A Literature Review on the Poor Knights Islands Marine Reserve

Photo: Aerial view of the Poor Knights Islands looking from the south (Keith Hawkins, Department of Conservation).

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Executive Summary

The Poor Knights Islands Marine Reserve is renowned for its unique assemblage of marine flora and fauna, its rich diversity of marine life, and unusual subtidal habitats, and consequently has been the focus of a number of scientific research studies. The last comprehensive literature review of the Poor Knights Islands Marine Reserve was by Kelly (1983). Over the last 25 years significant new information has been generated on the habitats of the Poor Knights Islands and the marine flora and fauna that inhabit them. The overall aim of this project is to collate and review scientific information that has been generated on the Poor Knights Islands Marine Reserve since 1983 to increase our overall understanding of the Poor Knights Islands ecosystem. However, owing to funding constraints the document will be written in stages as time and funding allows. This first report covers the physical environment of the reserve, marine vertebrates, fish monitoring, marine macroalgae, subtidal habitats, and biosecurity aspects.

The Poor Knights Islands (Tawhiti Rahi Island and Aorangi Island) lie slightly west of the East Auckland Current, and thus are influenced by waters of higher temperature, salinity, and clarity than the waters around the mainland or at other islands on the northeastern coastline. Larvae and eggs of numerous subtropical species are transported to the Poor Knights Islands from northern regions, and consequently there is a rich diversity of subtropical flora and fauna within the reserve. One hundred and eighty six species of fish have been recorded from the Poor Knights Islands, of which, approximately 38% are exotic, subtropical species. A number of these subtropical species are transient visitors that settle at the Poor Knights Islands in mid summer but are unable to survive over winter. Other subtropical species fail to establish successful breeding populations in New Zealand, relying on the continual transport of eggs and larvae from outside New Zealand to sustain population numbers at the Poor Knights Islands. Thus, the population size of these non-breeding species at the Poor Knights Islands varies greatly over time. Fish monitoring studies at the Poor Knights Islands show that fish abundances vary greatly on both temporal and spatial scales, with temporal patterns, in some cases, spanning several years. Following the establishment of full marine reserve status at the Poor Knights Islands in 1998 the abundance of fish species targeted by fishers such as snapper (*Pagrus auratus*) and pink maomao (*Caprodon longimanus*), increased by more than 100% in four years, whilst the abundance of most non-targeted species did not increase. However, by 2007 snapper was the only monitored species at the Poor Knights Islands to show a significant increase in abundance over 1998 abundance levels. Four species; banded wrasse (*Notolabrus fucicola*), butterfish (*Odax pullus*), crimson cleanerfish (*Suezichthys aylingi*), and pigfish (*Bodianus vulpinus*); showed a significant decrease in abundance since 1998, and the abundance of 19 other species was not significantly different between 1998 and 2007.

Ten marine mammal species have been recorded from waters around the Poor Knights Islands, consisting of five baleen whales, four toothed whales/dolphins, and the New Zealand fur seal. The most common marine mammals at the Poor Knights Islands are the common dolphin (*Delphinus*

delphis), the bottlenose dolphin (*Tursiops truncatus*), and New Zealand fur seals (*Arctocephalus forsteri*). Four turtle species also occur incidentally at the Poor Knights Islands but do not reside or breed in New Zealand waters.

One hundred and twenty one species of macroalgae have been recorded from the Poor Knights Islands, of which, 62 are intertidal species and 79 are subtidal species (20 species occur both intertidally and subtidally). However, the macroalge of the Poor Knights Islands has not been thoroughly studied and it is likely that this is a conservative estimate. The marine flora of the Poor Knights Islands is an unusual mixture of species common to northeastern New Zealand, subtropical species, and southern New Zealand species. This unlikely mixture of species is probably a result of the location of the islands, the influence of the East Auckland Current, and the high degree of wave exposure at certain locations around the islands. Several rare species of macroalgae are found at the Poor Knights Islands incuding *Gelidium allani, Palmophyllum umbracola,* and *Pedobesia clavaeformis*. A general pattern of zonation exists on intertidal rocky habitats. *Porphyra columbina* dominates the upper littoral zone, followed by *Apophlaea sinclairii* around mid-tide level, and then a band of thin encrusting red or coralline algae. *Xiphophora chondrophylla* dominates the lower intertidal zone on moderately exposed shores, but is replaced by *Durvillea antarctica* when wave exposure is extreme. In subtidal habitats *Carpophyllum angustifolium* and *C. maschalocarpum* dominate shallow waters (< 2 m), *Lessonia variegata* and red turfing algae dominate the 4–6 m depths, and *Ecklonia radiata* dominates deeper waters (6–18 m).

Schiel (1984) initially identified five subtidal habitat types at the Poor Knights Islands in waters less than 30 m deep; vertical reef walls and caves, macroalgal reef habitats, coralline flats/echinoid-dominated reefs, broken rock, and sand. Habitat mapping studies conducted by the National Institute of Water and Atmospheric Research (NIWA) at the Poor Knights Islands have identified two additional, deep water habitats; encrusting corallines, and Centro barrens (named after the moderately high abundances of the Australian sea urchin, *Centrostephenus rodgersii*). The vertical reef wall habitat and macroalgal reef habitat have been well described in the literature, but there is currently a paucity of available information on the other habitat types. NIWA's subtidal habitat mapping studies to be published in 2009 will provide us with detailed information on the other subtidal habitats at the Poor Knights Islands.

The Poor Knights Islands Marine Reserve is a high value area of national significance and the unique marine assemblages present in the reserve need to be protected from modification by invasive pest organisms. To date the only likely invasive pest species recorded from the Poor Knights Islands is the parchment tubeworm, *Chaetopterus* sp., though it is uncertain whether this species is endemic or introduced. The introduced clubbed tunicate, *Styela clava*, has been found in the nearby Tutukaka marina and good management practices need to be put in place to prevent the introduction of invasive species to the Poor Knights Islands.

In summary, this updated literature review of the Poor Knights Islands Marine Reserve has reviewed and interpreted over 60 new references relevant to the marine biota of the Poor Knights Islands since Kelly's 1983 bibliography. Significant new research has been conducted on fish abundance, fish diets, subtidal macroalgal communities, and vertical reef wall communities. Future work will review the biological marine environment, marine invertebrates, marine seabirds, and human use of the Poor Knights Islands marine reserve.

1. Introduction

The Poor Knights Islands Marine Reserve located 24 km off the northeastern coastline of New Zealand (Fig. 1) covers approximately 1890 ha of water, encompassing the waters within 800 m of the Poor Knights Islands (Tawhiti Rahi Island and Aorangi Island) and associated islets, and also includes waters within 800 m of the High Peak Rocks (Pinnacles or Poor Knights Rocks) and Sugar Loaf Rock that lie approximately 8 km to the south of the Poor Knights Islands (Fig. 2 & 3). The region was designated a marine reserve on 18th February 1981. At that time commercial fishing was prohibited but restricted recreational fishing was permitted, pursuant to section 3(3) of the Marine Reserves Act, using drift-line, trolling, or spear guns, of certain species of fish[1] in most areas, with the exception of two 'no-take' areas around Nursery Cove Reef/Bartle's Bay/Maroro Bay and Frasers Bay/South Harbour. In October 1998 the provisions that permitted restricted recreational fishing at the Poor Knights Islands Marine Reserve expired and the reserve became a fully protected marine reserve.

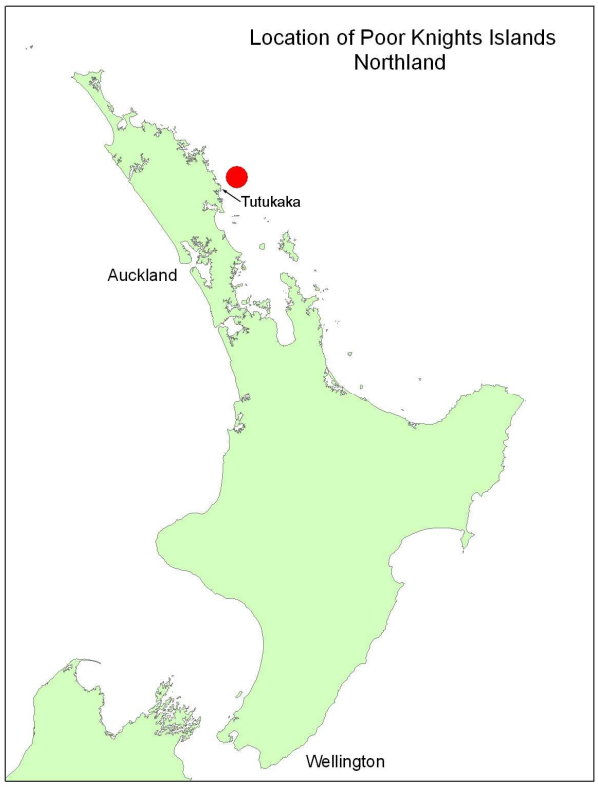

Figure 1 **Location of the Poor Knights Islands Marine Reserve (red dot) (Map: Department of Conservation, Northland Conservancy).**

[1] Recreational fishing of snapper, kingfish, trevally, mackerel, kahawai, shark, billfish, tuna, barracouta, and pink maomao was permitted prior to October 1998.

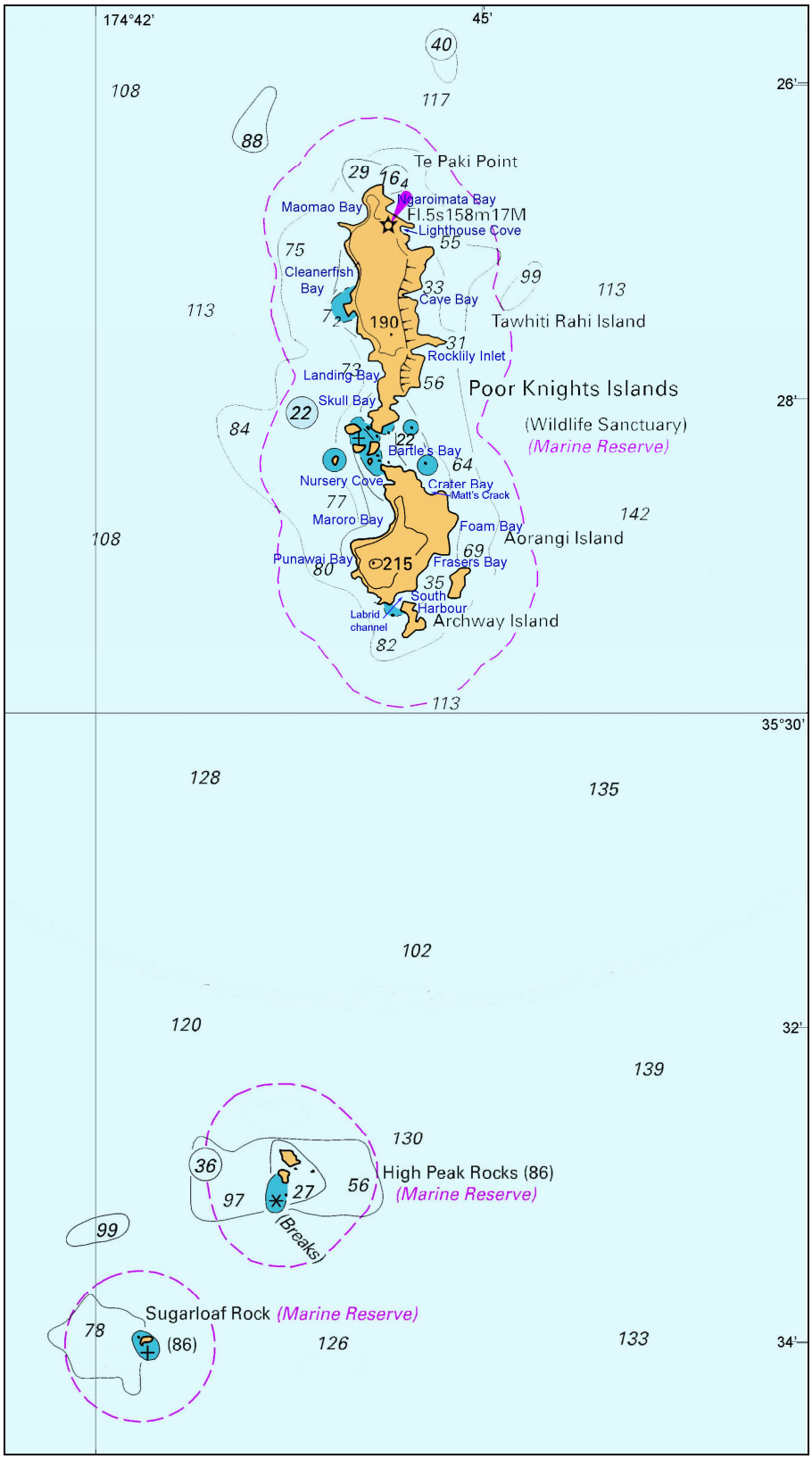

Figure 2 **The Poor Knights Islands Marine Reserve. The purple dashed line shows the reserve boundaries. (Map adapted from Land Information NZ chart NZ521).**

Figure 3 **Tawhiti Rahi Island (foreground) and Aorangi Island. The High Peak Rocks (Pinnacles) and Sugar Loaf Rock can be seen in the distance. (Photo: Keith Hawkins, Department of Conservation).**

The Poor Knights Islands Marine Reserve has a unique assemblage of marine flora and fauna owing to a number of factors including; 1) the East Auckland current that originates from the direction of Lord Howe Island and brings warm water and subtropical larvae to the reserve, 2) the steep, rocky, subtidal topography of the islands, 3) oceanic salinity levels, and 4) high water clarity. The combination of these environmental factors creates a unique environment that supports an unusual biological community at the Poor Knights Islands that has a strong subtropical component.

The Poor Knights Islands Marine Reserve has been the focus of a number of scientific research studies owing to the uniqueness of its flora and fauna and their protected status. However, the last comprehensive literature review of the Poor Knights Islands Marine Reserve was by Kelly in 1983 entitled “A Bibliography and Literature Review for the Poor Knights Islands Marine Reserve”. Over the last 25 years significant new information has been generated on the habitats of the Poor Knights Islands and the marine flora and fauna that inhabit them. While some of this information has been published much of the information resides in unpublished scientific reports and grey literature. The overall aim of this project is to collate and review scientific information that has been generated on the Poor Knights Islands Marine Reserve since 1983 to increase our overall understanding of the Poor Knights Islands ecosystem. The

eventual aim is to provide a single, comprehensive document on the Poor Knights Islands Marine Reserve that can be used to assist managers of the reserve to make appropriate management decisions. However, owing to funding constraints the document will be written in stages as time and funding allows. This first report covers the physical environment of the reserve, marine vertebrates, marine macroalgae, subtidal habitats, and biosecurity aspects.

2. The physical environment

2.1 Seabed geology and bathymetry

The Poor Knights Islands are located on New Zealand's northeastern continental shelf at 35°28'S, 174°44'E. The volcanic origin of the Poor Knights Islands is obvious in the geology of the islands and the seabed. The islands are extremely steep, with cliffs reaching over 200 m above and extending over 100 m below sea level. The seabed drops sharply away from the coastline along much of the island, reaching depths of over 100 m within the 800 m radius of the marine reserve. A shallow region joins Tawhiti Rahi Island and Aorangi Island, with depths typically less than 30 m (Fig. 4). Shallow, gently sloping rocky reefs exist at South Harbour, Maroro Bay, Nursery Cove, Bartle's Bay, Cleanerfish Bay, and Lighthouse Cove (Fig. 2). Away from the steep gradient of the islands the continental shelf is predominantly regular and flat, with the occasional peak rising sharply from the sea floor. The continental shelf edge occurs approximately 10 km offshore of the islands at approximately 150–180 m depth (Eade, 1967; Stewart, 2001).

Medium to coarse shelly sand is the predominant sediment type on the inner shelf around the Poor Knights Islands. Finer sand is present in areas of Maroro Bay and Skull Bay. The sediment is predominately bioclastic[2] with a small lithic[3] component and almost no mud. The bioclastic component of the sediment primarily consists of skeletal debris from bryozoans and molluscs, with smaller percentages of barnacle, brachiopod, echinoid, and scleractinian coral skeletons (Brook *et al.*, 2001). Further out towards the continential slope, the grain size of sediments differs significantly north and south of the Poor Knights Islands. North of the islands, coarse, shelly sands graduate into well-sorted fine sands on the shelf and upper slope down to about 500 m, which graduate into progressively finer deposits in deeper water. South of the islands, coarse shelly sands grade rapidly into sandy mud and mud deposits on the central

[2] Skeletal carbonate sands
[3] Rock/stone

shelf. On the outer shelf fine sands graduate into finer deposits in deeper water (Eade, 1967).

Most of the sediment on the continental shelf of northeastern New Zealand has a carbonate content of less than 40%. However, carbonate concentrations close inshore around the Poor Knights Islands are higher than average owing to the high proportion of bioclastic sands. East of the Poor Knights Islands, a region beyond the shelf edge at 300–500 m depth has an usually low percentage (<20%) of carbonate in the sediment owing a high percentage of volcanic glass (Eade, 1967).

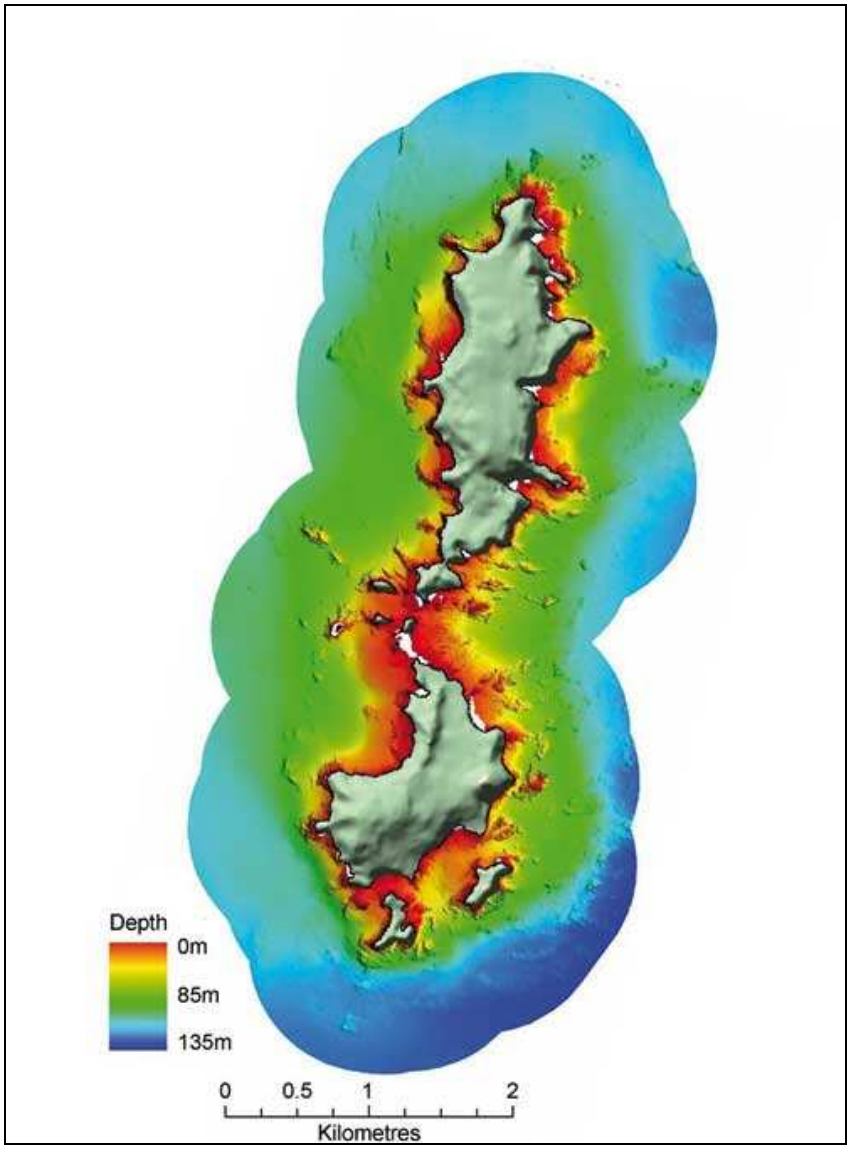

Figure 4 **Bathymetry map of Poor Knights Islands produced by high resolution multi-beam sonar. The edge of the coloured area aligns with the reserve boundary (Map reproduced with permission from Morrison *et al.*, 2007).**

2.2 Hydrology of the area

The East Australian Current forms the principle southward flowing current along the east coast of Australia. This very strong current, originating in the Coral Sea travels south to approximately Brisbane where a major branch turns eastward across the Tasman Sea towards New Zealand. The current, now called the East Auckland Current, passes north of New Zealand and flows down the northeastern coastline of New Zealand to East Cape following approximately the edge of the continental shelf (Fig. 5), at speeds of between 0.18–0.3 m/s (Harris, 1985). This current of warmer oceanic waters is usually held offshore by topographic trapping over the continental shelf (Sharples, 1997). Thus, a band of 'resident' hydrologically different coastal water usually exists between the mainland and the East Auckland Current. On occasions during periods of intense stratification in spring–summer, strong southeasterly winds may drive the clear, warm oceanic waters of the East Auckland Current closer towards the mainland resulting in a rapid increase in water temperatures (~2°C) and salinity (Sharples, 1997). This summer event, known by local communities as "the blue water coming in", transports oceanic plankton and planktonic life-stages of subtropical species closer towards the northeastern coastline of New Zealand (Zeldis *et al.*, 1995; Sharples, 1997).

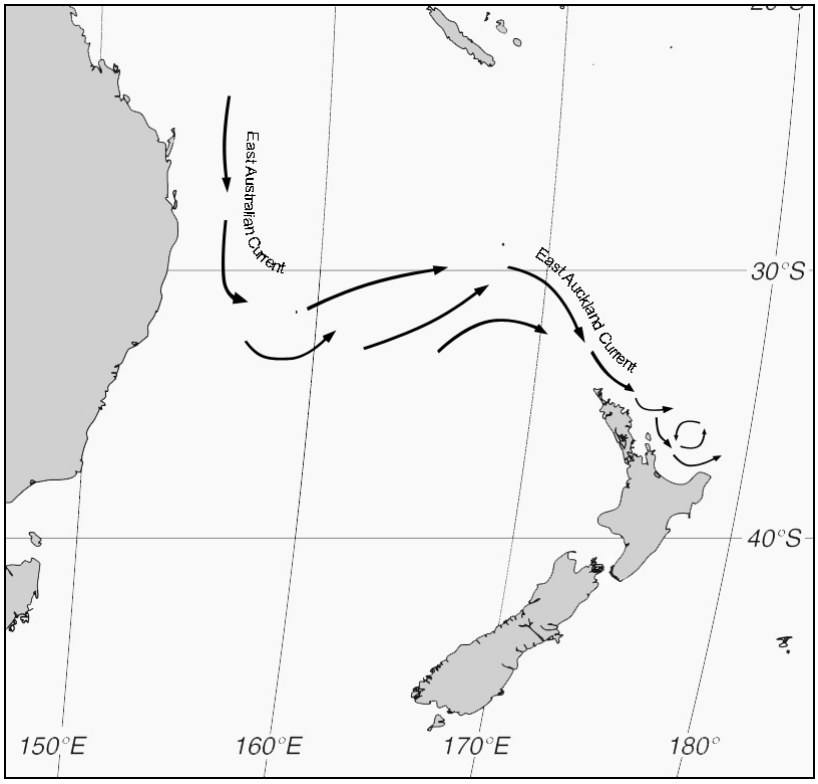

Figure 5 Generalised path of the East Australian and East Auckland currents.

The Poor Knights Islands are situated 5–10 km west of the shelf-break sea surface temperature front that separates the cooler coastal waters from the East Auckland Current (Stewart, 2001), and thus, the islands are more frequently influenced by waters of higher temperature, salinity, and clarity[4] than the waters around the mainland or at other islands on the northeastern coastline[5]. On certain days sea surface temperature (SST) at the Poor Knights Islands can be 2°C higher than on the adjacent coastline (Grace, 1983), but long-term SST data collected by satellite mounted Advanced Very High Resolution Radiometer shows much smaller differences in average SST between the Poor Knights Islands and the adjacent coastline. Comparison of the average monthly SST for the Poor Knights Islands and the Tutukaka coastline between 1993 and 2007 show a that the SST around the Poor Knights Islands is, on average, only 0.2°C higher than the SST of the Tutukaka coastline (NIWA Satellite Data Services[6], unpublished data). The largest temperature differences between the two regions appears to be during the winter months (July–September), when average SST at the Poor Knights Islands are 0.5–0.8°C higher than along the Tutukaka coastline (Fig. 6). Maximum SST of around 22°C occur in February at the Poor Knights Islands and minimum SST of around 13°C occur in September (NIWA Satellite Data Services, unpublished data). The water is thermally stratified with surface temperatures typically 5°C higher than temperatures at 100 m depth. The depth of the surface mixed layer varies but typically ranges between 30–50 m (Stewart, 2001).

[4] Water clarity at the Poor Knights can exceed 30 m (Grace, 1983)
[5] It should be noted that pronounced cold water upwellings at North Cape and the Three Kings Islands override the strong subtropical influence of the East Auckland Current that one might expect in these more northern regions (Kelly, 1983).
[6] http://www.niwascience.co.nz/services/paid/sat

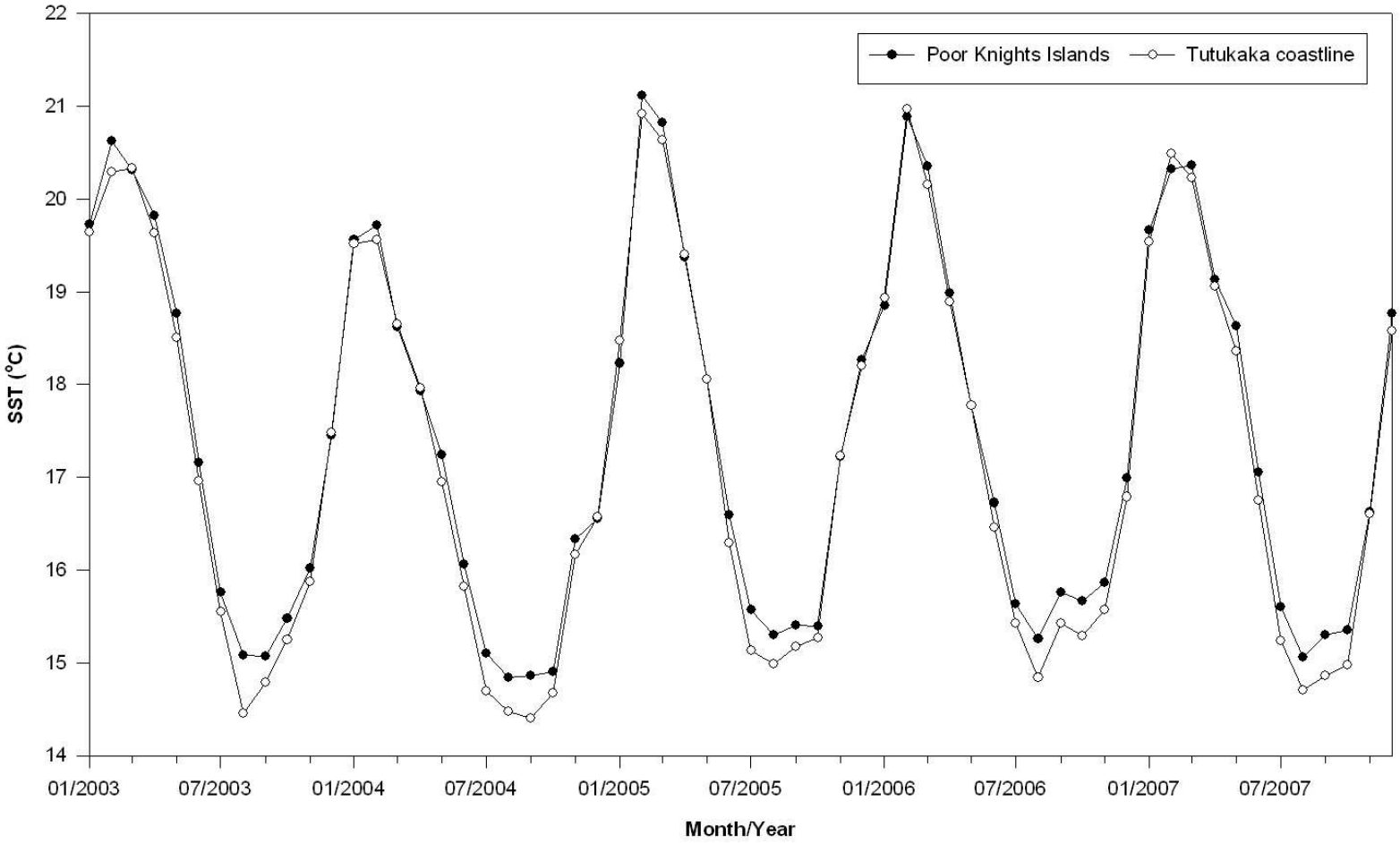

Figure 6 Average monthly Sea Surface Temperatures (SST) for the Poor Knights Islands and the Tutukaka coastline between 2003 and 2007 (Data from NIWA Satellite Services).

The East Auckland current is the main non-tidal current that affects the Poor Knights Islands, flowing predominantly southeast with a mean speed of 0.2 m/s (Sharples & Greig, 1998). Waters around the Poor Knights Islands are also affected by onshore internal waves and a strong north–south tidal current, which reverses direction depending on the state of the tide (Kingsford & MacDiarmid, 1988). Internal waves are generated by the interaction of tides, stratification, and bathymetry at the continental shelf edge. These waves facilitate vertical mixing of the water column drawing nutrients from deeper waters to the surface, and may provide a mechanism for the shoreward transport of larvae and plankton. The main tide-driven internal wave travels towards the Poor Knights Islands at a mean speed of 0.3 m/s and has a minimum travel time of 30 hours from the closest generation region (Stevens & Abraham, 2005).

Spring tides at the Poor Knights Islands have a maximum range of around 2 m and neap tides have a range of around 1 m (Stevens & Abraham, 2005).

3. The Vertebrates

3.1 Fish

There is a rich diversity of fish fauna at the Poor Knights Islands with around 186 species recorded from within the marine reserve. Many of these species are widespread around northern New Zealand including snapper (*Pagrus auratus*), tarakihi (*Nemadactylus macropterus*), goatfish (*Upeneichthys lineatus*), red gurnard (*Chelidonichthys kumu*), red moki (*Cheilodactylus spectabilis*), leatherjacket (*Parkia scaber*), kingfish (*Seriola lalandi*), koheru (*Decapterus koheru*), and trevally (*Pseudocaranx dentex*). Conversely, a number of common coastal fishes, such as spotties (*Notolabrus celidotus*), parore (*Girella tricuspidata*), and triplefins (*Forsterygion lapillum, F. malcomi, F. varium*), are infrequent around the Poor Knights Islands. Brook (2002) suggested that the low abundance of these common coastal fish was because of the isolated offshore location and the lack of shallow, sheltered habitats at the Poor Knights Islands. There is also a distinctive subtropical group of fish that are present at the Poor Knights Islands. This group includes many colourful reef fishes such as the toadstool grouper (*Trachypoma macracanthus*), blue knifefish, (*Labracoglossa nitida*), gold ribbon grouper (*Aulacocephalus temmincki*), and the striped boarfish (*Evistias acutirostris*), which also occur around Lord Howe Island, Norfolk Island, and eastern Australia. These exotic, subtropical fishes form a conspicuous element at the Poor Knights Islands comprising around 38% of the total number of fish species recorded from the Poor Knights Islands (Brook, 2002). In recent years a number of excellent photograph references of the fish fauna of Poor Knights Islands have been published (Doak, 1991; Edney, 2001; Anthoni, 2007).

The tropical and subtropical element of the Poor Knights Islands fish fauna is continually changing. While some tropical species are able to breed and recruit around the Poor Knights Islands, other species, such as the moon wrasse (*Thalassoma lunare*), the sunset wrasse (*T. lutescens*), the long-nosed butterfly fish *(Forcipiger flavissimus)*, and the lionfish *(Pterois volitans)* appear to be transient visitors. These species are probably transported to the Poor Knights Islands as eggs or larvae via the East Auckland Current from the broad Indo-Pacific region, including Norfolk Island, Lord Howe Island, and the Kermadec Islands (Francis, 1993), and settle at the Poor Knights Islands during mid-summer, but are unable to survive over winter. Other species apparently fail to establish successful breeding populations in New Zealand, presumably relying on the continual transport of eggs and larvae from outside New Zealand to sustain population numbers at the Poor Knights Islands. Thus, the population size of these non-breeding species varies greatly at the Poor Knights Islands. For example, four species of labrids, *Anampses elegans, Coris picta,*

Pseudojuloides elongatus, and *Suezichthys arquatus*, were relatively common in the Poor Knights Islands prior to 1974, but declined to extinction within the marine reserve by 1979, and were rare or absent until 1988 when there was a strong recruitment event (Schiel, 1984; Choat *et al.*, 1988) (See Section 3.1.1 for more details). Table 1 lists all the fish species recorded from the Poor Knights Islands Marine Reserve.

Table 1 Fish species that have been recorded from the Poor Knights Islands Marine Reserve.

Family	Species	Common name	Reference
CLASS CHONDRICHTHYES			
Order Carcharhiniformes			
Carcharhinidae	*Carcharhinus brachyurus*	Bronze whaler	Ayling & Schiel (2003)
	Prionace glauca	Blue shark	Froese & Pauly (2008)
Scyliorhinidae	*Cephaloscyllium isabellum*	Carpet shark	Edney (2001)
Sphyrnidae	*Sphyrna zygaena*	Hammerhead shark	Doak (2001c)
Triakidae	*Galeorhinus galeus*	School shark	Denny *et al*. (2003)
Order Hexanchiformes			
Hexanchidae	*Notorynchus cepedianus*	Broadnose seven gill shark	D. Abbot (unpub.)
Order Orectolobiformes			
Rhincodontidae	*Rhincodon typus*	Basking whale shark	Doak (2002)
Order Lamniformes			
Alopiidae	*Alopias vulpinus*	Thresher shark	Abbott & Rousseau (2002)
Isuridae	*Isurus oxyrinchus*	Mako shark	Abbott & Rousseau (2002)
Order Myliobatiformes			
Dasyatidae	*Dasyatis brevicaudata*	Short-tailed stingray	Le Port *et al.* (2008)
	Dasyatis thetidis	Long-tailed stingray	Edney (2001)
Mobulidae	*Manta birostris*	Manta ray	Duffy & Abbott (2003)
Myliobatidae	*Myliobatis tenuicaudatus*	Eagle ray	Edney (2001)
Order Torpediniformes			
Torpedinidae	*Torpedo fairchildi*	NZ Torpedo/Electric ray	Abbott & Rousseau (2002)
CLASS ACTINOPTERYGII			
Order Anguilliformes			
Muraenidae	*Enchelycore ramosa*	Mosaic moray	Edney (2001)
	Gymnothorax nubilus	Grey moray	Edney (2001)
	Gynonthorax obesus	Speckled moray	Edney (2001)

Family	Species	Common name	Reference
	Gymnothorax prasinus	Yellow moray	Edney (2001)
	Gymnothorax prionodon	Motttled moray	Edney (2001)
Congridae	*Conger verreauxi*	Southern conger eel	Edney (2001)
	Conger wilsoni	Short-finned conger eel	Brook (2002)
	Gorgasia japonica	Garden eel	Ayling & Cox (1982); Doak (1991); Castle & Randall (1999)
Ophichthidae	*Ophisurus serpens*	Snake eel	Doak (2001a)
Order Aulopiformes			
Synodontidae	*Synodus doaki*	Common lizardfish	Schiel (1984)
	Synodus similis	Lavender lizardfish	Brook (2002)
Order Beloniformes			
Exocoetidae	*Cypselurus lineatus*	Flying fish	Doak (2001a)
Hemiramphidae	*Hyporhamphus ihi*	Piper	Brook (2002)
Scomberesocidae	*Scormberesox saurus*	Saurie	Kelly (1983)
Order Beryciformes			
Berycidae	*Centroberyx affinis*	Golden snapper	Edney (2001)
Trachichthyidae	*Optivus elongatus*	Slender roughy	Edney (2001)
Order Clupeiformes			
Engraulidae	*Engraulis australis*	Anchovy	Kingsford (1989)
Order Gadiformes			
Moridae	*Lotella rhacinus*	Rock cod	Brook (2002)
	Pseudophycis bachus	Morid cod	Kelly (1983)
	Pseudophycis barbata	Bastard cod	Brook (2002)
	Pseudophycis breviuscula	Red cod	Kelly (1983)
Order Gasterosteiformes			
Syngnathidae	*Hippocampus adominalis*	Seahorse	Doak (2001a)
	Hippocampus jugumus	Collared seahorse	Edney et al. (2006)
	Hippocampus sp.	Pygmy seahorse	Survey Seahorse 2000 (2005)
Order Gobiesociformes			
Gobiesocidae	*Dellichthys morelandi*	Urchin clingfish	Kelly (1983)
Order Lampriformes			
Regalecidae	*Regalecus glesne*	Oarfish	M. Conmee (unpub.)
Trachipteridae	*Trachipterus trachypterus*	Dealfish	W. Doak (unpub.)
Order Lophiiformes			
Antennariidae	*Antennarius sp.*	Frogfish	Dive Tutukaka (2008)
Order Perciformes			
Acanthuridae	*Acanthurus dussumieri*	Eyestripe surgeonfish	Francis & Evans (1992)

Family	Species	Common name	Reference
Aplodactylidae	*Aplodactylus arctidens*	Marblefish	Schiel (1984)
	Aplodactylus etheridgii	Notch-head marblefish	Schiel (1984)
Arripidae	*Arripis trutta*	Kahawai	Brook (2002)
Blenniidae	*Parablennius laticlavius*	Crested blenny	Edney (2001)
	Plagiotremus rhinorhynchos	Blue mimic blenny	Doak (2001a)
	Plagiotremus tapeinosoma	Mimie blenny	Edney (2001)
Callanthiidae	*Callanthias allporti*	Splendid sea perch	Schiel (1984)
	Callanthias australis	Magnificent splendid perch/Northern splendid perch	Brook (2002)
Carangidae	*Decapterus koheru*	Koheru	Edney (2001)
	Pseudocaranx dentex	Trevally	Edney (2001)
	Seriola lalandi	Kingfish	Edney (2001)
	Trachurus declevis	Jack mackerel	Kingsford (1989)
	Trachurus novaezelandiae	Horse mackerel	Brook (2002)
Chaetodontidae	*Amphichaetodon howensis*	Lord Howe coralfish	Schiel (1984)
	Forcipiger flavissimus	Yellow longnose butterflyfish	Francis *et al.* (1999)
Cheilodactylidae	*Cheilodactylus ephippium*	Painted moki	Edney (2001)
	Cheilodactylus fuscus	Red morwong	Kelly (1983)
	Cheilodactylus nigripes	Magpie morwong	Kelly (1983)
	Cheilodactylus spectabilis	Red moki	Choat & Ayling (1987)
	Nemadactylus douglasii	Porae	Choat & Ayling (1987)
	Nemadactylus macropterus	Tarakihi	Schiel (1984)
Chironemidae	*Chironemus marmoratus*	Hiwihiwi	Choat & Ayling (1987)
Cirrhitidae	*Cyprinocirrhites polyactis*	Lyetail hawkfish/ swallowtail hawkfish	Francis & Evans (1992)
Clinidae	*Cristiceps aurantiacus*	Crested weedfish	Battershill (1986)
	Ericentrus rubrus	Banded weedfish	D. Abbot (unpub.)
Coryphaenidae	*Coryphaena hippurus*	Mahi Mahi	Doak (2001c)
Creediidae	*Limnichthys polyactis*	longfinned sand diver	Battershill (1986)
Gemphylidae	*Thrysites atun*	Barracouta	Russell (1983)
Istiophoridae	*Makaira indica*	Black marlin	Kelly (1983)
	Makaira mazara	Pacific blue marlin	Kelly (1983)
	Tetrapturus audax	Striped marlin	Kelly (1983)
Kyphosidae	*Atypichthys latus*	Mado	Schiel (1984)
	Bathystethus cultratus	Grey knifefish	Brook (2002)
	Girella cyanea	Bluefish	Schiel (1984)
	Girella tricuspidata	Parore	Brook (2002)
	Kyphosus bigibbus	Grey seachub	Francis & Evans (1992)

Family	Species	Common name	Reference
	Kyphosus sydneyanus	Silver drummer	Schiel (1984)
	Labracoglossa nitida	Blue knifefish	Francis *et al.* (1999)
	Scorpis aequipinnis	Sea sweep	Kingsford & MacDiarmid (1988)
	Scorpis lineolatus	Silver sweep	Edney (2001)
	Scorpis violaceus	Blue Maomao	Edney (2001)
Labridae	*Anampses elegans*	Elegant wrasse	Ward & Roberts (1986)
	Bodianus flavipinnis	NZ fox fish	Doak (1991; 2003)
	Bodianus unimaculatus[7]	Red pigfish	Edney (2001)
	Bodianus vulpinus	Pigfish	Choat *et al.* (1988)
	Coris dorsomacula	Pink-lined wrasse	Brook (2002)
	Coris picta	Combfish	Edney (2001)
	Coris sandageri	Sandager's wrasse	Ward & Roberts (1986)
	Notolabrus celidotus[8]	Paketi (spotty)	Ward & Roberts (1986)
	Notolabrus fucicola[8]	Banded wrasse	Ward & Roberts (1986)
	Notolabrus inscriptus[8]	Green wrasse	Ward & Roberts (1986)
	Pseudojuloides elongatus	Long green wrasse	Ayling & Russell (1977)
	Pseudolabrus luculentus	Orange wrasse	Ward & Roberts (1986)
	Pseudolabrus miles	Scarlet wrasse	Ward & Roberts (1986)
	Suezichthys arquatus	Rainbow fish	Francis & Evans (1992)
	Suezichthys aylingi	Crimson cleanerfish	Ward & Roberts (1986)
	Thalassoma amblycephalum	Blueheaded wrasse	Francis *et al.* (1999)
	Thalassoma lunare	Moon wrasse	Doak (2001a)
	Thalassoma lutescens	Sunset wrasse	Francis *et al.* (1999)
Latridae	*Latridopsis ciliaris*	Blue moki	Edney (2001)
	Latridopsis forsteri	Copper moki	Edney (2001)
Mugilidae	*Aldrichetta forsteri*	Yellow-eyed mullet	F. Brook (unpub.)
Mullidae	*Parupeneus spilurus*	Blackspot goatfish	Francis & Evans (1992)
	Upeneichthys lineatus	Goatfish/ red mullet	Choat & Ayling (1987)
	Upeneus francisi[9]	Bat-tailed goatfish	Randall & Gueze (1992)
Notothenidae	*Notothenia angustata*	Maori chief	Denny *et al*. (2003)
Odacidae	*Odax pullus*	Butterfish	Schiel (1984)
	Odax cyanoallix	Bluefinned butterfish	Brook (2002)
Pempheridae	*Pempheris adspersus*	Big eye	Edney (2001)
Pentacerotidae	*Evistias acutirostris*	Striped boarfish	Brook (2002)

[7] *Bodianus oxycephalus* in Ward & Roberts (1986) is believed to be *B. unimaculatus* (F. Brooks, pers. comm.).
[8] Genus previously *Pseudolabrus*
[9] Early records of *Upeneus francis* are believed to have been mis-identified as *Upeneus bensasi* (F. Brooks, pers. comm.)

Family	Species	Common name	Reference
	Paristiopterus labiosus	Giant boarfish	Doak (2001a)
	Zanclistius elevatus	Long-finned boarfish	Edney (2001)
Percichthyidae	*Polyprion moeone*	Bass	Kelly (1983)
	Polyprion oxygenios	Hapuku	Beentjes & Francis (1999)
Plesiopidae	*Acanthoclinus littoreus*	NZ rockfish	Battershill (1986)
Pinguipedidae	*Parapercis binivirgata*	Red-banded weever	Kelly (1983)
	Parapercis colias	Blue cod	Brook (2002)
Pomacentridae	*Chromis abyssicola*	Deepsea damselfish	Gregory (2008); D. Freeman, DOC, pers. comm.
	Chromis dispilus	Demoiselle	Edney (2001)
	Chromis fumea	Yellow demoiselle	Edney (2001)
	Chromis hypsilepis	One spot puller	Brook (2002)
	Chrysiptera rapanui	Easter damselfish	Francis *et al.* (1999)
	Parma alboscapularis	Black angelfish	Ward & Roberts (1986)
	Parma kermadecensis	Kermadec scalyfin	Francis *et al.* (1999)
	Parma polylepis	Banded Parma	Francis (1988)
	Stegastes gascoynei	Yellow damselfish	Doak (2001a)
Scaridae	*Leptoscarus vaigiensis*	Marbled parrotfish	Kelly (1983)
Scombridae	*Acanthocybium solandri*	Wahoo	Francis *et al.* (1999)
	Scomber australasicus	Blue mackerel	Kingsford (1989)
	Thunnus alalunga	Albacore tuna	Kelly (1983)
	Thunnus albacares	Yellow fin tuna	Kelly (1983)
	Thunnus obesus	Bigeye tuna	Kelly (1983)
	Katsuwonus pelamis	Skipjack tuna	Kelly (1983)
Serranidae	*Acanthistius cinctus*	Yellow banded perch	Edney (2001)
	Acanthistius littoreus	Black rockfish	Doak (2001a)
	Aulacocephalus temmincki	Gold-ribbon grouper	Brook (2002)
	Caesioperca lepidoptera	Butterfly perch	Schiel (1984)
	Caprodon longimanus	Pink Maomao	Edney (2001)
	Epinephelus daemelii	Saddled grouper/ Black spotted grouper	Brook (2002)
	Epinephelus lanceolatus	Giant grouper/ Queensland grouper	Francis & Evans (1992)
	Epinephelus octofasiatus	Convict grouper	D. Abbot (unpub.)
	Epinephelus rivulatus	Halfmoon grouper	Brook (2002)
	Hypoplectrodes huntii[10]	Red banded perch	Schiel (1984)
	Hypoplectrodes sp.	Half banded perch	Brook (2002)

[10] Previously *Ellerkeldia huntii*

Family	Species	Common name	Reference
	Trachypoma macracanthus	Toadstool grouper	Edney (2001)
Sparidae	*Pagrus auratus*	Snapper	Schiel (1984)
Sphyraenidae	*Sphyraena* cf. *acutipinnis*	Sharp-finned barracuda	Francis *et al.* (1999)
Tripterygiidae	*Forsterygion flavonigrum*	Yellow-black triplefin	Edney (2001)
	Forsterygion lapillum	Common triplefin	Brook (2002)
	Forsterygion malcolmi	Mottled triplefin	Brook (2002)
	Forsterygion varium	Striped triplefin	Brook (2002)
	Gilloblennius tripennis	Tripenny	Kelly (1983)
	Grahamina capito	Spotted robust triplefin	Battershill (1986)
	Bellapiscis medius[11]	Twister	Kelly (1983)
	Karalepis stewarti	Scaly-head triplefin	Edney (2001)
	Notoclinops caerulepunctus	Blue-dot triplefin	Edney (2001)
	Notoclinus fenestratus	Topknot	Battershill (1986)
	Notoclinops segmentatus[12]	Blue-eyed triplefin	Edney (2001)
	Notoclinops yaldwyni	Yaldwyn's triplefin	Edney (2001)
	Obliquichthys maryannae	Oblique-swimming triplefin	Edney (2001)
	Ruanoho decemdigitatus	Long-finned triplefin	Battershill (1986)
	Ruanoho whero	Spectacled triplefin	Edney (2001)
Uranoscopidae	*Kathetostoma giganteum*	Giant banded stargazer	Doak (2001a)
Xiphiidae	*Xiphias gladius*	Broadbill swordfish	Kelly (1983)
Order Pleuronectiformes			
Rhombosoleidae	*Rhombosolea plebeia*	Flounder	Doak (1991)
Soleidae	*Aseraggodes bahamondei*	South Pacific sole	Francis *et al.* (1999)
Order Scorpaeniformes			
Scorpaenidae	*Helicolenus percoides*	Reef ocean perch	Brook (2002)
	Pterois volitans	Red lionfish	Francis & Evans (1992)
	Scorpaena cardinalis	Scorpion fish	Schiel (1984)
	Scorpaena papillosus	Dwarf Scorpionfish	Brook (2002)
Triglidae	*Chelidonichthys kumu*	Red gurnard/ Bluefin gurnard	Battershill (1986)
Order Syngnathiformes			
Fistulariidae	*Fistularia* cf. *commersonii*	Bluespotted cornetfish	Francis *et al.* (1999)
Syngnathidae	*Leptonotus norae*	Longsnout pipefish	Battershill (1986)
	Stigmatopora macropterygia	Long-snouted pipefish	Battershill (1986)
Order Tetraodontiformes			
Diodontidae	*Allomycterus pilatus*[13]	Porcupine fish	Brook (2002)

[11] Previously *Helcogramma medium*
[12] Previously *Tripterygion bucknilli*
[13] Previously *Allomycterus jaculiferus*, referred to as *Allomycterus whitleyi* in Russell (1971)

Family	Species	Common name	Reference
Molidae	*Mola mola*	Ocean sunfish	Doak (1991)
	Ranzania laevis	Oblong sunfish	W. Doak (unpub.)
Monacanthidae	*Parika scaber*	Leatherjacket	Choat & Ayling (1987)
	Thamnaconus analis	Triggerfish/ morsecode leatherjacket	Francis & Evans (1992)
Ostraciidae	*Ostracion solorensis*	Striped boxfish	Doak (2001c)
Tetradontidae	*Canthigaster callisterna*	Sharp-nosed pufferfish	Schiel (1984)
Order Zeiformes			
Zeidae	*Zenion leptolepis*	Elongate dory	Kelly (1983)
	Zeus faber[14]	John dory	Edney (2001)

3.1.1 Fish monitoring

One of the aims of the Poor Knights Islands Marine Reserve is to protect the reef fish population around the islands from overfishing, particularly those species that are long-lived or have low reproductive rates. When the reserve was first established in 1981 recreational fishing of snapper, kingfish, trevally, mackerel, kahawai, shark, billfish, tuna, and pink maomao was permitted in 95% of the reserve. At the time it was thought that these species were pelagic and thus, were not a permanent part of the reserve's fish population (Denny, 2008). However, recent studies have found that trevally, snapper, pink maomao, and kingfish are largely or partially resident around reefs (Saul & Holdsworth, 1992; Willis *et al.*, 2001; Francis, 2002; Parsons *et al.*, 2003). The abundance of a number of common, conspicuous fish species at the Poor Knights Islands has been monitored since the establishment of the marine reserve.

Planktivorous fish

Planktivorous fish are the most conspicuous and abundant fish at the Poor Knights Islands with schools numbering in the hundreds commonplace. Accurate monitoring of planktivorous fish is difficult because of the schooling nature of these fish. Two studies on planktivorous fish at the Poor Knights Islands have been conducted by Kingsford & MacDiarmid (1988) and Kingsford (1989). The most abundant planktivorous reef fish in the upper 30 m of the water column was *Chromis dispilus* (Demoiselle), which had a mean density of 1125 $\pm$ 181 S.E. per 9000 m^3 and accounted for 85% of all planktivorous reef fish sampled at the Poor Knights Islands. Densities of *C. dispilus* were relatively stable between sites and times as the fish have a strong association with reefs and do not venture far from the reef during daytime.

[14] Previously *Zeus japonicus*

Scorpis violaceus (Blue maomao), *Caprodon longimanus* (Pink maomao), and *Decapterus koheru* (Koheru) were also common, but typically travelled around the reserve in large schools, and thus, their abundance varied greatly between sites and times, with mean densities ranging between 0 and 436 fish per 9000 m^3. All other planktivorous reef fish sampled[15] were found at low densities.

The localised distribution of planktivorous fish was influenced by current direction, with higher abundances of fish always present on the incurrent side of archways. The feeding activity of these dense schools of fish was capable of causing a significant reduction in zooplankton numbers directly downstream of the school. Diurnal planktivorous fish were absent from the reef at night, seeking shelter in deeper waters away from the islands (Kingsford & MacDiarmid, 1988).

The distribution patterns of planktivorous fish at the Poor Knights Islands differs from other nearby locations (Hen and Chickens Islands, Goat Island, Mokohinau Islands, Needles, Kawau Island, Little Barrier Island, and Whangarei Heads). The Poor Knights Islands had significantly higher numbers of *C. dispilus, S. violaceus, D. koheru*, and *C. longimanus* than other sites, but significantly lower numbers of *Scorpis aequipinnis* (sea sweep) than Goat Island, and significantly lower numbers of *Arripis trutta* (Kahawai) than the Mokohinau Islands (Kingsford, 1989). However, these results need to be interpreted with care as there is limited temporal data for many of the locations.

Labrids and other families

More labrid species have been recorded at the Poor Knights Islands than anywhere else in New Zealand (Ward & Roberts, 1986), with 18 wrasse species recorded at the Poor Knights Islands. All these wrasses are sex-changing hermaphrodites, starting life as females and later changing sex to become males. Labrids are especially abundant around tropical coral reefs, and some of these warm water species such as *Thalassoma lunare* (Moon wrasse), *Thalassoma amblycephalum* (Blueheaded wrasse), and *Suezichthys arquatus* (Rainbow fish) are uncommon at the Poor Knights Islands and may only be transient visitors. These species arrive in northeastern New Zealand, and particularly around the Poor Knights Islands, at the end of summer but do no appear to survive the cold winter months well and populations gradually dwindle (Doak, 2001a).

[15] *Caesioperca lepidoptera, Pseudocaranx dentex, Scorpis aequipinnis, Chromis hypsilepsis, Trachurus novaezelandiae, Labracoglossa nitida,* and *Scomber australasicus.*

One notable labrid found at the Poor Knights Islands is the rare *Suezichthys aylingi*, (Crimson cleanerfish), which is restricted to eastern Australia, the Three Kings Islands, and northeastern New Zealand. *Suezichthys aylingi* is only abundant at the Three Kings Islands and it is most likely that the Poor Knights Islands populations are derived from there (Choat *et al.*, 1988).

Choat *et al*. (1988) monitored 12 labrid species and 4 other fish species at the Poor Knights Islands over a period of 12 years from 1975 to 1986. The fish species were divided into three distributional groups; 1) widespread coastal species that are also found in southern temperate waters, 2) northern coastal species that are abundant on offshore islands, and 3) subtropical species that are normally rare in New Zealand (Table 2).

Table 2 Species of fish monitored by Choat *et al*. (1988) at the Poor Knights Islands.

Distributional grouping and species	Common name
1. Widespread coastal species with southern distribution	
Cheilodactylus spectabilis	Red moki
Nemadactylus douglasii	Porae
Parika scaber	Leatherjacket
Notolabrus celidotus	Spotty
Notolabrus fucicola	Banded wrasse
Pseudolabrus miles	Scarlet wrasse
2. Northern coastal species abundant on offshore islands	
Bodianus vulpinus	Pigfish
Coris sandageri	Sandager's wrasse
Parma alboscapularis	Black angelfish
Notolabrus inscriptus	Green wrasse
Pseudolabrus luculentus	Orange wrasse
Suezichthys aylingi	Crimson cleanerfish
3. Transient species of subtropical origin	
Anampses elegans	Elegant wrasse
Coris picta	Combfish
Pseudojuloides elongatus	Long green wrasse
Suezichthys arquatus	Rainbow fish

Results from the study showed distinct patterns in both temporal and spatial abundance. Temporal patterns in fish abundance at Nursery Cove varied between the three groups. Total mean abundance of the subtropical group gradually decreased from

approximately 13 fish per 500 m^2 in 1975 to 0 fish per 500 m^2 in 1979, and did not increase for the remainder of the study period. These subtropical species appear to be unable to successfully reproduce in New Zealand waters and thus populations at the Poor Knights Islands are dependent on recruitment from populations outside of New Zealand. Size structures of sampled fish indicate that populations at the Poor Knights Islands were derived from a single large recruitment event that occurred prior to 1975. The northern coastal group showed a similar decline in abundance between 1975 and 1982. Total mean abundance of *P. luculentus*, *C. sandageri*, and *S. aylingi* declined from >100 fish per 500 m^2 in 1975 to ~20 fish per 500 m^2 in 1982. However, abundance of all three species increased slightly between 1982 and 1985 suggesting recruitment to the local population. In contrast, the mean abundance of the widespread coastal species showed no consistent temporal pattern over the study period.

Distinct, localised spatial patterns also existed between sites and habitats. For example, high numbers of *S. aylingi* and *C. sandageri* were recorded at Nursery Cove, whereas the nearby Bartle's Bay had very low numbers of *S. aylingi* and *C. sandageri,* but high numbers of *P. alboscapularis.* Species abundances were also strongly influenced by habitat. *Coris sandageri* was most abundant in shallow, sandy reefs, *P. alboscapularis* was most abundant on exposed shores amongst algal stands, and *Parika scaber* was more abundant over *E. radiata* beds in waters deeper than 10 m. These variations in spatial distribution were emphasized, not masked, by temporal variations in abundances. The results of the study by Choat *et al.* (1988) showed that fish abundances vary greatly on both a temporal and spatial scale, and that temporal patterns can sometimes span several years. Management decisions based on fish abundance counts need to take into careful consideration the numerous factors that affect fish counts including species sampled, habitat, location, season, and sampling method.

Snapper (*Pagrus auratus*) and other reef fish species

Snapper are the most abundant demersal predatory fish in northeastern New Zealand and are thought to have an impact on the structure of coastal marine ecosystems (Shears & Babcock, 2002). Snapper are also heavily fished, both commercially and recreationally, and prior to implementation of full marine reserve status in October 1998 recreational fishing of snapper was permitted within the Poor Knights Islands Marine Reserve, with the exception of two small areas around Nursery Cove Reef/Bartle's Bay and Frasers Bay (~100 ha). Snapper abundances were monitored at the Poor Knights Islands biannually from September 1998 to September 2002 (Denny *et al.*, 2004). Two further surveys were conducted in autumn 2004 (Denny & Shears, 2004) and autumn 2007 (Denny, 2008). In 1998 there was no difference in snapper

density between the small fully protected areas and partially protected areas where snapper could be fished within the reserve, indicating that full protection of small areas is of little value for protecting targeted fish species. Four years after the implementation of full marine reserve status snapper abundance at the Poor Knights Islands had increased by nearly seven times, whereas snapper abundance at the nearby Mokohinau Islands and Cape Brett were unchanged. Abundances of snapper continued to increase until autumn 2004[16] but there was no significant change in snapper abundances between autumn 2004 and autumn 2007[17].

Although snapper abundance at the Poor Knights Islands appears to have reached a plateau, the mean size of snapper within the reserve appears to have steadily increased since the implementation of full marine reserve status. Mean fork length of snapper at the Poor Knights Islands increased from 274 ± 9 mm (S.E.) in 1999, to 324 ± 5 mm in 2001, to 354 ± 5 mm in 2004, to 384 ± 5 mm in 2007 (Denny *et al.*, 2003; Denny, 2008). The difference in the mean size of snapper between 1999 and 2001 is too large to be attributed to growth alone, and thus adult snapper must have immigrated into the reserve. It should be noted that it is possible that the increase in mean size between 2004 and 2007 may not be an accurate estimate of the real change in size between the two sampling dates owing to different methods being used to measure snapper size in 2004 and 2007 (see Denny, 2008 for more details).

A number of other species showed significant abundance changes of more than 100% in the four years following implementation of full marine reserve status at the Poor Knights Islands. Abundance of orange wrasse (*Pseudolabrus lucentus*), blue maomao, and pink maomao, were significantly higher in 2002 than in 1998, whereas abundances of banded wrasse (*Notolabrus fucicola*), butterfish (*Odax pullus*), crimson cleanerfish (*Suezichthys aylingi*), goatfish (*Upeneichthys lineatus*), red moki (*Cheilodactylus spectabilis*), and scarlet wrasse (*Pseudolabrus miles*) were significantly lower[18]. These results show that the reef fish community at the Poor Knights Islands changed rapidly following the establishment of a full marine reserve. Fish species targeted by recreational fishers such as snapper and pink maomao (Denny & Shears, 2004) increased significantly, whereas most non-target species showed no significant increase in abundance, with the exception of orange wrasse and blue maomao (Denny *et al.*, 2003). However, by 2007 snapper was the only monitored species at the Poor Knights Islands to show a significant increase in abundance in comparison to 1998 abundance levels. Four species (banded wrasse, butterfish, crimson cleanerfish, and pigfish (*Bodianus vulpinus*)), had significantly decreased in

[16] Taking into account the seasonal fluctuations in abundances of snapper
[17] Note that snapper abundances in 2007 may have been underestimated owing to a change in sampling method.
[18] These changes were not seen in the control sites (Mokohinau Islands and Cape Brett).

abundance since 1998, and 19 other species showed no significant change. Denny (2008) suggested that the lack of any long-term significant increase in fish densities, with the exception of snapper, nine years after implementation of full marine reserve status at the Poor Knights Islands may be explained by several reasons: 1) the large increase in snapper numbers may have caused a decrease in abundances of prey species or competiting species, 2) high snapper abundances may have caused habitat changes, 3) different divers used in different surveys had different fish estimates, and/or 4) long-term climatic changes many affect recruitment and subsequent survival of subtropical species to the Poor Knights Islands. Choat *et al*. (1988) recorded similar long-term declines in labrid abundances prior to implementation of full marine reserve status at the Poor Knights Islands (see above).

Hapuku (*Polyprion oxygeneios*)

Adult hapuku are deep water (50–350 m), demersal fish that are typically found near caves and other rocky reliefs. Juvenile fish are pelagic for a number of years and are rarely caught (Roberts, 1986; Paul, 2002). Schools of around 30 huge hapuku used to frequent waters < 40 m deep around the Poor Knights Islands, but the majority of the Poor Knights Islands hapuku population was caught prior to establishment of the full marine reserve (Doak, 1991). A tagging study conducted in 1988 around the vicinity of the Poor Knights Islands found that the median size of hapuku in deep waters around the reserve was 81.5 cm total length (TL), greater than the median size of fish from South Island (64.2 cm TL) or the Cook Strait (67.0 cm TL). Hapuku captured from around the Poor Knights Islands were largely residentiary, with fish recaptured within 51 km of their release location after a period of up to 3 years. In comparison, fish from South Island populations travelled distances of up to 1389 km before recapture. There was no evidence of mixing between the northeast Northland hapuku population and South Island populations suggesting that the northeast Northland hapuku population may be genetically distinct from South Island populations (Beentjes & Francis, 1999). Anecdotal reports state that the hapuku population around the Poor Knights Islands may be recovering with diver sightings of hapuku becoming more frequent (Grace, 2006).

Seasonal abundances

Snapper have a strong seasonal abundance at the Poor Knights Islands with higher abudance in autumn than in spring. It is thought that the snapper population at the Poor Knights Islands consists of ‘resident’ fish that are present all year round, and migratory fish that move in and out of the reserve seasonally. The influx of these

migratory fish can clearly been seen in the high autumn abundances at the Poor Knights Islands (Denny, 2008).

A number of other fish species show seasonal abundance patterns at the Poor Knights Islands. Scorpionfish (*Scorpaena cardinalis*), orange wrasse, Sandager's wrasse (*Coris sandageri*), pigfish, and spotties are significantly more abundant in autumn than spring, whereas porae, tarakihi (*Nemadactylus macropterus*), banded wrasse, and red moki are significantly more abundant in spring than in autumn (Denny *et al.*, 2003). Sting rays, eagle rays, and manta rays are common in the shallow waters around the Poor Knights Islands during summer and early autumn but are absent during winter (Doak, 2001c; Duffy & Abbott, 2003). There is some evidence that short-tailed stingrays (*Dasyatis brevicaudata*) do not travel far from the islands (<25 km) during winter, but spend increasing amounts of time in deeper waters (150–200 m) (Le Port *et al.*, 2008).

3.1.2 Fish diet

Russell (1983) examined the stomach contents of 50 species of fish common to northeastern New Zealand to provide information on their diet. Dietary information on fish species present at the Poor Knights Islands is given in Table 3. More detailed information on prey species and numerical percentage occurrence can be found in the original paper.

Table 3 **Percentage occurrence (by volume) of food in the stomachs of common fish at the Poor Knights Islands (Data summarised from Russell (1983).**

Fish species	Common name	Food	% Volume
Carnivorous fish			
Arripis trutta	Kawahai	Fish	66.6
		Euphausiids	33.3
Cheilodactylus spectabilis	Red moki	Amphipods	39.7
		Polychaetes	16
		Ophuriods	13
		Crabs	12.6
		Echinoids	8
		Molluscs	6.9
Chironemus marmoratus	Hiwihiwi	Molluscs	57.7
		Crabs	23.4
		Amphipods	6.6
		Hermit crabs	5.3
		Echinoids	4.3
Conger wilsoni	Short-finned conger eel	Crabs	95
		Hermit crabs	5
Dellichthys morelandi	Urchin clingfish	Echinoids	91.7
		Amphipods	8.3
Gilloblennius tripennis	Tripenny	Amphipods	30.8
		Hermit crabs	19.5
		Molluscs	19.4
		Crabs	7.5
		Polychaetes	6.3
		Barnacles	5.9
		Opiuroids	5.8
		Isopods	4.2
Gymnothorax prasinus	Yellow moray	Crab	86
		Fish	14
Helcogramma medium	Twister	Amphipods	57.1
		Molluscs	35.5
		Sandflies	4.3
Hypoplectrodes huntii	Red banded perch	Fish	58
		Crabs	24
		Hermit crabs	12
		Bivalves	2
		Amphipods	2
		Ophuroids	2
Latridopsis ciliaris	Blue moki	Amphipods	37.5
		Crabs	31
		Molluscs	9.9
		Corallina fragments	7.2
		Echinoids	5.7
		Polychaetes	5.0
		Isopods	3.5

Fish species	Common name	Food	% Volume
Lotella sp.	Rock cod	Crabs	50
		Fish	50
Myliobatis tenuicaudatus	Eagle ray	Gastropods	33.3
		Crabs	33.3
		Hermit crabs	30
		Shrimps	3.3
Nemadactylus douglasii	Porae	Polychaetes	19.5
		Ophuroids	19.4
		Amphipods	16.4
		Cephalochordates	16.4
		Echinoids	10.0
		Corallina fragments	6.2
		Crabs	5.0
		Molluscs	5.2
Notoclinops segmentatus	Blue-eyed triplefin	Amphipods	59.0
		Barnacles	25.3
		Polychaetes	5.3
		Rhabdocoels	4.7
		Ostracods	2.7
Notolabrus celidotus	Spotty	Molluscs	47.9
		Crabs	30.5
		Hermit crabs	12.8
		Amphipods	5.6
Notolabrus fucicola	Banded wrasse	Crabs	40.6
		Hermit crabs	30.6
		Molluscs	28.8
Optivus elongatus	Slender roughy	Shrimps	53.3
		Crustaceans	43.3
		Amphipods	3.3
Pagrus auratus	Snapper	Crabs	30.9
		Molluscs	30.6
		Echinoids	28.3
		Fish	3.3
		Polychaetes	2.7
		Ophuroids	2.6
Parablennius laticlavius	Crested blenny	Copepods	28.6
		Mollusc eggs	27.2
		Hydrozoans	17.4
		Barnacles	9.3
		Molluscs	8.3
		Cyanophyceae	6.4
		Amphipods	2.1
Parapercis colias	Blue cod	Fish	39.6
		Hermit crabs	35.8
		Crabs	15.4
		Molluscs	7.5

Fish species	Common name	Food	% Volume
Parika scaber	Leatherjacket	Sponges	36.8
		Ascidians	28.8
		Rhodophyceae	11.8
		Echinoids	9.4
		Bryozoans	6.9
		Hydrozoans	3.1
Paristiopterus labiosus	Giant boarfish	Holothurians	24
		Crabs	20
		Amphipods	15
		Echiuroids	12
		Ophiuroids	12
		Polychaetes	9
		Bivalves	8
Pempheris adspersus	Big eye	Polychaetes	78.3
		Gastropods & *Corallina* fragments	9.4
		Isopods	7.6
		Amphipods	2.8
Pseudolabrus miles	Scarlet wrasse	Hermit crabs	58.9
		Crabs	15.1
		Ophuroids	12.9
		Barnacles	7.9
		Molluscs	4.0
Pseudophycis breviuscula	Red cod	Amphipods	40
		Hermit crabs	20
		Barnacles	16.6
		Crabs	13.3
		Shrimps	10
Scorpaena cardinalis	Scorpion fish	Crabs	66.6
		Hermit crabs	16.7
		Shrimps	16.7
Seriola lalandii	Kingfish	Fish	100
Thrysites atun	Barracouta	Fish	100
Upeneichthys lineatus	Goatfish	Crabs	66.6
		Amphipods	30.0
		Bivalves	1.3
Zeus faber	John dory	Fish	100
Planktivorous fish			
Caesioperca lepidoptera	Butterfly perch	Copepods	70.5
		Paguran larvae	9.5
		Chaetognaths	8.0
		Euphausiid larvae	5.3
		Other plankton	6.7
Chromis dispilus	Demoiselle	Copepods	97.3
		Other plankton	2.7

Fish species	Common name	Food	% Volume
Decapterus koheru	Koheru	Copepods	42.2
		Mysids	20
		Euphausiid larvae	16.6
		Crab larvae	10.5
		Larvaceans	9.5
		Other plankton	0.9
Hyporhamphus ihi	Piper	Mysids	40
		Crab larvae	23
		Paguran larvae	15
		Polychaete larvae	13
		Ostracods	5
		Copepods	3
		Cumaceans	1
Scorpis aequipinnis	Sea sweep	Larvaceans	53
		Copepods	25
		Mysids	12.6
		Chaetognaths	4.5
		Paguran larvae	2.9
Herbivorous fish			
Aplodactylus arctidens	Marblefish	Rhodophyceae	80
		Phaeophyceae	15
		Chlorophyceae	5
Kyphosus sydneyanus	Silver drummer	Phaeophyceae	95
		Rhodophyceae	5
Odax pullus	Butterfish	Phaeophyceae	100
Parma alboscapularis	Black angelfish	Rhodophyceae	80
		Chlorophyceae	20

3.2 Sea snakes and turtles

Seven marine reptiles have been recorded from New Zealand; the loggerhead turtle (*Caretta caretta*), green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*), olive ridley turtle (*Lepidochelys olivacea*), leathery turtle (*Dermochelys coriacea*), yellow-bellied sea snake (*Pelmis platurus*), and the banded sea snake (*Laticauda colubrina*) (Gill, 1997). All these tropical species have been found around northeastern New Zealand, but they only occur incidentally and do not reside or breed in New Zealand waters. Most of the sightings of marine reptiles in New Zealand occur during the summer months as most species, with the exception of the leathery turtle, are likely to die or move out of New Zealand waters during winter. For example, the lower temperature limit for the yellow-bellied sea snake is 17°C (Whitaker, 2002). While turtles have occassionally been reported from around the Poor Knights Islands very few of the turtles are identified or recorded, therefore actual abundances are unknown. The green turtle, leathery turtle, loggerhead turtle, and hawksbill turtle have

been reported from the Poor Knights Islands (J. Choat, pers. comm. in Kelly, 1983; Gill, 1997; Abbott & Rousseau, 2002; Doak, 2008).

3.3 Marine mammals

Ten marine mammal species have been recorded from the waters around the Poor Knights Islands consisting of five species of baleen whales, four species of toothed whales/dolphins, and the New Zealand fur seal (Table 4). Six other marine mammal species have been recorded from the Tutukaka coastline and may also utilise the waters around the Poor Knights Islands (Kelly, 1983). The most common marine mammals at the Poor Knights Islands are the common dolphin (*Delphinus delphis*), the bottlenose dolphin (*Tursiops truncatus*), and the New Zealand fur seal (*Arctocephalus forsteri*). Common dolphins are most abundant at the Poor Knights Islands during spring and travel in pods ranging from a few individuals to hundreds (Doak, 2001b). Northern New Zealand populations are known to eat jack mackerel (*Trachurus novaezelandiae*), kahawai (*Arripis trutta*), yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus lineatus*), parore (*Girella tricuspidata*), and garfish (*Hyporamphus ihi*) (Neumann & Orams, 2003). Bottlenose dolphins are most abundant at the Poor Knights Islands during winter, but they are also common during January. Pods of up to 200 bottlenose dolphins have been encountered at the Poor Knights Islands. Both common and bottlenose dolphins frequently interact with divers and boats (Doak, 2001b). New Zealand fur seals are frequently visitors to the High Peak Rocks (Pinnacles) during winter and up to 45 seals have been sighted hauling out on the High Peak Rocks (Northland Regional Council, 2003). Individual fur seals are commonly seen in the waters around the Poor Knights Islands, and on occasion on the wave platform on the northeastern side of Aorangi Island (K. Hawkins, DOC, pers. comm.).

Table 4 **Marine mammals recorded from around the Poor Knights Islands (PK) or the Tutukaka (T) coastline.**

Family	Species	Common name	Recorded from PK or T	Reference
CLASS MAMMALIA				
Order Cetacea				
Balaenidae	*Eubalaena australis*	Southern right whale	PK	Patenaude (2003)
	Eubalaena glacialis	Northern right whale	T	Kelly (1983)
Balaenopteridae	*Balaenoptera acutorostrata*	Minke whale	PK	Doak (2001c)
	Balaenoptera borealis	Sei whale	PK	Doak (2001c)
	Balaenoptera edeni	Brydes whale	PK	Abbott & Rousseau (2002)
	Megaptera novaeangliae	Humpback whale	PK	Doak (2001c)
Delphinidae	*Delphinus delphis*	Common dolphin	PK	Abbott & Rousseau (2002)
	Globicephala melas	Long-finned pilot whale	PK	Abbott & Rousseau (2002)
	Grampus griseus	Risso's dolphin	T	Kelly (1983)
	Orcinus orca	Orca	PK	Abbott & Rousseau (2002)
	Pseudorca crassidens	False killer whale	T	Kelly (1983)
	Tursiops truncatus	Bottlenose dolphin	PK	Abbott & Rousseau (2002)
Kogiidae	*Kogia sima*	Dwarf sperm whale	T	Kelly (1983)
Physeteridae	*Physeter catodon*	Sperm whale	T	Kelly (1983)
Ziphiidae	*Mesoplodon* sp.		T	Kelly (1983)
Order Carnivora				
Otariidae	*Arctocephalus forsteri*	NZ fur seal	PK	Abbott & Rousseau (2002)

4. Marine flora

There is a rich abundance and diversity of macroalgae at the Poor Knights Islands with 121 species of algae recorded from the islands. A thorough taxonomic survey of the macroalgae of the Poor Knights Islands has not been conducted, and therefore this is likely to be a conservative estimate of the number of macroalgal species present. Some of the lushest kelp beds in New Zealand can be found at Nursery Cove and Cleanerfish Bay and subtidal reefs are covered with the golden seawrack, *Carpophyllum angustifolium*, the strap kelp, *Lessonia variegata*, and the common kelp, *Ecklonia radiata* (Ayling & Schiel, 2003). The marine flora of the Poor Knights Islands is an unusual mixture of species common to northeastern New Zealand such as *C. angustifolium* and *Gigartina alveata*, subtropical species such as *Pedobesia clavaeformis*, *Microdictyon umbilicatum*, and *Palmophyllum umbracola*, and southern New Zealand species, such as *Durvillea antarctica* and *Caulerpa brownii*. Bull kelp *(D. antarctica)* is a common species in southern New Zealand, but is not found in the North Island between North Cape and East Cape with the exception of some exposed offshore islands including the Poor Knights Islands. It is possible that at high levels of wave exposure *D. antarctica* can withstand higher water temperatures (Creese & Ballantine, 1986).

Several rare species of macroalgae are found at the Poor Knights Islands. In 1994 the rare, endemic red alga, *Gelidium allanii*, was discovered with a sample of *Pterocladia capillacea* taken from the Poor Knights Islands in 1978. Prior to 1994 *G. allanii* had only been recorded from the type locality in the Bay of Islands. The alga is typically found growing in intertidal pools on calcium carbonate substrata (Nelson *et al.*, 1994). A new species of green alga, *Palmophyllum umbracola*, was found at the Poor Knights Islands in 1982 (Nelson & Ryan, 1986). This subtidal species is found at the Poor Knights Islands, the Kermadec Islands, and occasionally on the mainland in waters down to 30 m in shaded areas such as caves and overhangs (W. Nelson, NIWA, pers. comm.). An unusual green alga, *Pedobesia clavaeformis*, was discovered at Nursery Cove in 1980. This species has also been recorded from the Kermadec Islands, the Three Kings Islands, the Bay of Islands, and Cape Rodney–Okakari Point Marine Reserve (Hawkes, 1983). An undescribed species of *Rhodymenia* that has previously been reported from the Three Kings Islands has also been collected at the Poor Knights Islands (W. Nelson, NIWA, pers. comm. in Shears & Babcock, 2004).

4.1 Intertidal macroalgae

Sixty two species of intertidal macroalgae have been recorded from the Poor Knights Islands (Table 5). While there have been several studies conducted on the subtidal communities at the Poor Knights Islands no recent studies have been conducted on

intertidal communities at the islands. Published information on the intertidal macroalgal community at the Poor Knights Islands is limited to two early studies by Cranwell & Moore (1938) and Creese & Ballantine (1986). There is also some information on macroalgal species collected at the Poor Knights Islands in Battershill (1986) and Nelson & Adams (1987). Unpublished algal collections taken from the Poor Knights Islands are held at Museum of New Zealand Te Papa Tongarewa, Wellington, and the Auckland Museum Herbarium (W. Nelson, NIWA, pers. comm.).

The intertidal substratum at the Poor Knights Islands is primarily volcanic rhyolite rock, with very limited areas of sand or shell. The majority of the intertidal region consists of steep rock walls. Gently sloping rocky platforms, such as at Ramariki, Hope Point, and Bartle's Bay, account for only a very small percentage of the intertidal area (Fig. 7, Section 5.1). On rocky shorelines there is a general pattern of algal zonation down the shore. Blue-green and filamentous algae grow high up on the shore in areas of freshwater runoff or where there is sustained sea spray. In the upper littoral zone the drought resistant red alga, *Porphyra columbina,* is common. *Porphyra columbina* has a seasonal abundance, being most prolific in spring but is often absent from large areas in summer. Below the high tide mark the predominant alga is a small endemic encrusting red alga, *Apophlaea sinclairii*. This alga is extremely resistant to desiccation and wave exposure, forming a dense, deep-red crust on the rocks. Within this region, *P. columbina* occurs sparingly. In the lower limits of the *A. sinclairii* zone, around mid-tide level, two other species of red algae, *Catenellopsis oligarthra*[19] and *Catenellopsis* sp. are frequently present. On pitted rocks, especially those kept damp by brackish water from the land, *Enteromorpha* sp. and *Ulva* sp. can be found. *Apophlaea sinclairii* appears to have a high light requirement, and does not grow much lower than mid-tide level. The rocks on the lower shore are covered with thin, encrusting red algae (*Hildenbrandia* sp., *Melobesia* sp.), and various types of coralline algae. This base provides a suitable substratum for the attachment of small gelatinous algae such as *Nemalion* sp., *Trematocarpus acicularis,* and dwarfed forms of *Gigartina alveata.* In shaded areas, tufts of *Ulva* sp., *Polysiphonia* sp., *Ceramium* sp., and *Callophyllis decumbens* occur. In areas of moderate exposure the brown alga, *Xiphophora chondrophylla*, dominates the lower intertidal zone. Interspersed between *X. chondrophylla* are several other algal species including *Pleurostichidium falkenbergii, Melanthalia abscissa, Pterocladia lucida, Rhodymenia leptophylla,* and *Champia* sp. In regions were wave exposure is extreme *Durvillea antarctica* replaces *X. chondrophylla* as the dominant alga. In the lower limit of the intertidal zone *Carpophyllum ausgustifolium* forms a dense band that extends into the subtidal zone. Other algal species commonly found in this zone include *Calophyllis decumbens, Champia* sp., *Rhodymenia leptophylla, Plocamium* sp., *Pterocladia lucida, P.*

[19] Previously *Nemostoma oligarthra*

capillacea, *Rhodymenia* sp., *Griffithsia traversii*[20], and *Osmundaria colensoi*[21] (Cranwell & Moore, 1938).

Table 5 Intertidal macroalgae recorded from the Poor Knights Islands.

Family	Species	Reference
CLASS BRYOPSIDOPHYCEAE		
Order Bryopsidales		
Derbesiaceae	*Bryopsis plumosa*	Battershill (1986)
	Derbesia novae-zelandiae	Battershill (1986)
CLASS ULVOPHYCEAE		
Order Cladophorales		
Cladophoraceae	*Cladophora crinalis*	Battershill (1986)
	Cladophoropsis herpestica	Nelson & Adams (1987)
	Rhizoclonium riparium	Battershill (1986)
Order Codiales		
Codiaceae	*Codium convolutum*	Battershill (1986)
	Codium cranwelliae	Nelson & Adams (1987)
Order Ulvales		
Ulvaceae	*Ulva lactuca*	Nelson & Adams (1987)
CLASS PHAEOPHYCEAE		
Order Dictyotales		
Dictyotaceae	*Dictyota ocellata*	Battershill (1986)
	Padina sp.	Battershill (1986)
Order Durvillaeales		
Durvillaeaceae	*Durvillaea antarctica*	Nelson & Adams (1987)
Order Fucales		
Sargassaceae	*Carpophyllum plumosum*	Nelson & Adams (1987)
	Cystophora retroflexa	Battershill (1986)
Hormosiraceae	*Hormosira banksii*	Battershill (1986)
Fucaceae	*Xiphophora chondrophylla* var. *minus*	Nelson & Adams (1987)
Order Ralfsiales		
Ralfsiaceae	*Ralfsia verrucosa*	Battershill (1986)
Order Scytothamnales		
Splachnidiaceae	*Splachnidium rugosum*	Battershill (1986)
Order Scytosiphonales		
Scytosiphonaceae	*Hydroclathrus clathratus*	Battershill (1986)

[20] Previously *Pandorea traversii*
[21] Previously *Vidalia colensoi*

Family	Species	Reference
Order Sphacelariales		
Stypocaulaceae	*Stypocaulon paniculatum*	Nelson & Adams (1987)
CLASS RHODOPHYCEAE		
Order Bangiales		
Bangiaceae	*Bangia atropurpurea*	Battershill (1986)
	Porphyra columbina	Cranwell & Moore (1938)
CLASS FLORIDEOPHYCEAE		
Order Ceramiales		
Ceramiales	*Centroceros clavulatum*	Nelson & Adams (1987)
	Ceramium sp.	Cranwell & Moore (1938)
	Cladhymenia oblongifolia	Battershill (1986)
	Griffithsia traversii	Cranwell & Moore (1938)
	Microcladia novae-zelandiae	Battershill (1986)
Rhodomelaceae	*Aphanocladia delicatula*	Battershill (1986)
	Laurencia distichophylla	Battershill (1986)
	Osmundaria colensoi	Nelson & Adams (1987)
	Polysiphonia sp.	Cranwell & Moore (1938)
Order Corallinales		
Corallinaceae	*Arthrocardia corymbosa*	Nelson & Adams (1987)
	Corallina officialis	Battershill (1986)
	Haliptilon rosea	Nelson & Adams (1987)
	Jania micrarthrodia	Battershill (1986)
	Jania novae-zelandiae	Nelson & Adams (1987)
	Melobesia sp.	Cranwell & Moore (1938)
Order Gelidiales		
Gelidiaceae	*Gelidium allanii*	Nelson *et al.* (1994)
	Gelidium caulacantheum	Battershill (1986)
	Gelidium pusillum	Battershill (1986)
	Pterocladia capillacea	Nelson & Adams (1987)
	Pterocladia lucida	Nelson & Adams (1987)
Order Gigartinales		
Areschougiaceae	*Placentophora colensoi*	Nelson & Adams (1987)
Catenellopsidaceae	*Catenellopsis oligarthra*	Cranwell & Moore (1938)
	Catenellopsis sp.	Cranwell & Moore (1938)
Caulacanthaceae	*Caulacanthus ustulatus*	Nelson & Adams (1987)
Gigartinaceae	*Gigartina alveata*	Cranwell & Moore (1938)
	Gigartina chapmanii	Battershill (1986)
Halymeniaceae	*Pachymenia lusoria*	Battershill (1986)
Kallymeniaceae	*Callophyllis decumbens*	Cranwell & Moore (1938)
Plocamiaceae	*Plocamium* sp.	Cranwell & Moore (1938)

Family	Species	Reference
Sarcodiaceae	*Trematocarpus acicularis*	Cranwell & Moore (1938)
Order Gracilariales		
Gracilariaceae	*Curdiea coriacea*	Nelson & Adams (1987)
	Melanthalia abscissa	Nelson & Adams (1987)
Order Hildenbrandiales		
Hildenbrandiaceae	*Apophlaea sinclairii*	Nelson & Adams (1987)
	Hildenbrandia sp.	Cranwell & Moore (1938)
Order Nemaliales		
Galaxauraceae	*Nothogenia pulvinata*	Battershill (1986)
Liagoraceae	*Liagora harveyana*	Battershill (1986)
	Nemalion sp.	Cranwell & Moore (1938)
Order Rhodymeniales		
Champiaceae	*Champia laingii*	Battershill (1986)
Lomentariaceae	*Lomentaria* sp.	Battershill (1986)
Rhodymeniaceae	*Rhodymenia australis*	Nelson & Adams (1987)
	Rhodymenia leptophylla	Nelson & Adams (1987)

4.2 Subtidal macroalgae

Seventy nine species of subtidal macroalgae have been recorded from the Poor Knights Islands (Table 6). Distribution of subtidal macroalgae around the Poor Knights Islands is greatly influenced by wave exposure and light intensity. On the exposed eastern side of the islands the sublittoral fringe (<2 m) is dominated by *Carpophyllum augustifolium* and red turfing and foliose algae including *Pterocladia lucida, Rhodymenia* sp., *Osmundaria* sp., and *Pachymenia crassa. Lessonia variegata*, coralline turf, and red turfing algae dominate the 4–6 m region, and coralline turf and red turfing algae dominate the deeper waters (<18 m).

Sites of moderate exposure such as Cleanerfish Bay are dominated by *C. angustifolium* and red turfing algae in shallow waters (<2 m). Red turfing algae (e.g. *Gigartina macrocarpa*), red foliose algae (*Osmundaria, Placentophora colensoi, P. crassa, Nesophila hoggardii*), *Ulva lactuca*, and *E. radiata* dominate the 4–6 m region, while deeper regions are predominately covered by an *E. radiata* forest interspersed with patches of *Caulerpa flexilis*.

In the more sheltered locations such as Nursery Cove, Skull Bay, Landing Bay, and Labrid Channel, a mixture of species is present in the shallow region (> 2 m) including; *Carpophyllum maschalocarpum, C. angustifolium, L. variegata, E. radiata*,

coralline turf, red turfing algae, red foliose algae (*Osmundaria, P. lucida, Pterocladia capillacea, Rhodymenia* sp.), and *Melanthalia abscissa* (Shears & Babcock, 2004). *Carpophyllum angustifolium* reaches a mean density of > 130 plants/m^2 in the shallows, but is quickly replaced by *L. variegata* and *E. radiata* at 4–6 m depths (Choat & Schiel, 1982). *Ecklonia radiata* dominates the deeper regions reaching densities of >70 plants/m^2 (Ayling & Schiel, 2003). Occasionally dense stands of *Carpophyllum flexuosum* can be found at depths between 10–20 m (Choat & Schiel, 1982). Underneath the *E. radiata* canopy a diverse assemblage of other species is present including *Distromium skottsbergii, Carpomitra costata, Phacelocarpus labillardieri, Delisea elegans, Plocamium* sp., and *Curdiea coriacea* (Shears & Babcock, 2004).

In deeper waters light intensity is the major environmental factor determining the distribution of macroalgae. Light penetration in the clear waters of the Poor Knights Islands is at least three times deeper than at nearby inshore coastal regions, and as a result algae can survive at more than twice the depth they are normally limited to in inshore coastal waters (Ayling, 1968). For example, light intensity governs the lower limit of *E. radiata* and in areas where light intensity is reduced, such as on a vertical rock face, the lower limit of *E. radiata* is around 28 m. However, on more gently angled rock slopes *E. radiata* can be found at 48 m depth at the Poor Knights Islands, whereas, the lower limit of *E. radiata* in the Hauraki Gulf is around 12 m (Doak, 1971). Ocassionally, in depths of 30 m and more, towering tangled 3 m high columns of *Sargassum sinclairii* can be found (Ayling, 1974c).

Shears and Babcock (2004) conducted a survey of nine shallow subtidal sites[22] (≤18 m depth) around the Poor Knights Islands (Fig. 1 in Shears & Babcock, 2004). Total average algal biomass was 475.6 g/m^2. The three most dominant species in terms of biomass were *E. radiata* (52.8 g/m^2), *C. angustifolium* (18.2 g/m^2), and *Lessonia variegata* (5.7 g/m^2). The most abundance algae in terms of percentage occurrence were crustose coralline algae (mixed species) (99.4%), red turfing algae (mixed species) (90%), coralline turfing algae (mixed species) (79.4%), and *E. radiata* (66.7%) (Table 7).

[22] Lighthouse Bay, Rocklily Inlet, Nursery Cove, Cleanerfish Bay, Skull Bay, Bartle's Bay, Matt's Crack, Frasers Bay, and Labrid Channel (see Fig. 2 for locations).

Table 6 **Subtidal macroalgae recorded from the Poor Knights Islands.**

Family	Species	Reference
CLASS BRYOPSIDOPHYCEAE		
Order Bryopsidales		
Caulerpaceae	*Caulerpa brownii*	Schiel (1984)
	Caulerpa flexilis	Nelson & Adams (1987)
	Caulerpa geminata	Nelson & Adams (1987)
Derbesiaceae	*Pedobesia clavaeformis*	Nelson & Adams (1987)
CLASS ULVOPHYCEAE		
Order Cladophorales		
Anadyomenaceae	*Microdictyon umbilicatum*	Nelson & Adams (1987)
Order Codiales		
Codiaceae	*Codium convolutum*	Shears & Babcock (2004)
	Codium cranwelliae	Nelson & Adams (1987)
Order Tetrasporales		
Palmellopsidaceae	*Palmophyllum umbracola*	Nelson & Ryan (1986)
Order Ulvales		
Ulvaceae	*Ulva lactuca*	Nelson & Adams (1987)
CLASS PHAEOPHYCEAE		
Order Dictyotales		
Dictyotaceae	*Distromium skottsbergii*	Nelson & Adams (1987)
	Glossophora kunthii	Schiel (1984)
	Taonia australasica	Battershill (1986)
	Zonaria turneriana	Shears & Babcock (2004)
Order Ectocarpales		
Chordariaceae	*Leathesia difformis*	Schiel (1984)
Ectocarpaceae	*Ectocarpus* sp.	Schiel (1984)
Order Ralfsiales		
Ralfsiaceae	*Ralfsia verrucosa*	Battershill (1986)
Order Sporochnales		
Sporochnaceae	*Carpomitra costata*	Nelson & Adams (1987)
Order Fucales		
Cystoseiraceae	*Landsburgia quercifolia*	Nelson & Adams (1987)
Fucaceae	*Xiphophora chondrophylla* var. *minus*	Nelson & Adams (1987)
Sargassaceae	*Carpophyllum angustifolium*	Nelson & Adams (1987)
	Carpophyllum maschalocarpum	Shears & Babcock (2004)
	Carpophyllum plumosum	Nelson & Adams (1987)
	Cystophora torulosa	Battershill (1986)
	Sargassum sinclairii	Ayling (1974c)

Family	Species	Reference
Order Laminariales		
Alariaceae	*Ecklonia radiata*	Nelson & Adams (1987)
Lessoniaceae	*Lessonia variegata*	Shears & Babcock (2004)
Order Scytosiphonales		
Scytosiphonaceae	*Colpomenia sinuosa*	Shears & Babcock (2004)
	Hydroclathrus clathratus	Battershill (1986)
Order Sphacelariales		
Stypocaulaceae	*Halopteris paniculata*	Nelson & Adams (1987)
CLASS FLORIDEOPHYCEAE		
Order Balliales		
Balliaceae	*Ballia callitricha*	Battershill (1986)
	Ballia scoparia	Battershill (1986)
Order Bonnemaisoniales		
Bonnemaisoniaceae	*Delisea compressa*	Nelson & Adams (1987)
	Delisea elegans	Shears & Babcock (2004)
	Delisea pulchra	Battershill (1986)
	Ptilonia mooreana	Schiel (1984)
Order Ceramiales		
Ceramiaceae	*Antithamnion* sp.	Battershill (1986)
	Callithamnion sp.	Battershill (1986)
	Euptilota formosissima	Nelson & Adams (1987)
	Spyridia sp.	Battershill (1986)
Delesseriaceae	*Abroteia orbicularis*	Nelson & Adams (1987)
	Hymenena sp.	Battershill (1986)
	Phycodrys profunda	Nelson & Adams (1987)
	Platyclinia purpurea	Nelson & Adams (1987)
Rhodomelaceae	*Aphanocladia delicatula*	Battershill (1986)
	Dasyclonium bipartitum	Nelson & Adams (1987)
	Dasyclonium incisum	Nelson & Adams (1987)
	Laurencia distichophylla	Battershill (1986)
	Osmundaria colensoi	Nelson & Adams (1987)
Order Corallinales		
Corallinaceae	*Amphiroa anceps*	Nelson & Adams (1987)
	Arthrocardia corymbosa	Nelson & Adams (1987)
	Cheilosporum sagittatum	Nelson & Adams (1987)
	Haliptilon rosea	Nelson & Adams (1987)
Order Gelidiales		
Gelidiaceae	*Pterocladia capillacea*	Shears & Babcock (2004)
	Pterocladia lucida	Nelson & Adams (1987)

Family	Species	Reference
Order Gigartinales		
Acrosymphytaceae	*Acrosymphyton firmum*	Nelson & Adams (1987)
Areschougiaceae	*Placentophora colensoi*	Nelson & Adams (1987)
Caulacanthaceae	*Taylorophycus filiformis*	Shears & Babcock (2004)
Gigartinaceae	*Gigartina macrocarpa*	Shears & Babcock (2004)
	Melanthalia abscissa	Nelson & Adams (1987)
Halymeniaceae	*Pachymenia crassa*	Nelson & Adams (1987)
Kallymeniaceae	*Callophyllis dichotoma*	Nelson & Adams (1987)
	Kallymenia berggrenii	Shears & Babcock (2004)
Peyssonneliaceae	*Peyssonnelia sp.*	Nelson & Adams (1987)
Phacelocarpaceae	*Phacelocarpus labillardieri*	Nelson & Adams (1987)
Plocamiaceae	*Plocamium costatum*	Nelson & Adams (1987)
Pseudoanemoniaceae	*Hummbrella hydra*	Nelson & Adams (1987)
Rhizophyllidaceae	*Nesophila hoggardii*	Nelson & Adams (1996)
Order Gracilariales		
Gracilariaceae	*Curdiea codioides*	Shears & Babcock (2004)
	Curdiea coriacea	Shears & Babcock (2004)
Order Halymeniales		
Halymeniaceae	*Cryptonemia latissima*	Nelson & Adams (1987)
Order Nemaliales		
Liagoraceae	*Liagora harveyana*	Battershill (1986)
Galaxauraceae	*Scinaia* sp.	Battershill (1986)
Order Rhodymeniales		
Champiaceae	*Champia novae-zelandiae*	Shears & Babcock (2004)
Faucheaceae	*Gloioderma saccatum*	Nelson & Adams (1987)
	Gloiodermatopsis setchellii	Nelson & Adams (1987)
Rhodymeniaceae	*Rhodymenia australis*	Nelson & Adams (1987)
	Rhodymenia leptophylla	Nelson & Adams (1987)
	Rhodymenia sp. aff. *R. hancockii*	Nelson & Adams (1987)
	Rhodymenia sp.	Nelson & Adams (1987)

Table 7 **Percentage occurrence of subtidal macroalgal species recorded from the waters of the Poor Knights Islands ≤ 18 m deep (Table adapted from Shears & Babcock, 2004).**

Species	% occurrence	Species	% occurrence
Large brown algae		**Foliose red algae**	
Ecklonia radiata	66.7	*Nesophila hoggardii*	40.0
Xiphophora chondrophylla	23.9	*Osmundaria colensoi*	32.8
Carpophyllum angustifolium	20.0	*Pterocladia lucida*	26.1
Lessonia variegata	20.0	*Plocamium* sp.	25.0
Carpophyllum maschalocarpum	18.3	*Euptilota formosissima*	21.7
Sargassum sinclairii	16.7	*Curdiea coriacea*	21.1
Carpophyllum plumosum	8.9	*Pachymenia crassa*	16.1
Carpophyllum flexuosum	7.8	*Rhodymenia* undescr. sp.	13.3
Landsburgia quercifolia	5.6	*Placentophora colensoi*	10.6
		Rhodymenia sp.	8.3
Small brown algae		*Delisea compressa*	8.3
Zonaria turneriana	21.7	*Melanthalia abscissa*	6.7
Brown encrusting algae*	8.9	*Phacelocarpus labillardieri*	2.8
Distromium scottsbergii	7.8	*Callophyllis* sp.	2.2
Carpomitra costata	4.4	*Kallymenia berggrenii*	1.7
Halopteris sp.	3.9	*Taylorophycus filiformis*	1.7
Colpomenia sinuosa	1.7	*Plocamium costatum*	1.1
Brown turfing algae*	0.6		
		Red turfing algae (<5 cm)	
Green algae		Red turfing algae*	90.0
Ulva sp.	58.9	Coralline turfing algae*	79.4
Codium convolutum	42.8	*Gigartina macrocarpa*	10.0
Codium cranwelliae	8.9	*Champia novae-zelandiae*	3.3
Caulerpa flexilis	7.2		
Caulerpa geminata	7.2	**Encrusting red algae**	
Pedobesia clavaeformis	1.1	Crustose coralline algae*	99.4
Green turfing algae	0.6	Red encrusting algae*	46.7
		Curdiea codioides	7.2

* Mixed species.

5. Subtidal zonation

5.1 Subtidal habitats

Schiel (1984) constructed the first habitat map of the Poor Knights Islands Marine Reserve (Fig. 7), which described five main subtidal habitat types for depths of less than 30 m; 1) vertical reef walls and caves, 2) macroalgal reef habitats, 3) coralline rock flats & echinoids, 4) broken rock, and 5) sand. The majority of the subtidal region consists of steep rock walls, caves, and archways that are covered with an abundance of sessile invertebrates and macroalgae. These rock wall regions are not represented on Schiel's two-dimensional map. The second major habitat type is gently sloping rocky reefs covered in laminarian macroalgae. Large areas of macroalgae reefs that extend down to 50+ m in some places are present at Frasers Bay, Bartle's Bay, Nursery Cove, Cleanerfish Bay, Te Paki Point, Lighthouse Cove, and the channel between the two main islands. Coralline-encrusted rock flats associated with large numbers of echinoids are present at Bartle's and Frasers Bays. Large areas of broken rock are present on the west side of Aorangi Island (The Gardens), around Ngaio Rock, and at the southern point of Tawhiti Rahi Island (Fig. 7).

Over the years the majority of habitats around the Poor Knights Islands have been stable, but there have been some changes. For example, prior to 1980 Nursery Cove Reef was covered in large brown macroalgae but by 1984 it was devoid of large macroalgae and instead dominated by the sea urchin, *Evechinus chloroticus*. This change in habitat was associated with an increase in abundance of the black angelfish, *Parma alboscapularis*, which builds nests on prominent boulders that are devoid of large brown macroalgae (Schiel, 1984). Between 1999 and 2006 the habitat at Bartle's Bay changed from turfing red algae to coralline flats/echinoid-dominated reefs. Areas of *Ecklonia radiata* forest at 10–12 m depth at Frasers Bay and Cleanerfish Bay were also replaced with coralline flats/echinoid-dominated reefs, but these areas were associated with the black sea urchin, *Centrostephanus rodgersii*, rather than *E. chloroticus* (Shears, 2007).

The first two habitat types have been well studied and more detailed descriptions of these habitats are given below. Very little information is available about the other habitat types.

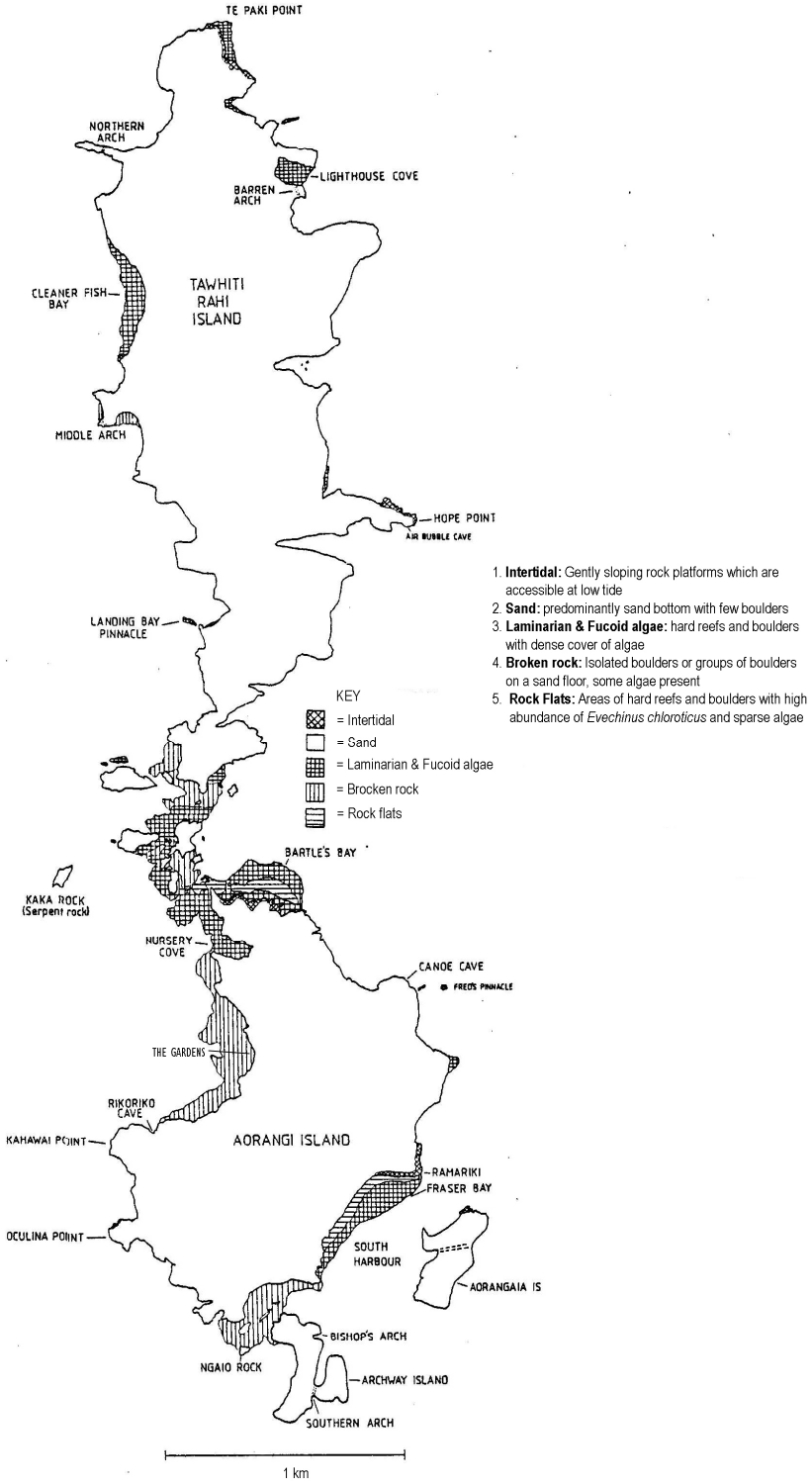

Figure 7 **Schiel's (1984) habitat map of the Poor Knights Islands (reproduced with permission).**

5.1.1 Vertical reef walls and caves

The Poor Knights Islands Marine Reserve is most renowned for its vertical reef walls and caves that are covered with an amazing diversity of flora and fauna including sponges, bryozoans, ascidians, anemones, and encrusting algae. The species diversity on these rock walls is much higher than the diversity at the Cape Rodney–Okakari Point Marine Reserve, with more than 140 sponges, 131 molluscs, 58 cnidarians, 43 echinoderms, and 36 bryozoans recorded from the Poor Knights Islands (Battershill, 1986). Notable components of deep reef communities include the rare black coral (*Antipathes lillei*), giant tube sponges (*Calyx imperialis*)[23], and organ pipe sponges (*Iophon laevistylus*).

Light and wave action are the major factors that determine the community composition on the rock surfaces, and a general pattern of change can be seen in the community composition with increasing depth. Near the sea surface the rock wall is covered by macroalgae, predominantly *Carpophyllum* sp. and red foliose algae, which are succeeded by *E. radiata* at depths between 5–30 m. Under the canopy of *E. radiata* the rock surface is covered by numerous sponges (e.g. species of *Tethya, Polymastia, Cliona, Tedania, Callyspongia*), bryozoans (*Bugula dentata, Emma triangula, Marginella hirsute*), anemones (*Corynactis australis, Corynactus haddoni*), hydroids (*Symplectosycphus* sp., *Thecocarpus* sp., *Aglaophenia* sp.), and encrusting algae. As depth increases beyond 30 m the community composition becomes dominated by sponges (*I. minor, Siphonochalina* sp., *C. imperialis*), hydroids, bryozoans, and gorgonians (e.g. *Primnoides* sp.), that thrive in the low light and calm water conditions. This pattern of change in community composition is also evident in caves but along a horizontal plane towards the back of the cave. Near the cave entrance the community is similar to that near surface overhangs, but growth is less profuse as water movement in the caves is limited. Further into the cave large finger sponges (*Callyspongia ramosa*) are absent and gorgonian fans are stunted. This community is dominated by encrusting sponges, compound ascidians, hydroids, and polyzoans. In the near dark depths of the cave the flora and fauna are sparse, predominantly simple ascidians and the solitary cup corals such as *Monomyces rubrum*[24] and *Tethocyathus cylindraceus*[25] (Doak, 1971; Ayling, 1974a; 1974b; Battershill, 1986; Ayling & Schiel, 2003).

Although the community composition of the rock walls varied greatly with location and depth Battershill (1986) observed some general trends:

[23] Previously *Haliclona imperialis*
[24] Previously *Flabellum rubrum*
[25] Has been referred to as *Paracyathus conceptus*

1. The most abundant groups of organisms in terms of percentage cover were thin encrusting sponges, thin encrusting algae, turfing hydroids, and turfing bryozoans.

2. Sites on the more exposed eastern side of the island had a higher percentage of ascidians (mainly *Cystodites* sp., *Leptoclinides* sp., and *Aplidium* sp.) and massive sponges (mainly *Stelletta* sp. and *Ancorina* sp.).

3. In shallow, turbulent areas thin encrusting sponges, ascidians, and algal species dominated, while in sheltered shallow waters bryozoans and turfing branching hydroids dominated.

4. Reef fish and urchins were found in low numbers on vertical walls.

5. The composition and distribution of the vertical reef community is stable over time.

5.1.2 Macroalgal reef habitats

A variety of macroalgal habitats are present in shallow waters (< 5m) including *Carpophyllum*, mixed algal, red foliose algal, and turfing algal habitat depending on location and wave exposure. Between 5 and 30 m *Ecklonia radiata* is the dominant algal species accounting for more than half of the total algal biomass (Shears, 2007) (See Section 4.2 for more detail). Sponges, bryozoans, hydroids, and ascidians are important substrate covers underneath the *E. radiata* canopy. The common sea urchin, *Evechinus chloroticus*, is the most common mobile macroinvertebrate on the reefs, accounting for approximately 90% of the total counts of all macroinvertebrates. Densities of herbivorous gastropods at the Poor Knights Islands are much lower than on similar coastal reefs, possibly because of recruitment limitation or the high abundance of predators (Shears & Babcock, 2004). The macroalgal habitats support a large numbers of small fish, primarily labrids (Choat & Ayling, 1987).

Shears and Babcock (2004) and Shears (2007) conducted surveys of nine reef sites[26] in 1999 just after all fishing was prohibited at the Poor Knights Islands, and again in 2006. The results showed that subtidal reef communities at the Poor Knights Islands were relatively stable over the eight year period, although there was a significant increase in the total macroalgal biomass. This increase was primarily because of a doubling in *E. radiata* biomass. There were no major changes in the species

[26] Lighthouse Bay, Rocklily Inlet, Nursery Cove, Cleanerfish Bay, Skull Bay, Bartle's Bay, Matt's Crack, Frasers Bay, and Labrid Channel (see Fig. 2 for locations).

composition or extent of the reef areas between the two surveys. There was a reduction in turfing algal habitat, and an increase in the coralline flats/echinoid-dominated reefs between 1999 and 2006. The increase in coralline flats/echinoid-dominated reefs was most apparent at Bartle's Bay. Surprisingly, the abundance of *E. chloroticus* was similar between the two sampling periods despite a significant increase in snapper numbers between 1998 and 2001 (Denny *et al.*, 2004). Generally, sea urchin numbers are negatively correlated to the numbers of large predators.

5.1.3 Coralline flats/echinoid-dominated reefs

The coralline flats/echninoid-dominated reef habitat (sometimes referred to as 'urchin barrens') was first described by Ayling (1981). This habitat is characterised by coralline covered rocks that are generally devoid of any large macroalgae, but with a high abundance of sea urchins (*E. chloroticus*). This habitat typically occurs at depths of between 5–10 m where *E. chloroticus* is most abundant (Choat & Schiel, 1982; Schiel, 1984). Coralline flats/echninoid-dominated reefs are uncommon at the Poor Knights Islands and large areas are only present at Bartle's Bay. Small patches of coralline flats/echninoid-dominated reefs are also present at Rocklily Inlet, Matt's Crack, Frasers Bay, Cleanerfish Bay, and Labrid Channel (Shears, 2007). Abundance of labrids around the coralline flats/echninoid-dominated reefs is lower than within macroalgal reef habitats, but higher numbers of large benthic carnivores such as snapper are present (Choat & Ayling, 1987).

5.2 Subtidal habitat mapping (by Jarrod Walker)

The National Institute of Water and Atmospheric Research Ltd (NIWA) are currently undertaking a research programme at the Poor Knights Islands Marine Reserve, entitled 'Marine Recreation' which is funded by the Foundation of Research, Science, and Technology (Contract no: C01X0506). This project sets out to determine whether the current levels of recreational diving has a detectable impact on the benthic flora and fauna associated with near-shore, shallow rocky reefs (0–50 m depth). NIWA are using a number of methods to determine what effect current diving intensities have at the Poor Knights Islands. The overall aim of this project is to move towards an ecosystem management framework that will allow managers, Iwi, and interested stakeholders to manage and sustainably progress the tourist industry while protecting the resources that are the foundation of the tourist industry at the Poor Knights Islands. One of the main outputs is to overlay, in GIS, biological and habitat information that has been collected onto a bathymetric map to produce habitat maps for public and managerial end users.

5.2.1 Methods

Bathymetric surveys of the Poor Knights Islands, using multi-beam sonar, were completed in 2006. Multi-beam technology is an advanced depth sounding and hydrographic mapping system which allows acoustic mapping of the topographic features of the seafloor. It provides detailed information about the rugosity (roughness) of the terrain and bathymetry (water depth), and can produce high resolution images and maps of the seafloor. It also collects information that can be used to predict the geology, and potential habitats available to marine life. This mapping exercise provided a detailed and accurate description of the major physical components of both the rocky reef and sandy areas of the sea floor in depths from approximately 2 to 100+ m (Fig. 4, Section 2.1).

In addition to this work, large scale biological surveys have been undertaken using both a dropped underwater video camera and diver operated video cameras (detailed below). From the images captured by video, counts and estimates of the percentage coverage of various organisms found inhabiting the reef were collected. A range of habitats were also recorded from the video footage along with the depth that they were found and GPS locations. The types of habitat classifications used in this study were those described by Ayling (1978) and more recently by Shears *et al*. (2004). This information, in particular the habitat data, will be compiled with the multi-beam maps to produce high resolution physical and biological maps of the Poor Knights Islands underwater seascape, due to be published in 2009.

Dropped underwater video surveys

To survey the subtidal rocky reef biota of the Poor Knights Islands a dropped underwater video system was employed. At 80 sites evenly distributed around the Island chain (Fig. 8) cameras were lowered along a series of transects to capture the biological communities residing on the reef. Transects were run from the shallow intertidal (~2 m depth) out to 50+ m, with the length of transects dictated by the slope of the reef (i.e. steep reefs = short transects, while gently sloping reefs = longer transects). A downward facing underwater camera was lowered to the rocky substrate 3–5 times in each of 9 depth strata (0–5, 5–10, 10–15, 15–20, 20–25, 25–30, 30–35, 40–50, and 50+ m), with each camera drop treated as a 0.5 m^2 sampling unit. From each quadrat, the benthic habitat was classified (e.g. kelp forest or mixed algae), and counts and estimates of the reef coverage of all major categories of invertebrates and macroalgae were recorded. Each camera drop was GPS, time, date, and depth stamped to enable the integration of these data with the multi-beam data.

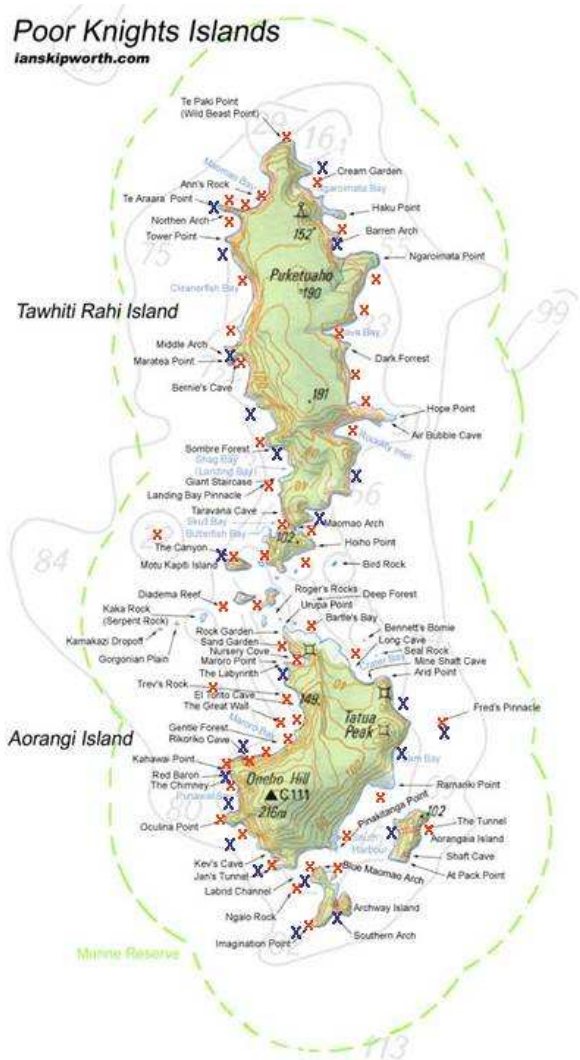

Figure 8 **Map of the Poor Knights Islands displaying sites where the dropped camera system (red x) and diver operated camera systems (blue x) were used to survey benthic biological communities. Not shown on the map are two sites at the Sugar Loaf Rock and four sites at the High Peak Rocks (Pinnacles) (Map courtesy of IanSkipworth.com).**

Diver operated underwater video and still photography

In places where the drop camera could not access, e.g. caves, archways and against vertical cliffs, a team of divers using video/still cameras sampled the biota using similar methodologies as to the dropped underwater camera surveys. Transects ran from shallow intertidal to 30 m depth and were typically vertical. Video footage was taken of the entire transect to obtain information on habitat variations down a depth gradient. Along each transect six still photos were taken within each of 6 depth strata (0–5, 5–10, 10–15, 15–20, 20–25, 25–30 m) with each photograph treated as a 0.5 m^2

sampling unit (Fig. 9). From each quadrat, the benthic habitat was classified (e.g. kelp forest or mixed algae), and counts and estimates of the reef coverage of all major categories of invertebrates and macroalgae were recorded. Each photo contained time, date, and depth information while the transect start point was GPS-ed enabling these data to be combined with the dropped camera data and integrated with the multi-beam maps.

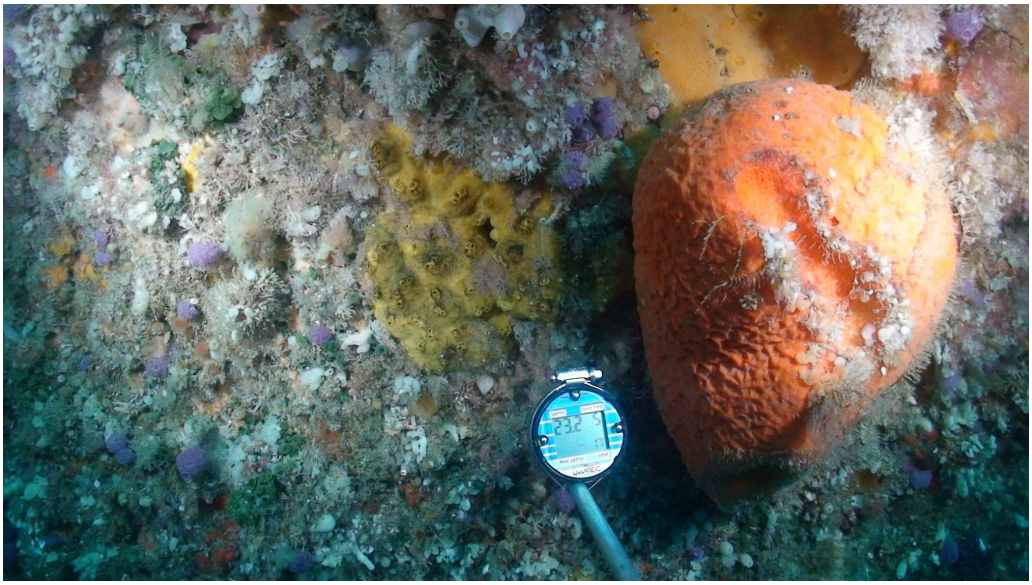

Figure 9 **Still photo from the diver operated underwater camera showing an orange massive sponge (*Stelletta* sp.) and a rich assemblage of encrusting ascidians and bryozoans at 23.2 m depth.**

5.2.2 New habitat types

The first habitat maps constructed by Schiel (1984) were detailed and well-constructed and displayed a range of habitat configurations and the depths at which these habitats altered. The current work undertaken by NIWA at the Poor Knight Islands covers a larger spatial scale (80 sites spread across the entire island chain, including the Sugar Loaf Rock and High Peak Rocks (Pinnacles), and down to depths greater than 40 m), than previous research at the Poor Knights Islands (Ayling, 1974b; 1974a; Schiel, 1984; Battershill, 1986; Shears & Babcock, 2004; Shears, 2007), and has lead to the development of two new habitat types.

The first habitat was predominantly found at depths greater than 40 m where divers have a very limited duration of safe dive times. Accordingly, very little scientific work has been undertaken at these depths. This habitat mainly consisted of encrusting coralline algae that formed leaf like plates and occupied the majority of the reef. As such this habitat has been name "encrusting corallines" and was recorded at a number of sites from around the two main islands.

A second habitat, equivalent to the urchin barrens habitat described in Shears *et al.* (2004) was also observed. Called "Centro barrens", this habitat consisted of moderate densities of the Australian sea urchin, *Centrostephenus rodgersii*. The Centro barrens habitat was found deeper (~20–25 m) than the previously described urchin barrens habitat (~4–10 m), which is formed by the New Zealand sea urchin *Evechinus chloroticus* (Choat & Schiel, 1982; Schiel, 1984; Shears, 2007).

This current survey has shed light on the ranges and breadth of subtidal habitats over a number of spatial scales (metres to kilometres) and at depths where few scientific divers are able to access. Accurate mapping of deep subtidal habitats will allow the identification of benthic communities that are vulnerable to damage, and allow management practices to be put in place to protect them.

6. Human use

6.1 Biosecurity

The Poor Knights Islands Marine Reserve is a high value area of national significance and the unique marine assemblages present in the reserve need to be protected from modification by invasive organisms. Vessel movement in the vicinity of the Poor Knights Islands is the most likely method for the introduction of invasive organisms to the islands via hull fouling, ballast water, and sea chests (water-intake recesses in hull). International and local shipping traffic to and from the port of Whangarei pass near the Poor Knights Islands and may discharge ballast water containing the larvae or spores of invasive species in the vicinity of the islands (Dodgshun *et al.*, 2007), which are then distributed at a local scale by water currents. Pleasure crafts visiting the Poor Knights Islands are also a significant biosecurity risk as many of these vessels remain inactive for long periods of time in sheltered marinas where invasive organisms are prevalent.

Biosecurity New Zealand has identified a number of non-indigenous marine organisms present in the country that have the potential to cause major changes to native species assemblages or cause large economic losses to our aquaculture and marine industries. These unwanted organisms include the Asian kelp, *Undaria pinnatifida*, the ascidians, *Styela clava, Didemnum vexillum, Ciona intestinalis*, and *Eudistoma elongatum*, and the Mediterranean fan worm, *Sabella spallanzanii* (Biosecurity New Zealand, 2008). Of the six invasive marine organisms listed above, the clubbed tunicate, *Styela clava*, has been recorded nearest to the Poor Knights Islands. This solitary ascidian has already been detected from the nearby Tutukaka Marina, Marsden Cove Marina (Whangarei), Hauraki Gulf, Waitemata Harbour, and Lyttelton Harbour (Biosecurity New Zealand, 2008). *Styela clava* can reach densities of 50–100 individuals/m^2 on natural substrates (Lutzen, 1999) and has the potential to cause significant environmental and economic impact through high-density fouling.

To date, the only likely invasive species recorded at the Poor Knights Islands is the parchment tubeworm, *Chaetopterus* sp., though it is not certain whether this worm is endemic to New Zealand or has been introduced from overseas (Tricklebank *et al.*, 2001). The earliest records of *Chaetopterus* sp. in New Zealand date back to circa 1966, but abundances around the country remained low until the mid 1990's when northern populations increased dramatically, particularly around the Hauraki Gulf region (Acosta, 2001). Taxonomic descriptions of the 'Hauraki' *Chaetopterus* sp. show that the species is new to science (Tricklebank *et al.*, 2001) and different from a second New Zealand species found around the Marlborough Sounds (G. Read, NIWA, pers. comm.). The 'Hauraki' *Chaetopterus* sp. was first discovered at the Poor Knights Islands in 1999 and underwent a major population explosion in the following years. Benthic surveys conducted at the Poor Knights Islands in 2001 recorded *Chaetopterus* sp. densities of up to ~20,000 individuals/m^2 on coarse soft sediments at Maroro Bay, Skull Bay, and Shag Bay at depths down to 69 m. The polychaete was also found on rocky reefs at much lower densities (Brook *et al.*, 2001). However, abundance of *Chaetopterus* sp. at the Poor Knights Islands drastically decreased in the years following Brook *et al's* study, and dense mats of the tubeworm at the Poor Knights Islands were no longer present by ~2003–2004 (F. Brooks, pers. comm.). The ecological impact of *Chaetopterus* sp. on the benthic community at the Poor Knights Islands is unknown.

7. Conclusions

This updated literature review of the Poor Knights Islands Marine Reserve has reviewed and interpreted over 60 new references relevant to the marine biota of the Poor Knights Islands since Kelly's 1983 bibliography. Significant new research has been conducted on fish abundance, fish diets, subtidal macroalgal communities, and vertical reef wall communities.

One hundred and eighty six species of fish have now been recorded from the Poor Knights Islands, 70 more than Kelly's tally of 116 species in 1983. Approximately 38% of the fish at the Poor Knights Islands are exotic, subtropical species, many of which are transient visitors or non-breeding species. Thus, the population size of these non-breeding species at the Poor Knights Islands varies greatly over time. Fish monitoring studies at the Poor Knights Islands show that fish abundances vary greatly on both temporal and spatial scales, and temporal patterns can span several years. Following the cessation of recreational fishing in the Poor Knights Islands Marine Reserve in 1998 the abundance of snapper in the marine reserve has increased by more than 1.8 times. The abundance of four other species, banded wrasse, crismon cleaner fish, butterfish, and pigfish decreased significantly, whilst the abundance of 19 other monitored species did not change significantly.

Ten marine mammal species and four turtle species have been recorded from waters around the Poor Knights Islands. The most common marine mammals at the Poor Knights Islands are the common dolphin and the bottlenose dolphin, which occur in pods of up to 200 individuals, and New Zealand fur seals, which haul out at the High Peak Rocks (Pinnacles) during winter.

One hundred and twenty one species of macroalgae have been recorded from the Poor Knights Islands, of which, 62 are intertidal species and 79 are subtidal species (20 species occur both intertidally and subtidally). However, the macroalge of the Poor Knights Islands has not been thoroughly studied and it is likely that this is a conservative estimate. Battershill recorded 102 algae species from the Poor Knights Islands in his 1986 study, but many of these species have subsequently been synomynised or their taxonomic status is unclear. A thorough taxonomic study of the macroalgae of the Poor Knights Islands would greatly benefit our understanding of the marine flora of the region.

Schiel (1984) initially identified five subtidal habitat types at the Poor Knights Islands in waters less than 30 m deep; vertical reef walls and caves, macroalgal reef habitats, coralline flats/echinoid-dominated reefs, broken rock, and sand. Current habitat

mapping studies conducted by NIWA at the Poor Knights Islands have identified two additional, deep water habitats; encrusting corallines, and Centro barrens. The vertical reef wall habitat and macroalgal reef habitat are the only two habitats that are well described in the literature.

The Poor Knights Islands Marine Reserve is a high value area of national significance and the unique marine assemblages present in the reserve need to be protected from modification by invasive pest organisms. To date, the only likely invasive species recorded at the Poor Knights Islands is the parchment tubeworm, *Chaetopterus* sp., though it is uncertain whether this polychaete is endemic or introduced to New Zealand. Biosecurity New Zealand has identified a number of invasive marine organisms that have the potential to cause large changes to native species assemblages, of which, the clubbed tunicate, *Styela clava*, has been detected closest to the Poor Knights Islands. Good management practices need to be put in place to prevent the introduction of invasive species to the Poor Knights Islands.

This report has reviewed five key information areas of the Poor Knights Islands marine ecosystem; the physical marine environment, marine vertebrates, marine macroalgae, subtidal habitats, and marine biosecurity. These areas were identified by the Department of Conservation Northland Conservancy to be the highest priority. Future work will review the biological marine environment, marine invertebrates, marine seabirds, and human use of the Poor Knights Islands Marine Reserve.

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