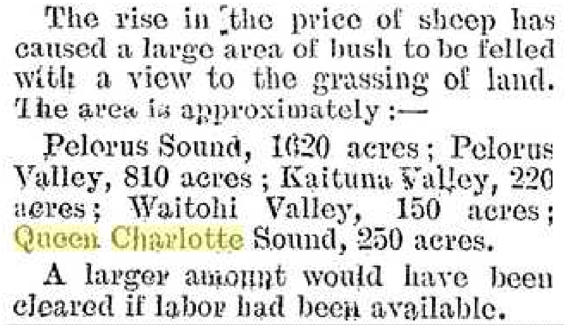


BARE HILLS AND STILL WATERS.

But Ship Cove is only one of many beautiful spots in the Sounds. There are others as fair in Queen Charlotte itself, their densely wooded sides reaching down to a thin selvedge of bare red earth at the water' edge. Tree ferns in Ship Cove grow on one slope so thickly together that the fronds overlap. Unfortunately settlement is baring, or will bare, every hill and dell of the bush. "A good burn" means much to the settler, but it desolates the Sounds. All along Queen Charlotte and in Tory Channel are chains of treeless hills with green patches of monotonousiy green—ssometimes light brown pastures, and marked by slips revealing the skin of the earth itself. The water is unchangeable clear and deep and blue. Far down may be seen the fish among the kelp, and on the surface scarlet whale-feed and shoals of herring.

In Pelorus, parts of Keneperu, and in all Tennyson Inlet the hills have not been stripped of their original covering. Around Picton itself there are high guardian hills, almost attaining to the dignity of mountains, which are covered with vegetation from base to summit. At close range there is a wide variety of shades of green. The Governmnt reserves are numerous and safe from spoliation. Their sentimental value is stupendous even to-day.

Land clearance, including felling and milling of timber was a common part of these early developments. Timber extraction was the usual method of financing the development of pastoral farming (Clarke, 2014). In the 1830's an early whaler Joseph Thoms bought 400 acres of land from his father-in-law Nohorua at the head of the Grove Arm at Okiwa, which later passed to various other settlers (Brehaut 2010). The name "The Grove" came from the extensive kahikatea forest there. By the late 1800's saw mills were present in many parts of the Sounds including The Grove, QCS (1901[3]):



The rise in the price of sheep has caused a large area of bush to be felled with a view to the grassing of land. The area is approximately :—

Pelorus Sound, 1620 acres; Pelorus Valley, 810 acres; Kaituna Valley, 220 acres; Waitohi Valley, 150 acres; Queen Charlotte Sound, 250 acres.

A larger amount would have been cleared if labor had been available.

[3] THE TIMBER INDUSTRY. Marlborough Express, Volume XXXV, Issue 87, 18 April 1901, Page 4

The land was cleared, the trees milled, but fire was always a hazard and the land was poor (Brehaut 2010). It is believed that about 18 million feet of timber was milled from The Grove. Ship building commenced, a timber mill and the Grove Hotel were built, the rough bridle track to Picton was started in 1861, with building of a “so called” road started in 1898. Being the middle access point between Picton and Cullensville and Mahakipawa, The Grove was an important location, and it remained important to the farmers for early dairy production established there in 1911 (Brehaut 2010).

Picton Bay has also suffered substantial negative human impacts over the last century or more, including historical input of sediment, which has presumably reduced seabed habitat integrity (Newcombe & Johnston 2016.). Deforestation in the area was widespread in the early European period (Figure 3-5). Since the 1980’s, degradation of shoreline habitats due to ferry wakes, land reclamation and construction has also been substantial, especially in Shakespeare Bay and in the area now occupied by the Picton and Waikawa marinas (Ian Shapcock, pers. com.). These reclamations had significant adverse effects on historically important intertidal and shallow subtidal kaimoana beds.

Figure 3-5: Buick, fl 1897. Overlooking Picton Township showing the ships Edwin Fox and Māori. Loach, A C (Mr): View of Queen's Wharf, Wellington. Ref: 1/2-031025-F. Alexander Turnbull Library, Wellington, New Zealand. http://natlib.govt.nz/records/22771418.

3.2.3 Mining

Although Picton was an active settlement in 1854, it wasn't until 1860 that Havelock at the head of the Pelorus Sound was established when Havelock became a service centre for nearby gold mining developments and later for milling and shipping of timber (Handley 2015). Queen Charlotte Sound, featured less prominently in mining deposits. Gold mining claims were established between QCS and Port Gore in 1878[4], Waiamanga Bay east of Picton in 1888[5], and most prominently, in 1873 antimony was discovered in Resolution Bay[6],[7] in 1873 (Brehaut 2015). Some land-clearance associated with the mine and development of structures occurred (Figure 3-6). At its peak in the 1890's the mine was one of the largest industries in Marlborough, with employees and housing of more than 100 men. A school opened in 1887 but closed and reopened many times, finally closing in 1895. Many tons of ore and smelted mineral were exported. Attempts to reopen the mine occurred in 1927 and 1933 and a new prospector's licence was granted in 1951 to no avail (Brehaut 2015).

Figure 3-6: Antimony Mine from above Endeavour Inlet, Mt Puhikereru [Mt Furneaux]. Picton Museum. (Brehaut 2015)

[4] TURNER GOLD MINING COMPANY. West Coast Times, Issue 2783, 4 March 1878, Page 2
[5] REPORTED GOLD FIND NEAR PICTON. Te Aroha News, Volume VI, Issue 319, 24 November 1888, Page 2
[6] NEW ZEALAND MINES. Ashburton Guardian, Volume VII, Issue 2220, 7 September 1889, Page 3
[7] DISCOVERY OF ANTIMONY. Thames Star, Volume XLIV, Issue 10538, 17 April 1907, Page 2

4 Decline of early fisheries resources – "paradise lost"?

4.1 Early fish trade

Māori were reportedly masters of fishing, using trolling line, superb barbed hooks, strong light lines and nets (MSMPB 1986).

On his return voyage in 1774 aboard the Endeavour, Captain James Cook was running low on provisions, and travelling via Norfolk Island, resorted to harpooning and eating a dolphin (Forster 1777). The meat, very dark, was reportedly rather dry. On arriving in New Zealand, the Endeavour returned to Ships Cove in Queen Charlotte Sound. The crew immediately proceeded to gather provisions, and there is an account of their first meal of snapper (*Chrysophrys auratus*) by Georg Forster, son of J.R. Forster the artist to the expedition (Forster 1777). The snapper is mentioned briefly but misidentified as the European species:

> "Tues. 18th October, 1774, in Queen Charlotte Sound. Our sailors dragged a net, but to no purpose; however, we were somewhat more successful with hook and line. Amongst others, a fine sea-bream (*Sparus pagrus*), weighing eleven pounds, was taken, it being one of those species which are to be met with in almost every ocean."

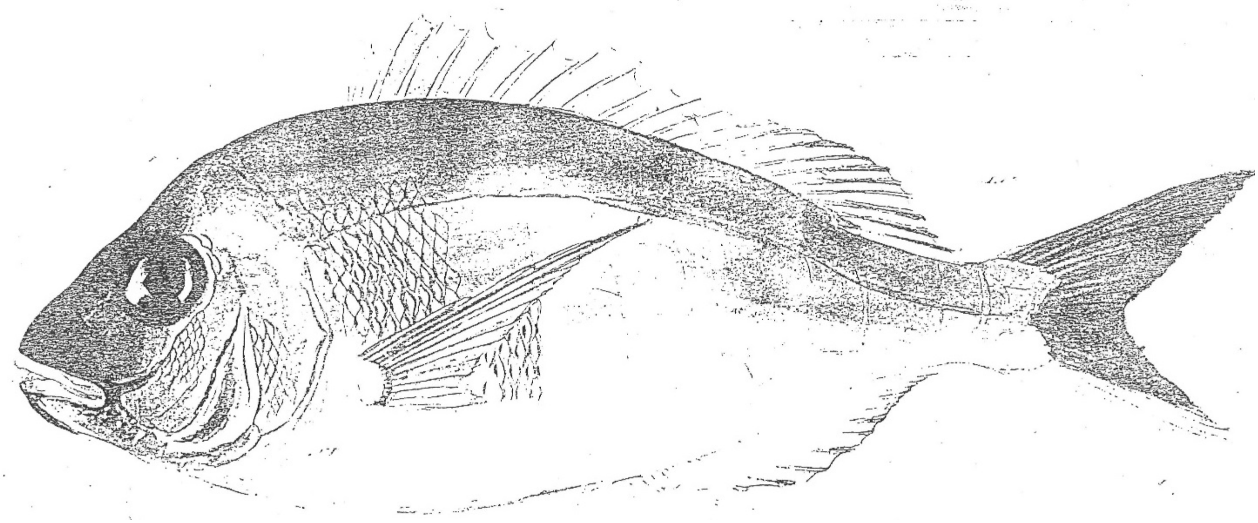
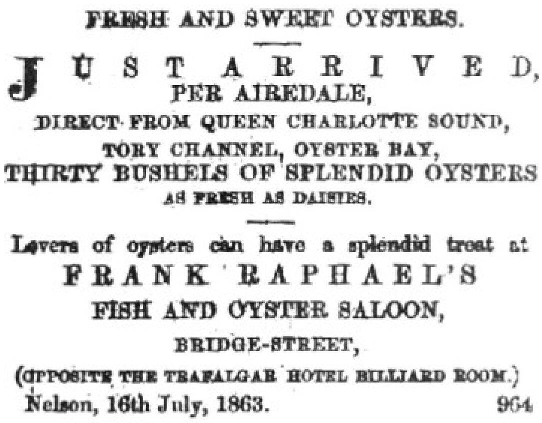


Figure 4-1: Line drawing of Captain Cook's first meal of snapper (*Chrysophrys auratus*) as drawn by J. Forster (Forster 1777). Picture kindly supplied by P. Rocco.

The crew of the Endeavour later located local Māori and the crew of the Endeavour, seemingly poor fishermen, eagerly began trading kai moana. "For a few pieces of Tahitian cloth, a nail, some medals, and a bit of red baize, we bought a sufficient quantity [fish] to supply our whole ship's company, and so far gained the confidence of the natives, that they promised to come to the ship the next day. They were indeed as good as their word, and came to us at sun-rise the next morning, in five canoes, selling a great quantity of fine fish, and thus restoring affluence on our tables".

Captain Cook not only traded with Māori for fish but also recorded the first case of overfishing, when his crew caught over 135 kg in one seine haul and over 80 fish from a single porthole (MSMPB 1986). The wastage and boasting of fishing exploits continued with early settlers catching "10 tonnes of kahawai and flounders in one day from Picton and the size and numbers of groper, cod and crayfish caught in a day's fishing are the stuff of old timers' legends" (MSMPB 1986).

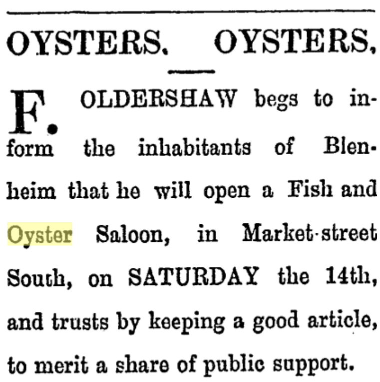
Reports of early fishing in QCS are scant. Shellfish including mussels: the green-lipped mussel (*Perna canaliculus*) the blue mussel (*Mytilus galloprovincialis*), fan mussel (Pinnidae), and the horse mussel (*Atrina zelandica*) were an important component of the diet of Māori (Best 1929; Smith 2011). Early accounts of shellfish exploitation in the Marlborough Sounds are rare, but intertidal mussels were likely a first meal for the first European settlers like the Harvey family on arrival in Crail Bay, Pelorus Sound (Ponder 1986). Reports of oyster bars in Nelson and Blenheim suggest shellfish sales were part of a thriving local economy from 1859 until over-fishing took its toll by the early 1900's (Wright 1990).


FRESH AND SWEET OYSTERS.

JUST ARRIVED,
PER AIREDALE,
DIRECT FROM QUEEN CHARLOTTE SOUND,
TORY CHANNEL, OYSTER BAY,
THIRTY BUSHELS OF SPLENDID OYSTERS
AS FRESH AS DAISIES.

Lovers of oysters can have a splendid treat at
FRANK RAPHAEL'S
FISH AND OYSTER SALOON,
BRIDGE-STREET,
(OPPOSITE THE TRAFALGAR HOTEL BILLIARD ROOM.)
Nelson, 16th July, 1863. 964

1863


OYSTERS. OYSTERS.

F. OLDERSHAW begs to inform the inhabitants of Blenheim that he will open a Fish and Oyster Saloon, in Market-street South, on SATURDAY the 14th, and trusts by keeping a good article, to merit a share of public support.

1891[8]

The extent of early shellfish beds can only be conjectured. Early accounts indicate that mussel beds covering the soft-sediment and rocky intertidal were present in many harbours throughout New Zealand (Chisholm 2005; Handley & Brown 2012; Paul 2012). Either by necessity or for profit, shellfish were clearly targeted by early settlers, hand-picked from foreshore, or dredged from the seabed. Little is known regarding the structure of the marine environment during European settlement, but there is increasing evidence that overexploitation of fisheries resources was apparent by the turn of the 19th century (Anderson 2008; Smith et al. 2009; Handley & Brown 2012). An excerpt from the Nelson Mail (1896) illustrates that mussels were considered over-exploited near the turn of the 20th century in Tasman Bay, Nelson, and that sponge beds were common around the coast, and appeared to be regarded as worthy of protection along with mussels. Because of the associated concern regarding sponge beds, we assume that mussels were being harvested by dredge.

[8] Marlborough Express, Volume XXVII, Issue 44, 21 February 1891, Page 3

The Sea Fisheries Act Amendment Bill was read a second time on the motion of Mr Walker, who explained that some of the mussel beds are getting exhausted. The measure was introduced with a view to giving them periodical rests for recovery as well as to protect sponge beds around the coast. 1896[9]

4.2 Marlborough Sounds better than Fiordland for an ideal fishing holiday!

Later settlers were attracted to the Marlborough Sounds as a holiday destination. In 1909 the Wanganui Herald noted "The sounds form an ideal cruising ground, giving practically smooth water voyaging, which, of course, will materially add to the pleasure of the trip. In addition, these waters swarm with fish, and splendid sport will be afforded in the pursuit of finny game"[10]. While in 1906 the Marlborough Express reported" Last year I spend a fortnight in the far South, Sounds, from Preservation Inlet to Milford, and tried the line daily. General disappointment was the result. How different was my experience recently in Queen Charlotte Sound! No matter where the line was dropped, there was fish." [11]

FINDING THE FISH.

As to the fishing, the summer just ended has been marked by as great good fortune for those adventurers of the open air and the fishing-line as in any past season. And this is admitting a great deal. Last year I spent a fortnight in the far South, Sounds, from Preservation Inlet to Milford, and tried the line daily. General disappointment was the result. How different was my experience recently in Queen Charlotte Sound! No matter where the line was dropped, there was fish. Off Waihi reef, which lies between Ship Cove and Jackson Head (in Cook Strait), great sport was obtained with hapuka, or groper, and here the rifle can be brought into play against shags and wild pigs and sheep. Off the White Rocks, which are on the other side of the North Entrance, just under the Brothers' Lighthouse, we got trumpeter, big cod, moki, and schnapper. At Cape Koamaru were various fish, including trumpeter, cod, conger eels, shark and moki. Cabbage Beach yielded rock cod and terakihi; in Port Cooper we hooked half a dozen schnapper and numerous cod; under the lee of a reef at the southern end of Blumine Island, which lies between the North Entrance and Tory Channel, we caught good-sized cod-fish (rock and the pretty Cloudy Bay variety) two at a time. Cod, schnapper, perch (spotties), skate, "Soldiers," "Maori Chiefs," sharks, and an octopus came out of the water under the lee of a small island at the entrance of Surgeon's Bay. In Patten's Passage, off Hawes Rock, in Endeavour Inlet, in Kumutoto Bay, and in the Bay of Many Coves we hooked various species of cod of all sizes and substantial weight.

4.3 Catastrophic events, enormous abundance, and the fate of the Picton Bloater

The Marlborough Sounds pilchard (*Sardinops neopilchardus*) fishery features as a prominent example of a decimated fisheries resource. The pilchard, mohimohi, Picton herring or Picton Bloater was enormously abundant in Queen Charlotte Sound in the 1860's. The pilchard was caught in abundance by early settlers and smoked and shipped to gold diggings in the Wakamarina. It is difficult to imagine the abundance of these fish, but rare catastrophic events resulted in a record of their abundance. In

[9] Nelson Evening Mail (1896) Mussel and sponge beds protected. Volume XXX, Issue 156, 3 July, Page 2
[10] THE MARLBOROUGH SOUNDS. Wanganui Herald, Volume XXXXIV, Issue 12736, 3 April 1909, Page 5
[11] MARLBOROUGH'S MODESTY! Marlborough Express, Volume XXXIX, Issue 85, 11 April 1906, Page 2

1865, there was an account of tons of fish coming ashore at Picton, perhaps resulting from a tsunami or unexplained toxin?

THE WHALE AND THE FISH

TO THE EDITOR.

Sir,—Undoubtedly the sensation of last week was the coming ashore on the Lyall Bay beach of the whale and the large quantities of fish, a sensation which proved profitable to tramway returns for the Lyall Bay and Island Bay services. The event has proved doubly interesting, inasmuch as it has led to much retrospection of similar events long past. One of the most interesting letters which appeared in the Evening Post of Friday last was Hare Hongi's story, probably mythical, where Hare described the good old days (old days are always good), when Maori canoes with a freeboard of a foot sailed in the hot water of Cook's Strait. A further picture might show the long canoe and potatoes towed astern cooking in the hot water for a great feast in Cook's Cove. Many of The Post readers, together with Hare Hongi, are perhaps not aware of the fact that forty-four years ago the great volcano that has so often disturbed Port Nicholson, as well as the living tribe, was discovered by a warship, whilst surveying Cook's Strait during her three years' cruise in the Tasman Sea, 1871 to 1874, with a view to finding a suitable sea bottom for laying Pacific cables. This great submarine crater is at the mouth, and near the middle of Palliser Bay. Lithographs of it can be seen in Sir George Nare's book, entitled "Cruising in the South Seas," published after his return to England. The lithographs show the crater with one side blown out by some great upheaval. Captain Cook, in his Journal, reports that violent earthquakes occurred whilst he was careening and refitting his ship The Discovery in Cook's Cove, Queen Charlotte's Sound, where a monument to Captain Cook's memory is to be erected this year. Concerning the quantities of fish being cast ashore, that is not a new experience for Wellington. The late Captain Peter Doyle, of the Stormbird, told me that after one of these submarine earthquakes he had sailed through miles of dead fish between Palliser Bay and Kaikoura, and within my own memory tons of fish came ashore in Picton Harbour, which, as there were no cool chambers to preserve them in those days, were used by the settlers to manure their potato fields.

The presumption is that the strong northerly and southerly winds affect the currents in the Straits, and therefore, after a marine disturbance has killed the fish they sometimes come ashore through Tory Channel and Queen Charlotte's Sound, and at other times as far north as Happy Valley and Island Bay.—I am, etc.,

JAMES M'DOWELL.

1912[12]

Relevant to shoreline and seabed habitats, the Cook Strait, present over significant fault lines, is reported to have experienced repeated tsunami events. Goff and Chagué-Goff (1999) reported a 1865 tsunami signature laid down in marine sediments collected from sediment cores from Totaranui Inlet, Abel Tasman National Park. Another significant catastrophic event, the 8.1-8.2 magnitude Wairarapa earthquake in 1855 on the West Wairarapa Fault (20 km E of Wellington) had estimated tsunami runup heights of up to 10 m on the South Wellington Coast (McSaveney et al. 2006; Clark et al. 2015). These events likely appeared recorded in oral tradition by Māori as myth and legend. Recent estimates of tsunami inundation show the extent of possible earlier inundation by tsunami runup, historically depositing pilchards (Figure 4-2).

[12] THE WHALE AND THE FISH Evening Post, Volume LXXXIV, Issue 20, 23 July 1912, Page 8

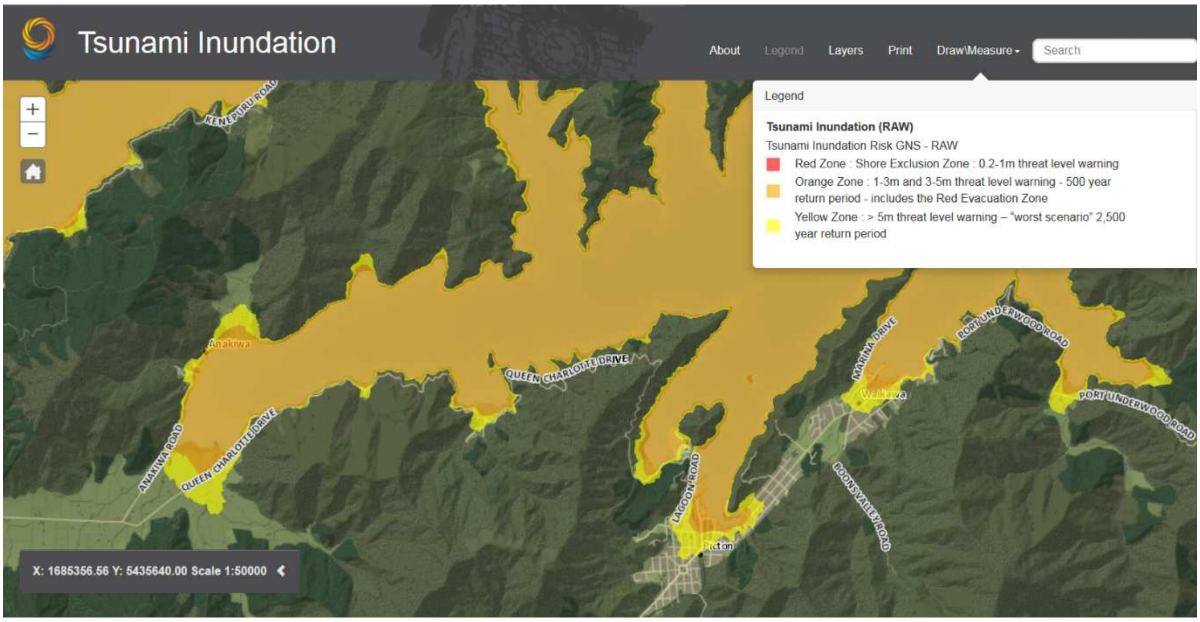


Figure 4-2: Tsunami inundation estimates and return period modelled by GNS for Marlborough District Council. (http://maps.marlborough.govt.nz/viewer/?webmap=61a36a29276b4d4888306321f4448b83).

Several pilchard preserving and canning factories sprang up in Picton in the early 1880's, with regular orders for 100 tins from throughout New Zealand (Simpson 2015b). One curing factory operated from 1880 for 10 years. It was not unusual to obtain hauls of up to 2 tons, with some up to 10 tons of pilchard off the Picton wharf as reported in 1892[13].

Mr Fell, writing to Mr Arthur, says: "The fish is found all round Queen Charlotte Sound, and also the adjoining Pelorus, but is only caught here (Picton). Generally it is believed that they do not extend outside, but my half-caste fisherman maintains that, if sought for properly, they would be found all round Blind Bay and in the Strait. They are not easy fish to find unless they are rushing to the surface, which is not often, and is a most peculiar sight. These herrings are in Queen Charlotte Sound during the whole year, but only come into the shallow bays during winter. At that time of the year they keep together in large shoals, but in summer time they keep more apart, and are sometimes caught then, though rather hard to find. No systematic fishing goes on during the summer; the fish prefer colder water, and thus leave the shallow bays when spring sets in. They spawn during summer, and are always full of roe about Christmas time, and then keep in small shoals. As to the probable numbers visiting the Sound, it is difficult to say, but four smoke-houses were kept going all last winter (1882). The hauls made average 1½ to 2 tons, but at times 10 tons have been landed."

[13] PILCHARD, OR SARDINE. Auckland Star, Volume XXIII, Issue 212, 6 September 1892, Page 2

The Pilchard fishery ceased in 1914 but was rekindled in 1942[14],[15]:

DOMINION SARDINES

NEW CANNING INDUSTRY

WELLINGTON, Tuesday.

A New Zealand industry, which flourished 30 years ago, and then, about 1914, suddenly ceased operation, is now being revived in a new form. As a result, locally-canned pilchards will soon be helping to relieve the present shortage of tinned fish.

The New Zealand pilchard is regarded as a climatal variety of the English pilchard. It is, moreover, specifically the same fish as the sardine, from which it differs only in some slight structural details.

The fish are widely distributed round the New Zealand coast. They are known to be present in Queen Charlotte Sound, Pelorus Sound and Tasman Bay all the year, and are also plentiful in Milford Sound, Hauraki Gulf and on the west coast of the North Island.

Picton fishermen many years ago caught them in large quantities, smoking some for the local market, and salting others for export. Catches of two tons were usual, and some of up to 10 tons were recorded.

Now a Dominion firm, operating under license from the Bureau of Industry, is establishing a cannery at Picton. It is expected to begin operation soon.

CANNING FACTORY AT PICTON

AUSTRALIA AND NEW ZEALAND SUPPLIED

Thousands of cases of Picton sardines have been shipped overseas for military consumption since the establishment of a canning factory on the shores of the Marlborough Sounds. This factory is playing an important part in New Zealand's war effort, for the sardines, which are cleaned, packed, sterilised, and cooked at the rate of about 3000 cans a day, go to Australia, islands in the Pacific, and camps and hospitals throughout the Dominion.

About two and a half tons of sardines are caught each day—there are approximately 20,000 fish to the ton—and the staff deals with two tons daily. The fish are scaled by being placed against a revolving wheel with an abrasive surface. Then they are topped, tailed, and cleaned, and placed in a 16oz can. Each can is loosely capped and moves into a rotary exhaust which removes the air completely. Next the cans go to the steam steriliser where the sardines are cooked. Anchovies are produced by a process which involves about six months of brining. The cured fish become anchovies and can be used for flavouring or in the manufacture of anchovy sauce.

The size and continuity of the harvest of sardines is still unknown, but indications are that 1000 tons of canned fish annually will not materially affect the supplies in the Marlborough Sounds as the schools are renewed from spawning grounds not in the fishing area. The schools of sardines run past Cloudy Bay, and they have been netted as far south as Sumner.

This factory had an output of 1,000 tons a year (Simpson 2015b). A later example of their abundance recounted by John Walsh (former Picton resident, pers. comm.) was his childhood memory in the 1960's of being able to stand in the water at Picton with a glass 'AGEA jar' with a piece of bread inside. "The Pilchard would swim in but not being equipped with reverse, would get trapped". He would catch 4-5 good sized fish with this method. He said they were so thick under the wharf in Picton, "you felt like you could walk on them".

[14] DOMINION SARDINES. Auckland Star, Volume LXXIII, Issue 77, 1 April 1942, Page 6
[15] SARDINES FOR TROOPS. Press, Volume LXXVIII, Issue 23745, 17 September 1942, Page 3

4.4 Commercial fishing and trawlers

Trawling for fish in deeper waters was started in the early 1900's for transport and sale in Wellington:

TRAWLERS FOR THE SOUNDS.

A more plenteous supply of fish for Wellington has often been spoken of as desirable, but though many schemes to this end have been tried, fish is still something of a luxury. A local syndicate has had the steamer Waitara altered to make her more fit for trawling, and she is to begin work within the next week or two in the waters of Queen Charlotte Sound. Mr. Smith, who came to New Zealand from Grimsby in the trawling steamer Nora Niven, is to have charge of the Waitara. Mr. Smith, who made a study of the Queen Charlotte Sounds during the experimental trawlings by the Nora Niven, is convinced that a highly profitable industry awaits development in those waters. It is not proposed to spend time in bringing the steamer to port with her catches; these are to be transhipped to the Sounds passenger steamers for carriage to Wellington. The Waitara's trawler has been altered, and on a trial trip made the other day it is reported to have acted admirably. Mr. Smith is of opinion that good fishing areas exist near Cape Palliser, and a trial of the fishing grounds in this vicinity is also a part of the scheme of the syndicate.

1908[16]

Again, it is hard to imagine the density of fish available to early settlers and commercial fishermen. For example, there was a 1908 report of immense surface feeding shoals of groper or hapuka (*Polyprion oxygeneios*) so dense that it was difficult to row amongst. The fish could be caught by harpoon, hook or gaff:

[16] TRAWLERS FOR THE SOUNDS, Evening Post, Volume LXXV, Issue 09, 11 January 1908, Page 5

If our New Zealand fishermen would adopt a similar plan for groper curing there need be no reason why that fish should not be dried as readily as the cod in Canada, and in the preserved state the groper would command as good a market as the far-famed cod of the northern hemisphere. Some members of the old whaling community have asserted that there are off-coast banks in from 50 to 100 fathoms of water where the groper spends the winter season, and that on these banks it may be taken all the year round. If that statement be correct, by employing the deep-sea system of fishing with long lines, groper fishing could be raised from a desultory and precarious occupation to a fixed and important industry. The habits of the groper are not well understood, and though essentially a deep water fish, there have at times appeared immense shoals of the fish at or near the surface of the sea, so that a boat could not be rowed among them without striking them with the oars, and numbers of them have at such times been caught with the harpoon or hooked with the gaff. When groper are met in with in great surface shoals they are feeding upon shrimps, or shoals of small fishes which habitually keep near the surface. On other occasions all the groper caught in a particular locality are found to be gorged with squid, which the fish must encounter off shore somewhere. Groper take bait best while the tide is flowing, and in the early morning, immediately after dawn. We hope to see enterprise enough developed ere long to raise groper fishing to the position of importance which it deserves, and in addition to finding a never failing supply of the fish in our own markets, see a large export trade established as well.

1908[17]

However, by 1925, there were comments from fisherman that blue cod (*Parapercis colias*) were becoming less plentiful. The reasons mooted for their decline, although speculative, indicate a large number of fishing vessels were working the fishing grounds:

A BLUE COD PROBLEM

"Blue cod, which used to be very, very plentiful in both Queen Charlotte and Pelorus Sounds and in the French Pass, seem for some reason or another to be petering out. We used to get very big supplies of blue cod from those places. Quite a number of reasons have been advanced for this state of affairs by the fishermen and by others who have made a study of the question. Some say they are going further afield. But, of course, they come in to breed in the Sounds, and there is such a large number of oil-driven motor-boats in the Sounds now that I believe the oil contaminates the surface of the water, and that the ova of the cod, which come to the surface at certain times, get contaminated. As you know, a drop of oil will cover a big surface of water. Some old hands, however, attribute the comparative scarcity of the blue cod to-day to the cutting down of the bush. They maintain that the pollen of the native trees and ferns gave the cod a certain amount of food, and that with the disappearance of the bush the cod are thinning out. But I think the oil theory is the most feasible and sensible one. Of course, though, there is not much oil at the French Pass, with the eight-mile current running through there.

1925[18]

Tom Norton, former whaler and resident of Te Awaiti, Tory Channel recalls as a youth working for his father whom spent 3 years hand-lining for cod in Tory Channel. In the 1940's they used to catch "15-20 dozen large cod a day aboard the Awatere."

In the early 1940's fish canning facilities were supported by government officials to provide for the establishment of fishing towns and villages to further encourage fisheries in New Zealand. In Queen Charlotte Sound, Arrowsmith Bay in Tory Channel and Resolution Inlet were suggested sites for development. Fisheries development was to offset canned fish import costs; "the inhabitants of a country, the sea coasts of which swarm with fish, pay this amount [for canned fish]…. because they are too supine to obtain the fish from the waters belonging to the land in which they dwell":

[17] THE FISHERIES COURT. Otago Witness , Issue 1980, 23 January 1890, Page 17
[18] FISH FOR WELLINGTON. Evening Post, Volume CX, Issue 100, 24 October 1925, Page 13

FISH CANNING

OLD LEGISLATION

STATE ENCOURAGEMENT

FISHING VILLAGES

The approaching shortage of canned fish in New Zealand due to import control has directed attention to the possibility of evolving a local product, but this is not the first time the establishment of canning factories in the Dominion has received serious attention.

Fifty-four years ago, when enthusiastic politicians looked upon New Zealand waters as the source of an abundant and inexhaustible supply of fish, an Act was passed called "The Fisheries Encouragement Act, 1885," under which State assistance was to be given as an encouragement for the establishment of fish canning for export. In the light of subsequent events this old and forgotten piece of legislation makes quaint and interesting reading.

"An Act to Provide for the Establishment of Fishing Towns and Villages, and Further to encourage Fisheries in New Zealand, and to promote the Production of Canned and Cured Fish for Export," the preamble states. The Governor is empowered, by Order in Council, "to set apart upon the coastline of New Zealand . . . any Crown lands for the purpose of the formation of fishing towns or fishing villages."

IMMENSE QUANTITIES.

"It is in the outer or seaward portion that the fishing industry will naturally take its rise, for every description of fish found on this coast can here be had in immense quantities. The large block of level land at the head of Anakoa Bay forms a natural centre for this portion of the district. . . ." In Queen Charlotte Sounds Mr. Rutland selected two blocks—one at Arrowsmith Bay, Tory Channel, and the other in Resolution Inlet.

R. A. A. Sherrin, in his "Handbook of the Fishes of New Zealand," published in 1886, after reviewing the Act and quoting the figures of fish imports into New Zealand, comments as follows:—

"It will be seen from the foregoing tables that we imported in six years fish of the declared value of over a quarter of a million sterling, which, with Customs duties added, and 15 per cent. allowed for profits on sales —little enough, we may depend—would cost the retail purchasers not less than £327,000; or, in other words, the inhabitants of a country, the sea coasts of which swarm with fish, pay this amount of money away in six years because they are too supine to obtain the fish from the waters belonging to the land in which they dwell. . . . Thus we pay annually for fish, which we could catch and cure ourselves, a sum of money more than sufficient to cover the interest on the loan for what is called the North Island Trunk Railway."

This article has been automatically clipped from the Evening Post, organised into

1939[19]

However inconceivable to early fishers, during the same period, Sir Harry Twyford, in 1939 on a return visit to New Zealand after a 35 year absence, lamented "a great deterioration of sea fishing at Cable Bay and in Queen Charlotte Sound" and the "loss of bush on the country that does not look good for grazing or anything else". He was told that "fishermen blamed trawlers for destroying breeding grounds" requiring management of where trawlers could fish.

[19] FISH CANNING. Evening Post, Volume CXXVII, Issue 109, 11 May 1939, Page 15

LITTLE CHANGED.

AUCKLAND AND WELLINGTON.

SIR H. TWYFORD'S IMPRESSIONS

(By Telegraph.—Press Association.)

WELLINGTON, Saturday

New Zealand's legislative experiments are being watched with keen interest in Britain and throughout the Empire, according to Sir Harry Twyford, former Lord Mayor of London, who was interviewed to-day. It is 35 years since he was last in the Dominion.

Except that wooden buildings have been replaced with stone, Sir Harry has seen little difference in Wellington and Auckland. Places in which he has noticed the greatest progress are those such as Nelson and Hamilton.

He notes a great deterioration of sea fishing at Cable Bay and in Queen Charlotte Sound. He said he had been told fishermen blamed trawlers for destroying breeding grounds, and he thought the Government would be wise if it made it illegal to fish within a stated limit of the shore, and they should not be allowed at all in the sounds.

He also regrets the loss of bush on country that does not look good for grazing or anything else.

1939[20]

Although line fishing blue cod was the mainstay of the Sounds fishery in the early days, trawling then became important up until the 1990's when by 1990/91 cod potting caught the majority of blue cod (Rapson 1956; MFish 2000). Bottom trawling for blue cod, potentially affected benthic habitats, caught a large proportion of the annual commercial blue cod catch, with 11 t caught during 1989/90 with only 4 t caught as by-catch. Since then, less than 3 t annually was targeted by trawlers, with the majority caught as by-catch from flatfish and gurnard target fisheries (MFish 2000).

4.5 The role of technology

New technology in recreational and commercial fishing, and the advent of underwater diving (SCUBA) further compounded the problem, with today the sounds' waters, by comparison, bereft of fish (MSMPB 1986, John Walsh pers. comm.). In the 1960's John Walsh, a former Picton resident, recounts the delight of being given his first ever fishing rod as a boy, only to be disappointed on its maiden outing aboard a fishing charter, to be told by the skipper that "only hand-lines were allowed on his vessel"! In those days, hand-lines consisted of green cotton, rusty hooks and mutton for bait. Before their family owned a freezer, no matter the old-style hand-line tackle, John would often be asked by his mother to row out into the bay in Waikawa to catch dinner. He never recalled having difficulty catching large blue cod, snapper or terakihi (*Nemadactylus macropterus*) for the table. He reports a neighbour catching 5 snapper with a rudimentary bamboo rod and open reel on the flats where the Waikawa Bay Marina now sits, weighing: 22, 21, 19, 14 & 14 lb. In that same bay, John caught his first snapper. John attributed a significant part of the deterioration of fish stocks to the fact that "technology has worked against the fish". This comment was also made independently by long-time resident Ian Shapcock (pers. comm.). The role of technology can be compared with the traditional technology of Māori who used a hoop net 7-8 feet in diameter extended by 2 hoops that was baited at centre, and dropped to the bottom. The fish being "hardly sensible of being lifted till they were almost out of the water, catching "an abundance of fish, (Joseph Banks 1770, (MSMPB 1986). John Walsh also remembers talking with an 'old-timer' from Kenepuru, who recounted to John the days when pink schools of spawning snapper used to be a common sight in the summer in Kenepuru Sound, before the trawlers started in there. He was told, early fishermen used to target those snapper with floating long-lines, and they only ever kept the fish whose tails stuck out of a sugar sack (ca. >80 cm).

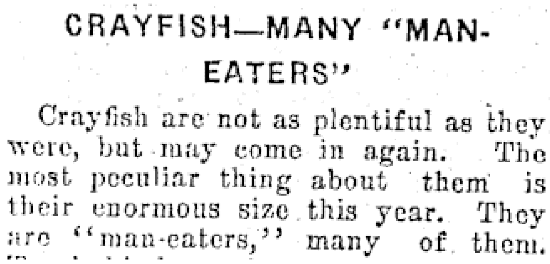
[20] LITTLE CHANGED. Auckland Star, Volume LXX, Issue 78, 3 April 1939, Page 13

In the 1990's, John Walsh returned to Picton after purchasing a Bach there. He revelled in the opportunity to re-live his childhood memories of fishing. Unfortunately, he was bitterly disappointed, calling the Sounds "paradise lost". For when he returned to former fishing spots like Blackwood Bay, where as a boy he could land any number of "bullhead cod", he could only catch 5-6 undersized cod. Ian Shapcock made a similar comment saying after the 1980's there was the loss of "cod on demand" where previously you could catch a decent cod in most places around Picton. Today, equipped with large fast boats, 3D acoustic sounder, fish finder, drop camera, GPS and modern fishing tackle and bait, "the fish don't stand a chance" (J. Walsh, pers. comm.) – and nonetheless catches are underwhelming.

As a boy, not accustomed to fishing way out in Queen Charlotte Sound, John Walsh also recalled a fishing trip with his father after a long, slow steam to Bluemine Island in their modest boat, a distance and destination rarely visited out of need to catch fish. He remembers a local commercial fisherman 'Fishburn' who was hauling up a set line. He was amazed to see on nearly every hook a bloated large silver or pink fish. Having never seen a groper (silver) before, he was amazed at their abundance and size, and also the size of the large snapper. On return in the 1970's as an adult, he could not catch a single groper or snapper. Tom Norton similarly recalls a youthful fishing trip at Diffenbach point, when he was a boy where they caught 32 groper. John Walsh, recalls hardly ever seeing a "work-up" of kahawai since 1996.

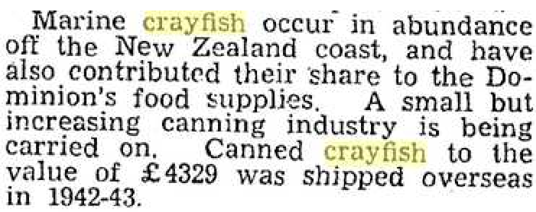
4.6 Rock lobster

The crayfish or rock lobster (*Jasus edwardsii*) were very abundant around coastal New Zealand when settlers arrived. An export canning industry operated, and the crayfish were very large, and apparently intimidating (1925):


CRAYFISH—MANY "MAN-EATERS"

Crayfish are not as plentiful as they were, but may come in again. The most peculiar thing about them is their enormous size this year. They are "man-eaters," many of them.

1925[21]


Marine crayfish occur in abundance off the New Zealand coast, and have also contributed their share to the Dominion's food supplies. A small but increasing canning industry is being carried on. Canned crayfish to the value of £4329 was shipped overseas in 1942-43.

1945[22]

John Walsh recalls that lobster were present on every rocky point in QCS, and that the development and widespread use of SCUBA diving decimated the stocks. Graeme Clarke from Crail Bay, Pelorus Sound recalls a similar drastic decline in lobster that he attributed to the subsequent explosion of kina (*Evichinus chloroticus*) populations causing "major habitat changes to the exposed shores of the outer Sounds" (Clarke 2014) (e.g. Figure 4-3). John also commented that before 1990's, he hardly ever saw a kina on the beaches in the Sounds, but noted they were very prolific between 1990-2000,

[21] FISH FOR WELLINGTON. Evening Post, Volume CX, Issue 100, 24 October 1925, Page 13

[22] FISHING BEDS, FISHING BEDS, DOMINION'S RESOURCES – EXPANSION OPPORTUNITIES. Evening Post, Volume CXXXIX, Issue 4, 5 January 1945, Page 7

and with their arrival, the “bladder weed” (*Macrocystis pyrifera*) disappeared. A similar anecdote was recorded by Brian Young who recalls being able to get plenty of crayfish, butterfish (*Odax pullus*), moki (*Latridopsis ciliaris*), terakihi, paua (*Haliotis iris*) and blue cod diving at the points of Double Bay, north of Tory Channel in the 1970-80’s. On returning about 5 years ago, the same area has a lot of silt, no weed to speak of, and very little in the way of fish life, leaving the area looking very dead.

The migration of large lobster has been observed in Tory Channel (L. McKenzie to S. Handley pers. comm. ca.1993). A protected population occurred in Picton Harbour as recently as 2001 (Handley, pers. observ.). NIWA divers, since 2001, have been undertaking routine six-monthly biosecurity surveys of the Picton Ferry terminal, Picton Marina and Waikawa Marina structures. During the first biosecurity survey of the Ferry Terminal structures, a nest of piles on the end of Waitohi wharf was inspected in December 2001 and found to contain a population of ca. 100 large lobster (Figure 4-4). These lobster were all of a similar size, and appeared to be feeding on the abundant mussels attached to the piles, seemingly unperturbed by the regular Ferry traffic that can cause considerable turbulence in the area (Handley, pers. observ.).

Figure 4-3: Kina can form large aggregations when their populations are kept unchecked by predators, and their grazing can form seaweed barrens (S. Handley, Dusky Sound, Fiordland, courtesy of Department of Conservation).

Figure 4-4: Rock lobster living on the Waitohi Ferry Terminal wharf piles, Picton Harbour, 2001 (Handley, pers. observ.).

On return surveys post-2003, these lobster disappeared. On talking with some of the Port workers, whom often joke “how many crays did you find”? One worker said that during repairs to the Terminal piles, somebody had dropped some tools over the side, and they hired divers to search and recover the tools. We surmised that the divers not only recovered the tools but also found the lobster, or their presence was transitory. Rock lobster are still occasionally seen in low numbers and small size in Picton, Waikawa and Wellington Ports, but their presence may result from individuals being released by fisherman returning to Port, as has been recounted on occasion to NIWA divers.

4.7 Whaling

Whales featured notably in the early QCS economy. With a large whale worth about £600 in 1910, it is not difficult to imagine the desire of early whalers to land such a prize. Technological developments also played a significant part of this industry. An article from 1913 speaks of the modernity of “present day” whaling on these “scientific stations”:

The present-day whaling modes are vastly different from those of the long ago. The throwing of harpoon by hand is unknown on these scientific stations. I went out in a modern boat. There is a gun in the bow of the boat, which is driven by motors instead of oars as formerly. The harpoon is fired by electricity. At the headlands at Tory Channel entrance can be seen small figures like ants pacing to and fro. These are whalers on the look-out over Cook Strait, with telescopes in their hands, scanning the waters for their prey. By and by the cry rings out "There she blows," 1913[23]

Whales were also once very numerous, as macabrely recounted by trophy display of their remains:

long. At Te Awaite, at Mr Norton's, one of the oldest whaling stations in the south seas, they have their fence all composed of jawbones. When one calculates that there are only two in a whale it gives some idea of the number of whales caught during the past seventy or eighty years. The steps to the front doors are composed of shoulder-blades of the sea mammal. Their boat sheds, instead of being supported by timber uprights, have 14ft and 16ft bones as posts and joists. On a moon-light night the appearances at Te Awaite is grotesque 1925[19]

A record catch of 70 whales landed in 1938:

RECORD EXCEEDED
TORY CHANNEL WHALERS
BLENHEIM, This Day

The Tory Channel whalers captured the seventieth whale this season, exceeding the previous record of 69. The season is now drawing to a close. 1938[24]

[23] "There She Blows." Horowhenua Chronicle, 1 December 1913, Page 4
[24] RECORD EXCEEDED. Evening Post, Volume CXXVI, Issue 26, 30 July 1938, Page 11

Then, by 1945, another record of 71 whales producing 500 tons of oil. Then a decline in whale numbers (and presumably seals) was noted; but eternal optimism was expressed in 1945 for more "expansion possibilities" of "fishing beds[25]":

> For many years the taking of seals in New Zealand waters has been prohibited. The latest extension carries the close season to March 31 of this year. The whaling industry has, of course, greatly declined. Only one shore station (that in Tory Channel, Queen Charlotte Sound) was operating in 1942. The season's catch then was 71 hump back whales, the total oil production being 500 tons.
>
> The Dominion's enormous resources of sea foods are still capable of greater development, and, doubtless, when the war is over, more attention will be paid to their undoubted potentialities. One of the difficulties in recent years has been lack of man-power for this work. Suitable vessels for the industry have also been utilised for other duties.

4.8 Top predators

Large predators including white sharks (*Carcharodon carcharias*), mako (*Isurus oxyrinchus*), and thresher (*Alopias vulpinus*) were common sight in the early days of whaling in Tory Channel. Tom Norton recalls the whalers catching large sharks that came to feed on the offal at Te Awaiti during whale processing, attracted to the blood staining the sea red (e.g. Horowhenua Cronicle, 1913) [26]:

> whales. The locality touched upon in the sketch is the old whaling station known as Te Awaite (in Queen Charlotte Sounds). Nowadays (we read in the article) a "right" whale is cut up in two days at Te Awaite. The blubber is stripped off the carcase as it is "beached" by men with long-handled knives, who cut "squares" off the body, while a winch and tackle drags it to an inclined platform, where other whalers cut it up into lengths, about the thickness of a bar of soap. It is then "cross cut" with knives, sharp as razors, which, however, appear to blunt very kuickly, and need the constant application of the steel. The outside coating of a whale is composed of a half-inch layer of dark rubber-like substance, and the flesh of the whale is white in appearance. There is little waste about a whale, as all, with the exception of the bowels and internal organs, is used. This is cut out with choppers by men who work inside the carcase, but who, unlike Jonah, come out every few hours. The owner of a whaling station is expected to haul up the carcass after it is stripped, and building huge fires, burn the refuse. But I saw one of them hitch up the head of a hump-back whale by the 15-knot motor boat and drag it out into the ebb tide. Soon it was travelling in a six-mile current to Cook Strait, and eventually the open sea. He gazed after

The whalers collected shark livers for oil as a bonus to their income. However, Tom Norton said that one day, one of the workers almost got killed attempting to land a large 21 ft shark at Te Awaiti, so the practice thereafter was stopped. He also recalled seeing large white sharks in QCS, with one particular instance strong in his memory from the 1940's. On their way back to Port after cod fishing, his father brought their fishing boat alongside a large specimen that was swimming at the surface

[25] FISHING BEDS, FISHING BEDS, DOMINION'S RESOURCES – EXPANSION OPPORTUNITIES. Evening Post, Volume CXXXIX, Issue 4, 5 January 1945, Page 7

[26] "There She Blows." Horowhenua Chronicle, 1 December 1913, Page 4

toward Picton. His father, not having a harpoon on board, resorted to attempting to gaff the shark with a sharpened fence batten. The shark, once attacked, went into a frenzy turning on their boat, making the whole boat shake and shudder, before recommencing swimming towards Picton. A second gaff attempt, sent the shark to the depths never to be seen again. His father told Tom never to approach large sharks in a row boat. The following account might have been different if the fisherman had been confronted with an aggressive adult white shark rather than a smaller mako:

MAKO SHARK

CAUGHT IN THE SOUNDS

The fishing attractions of the Sounds have taken on a new aspect, according to Mr. S. W. Moult, of Titahi Bay who has recently returned from a month's cruising across Cook Strait in his launch Miss Titahi.

About a fortnight ago, says Mr. Moult, an 11ft mako shark was captured in Endeavour Inlet, Queen Charlotte Sound, by Mr. W. Hilton, of Endeavour House, who was fishing from the launch. An exciting struggle of one and a half hours ensued before the shark was landed and towed triumphantly to the shoré. Such was its weight that six men were required to hoist it up to the crane where it was photographed. Mr. Moult also saw many black taniwha sharks in the Sounds and he was told that one of them had charged a man in a dinghy, armed only with a gaff. The man, so the story went, thrus tthe gaff into the shark's side, and so prevented it from overturning the boat.

1928[27]

John Walsh, when queried about sharks present in the 1960's said he never recalled seeing a spiny dogfish or carpet shark when he was a boy growing up in QCS.

4.9 Dredging for kina

John Walsh noted, it cannot be determined whether kina became more numerous a) after the reduction of fish stocks including lobster, snapper and blue cod, or b) because kina were targeted by dredge fishermen (due to the high quality of the kina that are fished today from Tory Channel). Tom Norton recalls fisherman using small 4 ft dredges with an iron bar at the base and encased in sheep netting to retain the catch. These would be dragged along the seabed in Tory Channel to harvest the kina. Similarly, Ian Shapcock also recalls kina dredging by the Connor family. John Walsh mentioned that some fishermen, later came in with a larger 2 m dredges and "cleaned them out", causing the decline of that dredge fishery.

4.10 Kelp beds and paua stocks

Former whaler and resident of Te Awaiti Tom Norton, when asked about kelp bed loss in QCS, commented that there was less kelp growing today than there used to be (pers. comm.). On his frequent journeys as a youth from Tory Channel to Picton and home again, he remembered notable

[27] MAKO SHARK. Evening Post, Volume CV, Issue 27, 3 February 1928, Page 8

channels in the weed beds off most of the headlands heading from Tory to Picton. He thought these channels resulted from the typical small and slow boats “by today’s standard”, navigating close to shore to make headway against the prevailing wind conditions each day. Their propellers trimming the weed. The weed beds and the channels are now practically gone. Having seen the effects of more modern boats, especially the fast ferries, which threw up piles of seaweed on the foreshore of Tory Channel, he thought they might be partially to blame for the loss of kelp.

In 2014, concerns about the long-term sustainability of the ‘Paua 7’ (Kahurangi Point, West Coast to Cape Campbell, East Coast) fishery and its supporting habitat including declining paua catch and kelp was investigated as part of an ecosystem service review (ESR) led by Aotearoa Fisheries Limited (AFL) and the Sustainable Business Council (SBC) (Short 2015). The ESR concluded that terrestrial sedimentation significantly impacts kelp (*Macrocystis pyrifera*) health and its effects are likely compounded by regional climate-change related impacts, including changing pH, temperature and other oceanographic and chemical factors. Research also highlights the strong inter-relationship between the health of kelp and population levels of kina, rock lobster and paua. A co-hosted workshop in June 2015 (AFL, Department of Conservation (DOC) and the Ministry for Primary Industries (MPI), Terra Moana) was attended by stakeholders and public. A participant at the stakeholder meeting, David Baker, a resident of Cape Jackson since 1965 recalled that on his arrival, the outer Sounds were a “pristine marine environment, similar to how Stewart Island appears today”. This corroborates the observations of Tom Norton. In 1975 David noted a decline in *Macrocystis* and other large kelp species around Blumine Island and Pickersgill area, with further losses between 1980 to 1990 in the inner QCS with some noticeable changes happening in the outer QCS later in that period (Figure 4-5). By 1990 to 2000 David claims that almost all *Macrocystis* has gone from inner QCS except for a few isolated areas that “have a good tidal flow” and he claims there has been “a slow but continued loss in the outer QCS”. In conjunction with the loss of *Macrocystis* canopy, David also noted a loss of understory base weed beds from the mid 1970’s onwards, particularly in the inner sound. Initially this went unnoticed. From 2010 to the present, most *Macrocystis* beds have continued to decline. He attributed the kelp decline to the high sediment levels in the water in and around Cook Strait. He said that, where once the water was dirty for a day or two after a storm, it can now remain dirty for weeks. He thought the sediment was not only coming from the Sounds, but also Nelson Bays, the Manawatu River and the Whanganui River. Interestingly, David did not attribute any of the kelp decline to grazing by kina, which he said had also declined in numbers, and are now rare within snorkelling depths in the outer QCS.

At first, David did not draw any links between the losses of algal beds with similar declines in paua stocks over the same period, initially thinking the decline was due to overfishing of paua. However, he noted that after the loss of the *Macrocystis* canopy, juvenile recruitment declined, especially in areas like Cape Jackson that supported a healthy juvenile biomass. Over the past seven or eight years he noticed quite an acceleration in loss of paua biomass in areas from Cape Koamaru right through to the west side of D’Urville Island with similar “drastic change in [understory] base weed”. Although he thought the total allowable commercial catch (TACC) quota was set too high in the initial years, since reductions were made for a short time in 2005-2007 there was a stabilisation in the biomass in the paua fishery. But David attributes the further loss of paua biomass, and stunting of individuals, to the continued loss of both *Macrocystis* and understory sea weed beds. He lamented the rate of kelp decline which he said has accelerated dramatically in the last decade, as compared with the first 15 years of its decline, and said “we need to do something quickly to turn it around”.

Figure 4-5: Kelp (*Macrocystis pyrifera*) bed loss as reported by David Baker, commercial fisherman and resident of Cape Jackson since 1965. Map kindly provided by David Baker.

4.11 Historical benthic habitat surveys

The earliest study of soft sediment communities was undertaken in the Marlborough Sounds by Dell (1951) who sampled three stations in the outer Queen Charlotte Sound; two adjacent to White Rocks, and one off Pickersgill Island with a 'naturalist' dredge. Dell described a "brachiopod [lampshell] (*Calloria* and *Tegulorhynchia*) – *Chlamys* [queen scallop] formation" from a hard bottom community dominated by a large percentage (59.2%) of particles >2 mm with an infaunal composition closer to the "*Tawera* [veneroid bivalve] + *Glycymeris* (dog cockle) formation described in Auckland Harbour by Powell (1937) and from other high-current areas in Fiordland by Fleming (1950). The second sample taken off-shore from White Rocks was described as an "*Echinocardium* [heart urchin]-Scaphopod [tusk shell] community" dominated by medium and fine sands. Along with the heart urchin *Echinocardium australe*, the scaphopod *Dentalium arenarium* and bivalves including *Tellinella charlottae*, *Nemocardium pulchellum, Ennucula strangei,* and *Nucula hartvigiana* were present. The third sample taken from inner Pickersgill Island was dominated by soft mud, and described as an "*Echinocardium* formation" of (Powell 1937). This assemblage was similar to that described by Estcourt (1967) who sampled over 50 stations at depths between 11–140 m in the Marlborough Sounds using a large grab. Escourt noted an "*Asychis* [tube-forming maldanid polychaete] – *Echinocardium* [heart urchin] – *Amphiura* [burrowing brittlestar] association" or "sheltered water muddy-bottom association" at the majority of sites. Although the similarities of the infauna between the Pelorus and QCS outweigh the differences, Estcourt (1967) reported that most species were detrital feeders and that differences in the composition of assemblages between the Sounds were mostly lack of maldanid polychaete *Asychis theodori*, the capitellid polychaete *Capitellethus dispar*, the heart urchin *Amphiura norae* [now *correcta*], and the bivalve *Dosinula zelandica* from samples collected in Pelorus Sound. Estcourt attributed a higher species diversity in Pelorus compared with QCS to higher detritus from attached algae on the sand and mudbanks fed by "nutrient salts" from the Pelorus river.

Estcourt (1967) noted the scarcity of live specimens of molluscs in the soft sediment fauna, which was a "remarkable contrast with the amount and variety of dead shells". Dell (1951) also reported a high number of dead mollusc shells, from species of which were not represented by living specimens. McKnight and Grange (1991) described from 97 benthic samples collected throughout the Marlborough Sounds and adjacent coast: "3 station groups could be recognised, each with a different suite of characteristic species. Both sounds contained a similar benthic community, dominated by infaunal, mud-dwelling species, whereas the outer coast contained two communities, separated by depth and coarseness of sediment". The species present were not "unexpected" and typical of muddy habitats described elsewhere in New Zealand. It appeared, however, that there had been marked changes in benthic communities over the 25 years between Estcourt's 1967 survey, with potential local effects from mussel and salmon farms and sediment discharge from forest clearing (McKight and Grange 1991).

No historic surveys of hard-bottom substratum are known from QCS. However, given that the soft bottom assemblages from Pelorus were similar to QCS, in 1951 a sample of greywacke ledge rock collected at 201 m off Stephens Island, Cook Strait (Dell 1951). This sample was likely representative of fauna living on rocky habitat off the outer QCS. The sample contained:

> The most prominent of the attached organisms were sponges and ascidians. A large *Balanus* was common and a large clump of *Scalpellum villosum* Leach was present. The attached molluscs included: *Arca novaezelandiae* Smith, *Cardita aoteana* Finlay, *Monia zelandica* (Gray), *Modiolus areolatus* (Gould), *Sigapatella novaezelandiae* (Lesson), *Modiolaria impacta* (Hermann), *Hiatella australis* Lamarck, *Ostrea* cf. *sinuata* Lamarck, *Chlamys gemmulata gemmulata* Reeve, *Notoplax* n.sp. The brachiopods: *Tegulorhynchia nigricans* (Sowerby), *Terebratella* (*Waltonia*) *inconspicua* (Sowerby), *Terebratella* (*Magasella*) *sanguinea* (Leach), were attached. Some molluscs were living among the rocks and are presumably normal members of this habitat—e.g.: *Pallium convexum* (Q. & G.), *Venericardia purpurata* Deshayes, *Notocorbula* (*Anisocorbula*) *zelandica* (Q. & G.), *Marikellia rotunda* Deshayes, *Trichosirius inornatus* (Hutton), *Emarginula striatula* (Q. & G.), *Tugali elegans* Gray, *Venustas punctulata* Martyn, *Herpetopoma larochei* n.subsp. A single specimen of the crab *Leptomithrax longipes* Thomson was obtained. In addition, among the shell debris, there was a broken valve of *Acar sandersonae* Powell.

1951

5 Contemporary changes to biogenic habitats

5.1 Long Island – Kokomohua marine reserve

The establishment of marine reserves combined with monitoring after protection can provide insight into historical changes to marine assemblages, including the benthos. With New Zealand having the highest proportion of endemic species in the world (Costello & Emblow 2005; Gordon et al. 2010), the need to conserve representative biodiversity is great. The Department of Conservation is tasked with protecting a full range of marine habitats and ecosystems that represent New Zealand's indigenous marine biodiversity (Director-General for Conservation, 2000; Lee et al. 2015). There are currently 38 marine reserves in New Zealand that fully protect biodiversity (i.e., completely no-take) (Ballantine 2014). The Long Island – Kokomohua marine reserve is the only marine reserve in the Marlborough Sounds representing approximately 0.2 % of the Marlborough Sounds marine environment (Davidson & Richards 2015). Encompassing Long and Kokomohua Islands, inside the entrance to Queen Charlotte Sound, the islands are attached to a large submerged reef. This marine reserve has been monitored for 22 years since March 1992, one year before it was established.

The provision of baseline survey data prior to the reservation of Long Island – Kokomohua marine reserve allows for a before-after-control-impact (BACI) comparisons of changes after cessation of commercial and recreational fishing. Conspicuous changes to abundance of species targeted by fishers inside the reserve include increases in the abundance of: blue cod (3x increase); blue moki (1.4x increase); rock lobster (11.5x increase); black foot paua (1.4x increase), and reductions in the number of kina (3x decrease), especially small (<45 mm) kina between 1992 and 2014 (Davidson et al. 2014). Associated with the decrease in the bag limit for cod in 1992, there was also an increase in the number of juvenile blue cod seen inside and outside the reserve. Large male and female rock lobsters dominated reserve populations whereas they were absent outside the reserve. Behavioural changes were also evident, including lack of fear by both blue cod and blue moki, which largely ignore divers in the reserve as compared with avoidance of divers outside the reserve. Also, rock lobsters occupied open rocky habitat lacking crevices or holes and were able to be handled with relatively little response (Davidson et al. 2014). The reduction in the number of smaller kina inside the reserve was attributed to increased predation, and was proposed as the first indirect change recorded inside the Long Island– Kokomohua marine reserve.

5.2 Degradation of significant marine sites (biogenic habitats)

A recent report by Davidson and Richards (2015) shows significant marine ecosystems in the Marlborough Sounds are being degraded or lost at an alarming rate since monitoring began in 2010. More than 1431 hectares of biogenic habitat, the size of Blenheim and its suburbs, had disappeared in the Sounds since the late 1980s (Simpson 2015a). Nine sites, ranked as significant because of their biological values, had decreased in area by 71 per cent.

Figure 5-1: On soft sediments, a horse mussel (barely visible here) can provide valuable settlement surface for a large range of species to colonise forming complex biogenic habitats including: macroalgae, sponges, ascidians, bryozoans. (S. Handley, Dusky Sound, Fiordland, courtesy of Department of Conservation).

Of twenty one sites monitored in 2014-15 within three study regions; QCS, Tory Channel, and Port Gore (Figure 5-2), 12 increased in reported size (113.8 ha) due to detection of new areas supporting medium or high biological values. However, 9 sites declined in size with the recommendation made for removal of 2 sites because they no longer represent locations containing biogenic habitat. The remaining seven sites declined by 27% to 96%. The initial size of two of these sites may have been over-estimated while the remaining five offshore, soft sediment sites decreased in size due to anthropogenic effects such as trawling, dredging and sedimentation. The report stated "Marlborough's significant marine sites are the remnants of much larger areas, however, based on the present investigation of 21 sites and sub-sites it is clear that these sites are being degraded or lost at an alarming rate". Damage directly observed and attributed to human activity were:

- Ships Cove to Cannibal Cove: "regularly dredged offshore and therefore influenced by physical disturbance and resuspension and subsequent smothering by disturbed sediments",
- Hitaua Bay Estuary: "appears to have recently been influenced by the deposition of fine sediment from the logged catchment. Observations show a build-up of fine sediment over and around intertidal cobbles and a disappearance of some intertidal species compared to a baseline survey conducted in 2003"
- Perano Shoal: "anchor damage was recorded at half of the samples collected by divers (15 of the 30 quadrats) with mean damage estimated at 13.7 % cover"

- Outer Queen Charlotte Sound including horse mussel beds (e.g. Figure 5-1): “recreational dredging was observed on a number of occasions re-suspending sediment at sufficient levels to obscure the underwater camera”. (Davidson & Richards 2015).

During presentation of the 2015 Significant Marine Site report findings to the MDC Environment Committee, Rob Davidson stated "If we don't do anything they [significant marine habitats] will gradually be degraded and lost. We can't sit and hope. Because sites are unseen, we are unaware our collective impact is causing severe disturbance and decline of our most significant habitats, of which there are relatively few remaining. If we think about these habitats as Marlborough versions of coral reefs, which are being damaged and destroyed, they need protection and restoration” (Simpson 2015a).

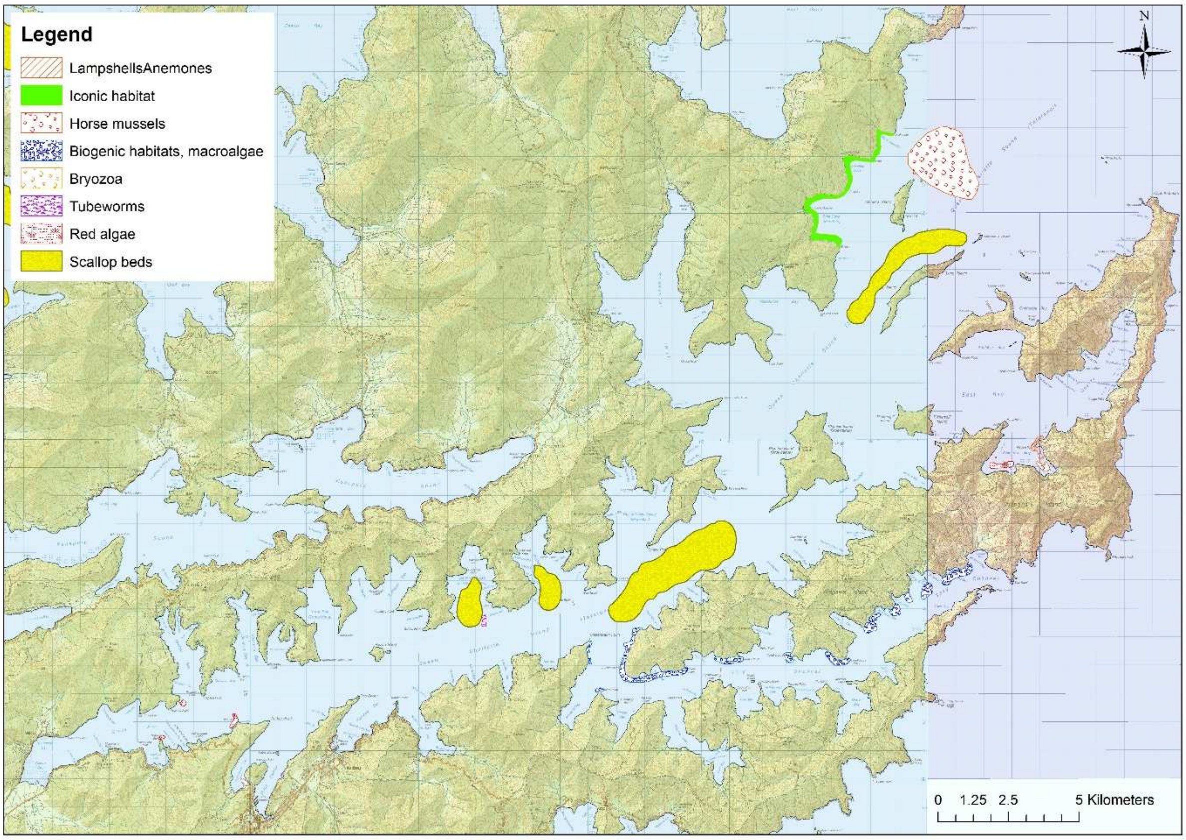


Figure 5-2: Map of biogenic habitats in Queen Charlotte Sound: habitats digitised from Davidson and Richards (2015) and historic scallop beds drawn by sBull (Unpub.) (Handley 2015).

5.3 Changes to the food web

In a similar review of changes to the seabed of Pelorus Sound (Handley 2015), the potential for a ‘regime shift’ (Scheffer & Carpenter 2003) having occurred was raised following the apparent changes to finfish species abundance and composition. Decreased numbers of large predators including rig, snapper and crayfish were reported. Regime shifts occur when an ecological system switches to an alternate system state (Scheffer & Carpenter 2003). For example, the loss of large apex predatory sharks can lead to increasing numbers of smaller sharks and rays that top predators feed on (Myers et al., 2007). It was hypothesised that the changes observed in increased numbers of smaller sharks in Pelorus might be the result of a ‘trophic cascade’, or an example of ‘predator release' whereby smaller sharks flourish when larger species are removed from the food web (Handley 2015).

It has been demonstrated in marine reserve studies that at fished locations without predation by rock lobster and snapper, kina populations increased and created grazed barrens (e.g. Figure 4-3), with reductions in the extent of macroalgae and associated abundance of invertebrates and fish (Cole & Keuskamp 1998; Shears & Babcock 2002; Shears & Babcock 2003; Eddy et al. 2014). As reported elsewhere in New Zealand and overseas, removal of apex predators and engineering species like lobster can lead to "trophic-cascade effects", altering finfish species composition and benthic communities over time.

In QCS, the obvious changes reported herein include dramatic declines of:

- migratory biomass of pilchard 'feed-fish';
- whale stocks;
- rock lobster as keystone reef species that control grazers;
- predatory blue cod, kahawai, groper/hapuka, snapper and large sharks.

As pilchards have few direct competitors, feed on both micro-zooplankton and phytoplankton, and are a favoured prey of larger fish, seabirds, and marine mammals, they occupy a key trophic position in their ecosystem (Paul & Parkinson 2001). Pilchards can directly use nutrients and energy captured during diatom blooms, and so they can rapidly increase in numbers when these blooms occur. Although studies of pilchard stocks and fisheries elsewhere reveal considerable short and long-term fluctuations in biomass size, linked to changes in climatic and oceanographic conditions, population declines may also result from overfishing a naturally shrinking stock (Paul & Parkinson 2001).

In the case of groper a "shifting baseline" was noted in Southern New Zealand whereby a lack of knowledge about virgin populations and these early fisheries has been revealed (Maxwell 2010). Sources of information from fisher's interviews, archaeological data and grey literature, was used to reconstruct the Otago groper fishery over the past 100 years (Maxwell 2010; Maxwell 2011). Maxwell's research supports evidence from newspaper accounts herein that groper were formerly abundant in nearshore areas of the Sounds early last century, and that fish size and catch size have decreased significantly over time. Groper recently occurred in remote shallow coastal locations like Spirits Bay, Northland, and in Fiordland (Handley, pers. observ., Figure 5-3). It was also reported that schools of surface feeding groper can occasionally be seen in remote locations in Fiordland (Rob Swales, Riverton, pers. comm. 2016) lending credence to past observations of the species in the inner Marlborough Sounds.

Figure 5-3: A groper at 5 m depth in Spirits Bay, Northland, 2003 (top; S. Handley**). School of groper observed by remote operated vehicle (ROV) swimming at 37 m amongst black coral in Fiordland (bottom;** S. Handley, courtesy of Department of Conservation**).**

Blue cod, that generally avoid silty waters, are most commonly found on gravelly bottoms, usually a strip about 70 m wide around the edge of the coastline in all areas of the Marlborough Sounds, except where there are fairly strong currents, such as Tory Channel or the Chetwode Islands (Rapson 1956; MFish 2000). They are also caught on the open coast over coral and rock formations, and in beds of kelp (*Macrocystis pyrifera*) (Rapson 1956). Blue cod congregate at the bottom for spawning over hard bottoms or reef, and blue cod larvae appear to settle after hatching following a short egg stage (4.75 d at French Pass, 9-11°C), perhaps in deeper waters, for example between Stephens Island and Kapiti Island (Rapson 1956). Although, 33 post-larval blue cod were obtained near the bottom in Croisilles Harbour. The colour of juvenile blue cod, being a rusty brown, "which is apparently typical of juveniles and indicates deep water habitat" (Rapson 1956). The diet of blue cod appears to change as they grow in size, and by location being largely opportunistic. In the Marlborough Sounds, they feed on the following in order of importance: pelagic fish (pilchards and sprats), ctenophores, salps, octopus, crustaceans, shelled molluscs, then sea squirts, sea anemones and seaweed (Rapson 1956; MFish 2000). It was recognised in early 1970's that gradual habitat change in QCS, from a once rocky bottom to that of sandy silt, has reduced the area of suitable blue cod habitat and hence is responsible for the decline of the fishery (MFish 2000). In the outer Marlborough Sounds, concerns were raised to MFish over the damage to coral on reefs [bryozoans or tubeworms?] by trawlers. The outer Sounds were thought to be important spawning grounds and juvenile nursery grounds (Rapson 1956; MFish 2000). Although pilchard and sprats have been historically important in blue cod diet, it is unknown if the decline in pilchard biomass from past numbers has had an effect on blue cod stocks.

5.4 Aquaculture

Suspended finfish aquaculture farms in operation are present in Te Pangu Bay, Clay Point, and Ngamahau Bays in Tory Channel and Ruakaka and Otanerau Bays in QCS with a permitted cage area of ca.10 ha (Table 5-1). Suspended shellfish farms are present in Ngaruru, Oyster and Hitaua Bays, Tory Channel, and in the southern bays in East Bay. Shellfish farms with a status of "granted" by MDC cover approximately 133 ha in QCS, as compared with ca. 2,500 ha farmed in Pelorus Sound (Handley 2015).

Table 5-1: Estimates of nitrogen discharged based on consented feed volumes. Estimated based on 45.6 kg per tonne (Knight 2012) plus an additional 20 % (9.12kg) to account for the possible release of seabed nitrogen deposited on the seabed around salmon farms (Taylor et al. 2015). ha = hectare, tpa = tonnes per annum.

Consent No.	Location	Cage area (ha)	Feed (tpa)	Nitrogen discharged (tpa)
U150081	Te Pangu	1.5	4,000	0.22
U060926	Clay Point	3.15	4,500	0.254
U021247	Ruakaka	2	3,200	0.18
U040217	Otanerau	2	4,000	0.22
U140296	Ngamahau	1.5	4,000	0.22
		10	**19,700**	**1.08**

The effects of aquaculture on benthic communities have been comprehensively summarised previously (Keeley et al. 2009; McKindsey et al. 2011; Keeley 2013) and will only be briefly reviewed herein. Finfish farms – or "fed aquaculture" – cause the deposition of faeces and uneaten feed, which leads to over-enrichment via organic particles reaching the seabed (Hargrave 2010; Wai et al. 2011; Keeley 2013). The principles governing the severity and spread of effects are similar for suspended shellfish farms, but finfish farms, because of the addition of feeds, and the nutrients they contain, add greatly to organic enrichment and smothering. Also, because of the requirement for net cleaning and net coatings, there is the potential for sediment contamination with trace metals (e.g., copper and zinc, (Keeley 2013).

Overall, the impacts from suspended shellfish farms have been described as typically limited in magnitude except under extreme conditions of poor tidal flushing or under very high stocking densities (McKindsey et al. 2011). Suspended marine farms form a porous barrier to tidal, wind, and wave driven circulation (Plew et al. 2005; Stevens et al. 2008) and because shellfish farms increase filtration capacity, they increase the deposition of faeces, pseudofaeces (un-digested material), and shell and associated fouling organisms – all additional sources of carbon and nitrogen (Christensen et al. 2003). The severity of effects on hydrodynamic circulation, sedimentation, and drop-off of fouling depends on the site, which brings other important mitigating factors into play. For example, farms exposed to large waves or currents typically produce lesser benthic effects than those sited in low flow sheltered locations, as deposited materials are dispersed more widely at exposed sites (Hartstein & Rowden 2004; McKindsey et al. 2011). Sheltered, deep locations also typically have finer sediments at the seabed, meaning oxygenation and chemical flux in and out of the sediment is inhibited at such sites (McKindsey et al. 2011). The accumulation of shellfish and shell beneath farms may armour sediments from erosion and resuspension, further amplifying sedimentation and enrichment rates within the zone of impact (Ysebaert et al. 2009; McKindsey et al. 2011; Kellogg et al. 2014). The magnitude of benthic enrichment is a function of quantity and the digestibility of the food (plankton) in the water column above the seabed, with greater deposition at sites with poor quality food and high sediment concentrations. The removal of biodeposits beneath a farm are affected by the rate of supply, initial dispersal, the rugosity (roughness) of the receiving seabed, the redistribution of biodeposits (via creep, siltation and/or resuspension) and the rate of decay of deposited material (Giles et al. 2009; McKindsey et al. 2011; Kellogg et al. 2014). However, under a typical mussel farm in the Marlborough Sounds, organic enrichment is seldom assessed to be above 'low to moderate levels' with ca. 7.5% enrichment of sediments (Keeley et al. 2009).

The extent and severity of benthic impacts depends on site characteristics such as hydrodynamic conditions (wind and tidal currents) and water depth (e.g. Kempf et al. 2002). Increased quantities of biodeposits from shellfish or waste feed pellets and faecal matter at the seabed beneath finfish farms pose both physical (smothering) and biogeochemical (microbial, geological, and chemical) effects which are interrelated (Giles 2008; Hargrave 2010; McKindsey et al. 2011). These biodeposits typically have high carbon and nitrogen content, are either eaten by deposit feeders or decomposed by microbes in the presence of oxygen (aerobic nitrification). If deposition rates are high and localised, the process of nitrification can strip the oxygen from the overlying water or surface sediments, rendering the sediments anaerobic (anoxic). Under anoxic conditions, sulphate reduction and methanogenesis of organic material can take place producing hydrogen sulphide and methane (Keeley 2013). Hydrogen sulphide, the gas that smells of "rotten eggs", can be toxic and enter living cells by passive diffusion (McKindsey et al. 2011). In extreme circumstances such as under a poorly managed fish farm, these anaerobic processes cause the sediments to be stained black and develop a whitish film or mat of filamentous *Beggiatoa* sp. bacteria at their surface (Hargrave 2010). Salmon farms sited in high flow areas of Tory Channel appear to have reduced benthic effects as compared with the farm in Ruakaka Bay (Handley, pers. observ.).

A study of the recovery of the seabed occupied by a mussel farm retired 12 years previously in East Bay, Queen Charlotte Sound, demonstrated two types of recovery (1) species recovery (e.g., return of species displaced by mussel farms), and (2) physical recovery of the habitat/substratum (Davidson & Richards 2014). The time-frame for the recovery of species was less than the recovery of habitats. In turn the recovery of silt and clay (mud) substrata was more rapid than areas supporting coarse substratum (e.g. sorted shell and fine sand). Physical recovery of deep mud took between 5 and 11 years after the cessation of mussel farming whereas recovery of coarse, shell gravel containing soft substratum took up to 11 years after the cessation of mussel farming (Davidson and Richards, 2014).

5.5 Forestry

Land clearance, including felling and milling of trees for timber was a common source of income for early settlers. Timber extraction was the usual method of financing the development of pastoral farming in the early European Sounds period (Clarke 2014). Many timber mills were established between 1900 to 1960 with nearly two thirds of the 1,480 km^2 native bush catchment of the Marlborough Sounds estimated to have been logged from the flatter lands by 1910 (Bowie 1963; Laffan & Daly 1985; Lauder 1987). The hills were also burned to develop into pasture and it is thought that the fertility for pastoral farming initially came from burning the bush (Clarke 2014). In contrast to modern forestry harvesting methods, the use of fire following bush clearance, created ash and wood debris that filtered the water, encouraging rapid growth of grass, fireweeds and liverwort which restricted sediment transport on lower slopes (O'Loughlin et al. 1980). By 1880, the hill slopes up to 100 and 300 m elevation were cleared of bush (Bowie 1963). The population of the Sounds is thought to have peaked at the turn of the century, with pastoral farming peaking by about 1910. By the 1950's the fertility of the land had declined necessitating the addition of artificial fertilizers to maintain farming productivity, otherwise land was abandoned and left to revert to native bush (Clarke 2014). Accelerated siltation from land clearance caused dramatic changes in the neighbouring coastal environment (Handley 2015).

Following land clearance for pastoral farming, it is estimated that 5,000 ha of land has been planted with exotic forest since 1963 - mainly in radiata pine (*Pinus radiata*) - with the potential for 40,000 ha of afforestation (Laffan & Daly 1985). A number of factors limit the profitability of forestry in the Marlborough Sounds, including; market forces, isolation, soil quality and environmental costs. Total nitrogen concentrations in the topsoils of the Marlborough Sounds are low, and critically low below the top 10-20 cm, meaning if the top layer of soil is eroded, then the soil becomes deficient for exotic forest growth (Laffan & Daly 1985). Similarly phosphorus levels are universally limited. The soils formed from greywacke and schist have moderate nutrient limitations, especially in the upper slopes of the Sounds, and soils formed from serpentine generally have moderate to severe physical and nutrient limitations for growing exotic forest (Laffan & Daly 1985). Environmental issues arising from forestry include impacts on water quality, transport and visual landscape issues (MDC 2008). Although forested catchments generally have lower rates of sediment discharge to the marine environment, forestry can increase erosion of soils during track construction and development, and during harvesting (Davidson et al. 2011). Increased sediment loading may have profound effects on marine biota (Schiel & Foster 1986; Estes et al. 1989; Cole & Babcock ; Airoldi & Virgilio 1998).

The slope and elevation of forestry land, road construction and particularly side-casting of excavated materials dominate activities associated with sediment runoff from forestry. Land available for forestry in QCS is generally steeply sloped. A study carried out on similar steep land near Reefton found a disproportionate sixty percent of the sediment discharged from clear-felled land originated from track surfaces or the loose soil and gravel accumulations which were sidecast onto the steep slopes below forestry tracks during their construction (O'Loughlin et al. 1980; Lauder 1987). The volumes can be significant following the construction of new roads and landings, with an estimated 218 tonnes of sediment per square km eroded from roadways during movement of logging trucks and machinery along roads, tracks, and landings in the Sounds each year (Fahey & Coker 1992) with sediment discharge increasing as much as five times following logging truck movements over roads consisting of weathered schist (Coker et al. 1993). As a result suspended sediment concentrations in adjacent coastal waters can increase to 1,000 milligrams per litre compared to background concentrations of 15-20 milligrams per litre (Fahey & Coker 1992) where it quickly settles out on the seafloor.

A review by Urlich (2015) highlighted that sedimentation derived from forestry harvesting in the Marlborough Sounds is inevitable no matter how many and how stringent the controls due to a combination of high intensity rainfall events, the steep aspect of the land, and the nature of the underlying lithology and soils in the Sounds. Susceptibility to erosion, or the 'window of vulnerability' is most pronounced in the 5-8 year interval between the decay of harvested tree root systems and the establishment of the next tree crop and/or seral plant species. Soil stratigraphy and composition predisposes the Marlborough Sounds to increased erosion from track construction as the subsoils are more erodible, and the clays more dispersive, than the upper soil layers (McQueen et al. 1985). The shallow soil mantle sits over weakly weathered rocks, which can slip under high rainfall due to relatively shallow shear planes between the thin soil and bedrock (Fahey & Coker 1992). The susceptibility of erosion in recently harvested areas is also related to the decay of harvested tree roots. Roots lose much of their soil holding strength a year after logging, leading to greater susceptibility to soil erosion before the roots of the new crop take hold 5-8 years after replanting (Johnston et al. 1981; O'Loughlin 1985). In the Sounds, multiple shallow landslides occur even in moderate storms on slopes over 30° during this 1-8 year "erosion window" post-harvest. These landslides (e.g. Figure 5-4) which intensify the scouring in ephemeral streams and swale areas, can end up in coastal waters (Urlich 2015). The range of grain sizes delivered to the coast (from fine to coarse) increased the closer the erosion takes place to the shore, and also the steeper the land adjacent to the coast (Lauder 1987).

The ramifications of these issues are exacerbated during large storm events or 'weather bombs'. During the "erosion window" of post-harvest and prior to early forestry growth, storm damage and erosion in plantation forests can be comparable to, or less, than other land uses, depending on the storm path and slope (Marden & Rowan 2015). However, recent observations following Easter 2014 storm-related damage from well-managed and well-maintained forestry blocks in the Marlborough Sounds, demonstrated that even under good management, good operators cannot protect the environment from rain storm damage (MDC 2014). For example, in two storm events that hit Farnham Forest QCS in 1983, the slopes on which landslides occurred were in the range of 30° to 40° in areas harvested one to three years prior to the storm (O'Loughlin 1985). Similarly, although storm-initiated slope failures following a major storm in the Coromandel occurred mostly in indigenous forests, sediment generation rates were greatest in the pine forests harvested three years prior to the storm. This was also the case for the December 2010 storm in Marlborough which caused widespread erosion (Gray & Spencer 2011). Under high rainfall intensity, considerable run-off into coastal waters occurs from erosion and land-sliding where hillslopes are directly coupled to the coast (Johnston et al. 1981). For example, an intense storm between 5 and 10 November 1994 resulted in widespread landslides in the Sounds, including within plantation forests. Landcare Research scientists identified eight landslides in a recently harvested forest above Opua Bay, Tory Channel (Phillips et al. 1996). All landslides were below 200 m elevation in gully depressions in steep slopes (often over 30°). Managing the window of vulnerability is problematic in a clear-fell system, as opposed to coupe harvesting (felling smaller clusters of trees) (O'Loughlin 1985; Phillips et al. 1996). This is because greater amounts of sediment are produced in a clear-fell system due to the area of bare soil exposed. In addition, there is a buffering effect from surrounding trees left in a coupe system which can partially contain sediment runoff. The reduction in evapotranspiration loss caused by widespread tree removal causes soils to become more waterlogged and prone to slipping (O'Loughlin 1985; Phillips et al. 1996). It is important therefore that the "erosion-window" of vulnerability is not prolonged by any delay in replanting, and sufficient seedlings are planted to hasten the establishment of a root network to hold erodible soils (Phillips et al. 2012).

Figure 5-4: Landsliding and debris flows on shallow soils Tory Channel (from Phillips et al. 1996: Fig 3b. p29).

5.6 Public roading and storm events

Although forestry roads may contribute disproportionately to erosion and slips, maintained public roadways constructed over unstable slopes bordering the Marlborough Sounds can also contribute significantly to sediment entering waterways and the sea. To illustrate this, a report by D. Miller, the former MDC Assets Manager for Roading, recounted 12 slips along the ca.21 km stretch of road connecting Picton and Linkwater between 1985 - 2010 (Miller 2015) (Table 5-2, Figure 5-5). The slips were predominantly caused by the road being inundated by uphill material slipping down-slope, sometimes causing the roadway to subside. Sidecast material and blocked culverts also contributed. When many of these roads were built Miller was advised that the standard was "12 feet wide on solid with grades less than 1:8" meaning there was considerable sidling fills (sidecasting), unbenched and uncompacted. Estimated volumes of the smaller slips ranged from 300-3,000 m^3 (Figure 5-6), with an average slip volume of approximately 1,250 m^3 and a total of 67,100 m^3. However, these smaller slips were dwarfed by a large natural slip estimated at over 55,000 m^3 and located 14 km from Picton at the Linkwater end of the road. This slip appears to have been on the move since at least 1960, with the road having been re-surfaced in this location at least 10 times. Miller (2015) also noted that large weather events like a 'weather bomb' storm that affected parts of the Sounds in 1992 affected D'Urville Island, French Pass, Waitata area, Anakoha and Titirangi roads, with an estimated 500,000 m^3 of material involved in slips.

Table 5-2: Slips recorded along the ca.21 km stretch of road between Picton and Linkwater between 1985 - 2010 (Miller 2015). Y = yes, sidecasting was a likely contributor to the slip.

Date	Distance from Picton (km)	Volume (m3)	Sidecasting	Potential cause
1990	3.5	400	Y	Slip inundating road
1990	6.1	600	-	Road widening
1995	6.3	600	-	Slip inundating road, undercutting?
1998	6.8	500	Y	Road widening
1996	7.2	1500	Y	Road widening
2000	7.55	800	Y	Slip inundating road, undercutting?
2003	9.2	300	Y	Private accessway collapse
1990	11.25	1200	Y	Slip inundating road, undercutting?
1993	11.5	3000	Y	Culvert blockage, rebuilding atop old road
1996	12.15	1200	Y	Slip inundation, blocked culverts, natural erosion
1994	13.7	2000	Y	Slip inundation, collapsed road/sidecasting?
1960-2004	14	55000	-	Uphill water conduits lubricating slip face, natural slip
Total:		**67100**		

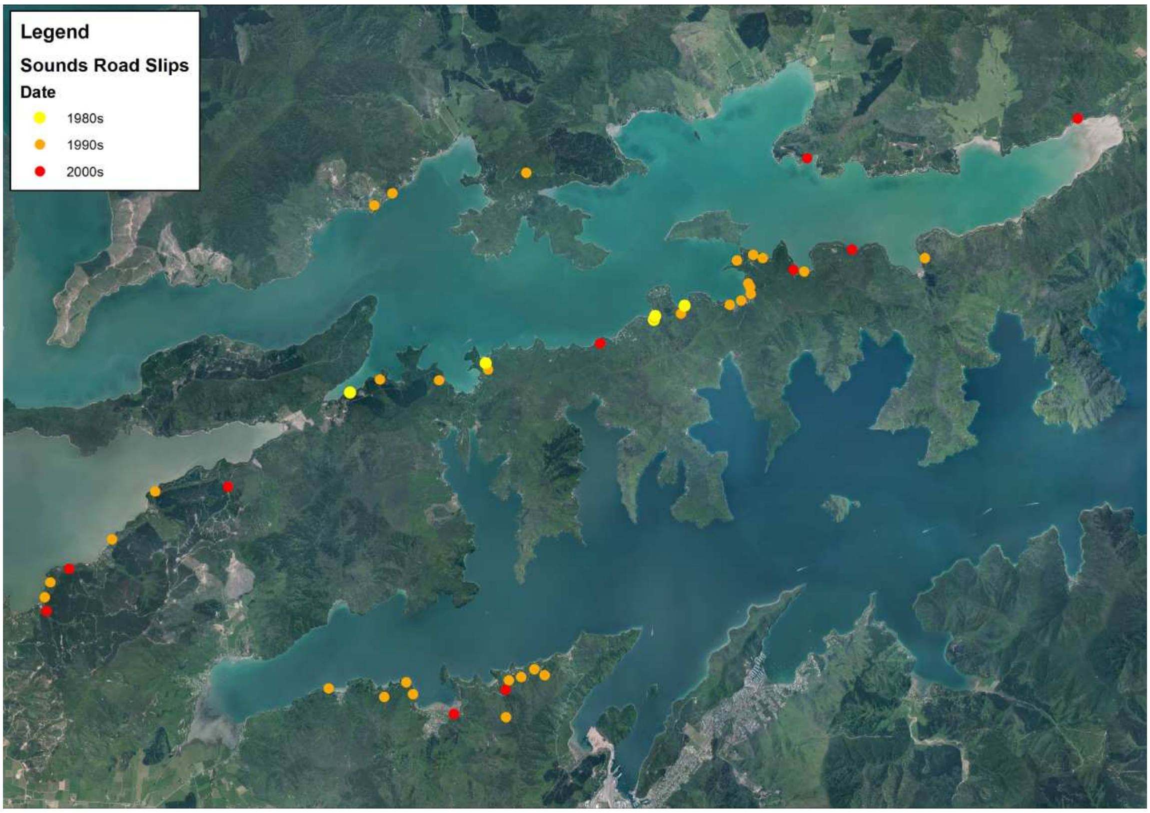


Figure 5-5: Slips that entered coastal waters associated with the transport road network on Queen Charlotte Drive (bottom centre – 12 dots) and the Kenepuru Road. Source: Miller (2015).

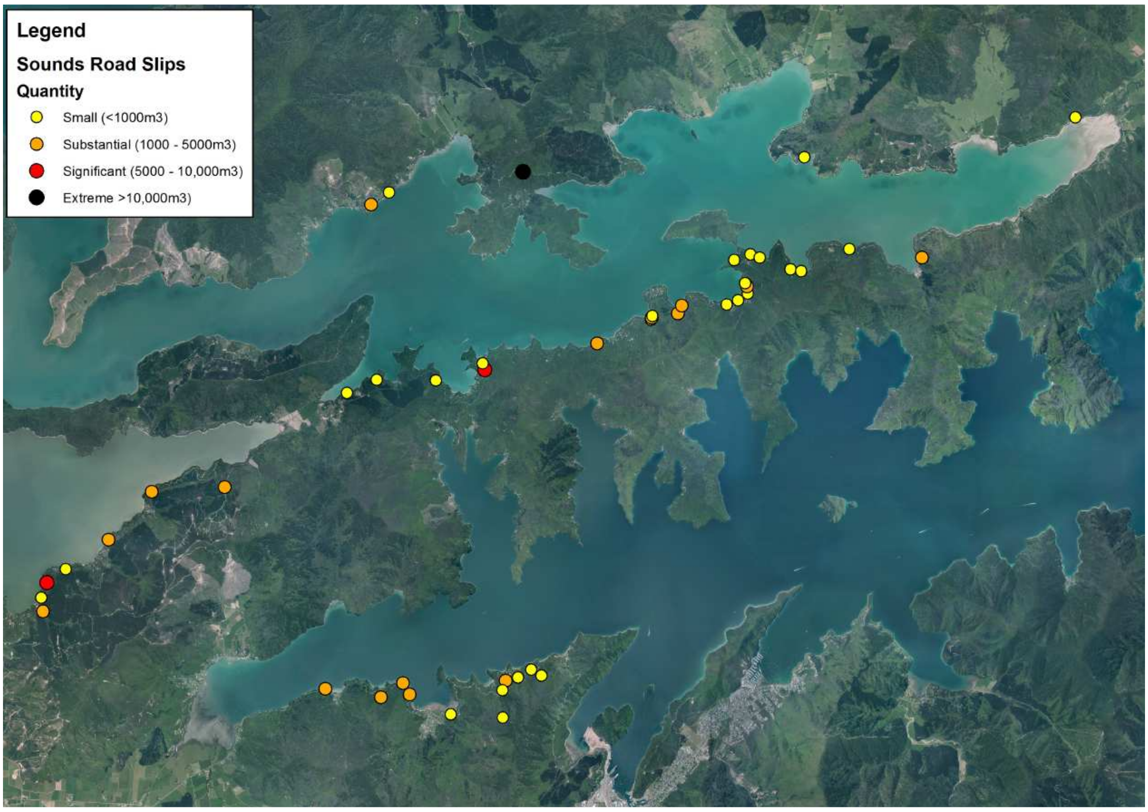


Figure 5-6: Estimated volume of slip material associated with the slips identified in Figure 5-5. Source: Miller (2015).

5.7 Sediment transport and deposition

Fine sediments washed off the land derives disproportionately from small rivers draining small and steep catchments (Milliman and Syvitski 1992) during storm events (Thrush et al. 2004). The resulting fine silts and clay sediment loads are orders of magnitude higher than average (Hicks et al. 2000). Sediment particles are mostly highly charged particles which flocculate on contact with seawater and are rapidly deposited, smothering estuarine and marine sediments (Thrush et al. 2004). The deposition of clay-rich soils, stained yellow-orange by the presence of iron-rich minerals, in the Sounds occurs rapidly upon contact with seawater according to laboratory tests (O'Loughlin 1979; Coker 1994). Those tests on Kenepuru series soils, which underlie many forestry areas in the Sounds, showed rapid flocculation and settlement of suspended sediment. The conclusion from that study was that sediment from coastal erosion was likely to settle out in close proximity to the shoreline, due to the chemical reaction of charged particles of clay reacting with seawater (Urlich 2015). Another mechanism for sediment deposition nearshore environments is by transport in tidal currents alongshore (O'Loughlin 1979) or via dilution by tidal currents. Sediments are more likely to be suspended and widely dispersed in fast flowing locations like Tory Channel and then settle out in slower flowing side bays (Hadfield et al. 2014) where the bottom stress from a tidal current is below a typical resuspension threshold of 0.1 newton m^2, (0.1 pascal) for clay-rich sediments (Figure 5-7). Therefore, the deposition of eroded sediment on the seabed depends somewhat on the hydrodynamics at a bay- and reach-scale (Urlich 2015).

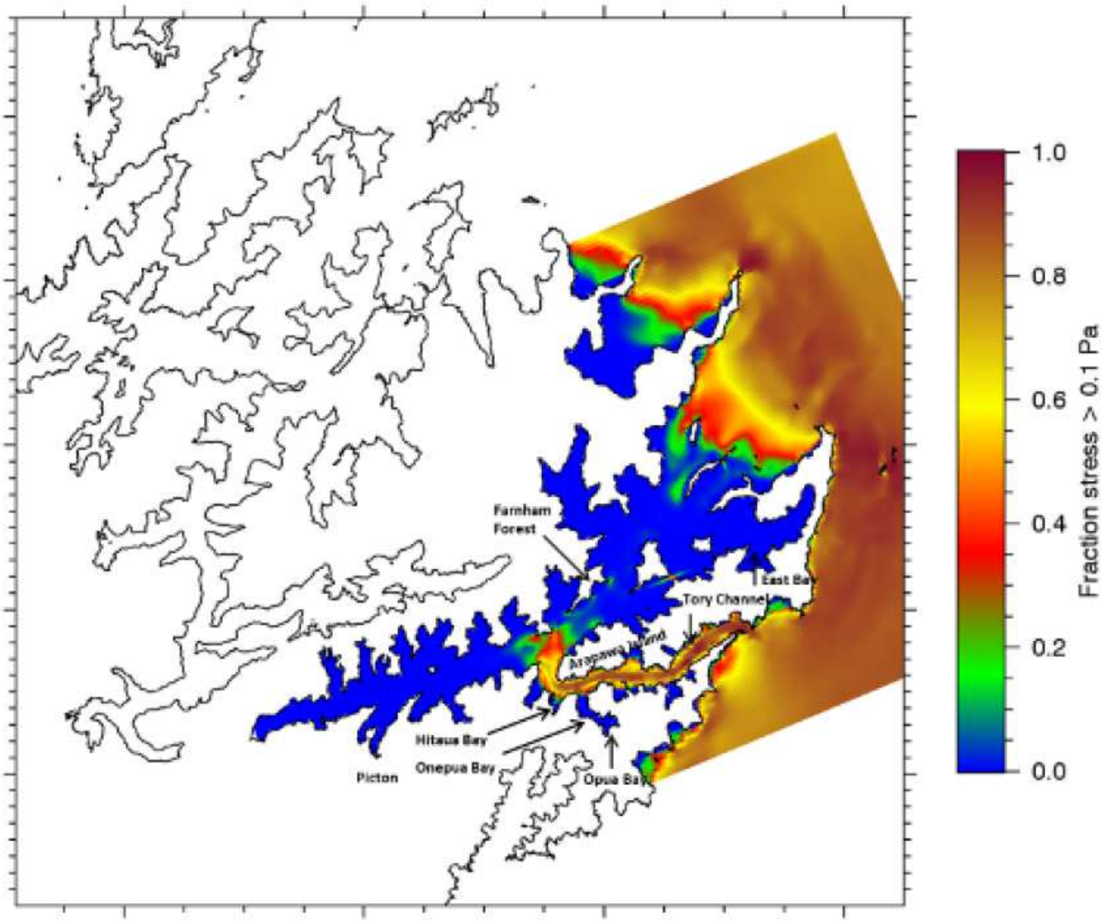


Figure 5-7: Areas within Queen Charlotte Sound and Tory Channel in dark blue where bottom stress from current action is likely to be below a resuspension threshold of > 0.1 Pascal (Pa) where fine sediment will settle out of suspension (Hadfield 2015).

5.8 Fast ferries

Large vessels generate wave energy that, in semi-enclosed sheltered seas, can have significant effects (Parnell et al. 2007). Changes to shoreline from vessel induced wave energy can result in beach and shoreline adjustment, including erosion, deposition and reorientation. On mobile beaches, larger waves may reach further up the beach, possibly overtopping beach ridges, whereas on hard shorelines increased weathering and splashing may occur.

The Tory Channel and inner QCS, being part of the national transportation route, have been the preferred route of ferry traffic since establishment in 1962, although large engine-powered ships have been using the route for at least a century (Kirk & Single 2000). As wave height and speed is related to speed of watercraft, dramatic changes to the wave climate were experienced with the introduction of high-speed fast ferries that were introduced to the Wellington to Picton ferry route in the summer of 1994-95, with up to 5 different craft operating (Parnell et al. 2007; Davidson et al. 2010). While it was accepted that changes to beach sediment movements and shoreline occurred in response to conventional ship and ferry movements prior to the use of fast ferries, considerable debate was had regarding whether the shoreline changes that took place after fast ferry traffic commenced were sustainable or significantly adverse (Kirk & Single 2000).

The use of fast ferries in Tory Channel and QCS caused initial rapid and significant accretion of gravel and movement along (some) beaches, deposition of mobile gravels, increased sediment supply by associated landslides of basal hill slope deposits, and apparent increase in siltation of near-shore and offshore areas (Valentine 1982; Kirk & Single 2000; Davidson et al. 2010). Shorelines in the far-field up to 7-10 km from the sailing line were affected – a conclusion supported by considerable anecdotal evidence (Parnell et al. 2007).

Following an Environment Court led by the "Save the Sounds, Stop the Wash", the Court stated that an adverse biological impact could not be proven due to a lack of 'before' fast ferry data and that a "new equilibrium" was established including both conventional and fast ferries (NZ Planning Tribunal, 1995). Although Kirk and Single (2000) argued that the changes to the shoreline due to fast ferries were small, self-balancing and most definitely reversible, Parnell et al. (2007) later reported that the changes especially to the far-field wake-exposed sites were irreversible, and that slowing fast ferries would not return shoreline conditions to the shape and texture that existed prior to their introduction.

Fast ferries operated at uncontrolled speeds during summer seasons from 1994-95 until an 18 knot speed restriction Navigation Bylaw was enacted in 2000, to reduce waves produced as determined by a "wash rule". The speed restriction was imposed to harmonise with the approach adopted in Navigation Bylaw 2000 that deals with elevated safety concerns related to the issues in the Marlborough Sounds caused by High Speed Craft (Croad & Parnell 2002). To improve on detection of recovery effects following implementation of this Bylaw, new intertidal and subtidal bedrock monitoring sites were sampled prior to its introduction (Davidson et al. 2010). In what was likely a bitter victory to the "Stop the Wash" appellants whom lost their Environment Court Case, the subsequent slowing of the fast ferries after 2000 led to dramatic recovery of biological communities at impact intertidal and subtidal cobble-small boulder shore as well as intertidal and shallow subtidal bedrock shores (Davidson et al. 2010). As similar changes were not evident at control sites, Davidson et al. (2010) concluded the only plausible explanation was due to the reduction in wave energy stating: "It took 15 years of monitoring to demonstrate that the concerns voiced by local Sounds residents during the summer of 1994-95 were correct and that the "new equilibrium" was in fact representative of a major adverse biological environmental impact". Interestingly, recovery of numbers of invertebrate species in shallow subtidal bedrock site, surpassed control levels; however intertidal shore recovery peaked in 2005-06 (a period of 5 years), and the density of invertebrates at intertidal and subtidal cobble shores and intertidal bedrock shores steadily declined after 2005-06. Davidson et al. (2010) attributed this recovery reversal to waves generated by conventional ferries and the introduction of the largest conventional ferry the Kaitaki in late 2005, but it could also reflect the community adjusting to a new shore-profile which may never recover to pre-impact conditions as predicted by Parnell et al. (2007).

5.9 Waste discharges

The dominant waste discharges into Picton Harbour during the early 1900s were from the Picton freezing works and the wastewater outfall. The freezing works operated on the western side of Picton Harbour discharging into Shakespeare Bay, opening in 1901 and closing in 1983 (McKinnon 2012). Tom Norton recalled seeing schools of snapper, pilchards and kahawai feeding at the surface offshore from the freezing works. He stated "you couldn't walk on the beach sometimes due to a layer of fat washing ashore".

Raw sewage generated in Picton in the early 1900s, was collected in a septic tank (Jenner et al. 2014). However population growth was such by 1948 that during heavy rain the sewage bypassed the tank directly to the nearby tidal flats. The tank was then abandoned and raw sewage was discharged into the harbour via a short outfall until 1968. Public health concerns then led to construction of a new outfall that discharged raw "primary treated" sewage from a diffuser off the northern tip of Kaipupu Point (Handley, pers. observ. ca.1993) until the Picton Sewage Treatment Plant was commissioned in 1999. The Picton wastewater treatment plant was recently upgraded in December 2012 that now discharges "tertiary" treated effluent from a diffuser on the south eastern side of the Kaipupu Point Wildlife Sanctuary (ACENZ 2015).

Wastewater treatment from accommodation facilities in the Marlborough Sounds generally requires a resource consent, granted with conditions requiring installation of high quality treatment systems, to be monitored for compliance. In QCS, historically many facilities discharged partially treated or treated waste water to sea, but now there are no longer any consents for discharge to sea. The following have permits to discharge to land: Furneaux Lodge, Endeavour Inlet; Outward Bound, Anakiwa; Punga Cove, Camp Bay, Endeavour Inlet; Bay of Many Coves Lochmara Lodge, Lochmara Bay; Mahana Homestead, Endeavour Inlet; DOC campiste, Momorangi Bay, The Grove; Mistletoe Bay, Anahau Bay; and Endeavour Lodge, Endeavour Inlet.

6 Discussion

In the presence of gradual drivers of change like natural erosion, disturbances are fast variables that trigger rapid and significant change in ecological communities (Turner 2010). The seabed of the QCS has been subjected to direct disturbance factors including burial by accelerated sedimentation, contact fishing gear (finfish trawling, shellfish and kina dredging), and modification on coastal fringes by land development and reclamations (Newcombe & Johnston 2016.). Indirect, and perhaps more pervasive disturbance factors include sediment and nutrient discharge relating to land clearance (agriculture, farming, forestry, urbanisation, industry), and now such indirect factors are likely to be exacerbated by anthropogenic climate change (Willis et al. 2007). The lack of recovery of biogenic habitats and their continued destruction in QCS (Davidson & Richards 2015) with similar changes observed in neighbouring Pelorus Sound (Handley 2015) indicates that the benthic habitats of the Marlborough Sounds have undergone a regime shift. This shift in species composition and distribution is likely to have many causative factors with complex interactions including bottlenecks created by the lack of suitable settlement substrata for recolonising organisms and the ongoing disturbance from fishing and sediment discharge from land. As these changes may have occurred over decades to centuries it is proposed a “shifting baseline” (Pauly 1995) has occurred resulting from gradual, and sometimes rapid changes to seafloor habitats in QCS. In low flow sites, where fine sediments accumulate, these habitats are now dominated by sedimentation such that what exists today is unlikely to resemble historical benthic communities and sediment composition. Also it is unlikely to recover without significant changes to the drivers of this change.

The following discussion elaborates on the types of disturbance factors at play in QCS, and how they may have impacted on benthic habitats.

6.1 Nutrient release to the sea from land based activities

Early land-clearance including the use of fire for agricultural activities by Māori were likely the first anthropogenic factors that affected sediment and nutrient discharges to the marine environment (Flannery 1994). These disturbance factors were likely accelerated greatly by European milling, farming and forestry activities that not only helped fertilise the land (Clarke 2014) but potentially the sea.

An example of how Māori agriculture altered local soils, and associated nutrient and sediment discharge to sea, is a report of significant areas of lowland soil modification by the use of charcoal on over 1,000 acres of the Waimea Plains in neighbouring Nelson (Rigg & Bruce 1923). Analysis of these gravel soils demonstrated that they contained a large percentage of fine gravel and coarse sand, dug from pits up to six feet deep, making the soil easy to cultivate and free draining. The black colour of these soils showed that they also contained considerable quantities of charcoal sourced from burning forest and regenerating species especially manuka (*Leptospermum ericoides*). The charcoal is thought to serve two purposes, that of heat absorption and the regulation of soil acidity due to charcoal’s high phosphoric acid and potash content. It was estimated that several hundred tons of trees must have been burnt on each acre in the Waimea Plains – fire was an important tool for Māori. Māori were well established in QCS (Figure 3-2) when Europeans first visited and the land there was presumably cultivated using methods similar to those on the Waimea Plains.

The use of fire by Europeans continued as a tool for clearing land for farming and later forestry, and also served to fertilise low fertility soils (whether deliberately or not). Farming on relatively unproductive land continued into the 1980’s with the addition of nitrogenous and phosphorous containing fertilizers (e.g. Clarke 2014). Together, deforestation of land for agricultural and farm-lands, urbanization and the addition of inorganic fertilizer represents the single largest anthropogenic alteration to the global nitrogen cycle, accounting for over half of bioavailable nitrogen supply discharged to coastal watersheds (Cebrián 2004; Hauxwell & Valiela 2004). Nitrogen, being a limiting nutrient in Pelorus Sound, has been shown to stimulate increased growth of phytoplankton and zooplankton (particulate nitrogen production) (Zeldis et al. 2013).

The percentage land under forest cover, and how forests are cleared, appears to result in different nutrient discharge characteristics which alter downstream effects with potential implications for the marine environment. For example, the percent of land covered by forest cover affects the ratio of N to P discharged to freshwater emerging from watersheds, with the N/P ratios in waters emerging from the most deforested watersheds being close to 4, and that ratio increasing in more forested tropical watersheds (Valiela et al. 2013). Recent studies have highlighted the ecological importance of bioavailable dissolved organic nitrogen (DON) that can be mineralized by microbial processes, (in part linked with dissolved organic carbon (DOC)), that supplies N readily available to primary producers in streams and estuaries (Seitzinger et al. 2002; Petrone et al. 2009). Interestingly, the form of nutrients and their downstream effects in freshwater was found to differ in Canadian lakes depending on whether fire was involved in clearing the forest (Pinel-Alloul et al. 2002). Mineral nutrient enrichment of lakes by burn-impacted land induced a surge in phytoplankton and micro-zooplankton production in the pelagic zone and higher periphyton algal production, whereas only a minor short term increase in phytoplankton was detected following clear-felled logging. The lower downstream productivity from logged land was attributed to higher DOC and lower light levels in the lakes, presumably from increased turbidity due to sediment discharge. A meta-analysis of 185 data sets showed that while fire does not appear to change the amount of nitrogen in soils, fire significantly increases soil ammonium (NH_4^+) (94%) and nitrate (NO_3^-) (152%) (Wan et al. 2001). The soil ammonium pool increased approximately two-fold immediately after fire, then gradually declined to the pre-fire level after one year. The increased availability of these highly soluble nutrients, that are readily absorbed by plants, may explain in part observed post-fire rapid vegetation regeneration (Turner 2010), and the growth of grass, fireweeds and liverwort which restricted sediment transport on lower slopes described by O'Loughlin et al. (1980) in Reefton. This rapid post-fire “flush” of growth has been thought to help retain nutrients on-land in some habitats. In the Marlborough Sounds that are characterised by highly erodible steep slopes, these nutrients are likely rapidly discharged to the sea (O'Loughlin et al. 1980). This hypothesis could explain the high phytoplankton productivity observed in Pelorus Sound by Clarke (2014) during early farming days following land-clearances. It is unclear whether the recent reduction of farming and the regeneration of bush, with the reduction in the use of fire has affected the quantity and bioavailability of nitrogen and phosphorus discharged to the Marlborough Sounds. It remains to be evaluated to what extent historical land-derived nutrients discharged as a result of anthropogenic disturbance has fuelled marine productivity (e.g. (Petersen et al. 2004)) including potential negative effects on benthic primary producers.

6.2 Sedimentation effects on benthic environment

Sedimentation dynamics, which are affected by supply, dispersal, and settlement, mean that many of the slow flowing side arms and the main channel of QCS are vulnerable to sedimentation (Figure 5-7). There appears to have been a “shifting baseline” of sedimentation occurring in QCS over centuries of human habitation, but due to the timescales involved and the unseen nature of sedimentation, it is difficult to appreciate the effects of historical deforestation and erosion on seabed habitats that have only recently been surveyed and monitored (e.g. (Davidson & Richards 2015). Also in the absence of historical empirical sedimentation measurements, it is difficult to evaluate modern sedimentation rates. However sediment coring studies incorporating fallout radionuclide and radiocarbon dating techniques from the Nelson-Marlborough region indicate sedimentation rates have increased significantly since human habitation, with recent accelerated erosion and sediment accretion (Table 6-1).

Table 6-1: Sediment accumulation rate estimates from Nelson-Marlborough. mm/a = millimetres of sediment accumulating per year.

Study	Location	Pre-human (mm/a)	Māori (mm/a)	European (mm/a)	Modern (mm/a)
Goff and Chagué-Goff (1999)	Abel Tasman National Park estuaries	0.5-1.7	0.98-1.19	1.6-2.7	2.3-3.3
Handley, (unpub. data)	Whariwharangi Bay, Separation Pt., Golden Bay	0.3-1.1	na	na	3.9-4
Handley et al. (unpub. data)	Kenepuru Sound	na	na	na	2.9-8.9

A recent review of the effects of land-based activities on coastal fisheries argued that the most important land-based stressor is sedimentation, including both suspended sediment and deposition effects, and associated decreases in water clarity (Morrison et al. 2009). Heavy inundations of sediment can completely bury infaunal and epifaunal bivalves (McKnight 1969) unless waves and currents can disperse the sediment plumes. As little as 3 mm of terrestrial mud can have significant effects on seafloor communities (Lohrer et al. 2004). And 26 mg/l of sediment fed continuously to sponges, oysters, and mussels adversely affected their health after thirteen days (Schwarz et al. 2006). Suspended sediments are also conjectured to have serious consequences at the ecosystem level from indirect effects, through reduced epifaunal abundance, as epifauna are responsible for about 80% of the flow of energy and materials through rocky reef animal communities (Taylor & Cole 1994). Schwarz et al. (2006) thought that it was likely that epifaunal density reductions will have knock-on effects throughout the rocky reef food webs, both downwards through reduced epifaunal grazing on seaweeds and algal epiphytes, and upwards through reduced availability of food for small fishes. Considering the heavy inundations of sediment expected during the European period of clear-felling and pastoral farm developments in QCS, it is interesting to note the comments by Estcourt (1967) about the scarcity of live specimens of molluscs in the soft sediment fauna, in contrast with the diversity of dead species. Perhaps increased sedimentation during the early European settlement period had already drastically reduced benthic faunal diversity?

The factors preventing intrinsic (or natural) recovery of biogenic habitats like soft-sediment mussel beds and scallop beds in Nelson Bays and Pelorus Sound are complex, potentially involving: over-exploitation of fish and shellfish stocks; habitat change; reduced water quality/clarity (eutrophication, sedimentation); and associated food chain effects (Handley & Brown 2012; Handley 2015). The most likely mechanism for lack of recovery is habitat change creating a “habitat bottleneck” (Morrison et al. 2009) from the loss of suitable settlement substrata for habitat forming benthic species. Examples from the Nelson Marlborough region discussed earlier included species/habitats previously important to shellfish including green-lipped mussels and scallops (Handley 2015). Stead (1971) reported that all <5 mm recruit green-lipped mussel spat in early fished populations in Kenepuru Sound were found amongst adults in the intertidal zone, rather than subtidally. Bull (1976) reported that scallops, which attach themselves as larvae using byssal threads, were formerly found in areas of the Pelorus Sound attached to brown alga *Cystophora retroflexa,* red algae attached to horse mussels *Atrina zelandica*, and drifting seagrass *Zostera* debris, with spat not colonising mud and broken shell. The loss of species that once provided settlement surfaces for mussels and scallops was likely driven by siltation, the concomitant loss of water clarity for photosynthesis in deeper water, and bottom-contact fishing methods (Handley & Brown 2012; Handley et al. 2014). In QCS, Bull (unpub. map, Figure 5-2) reported extensive scallop beds south west of Bluemine Island, in Tahuahua and Ruakaka Bays, and north west of Long Island. These beds were not recorded by Davidson and Richards (2015) and presumably like the scallop beds in the inner Pelorus Sound (Handley 2015), have suffered a similar decline.

The negative effect of sedimentation on shellfish populations is important as shellfish provide many ecosystem services, modifying the structure and composition of soft sediment habitats and communities. Large surface dwelling shellfish like horse mussels have been described as important ecosystem engineers as they provide settlement surfaces for other species, filter large amounts of water sequestering sediment and nutrients, and modifying neighbouring macrofaunal communities (Norkko et al. 2001; Hewitt et al. 2002; Norkko et al. 2006). Benthic green-lipped mussels that historically formed reefs over soft sediments in many parts of NZ, once provided structures facilitating increased biodiversity in marine invertebrate communities, and providing habitat for fish populations up to 10 times more dense than over adjoining muddy seabed (McLeod et al. 2014; Morrison et al. 2014). Shellfish also filter large volumes of water, clearing the water column of sediments, thus binding and stabilising sediments, and also play a role in nutrient sequestration and recycling (Rodhouse et al. 1984).

In the process of filtering suspended particles, and the production of biodeposits, shellfish (as beds or suspended on marine farms) concentrate and redistribute nutrients that affect nutrient cycling in two ways: through “top-down” control by grazing phytoplankton and clearing the water column and binding sediment in mucus thus allowing for increased light at the seabed; and also by “bottom-up” nutrient control on phytoplankton production (Christensen et al. 2003; Newell 2004; Ysebaert et al. 2009). In the former, the N and P are recycled by the regeneration of shellfish biodeposits at the seabed by aerobic bacteria (a process called “nitrification”) and through direct excretion by the shellfish of soluble nutrients like ammonium (NH_4^+). These dissolved nutrients in turn can be re-utilised by benthic primary producers (macroalgae and microphytobenthos) and phytoplankton in the water column (Ogilvie et al. 2000). The standing stock of algae is directly controlled by ambient nutrient levels, unless, in the case of fin-fish aquaculture, where feed containing N and P is added (Newell et al. 2005). Although the microphytobenthos (microscopic seabed plants including diatoms) may compete with bacteria that utilise N, the microphytobenthos retains N and P within sediments, further reducing return of these nutrients the water column, thus they can play a role in inhibiting harmful algal blooms (MacIntyre et al. 2004). In the case of “bottom-up” control, shellfish change the nutrient regenerative processes within the sediment, by helping deliver to and sometimes bury N and P in the sediment in the form of undigested mucus-bound biodeposits. At locations where surface sediments are aerated well, for example where there are abundant burrowing infauna that irrigate the sediment with oxygen (Pelegri et al. 1994; Christensen et al. 2003), anaerobic denitrifying bacteria (that don’t require oxygen) that live deeper in the sediment can convert buried N to inert nitrogen gas (N_2). If this N_2 gas bubbles to the surface of the sediment, it can be permanently removed from the system – a process called "denitrification". This process of degassing of nitrogen to the atmosphere is important in acting as a sink for global marine nitrogen which can help regulate the amount of primary production in coastal waters (Seitzinger et al. 1980; Seitzinger 1988). Ecosystem engineering by sediment-burrowing macrofauna stimulates benthic nitrification and denitrification, which together allows fixed nitrogen removal (Stief 2013). If biodeposit concentrations at the sediment surface become too great, and oxygen at the sediment surface is removed by bacterial degeneration of biodeposits, then hydrogen sulphide can be produced, which inhibits the activity of nitrifying bacteria which require oxygen (Kemp et al. 2005). When anoxic conditions occur, more efficient N and P recycling can occur via anaerobic pathways that release dissolved nutrients to the water column, which further supports production of phytoplankton production including harmful algal blooms – in effect, 'short-circuiting' nutrient release compared to aerobic processes. The other problem with this process is that with the loss of oxygen, the microphytobenthos and infaunal organisms that enhance denitrification are also inhibited, and the positive-feedback nature of these interactions means that they will tend to reinforce and accelerate the eutrophication process (Kemp et al. 2005).

In relation to water clarity affected by sediment content, it is not well understood what constitutes an acceptable balance between pelagic versus benthic primary production in coastal systems as discussed by Handley (2015). Benthic microalgae, or the "secret garden" (MacIntyre et al. 1996) can be overlooked, despite them contributing very significantly to coastal food supply (Valiela 1984; Kennish et al. 2014). For example, measures of benthic chlorophyll in the Nelson-Marlborough region were: 92, 89, and 84% of total production (benthic + planktonic) at depths of 8, 16, and 20 m, respectively in Tory Channel; and 32-51% in Tasman Bay; demonstrating benthic production can provide very significant contributions to food webs (Gillespie et al. 2000). Of concern, several studies have demonstrated that with increasing nutrient enrichment, phytoplankton production increases and shades out benthic production (Borum & Sand-Jensen 1996; Staehr et al. 2012). In cases of high nutrient inputs, eutrophication can become established, driven by short-circuited nutrient cycling via anaerobic pathways, and tipping points or regime shifts can occur which tip the system into an alternate, self-reinforcing state (Kemp et al. 2005). Early warning signs of drivers of 'regime shifts' (alternate system states; (Scheffer & Carpenter 2003)) include increased nutrient loadings, increases in chlorophyll concentrations and decreasing benthic primary production (e.g. (Kemp et al. 2005; Glibert et al. 2014; Riche et al. 2014)

Increased suspended sediment in the water column has the potential to not only affect bivalves, but also benthic and pelagic primary production (plants), having negative synergistic effects that are not linear (Kemp et al. 2005). Soft sediment plants are important as they provide important environmental services including providing food and nursery habitat for many commercially important fish, crustaceans, and molluscs (Heck et al. 2003; Francis et al. 2005; Peterson et al. 2010). Aquatic plants also help trap and stabilise sediments, and remove nutrients (Yallop et al. 1994; Underwood 1998; Disney et al. 2011), further maintaining water quality allowing more light to reach the seabed, again enhancing photosynthesis at the seabed. Suspension feeding bivalves symbiotically benefit submerged plants like benthic diatoms and seagrass in two ways: they exert 'top-down' control by grazing on phytoplankton which allows greater water clarity and light penetration (Everett et al. 1995; Carroll et al. 2008; Wall et al. 2008); and secondly, they fertilize the bottom with their bio-deposits and excretion of soluble nutrients (Dame & Libes 1993; Reusch et al. 1994; Everett et al. 1995; Peterson 1999; Peterson & Heck 2001a; Peterson & Heck 2001b; Carroll et al. 2008; Peterson et al. 2010). These symbiotic interactions between filter-feeders and soft sediment plants are thought to reinforce the restoration process by enhancing water quality improvements once they have been initiated through positive feedback (Kemp et al. 2005). For example, overseas restoration efforts indicate that once restoration is initiated (e.g., shellfish restoration), benefits flow to other components (like seagrass and benthic microalgae), which in-turn reinforces and enhances broader restoration goals including stabilisation of soft sediments that help maintain water clarity (Kemp et al. 2005; Greening et al. 2014).

6.3 Physical disturbance to benthos

Historical newspaper accounts and interviews indicated trawling for finfish and dredging for shellfish and kina in QCS may have had significant but unmeasured effects on formerly widespread complex biogenic habitats. These biogenic habitats are probably still decreasing in extent (e.g. (Davidson & Richards 2015). Trawling and dredging can cause physical disturbance to the seabed homogenising sediment structure and benthic assemblages which results in reduced habitat complexity and species diversity (Jennings & Kaiser 1998; Kaiser et al. 2006; Thrush et al. 2006; Tillin et al. 2006; Handley et al. 2014). Biogenic habitats brought about by living organisms, are in many respects 'self-structuring' (Reise 2002), as they are contingent on settlement, growth and death of the likes of large bivalves at the sediment water interface (Handley et al. 2014). Because biogenic species are often large and fragile, they can only persist in the absence of high disturbance. As biogenic habitats are key to increased biodiversity in QCS, benchmarking pre-impact sediment composition is important for management (Handley et al. 2014) and informing potential restoration efforts. In natural capital accounting exercises (Monfreda et al. 2004), to account for the lost biodiversity, biomass and productivity caused by contact fishing gear, it is necessary to benchmark potential lost natural capital. For example, maximum productivity of soft sediment habitats has been correlated with sediments containing a range of grain-sizes including shell or gravel (Bolam et al. 2014; Handley et al. 2014). Accounting for lost natural capital due to anthropogenic effects, especially physical disturbance such as contact fishing, may be possible using sediment coring and paleoecological techniques (e.g. Kidwell & Rothfus 2010).

6.4 Changes to the foodweb – knowledge from restoration

Due to the slow rate of change, lack of historical monitoring data, and inter-generational memory loss associated with 'shifting baselines', it is difficult to demonstrate cause and effect, and the flow on effects of changes within the foodweb of QCS. Perhaps the best tool to illustrate changes to the foodchain, is the study of restoration processes using marine reserves. That is, when you remove some of the direct effects of human disturbance, like fishing, what changes to species and habitats occur? The dramatic recovery of predatory blue cod (3x increase); blue moki (1.4x increase); rock lobster (11.5x increase); and grazing black foot paua (1.4x increase), and reductions in the number of grazing kina (3x decrease), especially small (<45 mm) kina since 1992 (Davidson et al. 2014) demonstrates cause and effect from fishing at Long Island – Kokomohua marine reserve. But what about flow-on or trophic-cascade effects? Although as yet there are no reported changes to seaweed cover at Long Island from reduced densities and size of kina, it has been shown at the Goat Island marine reserve that reduced kina grazing can increase algal densities over decadal time scales (Shears & Babcock 2002; Shears & Babcock 2003). Future studies may reveal other structural changes.

As most of the Marlborough Sounds is likely being affected by accelerated erosion, disturbance from fishing, aquaculture, and terrestrially derived nutrients, restoration actions may have their limitations. Whilst there are current proposals to restrict some forms of commercial fishing within the Sounds, it must be accepted that what exists today, is not pristine. Due to the susceptibility of the Marlborough Sounds to erosion from forestry, MDC have recommended Council proceed with developing its own rules to protect the Sounds, rather than adopt a proposed National Environmental Standard for forestry (Urlich 2015). Options to decrease sedimentation include a range of replanting setbacks from both the shoreline and permanent flowing streams; controls on replanting on slopes over 30°; removal of harvested materials from gullies; and a requirement on stricter engineering standards for forestry related earthworks, such as roading techniques for effective erosion and water control. There are also proposals to restrict benthic disturbance from contact fishing gear and anchoring by MDC under provisions of the Resource Management Act (S. Urlich, pers. comm.). There however appear to be a combination of factors that are preventing the natural recovery of biogenic habitats, for example, the lack of recovery of soft sediment mussel beds in Kenepuru Sound (Handley 2015). Studies associated with salmon farm developments in QCS and Pelorus have suggested that in many situations, the seabed can be 'naturally' enriched and/or disturbed (Keeley et al. 2014), but describing what is the 'natural' enrichment state of the Marlborough Sounds, may require the use of palaeoecological studies to reveal historical states of enrichment.

6.5 Ecosystem models and ecosystem management

It may be very difficult or impossible to demonstrate changes associated with the loss of: pilchard population biomass, whales, and large predators like sharks and groper, unless in the unlikely event they are left to recover to former levels. Also, what effect did the deforestation, burning, and loss of soil and nutrients to the sea over several centuries have on marine productivity in the Marlborough Sounds above pre-human baselines? Therefore, the use of ecosystem models may be the best tool for discovering potential cause and effect and any flow on foodweb effects. Ecosystem management approaches are gathering pace driven by the perception that single-species fisheries management by itself cannot deal effectively with complex biological systems faced with increasing demands on marine resources (Sharp et al. 2007; Fulton et al. 2011). Determining cause and effect, especially when monitoring data are limited, leaves analysis of long term changes to be based on anecdotes and open to speculation. For these reasons, stakeholders need to participate in the evaluation of shifting baselines in order to include societal valuation and perception of the detected changes (Swaney et al. 2012). For example, testing the significance of factors like the loss of 1,000 kg/annum pilchard fishery and its associated discharge of nutrients into QCS, and comparing it with the current addition of nitrogen associated with fish feed discharged from finfish farms.

6.5.1 Climate change future – long term monitoring

It has been predicted that climate change will increase stress in marine systems with increasing intensity and periodicity of storms (Willis et al., 2007) together with the increasing probability of regime shifts due to anthropogenic reductions in resilience as a result of reducing biodiversity (Folke et al. 2004; Turner 2010) and/or from removing whole functional groups of species (e.g. large predators, filter feeders). Therefore, any measures that can be taken to protect and enhance the resilience of the Marlborough Sounds should be encouraged, otherwise as more intense and frequent storms occur the rate of benthic degradation will likely increase.

Reviews commissioned nearly a decade ago on the potential effects of climate change on the Australian and New Zealand marine environment warned then of the difficulties associated with making specific predictions at scales at which appropriate management measures can be taken (Poloczanska et al. 2007; Willis et al. 2007). Predictions are hampered by: the lack of long-term time series of data to establish correlations with past environmental fluctuations; a limited understanding of the way ecosystems are structured by interactions between species and the environment; and lack of information on the tolerances of habitat-forming species to variability in the environmental factors that may be affected by climate change. In the continuing absence of such information, a precautionary and restorative management approach is highly recommended.

6.5.2 Restoration – a positive feedback solution?

Given that most of the changes due to climate change are likely to be exacerbated by anthropogenic impacts, restoration efforts directed toward keystone species and important habitats should be given highest priority to build more resilience into ecosystems (Folke et al. 2004; Willis et al. 2007; Benayas et al. 2009). To illustrate the complexities of this task, Willis et al. (2007) gave an example of restoration of seagrass beds in Chesapeake Bay in the United States. Restoration of seagrass there has been hampered by a range of non-linear ecological feedback mechanisms involving light, sedimentation, nutrient dynamics and species interactions (Kemp et al. 2005). In an unmodified benthos, enhanced particle trapping and sediment binding associated with benthic plants (seagrass, microalgae) help to maintain relatively clear water columns, allowing more light to support more benthic photosynthesis. Restoration or degradation can be driven either way by positive-feedback mechanisms. Enrichment creates turbidity, leading to the decline of benthic plants, allowing more resuspension, decreasing light further stressing benthic plants. Also, nutrient-enhancement stimulates phytoplankton growth and their subsequent sinking supports increased benthic respiration leading to anoxia, which causes more efficient benthic recycling of nitrogen and phosphorus which supports further algal blooms and so on. Initial seagrass restoration efforts failed without parallel oyster population restoration. Oysters are reported to provide negative feedback control on eutrophication by reducing phytoplankton biomass and increasing water quality, facilitating seagrass bed restoration (Fulford et al. 2007).

Successful restoration of ecosystems and fisheries have been shown to provide both direct and indirect benefits: a reversal of the "shifting baselines syndrome" and a motivation to manage fisheries sustainably, diversification of local economies and fisheries, community building, an increased sense of local pride, a demographic broadening of the conservation community, and enhanced ecosystem services and recreational opportunities (McClenachan et al. 2015). Like the positive feedback mechanisms between oysters and seagrass beds, restoration of ecosystems also provide positive feedback between economic benefits and other social benefits, with local boosts in revenue enhancing community engagement and providing motivation and presumably funding for further restoration (McClenachan et al. 2015).

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