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Characterising fisheries and other marine harvesting in the Bay of Islands, with ecological consequences, from first human settlement to the present

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J.D. Booth

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New Zealand was among the last major landmasses not only to be populated, but also to be colonised, and so has a rich archaeological record, less troubled by erosion and sea-level change than many other places. These writings explore the changes human intrusion has brought about among the marine food resources of New Zealand's Bay of Islands (35° 12′ S, 174° 10′ E): its fish and shellfish, marine mammals and seabirds, and the extent of loss of the shallow-reef kelp in the main basin of the Bay which has occurred along with the intensification of fishing. The main data sources are the contents of middens and the results of archaeological excavations; published historical accounts and pictorial records; published and archival catch statistics; and aerial imagery.

The earliest dated item associated with human settlement in the Bay of Islands so far is a rock oyster *Saccostrea glomerata* valve radiocarbon-dated to between 1256 and 1324 AD. A total Māori population for the Bay of Islands in 1750 AD on the order of 10 000 may not be an unreasonable estimate. The resident population appears to have fallen to around 1000 in 1900 AD, before building to around 40 000 today.

Bay of Islands' dated middens suggest that, during the first five centuries of human presence, there was change over time in the foods sought and consumed as the population became increasingly agriculture-based: marine mammal, seabirds and the Cook Strait limpet *Cellana denticulata* (as well as moa bones) were present only in early Bay of Islands sites; and fish and shellfish variety narrowed over time, with a growing focus on soft-shore estuarine shellfish.

It seems, however, that 500 years of pre-Contact Māori harvesting pressure left no distinguishable and enduring legacy on Bay of Islands' fish and shellfish resources - with the probable exception of the fishing-out of local populations of the Cook Strait limpet, and possibly initiating the extirpation of hapuku *Polyprion oxygeneios* from shallow waters. But, almost certainly, overharvesting in the Bay of Islands contributed to the extinction of the New Zealand sealion *Phocarctos hookeri* in the Early Period (pre-1450 AD), and to the extirpation of breeding colonies of the New Zealand fur seal *Arctocephalus forsteri* from Northland by 1500 AD. Moreover, the kiore (*Rattus exulans*) rats the early waka transported to this country, together with human harvesting, resulted in seabird extinctions and extirpations.

Although artisanal harvesting of fish and shellfish for domestic consumption and for inter-Hapu trade would have predominated in the Bay of Islands between 1800 and 1900, there was growing commerce as European arrivals escalated, their vessels in need of re-provisioning. But the first kai moana in the Bay of Islands to be commercially fished in a fully contemporary sense was the rock oyster *Saccostrea glomerata*. Although oyster numbers would have declined during the nineteenth century, it is most unlikely that there would have been any discernible and enduring ecological impact of consequence as a result of harvesting pressure. For grey mullet *Mugil cephalus*, and other finfish, the fishing pressure would probably have done little more than to reduce somewhat the abundance and mean size of fish in certain places: although there would have been flow-on implications for the broader ecology, it is doubtful that they were of any enduring consequence.

After 1900, fishing diversified as the resident and the visiting population increased, but it was not until the early- to mid-decades of the twentieth century that, with the collection of formal catch statistics, any meaningful sense of the scale and variety of the commercial finfish landings began to emerge for the Bay of Islands. More than a century and a half of rock-oystering has left a lasting legacy - not because of the harvesting of the shellfish but due to the ecological consequences of the addition of great masses

of rock onto various soft shores, and the transfer of original boulders down shores, remaining to this day.

Until the late 1970s, the mainstay commercial finfish species for the Bay of Islands in terms of weight - albeit with modest annual landings (up to about 100 t of each species) - were various flounder species, grey mullet, hapuku, and particularly snapper *Chrysophrys auratus*. Leading up to the immense management changes of the 1980s, annual snapper landings for the Bay of Islands area rose briefly to over 1000 t, with up to almost 180 commercial boats based in the Bay. Pelagic species such as mackerels and skipjack tuna *Katsuwonus pelamis* were first fished locally in the 1980s, after which large annual catches (thousands of tonnes) were being made along open waters just outside the Bay of Islands. The only invertebrate of significance has been the red rock lobster *Jasus edwardsii*, fished to any extent only since World War II, with recent local harvests averaging up to about 10 t a year.

Today, just a small handful of commercial fishers routinely fish waters within the Bay of Islands, their main finfish catch by weight including various flounder species, garfish *Hyporhamphus ihi*, grey mullet, snapper, and trevally *Pseudocaranx dentex* - totalling a few dozen tonnes in total each year and harvested using set nets and beach seines. However, from time to time, visiting vessels line, net and trawl for such fish as snapper, trevally, flatfish and grey mullet within the Bay of Islands, and purse seine pelagic species like skipjack tuna, pilchards *Sardinops neopilchardus*, and various mackerels near the entrance to the Bay of Islands.

The Bay of Islands recreational fishery is intensive and extensive, and is likely to continue to expand and intensify even more over the next five years, mainly through more and more vessels visiting the Bay, particularly from Auckland. Although the Bay of Islands became internationally known as early as the 1920s for its gamefish opportunities, snapper and kahawai *Arripis trutta* are today the main recreational species. Recreational harvests of snapper are substantial along the east coast of Northland, including within the Bay of Islands, in recent years having been up to two-thirds or more of the corresponding-area commercial catches. For kahawai, recreational catches are also high, often approaching or exceeding the commercial harvest. Red rock lobster recreational harvests are only about 20% of the Fishstock CRA 1 commercial landings.

None of the main finfish species in the Bay of Islands (nor the red rock lobster) is confined there throughout their entire lives. Because of the general mixing within many individual species during their life-histories, the status of most of Bay of Islands' fisheries is ultimately dependent on that of the underlying QMA stock or substock. For snapper, the East Northland Substock of SNA 1 has been fished down to a low level, much of the landed catch being not much larger than the minimum legal size, and overfishing is likely; most of the fishing pressure in the Bay of Islands itself today comes from recreational effort which has, anecdotally, led to areas of local depletion. In contrast, Fishstock KAH 1 (kahawai) appears to be in a healthy state. Although the stock assessment indicates a healthy and recovering Fishstock CRA 1, most of those landed are near the minimum legal size, which may indicate heavy fishing pressure. Anecdotal information, together with published research concerning abundance and/or individual-size, suggest that all other shellfish of significance are heavily harvested, with green-lipped mussels *Perna canaliculus* seemingly the least able to withstand this fishing pressure, perhaps because of its tendency to clump and be seen.

Much of the shallow-reef kelp community of the main basin of the Bay of Islands has disappeared. Losses were apparent by the 1970s, and today Bay of Islands presents one of the most extreme and extensive areas of 'sea-urchin barren' in all the country. The loss of significant areas of shallow-reef kelp is likely to have led to a multitude of cascading consequences, most of them not yet recognised or understood. Almost certainly this has resulted from ecological overfishing - overharvesting of such keystone predators as snapper and red rock lobsters. Reductions in the proportions of large individuals of these predatory species - the ones capable of preying on kina (*Evechinus chloroticus*) and other sea urchins - appear to have led to burgeoning sea-urchin populations and, in turn, to the widespread loss of shallow-reef kelp forests. The long-spined urchin *Centrostephanus rodgersii* has recently become significant in the development of sea-urchin barrens in more exposed parts of the Bay of Islands.

INTRODUCTION

Revealing the impact of human activity and pressure on pristine sea environments, the relatively new field of 'marine environmental history,' has archaeologists, historians and others joining forces with marine scientists to describe and quantify the changes wrought by human presence on the natural marine world, so allowing critical insight into the baseline state of nature.

New Zealand was among the last major landmasses not only to be populated, but also to be colonised, and so has a rich archaeological record, less troubled by erosion and sea-level change than many other places. *Tacking stock* has been the most significant investigation into this country's marine environmental history (MacDiarmid et al. 2016), a recent focus having been changes in the marine food resources of the Greater Hauraki Gulf in the north compared with those of the Otago-Catlins coast to the south (Smith 2013). Similar studies in smaller catchments such as the Bay of Islands contribute to this understanding by, for example, providing insight into any regional variation in the timing of changes in the presence, and even abundance, of particular taxa.

The discovery and first-colonisation of New Zealand was part of the burst of exploration that took place out of East Polynesia beginning in the 1200s AD and which extended to the Chatham Islands and beyond (Davidson et al. 2011). The first East Polynesians were greatly privileged to have surveyed Bay of Islands' unmodified and naturally functioning marine ecosystems. Perhaps as early as 1300 AD they entered a primeval seascape millions of years in the making, with - almost certainly - climax forest cloaking ridgelines and flats, and bordering waterways that were typically essentially transparent. The abundant fish and shellfish, marine mammal and seabird populations would today prompt all manner of ecological questions - difficult to even frame with confidence because of our unfamiliarity with the condition. But this setting was to change as a growing human population exerted increasing pressure - direct and indirect - on marine resources, and set in train increasing rates of sedimentation. Escalating European arrivals from the 1800s AD on were to increase these impacts exponentially.

Typically, a fish population exploited for the first time provides high catch rates and yields broad size- (and age-) distributions of individuals; catch rates usually remain high during the fish-down phase (often with serial depletion of localised groupings of individuals), with both the mean size and the proportion of large individuals declining only slowly; and after fish-down, the fishery becomes largely dependent on only a few recent year classes, with catch rates stabilising at a level much lower than when fishing began. Similarly, the harvesting of marine mammals and seabirds is typically characterised by harvest rates remaining high during the initial phase, often with serial depletion.

After providing brief physical, climatological and social settings, these writings explore the changes human intrusion has brought about among the marine food resources of New Zealand's Bay of Islands (35° 12′ S, 174° 10′ E): its fish and shellfish, marine mammals and seabirds (for scientific names, *see* Table 1). My focus is on changes which have left a signature over time. These impacts are broadly categorised into those attributable to direct harvesting of seafoods, including 1) lowered catch rate, 2) reduced individual mean size, and 3) extirpation/extinction of taxa. I also describe 4) the emergence of sea-urchin barrens that have almost certainly resulted from overharvesting of particular fish and shellfish. The implications of the arrival of alien species (particularly the Pacific rat or kiore, and later the Norway and ship rat and other mammalian predators) are necessarily part of this account.

Table 1: Scientific names for organisms referred to in text. (Bird names from *New Zealand Birds Online*.)

Species group	Common name	Scientific name
Kelps	Brown kelp	*Lessonia variegata*
	Common kelp	*Ecklonia radiata*
	Neptune's necklace	*Hormosira banksii*
	Seawrack	*Carpophyllum angustifolium*
	Seawrack	*Carpophyllum maschalocarpum*
	Seawrack	*Carpophyllum plumosum*
Molluscs	Arrow squid	*Nototodarus gouldi*
	Black nerita	*Nerita melanostragus*
	Black-foot paua	*Haliotis iris*
	Blue mussel	*Mytilus galloprovincialis*
	Circular slipper limpet	*Sigapatella novaezelandiae*
	Cockle	*Austrovenus stutchburyi*
	Cook Strait limpet	*Cellana denticulata*
	Cook's turban	*Cookia sulcata*
	Green-lipped mussel	*Perna canaliculus*
	Mud whelk	*Cominella glandiformis*
	Mudflat top shell	*Diloma subrostrata*
	Mudsnail	*Amphibola crenata*
	Oblong venus shell	*Ruditapes largillierti*
	Oyster borer	*Haustrum scobina*
	Pacific oyster	*Crassostrea glomerata*
	Pipi	*Paphies australis*
	Purple cockle	*Purpurocardia purpurata*
	Rock oyster	*Saccostrea glomerata*
	Scallop	*Pecten novaezelandiae*
	Speckled whelk	*Cominella adspersa*
	Spotted black top shell	*Diloma aethiops*
	Spotted whelk	*Cominella maculosa*
	Tuatua	*Paphies subtriangulata*
	White rock shell	*Dicathais orbita*
	White slipper limpet	*Maoricrypta monoxyla*
Other invertebrates	Long-spined urchin	*Centrostephanus rodgersii*
	Red rock lobster	*Jasus edwardsii*
	Sea urchin (kina)	*Evechinus chloroticus*
Finfish	Bass	*Polyprion americanus*
	Black marlin	*Istiompax indica*
	Blue mackerel	*Scomber australasicus*
	Blue maomao	*Scorpis violacea*
	Broadbill (swordfish)	*Xiphias gladius*
	Garfish (piper)	*Hyporhamphus ihi*
	Grey mullet	*Mugil cephalus*
	Hapuku	*Polyprion oxygeneios*
	Jack mackerel	*Trachurus declivis* and *T. novaezelandiae*
	John dory	*Zeus faber*
	Kahawai	*Arripis trutta*
	Kingfish	*Seriola lalandi*
	Mako shark	*Isurus oxyrinchus*
	Northern spiny dogfish	*Squalus griffini*
	Parore	*Girella tricuspidata*
	Pilchard	*Sardinops sagax*
	Red gurnard	*Chelidonichthys kumu*
	Sand flounder	*Rhombosolea plebeia*
	School shark	*Galeorhinus galeus*
	Skipjack tuna	*Katsuwonus pelamis*
	Snapper	*Chrysophrys auratus*
	Spotted spiny dogfish	*Squalus acanthias*
	Striped marlin	*Kajikia audax*
	Tarakihi	*Nemadactylus macropterus*
	Trevally	*Pseudocaranx georgianus*
	Yellowbelly flounder	*Rhombosolea leporina*
	Yellow-eyed mullet	*Aldrichetta forsteri*
Seabirds & shorebirds	Arctic skua gull	*Stercorarius parasiticus*
	Australasian gannet	*Morus serrator*
	Black shag	*Phalacrocorax carbo novaehollandiae*
	Black-backed gull (southern)	*Larus dominicanus*
	Blue (reef) heron	*Egretta sacra*
	Caspian tern	*Hydroprogne capsia*
	Common diving petrel	*Pelecanoides urinatrix*
	Grey-faced petrel (oi)	*Pterodroma macroptera*
	Little penguin	*Eudyptula minor*
	Little shag	*Phalacrocorax melanoleucos*
	Northern giant petrel	*Macronectes halli*

Species group	Common name	Scientific name
	Pied shag	*Phalacrocorax varius*
	Red-billed gull	*Larus novaehollandiae*
	Sooty shearwater mutton-bird	*Puffinus griseus*
	Wandering albatross	*Diomedea exulans*
	White-fronted tern	*Sterna striata*
Marine Mammals	Bottlenose dolphin	*Tursiops truncatus*
	Bryde's whale	*Balaenoptera* cf. *brydei*
	Common dolphin	*Delphinus delphis*
	Hector's dolphin	*Cephalorhynchus hectori*
	Humpback whale	*Megaptera novaeangliae*
	New Zealand fur seal	*Arctocephalus forsteri*
	New Zealand sealion	*Phocarctos hookeri*
	Orca	*Orcinas orca*
	Southern elephant seal	*Mirounga leonina*
	Southern right whale	*Eubalaena australis*
	Sperm whale	*Physeter macrocephalus*
Terrestrial mammals	Norway rat	*Rattus norvegicus*
	Pacific rat (kiore)	*Rattus exulans*
	Ship rat	*Rattus rattus*

The main data sources are the contents of middens and results of archaeological excavations; published historical accounts and pictorial records, beginning with those of the first Europeans; published and archival catch statistics; and aerial imagery. The state of, and changes in, the marine resources (fish and shellfish, marine mammals and seabirds) and marine communities of the Bay of Islands, from first settlement to the present day, are addressed in the following order.

1. Pre-Contact (pre-1800) resources
2. Early post-Contact (1800–1900) resources
3. Recent (post-1900) resources
4. Current status of fish, shellfish, marine mammals and seabirds
5. Progressive loss of shallow-reef kelp communities

Physical and climatological setting

Bay of Islands (Figure 1) is a ria (a coastal inlet formed by the partial submergence of an unglaciated river valley) - at high tide about 180 km^2 in surface area (Heath 1976), many of its numerous islands marking the summits of what once were hills. The underlying geology is predominantly greywacke, the resultant soils and clays being prone to erosion and aquatic leaching.

Bay of Islands is in a warm-temperate zone with strong subtropical and tropical influences, particularly during summer. Surface waters reach 20–22° C in late summer and drop to 13–16° C in late winter (Booth 1974). However there has been considerable variation in temperature in the South Pacific over the past millennium, in line with global changes in climate, which would have potentially influenced recruitment, growth and survival of marine species. Briefly, the 'Polynesian Warm Period', from 1150 to 1450 or 1500 AD, was followed by the Little Ice Age between 1500 and 1900 AD. In the thirteenth century, average annual air temperatures may have been 0.3 to 0.5°C above today's; and during the eighteenth century about 0.8°C lower than today (Anderson et al. 2014).

Net direction of flow in the water column off the mouth of the Bay of Islands is southeast, as the subtropical East Auckland Current, with some of this water directed into the Bay by the Cape Brett Peninsula (Booth 1974). The semi-diurnal tides have amplitudes of 2.0 and 1.5 m for spring and neap highs respectively. The bay is reasonably well-mixed: one estimate of the residence time for waters of the Bay of Islands is 19 tidal periods (Heath 1976).

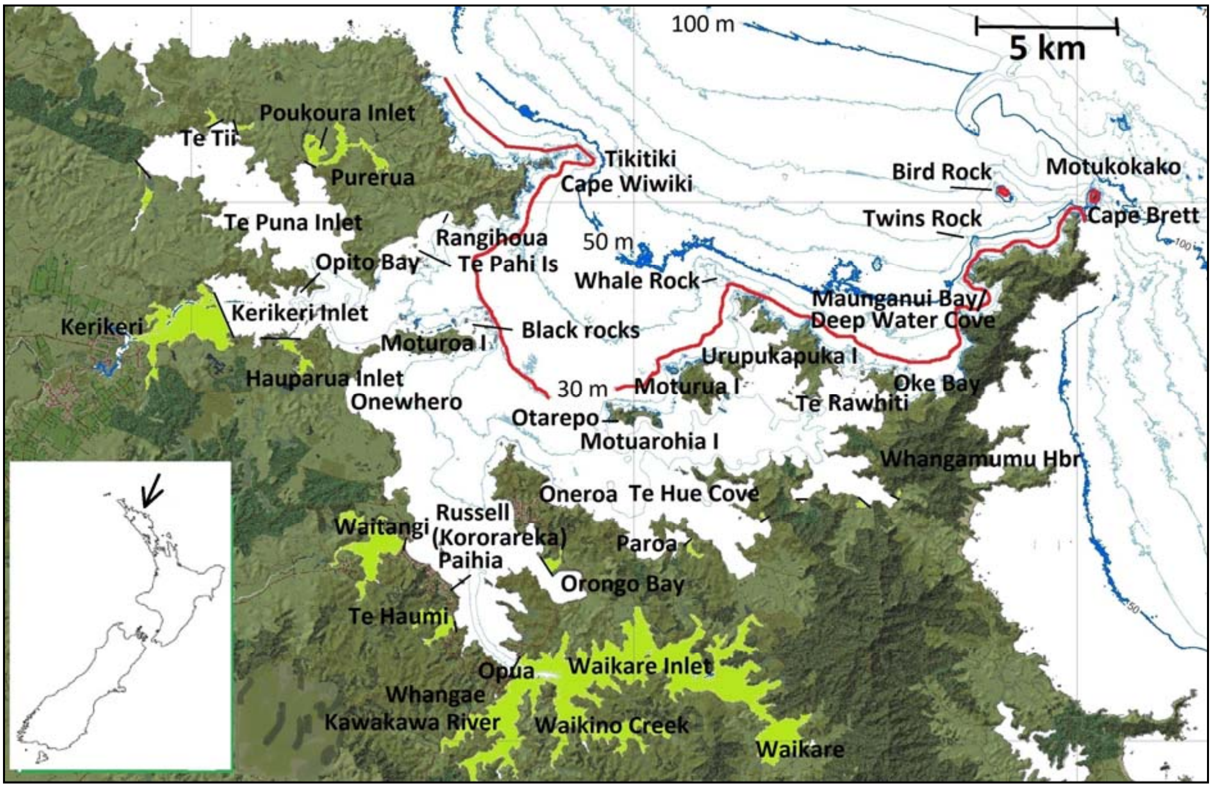

Figure 1: The waters of the Bay of Islands reach 80 m depth near the entrance, but the main body of the bay is between 30 m and 50 m deep. The exposed shores exist in counterpoint to the relative seclusion of the estuaries (green).

History of settlement, European colonisation, and population growth

The earliest dated item associated with human settlement in the Bay of Islands so far is a rock oyster valve, from the initial layer of occupation at Mangahawea Bay on Moturua Island. Radiocarbon-dated to between 1268 and 1356 AD (DOC 1981, but as yet uncorroborated), the centre of this 1-SD range is near what is now thought to be the first arrival-decade of East Polynesians in New Zealand (1280s AD - Wilmshurst et al. 2008). At least four other Early-period (before 1450 AD; Smith 2013) sites have been revealed in the Bay of Islands, with several others also being old, characterised by their moa, marine mammal and/or seabird bone (Booth 2016). (The Early Period is more-or-less synonymous with both the 'Archaic' and 'Moa-hunter' periods.)

There appears to be no human-population trajectory available for the Bay of Islands. But there does seem to be consensus that the total Māori population of New Zealand at first European Contact was near what James Cook/John Forster had estimated in 1769, about 100 000 (Pool 1991; King 2007; although Salmond 1997: 223 thinks this is conservative), with perhaps 15% living in Northland (Pool 1991, Leach 2006). Smith (2013: 13–14) estimated a population of 12 150 (lower to upper estimates 10 800–13 500) living in the broader Hauraki Gulf (Whananaki to Waihi Beach) in the Late Period (1650–1800, centred on 1750 AD), from an Early-period (centred on 1400 AD) population of 1800 (500–2500). Intuitively, the population of the Bay of Islands would have been far smaller than the adjacent, and much more extensive, Hauraki Gulf region, perhaps up to half (around 6 000) being a reasonable estimate for 1750 AD.

On the other hand, various early accounts suggest that many more people may have been present in the Bay of Islands at first Contact. For example, 1) James Cook declared, after having just sailed from the Firth of Thames in the Hauraki Gulf, how 'The Inhabitants of this Bay [of Islands] are far more numerous than at any other place we have yet been in…'(Cook's journal entry for 5 December 1769);

2) in the course of entering the Bay of Islands, Cook estimated 'not less than four or five hundred of the Natives alongside and on board the ship' (journal entry for 27 November 1769); 3) soon after, Joseph Banks reported 37 waka (containing 300–400 individuals, according to Cook) about them as they anchored off Motuarohia (journal entry for 29 November 1769); and then 4) 200–300 present according to Cook when they landed on Motuarohia (journal entry for 30 November 1769; 500–600 if the ship-crew's estimate is to be believed). Although these numbers cannot simply be summed and extrapolated across the landscape, they did apply to just one day for one part of coastal Bay of Islands, not considering at all other parts or the hinterland.

And soon after, in the winter of 1772, when the French were camped in the Bay of Islands, it appears that 4000–5000 were living near Te Rawhiti alone (Clunie n.d.: 36), the southeast of the Bay having 'a truly immense population for a Maori district' (Shawcross 1967). By the early 1800s, it appears 'many thousands' of Māori were living on either side of Kerikeri Inlet (Middleton 2014: 114); and 'several thousand' were associated with Pouerua in the immediate hinterland (Clunie n.d.: 104).

Based on these figures, a total Māori population for the Bay of Islands in 1750 AD on the order of 10 000 (about half the present-day population resident near the shores of the Bay, and about one quarter of the population living within the Bay of Islands catchment) may not be an unreasonable estimate; indeed, Salmond (1997: 209) estimated 15 000 in the Bay of Islands in 1793, but was not specific as to how she derived this figure. Largely as a result of illnesses contracted from the Europeans (Clunie n.d.), but also intertribal warfare (Shawcross 1967), the total New Zealand Māori population dropped by 30% between 1840 and 1860 (http://www.TeAra.govt.nz/en/population-change/page-6). By the mid-1800s the entire population of the mid-north iwi Ngā Puhi had been reduced to about 6000 (Taylor 1855 in Clunie n.d.:104), with a 'few hundred' at Rawhiti. It was not until the late 1890s that the Māori population once again grew.

The country's first European community, a Church Missionary Society mission, was established at Hohi (Rangihoua Bay), in the north of the Bay of Islands, in 1814. With the other missions to follow (Te Puna, Kerikeri and Paihia), and with a small number of other settlers as well as runaways, the total European population of the Bay of Islands may have been a little over 100 by 1830 (Shawcross 1967). Another influx of Europeans into the Bay of Islands was associated with provisioning, repair and recreation of the sperm-whale fleet, and was centred on Kororareka (now Russell) (Shawcross 1967), for which Charles Darwin estimated 200–300 English residents in 1835.

Following the land wars of the 1840s, Europeans virtually abandoned regions of the north for a decade (Statistics New Zealand 1999) - although James Clendon still counted around 160 Europeans resident in Kororareka in 1846 (http://russellmuseum.org.nz/services/heritage-corner/population-polls-103/). By 1851, the coastal population of the Bay of Islands may have been around 400 (King 1949: 85). These accounts do not allow any precise estimate of population size, but 1000 may not be an unreasonable estimate for the total Māori and Pakeha population of the Bay of Islands in 1900 AD.

The shape of the district's population trajectory from the early 1900s has proven no more tractable. From perhaps 1000 people in 1900, it is presumed there was a more-or-less steady increase in numbers through to 1999, when it was 53 000 for the Far North District Council's area (Bay of Islands north; http://www.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/local-population-trends) (Figure 2). However, this is an oversimplification, because timber production and kauri-gum digging, particularly in the late 1800s to 1920s, would likely have led to population spikes. From the early to mid-1900s, fruit-growing in the Kerikeri area brought a flush of new settlers; and then the rising reputation of the Bay of Islands as a tourist destination, from the 1950s, would have spurred substantial increases in the local population.

The 'usually resident' population of the Bay of Islands today is around 40 000, with perhaps as many as half living on or within 5 km of the shore (http://www.fndc.govt.nz/home). But the numbers of people visiting the Bay over the peak summer holidays may double the population, many of them on boats.

The key point is that there had been a significant population of people living in and near the Bay of Islands since at least 1750 (albeit with a reduction in the mid-1800s to early 1900s), and it would be remarkable if harvesting pressure had not had at least local impacts on the diversity, distribution, abundance, and individual mean-size of shallow-water coastal marine stocks of the Bay of Islands.

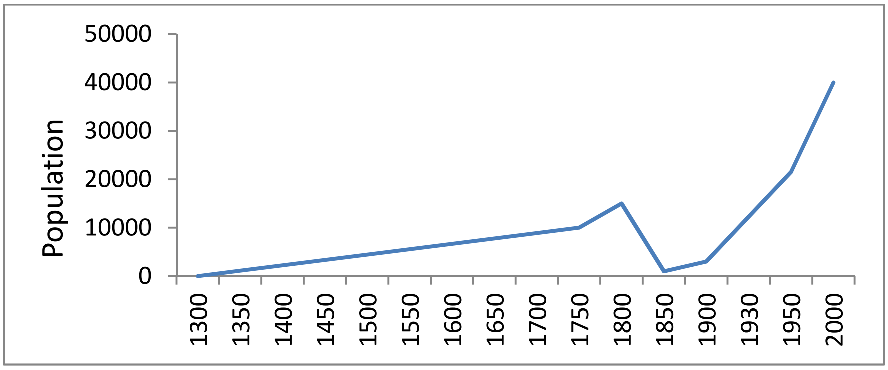

Figure 2: Indicative estimated resident human population of the Bay of Islands catchment, 1300–present.

1. PRE-CONTACT (pre-1800) RESOURCES

Because early Māori left no written records, we must rely on handed-down testimony, the reports of early Europeans, and - particularly - the contents of middens. Although plagued with such technical issues as variable longevity of taxa in the ground, midden-contents provide insight into local marine resources and harvesting strategies, and even social arrangements, of the time (Anon 2014). But because people seldom consume foods available to them in the proportion in which they occur, middens are more a harvest record rather than saying anything categoric about natural abundance (Anderson 1981).

The first Europeans were privileged 'to catch prehistory alive' (Leach 2006), and for the Bay of Islands the picture painted by James Cook in 1769, and the French soon after, is one of bounteous fish and shellfish resources despite almost 500 years of continuous occupation. In this section I first background general and published accounts concerning northern shellfish and fish, and marine mammals and seabirds; and then I report in more detail about Bay of Islands midden contents.

James Cook's *Endeavour* crew procured almost all their fish in the Bay of Islands by barter: in Cook's journal (5 December 1769) '…we got only fish. Some few we caught our selves with hook and line and in the Saine but by farr the greatest part we purchass'd of the Natives and these of Various sorts, such as Shirks, sting-rays, Breams, Mullet, Mackarel and several other sorts; their way of catching them are the same as ours, (viz) with hooks and lines and with saines; of these last they have some prodigious large made of a Strong kind of grass…' James Cook, and later Marc-Joseph Marion du Fresne, also remarked on the abundance and quality of the rock oysters (Salmond 1991), as did soon after surgeon on the *Ferret*, John Savage, in 1805 (Savage 1807: 11).

Although surviving artefacts from the time are dominated by line-fishing gear, almost certainly netting was the main method of fishing. Banks' diary entry for 4 December 1769: '…. after having a little laught at our seine, which was a common kings seine, [they] shewd us one of theirs which was 5 fathom deep and its length we could only guess, as it was not stretchd out, but it could not from its bulk be less than 4 or 500 fathom [almost 1 km]. Fishing seems to be the cheif business of this part of the countrey; about all their towns are abundance of netts layed upon small heaps like haycocks and thatchd over and almost every house you go into has netts in it making.'

Two and a half years later, the French were to echo the *Endeavour* accounts.

> Fish are very abundant on this coast [Bay of Islands] of New Zealand, and splendid barbots, mullet, and conger-eels are caught, as well as incredible quantities of mackerel much bigger than those from the coasts of France, but very good; many balistes of various colours, codfish in smaller quantities, two varieties of red fish like the gurnard which I have not met with elsewhere, and of which one variety is of about the size of a cod. ….It appears that migratory fish are to be met with on the coasts at different seasons of the year, and I am convinced that the fishery must be much more abundant in the straits which separate the two big islands of this country. In the rocks which fringe the coasts many lobsters, crabs, and shellfish of every variety are to be met with and similar to those which we found in Frederic Henry Bay in Van Diemen's Land (Roth 1891: 77–78).

> Out at sea at some distance from the land many whales and white porpoises are seen, all of which could be hunted….. On the sea-coast one meets with many curlews, snipe, cormorants, black and white egrets similar to those of France, and a very beautiful black bird of the size of a sea-snipe, with bright red beak and feet…..We found neither penguins or sea-wolves on this coast (Roth 1891: 77–78).

The sheer scale of pre-Contact harvesting became clearer from subsequent European reports. Charles Darwin was in error during his visit in 1835 when he declared the 'great piles of shells' in the Bay of Islands simply too extensive to be middens - instead interpreting them as evidence of land rising or sea-level falling (Armstrong 1992). Indeed, middens in Kerikeri Inlet and Waikino Creek (Figure 3) - later mined and kiln-burnt to sweeten local soils (Nevin 1984; NAR 2004) - were so prominent as to be singled out in the 1922 geological chart (Ferrar & Cropp 1922). Similarly, for fish, at the great 1843 hakari at Kororipo Pa (at the head of Kerikeri Inlet) the fare included 2000 baskets of dried fish (perhaps 3 t, and two to three times that in green weight) (Mulcare 2013). Such examples point to intensive harvesting. It is no wonder, then, that Māori had more than 300 words for 'Mollusc', and close to 200 for 'Fish' (Strickland 1990), with missionary William Colenso being moved to refer to them as 'true ichthyophagi' (Colenso 1869). Nevertheless, Leach (2006) concluded that, after 500 years of harvesting '…catching fish for food presented no real problem for Māori….[and] signifies that a ready supply of protein for their diet was simply there for the taking without too much difficulty', almost all being caught inshore (within 100 m of the shore and within 50 m depth).

But far less is known for the Bay of Islands about pre-Contact harvesting pressure on other marine taxa. New Zealand fur seals were important in early diets of the north (Smith 1989; Furey 2002), in many places second only to fish as a source of meat - and unmatched for available energy (Smith 2002). Indeed, some of the richest sealing sites - containing breeding adults and their pups - were in Northland where exploitation was locally intensive, with serial depletion of colonies meaning that by about 1500 AD fur seals had disappeared from the northern North Island (Smith 1989). Further, an as-yet-to-be-named 'sister lineage' distinct from today's New Zealand sealion, once lived and bred along the entire coast of mainland New Zealand (Collins et al. 2014) - but was hunted to extinction (Smith 1989). Their bones have been found associated with early Māori living-sites both north and south of the Bay of Islands - on Aupouri Peninsula, in the Auckland-Hauraki Gulf area, and on Coromandel Peninsula - and all confined to early prehistoric times. Dolphins - mainly the smaller species - also appear in early northern middens, together with the occasional non-breeding southern elephant seal (Smith 1989); it is also likely that Hector's dolphins once lived along the east coast of Northland (Alison MacDiarmid, NIWA Wellington, pers. comm.), and may well have been hunted. But by the time of first European Contact, Māori interest in marine mammals had become largely confined to the occasional beached whale.

> A stranded whale was as a gift from the gods to the Māori, inasmuch as it provided him with a bounteous "cut and come again" dish. The bones of whales were used wherefrom to fashion many kinds of implements, those of the sperm whale being apparently preferred for such purposes (Best 1929).

Early Polynesians were renowned bird-hunters, using snares and spears, as well as directly harvesting burrow-nesting birds and those seabirds that lived in colonies (Orbell 1985). Yet petrel bones - ubiquitous in the natural fossil remains - are essentially absent from the archaeological record on mainland New Zealand (Holdaway 1999: 197). Either people derived most of their protein from moa and marine mammals, eschewing the smaller birds, or - and much more likely - the petrels were not available, at least not in useful numbers, to any but the earliest of the settlers, which supports the hypothesis of very early extinctions or extirpations (Holdaway 1999). Indeed, almost half of all bird species (together with at least half the frogs, and unknown proportions of the lizards and invertebrates) disappeared soon after the arrival of East Polynesians, almost certainly as a result of predation by the kiore they had brought with them (Holdaway et al. 2001). '….entering the dense forest, and reproducing exponentially in the presence of unlimited food….[kiore] may have advanced across the landscape; a grey tide, turning everything edible into rat protein as it went' (Holdaway 1989: 15). Petrels - together with small ground-dwellers - bore the brunt of the extinctions, resulting in an unusually strong bias towards marine species able to persist on offshore islands (Holdaway et al. 2001). Motukokako (Piercy Island) had for a long time been an important - perhaps the principal - breeding place for oi, the grey-faced petrel, in the Bay of Islands (Phillipps 1956). Young birds - fat and taken just before being ready to fly - were extricated from their burrows using a stick, poked in and twisted to engage the downy feathers (Orbell 1985).

The evidence for any enduring ecological change resulting from human harvesting is now explored for the Bay of Islands, using mainly midden contents and focussing on those that have been dated.

1.1 Midden contents

There are hundreds of middens in and around the Bay of Islands, but the contents of few have been delved into in any detail, or an age formally estimated. Nevertheless, most are almost certainly Middle Period (1450–1650 AD) to Late Period (1650–1800 AD; Kennedy 1969; Nugent & Nugent 1977; Leahy & Walsh 1978; Nevin 1984; Fiske 2004). With 260 sites recorded during 1984, Glenis Nevin's sampling was the most extensive (Nevin 1984), with notable findings including the following:

1) Cockles predominated; they were present in essentially all middens irrespective of distance from harvestable stocks, suggesting that they were a preferred species.
2) Very large cockles (55–58 mm long) were present in the lower Waikare and Te Puna inlets, with smaller ones (generally 22–28 mm) in upper estuaries.
3) Apparently pipi were not a preferred species as their presence and abundance in middens was generally no more than expected in proportion to today's local occurrence. Kawakawa River was anomalous, with several middens having 20–60% pipi and yet only two extant pipi beds could be located in 1984. Nevin believed that the former pipi beds had disappeared after having become buried by silt from 'logging, forest clearance and farming activities of the last 150 years'.
4) Waikare Inlet and Waikino Creek middens often contained up to 1% mudsnail; several in Te Puna and Kerikeri inlets contained 2% blue mussel.
5) The other shellfish occasionally present, including rocky shore species, generally reflected those available nearby.

Booth (2016) updated these early data by subdividing the Bay of Islands into 28 compartments based on physical attributes (Figure 3 and Appendix 1), and allocating the reported midden-contents of the 767 (as of August 2014) middens on New Zealand Archaeological Association's Archaeological Site Recording Scheme Site Record Forms (http://www.archsite.org.nz/) among them. Midden contents in each compartment were summarised according to the presence of four key species: cockles, pipi, tuatua, and rock oysters. Other reef species were recorded in three categories: those confined to exposed places, sheltered places, or which are widespread (similarly for the other, soft-shore shellfish). Marine mammal and seabird remains were reported at the most-specific taxonomic level possible; other key markers such as the presence of moa bone, Tahanga (Coromandel Peninsula) basalt and Mayor Island obsidian were also recorded, these being typical of early east-coast North Island sites as far south as eastern Bay of Plenty (Furey et al. 2008).

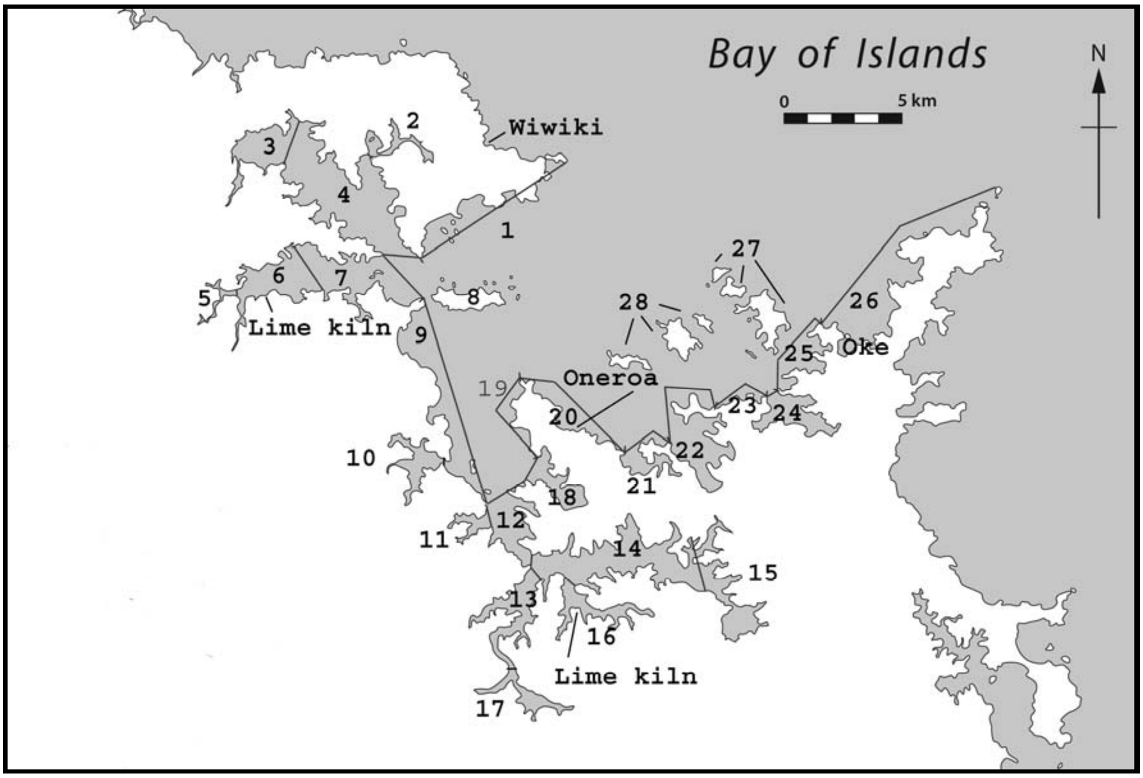

Figure 3: Compartments by which contents of Bay of Islands middens were analysed by Booth (2016). For compartment details, see Appendix 1.

Booth (2016) found that shellfish were overwhelmingly the dominant taxon present in the middens (Table 2; Appendix 1), with key findings concerning them (most of them additional to those of Nevin 1984) including the following:

1) Shellfish were present in all middens. On the other hand, bone of any sort was reported most often from middens that had been subject to formal archaeological examination, and mostly from the early ones among these.
2) With the exception of cockles and tuatua, the data were consistent with the hypothesis that most shellfish were harvested within the immediate vicinity of the midden. Cockles were typically overrepresented in that they were present in all but one of the 767 middens, many of these middens being well removed from estuaries; tuatua were sometimes found well inland from their exposed-beach habitat (Wiwiki, Oneroa and Oke in Figure 3).
3) In contrast, the abundant and easily harvested pipi was rarely found in middens at any distance from typical pipi habitat. This may be because this shellfish often contains grit, and many pre-Contact Māori suffered heavy, often debilitating, tooth wear (George 2013).
4) With rock oysters in only 15% of the middens, and then usually in trifling proportions, it might be concluded that they were uncommon and/or not particularly favoured - but in fact this more probably reflects breaking of the shells at source.
5) Occasionally, less well-known shellfish dominated middens: one midden at Waitangi had a high proportion of purple cockles, a shellfish of semi-exposed soft bottoms and perhaps harvested in nearby Te Ti Bay (Prince 2013a); and the oblong venus shell dominated two middens in the eastern Bay of Islands (NAR 2009).
6) Many shellfish in the middens were of species that do not grow to a large size. Some, such as the circular and the white slipper limpets, may have arrived attached to larger shellfish, but this will not be true of other species such as the mudsnail; speckled, spotted and mud whelk; spotted

black and mudflat top shells; and black nerita. Possibly such shellfish were considered particularly good-eating, being cooked on top of vegetables, for example, their juices permeating through the food below; or they may have been consumed as condiments with other food.

7) There were no comprehensive measurements of individual animal-size available that might be used to infer the effects of harvesting pressure over time on specific taxa. However middens alongside certain beaches, still known today for abundant and sometimes large cockles, often contained very small, uneaten cockles, the valves invariably still together. This may reflect the use of a kete or dredge, drawn through surface layers of soft sediment, the contents rinsed ('stoop, scoop, rinse and take all'), and then placed on embers to cook, with only the larger shellfish opened for their meat.
8) Cockles formed such extensive middens that, much later, lime kilns were used to convert the shell into agricultural dressing (*see* Figure 3). The mainly medium to large shellfish in Kerikeri Inlet and Waikino Creek were almost certainly collected en masse, to be cooked and dried for storage or trade.
9) The presence of tuatua in middens far from where they were harvested (e.g., Upper Kerikeri Inlet and Waitangi) suggests wide-ranging expeditions, trade, or gifting.

1.2 Dated sites

Only dated middens allow understanding of changes over time in midden contents, including any loss of taxa. Māori harvested invertebrates from the shore by hand, and finfish from the shore and by canoe using hooks, spears, nets and traps (Paulin 2007). Because wooden components, flax lashings and nets do not survive well in archaeological sites, the use of nets tends to be underestimated, and perhaps nowhere more so than in the Bay of Islands (e.g., Banks' 400–500 fathom net mentioned earlier). Nets (kupenga) were made from strips of undressed harakeke (flax), partially dried to prevent the knots from loosening after the net was made - although small nets were often made using two-ply strands of curly dressed flax fibre, or muka (Hiroa 1970). The techniques in which nets were knotted and slung were essentially the same as we use today. In contrast, 'Fishhooks were fashioned from wood, stone, bone, ivory or shell, based on traditional designs which were refined based on the experience of generations of fishing in Aotearoa' (Paulin 2007): there were suspended hooks (matau, either C-shaped or of jabbing, J-shape) as well as trolled lures (pā kahawai). Early-period fishhooks were typically plain and of one-piece construction (Figure 4), as reported from Mangahawea Bay on Moturua Island (*see* Figure 1; DOC 1981), whereas most in later times were of two-piece construction (Davidson 1984).

Figure 4: Items of pre-Contact fishing gear from the Bay of Islands, part of the Booth Whānau Collection, Te Kōngahu Museum of Waitangi. Early-period fishhooks were typically one-piece and made of moa or marine-mammal bone (top left). By the Late Period, although one-piece, C-type Cook's turban hooks persisted (top right), most hooks were of two-piece construction. In two-piece hooks, the points were of paua (lower left), dog bone and teeth (lower middle pair), and dogfish spines (lower right); most had barbs and were therefore of the jabbing J-form (artefacts from Wiwiki, in Figure 3). Points such as these were bound to the base of (often wooden) shanks. (Images by author)

Only a handful of dated early sites of occupation have been identified in the Bay of Islands (Table 2 and Figure 5); because of their significance, each is briefly described. It was only among these early sites that the Cook Strait limpet, and seabird and marine mammal bones, were reported, and these were always together with moa remains. It is likely that these early sites represent just a few major villages (each vacated once immediately local resources had been exhausted, but sometimes returned to some time later), with outposts, some of which were seasonally attended according to the foods available (Smith 2013).

1) Mangahawea (1 in Figure 5 and Table 2) may be the earliest-settled spot in the Bay of Islands. Jan McKay's 1981 University of Auckland excavation has not been published, but field notes (DOC 1981) describe a deep horizon of subsistence living. The single radiocarbon date from the earliest occupation layer, based on a rock oyster shell, is between 1268 and 1356 AD. But apparently there was no evidence of Kaharoa Tephra (a distinctive layer of ash and rock fragments ejected in the eruption of Mt Tarawera), suggesting that people had not lived at Mangahawea until after 1314 AD (Hogg et al. 2003). This was the only site to contain Cook Strait limpets.
2) Leigh Johnson investigated Opunga Bay (4), a couple of ridges over from Mangahawea and settled by the AD 1400s, contemporaneously with adjoining Hahangarua (3) (NAR 1997, 1998). The lowest horizon had early East-Polynesian characteristics. Of the bones, most were sea mammal - particularly New Zealand fur seals, with unidentified others. But there were birds too - petrel, and large moa; and snapper bones. There was also a wide variety of both bivalves and gastropods - all of which are found there today - but with pipi predominating.

Table 2: Presence of fish and shellfish, marine mammals and seabirds in dated archaeological sites for the Bay of Islands (for full details *see* Booth 2016). For sites, *see* Figures 5 and 6. For Era, E, Early Period (before 1450); M, Middle Period (1450–1650); L, Late Period (1650–1800); H, Historical Period (after 1800). ArchSite denotation is from www.archsite.org.nz. 'Y' indicates presence of the taxon; blank indicates the taxon not reported as being present; numerals give the number of species present.

Site	Era	Location	ArchSite	Date	Setting	Fish		Shellfish				Marine Mammal	Seabird
						Reef spp.	Non-reef spp.	Cockle	Pipi	Soft-sed. spp.	Rocky spp.		
1	E	Mangahawea	Q05/682	1268–1356	Midden	3	1	Y	Y	7	12	Y	Y
2a		Wairoa	P05/853	1413–1446	Midden	1		Y	Y	3	5	Y (?)	
2b	E/M	Wairoa	P05/853	1385–1475	Midden								
3a		Hahangarua (a)	Q05/44	1392–1503	Garden (c)								
3b		Hahangarua (a)	Q05/44	1388–1498	Garden (c)								
4a		Opunga	Q05/46 & 73	1384–1500	Garden &	1			Y	3	4	Y	Y
4b		Opunga	Q05/46 & 73		midden								
5		Waitangi	P05/1055	1436–1516	Midden	Y (?)	Y (?)		Y	2	3		
6		Wairoa	P05/853	1439–1498	Midden	2		Y	Y	4	4		
7		Patunui	P05/986	1448–1497	Midden	3	3	Y	Y	9	7		
8	M	Oneroa	Q05/1261	1459–1566	Midden								
9		Paroa	Q05/1231	1520–1630	?								
10		Wairoa	P05/853	1530–1649	Midden			Y		3	3		
11a	M/L	Opunga	Q05/46 & 73	1544–1682	Garden								
11b		Opunga	Q05/46 & 73		Garden								
12		Waitangi	P05/1050	1551–1666	Midden	Y (?)	Y (?)	Y	Y	3	0		
13		Wairoa	P05/853	1549–1676	Midden	Y (?)		Y	Y	3	5		
14		Mataka	Q04/69	1625–1765	Midden								
15		Rangitane	P05/18	1623–1765	Midden			Y		2	2		
16		Waitangi	P05/611	1590–1760	Kainga								
17	L	Haruru	P05/959	1741–1774	Midden (?)								

Site	Era	Location	ArchSite	Date	Setting	Fish		Shellfish				Marine	Seabird
						Reef	Non-reef	Cockle	Pipi	Soft-sed.	Rocky	Mammal	
18	L/H	Kauri Point	P04/349	1687–1832	Midden (?)								
19		Wairoa	P05/853	1723–1809	Midden								
20		Waipapa	P05/454	1685–1824	Midden			Y		1	1		
21		Okura	P05/760	1635–1775	Midden								
22		Waitangi	P05/1051	1685–1822	Midden	Y (?)	Y (?)	Y	Y	4	0		
23		Whiorau	Q05/376	1669–1807	Midden								
24a		Paroa	Q05/353	1665–1808	Midden								
24b		Paroa	Q05/353	1805–1949	Midden								
25		Wairoa	P05/854	1708–1870	Midden			Y		3	2		
26		Kauri Point	P04/346	1702–1856	Midden								
27a		Haruru	P05/959	1727–1805	Midden (?)								
27b	H	Haruru	P05/959	1830–1891	Midden (?)								
28		Paihia	Q05/1293	1672–1810	Midden			Y	Y	2	0		

3) Early habitation on the other side of the Bay of Islands, at Wairoa Bay (2), was reported by Simon Best (2003). At one small site there were snapper and shellfish, as well as a moa leg and part of a dog.
4) A Waitangi (5) midden examined by Don Prince (2013a) contained hard- and soft-shore shellfish and fish bone, with a pipi shell dating to 1436–1516 AD. Nearby were midden remains more recent by up to 250 years (22), illustrating how rich and deep the record of human occupation is at this site (Prince 2013b in Figure 6).
5) Another dated site on the cusp of the Middle Period of occupation, and the first associated with the inner Bay of Islands, is Patunui (7). Dating to 1448–1497 AD, the variety of food consumed was typical of the Early Period. Mark McCoy and Thegn Ladefoged (McCoy & Ladefoged 2012) found at least six species of fish and 16 estuarine soft- and hard-bottom shellfish (the second richest shellfish assemblage reported for any site in the Bay of Islands).

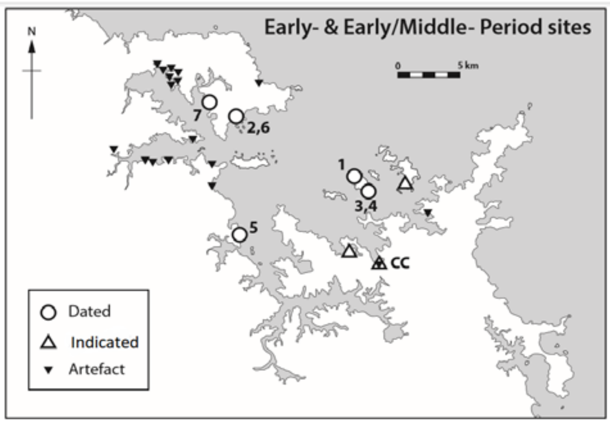

Figure 5: Early sites, dated (O, Early and Early/Middle Period, the associated digits referring to Table 2), or containing items indicative of early settlement such as moa bone (∆), or where ancient stone artefacts have been found (▼, identified by Ian Smith, University of Otago, and housed in the Booth Whānau Collection, Te Kōngahu Museum of Waitangi). Note that we cannot be sure the artefacts had not been taken to their find-spot by later peoples, although the concentration of artefacts in upper Te Puna Inlet is strongly suggestive of early occupation there. CC is Clendon Cove where moa bone, as well as a cache of buried Tahanga (Coromandel Peninsula) basalt adzes, was found (Best 1996; NAR 2011).

Three dated sites in the Bay of Islands are Middle Period, with double this number from the Early/Middle- and Middle/Late-periods (Figure 6 and Table 2). Some sites seem characteristic of the Late Period - dominated by cockles and to a less extent pipi - yet are in fact pre-1650 AD. The remainder are similar to the Early-period middens in that they contain several other shellfish species as well.

By the Late Period the variety of animal-food types had shrunk to a handful, probably because there was now greater emphasis on gardening. The nine dated Late- and Late/Historical-period sites were overwhelmingly dominated by cockles (Figure 6 and Table 2), and pipi were common. One of the best studied of the later sites is Rangitane (15) - the level-topped, 100-m-high summit near Kerikeri. Great volumes of shellfish were lugged up to the safety of this hill whole (along with firewood, and probably hangi stones too), rather than being processed on the shore below. Shell samples here dated to between 1623 and 1765 AD (Phillips 2005).

Also in the Late Period, one-piece hooks had largely been replaced by composite (shank plus point) hooks, frequently adorned with bait knobs or snood attachment knobs (Paulin 2007). The finding of numerous northern spiny dogfish spines, several having been used as fishhook points, at Wiwiki (*see* Figure 3) strongly suggests waka-fishing to considerable depths (Booth et al. 2018 in press). With 90% of the northern spiny dogfish population being found within the 100–500 m depth range (http://www.nabis.govt.nz/; McMillan et al. 2011), its mean depth being 290 m (range 15–954 m; Anderson et al. 1998), this dogfish is part of the outer shelf and upper slope, rather than inshore, fish assemblage; it is not known to make inshore migrations. (The spotted spiny dogfish - which does migrate into shallow waters - is rare off the northeast coast of the North Island; Anderson et al. 1998).

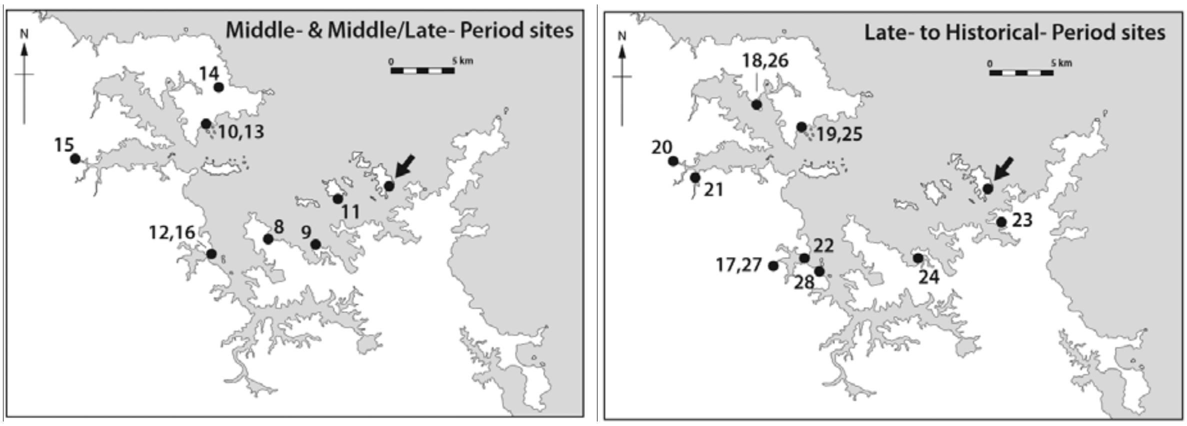

Figure 6: Dated Middle-period to Historical-period sites, the associated digits referring to Table 2. The arrowed site is Urupukapuka Bay with altogether six radiocarbon datings (Thegn Ladefoged, University of Auckland, pers. comm.).

Later Māori also built fish traps. The dozen or so in the area of Hauparua in Kerikeri Inlet (*see* Figure 1) characterise a specialised form of fish harvesting undertaken on sheltered, gradually sloping shores where there was a ready supply of moveable boulders (Figure 7).

'[The Kerikeri fish traps] usually consisted of one or more stone walls cutting off a large area of intertidal zone which was completely uncovered at low tide. The walls and breaches in them, were closed at high tide. Fish, particularly flounder and possibly mullet, follow the tide up to feed on the upper shore at high tide. These devices trapped them with the outgoing tide, making the catching a simple matter.' (Nugent & Nugent 1977).

Figure 7: Fish traps such as this at Quinces Landing, Hauparua (*see* Figure 1) continued to be used well into historic times (Ocean Survey 20/20 image AV29_3322).

1.3 Discussion and conclusions

Bay of Islands' dated middens suggest that there were changes over time in the foods sought and consumed during the first five centuries of human presence. Although there are far fewer dated sites in the Bay of Islands, the pattern of change there appears similar to that which took place in the Hauraki Gulf (Smith 2013): marine mammals, seabirds and the Cook Strait limpet (with moa bones) were present only in early sites; and fish and shellfish variety narrowed over time, with a growing focus on soft-shore estuarine shellfish (Table 2). And, there is a suggestion that whereas colonisation started out being focussed on and near the outer islands, it extended further westward into the Bay over time.

Extirpations and extinctions

The changes in foods consumed certainly cannot necessarily be attributed to extirpation or extinction of species through overharvesting. It appears that Early-period human populations of the Bay of Islands were small and occupations impermanent. Therefore harvesting could have had only minimal impact - localised and none with implicit potential to endure - on productive (highly fecund, fast-growing and early-maturing) fishes, or on widespread and abundant species. But for fishes with low productivity (few offspring, slow-growing, late-maturing and long-lived) and which lived their lives in one place, it could have been different.

The Cook Strait limpet is a species whose preferred waters are cool and well to the south (Cook 2010) and unlike most other shellfish, which produce millions of gametes each year, the Cook Strait limpet, with its modest numbers of eggs, is thought to be restricted in dispersal potential (Goldstien 2005). Further, it may not even breed in northeastern waters, recruitment to its outposts there may instead have resulted from intermittent delivery of larvae from the south. Middens show how this large (up to 75 mm long), intertidal, mainly open-coast limpet must have been present in reasonable numbers along the east Northland coast pre-1450 AD and then become locally extinct (or - although this is much less likely because other open-reef species continued to be harvested - it was no longer sought as food). That climatic change could have led to the extirpation of this species from northeastern waters seems unlikely, because the early part of the last millennium was actually warmer (and presumably less suitable for this species) than the middle centuries (Anderson et al. 2014). It is very likely, therefore, that populations of the Cook Strait limpet that had established themselves in the northeast over the millennia were quite quickly harvested to local extinction by the early settlers.

The only finfish species to have conceivably been locally extirpated in the Bay of Islands is the highly territorial and slow-growing hapuku. Northland remains to this day a hotspot for hapuku, the mature fish living 50 m and deeper. But adults were previously not uncommon in much shallower waters (http://www.nabis.govt.nz/; MacDiarmid et al. 2016), and fishing pressure continues to banish them to increasingly deeper waters. In line with this, hapuku remains were found in the Greater Hauraki Gulf in Middle-period, but not in Late-period, middens (Smith 2013).

Also in the Early Period, the mainland-New Zealand lineage of the New Zealand sealion in the Bay of Islands was almost certainly hunted to extinction - as it was in other parts of Northland. New Zealand fur seals were extirpated through overharvesting, but dolphins (apart from, perhaps, Hector's dolphins) were apparently too difficult to capture (and perhaps too numerous) to be overharvested. The New Zealand sealion and New Zealand fur seal are examples of how even low levels of artisanal fishing can critically impact stocks of species that have low productivity (Pinnegar & Engelhard 2008).

And the kiore Māori brought with them led to the early extinction - as well as extirpation from the mainland - of many seabird species (Holdaway et al. 2001). In line with the Hauraki Gulf-region results, few archaeological sites in the Bay of Islands have yielded seabird bones, and those that did were either Early Period or Early/Middle Period. None of the bones has been identified to species level, but Smith

(2013: 31) suggests that petrels, shags and penguins would probably have dominated coastal harvests in the north because they were the species most abundant and because their breeding habits made them easily and predictably accessible.

Other impacts from harvesting

For most shellfish and fish taxa, however, there is no evidence for overexploitation - even in the presence of a substantial local polulation.

For shellfish, the numerous cockle-dominated middens along sheltered inner Bay of Islands shores are consistent with significant late pre-Contact and early Historical-period harvesting pressure. Even on the islands in the southeast of the Bay, cockles that had been imported were present in high proportions and high densities well into the Historical Period (Thegn Ladefoged, University of Auckland, pers. comm.). The extent of the great cockle middens of the Kerikeri and Waikino was arguably evidence of something more than mere artisanal harvesting of shellfish in at least parts of the Bay of Islands during the Late Period and perhaps into the Historical Period, but it seems that there was no lasting ecological legacy (c.f., the failure of some of the cockle beaches near Auckland to recover after long closures in recent times; Berkenbusch & Neubauer 2016). This is likely to be because, for at least the easily accessible and highly sought species, there was 'ownership' and active stock management that prevented abundance and mean-size from plummeting. For example, in Kerikeri Inlet:

> The cockle beds belonged strictly to certain tribes. Their extent and ownership were marked by poles, sometimes with old flax mats hung upon them. Violation could bring retribution (or be used as an excuse for such) when, as was the case in 1819, Hongi's slaves gathered cockles from a bed in the Kerikeri Inlet, tapu to his enemy Te Morenga and his tribe. Twenty of Hongi's war canoes were subsequently burnt at Kerikeri and a fight took place inland near Taiamai (Easdale 1991).

Indeed, Atholl Anderson concluded that there was no indisputable archaeological evidence for the extinction of shellfish or of widespread, sustained depression in the mean size of any species anywhere in New Zealand - even though there were, in places, reductions in the average size of rocky shore shellfish, in accordance with localised depletion, and there was some evidence of foraging down the food web (Anderson 2008).

The story for finfish seems similar. For snapper, the most highly sought species in the north, independent estimates are that each adult person consumed 37 or 46 fish annually, giving an annual harvest of this species in Northland at the period of first European Contact on the order of 2000 t (Leach 2006; Smith 2011; *see* also Figure 39). This is a substantial harvest, given that the current total snapper catches for Northland are close to 3000 t when commercial, recreational and estimated illegal components are summed across the applicable parts of Quota Management Areas SNA 1 and SNA 8. Even with their giant seines, Māori did not fish snapper stocks down to anywhere near the low levels of today (with stocks only 24% B_0; MPI 2017: 1350). Indeed, it appears that, in the face of significant and sustained Māori fishing, average snapper size in Northland actually *increased* over time (Leach 2006: 9).

To sum up

Although any ecological impact on the fish and shellfish resources of the Bay of Islands brought about by pre-Contact harvesting is difficult to distinguish from that resulting from the harvestings and activities of an expanding post-Contact population, it seems that 500 years of Māori harvesting pressure (and a local population of perhaps as many as 10 000 or more in 1750 AD) left no discernible enduring legacy on Bay of Islands' fish and shellfish resources - with the probable exception of the fishing-out of local populations of the Cook Strait limpet, and possibly initiating the extirpation of hapuku from shallow waters. Undoubtedly this had a lot to do with most Māori fishing having been close to shore, yet a large proportion of the individuals of the respective underlying stocks were located in unfished and often deep and more remote places. But, almost certainly, overharvesting in the Bay of Islands contributed to the extinction of the New Zealand sealion in the Early Period, and to the extirpation of breeding colonies of the New Zealand fur seal from Northland by 1500 AD. Moreover, the kiore rats the early waka transported to this country, together with human harvesting, resulted in seabird extinctions and extirpations.

2. EARLY POST-CONTACT (1800–1900) RESOURCES

Heavy extractions of estuarine shellfish by Māori continued well into the nineteenth century. Two dated middens are from the Historical Period (after 1800), both located in the central west Bay of Islands (27, 28 in Figure 6; Table 2); the one analysed in detail contained only estuarine shellfish. Both are near Te Haumi, which remains to this day one of the most productive cockle beaches in the entire Bay of Islands. Early in the Historical Period, several hundred Māori lived between Te Haumi and Whangae in the lower Kawakawa River, harvesting shellfish, flatfish and other marine resources, and leading to a '…packed archaeological landscape' with an average seven recorded sites per square kilometre (Crown 2012).

Although artisanal harvesting of fish and shellfish for domestic consumption and for inter-Hapu trade would have remained intensive throughout the Bay of Islands, there was also growing commerce as European arrivals escalated, their vessels in need of re-provisioning. Among the most significant of these ships were whalers, their crews seeking salted meat, potatoes, vegetables and dried fish in particular. Whaleships began turning up in northern New Zealand waters near the beginning of the 1800s, and their visits to the Bay of Islands grew to a dozen or so per year, until 1810 (Richards & Chisholm 1992). By 1815 numbers had again reached double figures, and during the 1820s there were an average 24 whalers each year, before numbers dropped again. Numbers began to rise once more in the mid-1830s (Alexander 2011), with an average 118 visits annually, each with a crew of 20–30 (Richards & Chisholm 1992). Total known whaleship arrivals between 1830 and 1840 was 806, and 1261 for the period 1841–94 (Alexander 2011: 9); provisioning such numbers of vessels and people would undoubtedly have put significant pressure on local resources of such species as snapper and grey mullet. But the first kai moana in the Bay of Islands to be commercially fished in a fully contemporary sense was, however, the rock oyster.

2.1 Rock oysters

With oysters prominent in the fashionable cuisine of nineteenth-century England, abundant and available rock oysters were attractive to the settlers. And for more than 100 years, the native rock oyster chipped from solid surfaces was a significant source of food for colonists, but also an on-going issue for administrators. By the 1860s heavy harvesting of this easily accessed resource was taking its toll on the Bay of Islands' stock, driven by an enthusiastic Auckland market as the shellfish survived well out of water, especially if transported in sacks as deck cargo where they remained cool and wet (Johnson & Haworth 2004).

Concern around overharvesting meant that in 1866 rock oysters came under the Oyster Fisheries Act which allowed 'the Commissioner of Crown Lands….to lease areas of foreshore adjacent to Crown land for a term of 14 years for the purpose of establishing oyster farms…. Anyone who established a farm had to pay to lease the foreshore and pay again to pick his own oysters' (Johnson & Haworth 2004).

With steamship *Rowena*'s regular service from the Bay of Islands to Auckland underway by 1872, oyster-gathering on a commercial scale became a regular rather than an occasional occupation. Soon the shellfish was even being delivered to oyster saloons in Australia: by 1883, no fewer than four Union

Company steamers were regularly crossing the Tasman, sailing from Auckland to Russell to load oysters, and coaling at Opua before setting off for Sydney (Johnson & Haworth 2004).

In October 1882, the *Northern Luminary* - a weekly newspaper servicing the Bay of Islands - bemoaned how oysters were being shipped out 'without any regard being taken for future supplies'. Even an 1884 act prohibiting harvests from December to March had no impact: the very next year exports more than doubled (Johnson & Haworth 2004). This came about largely through deception, the harvesters maintaining that oysters growing on mangroves and tree trunks - which they continued to gather unabated - could not possibly be rock oysters. In response, the beds of the Bay of Islands were closed altogether in 1886 'in order to prevent their absolute destruction', this time for three years. Rock oysters were then being deliberately smeared with sediment in order to be labelled mud (dredge) oysters, which had a different closed season altogether.

In desperation the export of 'rock, shore, drift or mangrove oysters, or by whatever name they may be locally known' was prohibited - only to be allowed again three months later because of the uproar that ensued. Instead, an export duty of a shilling a hundredweight (51 kg) was imposed - which stung the exporters at precisely the time that the Sydney market was being flooded with oysters from Queensland (Johnson & Haworth 2004). At last, exports plummeted.

The story of the northern rock oyster from the late 1880s to 1907 had become a litany of beds opened/beds stripped/beds closed (Johnson & Haworth 2004). Management had become a nightmare. Because of this, and with typhoid deaths in Auckland attributed to rock oysters harvested near sewers, the Government itself in 1907 took over the whole business of commercial oystering.

2.2 Finfish

Rock oysters may have been popular among both Māori and Pakeha, but finfish, surely, would have been the lifeblood of most coastal communities, and one fish in particular to compare favourably with canned imports was the grey mullet. Extraordinarily abundant along Northland's west coast and its harbours, mullet were also plentiful in the tidal reaches of east-coast inlets. Specialised 'mulleties' were developed to net them: half-decked, flat-bottomed, centre-board boats up to 8 m long. The rudder was removed when fishing, and as one crew member rowed the boat using huge sweep oars, the other ran out the net (http://heritageetal.blogspot.co.nz/2015_05_01_archive.html).

It seems that the Auckland Fish Company was first to set up mullet-canning in the Bay of Islands, in Russell in about 1883, followed for a brief spell in 1891 by Ewing & Co. (Boese n.d.). Another early initiative was Henry Lane's 'Waterfall' brand fish cannery, in production in the late 1800s at Waikare (Ward 2011).

But the first substantial canning operation was Masefield Brothers', established on the north end of Kororareka Bay, Russell in 1889 (Figure 8). Their most popular product was *Star*-brand one-pound (0.45 kg) tins of mullet (Boese n.d.) - but also kippered (split butterfly fashion, and salted or pickled, then smoked) mullet and snapper - '….sold not only through New Zealand but also exported to the South Seas and Great Britain' (Spicer 1993). In 1891, the company was taking an average 7200 fish each month with up to 10 boats, with a record catch of 1500 fish having been made by C. Baker in September 1892. The cannery operated until 1906, when it seems it was taken over by the Oceanic Fish Company, who preserved fish in a fluid of some sort - until apparently folding in 1911 (Boese n.d.).

Figure 8: Masefield's Canning Factory and wharf at the north end of Kororareka Bay, with a mulletie to the right of the loading jib. (Photograph: Alexander Turnbull Library, Wellington. New Zealand Reference 1/2-052135-F)

In about 1891, on the other side of the Bay, another cannery started, and this one lasted longer. George Mountain, the son of a convicted horse-stealer who had been transported to Australia, established a factory on the northwest side of the Bay at Purerua, but it wasn't until his son Walter established the *Penguin* brand (Figure 9) that medals were being won in London, and the enterprise burgeoned (Anon n.d.).

Most fish were netted in Kerikeri and Te Puna inlets, a couple of boats being engaged all year round. Opening of the rail link from Opua to Auckland in 1912 stimulated the industry, with the Purerua cannery producing 545 cases in 1914, each containing 6 dozen tins (Boese n.d.).

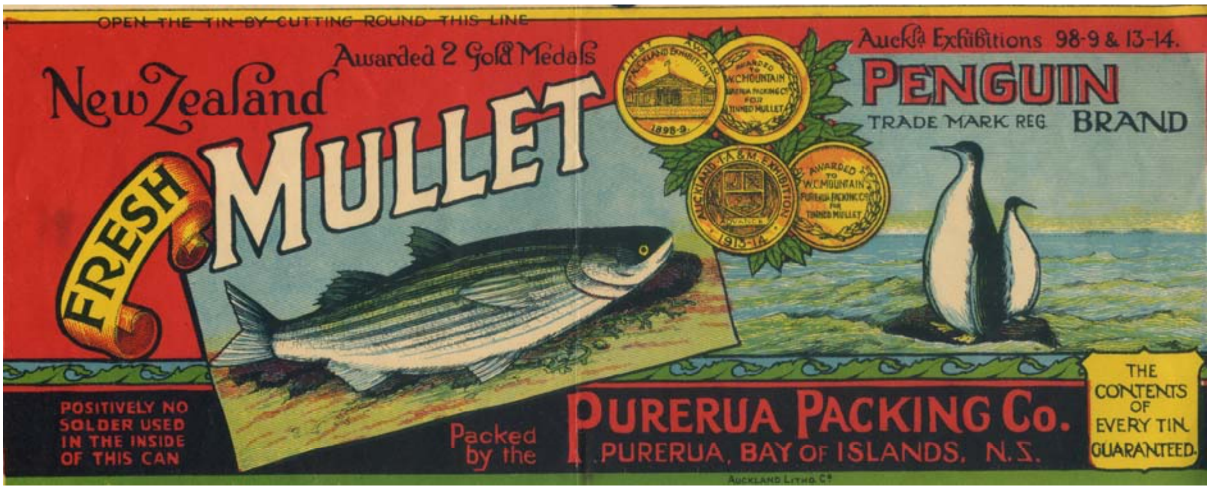

Figure 9: Purerua Packing Co's *Penguin* 'fresh' grey mullet was - of course - canned, 'every tin guaranteed'. Auckland Litho. Co's eye-catching label rewards close scrutiny, including the over-portly penguins and mischievous reversal of 'Z' in 'NZ'. (Image: Russell Museum Collection, 97/1595/1)

> The canning factory was called 'The Penguin' and there was a thriving community of about eight hundred people living there…..Wooden boxes were made to hold six dozen tins and about 1400 cases were put up each year….. The canning factory was built in a small bay in the Poukoura Inlet, a branch of the Te Puna Inlet. The factory was built half over the water…. in one 18-day fishing period they [the brothers] caught 975 dozen fish. They would go out fishing all night, have a few hours' sleep the next morning and then dispose of their fish to the factory, [then] to Kerikeri and [then they] would take fish and crayfish to Russell to catch the *Clansman* for the Auckland market (Malcolm 1994: 114–116).

Closure of the factory, in 1935, 'was due to the scarcity of the mullet; the depression; and the high cost of importing the ingot sheet-tin from England.' (Boese n.d.).

Grey mullet is the finfish to have historically received most mention in the Bay of Islands at this time - but only because it was the first to form the basis of a commercial fishery in a contemporary sense. In fact, fish-smokers outnumbered fish-canners around the turn of the century - with no fewer than ten operating in the Bay in 1909 (Marine Department 1909), their primary products being not only grey mullet, but also snapper, blue maomao, and parore. But domestically, the ubiquitous and highly prized snapper is likely to have been the main focus of the Bay of Islands finfishery, although we have no quantified estimates of the scale of this fishery.

During this time, Māori adapted to European technology, but some continued to fashion fishhooks in traditional forms using new materials, particularly for use in customary harvesting of highly favoured fishes such as certain sharks (Paulin 2016) (Figure 10).

Figure 10: Early Historical-period iron shark hooks from Kerikeri Inlet (part of the Booth Whānau Collection, Te Kōngahu Museum of Waitangi) appear to take on both J- and C-shapes (the rule is 30 cm long). (Image by author)

2.3 Marine mammals

> A few days before [in 1820], to the inexpressible astonishment of the islanders [local Māori], two [probably humpback] whales that came into the Bay of Islands, were attacked by the boats of the whale ships, and killed; after the blubber had been cut off, the carcass floated on shore. The flesh of the whale being considered by these people a first-rate delicacy, they gathered from every corner of the bay to feed upon it. Innumerable quarrels took place upon the back of the fish, and even the native girls who lived as servants to the missionaries, and were fed as well as their masters, either abandoned their employment to take their station at the carcass of the whale, or insisted that some of it should be purchased for their consumption (Cruise 1921).

By the mid-1800s, local Māori and Pakeha alike were shore whaling. The record is thin, but it seems shore-whaling in the Bay of Islands was for the most part carried out in a rather casual way. 'A family or a community in the outer harbour might sight a whale and go after it. Many of the Bay's men, Maori and Pakeha, had been on whaling voyages, and a number of families had whaleboats and knew how to handle them' (King 1992). Occasionally foreign whaling ships also joined in, 'bay whaling' (Alexander 2011).

Whaling was seasonal and focused on migrating humpback whales that were northbound in winter and southbound in late spring/early summer (Alexander 2015). Hunting would have most often taken place in the outer bay or outside the Bay of Islands itself, and once killed, a whale would be beached. 'Requirements seemed to be for the beach to have been reasonably sheltered, close to where the whales were, sandy and relatively deep water close in to get the whale close to shore.' (L. Alexander, Russell, pers. comm.). Then began the laborious process of flensing and mincing the blubber into smaller pieces - 'bible leaves' - before being pitched into try pots where it was boiled to extract the oil. 'By all accounts an overpowering stench pervaded the stations and monstrous amounts of bone and meat remained'…. (Trotter & McCulloch 1989). The oil was then taken to Kororareka to sell (Figure 11) (King 1992).

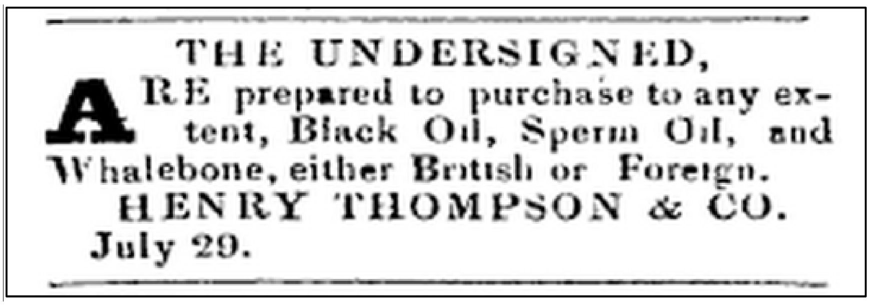
THE UNDERSIGNED,
ARE prepared to purchase to any extent, Black Oil, Sperm Oil, and Whalebone, either British or Foreign.
HENRY THOMPSON & CO.
July 29.

Figure 11: Advertisement for purchase of whale oil and other whale products, from the 20 August 1840 edition of the *New Zealand Advertiser, and Bay of Islands Gazette* ('British' includes New Zealand). (https://paperspast.natlib.govt.nz/newspapers/new-zealand-advertiser-and-bay-of-islands-gazette)

Apparently in the mid-1800s there were at least three whale boats operating in the eastern Bay of Islands alone (Figure 12). The one based at Moturua was owned by Ihaka te Tai; at Otehei Bay, Rewiri Tarapata from Bay of Plenty had his camp; and Rewha was based in Hauai (Shepherd 1966). And later, it seems, Tamati Waaka Hakuene whaled out of Okahu (Anon 1901), with yet others using Deep Water Cove (Alexander 2015) (Figure 12).

But Bay of Islands' most significant shore whaling station operated for a number of spring seasons in the early 1890s at Whale Bay, just inside Cape Wiwiki (Dawbin 1956), probably by the Bay Whaling Company (King 1992). Here, 'Some humpbacks follow the coast so closely that they pass Ninepins [Tikitiki] Island[,] on the western side of the Bay of Islands' (Dawbin 1956).

By the late 1890s shore whaling within the Bay of Islands itself appears to have run its course (Alexander 2015), but a little south of the Bay humpback-hunting persisted until the early 1930s.

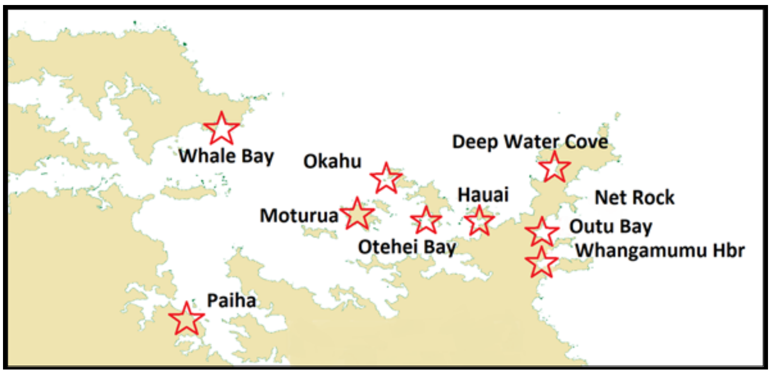

Figure 12: Known humpback shore-whaling stations of the Bay of Islands and nearby, mid- to late-1800s. (Whaling continued at Whangamumu until the early 1930s.) (Map prepared by author)

Historian Marie King records how Whangamumu (Figures 12–14), 8 km south of the Bay of Islands, was first used for whaling by Andrew Gibson and John Johnson for a short time in 1844 (King 1992). Later, Outu Bay, a couple of kilometres north, and just inshore of Net Rock, was to become the base ahead of the Cook brothers' Whangamumu station really getting underway in the early 1890s (Alexander 2015).

Figure 13: Whangamumu Harbour was the site of a shore station hunting humpbacks, until 1931. Net Rock is this side of the distant headland at right, and Cape Brett lies out of sight just beyond that headland. (Photograph: Dean Wright Photography, Kerikeri)

'….Whangamumu whalers have described humpbacks coming in close enough to shore to rub themselves against the rocks in waters of 3–5 fathoms [6–10 m]' (Dawbin 1956). Such observations led to the use of nets to slow the fast-moving humpbacks sufficiently for oar-driven whaleboats to catch up and harpoon and then lance them (Alexander 2013) (Figure 14).

Jubilant, George Cook predicted they would soon be catching whales and "stringing them up like patiki [flounder]" (King 1992). But the nets produced small catches and were disbanded after 20 years in favour of a powered vessel (Dawbin 1956). The steam-driven chaser *Hananui II* was used from 1912, armed with 14 lb [about 6 kg] bombs to drive into the whales (Jones n.d.). In 1927, the peak year, 74 humpbacks were killed, 'providing 388 tons [about 388 t] of oil and 70 tons of bonedust for fertilizer' (Jones n.d.).

Figure 14: Left: The nets that were set across the 20 m gap between Net Rock and the mainland (http://www.os2020.org.nz/) did not ensnare but confused and slowed the humpbacks, allowing them to be harpooned. Right: Whaling at Whangamumu, 'setting the net' c. 1890 (Russell Museum Collection, 97/1419). (Nets were also laid seaward of the island, in waters 60 m or so deep; Fagan n.d.)

Between 1912 and 1931, 963 humpback whales were caught and processed at Whangamumu (Dawbin 1956). The Bay of Islands area had been a small part of the great world-wide, nineteenth century, oceanic whaling industry which, although based mainly on the southern right whale in the New Zealand region (Prickett 1998), had also taken sperm whales and humpbacks.

2.4 Seabirds

History seems to have had little specific to say about the abundance of the various seabirds of the Bay of Islands of the 1800s. It appears that most if not all seabird extinctions had already taken place, primarily as a result of predation by kiore, and expedited by human-harvesting; pressure was to increase with the arrival of Norway and ship rats, and other mammalian predators. Accordingly, during the 1800s mainland seabird populations were further reduced and most species were essentially banished to offshore islands and stacks.

The rats noted by James Cook and Joseph Banks were 'small and very scarce', and later Europeans emphasised how much smaller kiore were than the European rat(s). Yet, soon after James Cook, Julien Crozet wrote that the rats in the eastern Bay of Islands were 'the same species as those we have in our fields and forests' (Roth 1891: 76). It is possible therefore that rats - probably Norway rats - were already established in at least the eastern Bay of Islands by the time of the visit of Marc-Joseph Marion du Fresne, presumably as a result of the *Endeavour*'s visit three years before. James Cook has been held responsible for distributing Norway rats far and wide, including to other parts of New Zealand (http://halo.org.nz/know-rodents-dr-james-russell/reference; Salmond 1997: 142, 145). The oral history of tangatawhenua is silent on the matter, which is not surprising because Ngare Raumati - the people of the eastern Bay of Islands at that time - were vanquished by others from the west in the early 1800s; presumably all such knowledge was lost with them.

At Motukokako, birders of the nineteenth and early twentieth century took up to 500 oi each season. Before the arrival of Europeans, the opening date for harvesting oi on Motukokako was decided by the tohunga*;* but later it became fixed at November 15th. Apparently much ritual attended this opening ceremony, which lasted a full day and was to lift the tapu placed on the birds at the end of the previous season (Phillipps 1956). Indeed, petrels have maintained a place in the life and lore of Bay of Islands Māori right through into colonial times, but almost certainly based on island-refuge populations rather than mainland ones. Oi remain on the list of kurataiao (particularly treasured living things) of the people of Ngati Kuta and Patukeha in the eastern Bay of Islands. Accordingly, from time to time on Te Rawhiti Marae the welcoming mihi rings 'Ka tangi te tii-ti [oi], ka tangi te ka-ka, ka tangi hoki ahau. Tihei Mauriora' - 'The titi [oi] is calling, the kaka is calling. And I wish to call too. Behold! There is life!' (Marara Hook, Te Rawhiti, pers. comm.).

Arthur Pycroft, stationmaster for Opua, noted in the late 1890s how the southern black-backed gull was very common (and breeding) in the Bay, as were the red-billed gull, the white-fronted tern, and the blue (reef) heron; all of these bred on the Black Rocks (Pycroft 1898). He also found breeding sooty shearwaters - whose nearest breeding spots these days are the Cavalli Islands (30 km northwest of the Bay of Islands) and the Hen and Chickens Islands (100 km to the southeast) - on nearby Moturoa Island, and little penguins nested in many places around the harbour. Other seabirds he saw - but did not find breeding in the Bay of Islands - were, commonly, the Arctic skua gull, Caspian tern, common diving petrel, and Australasian gannet; and, occasionally, the wandering albatross, and northern giant petrel. Among the shorebirds, the black shag was common, and there were also pied shags and little shags. 'I secured eight of these birds at one shot when a flock of about sixty were fishing in front of the Opua Railway-station.' (Pycroft 1898).

2.5 Discussion and conclusions

Although rock-oyster numbers would have declined over this early period as a result of heavy harvesting pressure, it is most unlikely there would have been any distinguishable irreversible ecological impact of consequence. For grey mullet, and other finfish, the fishing pressure would probably have done little more than to reduce somewhat the abundance and mean size of fish in certain places - something that would persist with ongoing harvesting. There would have been, however, flow-on implications for the broader ecology, most of them so complex as to be difficult to frame. The Bay of Islands shore-whalers may have had only a small hand in reducing humpback numbers in the Southern Hemisphere from their original 120 000 individuals (now around 15 000) - but nevertheless they did contribute to that harvesting pressure. Finally, the hunting of seabirds and their eggs would have added to the pressure exerted by aliens such as rats in ensuring that colonies were extirpated to offshore stacks and islets, and denied opportunities to re-establish on the mainland.

3. RECENT (POST-1900) RESOURCES

3.1 COMMERCIAL FISHERY

Fishing diversified as the resident population increased, but it was not until the dawn of the twentieth century, with the collection of formal fishery statistics, that the scale and variety of commercial landings in the Bay of Islands begins to become clear. From 1904, fishers had to provide for the first time details of their fish caught (Johnson & Haworth 2004; the annual *Report on Fisheries*, published by the Marine Department/Ministry of Agriculture and Fisheries from the late-1800s to mid-1970s and evaluated by Paul 2012: 6).

3.1.1 Rock oysters

Between 1912 and 1973 the Marine Department gathered and marketed close to an average 2000 sacks of Bay of Islands rock oysters (each containing 90 dozen; Marine Department 1931) each year, the peak approaching 6000 sacks, in 1914 (Figure 15).

Figure 15: The government inspector of oyster fisheries superintending picking operations in the Bay of Islands in 1909. (Photograph: Sir George Grey Special Collections, Auckland Libraries, AWNS-19090513-10-3)

The fishery at this time also involved the first serious attempt at marine fishery enhancement in New Zealand, with rocks for oyster spat to settle on being distributed widely about the Bay of Islands. These ‘farms’ were not permitted in front of popular beaches, recreational boating areas, anchorages, in places used for hauling fish, on shellfish grounds, or in the vicinity of sewer outfalls. By 1916, high-level oyster rocks were being moved down to half-tide level, and soon kilometres of rock wall had been established (Marine Department 1916), much of it altering greatly the ecology of otherwise soft shores (Figures 16 and 17).

> Within the last year or two [of 1922]…..the Australian system has been introduced with very promising results. This consists of the building of rock walls, which extend in orderly rows from about 2ft below high-water mark to 2ft above low water. The rocks are placed in triangular position, one resting lengthwise on top of two others, so that the water washes in and out between them quite freely. When spawning time comes, the oyster spat flowing on the surface of the waves attaches itself to the underside of the rocks, which are allowed to remain in that position until the spat is sufficiently developed to be able to withstand the heat of the sun. The rocks are then turned, and the upper surface in turn also becomes covered with spat.......sheltered portions of the Bay of lslands, Whangarei and Whangaroa are stated to be showing very good results (New Zealand Herald 1922).

Figure 16: Large area of newly laid-out rocks in the lower reach of Kerikeri Inlet in 1922. (Photograph: Sir George Grey Special Collections, Auckland Libraries, Auckland Weekly News AWNS-19210224-40-4)

But the oysters themselves were not the only management focus; by 1928, oyster drills and competing organisms were also receiving attention. Decimating the young oysters in particular, the oyster borer (and - much less abundant, and lower down in the intertidal - the white rock shell), leave one half of the oyster shell adhering to the rock and onto which new oyster spat will fix - but apparently not survive (Marine Department 1931). Contractors were paid one shilling per thousand to remove the snails, and for the next quarter of a century, on average about one million borers were despatched each year, with numbers peaking at 7.5 million in 1941. In addition, vast areas of rock were regularly water-blasted of every scrap of marine life - and especially 'grape weed', or Neptune's necklace; and areas of dead oysters were 'cleaned up'.

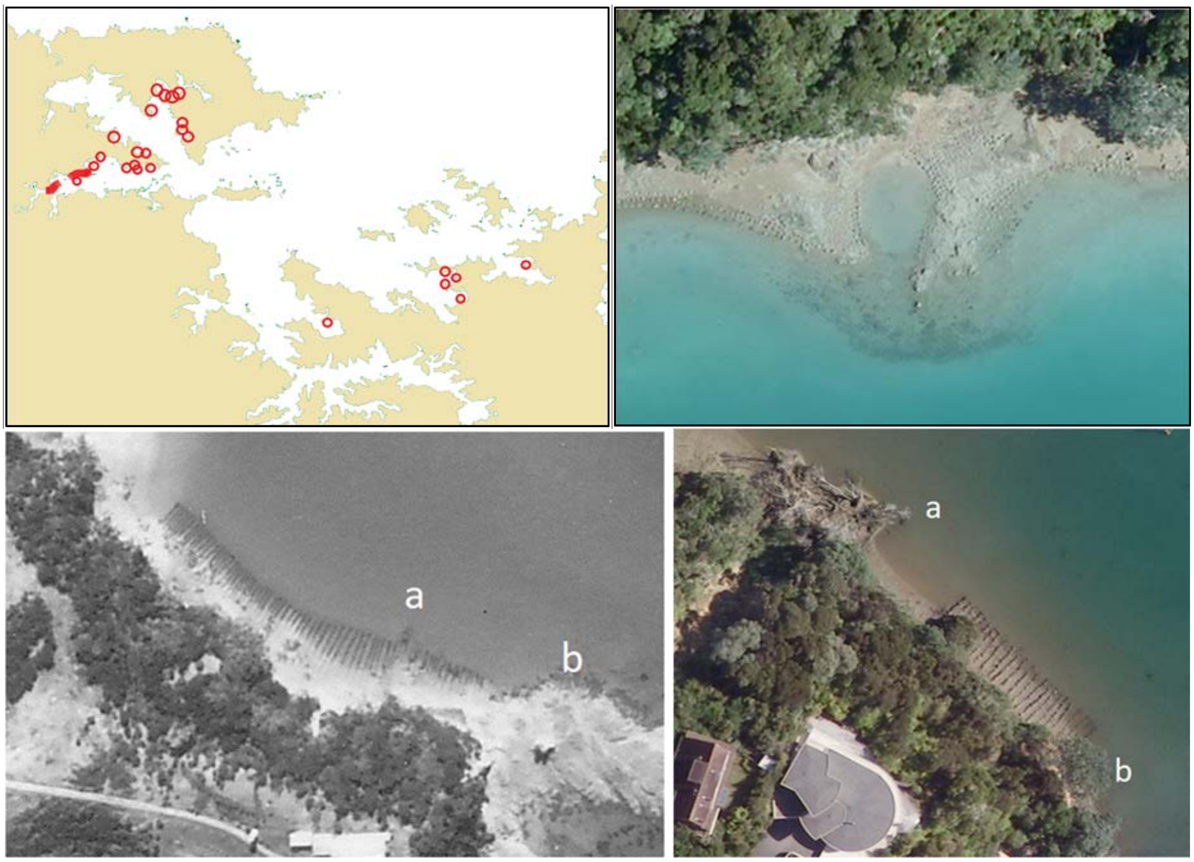

Figure 17: Upper left: Places where oyster groynes, or groynes and rocks, established early in the twentieth century are still clearly visible in the 2009 Ocean Survey 20/20 aerial images. The rocks were gathered mainly, it seems, from Te Puna Inlet. (Map prepared by author) Upper right: Placed oyster-rocks surround what is possibly a fishing-waka haul-out in Te Hue Cove, perhaps dating back to the time of Te Kuri, whose pa located directly above was sacked by the French in 1772 (Image: Ocean Survey 20/20 AV30_3904). Many tonnes of rocks were associated with the oyster project, but several hundred tonnes would have been moved in order to create the waka haul-out. Lower pair: Extensive areas of oyster-groyne clearly visible in 1971 in Kerikeri Inlet (left image: NZ Aerial Mapping Ltd. 4476-5, part of S.N. 3406) had been partly removed by 2009 (right image: Ocean Survey 20/20 AV29_3021).

Managing in this manner a wild stock which occupied an easily accessed band of the intertidal around many of the hard (and often remote) shores of the Bay of Islands, was never likely to succeed commercially. Accordingly, the first trial rock oyster farm was established on leased shore in Orongo Bay, in the mid-1960s; the next one, established at Te Tii soon after, was followed by a flood of new applications. Feral oysters were picked for transfer to the farms, and soon spat caught from the wild on sticks in harbours to the south were being trucked north (Johnson & Haworth 2004).

These small oysters came mainly from Mahurangi, a little north of Auckland, where it transpired the spat being collected were not the native rock oyster, but the Pacific oyster instead; this is how this alien species promptly gained a foothold throughout much of Northland. The Pacific oyster grows quarter again heavier in half the time compared with the native one, and is harvestable in a little over a year as opposed to three years. It was first officially registered on spat sticks at Mahurangi in 1970, its arrival possibly connected to ships bringing the ‘Nippon clip-ons’ (the outrigger lanes) for the Auckland Harbour Bridge in the late 1960s, or to the emptying of ships’ ballast tanks off Northland. In any event, by 1977 most commercial growers had changed to Pacific oysters (Johnson & Haworth 2004), and in no time, it seemed, hard shores throughout much of the Bay of Islands were peppered with their spat.

Arguably the ecological impacts of the arrival of the alien Pacific oyster on the native rock oyster (and other taxa) in the Bay of Islands can be laid squarely at the feet of the oyster fishery, yet these impacts remain largely unstudied. One reason for this is that it is often difficult to distinguish between the species without opening them. It is frequently claimed by locals that there are few rock oysters left - but no evidence for this has been found (apart from the loss of native oysters suggested in Figure 18, which is only one site examined on just two occasions and which may or may not represent broader areas and other time scales). There will be some competition for settlement space, but rock oysters survive higher on the shore than do Pacifics, being more tolerant of emersion (*see* Figure 42). In any event, rock oysters settle on hard surfaces - and other oysters, including Pacifics, provide exactly that type of surface.

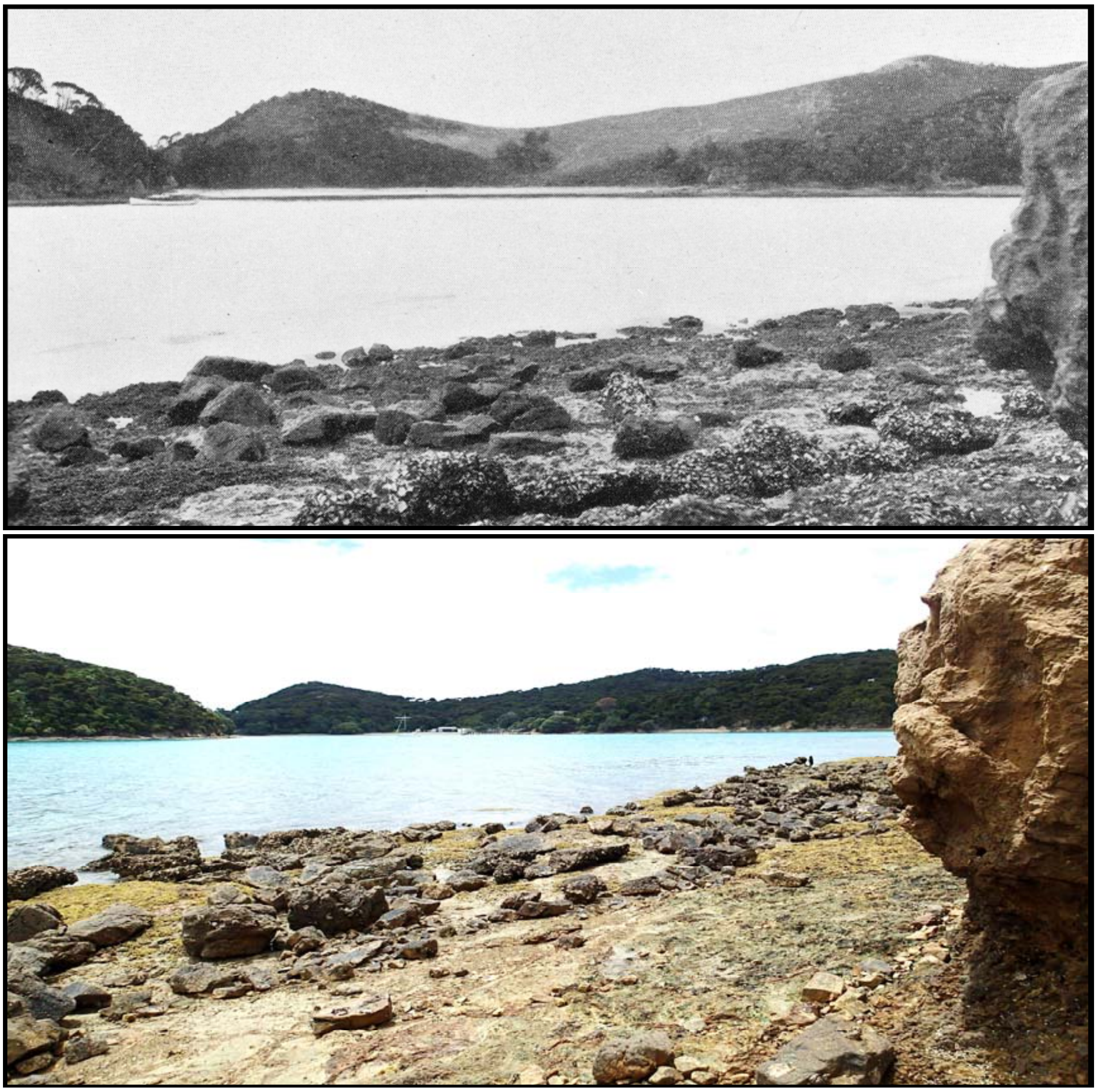

Figure 18: Upper: Native rock oysters in about 1950, on rocks placed there in the 1920s, with Te Hue Cove in the distance (Kelly 1951). Lower: Similar view in 2016, with few oysters visible in the upper intertidal, and Pacific oysters dominating the lower shore. (Image by author)

3.1.2 Finfish

The Bay of Islands (Russell) Port of Landing catch statistics were essentially for the Bay itself, rather than the much more extensive coastlines applying to most other Ports of Landing around the country. Reporting was at first sporadic, the main fish by weight for the Bay of Islands between 1906 and 1930 being snapper, grey mullet and flounder; the next most-caught brackets took in kingfish, hapuku and kahawai; and then tarakihi, blue maomao and garfish (piper) (Booth 2015). It was not until 1931, however, that annual tables of landings data species-by-species were being routinely published - although they remain, at best, the lower bounds of actual landings (Francis & Paul 2013).

The Marine Department annual *Report on Fisheries* show how set-netters and liners dominated the early commercial fleet in the Bay of Islands (Figure 19) - just as they do today. During the 1920s and 1930s, a total of 30–60 vessels were fishing the Bay and its immediate environs. For Northland generally, sail and row boats were overtaken by a progression of more efficient commercial methods: beam trawlers from about 1899; long liners from about 1912; steam trawlers from about 1915 (although not, it seems, in the Bay of Islands); Danish seiners from about 1923; and pair trawlers during the 1970s to 1980s (Parsons et al. 2009). And soon after the war, rock lobster vessels had joined the fishing fleet. By the early 1980s, up to 176 commercial vessels were based in the Bay of Islands, landing around 700 t of wetfish - mostly from set netting and lining - and shellfish each year (King 1985).

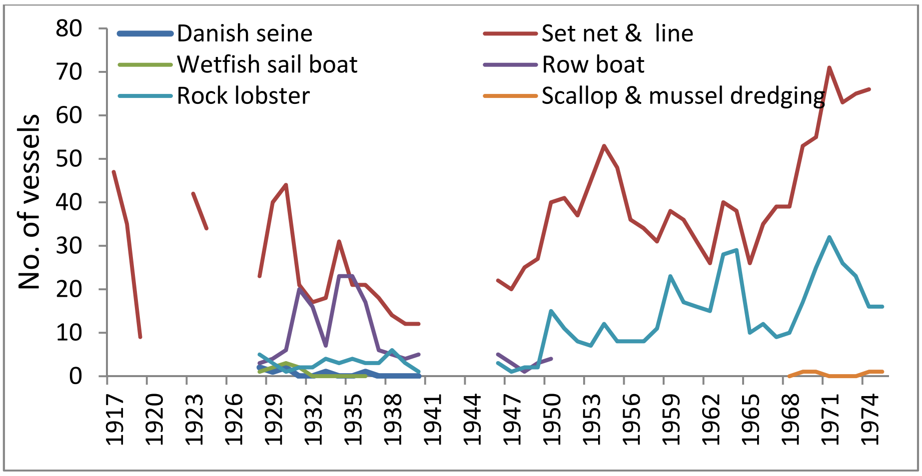

Figure 19: Indicative numbers of commercial fishing vessels for Bay of Islands (Russell), 1917–75, from the annual Marine Department *Report on Fisheries*.

Monumental changes in fisheries management took place in the early- and mid-1980s. Centred on a campaign of effort reduction aimed at conserving stocks, introduction of Controlled Fisheries turned out in the end to be more about shoring-up access to the fish stocks for select quarters of the industry. With full support of the Federation of Commercial Fishermen, the Ministry of Agriculture and Fisheries began to weed out part-time commercial fishermen. A full-time finfisherman was one who fished year-round, or for a specified season. Income from fishing had to be at least $10 000 a year, and 80% of annual income had to be derived from fishing (although there was a saving provision if fishing was a ‘vital part’ of an annual subsistence income) (Johnson & Haworth 2004).

So keen was the Bay of Islands Fishermen’s Association for the numbers of fishers to be reduced, it had asked in March 1983 for action immediately the new Fisheries Act came into force on 1 October that year.

> It [the Bay of Islands Fishermen’s Association] calculated that the average catch for [Bay of Islands’] 70 boats fishing for snapper was 7.14 t a year. If the top ten boats were excluded, the average was only 4.26 t. With the cost of running a boat 40 percent of receipts, even 7.14 t left only $177 a week, less than the average wage and no return for a fisherman’s investment in boat and gear. Working days had increased by 4 hours to 16–20 hours a day, which meant fishermen had to live on their boats…. The Fishermen’s Association suggested compensation payments be split 50:50 between the government and the fishermen, with those who remained having the right to sell their licences. Once a buy-out had been completed they envisaged a quota system of some sort (Johnson & Haworth 2004).

But this flurry of management intervention was itself overtaken when, on 1 October 1986, the entire New Zealand finfishery - inshore and deepwater - came under the Quota Management System (QMS), and with it came the instruments of Total Allowable Catches (TACs) and Individual Transferrable Quotas (ITQs). ITQs for finfish were to be based on the average annual catch of each fisher for the years 1981 to 1983. Rock lobsters came under the QMS in 1990; and today almost all commercial and potentially commercial fish, invertebrates and seaweeds are subject to it.

We are now able to draw together information for the Bay of Islands fishery for the entire period 1931 to the present. The scale of landings for key individual species in and near the Bay of Islands is indicated in Figure 20, the main points being as follows.

- Up until the late 1970s, the mainstay species in terms of weight - albeit with modest annual landings (up to about 100 t of each species) - were flounder, grey mullet, hapuku and snapper;
- Leading up to the management changes of the 1980s, annual snapper landings rose briefly to more than 1000 t;
- Parore and yellow-eyed mullet were briefly significant soon after World War II, the latter netted in quite large quantities (up to 60 t a year) near Opua in particular (R. Civil, Kerikeri, pers. comm.);
- Pelagic species such as blue mackerel, jack mackerel and skipjack tuna were first fished in the 1980s, after which large annual catches (thousands of tonnes) were being made in open waters just outside the Bay of Islands;
- The only invertebrate of significance has been the red rock lobster, fished to any extent only since World War II, with recent local harvests averaging up to about 10 t a year.

3.1.3 Commercial fisheries in Statistical Area 003 over the past 10 years

The finest-scale geographic subdivisions of catch and effort data for today’s tiny fleet of mainly small commercial vessels in the Bay of Islands routinely available are for (General) Statistical Area 003 (Karangi, near the west end of Taupo Bay, south about 200 km to Waipu Cove; *see* Figure 23), available on the National Aquatic Biodiversity Index System (NABIS) website (http://www.nabis.govt.nz/). The fishing year for most species begins 1 October (but 1 April for rock lobsters).

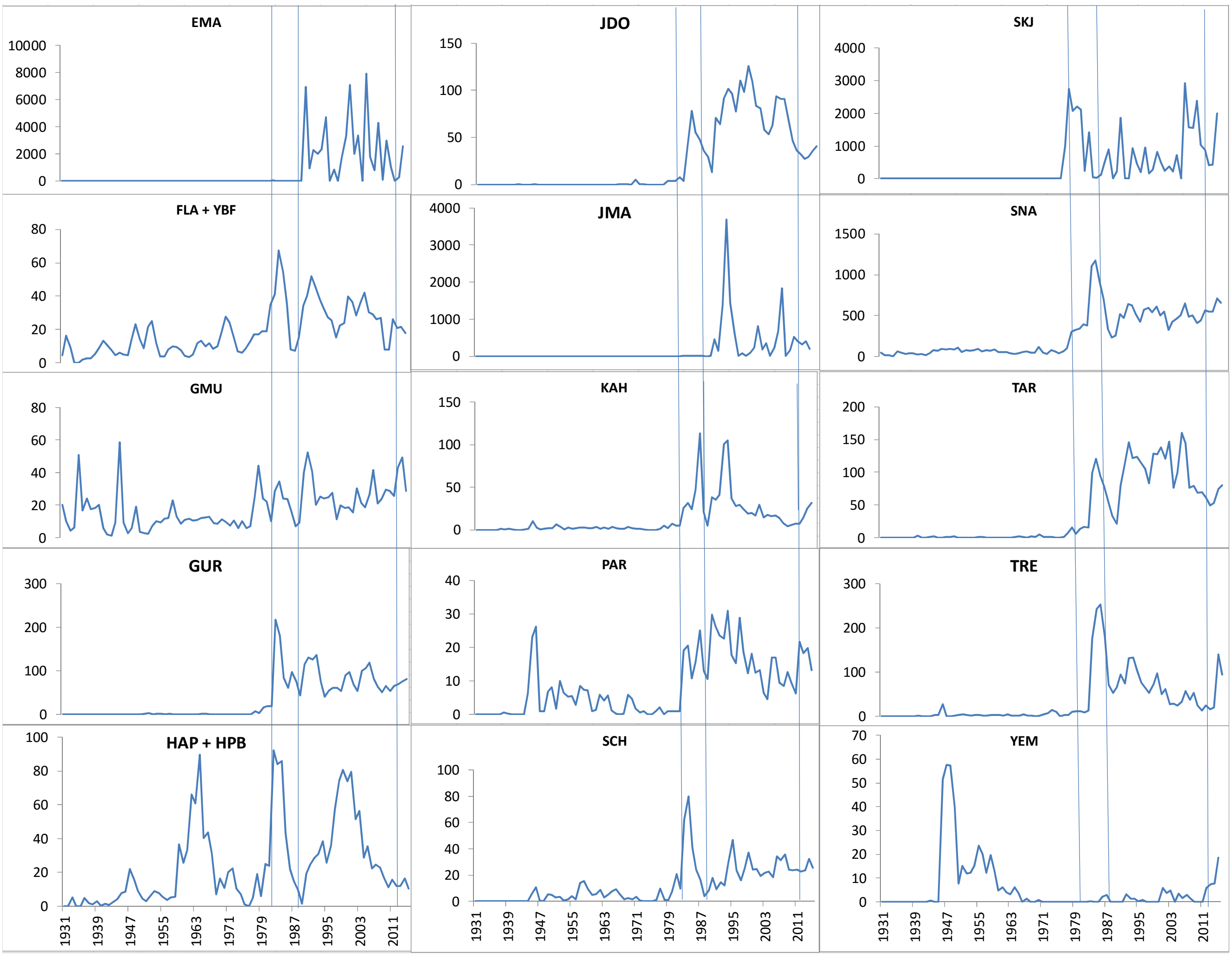

Figure 20: Indicative annual commercial catches/landings (t greenweight) of principal finfish species (as well as others of interest) for the northeast of the North Island centred on the Bay of Islands, 1931–2015. The vertical lines separate very different areas and/or sources of fishery reporting. Values for 1931–82 for the Russell Port of Landing (Nine Pin to Cape Brett, and subsequently referred to in the record as 'Bay of Islands'), can at best be considered a lower bound of true landings (Francis & Paul 2013). Values for 1983–88 are the estimated catches for Statistical Area 003 (*see* Figure 23) from the Ministry for Primary Industries' (MPI) *new_fsu* database at 17 July 2013, but are considered incomplete. For some species, no landings were reported before 1983. Values for 1989 to 2012 are the estimated catches for Statistical Area 003 from the MPI *catch-effort database* at 17 July 2013. Values for 2013 to 2015 are the estimated catches (all methods) for Statistical Area 003 from MPI's NABIS website (http://www.nabis.govt.nz/) at 21 August 2016. (EMA, blue mackerel; FLA, flounder; GMU, grey mullet; GUR, red gurnard; HAP, hapuku; HPB, hapuku/bass; JDO, john dory; JMA, jack mackerel; KAH, kahawai; PAR, parore; SCH, school shark; SKJ, skipjack; SNA, snapper; TAR, tarakihi; TRE, trevally; YBF, yellowbelly flounder; YEM, yellow-eyed mullet.)

Restrictions applying to commercial fishing within the Bay of Islands itself today are summarised in Figure 21.

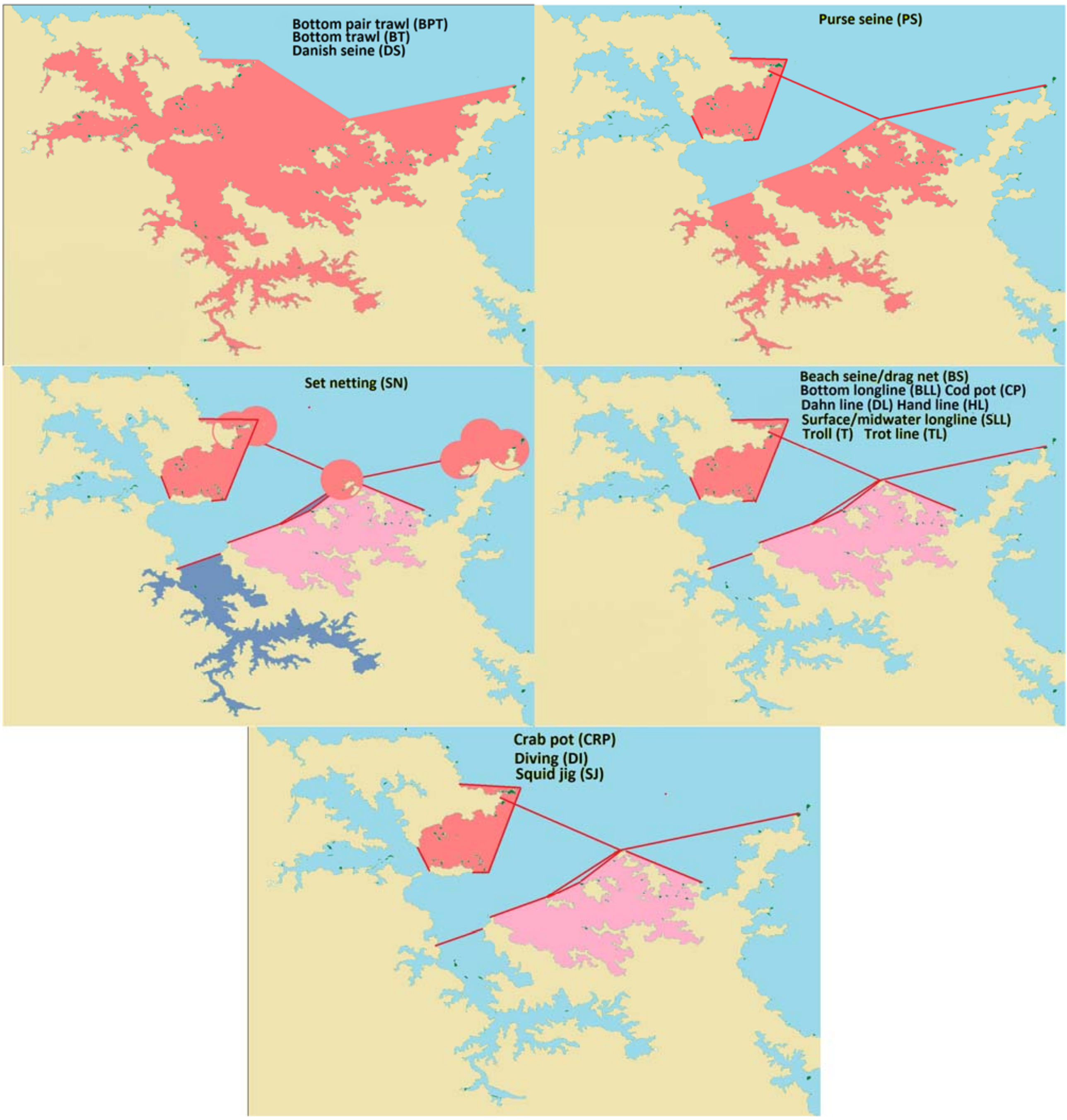

Figure 21: Upper two rows: Areas and times of year various fishing methods for finfish can be used commercially in the Bay of Islands. Red, prohibited altogether (circles have a 1-nautical mile radius and are for set netting at Cape Wiwiki, Whale Rock and Twins Rock; and all netting at Nine Pin [Tikitiki], Cape Brett and Bird Rock; in the north is Te Puna Mataitai Reserve, established in 2013); pink, permitted 1 May to 30 September (but set nets must be less than 1 km long); dark blue, permitted all year for set nets less than 1 km long; light blue, permitted year-round. Bottom: Areas and times of the year various fishing methods for invertebrates can be used commercially in the Bay of Islands. Red, prohibited altogether (Te Puna Mataitai Reserve); pink, permitted 1 May to 30 September; blue, permitted year-round. Rock lobsters can be fished anywhere at any time (apart from within the mataitai); commercial scallop fishing is banned altogether. (Maps prepared by author)

Thirty finfish species/taxa managed under the QMS, and two tuna species, have been harvested to a significant extent (usually over 10 t total across five years) in Statistical Area 003 in recent times, using

12 methods (Booth 2015). Of these species, blue mackerel, skipjack, snapper and jack mackerel supported the highest individual landings during the 7-year period 2008–09 to 2014–15, but with a lot of variability from year to year; landings of most other species were less variable (Figure 22). The methods resulting in highest tonnages were, in order, purse seining, bottom trawling and Danish seining.

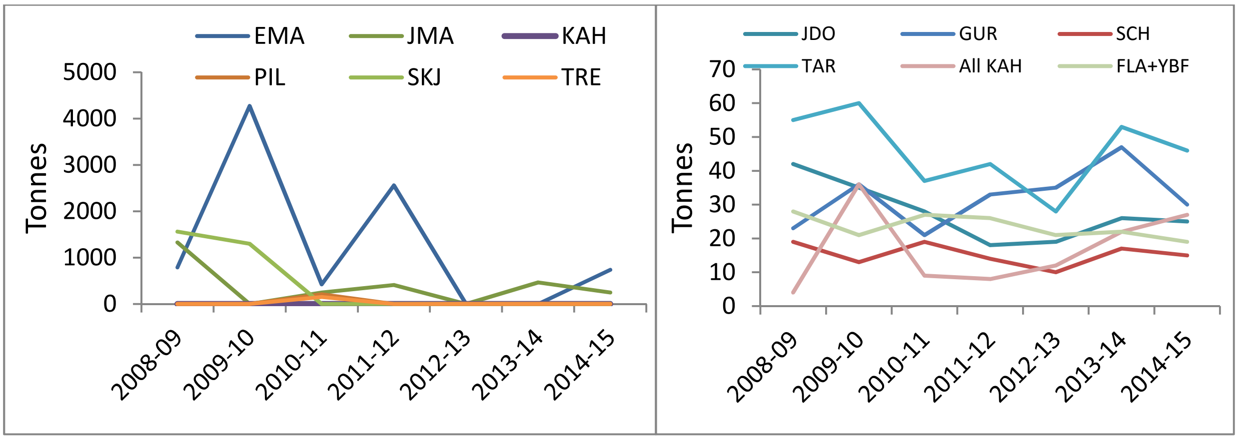

Figure 22: Harvests of principal finfish species (as well as flounder species combined, and kahawai) in Statistical Area 003 by the main methods for the 2008–09 to 2014–15 October fishing years (NABIS download 21 August 2016). Left: Purse-seined fish (EMA, blue mackerel; JMA, jack mackerel; KAH, kahawai; PIL, pilchard; SKJ, skipjack; TRE, trevally), but note that some 'zero' catches were in fact years in which data were judged unreliable or were withheld (usually to protect the identity of the few vessels fishing the area). Right: Fish taken by methods other than purse-seine (JDO, john dory by bottom trawl; GUR, red gurnard by Danish seine; SCH, school shark by bottom long line; TAR, tarakihi by bottom trawl; KAH, kahawai by all methods; and FLA, flounder and YBF, yellowbelly flounder combined by set net).

For the Bay of Islands itself (waters inshore of a line from Tikitiki to Motukokako) today, just a small handful of commercial fishers routinely operate. Most use small (less than 7 m long) vessels with set nets and beach seines, their main finfish by weight including flounder, garfish, grey mullet, pilchard, snapper and trevally and totalling a few dozen tonnes across the board each year .

However, from time to time, visiting vessels line, net and trawl within the Bay of Islands for such fish as snapper, trevally, flatfish and grey mullet, and, near the entrance to the Bay, purse seine pelagic species like skipjack tuna, pilchards and mackerels. General spatial overviews of catch and effort in Statistical Area 003, and within the Bay itself, at fine scale for the lining, netting and trawling vessels for the 2007–08 to 2012–13 fishing years (the most recent data routinely available) are given in Figures 23 and 24. The total number of fishing events each year amounts to an average of around a dozen net-sets and fewer than a dozen trawls, but around 33 long-line sets (but note that it could be - although I doubt - that not all such fishing events have been captured, as described in the caption). The lines and nets will have taken essentially only finfish, whereas trawls may have also taken significant quantities of such invertebrates as arrow squid.

It has been difficult to judge just what level of effort an-average 33 long-line-sets each year actually represents. Advice from fishery scientists (B. Hartill and C. Walsh, NIWA Auckland, pers. comm.) suggests that each set typically involves up to 1500 baited-hooks (although other, local advice suggests it could be as many as 7000 hooks). Also, it is not clear if any one set ever involves more than one check of each hook, although Langley (2016: 14) indicates that 1500 baited hooks is a typical daily rate in Statistical Area 003. In any event, it may not be unreasonable to conclude that 33 long-line-sets represent no fewer than 6.6×10^4 hook-fishing events.

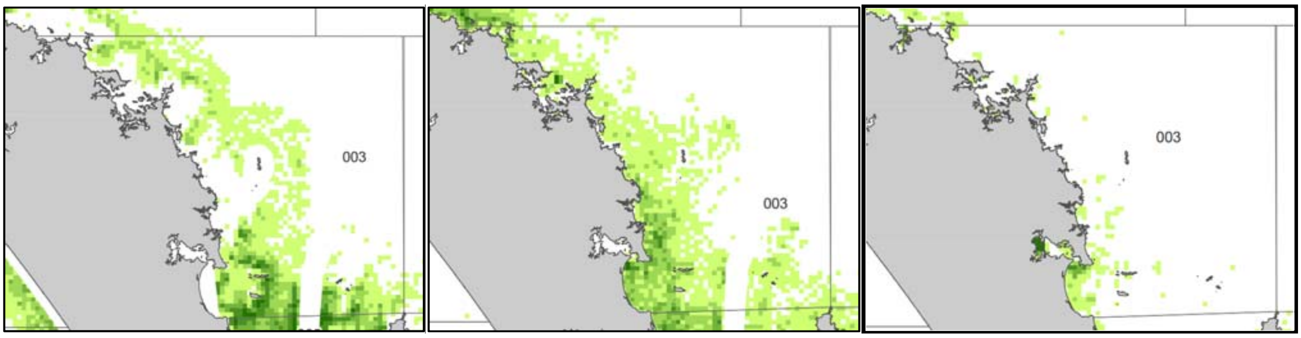

Figure 23: Spatial pattern of average annual number of fishing events (from left, trawl, longline then set net) starting in each 1-nautical mile grid for 1 October fishing years 2007–08 to 2012–13 in Statistical Area 003 for those vessels obliged to furnish such data (approximately 70% of longline events, 33% of set-net events, and essentially all trawls). The five categories, from lightest green, are 0–1 event, 1–2 events, 2–3 events, 3–5 events and >5 events. (http://www.fish.govt.nz/en-nz/Commercial/About+the+Fishing+Industry/Maps+of+Commercial+Inshore +Fishing+Activity/default.htm downloaded 21 August 2016, which also provides catch rates.)

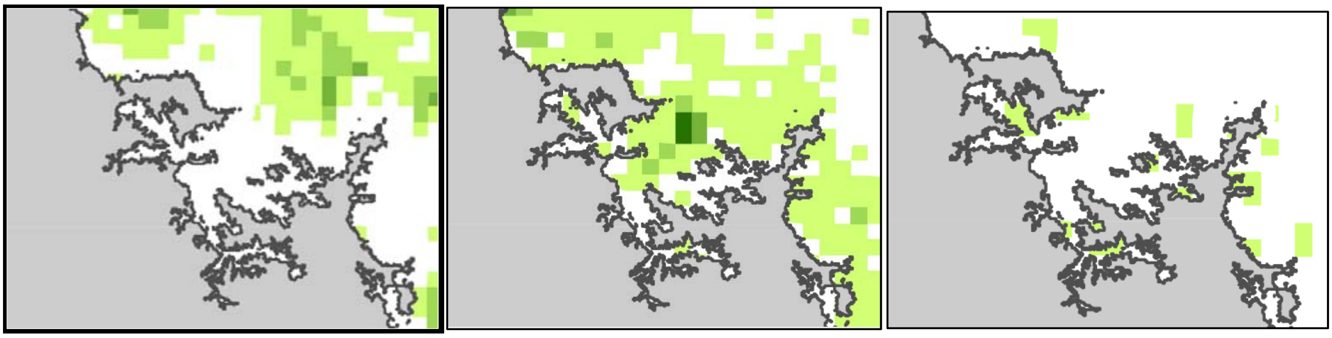

Figure 24: Spatial pattern of average annual number of fishing events (from left, trawl, longline then set net) starting in each 1 nautical mile grid for 1 October fishing years 2007–08 to 2012–13 in and near the Bay of Islands (a zoom-in of Figure 23). The five categories, from lightest green, are 0–1 event, 1–2 events, 2–3 events, 3–5 events and >5 events.

Only one invertebrate is of commercial significance - the red rock lobster. Recent Rock Lobster Statistical Area 904 landings have remained steady at 13 ± 3 t per year (Figure 25).

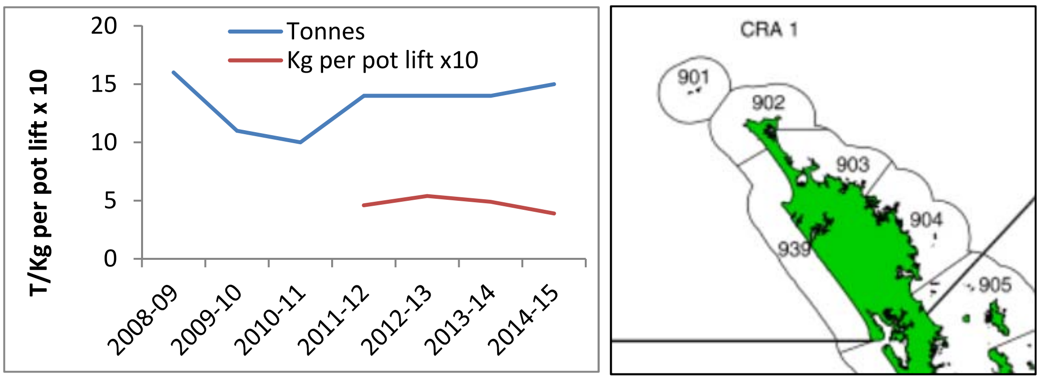

Figure 25: Harvest of red rock lobster (CRA) in Statistical Area 904 (Takou Bay to Bream Bay) using rock lobster pots, and catch (kg) per pot lift, 1 October 2008–09 to 2014–15 fishing years (NABIS download 21 August 2016 and MPI 2016, with more recent figures withheld because of the small number of fishers).

3.1.4 Discussion and conclusions

More than a century and a half of rock-oystering has left a lasting legacy - but not because of the harvesting of shellfish *per se*. It is hard to imagine that the removal of tens of millions of oysters and oyster borers could have had any detectable and irreversible impact on the marine ecology of the Bay of Islands. But the ecological consequences of the addition of great masses of rock onto various soft shores, and the transfer of original boulders down shores, remain to this day. Although some of the rock has broken up or moved in the intervening decades, it still imposes itself on the intertidal of parts of the Bay, having already crushed and asphyxiated the original incumbents and provided settlement surfaces for species (such as oyster borers) that would normally not have lived there. And the slowing of water flow has accelerated accumulation of sediment.

Useful statistics around finfish catches began to emerge in the 1930s: until the late 1970s, the mainstay species for the Bay of Islands in terms of weight - albeit with modest annual landings (up to about 100 t of each species) - were flounder, grey mullet, hapuku and snapper. Leading up to the management changes of the 1980s, annual snapper landings for the Bay of Islands area rose briefly to over 1000 t, and there were up to almost 180 commercial boats based in the Bay. Pelagic species such as blue mackerel, jack mackerel and skipjack tuna were first fished in the 1980s, after which large annual catches (thousands of tonnes) were being made along open waters just outside the Bay of Islands. The only invertebrate of significance has been the red rock lobster, fished to any extent only since World War II, with recent local harvests averaging up to about 10 t a year.

Today, just a small handful of commercial fishers routinely fish waters within the Bay of Islands, their main finfish by weight including flounder, garfish, grey mullet, snapper and trevally - totalling a few dozen tonnes across the board each year and harvested using set nets and beach seines. However, from time to time, visiting vessels line, net and trawl for such fish as snapper, trevally, flatfish and grey mullet within the Bay of Islands, and purse seine pelagic species like skipjack tuna, pilchards and mackerels near the entrance to the Bay of Islands.

3.2 RECREATIONAL FISHERY

The Bay of Islands has long been known for its recreational fishing opportunities - for gamefish as well as other fishes such as snapper and kahawai, and dive-quarry such as rock lobsters and scallops.

3.2.1 Gamefish

Fifteen species of tuna, swordfish and marlin seasonally patrol offshore-Northland waters, with swordfish, black marlin, and striped marlin, in particular, known to Māori (Paulin 2007). Although swordfish (also known as broadbill) are caught from time to time, more than 90% of the bill fish taken off the Bay of Islands are marlin, especially striped marlin (Warne 2010.) Indeed, one day in August 1819, coming around the northern tip of New Zealand, missionary Samuel Marsden was confronted with 40 canoe-loads of Māori handlining marlin.

> ‘They were fishing for none but swordfish [almost certainly striped marlin], with short lines, and all the fish they caught of this kind were tabooed, and could not be disposed of as they were to be preserved for their winter food.’ (Elder 1932).

But it was Major A.D. Campbell who is credited with being the first to catch a striped marlin on rod and line in the Bay of Islands (and New Zealand), in February 1915 (Warne 2010; Pullen 2014). Catches were extraordinary. The Londoner H. White-Wickham racked up 1.5 t of gamefish in little over a fortnight’s fishing in 1922 (and half again as much the following season) (Holden 1984). George Warne landed a 130 kg marlin from a 5 m dinghy (Northern Advocate 1925a). Two large marlin were hooked from one launch at the same time - and landed (a double header) (Northern Advocate 1925b). An individual launch landed four marlin, all between 94 and 144 kg, on the one day (Northern Advocate 1925c).

Novelist Zane Grey became the international ambassador for Bay of Islands' game-fishing. Charles Alma Baker, a wealthy Otago-born expat, had 'discovered' the Bay's fishing potential during a two-week excursion in 1923, coming away convinced of its tourism possibilities (Warne 2010). All this aligned well with the Department of Tourist and Health Resorts' 'sportsman's paradise' aspirations (Figure 26), and 'Who better than a man of such boundless ambition and bankable fame as Zane Grey?' asked Kennedy Warne, grandson of Leon, one of Zane's hired skippers (Warne 2010).

Zane Grey set out onto the Bay of Islands grounds in early 1926 (Grey 1926). Catching several types of game-fish, including a new challenge, the mako shark, he dubbed the Bay of Islands the 'angler's Eldorado'. Not known for understatement, he wrote 'New Zealand waters are undoubtedly the most remarkable in the Seven Seas for magnificent game fish' (Grey 1926). His writings ensured that his Camp of the Larks (later Otehei Lodge) on Urupukapuka Island lured the rich and the famous. 'The camp boasted fine cuisine, a lounge, comfortable cabins, private bathrooms and two fast launches for hire.'(McClure 2004). Meanwhile, the resident taxidermist was busy preserving trophies, many of them hacked-off bills (Mabin 1928).

Figure 26: Vibrant posters issued by a succession of tourist departments in the 1920s and 1930s lured sport-fishers to the Bay of Islands. (Alexander Turnbull Library, Wellington. New Zealand Reference Eph-E-RAIL-1930s-02)

In 1926 with his fishing companion Laurie Mitchell, Zane Grey managed a record catch of 10 striped marlin in a single day (Figure 27), probably near Cape Brett (Zane Grey Inc. 1978). According to Kennedy Warne, in the early days the catch was not even eaten 'Some was brined and used for bait, but 90 per cent was deep-sixed.' (Warne 2010).

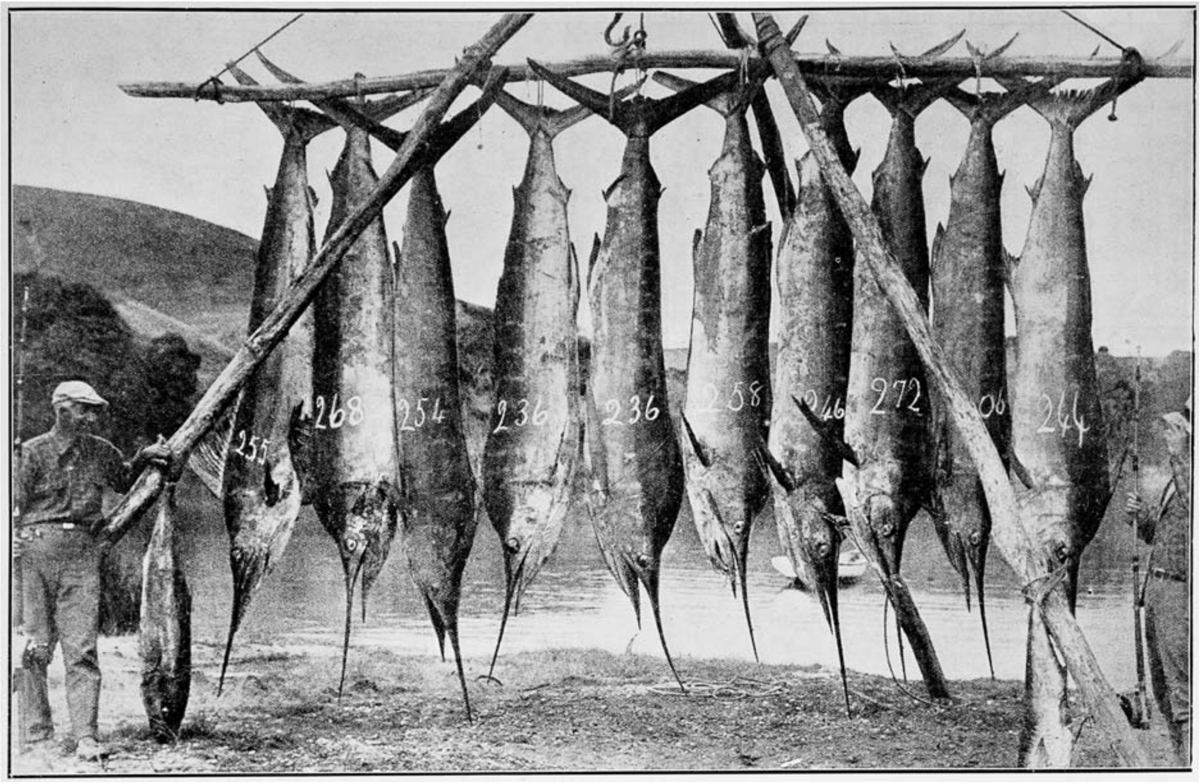

Figure 27: American angler Zane Grey (right) with his fishing companion Captain Laurie Mitchell (left), and the 10 striped marlin the pair took in one day in 1926 at the Bay of Islands. The individual weights are chalked on each fish, nine of which can be read: 236–290 pounds (106–131 kg). (Photograph: Sir George Grey Special Collections, Auckland Libraries, AWNS-19260415-40-1)

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Zane Grey returned to the Bay of Islands the next year, this time on his own 60-m three-masted schooner *Fisherman*. But this time the weather was squally and the fishing patchy. 'We had caught sixty-one fish, but that seemed nothing. I had expected to catch 601.' (Zane Grey Inc. 1978). He left considering 'the five-month trip a gigantic failure, the worst of his life' (Warne 2010), and bypassed the Bay of Islands altogether in his later fishing visits to New Zealand.

But others were not put off, and many notables tried their hand. The Duke of York (later King George VI) was so delighted with his adventure, in 1927, that he announced how keen he was to spend a whole month on the fishing grounds in the near future (Mabin 1928). Deep Water Cove became a popular headquarters for anglers such as H. White-Wickham, its unique dining room spanning 'a typical New Zealand bush-clad gully, with a rippling stream beneath, and its walls are simply the glorious native bush of New Zealand' (Holden 1984).

Over the decades thousands upon thousands of gamefish - most of them striped marlin, but also swordfish, sharks and tuna - were ferried to shore to be weighed, and then discarded. Many of the fish were hooked close to the entrance to the Bay (Figure 28).

Figure 28: Many swordfish (striped marlin) were indeed caught this close to Motukokako.

The Bay of Islands Swordfish Club has kept a remarkably comprehensive record of striped marlin catches - both numbers and weights - since 1925 (Figure 29). A recreational game-fishery dataset probably unmatched, there are only seven years of data missing (Kopf et al. 2005: 1152).

Initially striped marlin were essentially a purely New Zealand recreational fishery. But by the late-1950s Japanese tuna longline vessels in the South Pacific were fishing the same striped-marlin stock, and, joined by vessels flying other flags, were approaching the coast of New Zealand. New Zealand domestic vessels then also joined the fishery (NZSFC 2011). The combined fishing pressure of the commercial fleet now outstripped that of the recreational fishery, and annual recreational catches plummeted.

In 1987, an election year, the-then Minister of Fisheries was persuaded - mainly by very low recreational catch rates - of the need for a moratorium on commercial marlin catches in the Auckland Fisheries Management Area. In return, recreational anglers agreed to tag and release at least half the marlin caught, and a minimum fish-weight of 90 kg was imposed (NZSFC 2011). A complete ban on the commercial fishing of striped marlin over the entire New Zealand Exclusive Economic Zone followed, in 1991.

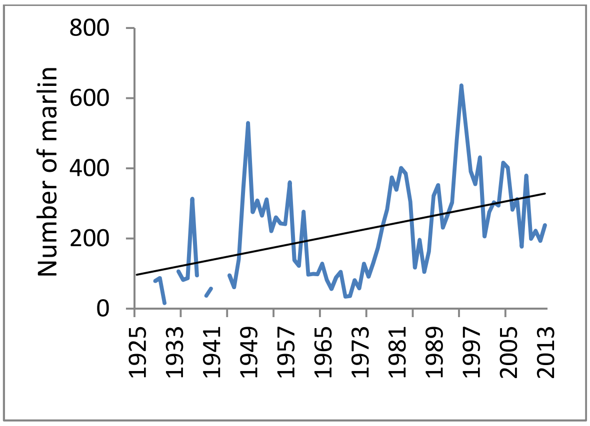


Figure 29: Numbers of striped marlin recorded by the Bay of Islands Swordfish Club (data supplied by John Holdsworth, Blue Water Marine Research, Tutukaka).

3.2.2 Other finfish, and shellfish

Typically, recreational-fishing catch and effort data are notoriously difficult to estimate - particularly as in New Zealand where no licence is required in order to fish. Estimating recreational catches for the Bay of Islands (and elsewhere) is further complicated by the likelihood that a portion of the catch represents customary take, as not all customary harvesting is undertaken with permits issued under

Table 3: Overview of FMA 1 estimated recreational and commercial harvests (t). TAC, Total Allowable Catch in 2017 (2016 for red rock lobster); TACC, Total Allowable Commercial Catch in 2017 (2016 for red rock lobster); Rec., Recreational Estimates; Comm., Commercial; Allow, Allowance. Sources: [1], MPI (2017) (2016 for red rock lobster); [2], Hartill et al. (2013); [3], Holdsworth (2014); [4], Hartill et al. (2015); [5], Hartill et al. (2007); [6], Wynne-Jones et al. (2014); [7], 2010 Plenary appears to be the most recent available; [8], meat weight × 8; [9], Sum of catches from Statistical Areas 002, 003 and 005 from NABIS, which together closely approximate ENLD; [10], Sum of catches from Rock Lobster Statistical Areas 903 and 904 from NABIS, which together closely approximate ENLD (*see* Figure 25); -, not applicable or not available. Note that what is referred to as 'ENLD' differs a little between species and between recreational/commercial fishing (*see* text). Shading distinguishes the principal species.

Fishstock	Species	Current catch limits and allowances				Harvest 2004–05		Harvest 2011–12			Harvest 2012–13		Harvest 2013–14	
		TAC	TACC	Rec. Allow	Customary Allow	Rec. (Aerial)	Comm.	Rec. (Aerial)	Rec. (Panel)	Comm.	Rec. (Access)	Comm.	Rec. (Access)	Comm.
BCO 1	Blue cod	46[1]	46[1]	2[1]	2[1]	-	9[1]	-	8[1]	6[1]	-	9[1]	-	9[1]
GUR 1	Red gurnard	-	2287[1]	-	-	-	1354[1]	-	98[1]	981[1]	-	1103[1]	-	1005[1]
GUR 1 (ENLD)	Red gurnard	-	-	-	-	127[2]	-	24[2]	-	-	-	-	6[3]	-
KAH 1	Kahawai	2200[1]	1075[1]	900[1]	200[1]	530[1]	1147[1]	942[1]	958[1]	1004[1]	-	1095[1]	-	1062[1]
KAH 1 (ENLD)	Kahawai	-	-	-	-	129[1]	112[9]	191[1]	198[1]	117[9]	186[4]	124[9]	349[3]; 97[4]	71[9]
KAH 1 (Waitangi)	Kahawai	-	-	-	-	-	-	8[4]	-	-	8[4]	-	4[4]	-
KIN 1	Kingfish	673[1]	91[1]	459[1]	76[1]	-	58[1]	-	488[1]	87[1]	-	88[1]	-	100[1]
KIN 1 (ENLD)	Kingfish	-	-	-	-	77[5]	-	-	-	-	-	-	-	-
SNA 1	Snapper	8050[1]	4500[1]	3050[1]	50[1]	2419[1]	4641[1]	3754[1]	3792[1]	4614[1]	-	4457[1]	-	4459[1]
SNA 1 (ENLD)	Snapper	-	-	-	-	557[1]	~1000[1]	718[1]	869[1]	~1000[1]	837[4]	1537[9]	585[4]	1664[9]
SNA 1 (Waitangi)	Snapper	-	-	-	-	-	-	22[4]	-	-	26[4]	-	18[4]	-
TAR 1	Tarakihi	2029[1]	1447[1]	487[1]	73[1]	90[1]	1527[1]	67[1]	97[1]	1134[1]	-	1184[1]	-	1425[1]
TRE 1	Trevally	1507[1]	1507[1]	-	-	105[1]	977[1]	124[1]	154[1]	1050[1]	-	1301[1]	-	1431[1]
TRE 1 (ENLD)	Trevally	-	-	-	-	-	-	-	-	-	-	-	88[3]	-
CRA 1	Rock lobster	273.1[1]	131.1[1]	-	-	24[3]	131[1]	-	24[1]	130[1]	-	131[1]	42[3]	131[1]
CRA 1 (ENLD)[3]	Rock lobster	-	-	-	-	-	27[10]	-	-	26[10]	-	30[10]	25[3]	32[10]
SCA 1	Scallop	600[7,8]	320[7,8]	60[7,8]	60[7,8]	-	319[7]	-	84[6]	?[7]	-	?[7]	-	?[7]

customary regulations (http://fs.fish.govt.nz/Page.aspx?pk=61&tk=212). (The reported annual customary harvests taken under permit for the Bay of Islands area in both 2015 and 2016 are unlikely to have exceeded 10 t across all species - Appendix 2.)

By the latter decades of the twentieth century Bay of Islands had become a recreational mecca, fished by a growing local fleet that was soon to be pipped by the great summer influx of visiting vessels, many from Auckland. Recreational fishing can be undertaken year round throughout the Bay of Islands, apart from the exclusions shown in Figure 30. Table 3 gives information on TACs and TACCs; and on estimated recreational versus commercial catches for northern substocks/stocks.

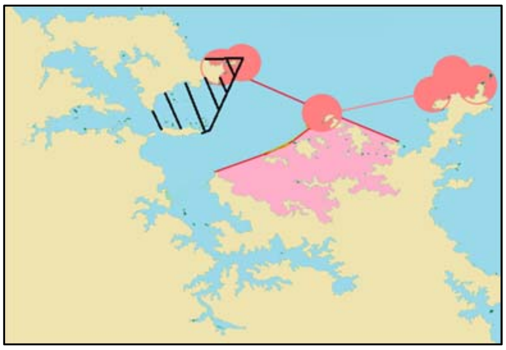


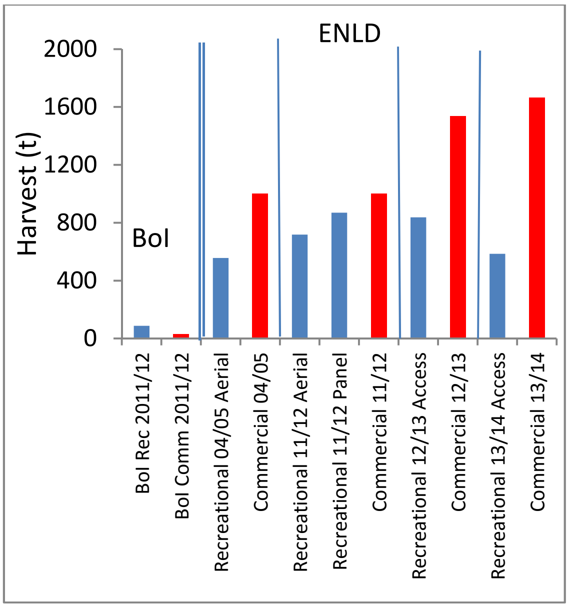
Figure 30: Area prohibitions applying to recreational fishing in the Bay of Islands. Red, where set netting is totally prohibited (circles have 1-nautical mile radius); pink, where set netting is prohibited 1 October to 30 April, except for use of grey mullet and flatfish nets. The hatched area is Te Puna Mataitai, where only customary and recreational fishing is allowed, but no special rules have yet been instituted. (Map prepared by author)

Species most-sought and most-caught

Snapper are the most-sought after and most-caught finfish in the Bay of Islands, followed by kahawai (Hartill et al. 2015). Average estimated annual recreational harvests landed over the Waitangi Ramp from 2011 to 2014 are on the order of 21 and 6 t respectively (*see* Table 4), with fish-ratios for Waitangi believed to reflect those of other ramps, and for shore-fishing, in the Bay of Islands. Other finfish of particular interest include john dory, kingfish, red gurnard, tarakihi and trevally (Muller 2013; Hartill et al. 2013, 2015; Holdsworth 2014). Among the invertebrates, red rock lobsters, scallops, green-lipped mussels, and cockles and pipi are the principal species.

For the Bay of Islands itself, the estimated recreational catches of snapper and kahawai are significant relative to the respective commercial catch (Figure 31 and Table 3). For East Northland as a whole (North Cape to Bream Tail/Cape Rodney), estimated recreational harvests of snapper are highly significant, in some years almost equalling the commercial landings; for kahawai they usually far exceed the commercial harvest. High-grading, and the mortality associated with gut-hooked undersized fish, further increase the effective recreational fishing pressure, particularly for snapper.

Similarly, the estimated recreational catch of red rock lobsters in the Bay of Islands is high relative to that of the commercial catch; in turn the Bay of Islands recreational harvest is a significant component of the East Northland landings (Figure 32).



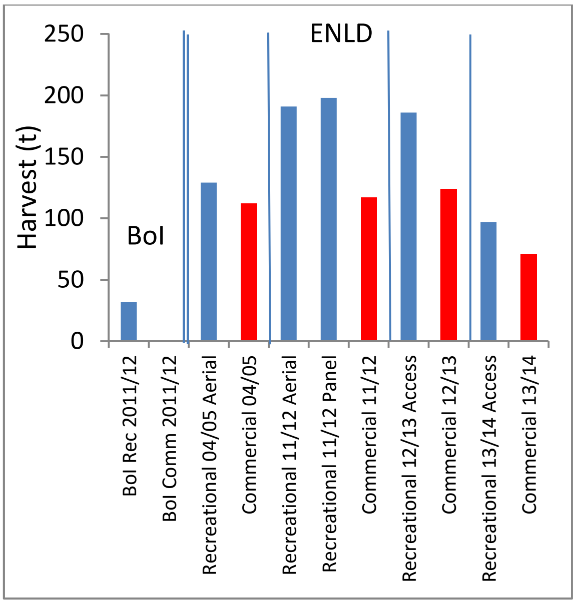


Figure 31: Estimated recent commercial (red) and recreational (blue) harvests of snapper (left) and kahawai (right) in the Bay of Islands compared with those for East Northland (Table 3). For commercial fishing, the southern boundary is Bream Tail; for recreational fishing it is Cape Rodney. (Double thin blue vertical lines separate Bay of Islands data from those applying to East Northland; single thin blue vertical lines separate years; there were no known commercial harvests of kahawai within the Bay of Islands in 2011–12.) The estimated recreational harvests for the Bay of Islands are given as the Waitangi Ramp values multiplied by 3 to account for other ramps (including the well-used one at Opito Bay in Kerikeri Inlet) and shore catches; they are considered conservative. Bay of Islands makes up about 10% of East Northland's coastline.

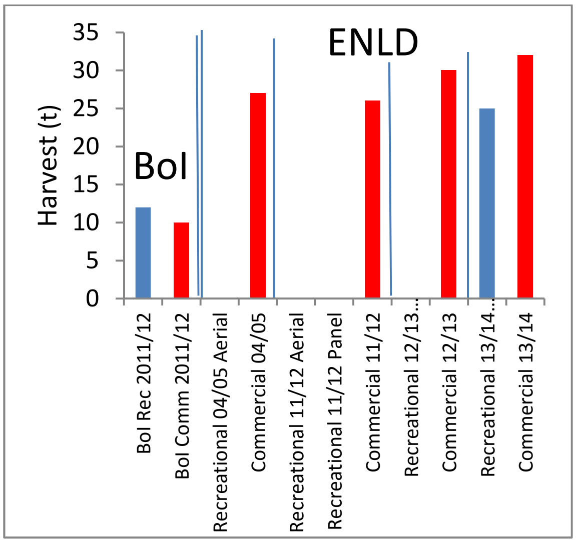


Figure 32: Estimated commercial (red) and recreational (blue) harvests of red rock lobster in the Bay of Islands, compared with those of East Northland (Table 3). (Double thin blue vertical lines separate Bay of Islands data from those applying to East Northland; single thin blue vertical lines separate years.) Bay of Islands makes up about 10% of East Northland's coastline.

Intensity of fishing effort

There are hotspots (more than 100 vessels/km^2 over the course of a year) of recreational boat-fishing north and southeast of Moturoa Island, near Tikitiki and Whale Rock, and north of Motuarohia Island (Figures 33 and 34).

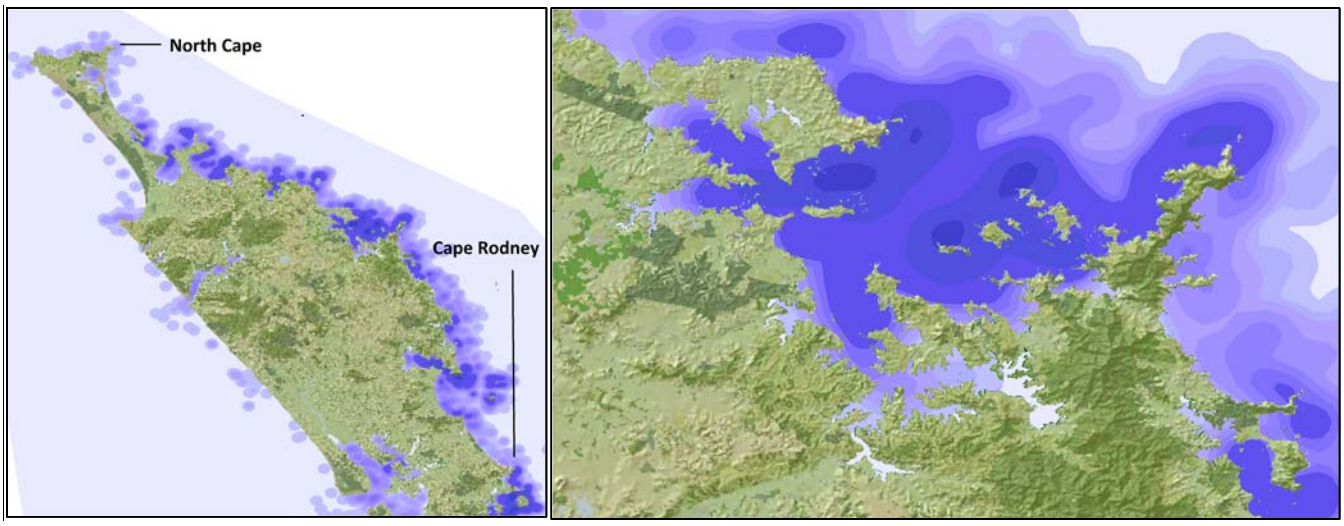


Figure 33: Distribution of stationary vessels recreationally fishing (vessels/km^2), 1 December 2004 to 30 November 2005, North Cape to Cape Rodney (Hartill et al. 2007, downloaded from NABIS [www.nabis.govt.nz/Map.aspx]). For the Bay of Islands, the areas with most-intense fishing activity (dark blue) contained 100–150 vessels/km^2.

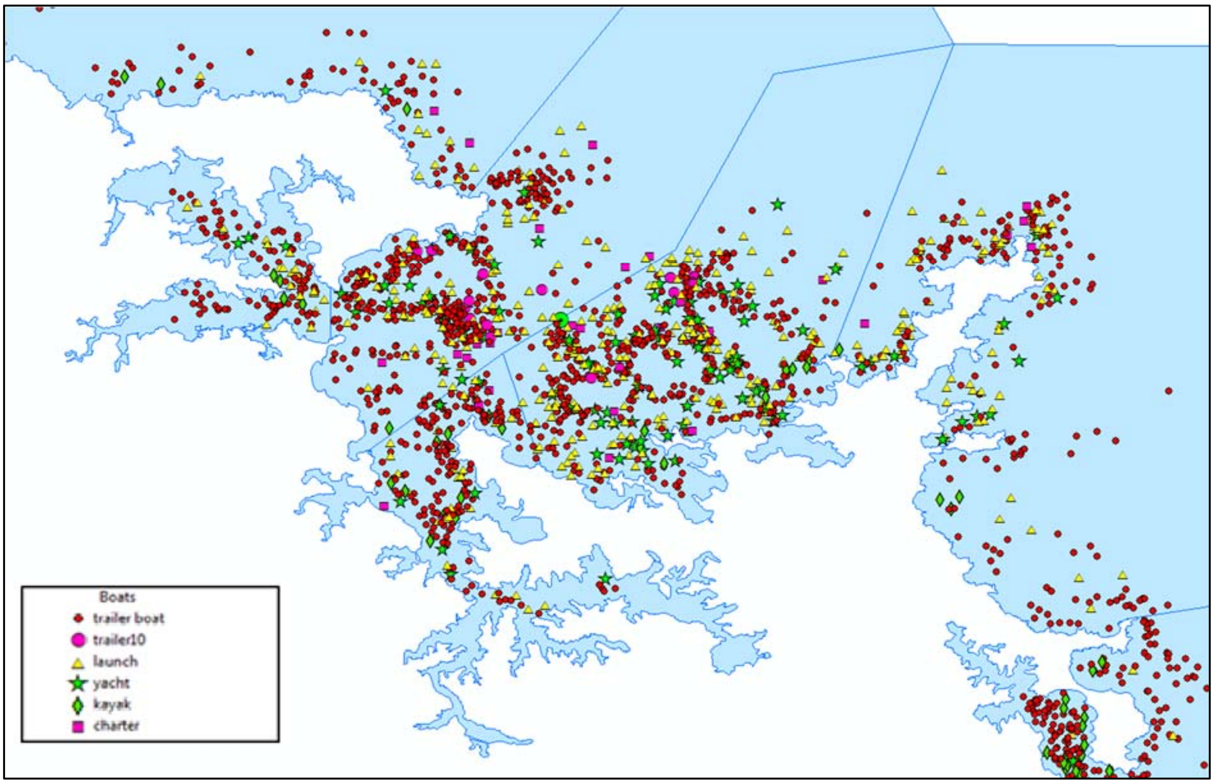


Figure 34: Distribution of stationary vessels recreationally fishing, 1 April 2011 to 31 March 2012 (Bruce Hartill, NIWA, pers. comm.).

A subsequent study of recreational harvesting, in 2013–14, was entirely consistent in that the Bay of Islands (Sections 4 and 5 in Figure 35) included nominally the greatest boat-fishing effort in east Northland, followed by the Whangarei area.

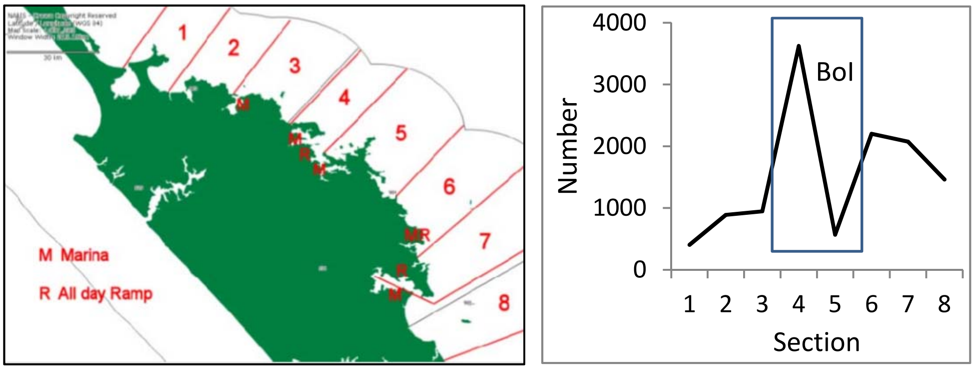


Figure 35: Sections of Holdsworth's (2014) survey area (left), and nominal numbers of fishing vessels, 2013–14 (right, with Bay of Islands sections boxed).

Time-series of harvests

Hartill et al. (2015) provide a time series of recreational harvest rates and catches for the Bay of Islands. For finfish, the relative recreational fishing effort, based on comings and goings of boats at the Waitangi Ramp, has remained steady over nearly 10 years (Figure 36), as did snapper harvest rates during 2011–14 (Table 4). On the other hand, average kahawai boat-harvests fell significantly in 2013–14, to 0.75 kg.

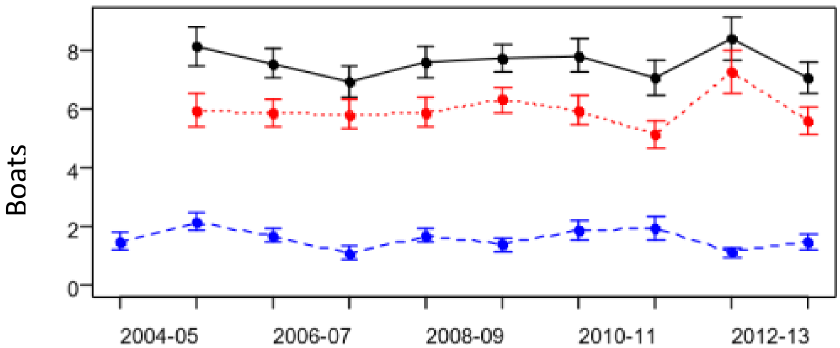


Figure 36: Indices of recreational effort (number of boats returning to ramp ± SE), based on web camera counts at Waitangi Ramp and a subsample of 60 days per fishing year, for the period 2004–05 to 2013–14 (Hartill et al. 2015). Black curve, total; red curve, summer; blue curve, winter.

Table 4. Annual estimates of numbers of boats using Waitangi Ramp (based on web camera counts); the proportion of observed boats that were being used for fishing; the average weight of snapper and kahawai harvested per boat; and the estimated annual snapper and kahawai harvests landed at the ramp (Hartill et al. 2015).

			Snapper		Kahawai	
	Boat numbers	Proportion of boats	Average harvest per boat (kg)	Annual ramp harvest (t)	Average harvest per boat (kg)	Average ramp harvest (t)
2011–12	6995	0.77	4.09	22.0	1.49	8.0
2012–13	8455	0.71	4.25	25.7	1.29	7.8
2013–14	7549	0.72	3.29	18.0	0.75	4.1

In the other localised survey (Holdsworth 2014), in 2013–14, east-Northland (in this case, Rangiputa to Mangawhai Heads) catch rates of kahawai greatly exceeded those of trevally, and, in turn, red gurnard (Holdsworth 2014; no data were provided for snapper), and Bay of Islands catch rates were average or above average for kahawai and trevally, but below average for red gurnard, when compared to other areas (Figure 37). Red rock lobster recreational harvests in East Northland were estimated as 25.4 t during 2013–14, the highest average catch rates being made between the Bay of Islands and Whangarei (Sections 5 and 6) (Figure 37 and Table 3) (Holdsworth 2014). Also, part of the Bay of Islands recreational harvest was an estimated 1709 lobsters, or about 1.25 t, taken in Te Puna Mataitai over the last seven months of 2013–14 (Holdsworth 2014).

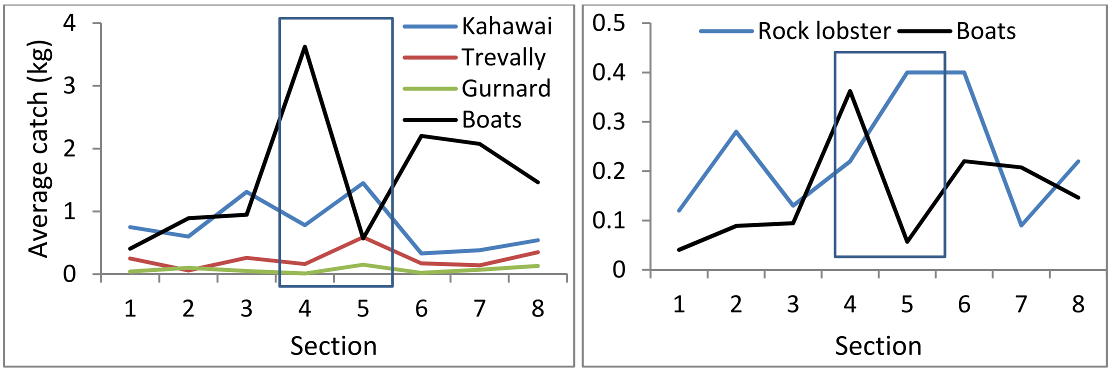


Figure 37: Average catch per interviewed fishing trip (kg) for finfish (left) and red rock lobsters (right) by section (*see* Figure 35), 2013–14, for Rangiputa to Mangawhai Heads with the Bay of Islands sections boxed (Holdsworth 2014). (Nominal boat numbers are shown in black, ×10^{-1} at left and ×10^{-2} at right).

3.2.3 Discussion and conclusions

Based on this overview of available information, recreational harvests of snapper are substantial along the east coast of Northland (including within the Bay of Islands), in recent years having been approximately two-thirds or more of the corresponding-area commercial catches. For kahawai, recreational catches are also high, being of similar or greater scale to the commercial catches. For finfish species with smaller recreational harvests, kingfish is of note: the estimated recreational harvest in 2011–12 was five times that of the corresponding commercial harvest (Table 3). Red gurnard, tarakihi and trevally recreational harvests are small compared with their respective commercial harvests (Table 3). Although in CRA 1 recreational harvests of the red rock lobster are only about 20% of the commercial landings, recreational and commercial harvests are similar for the Bay of Islands itself, and for east Northland..

Bay of Islands' recreational fishery is intensive and extensive, and is likely to continue to expand and intensify further over the next five years, mainly through more and more vessels visiting the Bay, particularly from Auckland over summer.

3.3 MARINE MAMMALS AND SEABIRDS

Although shore whaling within the Bay of Islands had ceased by the beginning of the twentieth century, it did persist at Whangamumu until the early 1930s, as described previously. Information on the abundance of other marine mammals - especially bottlenose dolphins - started to become available late in the century, as will be outlined shortly.

Little seems to have been published concerning the Bay of Islands' post-1900 seabirds and shorebirds. Phillipps (1956) noted that fewer oi were being taken on Motukokako from the early 1900s on than before - partly because there were not many hardy souls prepared to take on the precipitous path to the top, and also because it had become apparent that parties armed with the new harvesting tools - spades, for gouging out the burrows - were making it difficult for birds to find breeding places. (He also referred to the 'Nine Pinnacles' [presumably the Nine Pin - or Tikitiki Rock - of today] as being an important breeding site for oi, but this seems unlikely: there is little soil on the islet, whereas the crown of the much larger and forested nearby Harakeke Island remains to this day peppered with oi burrows [pers. obs.]).

4. CURRENT STATUS OF FISH, SHELLFISH, MARINE MAMMALS & SEABIRDS

This section examines the current status of the fish and shellfish stocks that underpin the fisheries of the Bay of Islands, and reports on the well-being of marine mammals and seabirds locally. Together with stock-size estimates, the mean and median size of the fish and shellfish landed, and the proportions of large individuals present, provide insight into the status of stocks (MPI 2017), and are also key to the environmental roles fulfilled by particular species.

4.1 Fish and shellfish

None of the main finfish species of the Bay of Islands (nor the red rock lobster) is confined there throughout their entire lives. Because of the general mixing within many individual species during their life-histories, the status of most of Bay of Islands' finfish fisheries is ultimately dependent on that of the underlying QMA stock or substock.

All exploited coastal finfish species around New Zealand have declined dramatically in abundance since colonisation using every acceptable measure. In northern New Zealand, many predatory finfish species (as well as the red rock lobster) had by the mid-1980s declined in biomass to less than one quarter of their unfished state (annual MPI Plenary reports). Despite advances in fishery modelling, and a lot more research, there is no information on, or considerable uncertainty remains around, the status of all but a couple of the main stocks/substocks underpinning the fisheries of the Bay of Islands (Table 5) - and there is evidence of overfishing. (Overfishing in this context is deemed to be taking place if F_{MSY} [the maximum fishing pressure that can be applied constantly without impairing the stock's renewability through natural growth and reproduction], or its proxy, is exceeded, on average.)

4.1.1 Status of East Northland Substock of SNA 1 (snapper)

There is little mixing between East Northland and the other two SNA 1 snapper substocks (Hauraki Gulf and Bay of Plenty) (MPI 2017). (Apparently, for commercial assessments the southern boundary of the East Northland Substock is at Bream Tail, the southern border of General Statistical Area 003, but for recreational assessments, it is further south, at Cape Rodney; Bruce Hartill, NIWA Auckland, pers. comm.) There are no reported alongshore migrations, but there is seasonal mixing within substocks once juveniles have dispersed from shallow nursery habitats (MPI 2017).

The East Northland Substock experienced a long, steep decline, from 3500 t in 1970 to about a quarter of that by 1985, and has fluctuated without trend since (MPI 2017). Overfishing in the East Northland Substock appears likely: the 2013 biomass was estimated to be only 24% of the unfished state, compared with the target of 40% (MPI 2017). Although five-year projections pointed to increasing stock biomass, current catches were nevertheless considered likely to lead to continued overfishing (MPI 2017: 1352). Furthermore, there are - anecdotally - many areas of local depletion within the Bay of Islands.

Table 5: Stock status of finfish of commercial/recreational importance (and of red rock lobsters) in the Bay of Islands (MPI 2017; 2016 for red rock lobsters). Fishstock, the stock or substock applying to the Bay of Islands; assess, assessment; B_{MSY}, the average biomass associated with a maximum sustainable yield strategy; B_0, the biomass of the unfished stock; SSB_0, the biomass of the unfished spawning stock; AW (1979–88), mean of beginning autumn-winter vulnerable biomass for period 1979–88; -, not given; HG, Hauraki Gulf; ENLD, East Northland (North Cape to Bream Tail). The target and limits for TRE 1 are based on those for TRE 7. The terms used in relation to targets and limits are as given in MPI (2017). Stocks likely to be overfished, and those whose status is unknown, are shaded. (Note that skipjack tuna are not part of the Quota Management System.)

Fishstock	Species	Last assess	Target	At or above target?	Soft limit	Below the soft limit?	Hard limit	Below the hard limit?	Overfishing?
CRA 1	Rock lobster	2014/ 2016	AW (1979–88)	Virtually certain	20% SSB_0	Exceptionally unlikely	10% SSB_0	Exceptionally unlikely	Exceptionally unlikely
EMA 1	Blue mackerel	None	-	-	-	-	-	-	Unknown
GAR 1	Garfish	None	-	-	-	-	-	-	Unknown
GMU 1	Grey mullet	None	-	-	-	-	-	-	Unknown
GUR 1E	Red gurnard	2013	B_{MSY}	Unclear	50% B_{MSY}	Unlikely	25% B_{MSY}	Very unlikely	Unknown
JDO 1 (HG + ENLD)	John dory	2015	*See* CPUE (Plenary 2017)	Very unlikely	50% target	Either/or	25% target	Unlikely	Unlikely
JMA 1	Jack mackerel 3 spp.	1993	B_{MSY}	Unknown	20% B_0	Unknown	10% B_0	Unknown	Unknown
KAH 1	Kahawai	2015	52% B_0	Very likely	20% B_0	Very unlikely	10% B_0	Exceptionally unlikely	Very unlikely
PIL 1	Pilchard	None	-	-	-	-	-	-	Unknown
SCH 1	School shark	2014	B_{MSY}	Unknown	20% B_0	Unknown	10% B_0	Unlikely	Unknown
SNA 1 (East Northland)	Snapper	2013	40% B_0	Very unlikely	20% B_0	Either/or	10% B_0	Very unlikely	Likely
TAR 1	Tarakihi	2012	B_{MSY}	Unknown	20% B_0	Unknown	10% B_0	Unknown	Unknown
TRE 1	Trevally	?	40% SSB_0	Unknown	20% SSB_0	Unknown	10% SSB_0	Unknown	Unknown
YBF 1	Yellow-belly flounder	2015	B_{MSY}	Unknown	20% B_0	Unknown	10% B_0	Unknown	Unknown

Size and age are linked in snapper, but the relationship is not necessarily direct: for example, Hauraki Gulf snapper appear to have increased in growth rate as the stock was historically fished down, meaning that large fish were not necessarily as old as they had before been (Paul 2014). But in terms of the predatory impact of snapper (and other species) in the ecology of the Bay of Islands, it is much more fish-size, rather than age, that is important.

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Most of the snapper landed recreationally in the Bay of Islands - and generally in east Northland - are near the MLS (even after high-grading for larger fish that is likely to be taking place). Snapper harvested recreationally in the East Northland Substock of SNA 1 in 2011–12 had a mean length of 37.1 cm (Hartill & Davey 2015), while fish taken commercially from the East Northland Substock (and SNA 1) in recent years have averaged 35-cm length (Walsh et al. 2011, 2014). On the other hand, the mean length of snapper from early northern middens (such as at Houhora, Twilight Beach and Kokohuia, and reflecting a relatively unfished state) was around 50 cm (Leach 2006, Leach & Davidson 2000) (Figure 38). This all points to intensive overall fishing pressure today, which is consistent with the stock assessment (Table 5).

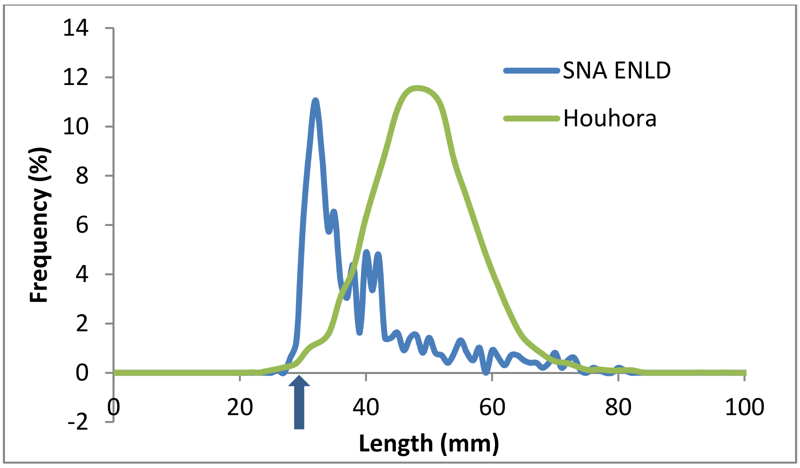

Figure 38: Length-frequency distribution (mm fork length) of snapper from a pre-Contact archaeological site at Houhora, 100 km northwest of the Bay of Islands (green; *n* = 8847; Leach 2006) and for snapper recreationally harvested in the East Northland Substock of SNA 1 since the increase in MLS to 30 cm (blue arrow) (blue; *n* = 985; Bruce Hartill, NIWA, pers. comm.). (Plot based on data conveyed by Karen Field)

Fishing in and near the Bay of Islands is likely to have contributed significantly to the present status of the East Northland substock, and a sense of the scale of snapper landings for the Bay of Islands, from first settlement to the present, can be derived from the human-population trajectory and estimates of consumption per capita over time. Leach (2006) and Smith (2013) offered estimates, respectively, of 46 and 37 (mean 41.5) individual snapper (averaging 2.2 kg) being consumed each year, on average, by pre-Contact Māori; lower levels of consumption are assumed post-Contact. These are combined in Figure 39, although any meaningful error structure around these annual point estimates would be large.

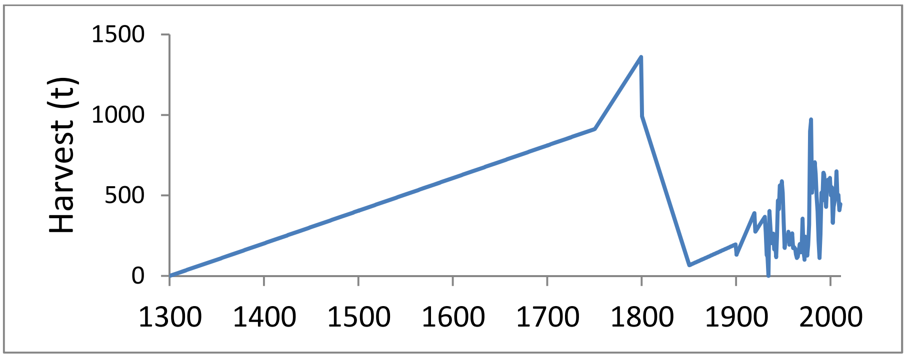

Figure 39: An indicative trajectory of snapper harvests (t) for the Bay of Islands from first settlement to the present, based on the human-population estimates shown in Figure 2, and the following criteria. For 1300–1799, the harvest estimate is based on 41.5 fish averaging 2.2 kg consumed by each person each year. For 1800–1899, an average harvest of 30 fish at 2.2 kg was used, to reflect a greater proportion of Europeans for whom fish may have been of less significance than for Māori; similarly, for 1900–1919, when the annual harvest was set at 20 fish per person. For 1920–1930, the annual harvest was set at 15 fish per person, with the lower mean weight of 2.0 kg reflecting the impacts of increased fishing pressure. For 1931–1949, the Russell (Bay of Islands) Port of Landing commercial figures were multiplied by a factor of six to take into account the likely severe underreporting referred to by Francis & Paul (2013); a smaller multiplier (3) was applied to the 1950–1979 landings to account for improved accuracy in reporting. For 1980–1982, just ahead of the introduction of the QMS, it was assumed there was no underreporting, but a multiplier of 1.5 was applied to the Port of Landing figures to reflect a growing recreational take. Values for 1983–88 are the estimated commercial catches for Statistical Area 003, with the clearly overstated Bay of Islands-only commercial catches balanced by a local recreational catch edging close to that of the commercial fleet; from 1989, it was assumed Statistical Area 003 harvests may have been a reasonable estimate of the entire catch (commercial plus recreational and customary) for the Bay of Islands.

This estimated historic trajectory appears, on the face of it, to be unlikely: it suggests that pre-Contact harvests within the Bay of Islands exceeded those of Statistical Area 003 today on a lasting basis (and, apparently, without leading to evidence for overfishing). The two per-capita annual fish-consumption estimates are independent and not mine - and therefore stand. The solution to the conundrum may lie in the fact that in fishing locally, Bay of Islands Māori were putting pressure on only a small fraction of the East Northland Substock, other parts of the substock receiving much less attention, or none at all.

Fishing pressure in and near the Bay of Islands area today comes mainly from recreational and commercial fishing, and - on the face of it - the recreational pressure on snapper is likely to be outstripping that of the commercial fleet (comprised of a handful of local boats, with visiting vessels from time to time).

FMA 1, and especially the east coast of the North Island Hauraki Gulf north, is among the most-intensively fished parts of the country recreationally, and, in turn, the Bay of Islands is arguably the shore north of the Hauraki Gulf most heavily fished by recreational fishers (Hartill et al. 2007) (Figure 33). Although the measures of effort are somewhat different, and the effort associated with the handful of small, locally-based (mainly netting) commercial vessels is not included, almost certainly the recreational fishing effort exceeds that of the commercial fleet (Figures 24 and 33), the commercial vessels also having greater extent of area restrictions. For example, whereas there may be on the order of 7×10^4 commercial hook-fishing events each year (based on 2000 hooks per set), the corresponding recreational value may be ten times greater, on the order of 5×10^5 (low 8×10^4; high 12×10^5) events (based on Figure 33, and 3 [1, 5] people per boat, each baiting one hook 10 [5, 15] times). (Note, however, it is possible that not all longline events have been captured - *see* Figures 23 and 24.)

To summarise, the East Northland Substock of SNA 1 (including within the Bay of Islands) has been fished down to a low level, and overfishing is likely. For the Bay of Islands itself, the recreational fleet may be exerting an order of magnitude more fishing pressure than the commercial fleet, anecdotally in turn having led to areas of local depletion. The mean fish-length of both the commercial and recreational harvests, at around 35 cm, is near the extreme left limb of the length-frequency distribution of a lightly fished northern population (Figure 38).

4.1.2 Status of KAH 1 (kahawai, North Cape to Cape Runaway)

Northland kahawai are assumed to be part of a northern stock (the other stock being focussed at the northern tip of the South Island) (Hartill & Bian 2016; MPI 2017). Tagging suggests that most kahawai remain in the same general area for several years. Recreational fishers typically land a wider size-range of kahawai, from a far greater number of geographically dispersed schools, than does the commercial fishery (Armiger et al. 2014).

The KAH 1 stock was gradually fished down until the late 1970s, followed by a steeper decline coinciding with the development of the purse seine fishery during the 1980s (MPI 2017). There have been marked fluctuations in stock size since the early 2000s, with evidence of rebuild: only recently have commercial landings become constrained by the TACC, probably a result, at least in part, of the halving of commercial landings over the past 10–15 years (Armiger et al. 2014). The KAH 1 stock is, therefore, not considered overfished, and is very likely to be above the reference target of 52% B_0 (Table 5), with high probability of this continuing into the near future (Hartill & Bian 2016).

Recreational catches of kahawai are high - of similar or greater scale to the commercial catches - but there are significant proportions of large fish in the recreational catches suggesting a less-intensively fished stock, which is again consistent with the stock assessment (Table 5). The median size of kahawai recently caught recreationally in East Northland is around 40 cm, but the length-frequency distributions show strong bimodality (Figure 40) which has been attributed to influxes of larger, older fish (Hartill et al. 2013).

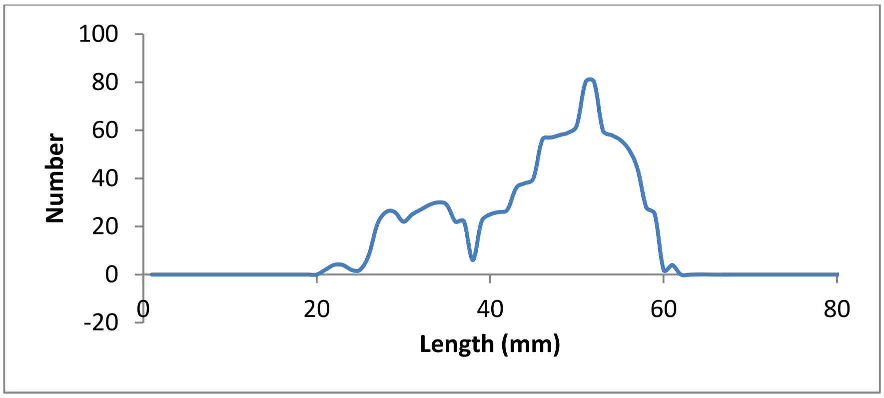

Figure 40: Length-frequency distribution of kahawai from the 2011–12 East Northland recreational catch (redrawn from Hartill & Davey 2015). There is no size limit for kahawai.

To summarise, despite a widely held belief locally that kahawai are presently overfished (the numbers and concentrations of schooling fish having, apparently, diminished greatly from even 20 years ago), the fish-size distribution of the recreational harvest, as well as the stock assessment referred to above, suggest otherwise for KAH 1 East Northland.

4.1.3 Status of recreational fishery for striped marlin

Although many other varieties of game-fish and various tuna are still caught along the east Northland coast today, striped marlin remain the mainstay of the recreational fishery. It appears that New Zealand boats fish a reasonably discrete Southwest Pacific substock of striped marlin that is relatively productive in fishery terms: the fish mature early, produce lots of eggs, and grow fast (Langley et al. 2006). The marlin spawn during November-December in the region of the Coral Sea, and within their first year they reach nearly half their adult size. After maturing at about 3-years of age (and 30 kg or so in weight) and spawning, they migrate towards southeast Australia and New Zealand. The largest fish - up to 12-years old and 250 kg (Holdsworth & Kopf 2011: 39) - are taken in northern New Zealand, in summer and autumn. Tagging has shown how fish off New Zealand then head generally north to the region of Fiji, before returning to the Coral Sea spawning grounds during winter and spring (Chambers et al. 2013: 3).

Bay of Islands marlin are now far less abundant than when the recreational fishery began, and those landed today are on average considerably smaller. Whereas in 1926 two boats were able to land 10 huge marlin in one day (and there were many other extraordinary catches), it now takes an average 5 days' trolling to hook just one (MPI 2013: 3). And whereas the average weight of a striped marlin in 1926 was just shy of 120 kg, today it is 24 kg less than this (Kopf et al. 2005: 1152). But both the commercial and recreational catch rates of striped marlin have been reasonably stable in recent times, suggesting that current levels of fishing pressure are not affecting the stock's production significantly. Commercial catches from the Southwest Pacific Ocean average about 2500 t each year (Holdsworth & Kopf 2011: 3), and the New Zealand recreational fishery as a whole, and Bay of Islands' one in particular, remains world class (NZSFC 2011). Indeed, the total numbers of striped marlin caught each year has shown an increasing trend since the late 1970s (Figure 29).

4.1.4 Status of other finfish of commercial/recreational importance

For most other species, the status of the associated stock is unknown (Table 5); only for Fishstock JDO 1 (john dory: Hauraki Gulf and east Northland) is overfishing acknowledged as being unlikely (MPI 2017: 598).

4.1.5 Status of CRA 1 (red rock lobster, North Cape to Cape Runaway)

There is no evidence for genetic subdivision of lobster stocks within New Zealand (MPI 2016). Most postlarvae settling along the east Northland coast were spawned along the west coast of central New Zealand; spawnings in east Northland result in settlement in eastern Bay of Plenty and as far south as about Cook Strait (Chiswell & Booth 2008). There may be alongshore migrations northward by some proportion of the juveniles approaching maturity, but in any event there is seasonal mixing associated with inshore-offshore movements to do with moulting and mating (Booth 1997).

CRA 1 catches built steadily after World War II, rapidly peaking in the late 1960s as many new vessels joined the fleet, spurred on by the Chatham Islands rock lobster fishing boon (MPI 2016). The CRA 1 stock assessment shows how the vulnerable biomass collapsed to one quarter of its original, from 3000 t in the mid-1940s to only 600 t, in the early 1970s. It has fluctuated since, with a modest overall increase; projections are that the vulnerable biomass will remain steady (MPI 2016). Despite the big fall from its original size, this fishery is not considered overfished (perhaps because the target biomass is that associated with the stock during 1979–88, when vulnerable biomass was near a nadir).

Bay of Islands lies within Rock Lobster Statistical Area 904 (*see* Figure 25) where the recent commercial CPUE has averaged around 0.5 kg per pot lift, only 20% of that of the other CRA 1 statistical areas, and one of the lowest in the country (MPI 2016: 246). This points to severe regional depletion. Consistent with intense fishing pressure, most red rock lobsters caught commercially in and near the Bay of Islands are not much larger than the MLS; the recreational catch does, however, contain larger individuals - probably diver-selected and trophy catches (Figure 41). By way of comparison, the much wider size-distribution, and predominance of large lobsters, that made up a lightly fished red rock lobster population is clear.

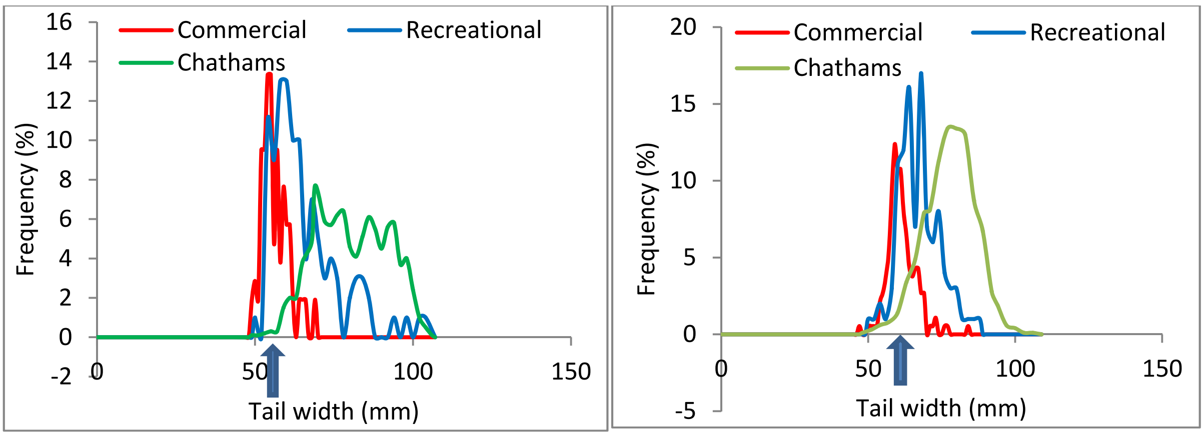

Figure 41: Tail-width-frequency distribution (%) of male (left) and female red rock lobsters (right) taken in a) observer commercial-catch samples in Statistical Area 904, 2011–12 (red; *n* = 105 and 186 respectively; D. Sykes, Rock Lobster Industry Council, pers. comm.); b) recreational catch samples from the Bay of Islands in 2013–14 (green; *n* = 229 and 172; Holdsworth 2014); and c) a market sample from the Chatham Islands in October 1966, soon after commercial fishing had begun (black; *n* = 1152 and 1339; Kensler 1969). (Chathams carapace lengths were converted to tail widths using equations in Fry et al. 2013; graphs indicative only because of some samples being small.) The minimum legal sizes (blue arrows) are 54- and 60-mm tail width for males and females respectively, but the commercial catch also includes undersized lobsters.

To summarise, although the CRA 1 lobster stock is said to be healthy overall, the low commercial CPUE in at least Statistical Area 904, as well as the high proportion of lobsters near MLS and the low proportions of large animals in both the commercial and recreational catches in the region, point to severe regional depletion.

4.1.6 Status of other shellfish

For **scallops**, over the past 10 years the principal beds in the Bay of Islands have been in the east (Ipipiri), with other beds seemingly now small and diffuse. Yet scallops were once common in the northwest off Rangihoua and Onewhero, off the western side of Motuarohia, and in Maunganui Bay (Nevin 1984; Mountain Harte et al. 2007).

In Ipipiri today, the main beds coincide with areas of rhodolith/dog-cockle habitat, a structurally complex but vulnerable habitat: 1) Albert Channel between Urupukapuka Island and the Rawhiti mainland (including Urupukapuka Bay); 2) the area between Paramena Reef, Poroporo Island and Ngatokaparangi Islands/reefs to the south of Motukiekie; and 3) Motukiekie Channel between Urupukapuka and Motukiekie Islands (Figure 42). Scallop abundance on all beds has declined markedly over the past decade (Pacific Eco-logic Ltd. 2016).

Overall, Bay of Islands scallops are heavily fished, and appear to occupy in any significant quantities a much-reduced geographic distribution compared with 20–30 years ago.

Huge reefs of **green-lipped mussels** overlying soft subtidal seafloors were once characteristic of several harbours in Northland - and particularly of the Hauraki Gulf. Their overfishing by dredge - without recovery - in the Firth of Thames (McLeod et al. 2011) may be a core reason for decline in several fish stocks in the Gulf, the fish having been robbed of critical juvenile habitat. But only small quantities of dredged mussels (between 5 and 11 cwt [about 0.3–0.6 t] per year in 1968, 1969, 1970 and 1971) have been reported from the Bay of Islands (Marine Department annual *Report on Fisheries*). (The significant landings indicated for the early- and mid-1920s [Paul 2012: 27] are unlikely to have come from the Bay of Islands.) If dense beds of green-lipped mussels ever did exist on soft seafloors of the Bay of Islands, it is unlikely that they were extensive.

The green-lipped mussel is harvested today on hard shores in open parts of the Bay of Islands (Figure 42), but stocks have declined markedly over the past 10 years. In the eastern part, overharvesting of the intertidal beds was followed by increasing focus on subtidal beds, only a few of which are now known to survive, most of them on the west side of Cape Brett Peninsula (Pacific Eco-logic Ltd. 2016). At the Black Rocks, the principal site for these mussels, there are various levels of depletion among intertidal and subtidal beds (Pacific Eco-logic Ltd. 2016).

For the estuarine/sheltered-water **cockle** and **pipi**, there are no known estimates of harvest rates over time. The important sheltered-water shellfish-gathering bays in the Bay of Islands include Te Haumi, Parekura and Whiorau (Figure 42). At Te Haumi, there have been significant reductions in the proportions of large individuals since the late 1990s in both species (Berkenbusch & Neubauer 2015).

Tuatua are - and probably always have been - confined to Long Beach (Oneroa), and particularly Oke Bay, where small recreational harvests continue (*see* Figure 3).

Oysters (Pacific oysters, and presumably rock oysters too) are widespread and abundant in sheltered inner areas in particular (Figure 42), but are not particularly sought, probably because they are often difficult to harvest, handle and open. If anything, populations continue to expand.

Kina are also widespread and abundant, but mostly in places not affected by freshwater, siltation or heavy surge. There are small recreational and commercial fisheries for them, but large individuals are not common.

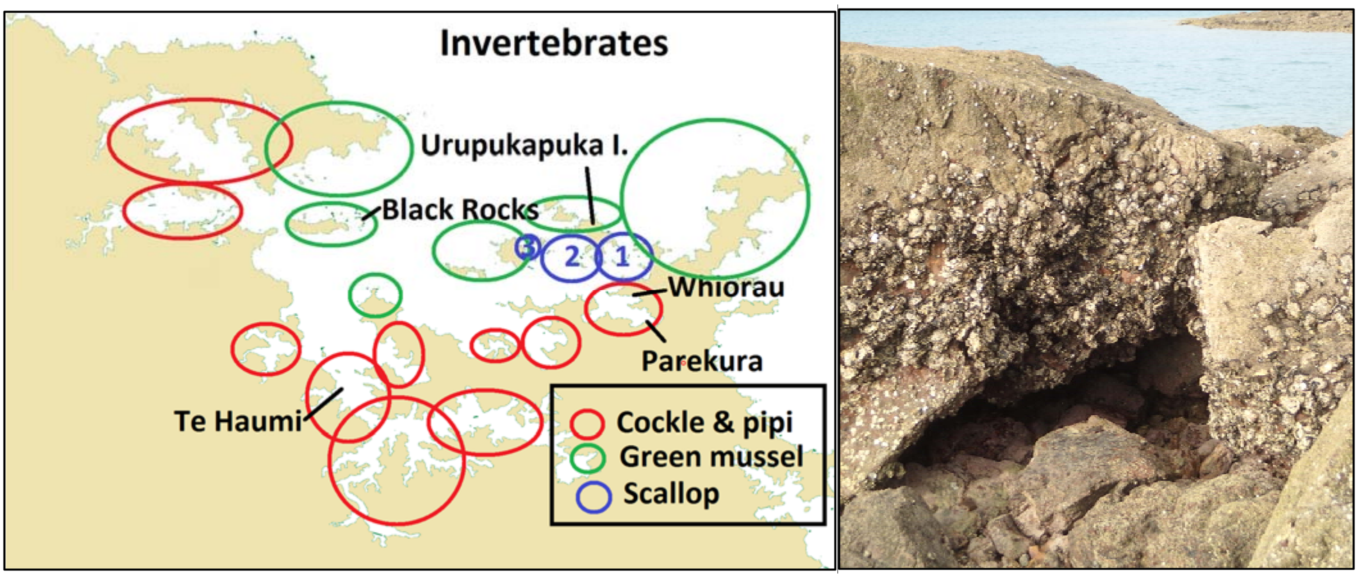

Figure 42: Main shellfish-harvesting areas. Blue numerals refer to the scallop grounds referred to in the text. (Map prepared by author) Oysters (in this example, mostly native rock oysters) remain abundant and widespread around the Bay. (Image by author)

4.2 Marine mammals

Far fewer **bottlenose dolphins** use the Bay on a regular basis than in the recent past (Tezanos-Pinto 2013). The three regional populations (Tezanos-Pinto et al. 2009) - the northernmost, along the 500 km of coast from Doubtless Bay to Tauranga (Constantine 2002); the others in the Marlborough Sounds and in Fiordland - are genetically isolated from one another. The bottlenose is classified as Nationally Endangered because of the relatively small population sizes and reports of high calf mortality.

At any given time, there is generally only one group of bottlenose dolphins in the Bay of Islands (Figure 43), but the group is seldom stable for more than a few days (Tezanos-Pinto et al. 2009, 2013). In addition to concern over reduced numbers of bottlenose, it appears that the tour-operator exclusion zones, introduced to provide respite for the dolphins, no longer provide effective refuges (Hartel et al. 2015). But most disturbing is the unsustainably high calf mortality, together with an average calving rate of only once every four years (Tezanos-Pinto et al. 2015). 'Consequently, it seems that a change in habitat use, mortality and possibly low recruitment underlie the apparent local decline' (Tezanos-Pinto et al. 2009).

Although regularly seen in the Bay of Islands (Figure 43), little is known about the **common dolphin**. These dolphins may or (more likely) may not be resident; numbers could be declining (Jochen Zaeschmar, Ecocruz Bay of Islands, pers. comm. 2014).

The next most-often sighted marine mammal in the Bay of Islands today is the **orca** - an apex predator whose status is Nationally Critical (Baker et al. 2010), with fewer than 200 surviving in New Zealand waters (http://www.doc.govt.nz/nature/native-animals/marine-mammals/dolphins/killer-whale-orca/). New Zealand orcas do not have a confined home patch, but move around from season to season (http://www.teara.govt.nz/en/orcas/page-1.) '….there are probably three resident populations in New Zealand: one off the North Island, one off the South Island, and a third group that spends its time in both regions…. It is not yet known whether these separate groups of orcas interbreed…' Northern orca have an unusual diet. They are the only group known to eat rays (stingrays, eagle rays and electric rays) as staple food (http://www.teara.govt.nz/en/orcas/page-2). Cruising shallow waters in harbours, they seize rays by the head or tail tip in order to avoid the barb halfway along the tail. This feeding behaviour explains, at least in part, why orca in the Bay of Islands are often seen in inner areas (MacDiarmid et al. 2009) (Figure 43).

The whale most often encountered today in inshore waters of east Northland in general - and the Bay of Islands in particular - is the **Bryde's whale** (Baker & Madon 2007) (Figure 43), its conservation status also being Nationally Critical (Baker et al. 2010). Bryde's whales tend to concentrate around headlands jutting into the East Australian Current, often being associated with common and bottlenose dolphins in feeding workups, attended also by seabirds. The waters of the Bay of Islands are critical habitat for Bryde's whales because this is where they habitually come to feed, breed and nurse young, and to socialise (Baker & Madon 2007). This whale is vulnerable to shipping, with, for example, on average two killed by vessels each year in the Hauraki Gulf.

Humpback whales continue to be occasionally seen within and near the Bay of Islands: they are not resident here, but resting or having been diverted while migrating by (Alan Baker, pers. comm.).

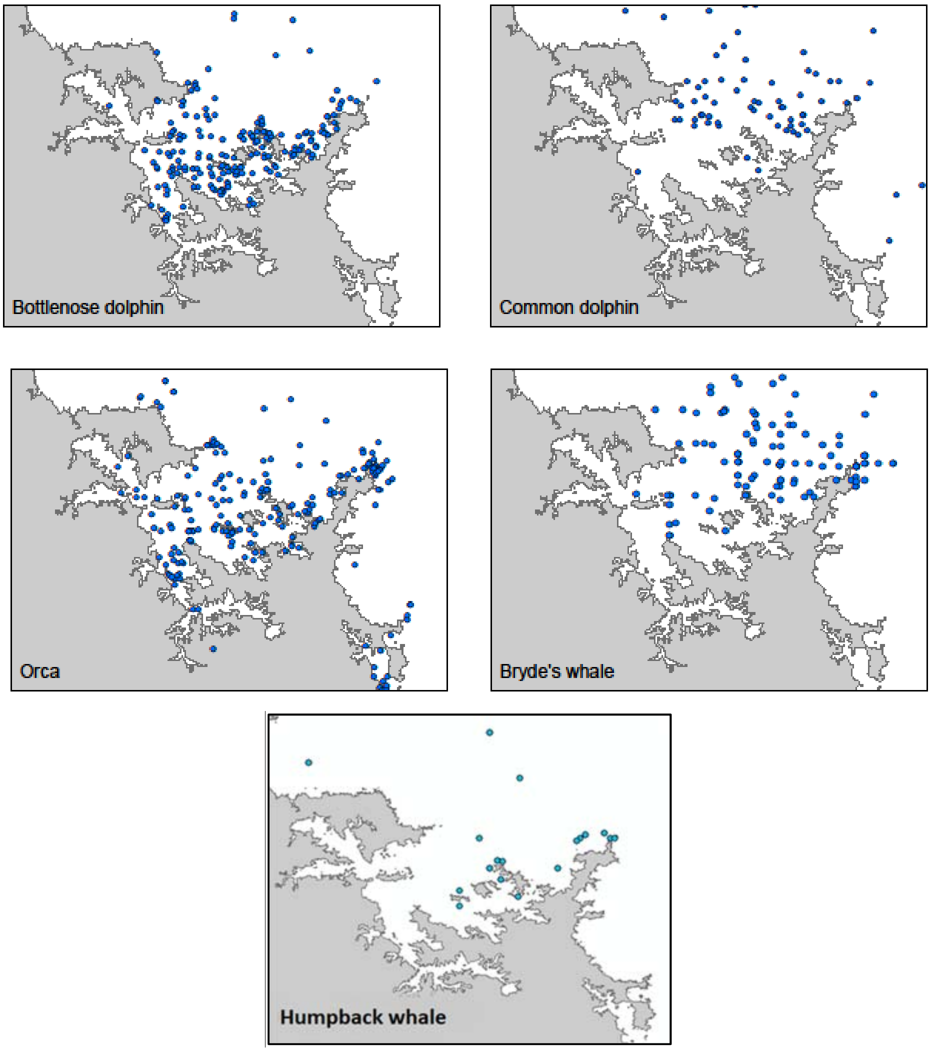

Figure 43: Sightings in the Bay of Islands of bottlenose dolphin, common dolphin, orca and Bryde's whale, 1993–2003; and humpback whales, 1993–2009 (maps prepared and made available by Terry Conaghan and Hannah Hendriks, Department of Conservation 2015).

Although the **New Zealand fur seal** population today is still much smaller than it was pre-1500 AD, it is recovering, with colonies steadily re-establishing progressively further northward (Boren 2009). Adults are regularly seen around Motukokako, and juveniles are commonly reported within the Bay itself - although there is no evidence yet for local breeding.

4.3 Seabirds

A survey of Motukokako in November 1987 revealed perhaps 500 oi burrows sparsely distributed over the island, with a total estimated breeding population of around 200–300 pairs (Cameron & Taylor 1991: 130). And follow-up surveys in 2014 and 2015 revealed that oi were still present on the island (with one report from the mainland too) (Figure 44).

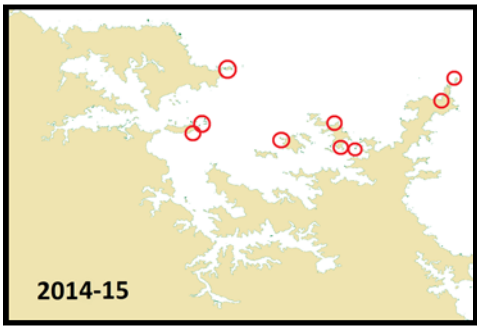

Figure 44: Oi (grey-faced petrel) breeding (red circles) in the Bay of Islands. Data mainly from Department of Conservation reports; the record for Rakaumangamanga summit is based on what was presumed to be a breeding bird departing its burrow in 2014 (Ian Flux, pers. comm.) Other breeding sites over the past 30 years have included Te Pahi Islands. (Map prepared by author)

But the Black Rocks (Figure 45) are probably the main seabird breeding site in the Bay of Islands today (Clifford 1985). Ornithologist C. John Ralph (pers. comm.) recently assembled a checklist of the birds of the Black Rocks and nearby Moturoa Island. He listed no fewer than 29 seabirds and shorebirds, with the following known to breed on the Black Rocks in recent times: little penguin, grey-faced petrel, little shag, pied shag, white-faced heron, blue (reef) heron, black-backed gull, red-billed gull, Caspian tern and white-fronted tern.

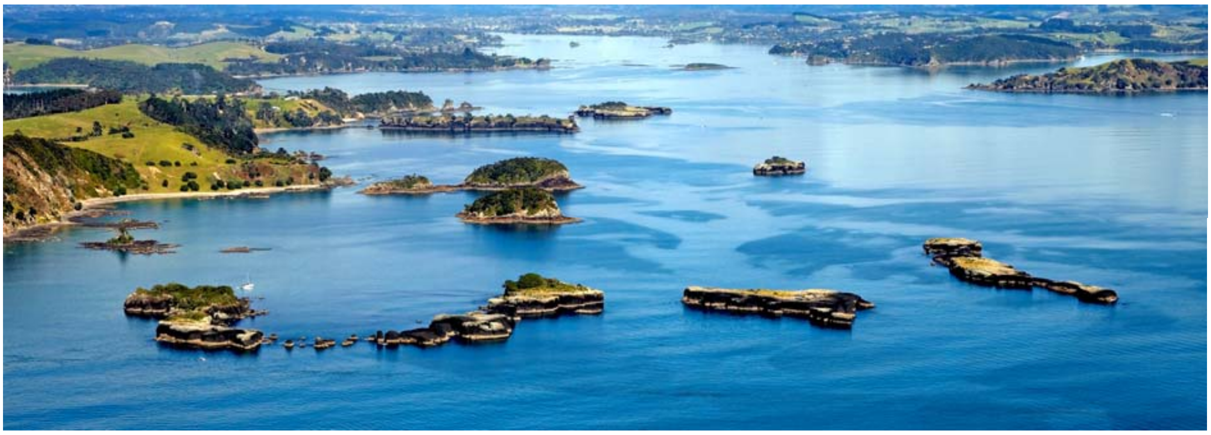

Figure 45: The islands of the Black Rocks lie off Moturoa Island (at left) near the entrance to Kerikeri Inlet (centre distance). (Image: Salt Air, Paihia)

4.4 Discussion and conclusions

Intensive commercial and recreational fishing pressure means that east-Northland stocks of most of the prominent fish and shellfish species are likely to be stressed: Bay of Islands-localised depletion appears evident for several. The East Northland Substock of SNA 1 has been fished down to a low level, and overfishing is likely. A variety of flow-on ecological impacts from this is inevitable, but most of them are essentially intractable given our current poor understanding of complex ecosystems.

On the other hand, for kahawai, the wide range of fish sizes in the recreational harvest, as well as the stock assessment, suggest that the KAH 1 East Northland stock is healthy. Similarly, the New Zealand recreational fishery for striped marlin as a whole, and that of the Bay of Islands in particular, remains world class.

The CRA 1 red rock lobster stock is said to be healthy overall, even though the commercial CPUE is low in at least Statistical Area 904, and a high proportion of lobsters landed in east Northland are near MLS. Of the other shellfish, only the stocks of oysters (Pacific oysters, and probably rock oysters) and kina can be thought of as being abundant and healthy.

Many marine mammals and seabirds of the Bay of Islands area are under threat; some are on the brink of extinction, being Nationally Critical.

5. PROGRESSIVE LOSS OF SHALLOW-REEF KELP COMMUNITIES

Most of the commercial finfisheries of the east coast of Northland have been subject to decades of heavy fishing pressure; for the Bay of Islands itself as well as other parts of Northland, this pressure has been augmented in recent times by intense recreational effort. It is likely that the overfishing of the East Northland Substock of SNA 1 (Plenary 2017: 1350) is also mirrored in low biomass of other commercial predatory species, and the ecological impact of highly reduced abundance, and greatly reduced proportions of large individual fish, is likely to be extremely complex and far-reaching.

The most obvious ecological impact of heavy fishing pressure has been the loss of the shallow-reef kelp communities throughout much of the main basin of the Bay of Islands, among the most severe to be documented for the entire country. Areas of kelp-loss of this sort are known widely around the world as ‘sea-urchin barrens’, whereas in New Zealand they are typically ‘kina barrens’, referring to the sea urchin *Evechinus chloroticus*. However, as described below, ‘sea-urchin barren’ is the appropriate term for northeastern New Zealand, now that more than one species of sea urchin is implicated.

5.1 Bay of Islands-wide

Kelp was once widespread on shallow reefs of the Bay of Islands (Figures 46–53), but is now sparse, at least in the main basin of the Bay. The zone most-impacted is from a little below low-tide level to 3–8 m depth, which takes in the main depth distribution of kina (Miller & Abraham 2011).

A diver swimming away from a northeastern shore that is in its more-or-less natural state would likely be to first encounter a few stragglers of the intertidal Neptune’s necklace (Schiel 2003: 41). Often extending into the subtidal zone would be dense beds of the (laminarian kelp) seawrack (referring to material cast ashore, especially seaweed), or flapjack, *Carpophyllum* species: *C. angustifolium* and *C. maschalocarpum* on more open shores, and *C. plumosum* in quieter waters. Fucalean (true kelp) species in the genus *Xiphophora* can also form dense beds in the shallow waters. Intermediate depths (3–10 m) would be dominated by fucalean algae, but with *C. angustifolium* also being prominent. Laminarian algae - including the brown kelp and the common kelp - can also form forests to 10 m depth. Forests of the deep reefs are composed mainly of common kelp (Schiel 2003: 41-44).

Early aerial photographs (early 1950s and 1959–61) for all Bay of Islands shores were examined in order to estimate the extent of the shallow-reef kelp at those times (Figure 46 and Appendix 3). Not all images were useful because of effects such as sun-strike, shores being in shadow, and poor focus; the images were found to be more useful in demonstrating shade (indicating kelp and/or dark-coloured rock) than in indicating absence of kelp. Accordingly, areas with strong suggestion of kelp cover indicated in Figure 46 will by no means have been the only shores with intact kelp communities. But the impression is that shallow-reef kelp was widespread in both inner and outer parts of the Bay of Islands - as well as throughout the main basin.

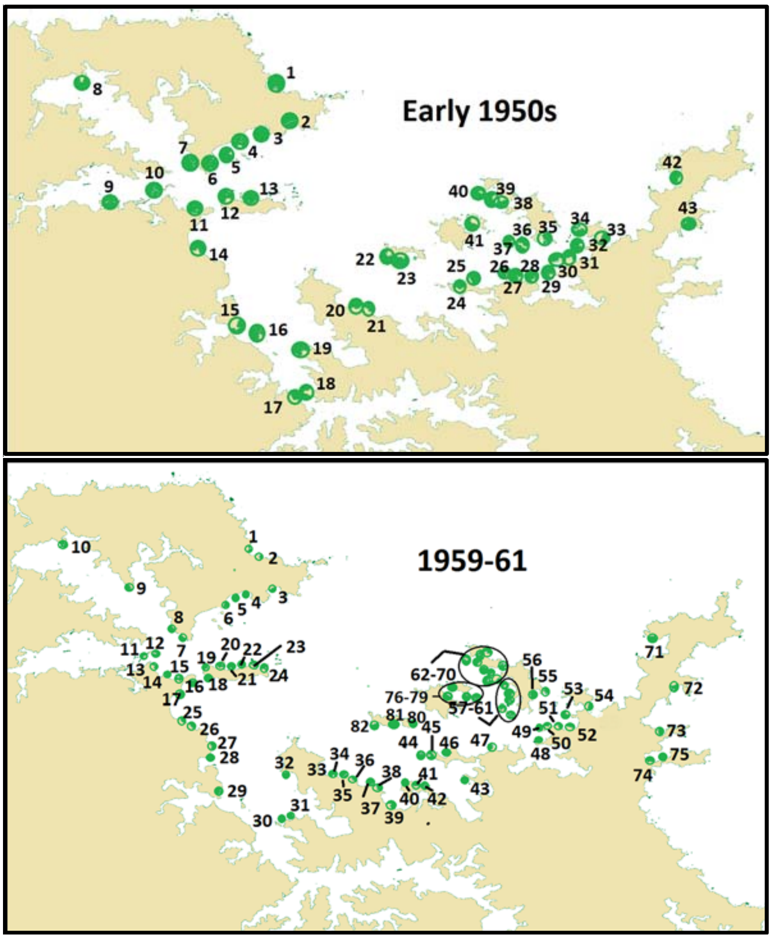

Figure 46: Early aerial photographs (upper, early 1950s; lower, 1959-61) which showed extensive kelp cover (or dark rock) clearly visible below low tide level (green dots). Note that absence of a green dot does not necessarily mean no kelp was present. Numerals refer to the photographs listed in Appendix 3. (Maps prepared by author)

Of these, 29 discrete locations for which there was a time-series of aerial images in which the extent of shallow-reef kelp cover could be clearly discerned, from the 1950s/1960s through to 2009, were assembled (Figure 47, Table 6, and Appendix 4) in order to estimate changes in kelp cover over time. For most sites there were at least four aerial images (most or all being separated by about a decade), and among which at least two of the early images showed extensive dark shadows associated with reef (usually kelp but possibly sometimes dark-coloured rock). The resolution of the early images usually allowed only kelp presence/absence judgements to be made, but, in some instances, thinning of kelp was detectable as well. The current status of the kelp beds is assumed to be the same as that in 2009 (Appendix 5 shows how each of the November 2009 Ocean Survey 20/20 images - NZ Aerial Mapping Ltd. SN50765X - was examined and recorded).

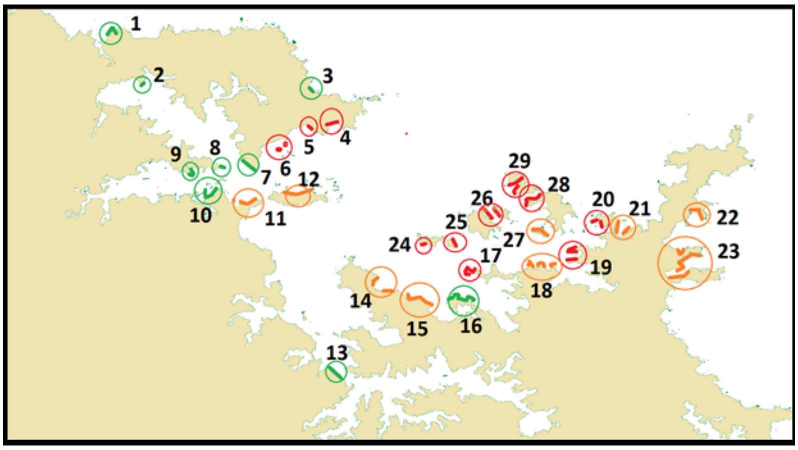

Figure 47: Changes in kelp cover between the 1950s/early 1960s and 2009 (*see* Table 6). Previously existing dark shadows had largely vanished by the 1970s (red), or certainly by the 2000s (orange); green indicates little apparent change in the intensity or extent of shadow (although thinning of kelp was sometimes obvious). Reference aerial images are listed in Appendix 4. (Map prepared by author)

For most parts of the Bay of Islands the change in kelp cover has been monumental: loss of shallow-reef kelp was obvious by the 1970s, although some kelp forests seem to have persisted until quite recently (Figures 47–53 and Table 6). For most parts of the main basin of the Bay of Islands, previously existing dark shadows had largely vanished by the 1970s, and certainly by the 2000s. Extensive dive surveys in 1985–86 (Trenery et al. 1987), and again in 1991 (Brook & Carlin 1992), confirmed widespread sea-urchin barrens in the Bay of Islands at those times.

Table 6: Changes over time in Bay of Islands kelp cover for sites shown in Figure 47 (*see* Appendix 4 for further details). The primary resource for estimating the recent extent of kelp cover was the November 2009 Ocean Survey 20/20 aerial images of Land Information New Zealand (*see* Appendix 5). Y, apparently healthy kelp present; N, kelp apparently absent; *, no image available/examined, or image held not useful.

Site		Early 1940s	Before 1951	Early 1950s	1951 –55	1959 –61	1970 –72	1976 –79	1980 –81	1981 –82	1993	2005	2009	Commentary (Kelp largely gone by)
1	Tapuatahi	*	*	Y	*	Y	Y	*	*	*	*	*	Y	Little change
2	Te Tii	*	*	Y	*	*	*	*	*	*	*	*	Y	No change
3	Mataka	*	*	Y	*	*	*	*	*	*	*	*	Y	No change
4	Whale	*	*	*	*	Y	N	*	*	*	*	N	N	(1970–72)
5	Rangihoua	*	*	Y	*	Y	N	N	N	*	*	N	N	(1970–72)
6	Te Pahi	*	*	Y	*	*	N	*	*	*	*	*	N	(1970–72)
7	Poraenui	*	*	Y	*	*	Y	*	*	*	*	*	Y	No change
8	Akeake	*	*	Y	*	*	*	*	*	*	*	*	Y	No change
9	Doves	*	*	Y	*	*	*	*	*	*	*	*	Y	No change
10	Hauparua W	*	*	Y	*	*	*	*	*	*	*	*	Y	No change
11	Waireka	*	*	Y	*	Y	Y	*	*	*	*	*	N	(Before 2009)
12	Moturoa N	*	*	*	*	Y	Y	*	*	*	*	*	N	(Before 2009)
13	Veronica	*	*	Y	*	*	*	*	*	*	*	*	Y	Just thinning
14	Oneroa	*	Y	Y	Y	Y	Y	*	*	*	Y	*	N	(Before 2009)
15	Oneroa/Paroa	*	*	*	*	Y	Y	Y	Y	Y	*	*	N	(Before 2009)
16	Kahuwera	*	*	Y	*	Y	*	*	*	*	*	*	Y	Just thinning
17	Motukauri	*	*	*	*	Y	N	*	*	*	*	*	N	(1971)
18	Omarino	*	*	Y	*	*	Y	Y	*	*	*	*	N	(Before 2009)
19	Omakiwi	*	*	Y	Y	*	Y/N	N	*	*	*	*	N	(1972–79)
20	Rawhiti	*	*	Y	Y	Y	N	N	N	*	*	*	N	(1971)
21	Oke	*	Y	Y	*	Y	Y	*	*	N	*	*	N	(1981–82)
22	Outu	*	*	Y	*	Y	*	*	Y	*	*	*	N	(Before 2009)
23	Whangamumu	*	*	*	*	Y	Y	*	Y	*	*	*	N	(Before 2009)
24	Otarepo	Y	*	Y	*	Y	N	N	N	*	N	N	N	(1971)
25	SE Motuarohia	Y	Y	Y	*	Y	N	N	*	*	N	N	N	(1971)
26	NE Moturua	*	*	*	*	Y	Y/N	Y/N	N	*	*	*	N	(1971–78)
27	Poroporo	*	*	Y	Y	Y	Y	Y	Y	*	*	*	N	(Before 2009)
28	Te Akeake Pt	*	*	*	*	Y	Y	Y/N	N	*	*	*	N	(1978–80)
29	Okahu Ch	*	*	Y	*	Y	Y/N	Y/N	N	*	*	*	N	(1971–80)

On the other hand, little change was sometimes evident in the intensity or extent of shadow (although thinning of kelp was sometimes obvious) over the full period through to the present, most often near inlets and other places where waters are presumably too fresh for kina and other sea urchins. Also, kelp cover was often patchy (rather than being completely absent) in the outer, more exposed parts of the Bay - presumably because exposure to swells sometimes limited sea urchin distribution and abundance.

By 2009, sea-urchin barrens were widespread on shallow reefs in the Bay of Islands, particularly in the main basin where essentially 100% of shores were coded red or blue (with red shores usually greatly exceeding blue shores; Figures 48–53 and Table 7). Areas with least evidence for loss of shallow-reef kelp (coded green) were in open parts of estuaries (particularly in the outer Te Puna and Kerikeri inlets and Veronica Channel): not only were there only short lengths of shoreline coded red, but also few areas were ambiguous (blue) (Table 7). Many of the more exposed outer parts of the Bay (a line from Cape Wiwiki, to the exposed shores of the islands of Ipipiri, to the base of the Cape Brett Peninsula) were ambiguous, usually because of the steepness of the shore - but there was, nevertheless, evidence for widespread sea-urchin barrens, at least in places. For the area between these inner and outer parts, the main basin of the Bay, the predominant codings were red and then blue, with virtually no green at all.

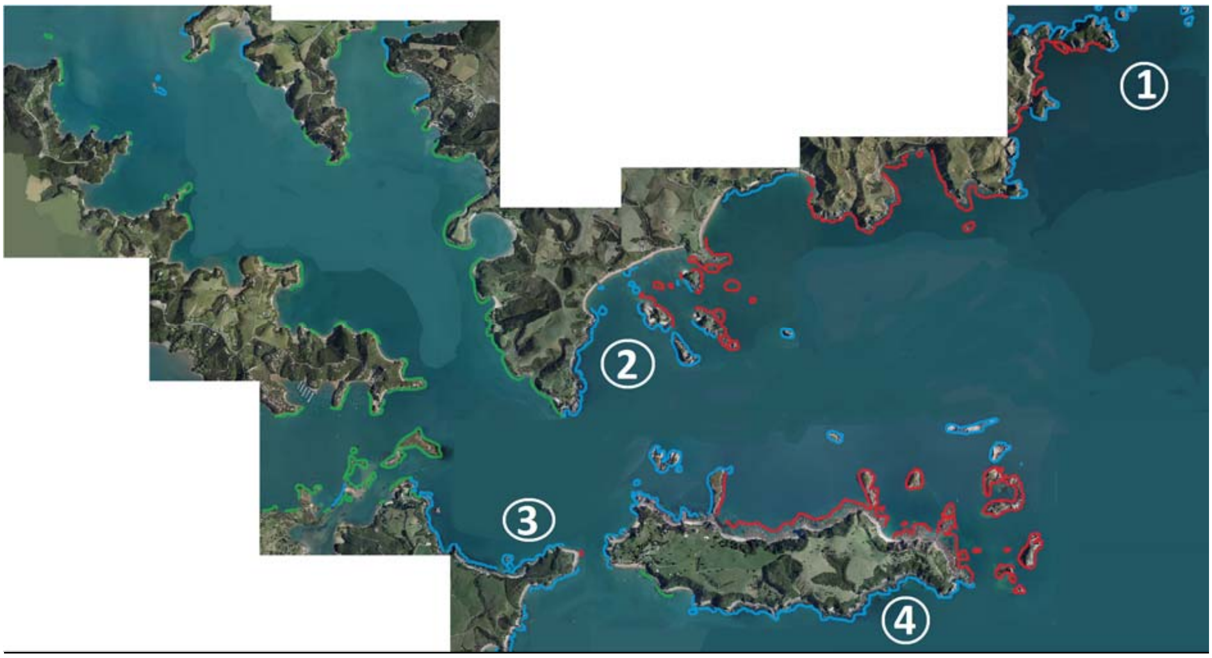

Figure 48: Estimated extent of sea-urchin barrens (red) in the northwest of the Bay of Islands in November 2009. In some areas the reef was too steep to assess, or was in shadow (1); or the reef itself appeared dark, most probably for reasons other than kelp cover (2-4). (Image: Ocean Survey 20/20)

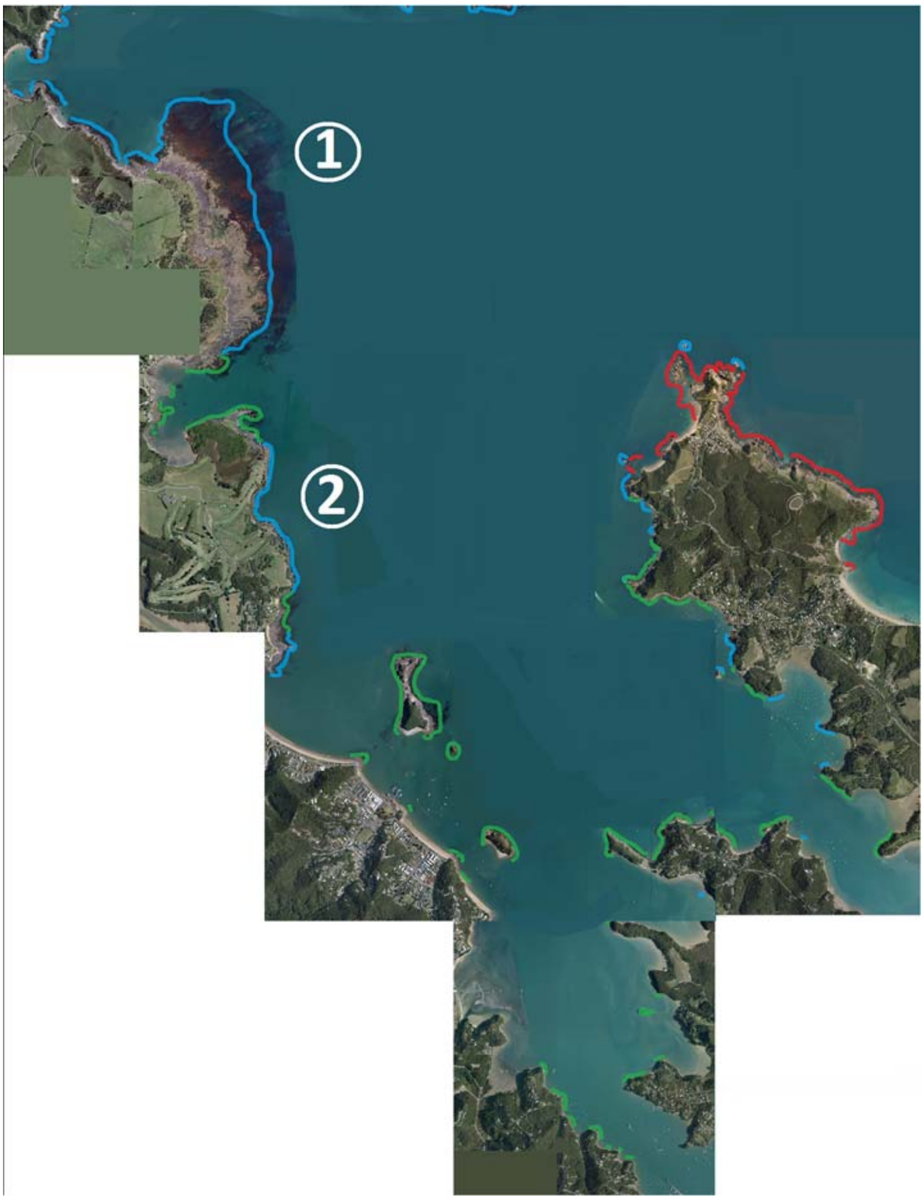

Figure 49: Estimated extent of sea-urchin barrens (red) in the west of the Bay of Islands in November 2009. In places, the reef itself appeared dark, but not necessarily because of kelp cover (1 and 2). (Image: Ocean Survey 20/20)

Figure 50: Estimated extent of sea-urchin barrens (red) in the south of the Bay of Islands in November 2009. In places, the reef itself appeared dark, but not necessarily because of kelp cover (blue); in some places the kelp appeared to be intact (green). (Image: Ocean Survey 20/20)

Figure 51: Estimated extent of sea-urchin barrens (red) in the southeast of the Bay of Islands in November 2009. In some places the kelp appeared to be intact (green). (Image: Ocean Survey 20/20)

Figure 52: Estimated extent of sea-urchin barrens (red) in the Ipipiri part of southeast Bay of Islands in November 2009. In some places the reef was too steep to assess, or was in shadow (blue). (Image: Ocean Survey 20/20)

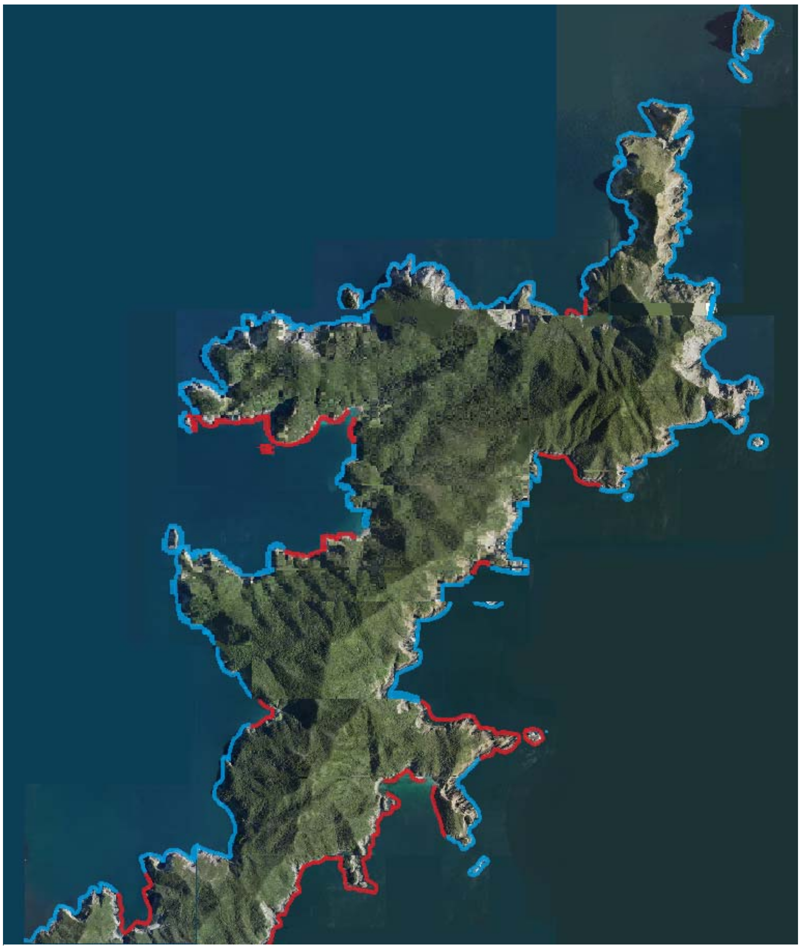

Figure 53: Estimated extent of sea-urchin barrens (red) in the east of the Bay of Islands in November 2009. In many places the reef was too steep to assess, or was in shadow (blue). (Image: Ocean Survey 20/20)

Table 7: Indicative estimates of the extent of the sea-urchin barrens in the various parts of the Bay of Islands in 2009 (Ocean Survey 20/20 images).

Part of Bay of Islands	Figure no.	Total coastline length (km)	Total rocky coastline length (km)	Percentage of rocky shores coded red	Percentage of rocky shores coded green	Percentage of rocky shores coded blue
North & west	48	58.25	40.92	31.5	29.8	38.7
Southwest	49	45.32	26.39	15.9	46.9	37.2
Central south	50	11.87	5.41	50.0	2.0	48.0
Southeast	51	26.85	14.25	96.8	3.2	0
Ipipiri Is area	52	44.53	36.04	74.5	0	25.5
Cape Brett Peninsula	53	35.67	34.37	28.3	0	71.7

5.2 Case studies

In this section three examples are illustrated of where kelp cover has declined over time, and one where it seems to have changed little. Images more-recent than 2009 are available for two sites.

Te Akeake Point, Urupukapuka Island

At Te Akeake, off the northwest extremity of Urupukapuka Island (28 in Figure 47), some shallow kelp was still apparent in 1971, but virtually all had disappeared by 1980. There had been no recovery evident by 2015 (Figure 54).

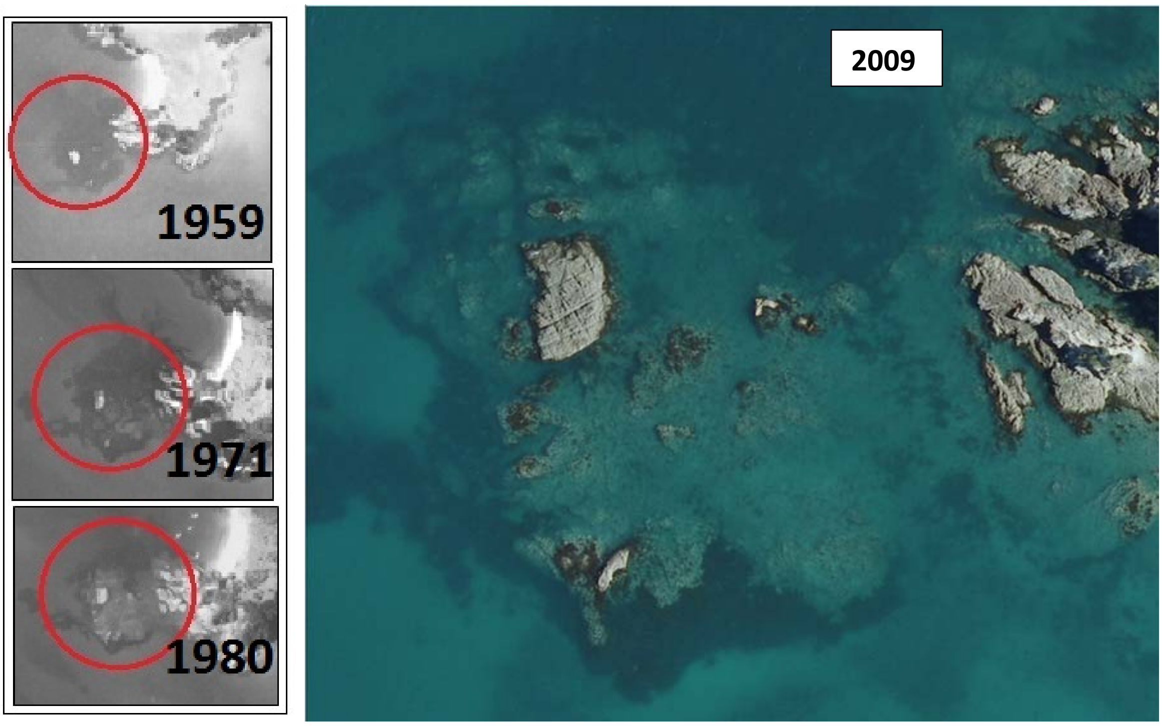

Figure 54: Te Akeake, off the northwest extremity of Urupukapuka Island. (Images: 1959: NZ Aerial Mapping Ltd. 2789-2 and part of Survey No. 1223; 1971: NZ Aerial Mapping Ltd. 4477_24 and part of S.N. 3406; 1980: NZ Aerial Mapping Ltd. S.N.5651_I2; 2009: Ocean Survey 20/20 AV30_3306; 2015: Dean Wright Photography, Kerikeri)

Rangihoua

Virtually no kelp cover remains on the reef phalanges and faces that stretch out from the eastern part of Rangihoua Bay (5 in Figure 47), which would presumably horrify missionary Samuel Marsden, who set up his mission here in 1814. Significant kelp cover had largely vanished by 1972; there had been no recovery evident by 2017 (Figure 55).

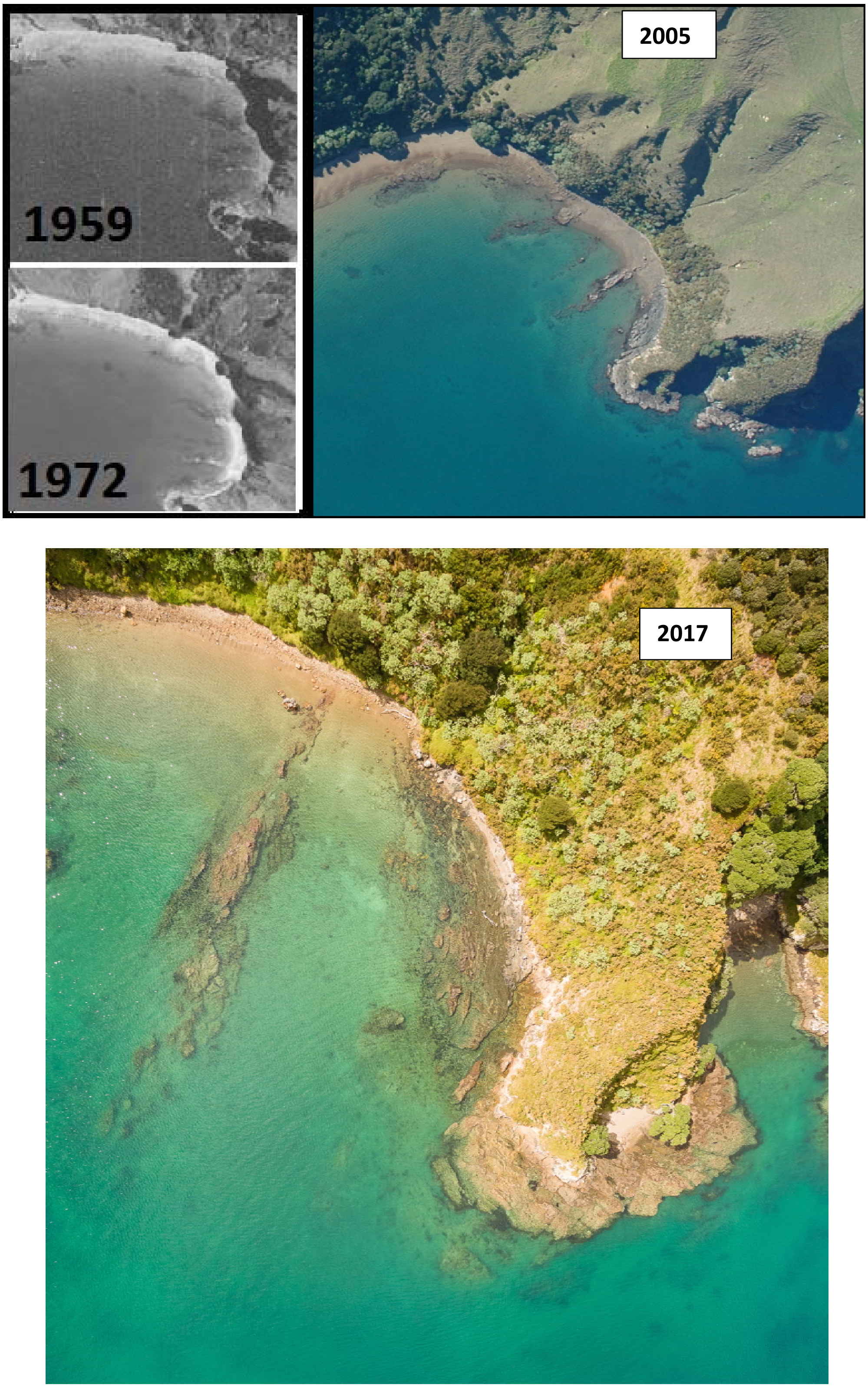

Figure 55: Eastern end of Rangihoua Bay (5 in Figure 47). (Images: 1959: NZ Aerial Mapping Ltd. 2786-1 and part of Survey No. 1223; 1972: NZ Aerial Mapping Ltd. 4475_9 and part of S.N. 3406; 2005: Kerr & Associates dsc_0673; 2017: Dean Wright Photography, Kerikeri)

Otarepo, Motuarohia Island

The reef at the western end of Otarepo Bay on Motuarohia Island (24 in Figure 47), 10 m across, was once festooned with kelp, becoming essentially bereft of it by 1971 (Figure 56). This would presumably horrify James Cook, who first stepped ashore in the Bay of Islands here in 1769.

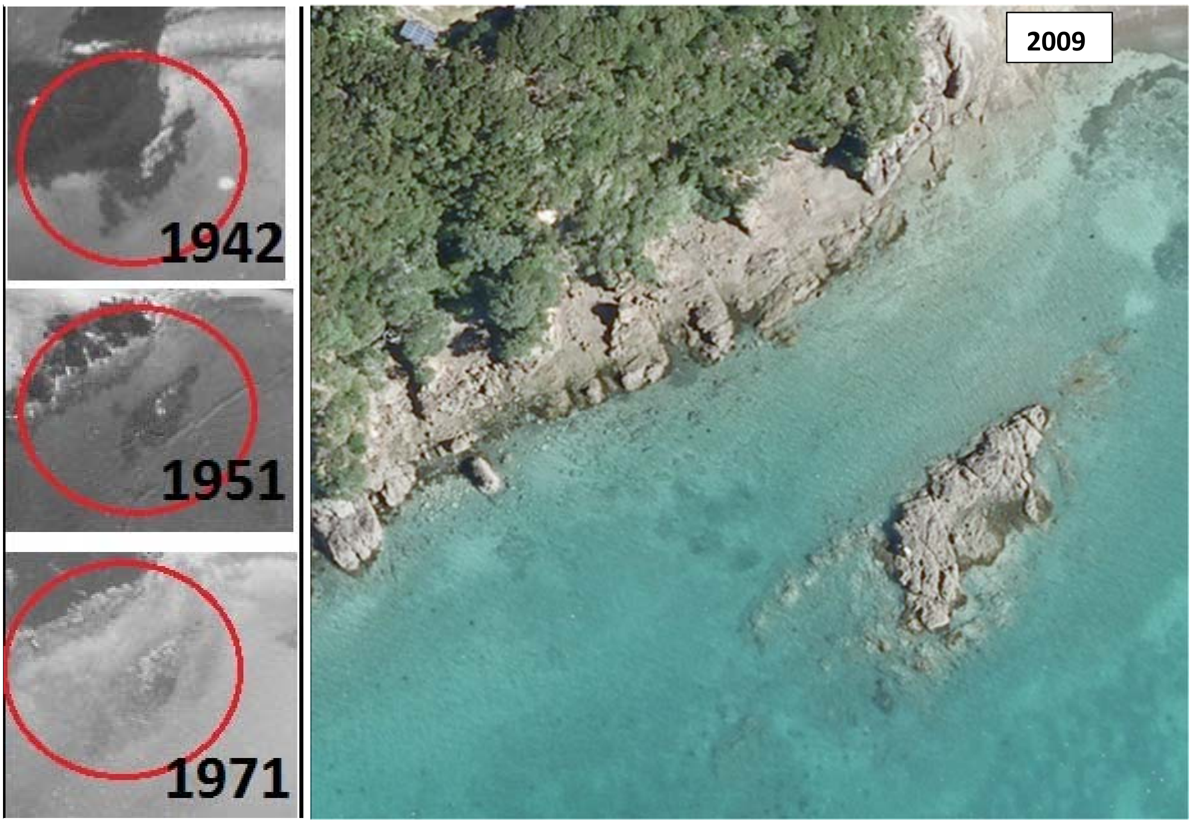

Figure 56: Western end of Otarepo Bay on Motuarohia Island (24 in Figure 47). (Images: 1942: 235 A-1, held by Department of Conservation Kerikeri; 1951: NZ Aerial Mapping Ltd. 543-16 and part of Survey No. 209; 1971: 4479-15 and part of S.N. 3406; 2009: Ocean Survey 20/20 AV29_3645)

Hauparua, Kerikeri Inlet

The impression is that the kelp around islets of basalt at Hauparua, at the mouth of Kerikeri Inlet (10 in Figure 47), was just as prolific in 2009 as it was in 1961 (Figure 57). Ngā Puhi chief Hongi Hika, who regularly paddled past this place, would presumably be content.

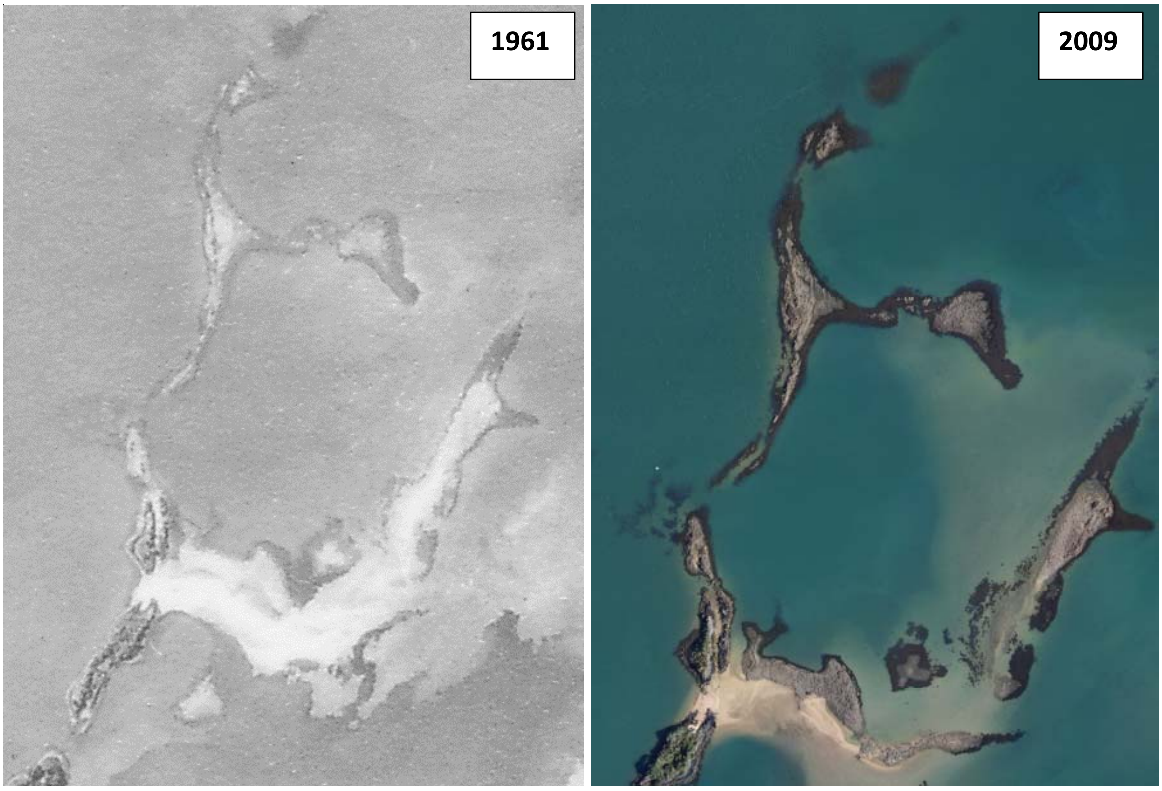

Figure 57: Islets at Hauparua, near the mouth of Kerikeri Inlet (10 in Figure 47). (Images: 1961: NZ Aerial Mapping Ltd. 2787-1 and part of Survey No. 1223; 2009: Ocean Survey 20/20 AV29_3123)

5.3 Discussion and conclusions

The loss of shallow-reef kelp in the Bay of Islands has been intensive and extensive (up to 90% or more in places), and is likely to have led to a multitude of cascading consequences, most of them not yet even recognised let alone understood. The kelp community plays pivotal ecological roles (e.g., Tegner & Dayton 2000; Schiel, 2003; Leleu et al. 2012; Hesse et al. 2016): kelps are highly productive, fixing carbon, and fuelling the ecosystem; and they provide habitat for all manner of animals and plants. Shallow kelp forests provide areas for fish spawning and larval settlement, and shelter for juveniles, by reducing exposure to water movement and predation. Red rock lobster postlarvae often settle out of the plankton among shallow-reef kelp, and juvenile snapper are strongly associated with it.

Whereas the reason for the emergence of sea-urchin/kina barrens in northeastern New Zealand was for a time contested, there now appears to be consensus that these barrens are a direct result of the overharvesting of keystone predators (predators whose impact on the ecosystem is disproportionately large relative to their abundance) such as snapper and red rock lobsters - the ones capable of preying on kina (Andrew & MacDiarmid 1991, Shears & Babcock 2002, Ayling & Babcock 2003, Schiel 2013, Ballantine 2014) and other sea urchins. In Schiel’s (2013) cascading, ‘trophic-effect model’ for northeast Northland, reductions in the proportions of large individuals of these predatory species have led to burgeoning sea urchin (kina in particular) populations and to the widespread loss of shallow-reef kelp. Resulting sea-urchin barrens such as these are a world-wide phenomenon and one surprisingly difficult to reverse (Ling et al. 2014).

Some have argued that ascribing such changes in kelp abundance to essentially a single herbivore may be oversimplifying a complex ecology, with innumerable other-explanations for kelp loss that do not necessarily implicate overfishing of keystone predators - a ‘multi-effects model’.

> Gaps in kelp beds can be created by grazing, storms, natural deaths of plants and, increasingly, damage by boat anchors. Such disturbances, even if they remove only a few kelp plants, trigger a series of responses. Light gaps are formed in the dense kelp canopy, in much the same way that the sun shines through a forest canopy where a large tree has fallen….. Diseases and wider oceanic processes can disrupt kelp beds, sometimes on a large scale. Die-offs related to kelp diseases also occurred in common kelp along northeastern [New Zealand] shores in the early 1990s, although it is unclear what triggered them….. On a wider scale, the alternating sequence of El Niño and La Niña events brings large changes in seawater temperature, wind patterns, storms and nutrients. …. The natural loss of kelp bed plants can be exacerbated by human-induced processes. Changes in landuse and urban expansion often lead to increased sedimentation and nutrient loads in coastal waters. This can decrease water clarity and light penetration, and lead to increases in the abundance of epiphytes and fast-growing ephemeral algae. Even a fine layer of sediment can decrease kelp photosynthetic ability and prevent spores and zygotes from attaching and recruiting (Schiel 2003: 45–47).

But if any of these was the cause of kelp retrenchment on shallow reefs in the Bay of Islands, the expectation would have been that the fortunes of individual patches of kelp would have varied independently of each other over time, or extensive areas would wax and wane without obvious trend. Yet in the 29 locations in the Bay of Islands for which there was a long time-series of aerial images in which the extent of seaweed cover could be clearly discerned, the kelp communities were all in decline, and this has applied only to the upper few metres of the subtidal, not deeper. Furthermore, it is hard to see how the limited levels of ocean warming (e.g., Schiel 2013) or ocean acidification evident so far could have brought about such widespread destruction of kelp within just the main depth zone of kina.

It is hardly a coincidence that the 1970s to 1980s was for East Northland the period of heaviest fish-down of many commercial demersal finfish stocks, and rock lobsters, after relatively light exploitation in previous years. For example, commercial-boat numbers for the Bay of Islands itself rose from around 50 in the mid-1930s to around 100 in the mid-1950s, almost 120 in the early 1970s (Figure 19), and reaching a maximum of 176 in the early 1980s (King 1985) - all with concomitant increases in effectiveness as vessels and technology improved. This ramped-up fishing pressure led to significant reductions in the proportions of large individual-fish. Today, the commercial fishing pressure in and near the Bay of Islands is much lower, but appears to have been largely replaced by recreational effort.

In a recent development, the long-spined urchin now appears to be significant in the overgrazing of shallow-reef kelp, particularly in the more exposed, outer parts of the Bay of Islands (C. Richmond and V. Froude, Pacific Eco-logic Ltd.; V. Kerr, Kerr & Associates, pers. comm.). This sea urchin, which is also found on the east coast of Australia and has recently reached plague status in Tasmania (Sinauer Associates 2014), was reported as early as the late 1960s to be extending its distribution and increasing in abundance in the north of New Zealand (Morton & Miller 1968), and it is now common in shallow open waters of the Bay of Islands. In the southeast of mainland Australia, it has long been known as a significant contributor to sea-urchin barrens there (Andrew & Underwood 1993); furthermore, the commercially valuable rock lobster there (also *Jasus edwardsii*) is this sea urchin's important predator (Sinauer Associates 2014).

The Bay of Islands presents an extreme example of ecological overfishing of the main predators of sea urchins, which has resulted in increases in abundance of the echinoderm and the concomitant loss of shallow-reef kelp (Figure 58). My main measure of the current state of the kelp has been the Ocean Survey 20/20 images, but at places where more recent images are available, no improvement in the kelp is apparent. The experience in the marine reserve at Leigh and elsewhere is, however, that once large keystone predators return, the sea urchins are held in check, and the kelp gradually recovers (Ayling & Babcock 2003, Ballantine 2014). (But note that kelp has recovered only in no-take marine reserves, and not in others where only commercial [but not recreational or customary] fishing has been banned, such as in the Mimiwhangata Marine Park; Shears et al. 2006: 229). Because of biological links between Bay of Islands' keystone predator populations and those of the respective FMA (or subarea), reduction of fishing effort in the Bay of Islands alone is unlikely to bring much relief; across-the-board measures at the stock/substock level would be required.

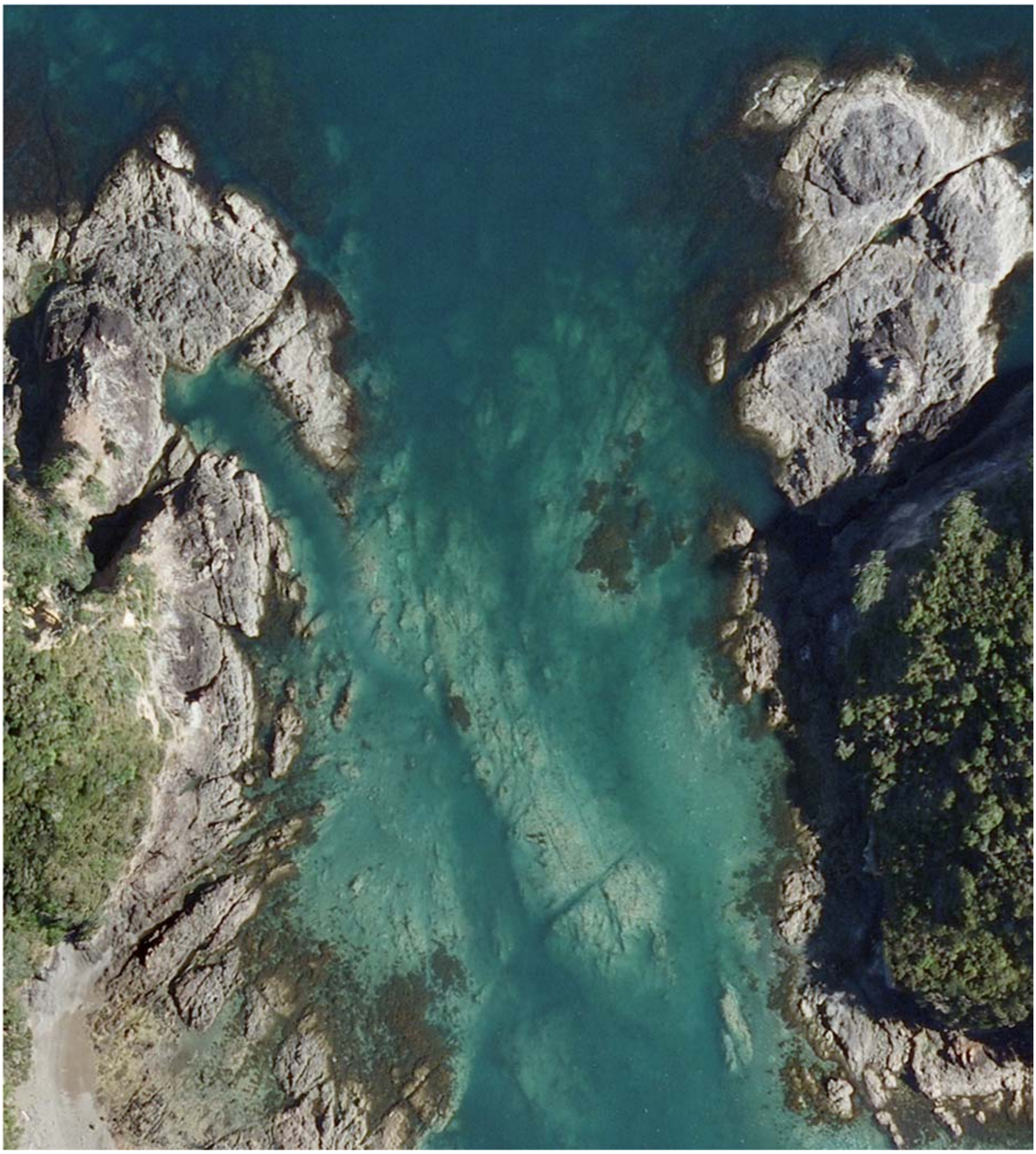

Figure 58: The rocky seafloor in this gap between Te Rawhiti Peninsula and Moturahurahu Island (about 30 m across and up to 5 m deep), at the northern entrance to Oke Bay (*see* Figure 1 and Appendix 5), is now essentially bereft of kelp, only a fringe remaining at extreme low-water level. Changing from flourishing kelp to basically bare rock, the loss of structural complexity is dramatic. (Image: Ocean Survey 20/20 AV30_3416)

OVERALL CONCLUSIONS

Pre-Contact (pre-1800) resources

1. It seems that 500 years of pre-Contact Māori harvesting pressure left no discernible and lasting legacy on Bay of Islands' fish and shellfish resources - with the probable exception of the fishing-out of local populations of the Cook Strait limpet, and possibly initiating the extirpation of hapuku from shallow waters.
2. It is likely that Bay of Islands' annual harvest levels of snapper in the late eighteenth century were similar to, or even exceeded, the highs of the 1980s, but did not bring about noticeable fish-size reductions, probably because offshore and remote parts of the East Northland SNA 1 substock were barely fished.
3. Almost certainly, overharvesting in the Bay of Islands contributed to the extinction of the New Zealand sealion in the northeast of the country in the Early Period, and to the extirpation of breeding colonies of the New Zealand fur seal from Northland by 1500 AD.
4. Moreover, the kiore rats that the early waka had transported to this country, together with human harvesting, resulted in seabird extinctions and extirpations.

Early post-Contact (1800-1900) resources

5. The earliest commercial fishery in the Bay of Islands was for rock oysters. Although rock-oyster numbers would have declined as a result of heavy harvesting pressure, it is most unlikely there would have been any discernible and enduring ecological impact.
6. For grey mullet, and other finfish, the fishing pressure would noticeably have done little more than to reduce somewhat the abundance and mean size of fish in certain places - but with far less tractable flow-on ecological effects.
7. The Bay of Islands shore-whalers - apart from those at Whangamumu - would have exerted relatively little harvesting pressure on the humpback whales because catches were almost certainly miniscule. The impact of harvesting by the Whangamumu Station on the stocks of humpback whales may, however, have been significant, with almost 1000 individuals taken in fewer than 20 years.
8. The harvesting of seabirds and their eggs would have added to the pressure of the aliens such as rats in ensuring remaining mainland colonies were extirpated to offshore stacks and islands, and not allowed to re-establish on the mainland.

Recent (post-1900) resources

9. By the early 1900s a wide variety of finfish were being landed for market, and useful statistics around these commercial catches began to emerge in the 1930s.
10. Until the late 1970s, the mainstay species for the Bay of Islands in terms of weight - albeit with modest annual landings (up to about 100 t of each species) - were flounder, grey mullet, hapuku and snapper.
11. Leading up to the management changes of the 1980s, annual commercial snapper landings of the broader Bay of Islands area rose briefly to over 1000 t, and boat numbers approached 180.
12. Pelagic species such as blue mackerel, jack mackerel and skipjack tuna were first fished commercially in the area in the 1980s, after which large annual catches (thousands of tonnes) were being made along open waters just outside the Bay of Islands.
13. The only invertebrate of commercial significance in and near the Bay of Islands has been the red rock lobster, fished to any extent only since World War II, with recent local harvests averaging up to about 10 t a year.
14. Today, just a small handful of commercial fishers routinely fish the waters within the Bay of Islands, their main finfish by weight including flounder, garfish, grey mullet, snapper and trevally - totalling a few dozen tonnes across the board each year and harvested using set nets and beach seines.

15. However, from time to time, larger visiting vessels line, net and trawl for such fish as snapper, trevally, flatfish and grey mullet within the Bay of Islands, and purse seine pelagic species such as skipjack tuna, pilchards and mackerels near the entrance to the Bay of Islands.
16. The principal finfish recreationally sought and caught in the Bay of Islands is snapper, followed by kahawai. The most important invertebrates are red rock lobsters, scallops, green-lipped mussels, cockles and pipi.
17. Bay of Islands takes in the most extensive area of intense recreational boat-fishing in the whole of East Northland. This fishing effort almost certainly exceeds that of the commercial fleet for most species (possibly by an order of magnitude), and recreational catches are similar to or exceed those commercial.
18. There are hotspots (more than 100 vessels/km^2, annualised) of recreational boat-fishing north and southeast of Moturoa Island, near Tikitiki and Whale Rock, and north of Motuarohia Island.
19. It is likely that recreational fishing pressure will continue to intensify and expand in the Bay of Islands over the next five years, mainly through ever more vessels visiting, particularly from Auckland over the summer.

Current status of fish, shellfish, marine mammals and seabirds

20. It is likely that overfishing is occurring in the East Northland snapper substock of SNA 1. In recent years most fish landed both recreationally and commercially have been little larger than the MLS, and near the extreme left-hand limb of a size-distribution frequency from a lightly fished northern stock.
21. The Bay of Islands component of the snapper fishery is inextricably linked through seasonal migration to the rest of East Northland, so fishing in the Bay of Islands contributes to the state of the substock.
22. The KAH 1 kahawai stock is not considered overfished, and the size range of landed fish is broad.
23. Although the CRA 1 red rock lobster stock is not considered overfished, most lobsters locally caught recreationally and commercially are at or only a little above MLS, which is consistent with heavy fishing pressure. The Bay of Islands component is linked through larval drift to other parts of the lobster fishery, so local recreational fishing contributes to pressure on the stock.
24. Most of the other most-sought shellfish species are heavily fished, demonstrated through declining abundance and/or reduced average size. (Kina and Pacific oysters, and possibly rock oysters, are the exceptions.)
25. All marine mammals (apart from the New Zealand fur seal, and possibly the common dolphin and humpback whale) are endangered.
26. Seabird and shorebird breeding continues to be largely confined to islands, whereas in pre-human times it was widespread on both islands and on the mainland.

Progressive loss of shallow-reef kelp communities

27. In northeast New Zealand, (mainly) commercial fishing had, by the mid-1980s, reduced the biomass of snapper (and probably other predatory finfish species), and rock lobsters, to less than one quarter of their unfished state. Consequently, freed from the pressure of their main predators, sea-urchin grazing burgeoned, resulting in loss of much of the shallow-reef kelp in places like the Bay of Islands.
28. Whereas until now kina has been the only species implicated, it is now clear that the long-spined urchin is also overgrazing reefs.
29. Ongoing intense recreational fishing pressure, together with the commercial effort, within and near the Bay of Islands means little or no recovery of the kelp is likely in the near future.

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I am grateful to the Ministry for Primary Industries (particularly Mary Livingston and Marianne Vignaux) for publishing this work in the *New Zealand Aquatic Environment and Biodiversity Report* series. It has given me considerable satisfaction (note I didn't say joy) to prepare this document, one which - I trust - sits usefully alongside others concerning Aotearoa's marine environmental history. In fact, this may be among few attempts to document in a reasonably comprehensive manner change over time in the marine resources of one particular catchment in New Zealand, from first East Polynesian settlement to the present.

People to provide useful feed-back and reviews of these writings include Lindsay Alexander, Alan Baker, Richard Civil, Malcolm Francis, Vicky Froude, Bruce Hartill, John Holdsworth, Larry Paul, C. John Ralph, Elke Reufels, Chris Richmond, and Ian Smith (alphabetically): thank you all. Kerr & Associates Kamo and Salt Air Paihia, and particularly Dean Wright Photography Kerikeri, kindly provided crucial imagery.

I believe (and trust) my most significant contribution here has been to demand (again) the attention of researchers and managers, and the industry, over the worrisome scale of shallow-reef kelp loss in the Bay of Islands - a loss echoed to a large extent in other parts of east Northland, too. There isn't really anyone to blame: no one in the 1970s and 1980s could have confidently predicted the impacts on the shallow-reef flora of an ever-increasing inshore fishing pressure (mostly commercial, but later recreational too) such as we have seen here - but balance was lost, and the result is there for all to see. I often have visitors wax lyrically over the beauty of the seascape of the Bay of Islands - and then puzzle over what has happened to the snorkable reefs. And we're all to blame.

Worryingly, we still have no real sense of the ecological impacts of such gross alteration in structural complexity of our shallow reefs, changes which will have affected species familiar to us as well as others less known, even not known. But we do know that a sea-urchin barren is a comparatively stable state: it takes more than quarter-of-a-century to reverse, and then only when there is complete protection from all fishing.

For reviewing and editing these writings, Marianne: thank you for your insightful suggestions and comments.

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APPENDICES

Appendix 1: Analysis of shellfish in Bay of Islands middens according to compartments shown in Figure 3. For details, including species considered, *see* Booth (2016). Low midden density is <1 midden/km; high is >3 middens/km.

Compartment	Location	Coast		Middens		Notes
		Exposure	Physical	No.	No./km	
1	Rangihoua	Exposed	Beach to reef	10	0.69	Low midden density; cockles & oysters imported from sheltered shores (Te Puna Inlet?); tuatua harvested at nearby Wiwiki Beach?
2	Poukoura	Sheltered	Mudflat	13	0.85	Low midden density; pipi and other sheltered, soft-shore species underrepresented
3	Upper Te Puna	Sheltered	Mudflat to reef	18	1.77	Pipi, and oysters and other reef species, underrepresented
4	Te Puna	Sheltered	Mudflat to reef	28	0.78	Low midden density; cockles overrepresented
5	Upper Kerikeri	Sheltered	Mudflat to reef	19	1.89	Tuatua in 11% of middens; sheltered-shore species underrepresented
6	Mid Kerikeri	Sheltered	Mudflat to reef	62	3.96	High midden density; cockles overrepresented; pipi underrepresented
7	Lower Kerikeri	Sheltered	Mudflat to reef	79	3.79	High midden density; cockles overrepresented; pipi underrepresented; brackish water mussel abundant in many middens, and dominating one
8	Moturoa	Exposed	Beach to reef	3	0.38	Very low midden density; significant presence of cockles from harvesting of sheltered soft shores
9	Wairoa	Exposed	Beach to reef	22	1.46	Cockles overrepresented; oysters underrepresented; tuatua in 6% of middens; catseye predominant in one midden
10	Waitangi	Sheltered	Mudflat to reef	93	6.54	Very high midden density; oysters underrepresented
11	Te Haumi	Sheltered	Mudflat	26	2.81	High pipi presence, pointing probably to less-silted conditions than now
12	Veronica	Sheltered	Mudflat to reef	36	3.06	High midden density; cockles overrepresented; oysters underrepresented
13	Kawakawa	Sheltered	Mudflat to reef	71	3.31	High midden density; high pipi presence (predominating 38% of middens) points to a less-silted environment than now; oysters underrepresented

Compartment	Location	Coast		Middens		Notes
		Exposure	Physical	No.	No./km	
14	Waikare	Sheltered	Mudflat to reef	40	1.04	High pipi presence (50% of middens) points to less-silted conditions than now; oysters underrepresented
15	Upper Waikare	Sheltered	Mudflat	39	1.56	Midden contents reflect local resources
16	Waikino	Sheltered	Mudflat to reef	23	1.26	High pipi presence points to less-silted conditions than now; oysters underrepresented.
17	Upper Kawakawa	Sheltered	Mudflat	7	0.55	Low midden density, dominated by cockles; pipi overrepresented, pointing to less-silted conditions than now; other sheltered soft-shore species underrepresented
18	Pomare	Sheltered	Mudflat to reef	20	1.7	Oysters underrepresented; tuatua probably from Oneroa Bay; other sheltered-shore species underrepresented
19	Russell	Semi-exposed	Beach to reef	7	1.28	Cockles over-represented; absence of other reef species; tuatua probably from Oneroa Bay
20	Oneroa	Exposed	Beach to reef	6	0.83	Low midden density; cockles and pipi over-represented; absence of other reef species
21	Paroa	Exposed to sheltered	Mudflat to reef	48	4.33	High midden density
22	Manawaora	Exposed to sheltered	Mudflat to reef	34	1.74	Oysters underrepresented; oblong venus shell dominating two middens at Huruhi Bay points to less-silted conditions than now (NAR 2009)
23	Omarino	Exposed	Beach to reef	5	2	Cockles overrepresented
24	Parekura	Sheltered	Mudflat to reef	25	1.74	Oysters underrepresented
25	Rawhiti	Exposed to sheltered	Beach to reef	5	0.61	Low midden density; low presence, or absence, of other reef and soft-shore species
26	Cape Brett	Exposed	Reef	1	0.04	Very low midden density.
27	Outer islands	Exposed to sheltered	Beach to reef	18	0.84	Low midden density; cockles & pipi overrepresented
28	Inner islands	Exposed to sheltered	Beach to reef	9	0.51	Low midden density; cockles & tuatua overrepresented

Appendix 2: Customary fishery extractions for the rohe moana areas Nga Hapu o Taiamai ki Te Marangi and Ngati Kuta/Patukeha, 2015 and 2016. -, zero. (Official Information Act request OIA17-0076 of Ministry for Primary Industries, March 2017.)

Fishstock code	Species	Unit type	2015	2016	Total
COC 1B	Cockle	Litres	-	10	10
CRA 1	Red rock lobster	Not provided	79	123	202
MUS 1	Mussels	Not provided	3200	7980	11180
OYS 1	Dredge oyster	Not provided	-	400	400
PPI 1B	Pipi	Litres	-	30	30
SCA 1	Scallop	Not provided	1260	3030	4290
SUR 1A	Kina	Not provided	5050	6800	11850
WET 1	Unspecified finfish	Bins	-	2	2

Appendix 3: NZ Aerial Mapping Ltd. images used in construction of Figure 46. Numerals 1–43 and 1–82 refer to the sites shown.

Early 1950s

1	1366/84	11	542/8	21	544/14	31	543/22	41	542/16
2	540/97	12	541/70	22	543/16	32	543/22	42	541/79
3	540/95	13	541/71	23	543/16	33	542/22	43	542/25
4	540/95	14	543/9	24	544/16	34	542/21		
5	541/69	15	544/8&9	25	543/19	35	543/22		
6	541/69	16	545/53	26	543/20	36	542/19		
7	1541/68	17	546/77	27	543/20	37	542/19		
8	1366/76	18	546/77	28	543/21	38	541/74&75		
9	541/64	19	545/55	29	543/21	39	541/74&75		
10	541/67	20	544/13&14	30	543/22	40	541/74&75		

1959-61

1	2786/1&2785/6	11	2604/7&2787/1	21	2787/2	31	2604/11	41	2789/3	51	2607/1&2	61	2789/1	71	2790/1	81	2789/2
2	2786/1&2785/6	12	2604/7&2787/1	22	2787/2	32	2788/2	42	2789/3	52	2607/1&2	62	2789/1	72	2790/2	82	2789/2
3	2786/1&2785/6	13	2604/7&2787/1	23	2787/2&3	33	2788/2	43	2789/3	53	2607/1&2	63	2789/1	73	2791/1		
4	2786/1&2785/6	14	2604/7&2787/1	24	2787/2&3	34	2788/2	44	2789/3	54	2607/1&2	64	2789/1	74	2791/1		
5	2786/1&2785/6	15	2787/1	25	2787/1&2	35	2788/2	45	2789/3	55	2607/1&2	65	2789/1	75	2791/1		
6	2786/1&2785/6	16	2787/1&2	26	2787/1&2	36	2788/2	46	2789/3	56	2789/1	66	2789/1	76	2789/2		
7	2787/1	17	2787/1&2	27	2604/10	37	2788/2	47	2607/1&2	57	2789/1	67	2789/1	77	2789/2		
8	2787/1	18	2787/1&2	28	2604/10	38	2789/3	48	2607/1&2	58	2789/1	68	2789/1	78	2789/2		
9	2785/3&4	19	2787/1&2	29	2604/10	39	2789/3	49	2607/1&2	59	2789/1	69	2789/1	79	2789/2		
10	2785/3&4	20	2787/2	30	2604/11	40	2789/3	50	2607/1&2	60	2789/1	70	2789/1	80	2789/2		

Appendix 4: Identification of aerial images used in analysis for Table 6. Early 1940s, images (presumably N.Z. Air Force) held by Department of Conservation Kerikeri; Before 1951, Whites Aviation Ltd. (National Library) images; Early 1950s, images part of NZ Aerial Mapping Ltd. (NZAM) Survey No. 209; 1951-55, Whites Aviation Ltd. (National Library) images; 1959-61, images part of NZAM Survey No. 1223; 1970–72, images part of NZAM S.N. 3406; 1976–79, images part of NZAM S.N. 5006; 1980–81, images part of NZAM S.N. 5651; 1981–82, images part of NZAM S.N. 5932A; Kerr, image held by Kerr & Associates, Kamo; OS 20/20, November 2009 Ocean Survey 20/20 aerial images (NZAM SN50765X); No, little or no kelp obvious; *, no image available/examined, or image held not useful.

	Site	Early 1940s	Before 1951	Early 1950s	1951–55	1959–61	1970–72	1976–79	1980–81	1981–82	1993 (Kerr)	2005 (Kerr)	2009 (OS 20/20; Kerr)
1	Tapuatahi	*	*	1365-75 & 76	*	2785-3	4473-1	*	*	*	*	*	DSC_0136
2	Te Tii	*	*	1366-77	*	*	*	*	*	*	*	*	2216, 2316
3	Mataka	*	*	1366-84	*	*	*	*	*	*	*	*	2334
4	Whale	*	*	*	*	2786-1	4475-11	*	*	*	*	DSC 0674	2635-2637
5	Rangihoua	*	*	540-95	*	2786-1	4475-9	5006-O3-A	5651 C15	*	*	DSC0673	2634
6	Te Pahi	*	*	540-94; 541-69	*	*	4475-8	*	*	*	*	*	2730-2731 2829-2831
7	Poraenui	*	*	1541-68	*	*	4476-7	*	*	*	*	*	2826, 2926, 2927, 3208
8	Akeake	*	*	541-67	*	*	*	*	*	*	*	*	2924
9	Doves	*	*	541-65	*	*	*	*	*	*	*	*	3021, 3022
10	Hauparua West	*	*	541-64	*	*	*	*	*	*	*	*	3218-3220
11	Waireka	*	*	542-8	*	2787-1	4478-7	*	*	*	*	*	3326, 3327
12	Moturoa North	*	*	*	*	2787-2	4477-9	*	*	*	*	*	3230-3234
13	Veronica	*	*	546-77		*	*	*	*	*	*	*	4736, 4837
14	Oneroa	*	1419849	544-13	1458949	2788-2	4480-13	*	*	*	No	*	3940, 4040-4042
15	Oneroa to Paroa	*	*	*	*	2788-1, 2789-3; 2606-1	4481-19	5006 J1 C(1)	5651 F1	5932A J42	*	*	4043, 4044, 4144-4146, 4247
16	Kahuwera	*	*	544-16	*	2606-1	*	*	*	*	*	*	4148-4150
17	Motukauri	*	*	*	*	2789-3; 2606-1	4479-16; 4480-15	*	*	*	*	*	3850, 3950, 3901
18	Omarino	*	*	543-20	*	*	4480-18	5006 J3 D(1)	*	*	*	*	3806-3809
19	Omakiwi	*	*	543-22	1458966	*	4479-22	5006 J3 D(1)	*	*	*	*	3711, 3810, 3811, 3710
20	Rawhiti	*	*	542-21	1269863, 1269872	2607-1	4478-21	5006 J2	5651 J7	*	*	*	3513-3515, 3613, 3614
21	Oke	*	1419855	542-22	*	2607-1	4478-23	*	*	5932A I46	*	*	3416, 3515
22	Outu	*	*	542-25	*	2790-1	*	*	5651 J11	*	*	*	3423, 3523
23	Whangamumu	*	*	*	*	2791-1	4479-29	*	5651 K-2	*	*	*	3722, 3822, 3921
24	Otarepo	235 A-1		543-16	*	2789-3	4479-15	*	5651 J1	*	No	DSC0686	3645
25	SE Motuarohia	235 A-3	1419851	543-16	*	2789-2	4479-16	5006 J1 C(2)	*	*	No	DSC0691	3649
26	NE Moturua	*	*	*	*	2789-1	4478-16	5006 J2	5651 J4	*	*	*	3302, 3303, 3402-3404
27	Poroporo	*	*	543-21	1458964	2789-1; 2607-1	4478-19	5006 J3	5651 J6, 5651 J5	*	*	*	3507, 3508, 3608
28	Te Akeake Pt	*	*	*	*	2789-1	4477-24	5006 J2	5651 I2, 5651 J5	*	*	*	3306, 3307
29	Okahu Ch	*	*	541-75	*	2789-1	4477-23	5006 J2	5651 I1	*	*	*	3104, 3105, 3205

Appendix 5. The primary resource for estimating the modern extent of urchin barrens was the November 2009 Ocean Survey 20/20 aerial images of Land Information New Zealand (NZ Aerial Mapping Ltd. SN50765X). For each .tif image (around 25 MB, and with a footprint approximately 0.5 km east-west and 0.75 km north-south), urchin-barren presence was marked red; green was where the kelp forest appeared to be intact, and blue showed places where it was unclear one way or the other whether there had been kelp loss (usually because of shadow or the steepness of the slope). Adjacent images were joined, and urchin-barren presence interpolated over the broader area. The example given below is for Moturahurahu Island (AV30_3416) on Te Rawhiti Peninsula (*see* Figure 58).