# South Taranaki Bight Fish and Fisheries

## Prepared for Trans-Tasman Resources Ltd

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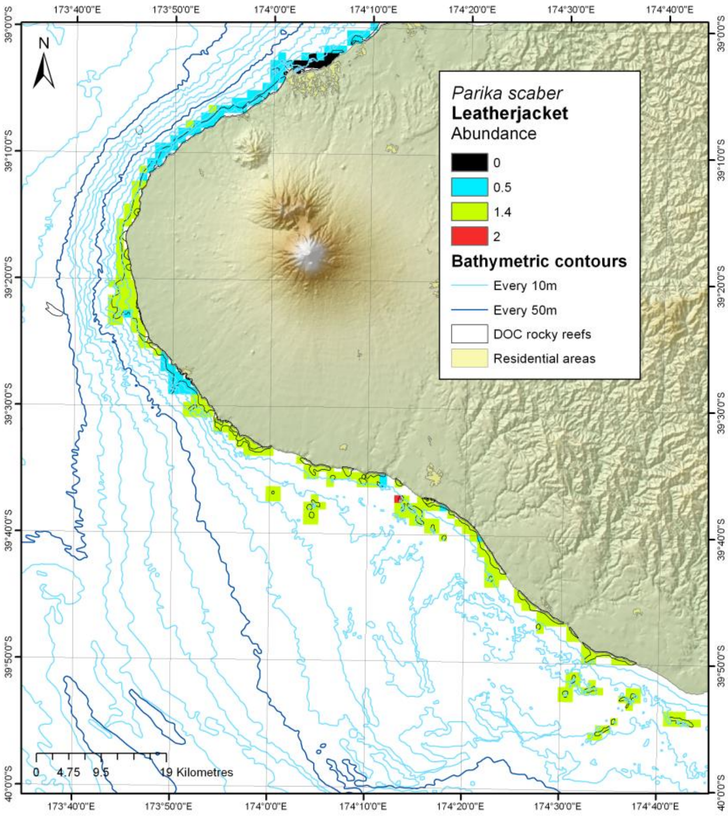

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Cover image: Modelled distributions of leather jacket on Taranaki reefs. Data are estimated abundance in 1 $km^2$ grid squares. Note that on the scale provided 0 = absent, 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100).

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# Executive summary

The initial focus by Trans-Tasman Resources for iron sand extraction operations is in the South Taranaki Bight (STB) with the proposed seabed extraction site located 22-40 km offshore, outside the 12 nautical mile limit to the territorial sea. This report focuses on the fish and fisheries of the STB that may be impacted by the seabed extraction operations. The distribution and abundance of reef fish, pelagic fish, and demersal or seabed associated fish species are described using predictive models based on survey information conducted around New Zealand together with a set of environmental predictor variables. General features of the distribution, abundance, and ecology of rock lobsters are also described on the basis of extensive studies conducted elsewhere in New Zealand. Commercial fisheries for fin fish and rock lobsters in the STB are described based on catch and effort information held by the Ministry for Primary Industries. Customary fisheries in the STB are also described.

A range of marine habitats occur in the STB that support a variety of organisms including reef fish and invertebrates, crayfish, demersal fish and pelagic fish species. The species richness of the reef fish, demersal fish and pelagic fish assemblages is moderate on a national scale. None of the strictly marine species reviewed in this report are nationally rare or threatened, although several diadromous species (species with a phase in both marine and fresh waters) occurring in the region are listed as 'at risk – declining'

Some of the identified fish and invertebrate species support locally important commercial and customary fisheries. We did not investigate the extent or location of recreational fisheries.

The distribution of the marine life stages of diadromous fish in the STB is unknown.

There is some evidence for spawning activity by 13 demersal or pelagic fish species in the STB while larger juveniles of 24 species also occur in the region. However, the distributions of spawning adults and juveniles are poorly defined.

Demersal and pelagic fish species with predicted distributions in the STB that particularly coincide with areas potentially affected by iron sand extraction operations (i.e. those species with % occurrence > 50%) include barracouta, blue cod, carpet shark, eagle rays, John dory, golden mackerel, kahawai, leather jacket, lemon sole, red cod, red gurnard, rig, school shark, snapper, spiny dogfish, tarakihi, trevally, common warehou, and witch. Species that are predicted to be particularly abundant (> 50 kg per hour standard trawling) in the TTR proposed project area include barracouta, red gurnard, leather jacket, school shark, snapper, spiny dogfish, rig, tarakihi, and trevally.

The demersal and pelagic fisheries likely to be most affected by iron sand extraction operations are the commercial set-net fisheries for rig, warehou, and school shark, and customary fisheries for rig and leather jacket. The greatest effort and catch in these commercial fisheries in the STB is located to the south and east of the banks where the extraction operations are proposed to take place, while the greatest abundance of rig and leather jacket also occurs in this area.

Marine fisheries have traditionally been a source of cultural and economic wealth for Māori. The iwi likely to be most affected by iron sand extraction in the STB are Nga Ruahine, Ngāti Ruanui, and Ngā Rauru. At least forty species of invertebrates and fish are customarily gathered or fished from the STB.  Harvesting sites vary from intertidal reefs to deep offshore areas and methods of collection vary from hand picking or gathering to specialised hook and line and potting techniques. Customary species occurring on inshore reefs most vulnerable to the effects of offshore sand extraction are sedentary species that cannot move sufficiently far or fast to avoid impacts. The customary fisheries offshore most vulnerable to the effects of iron sand extraction are those for species such as rig and leatherjacket which are abundant directly over TTR's proposed project area.

Information relating to TTR's additional scientific work undertaken since 2014 has been provided and the conclusions is this report remain valid.

# 1 General Introduction

## 1.1 Background

Trans-Tasman Resources Ltd (TTR) has secured permits and is prospecting for offshore iron sands along the West Coast, North Island, within the 12 nautical mile (nm) territorial sea along the southern and northern Taranaki bights (PP 50 383), and in the area beyond the 12 nm sea (PP 50 753) in South Taranaki Bight (STB) (Figure 1-1). The total area under consideration is 6,319 km$^2$. The initial focus by TTR for potential extraction operations is in the STB with a proposed project area located 22-40 km offshore, outside the 12 nautical mile limit to the territorial sea (Figure 1-2).

A range of marine habitats occur in the STB. Along the coastal fringes, 15 km or more from the proposed mining sites, there are rocky reefs (Figure 1-2) that support a variety of organisms including seaweeds, kelp, invertebrates, and reef fish. Many reef species support important customary, recreational and/or commercial fisheries. Reef structures on the south Taranaki coastline are often of low relief, and may be subject to occasional burial by sediment and exposure by scour dependent on the wave climate, currents and sediment availability. Some offshore reefs (e.g. the Traps off Patea) are substantial and of high relief offering micro-habitat suitable for a range of fish, invertebrate, and algal species. Offshore there are extensive areas of sands, shell-hash and mud (Gillespie & Nelson 1996) that also support commercial, recreational and customary fisheries.

NIWA is undertaking a range of biogeophysical studies in the STB for TTR to meet the likely requirements of consenting procedures under the new EEZ environmental effects legislation. This report focuses on the fish and fisheries of the STB. The distribution and abundance of reef fish, pelagic fish, and demersal or seabed associated fish species are described using predictive models based on survey information conducted around New Zealand together with a set of environmental predictor variables. General features of the distribution, abundance, and ecology of rock lobsters are also described on the basis of extensive studies conducted elsewhere in New Zealand.

Commercial fisheries for fin fish and rock lobsters in the STB are described based on catch and effort information held by the Ministry for Primary Industries. Customary fisheries in the STB are also described based on the available published information.


**Figure 1-1: Trans-Tasman Resources Ltd Permit (yellow) and Licence (blue) areas.**

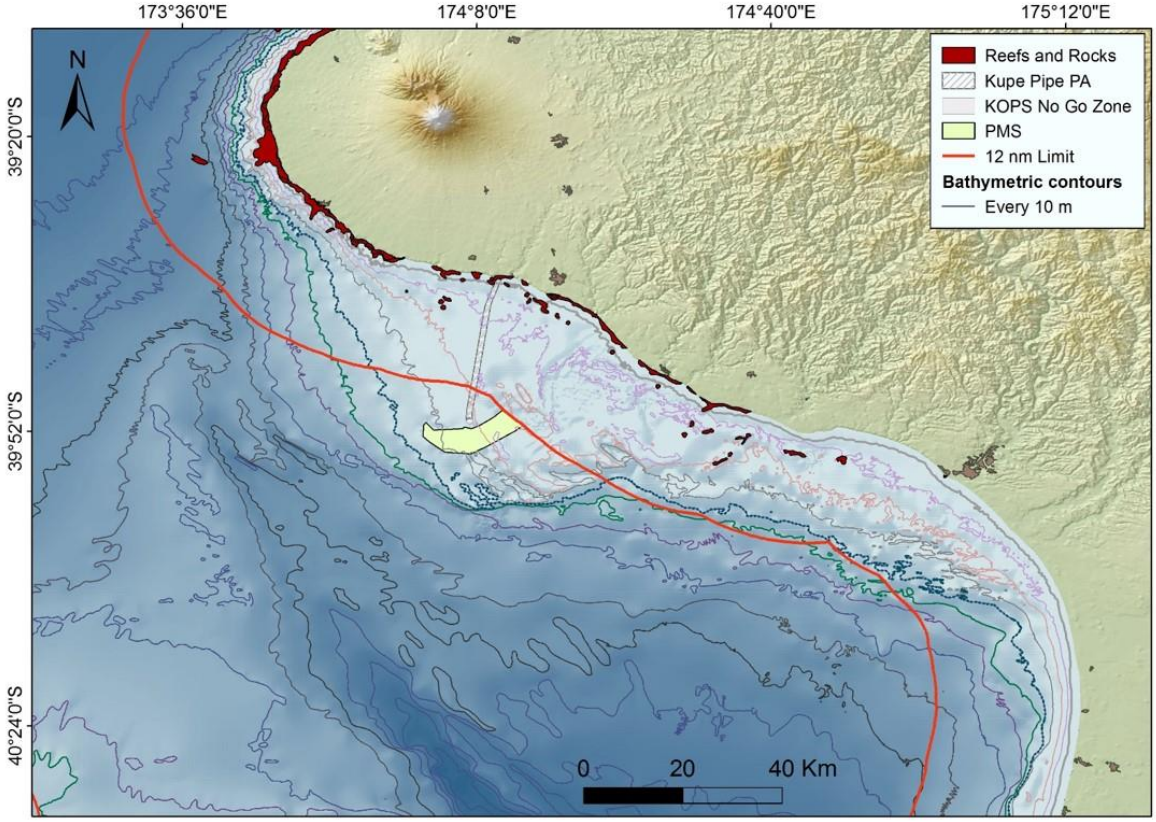


**Figure 1-2: Location of the TTR proposed project area (PPA).** The location of coastal reefs amended from the Department of Conservation (DOC) data set, the 12 nautical mile boundary to the Territorial Sea, and main coastal towns are also shown.

# 2 Reef fish

## 2.1 Background

This section focuses on the reef fish community and describes the distribution and abundance of the main species as well as identifying which reef areas have the highest diversity of reef fish species. In this report we use the results of Smith (2008) who estimated expected reef fish abundance in the region from surveys conducted elsewhere, together with a set of environmental and geographical predictors to describe the expected distribution, abundance and species richness of reef fish along the Taranaki coast. Because Smith's (2008) analysis was dependent on field count data it ignores rare and/or cryptic species for which little or no count data were available.

## 2.2 Methods

The predicted distributions and relative abundance of fishes on shallow subtidal reefs around New Zealand were obtained from models produced by Smith (2008). The predictions were produced by applying boosted regression trees (BRT) (an ensemble method for fitting statistical models – see Elith et al. 2008) to diver surveys of fish abundance, using environmental and geographic variables as predictors. Smith's (2008) model predictions were produced as a grid of 1 $km^2$ cells. This grid was then overlain with a shape file that showed the positions of known and presumed subtidal reefs around New Zealand, and those grid cells that contained no reef were removed from the final output.

The original fish count data consisted of relative abundance recorded by divers on a 5-level abundance scale (0 = absent; 1 = 1; 2 = 2-10; 3 = 11-100; 4 = greater than 100 individuals of a species observed per dive) at 467 sites throughout New Zealand. However, the distribution of sites was not uniform, and no sites were surveyed along the south Taranaki coast. The closest sites were at the Sugar Loaf Islands off New Plymouth, at Kapiti Island north of Wellington and in the Marlborough Sounds.

The 15 environmental variables consisted of a range of measures available at high spatial resolution including sea surface temperature, salinity, dissolved organic matter, tidal current, wind fetch, distance from coast and several variables defining the characteristics of each dive. BRTs were used to predict the abundance of each species in a 1 $km^2$ grid for 9,605 grid squares having shallow (< 50 m depth) rocky reefs. The most important variable for explaining variation in fish abundance was sea surface temperature, followed by average fetch and salinity. On average, 64% of the variation in reef fish abundance was explained by the models (Smith 2008).

The model predictions produced by Smith (2008) for each fish species were re-plotted in a Geographical Information System (GIS) for the region covered by the present study. These predicted distribution maps provide an easily interpreted, visual summary of the parts of the study area inhabited by each species, and its relative abundance (at a coarse level) in the inhabited areas.

In Smith's (2008) study, all seabed features with abrupt changes in vertical relief were assumed to be reef structures, but this may not always be the case. In some cases large sand waves may have been interpreted as reefs and the modelled predictions of reef fish abundance applied to these areas. We used visual, acoustic (sidescan or backscatter), and drilling information collected by TTR field teams working in the region during 2010-2012 as well as chart data and other published information (Vermeulen 2012) to eliminate non-reef areas in South Taranaki from Smith's (2008) model outputs.

The number of species predicted to occur within 1 $km^2$ grid squares was also calculated as an indication of the spatial distribution of species richness.

## 2.3 Results

Reef fish diversity is predicted to be highest along the coastal fringing reefs south and east of Cape Egmont, and especially those between 174$^{o}$ 20' E and 174$^{o}$ 40' E. Up to 21 of the 37 species occurring within the region were predicted to occur within each 1 $km^2$ grid square (Figure 2-7).

Just 37 of the 72 species of New Zealand reef fish modelled by Smith (2008) are predicted to occur in the region (Table 2-1). None are nationally rare or threatened. A total of 11 species such as common roughy (*Paratrachichthys trailli*) and blue moki (*Latridopsis ciliaris*) occur very infrequently and on reefs where they do occur are likely to be observed just once during two or more one-hour dives (Table 2-1).  Another ten species, including the scaly-headed triple fin (*Karalepis stewarti*) and red-banded perch (*Hypoplectrodes huntii*), were likely to be observed a maximum of once during a single one-hour dive on reefs. With one exception, between two and ten individuals of the remaining species were likely to be encountered during a one-hour dive on reefs where they occurred at all. This group included leatherjacket (*Parika scaber*), butterfish (*Odax pullus*) and yellow-black triple fin (*Forsterygion flavonigrum*). The exceptional species was butterfly perch (*Caesioperca lepidoptera*) with between 11 and 100 individuals predicted to be encountered during a one-hour dive on some reefs (Table 2-1).

The distribution and abundance of the 37 reef fish species occurring in the region are provided in Appendix A. Two species, common conger eel (*Conger verreauxi*) (Figure 2-1) and tarakihi (*Nemadactylus macropterus*) are rare on reefs in the region, predicted to occur on just one or two small reef areas (Table 2-1). Six other species, common roughy (Figure 2-2), porae (*Nemadactylus douglasii*) (Figure 2-3), black angelfish (*Parma alboscapularis*), common triplefin (*Forsterygion lapillum*), blue moki , and scaly-headed triplefin, are predicted to have a restricted distribution, occurring at fewer than 50% of the reef areas. Most other species (e.g., sea perch (*Helicolenus percoides*) and blue cod (*Parapercis colias*), (Figures 2-4 and 2-5) are widespread occurring at most reefs within the region. Five species (red moki, *Cheilodactylus spectabilis*, scarlet wrasse, *Pseudolabrus miles*, banded triplefin, *Forsterygion malcolmi*, yellow-black triplefin and butterfly perch, Figure 2-6) are ubiquitous, predicted to occur at all of the reefs within the study region.

Mapping the reef fish predicted species richness along the coastal fringing reefs south and east of Cape Egmont, and especially those between 174$^{o}$ 20' E and 174$^{o}$ 40' E revealed they were the most diverse with up to 21 of the 37 species occurring within the region predicted to occur within each 1 km$^2$ grid square (Figure 2-7).

**Table 2-1: Modelled reef fish species predicted to occur on south Taranaki reefs arranged by increasing order of estimated maximum abundance in 1 km$^2$ grid cells.** Specifically, 0 = absent (no individuals likely to be seen per 1 hour dive), 1 = single (1 individual seen per 1 hour dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). See text for definitions of distribution descriptors.

| Common Name | *Genus species* | Maximum abundance on reefs within SCUBA range | Distribution within region |
|---|---|---|---|
| Common roughy | *Paratrachichthys trailli* | 0.2 | Restricted |
| Common conger eel | *Conger verreauxi* | 0.3 | Rare |
| Trevally | *Pseudocaranx dentex* | 0.4 | Widespread |
| Porae | *Nemadactylus douglasii* | 0.4 | Restricted |
| Red pigfish | *Bodianus unimaculatus* | 0.4 | Widespread |
| Goatfish | *Upeneichthys lineatus* | 0.6 | Widespread |
| Black angelfish | *Parma alboscapularis* | 0.6 | Restricted |
| Sea perch | *Helicolenus percoides* | 0.6 | Widespread |
| Slender roughy | *Optivus elongatus* | 0.8 | Widespread |
| Common triplefin | *Forsterygion lapillum* | 0.8 | Restricted |
| Blue moki | *Latridopsis ciliaris* | 0.9 | Restricted |
| Scaly-headed triplefin | *Karalepis stewarti* | 1.1 | Restricted |
| Blue dot triplefin | *Notoclinops caerulepunctus* | 1.1 | Widespread |
| Tarakihi | *Nemadactylus macropterus* | 1.3 | Rare |
| Rock cod | *Lotella rhacinus* | 1.5 | Widespread |
| Southern bastard cod | *Pseudophycis barbata* | 1.6 | Widespread |
| Blue cod | *Parapercis colias* | 1.8 | Widespread |
| Marblefish | *Aplodactylus arctidens* | 1.8 | Widespread |
| Spotty | *Notolabrus celidotus* | 1.9 | Widespread |
| Dwarf scorpionfish | *Scorpaena papillosus* | 1.9 | Widespread |

| | | | |
|---|---|---|---|
| Red-banded perch | *Hypoplectrodes huntii* | 1.9 | Widespread |
| Leatherjacket | *Parika scaber* | 2.0 | Widespread |
| Spectacled triplefin | *Ruanoho whero* | 2.0 | Widespread |
| Kingfish | *Seriola lalandi* | 2.1 | Widespread |
| Yaldwyn's triplefin | *Notoclinops yaldwyni* | 2.1 | Widespread |
| Variable triplefin | *Forsterygion varium* | 2.1 | Widespread |
| Butterfish | *Odax pullus* | 2.1 | Widespread |
| Oblique-swimming triplefin | *Obliquichthys maryannae* | 2.2 | Widespread |
| Parore | *Girella tricuspidata* | 2.2 | Widespread |
| Blue-eyed triplefin | *Notoclinops segmentatus* | 2.2 | Widespread |
| Red moki | *Cheilodactylus spectabilis* | 2.6 | Ubiquitous |
| Scarlet wrasse | *Pseudolabrus miles* | 2.6 | Ubiquitous |
| Banded triplefin | *Forsterygion malcolmi* | 2.7 | Ubiquitous |
| Sweep | *Scorpis lineolatus* | 2.8 | Widespread |
| Banded wrasse | *Notolabrus fucicola* | 2.8 | Widespread |
| Yellow-black triplefin | *Forsterygion flavonigrum* | 2.9 | Ubiquitous |
| Butterfly perch | *Caesioperca lepidoptera* | 3.7 | Ubiquitous |

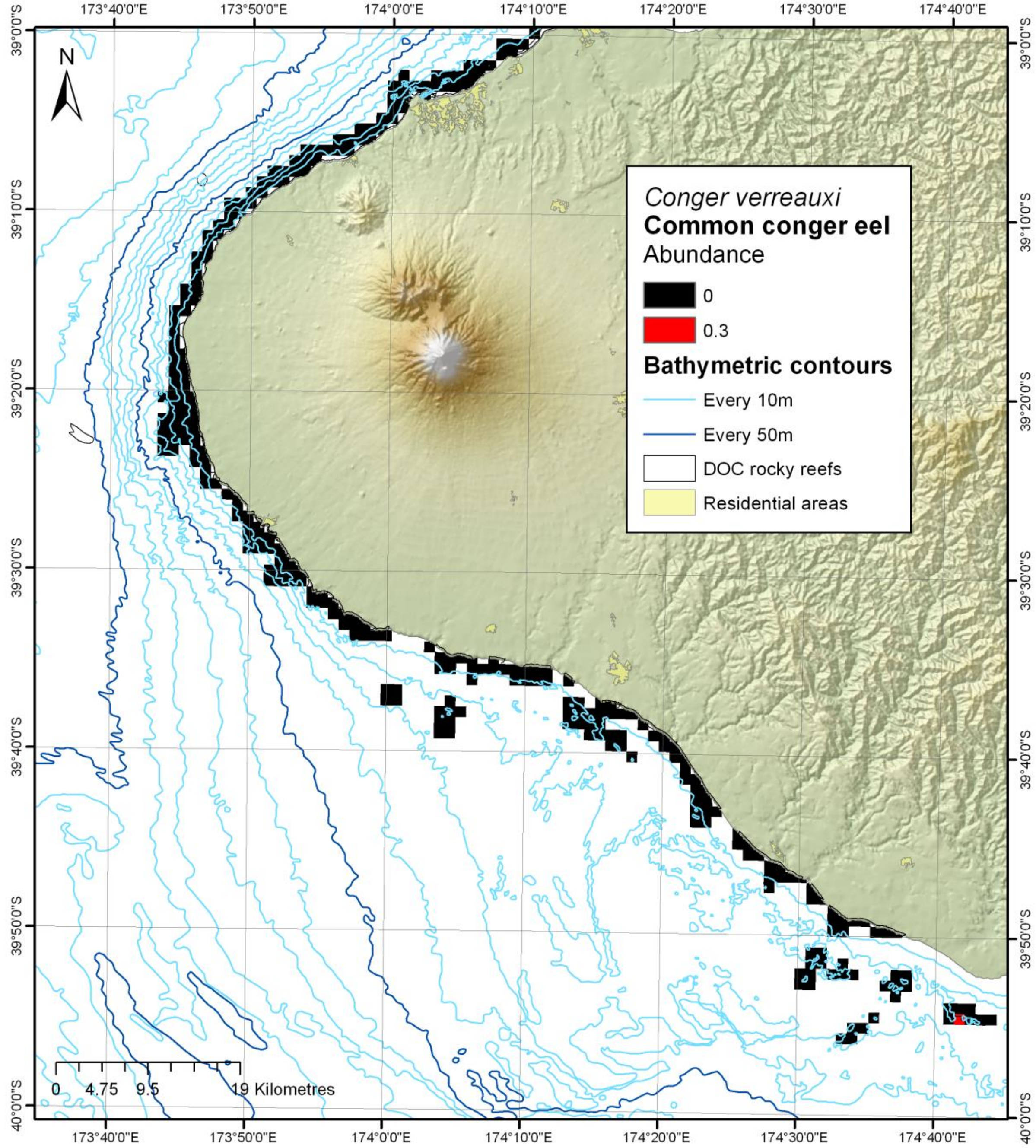


**Figure 2-1: Distribution and abundance of common conger eel on reefs in the South Taranaki Bight.** Data are estimated abundance in 1 km$^2$ grid squares. Note on the scale 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). Model output from Smith (2008).

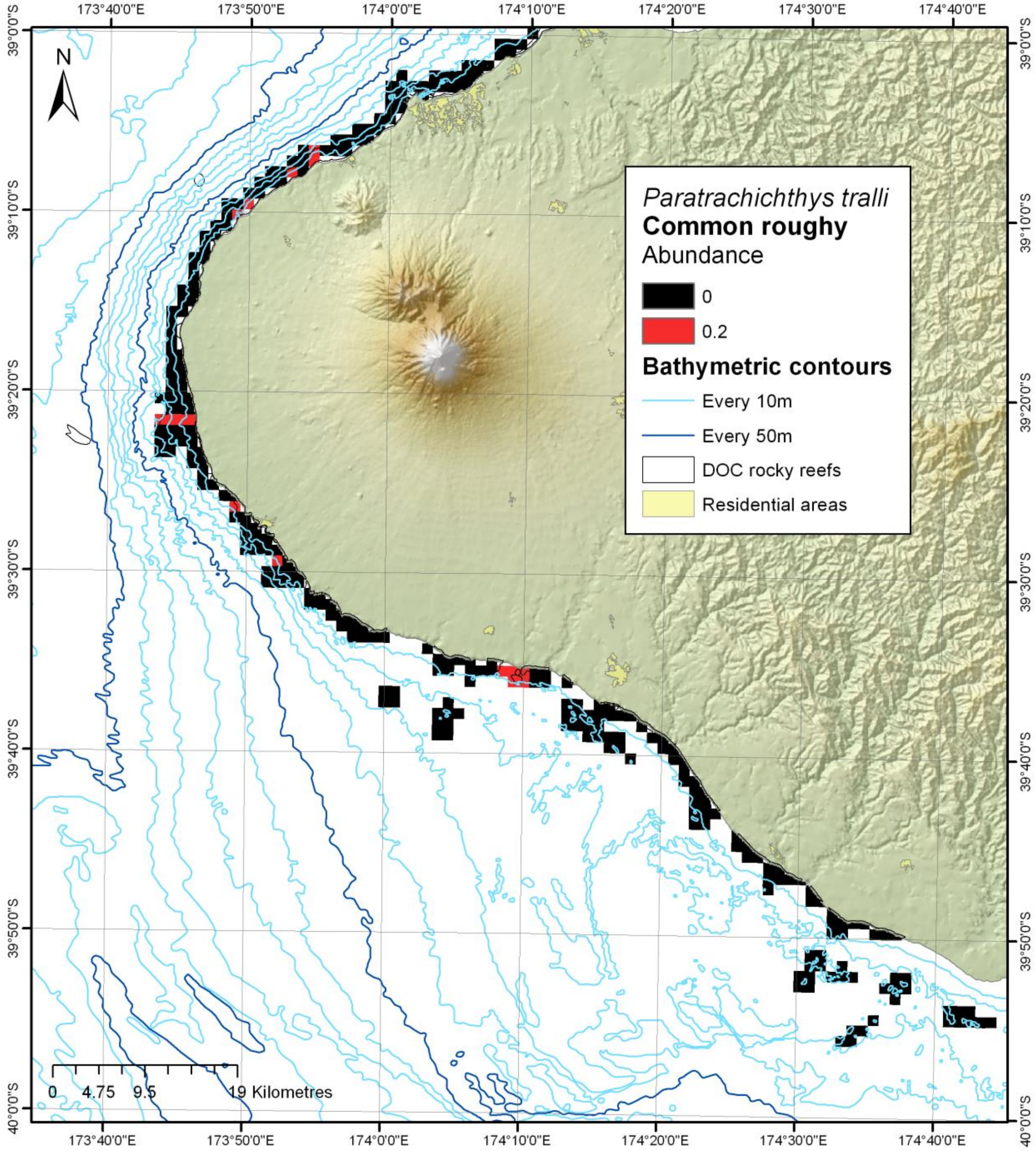


**Figure 2-2: Distribution and abundance of common roughy on reefs in the South Taranaki Bight.** Data are estimated abundance in 1 km$^2$ grid squares. Note on the scale 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). Model output from Smith (2008).

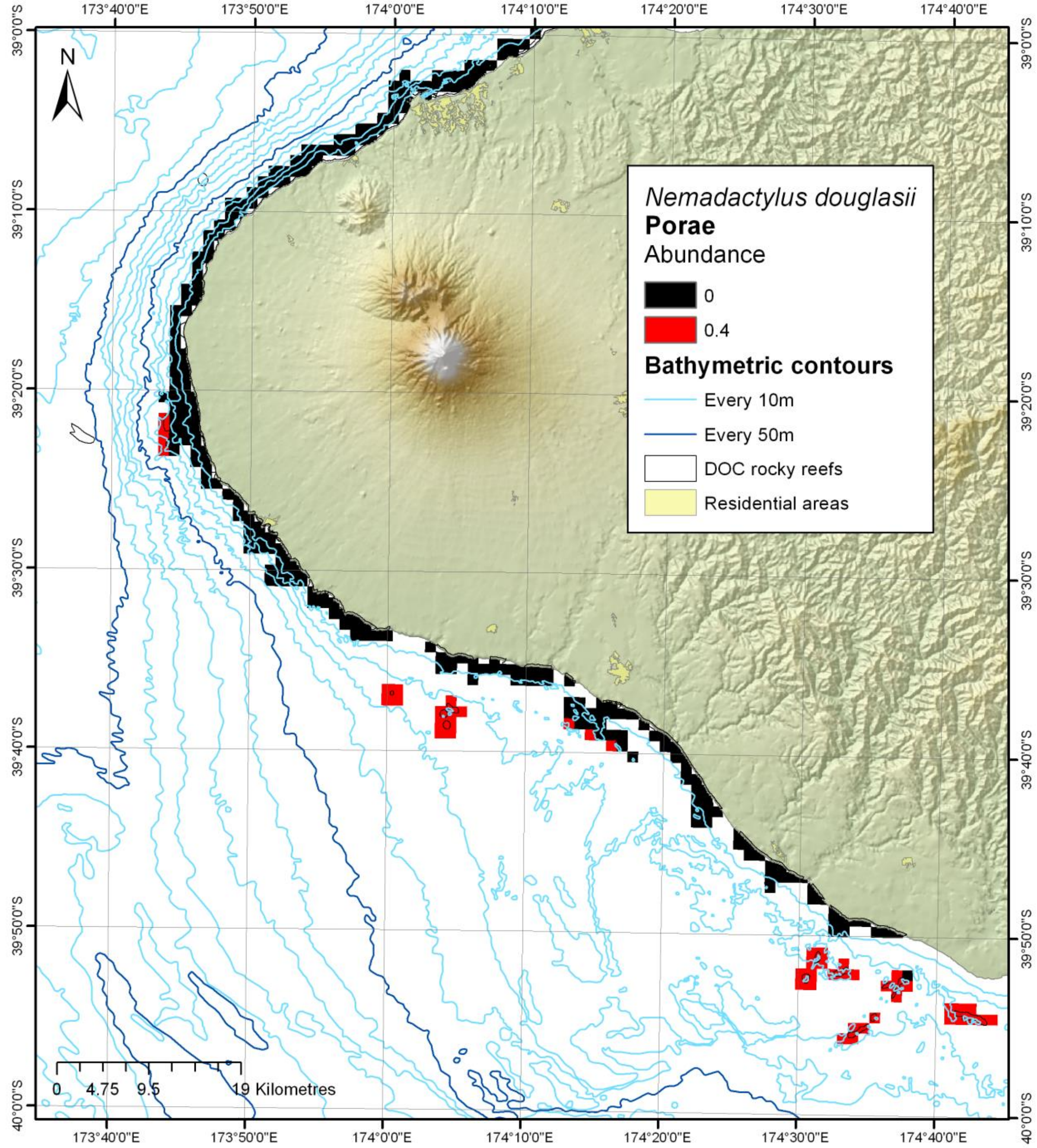


**Figure 2-3: Distribution and abundance of porae on reefs in the South Taranaki Bight.** Data are estimated abundance in 1 $km^2$ grid squares. Note on the scale 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). Model output from Smith (2008).

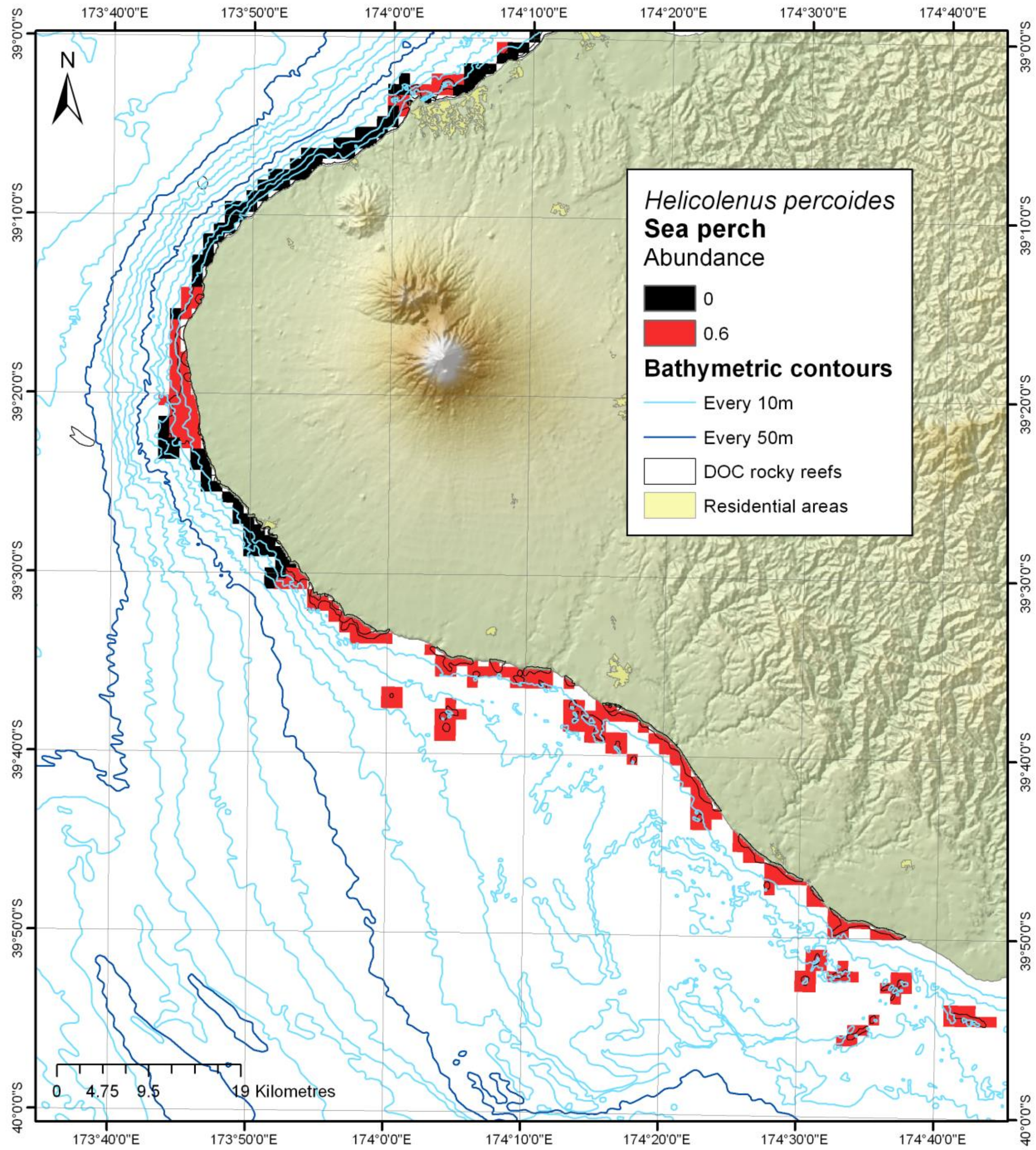


**Figure 2-4: Distribution and abundance of sea perch on reefs in the South Taranaki Bight.** Data are estimated abundance in 1 km² grid squares. Note on the scale 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). Model output from Smith (2008).

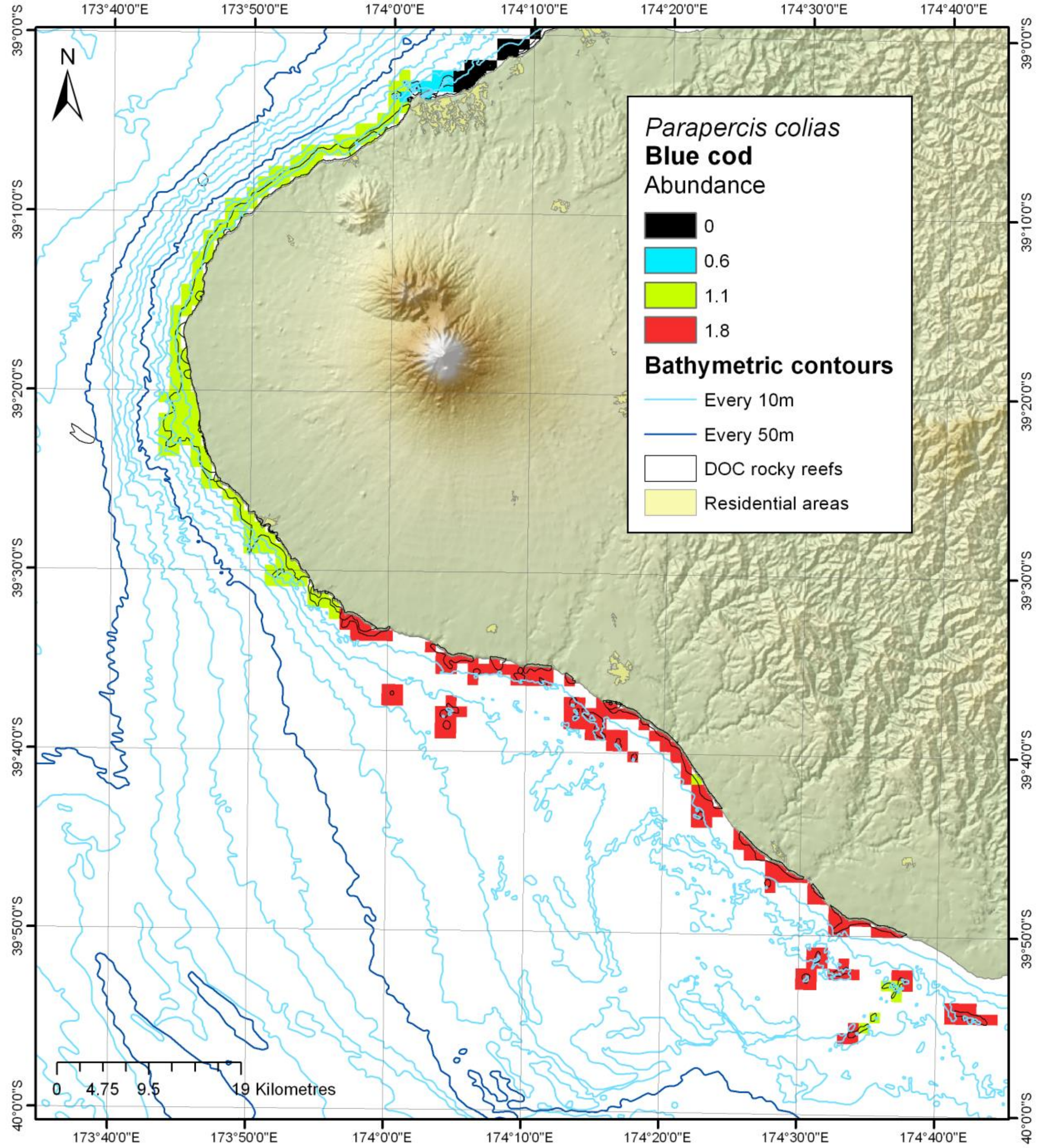


**Figure 2-5: Distribution and abundance of blue cod on reefs in the South Taranaki Bight.** Data are estimated abundance in 1 $km^2$ grid squares. Note on the scale 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). Model output from Smith (2008).

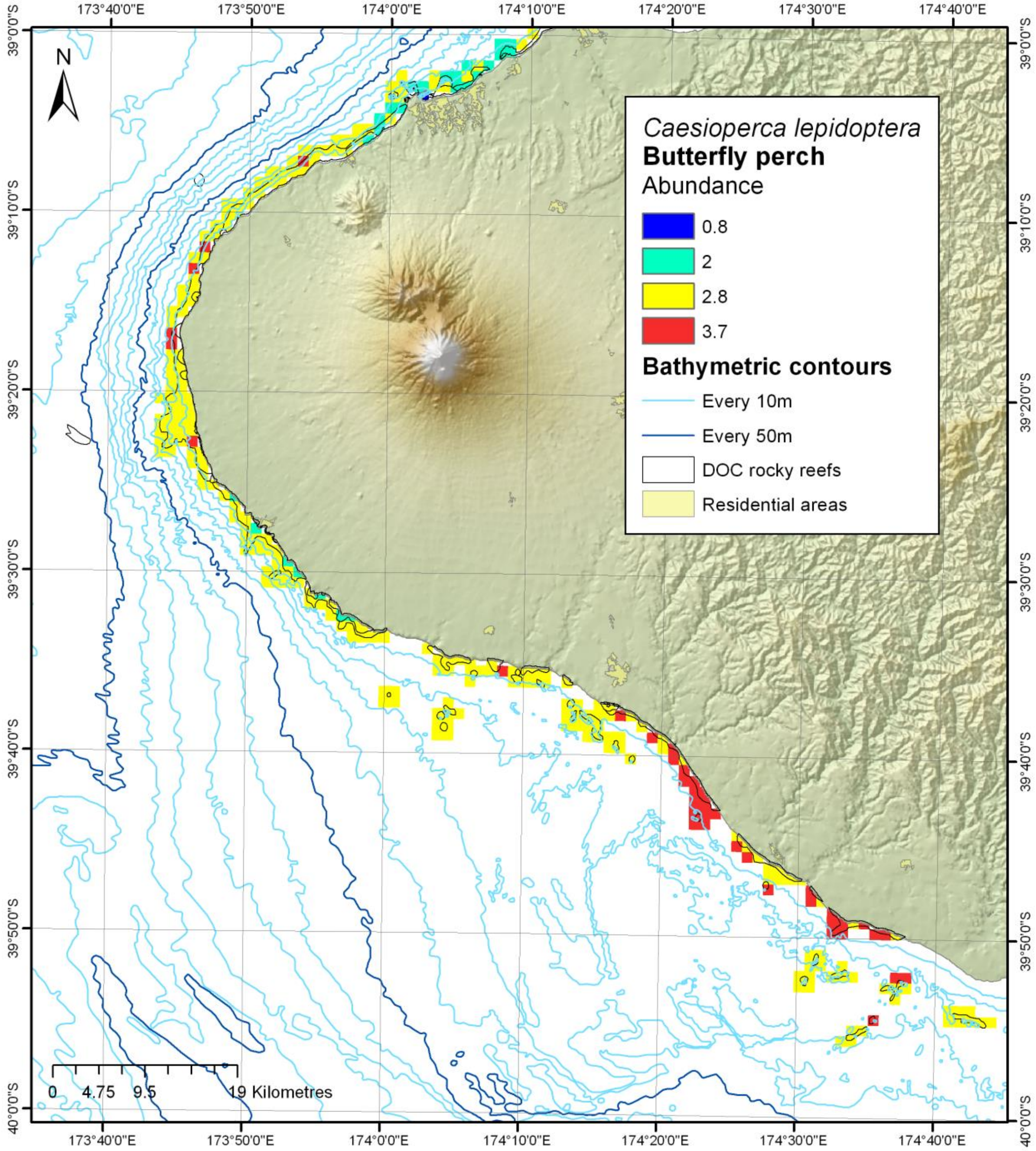


**Figure 2-6: Distribution and abundance of butterfly perch on reefs in the South Taranaki Bight.** Data are estimated abundance in 1 km² grid squares. Note on the scale 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). Model output from Smith (2008).

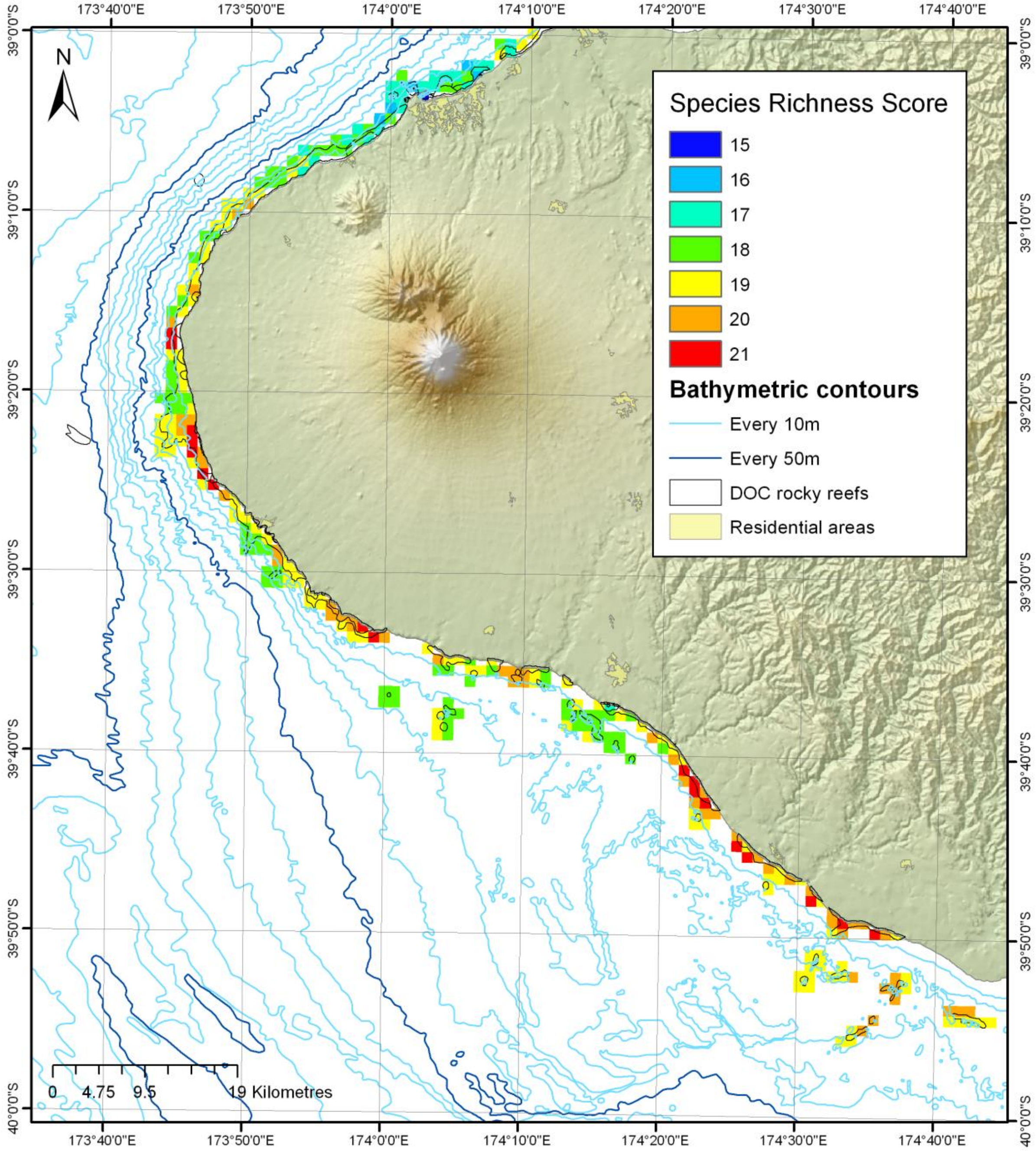


**Figure 2-7: Reef fish predicted species richness.** Total number of reef fish species predicted to occur within each 1 $km^2$ grid square within the study area. Model output from Beaumont et al. (2008).

## 2.4 Discussion

The STB has a moderately diverse reef fish fauna with only 37 of the 72 species modelled by Smith (2008) New Zealand-wide, predicted to occur on reefs within SCUBA diving depth range (<30 m) in the region. None of the modelled species are nationally threatened (Hitchmough et al. 2007, Townsend et al. 2008). However, two species, common conger eel and tarakihi, are predicted to be rare in the region, occurring at low abundance on just a few coastal reefs. Additionally, six other species are likely to have restricted distributions, predicted to occur at fewer than 50% of the reef sites in the region. All other twenty-nine species are predicted to be much more widespread occurring at the majority (24 species) or all (5 species) reefs within the region.

Despite their potential utility, Smith (2008) pointed out that his reef fish abundance predictions have a number of limitations. These include problems with counting fishes underwater (e.g., some species are attracted to divers and others are repelled, while small cryptic species are rarely observed, e.g., Willis & Anderson 2003), depth limitations (most dives were to less than 30 m depth), coarse spatial resolution (1 $km^2$) relative to the scale of habitat variation known to affect reef fish abundance (a few metres to tens of metres), and use of surrogate variables that may be inappropriate for reef fishes (e.g. wind fetch instead of wave exposure). It should be noted that the modelled reef fish distributions, abundances and diversity only applies to rocky reef habitats. Some species, such as leather jackets and tarakihi, also occur over open habitats. The distributions of these species in these habitats were modelled separately (see Section 4.0). Nonetheless, NIWA considers that the information from Smith (2008) provides an appropriate basis for subsequent consideration of potential effects associated with the TTR project on fish occurring on rocky reef habitats in the STB.

# 3 Crayfish ecology

## 3.1 Background

Marine crayfish, otherwise known as rock lobsters are typically the largest and most abundant invertebrate predator on coastal rocky reefs throughout New Zealand. The common species of crayfish in the STB is the red rock lobster (*Jasus edwardsii*), although occasional specimens of the packhorse rock lobster, (*Sagmariasus verreauxi*) are caught on the Taranaki coast (Booth 2011). The red rock lobster sustains important customary, recreational and commercial fisheries around New Zealand's entire coast and, where it is abundant, it is important in determining the structure and function of reef habitats (Shears & Babcock 2002, Ministry of Fisheries 2010). For this reason, in this section we review its ecology by drawing upon a large published literature on rock lobster distribution, abundance, patterns of movement, ecological interactions, and population connectivity around New Zealand.

## 3.2 Distribution and abundance

### 3.2.1 Depth distribution

Red rock lobsters occur predominately on rocky reefs from the shallow subtidal to depths of about 50 m but in some areas they occur as deep as 250 m (Annala & Bycroft 1984). However, at particular times of the year they may also occur on open ground within a few km of the coastline to feed on shellfish, hatch their offspring or to migrate (Street 1969, McKoy & Leachman 1982, Kelly et al. 1999, Langlois et al. 2005).

Juveniles are much more common on shallow reef areas (1 –10 m) than on deeper reef areas. In the Cape Rodney to Okakari Point (CROP) Marine Reserve near Leigh in the outer Hauraki Gulf, MacDiarmid (1991) found that of the 1521 juveniles counted during routine monthly surveys 55% occurred at depths less than 10 m, 33% occurred between 10 -17 m and only 12% occurred at depths greater than 17 m.

### 3.2.2 Abundance

High abundances of red rock lobsters can occur where exploitation levels are low. For example, in the Long Island-Kokomohua Marine Reserve in the Marlborough Sounds, rock lobsters currently occur at mean densities of 1200 $\pm$ 200 (SE) per ha of reef. In contrast, in most fished areas densities are much lower at between 20 and 200 $\pm$ 40 (SE) lobsters per ha (Freeman et al. in press).

### 3.2.3 Small scale patchiness

For a variety of reasons rock lobsters are patchily distributed within a reef system and this small scale distribution varies with lobster size, sex and moult and reproductive state. This affects the ecological impact lobsters have on the prey species and also affects the dynamics of the fishery.

Field surveys carried out by Butler et al. (1999) showed that red rock lobsters are solitary as newly settled juveniles and become social and aggregate as they grow larger. Butler at al. (1999) then demonstrated, using laboratory experiments, that there is a size specific increase in the response of larger juveniles to the chemical cues of larger lobsters which facilitates these life-stage changes in aggregation. Finally, results of field tethering experiments confirmed that this change in social condition is selectively advantageous: aggregation did not increase the survival of small lobsters, but larger juveniles survived better in groups (Butler et al.1999).

In adult red rock lobsters the tendency to cohabit with other lobsters varied between males and females and the time of year. Mature males tend to aggregate with other males during their moulting season in spring but den alone during the mating season in autumn/early winter when males compete for access to females. In contrast mature females are most highly aggregated over summer and slightly less so over the egg-bearing stage in winter (MacDiarmid 1994). During the peak period of mating activity (May-June) the majority of post-moult, un-mated females cohabit with a large mature male with most females associating with the largest males. This may result in as many as 16-20 females cohabiting with a single large male (MacDiarmid 1994).

## 3.3 Movements

### 3.3.1 Moulting

Red rock lobsters increase in size by periodically growing a new exoskeleton beneath their old one and then shedding or moulting the old exoskeleton. The new exposed exoskeleton is then inflated with water and hardened with calcium carbonate. Small juveniles go through this entire process several times a year but mature adults usually only moult once a year (MacDiarmid 1989). Most red rock lobsters moult at night (MacDiarmid 1989).

Red rock lobsters generally moult in depths of about 10 m or less (MacDiarmid 1991). As most juveniles live in this depth range they generally don’t move far, if at all, when moulting. But for deeper living mature lobsters moulting may entail an annual migration of a few hundred metres or a few km inshore to moult followed by a return movement a few days or weeks later. Highest densities of females in shallow water coincide with the moulting season in April/May. Males move inshore briefly to moult in spring (MacDiarmid 1991).

### 3.3.2 Reproduction

During the mating season mature male red rock lobsters attempt to defend dens containing mature females from other males, with larger males successfully displacing smaller males (MacDiarmid & Sainte-Marie 2006). MacDiarmid et al. (1991) found a significant negative relationship between male body size and distance moved at night during the mating season. Large males of 2 kg or more moved only 1-2 m immediately around their favoured den while smaller mature males were successively rebuffed by larger males, moving up to 90 m each night.

After moulting in autumn mature females seek out the largest mature male available in the vicinity (MacDiarmid et al. 2000, MacDiarmid & Sainte-Marie 2006). They make repeated movements among dens on a reef to check male availability moving a median total of 24 m each night (MacDiarmid et al. 1991). Once mated and brooding eggs externally on flaps (pleopods) beneath the abdomen, female movements initially decline substantially, moving a median of less than 5 m while foraging at night (MacDiarmid et al. 1991). Kelly (2001) tracked female lobsters using acoustic tags and found that females were more active toward the end of the 3.5 month egg-brooding season around September and October. Over this period females start to accumulate on the deep seaward margin of reefs or move across the adjoining sand flats and form aggregations in deep water where there is a strong current (McKoy & Leachman 1982, MacDiarmid 1991, Kelly et al. 1999). Here their larvae hatch at dawn each day over a period of 3-5 days to begin their long planktonic phase (MacDiarmid 1985).

### 3.3.3 Feeding

Rock lobsters leave their daytime shelters at dusk to feed upon on a wide range of sedentary prey (see 3.4.2), normally returning prior to dawn (Williams & Dean 1989, MacDiarmid et al. 1991). Nocturnal foraging distances on rocky reefs increase with body size with small juveniles foraging only about 2 m away from dens while larger adults forage up to 24 m (MacDiarmid et al. 1991, Oliver 2007).

Kelly (2001) tracked acoustic tagged large male lobsters in and around the Leigh Marine Reserve and found that they displayed two peaks in activity over the year, one in summer near the start of the new moult cycle, and another in winter following the mating season. These coincide with peaks in feeding activities which immediately follow moulting and mating respectively, when males rarely feed (Kelly & MacDiarmid 2003). During these peaks in feeding activity some males travelled up to 2 km from the deep seaward margin of reefs across adjacent sand flats to feed on bivalves, gastropods and crustaceans at depths of 30-40 m (Kelly & MacDiarmid 2003, Langlois et al. 2005, Langlois et al. 2006 b & c). Here they form large daytime aggregations and forage nocturnally (Kelly et al. 1999). Some females move onto the sandflats during spring to hatch their larvae, forming similar daytime aggregations and may forage during this time. Some females also forage on sandflats during summer (Kelly & MacDiarmid 2003). The mean size of lobsters in offshore aggregations is typically greater than the mean size of reef populations (Kelly et al. 1999) but smaller adults may forage nocturnally on sandflats immediately adjacent to the reef, returning to shelter on the reef by day.

Sightings by TTR field staff of large male rock lobsters offshore on small patch reefs and open sand at depths of 30-50 m are consistent with offshore foraging for shellfish observed by Kelly & MacDiarmid (2003).

### 3.3.4 Site association

Red rock lobsters may associate with a reef or reefs along one section of coastline for months or years. Freeman et al. (2009) found that nearly all tagged lobsters on reef systems on the east coast of North Island near Gisborne were recaptured over three years on the same reef on which they were originally tagged. Females moved a median distance of less than 50 m between tagging and recapture while males moved a median of 100-200 m (Freeman et al. 2009). In the Leigh Marine Reserve in the Hauraki Gulf, Kelly and MacDiarmid (2003) found that at least 21% of tagged lobsters maintained an association with a single 15 ha reef system for 1-8 years. Site association tended to increase with female size, whereas site association in males was relatively constant until about 1 kg body weight and then markedly increased. About 30% of lobsters tagged by Kelly and MacDiarmid (2003) moved 0.25-6 km from their tagging site but homing behaviour meant that many lobsters eventually returned to their original reef. Kelly (1999) fitted individual large mature red rock lobsters with acoustic tags and tracked their position within the Leigh Marine Reserve and Tawharanui Marine Park in north-east New Zealand at regular intervals for up to one year.

They displayed a high degree of site fidelity, spending a median of 84% of their time at the primary home site. Twenty-one percent of 32 lobsters tracked with acoustic tags never left the home site and of those that moved more than 100 m away, 56% returned. Five lobsters had strong associations with two alternate home sites that were between 200 m and 1.3 km apart, and made repeated movements between them. However, during homing movements individuals did not settle in intermediate areas, even though they contained suitable habitat. The maximum distances lobsters moved away from the home site were bimodally distributed, with one peak between 200 and 500 m and another between 1 and 3 km. The time lobsters spent away from the primary home site on any one excursion ranged from one to 103 days, with most lobsters spending less than 40 days away in a continuous period. During larger scale homing movements, over 1 km in length, lobsters appeared to retrace their outward route on the return journey, and no evidence for novel shortcutting was observed. We expect lobsters around the STB to display similar strong associations with the same stretch coastline.

### 3.3.5 Mass Migration

Mass migration of juvenile or sub-adult red rock lobsters is a well recorded phenomenon around the southern coasts of South Island (Street 1969, McKoy 1983, Booth 1997). During spring and early summer, some immature individuals migrate against the main current flow from the east and south-eastern coasts of South Island around Stewart Island towards Fiordland and southern Westland. The numbers moving varies from year to year (Booth 1997). There is no evidence for similar large scale mass migrations around any North Island (Annala 1981, Booth 1997).

## 3.4 Ecological Interactions

### 3.4.1 Predators

Records of spiny lobster in gut content analysis are rare, but most species of large fish are probably capable of consuming adult lobsters. Spiny lobsters have been recorded in the gut of bronze whaler shark (*Carcharhinus brachyurus*), rig (*Mustelus lenticulatus*), hapuka (*Polyprion oxygeneios*), snapper (*Pagrus auratus*) and blue cod (Ayling and Cox 1982, Francis 2001, Malcolm Francis personal observation). They are likely preyed upon by other large predatory fishes (e.g. sharks and sting rays), but are unlikely to form a large proportion of the diet of these species. Historically, “crayfish” were frequently recorded from guts of snapper caught by lighthouse keepers in northern New Zealand (Thomson 1892), and, around Otago, lobster 18-28 cm long were common in the guts of hapuka (Graham 1957). In more recent studies, red rock lobsters were found in the guts of only two out of 450 banded wrasse (*Notolabrus fucicola*) caught at Kaikoura (Denny & Schiel 2001), and were not found in the guts of any of the rocky reef fishes sampled by Russell (1983), which included 23 snapper. Spiny lobsters were also absent from the guts of a large number of Hauraki Gulf snapper (Godfriaux 1969, Colman 1972), but these fishes were trawled from soft sediments where juvenile lobsters were not likely to be present anyway.

However, gut contents do not necessarily reflect the impact of a predator on its prey, as highly preferred food items may be suppressed to the point where they are rarely available for consumption (Choat 1982).

Although octopus (*Pinnoctopus cordiformis*) are widely acknowledged as being an important predator of spiny lobsters very little is known of their effects other than that they do prey upon spiny lobsters caught in commercial and recreational traps (Ritchie 1972). Their effects are likely to be highly variable as octopus populations vary substantially among localities and from year to year.

Since most of the predators of adult spiny lobster are large and mobile, predation pressure may vary with season if predators make wide ranging seasonal movements.

Juvenile spiny lobsters are likely vulnerable to more species of predatory fishes than adults, and are probably consumed at higher rates by the above mentioned fish. MacDiarmid and Booth (2003) list blue cod, snapper, banded wrasse, spotty (*Notolabrus celidotus*), scorpionfishes (*Scorpaena* spp), conger eel (*Conger* spp.) and small sharks as predators of newly-settled lobsters, and consider that “predation probably claims most juveniles settling on reefs each year”. Additional potential predators include moray eels (*Gymnothorax* spp.), rock cod (*Lotella rhacinus*), bastard cod (*Pseudophycis barbata*), hiwihiwi (*Chironemus marmoratus*), and red moki (Ayling & Cox 1982, Francis 2001).

Despite drawbacks, tethering prey in the field is a useful way to quantify relative predation rates, and predators can be identified if the tethers are connected to an underwater camera. At Leigh, 19 of 25 (76%) juvenile lobsters (carapace length 10-29 mm) tethered on sand over a daytime high tide were removed by predators, while 5 of 15 lobsters (33%) tethered at night were taken (Bassett et al. 2008). In decreasing order of importance, the main daytime predators of small juvenile red rock lobsters were banded wrasse, spotty, blue cod, and snapper. The main night-time predators were hiwihiwi, octopus and long-tailed stingray (*Dasyatis thetidis*). In another Leigh tethering study, juvenile lobsters <25 mm carapace length were most vulnerable to predators, with individuals >30 mm less susceptible (Kington 1999). Survival differed little between day and night. Fishes observed taking juvenile lobsters were bastard cod, rock cod, blue cod, leatherjacket and red-banded perch. At Wellington, divers observed schools of spotty attacking and killing tethered juvenile lobsters (Oliver et al. 2005).

In Tasmania, 46% of 37 tethered juvenile red rock lobsters taken by predators fell to fish, mainly wrasses *Notolabrus* spp. (incl. *N. fucicola*) and a conger eel, with the remainder taken by octopus (19%), swimming crabs *Nectocarcinus* spp. (19%), and larger lobsters (16%) (Oliver et al. 2005). Blue-throated wrasses (*Notolabrus tetricus*) were observed taking tethered juvenile rock lobsters in another Tasmanian experiment (Mills et al. 2006).

Tethering experiments by Butler et al. (1999) indicated that predation of juvenile red rock lobsters can be modulated by aggregation. They found while aggregation does not increase the survival of small newly settled lobsters, larger juveniles survive better in groups.

In summary, wrasses and snapper appear to be consistently important predators of juvenile lobsters around North Island, with numerous other fish species also capable of eating them.

### 3.4.2 Prey

Kelly et al. (in prep) have undertaken a comprehensive study of the diet of red rock lobsters from near Leigh in north-eastern New Zealand and from Wellington. They found a broad range of prey including molluscs, crustaceans, annelid worms, macro-algae, echinoderms, sponges, bryozoans, fish, forams and brachiopods. Kelly et al. (in prep) found that the highest frequencies of occurrence in lobster guts were for three mytilid bivalves (mussels), which were present in nearly half of the lobster guts containing food where they comprised 40% of stomach volume. The trochid gastropods, *Cantharidus purpureus* and *Trochus viridus*, also appear to be an important molluscan prey for red rock lobsters, being found by Kelly et al. (in prep) in over a third of the guts containing food.

Crustacean remains were found by Kelly et al. (in prep) in 66% of the guts containing food. A variety of decapods, ostracods, amphipods and barnacles were distinguishable, with decapods comprising the bulk of crustacean material. Recent work by Freeman (2007) and Pinkerton et al. (2010) indicated that higher density populations of lobsters may exhibit quite high levels of cannibalism – presumably larger individuals eating smaller ones or intermoult animals preying on just moulted individuals. Using stable isotope signatures it was estimated that up to 50% of the energetic requirements of lobsters within the Te Tapuwae o Rongokako Marine Reserve north of Gisborne on the east coast of North Island came from other lobsters. In lower density fished populations only about 15% of energetic needs were met through cannibalism. Likewise Kelly et al. (in prep.) found that lobster remains frequently occur in gut samples of a wide size range of lobsters.

Like many other lobster species, macroalgae appear to comprise a significant dietary component for red rock lobsters with fleshy green, brown and red algae occurring in around 15% of the stomachs examined by Kelly et al. (in prep.) that contained food and 40-60% of lobster stomachs sampled by Freeman (2007) north of Gisborne. Consumption of macroalgae does not appear to have been due to a limited supply of animal prey, as has been suggested for other lobster species, indicating that red rock lobsters may obtain specific nutritional benefits from the consumption of algae (Freeman 2007).

Kelly et al. (in prep) recorded some coralline algae in the diet of lobsters sampled in north-eastern New Zealand while Freeman (2007) found that this group occurred in 90% of the lobsters she sampled, but comprised only about 14% of the diet by volume. Moreover Freeman (2007) also found that coralline turf was less abundant where lobsters were abundant and inferred that their grazing has a significant influence on turf populations.

It has always been difficult to determine the significance of the presence of fishes in the guts of lobsters as fish remains are often used as bait in traps and lobsters can readily enter, feed and later escape. Fish remains in the guts of red rock lobsters sampled by Kelly et al. (in prep) from inside the Leigh Marine Reserve where baited pots are absent indicated that fish do constitute a natural, although relatively unimportant, component of lobster diet. In contrast, Freeman (2007) found no fish in the diet of lobsters sampled from within the Te Tapuwae o Rongokako Marine Reserve north of Gisborne. In nearby fished areas however, she found fish bait species comprised about 45% of the diet of lobsters.

It has been proposed that red rock lobsters are a major predator of sea urchins (*Evechinus chloroticus*) and thus are important in modulating the grazing by sea urchins on kelp (Shears and Babcock 2002). The test diameter of kina eaten by spiny lobsters is dependent on their body size. Adult lobsters > 130 mm carapace length (CL) are capable of preying on the whole size range of kina while smaller lobsters take progressively smaller kina (Andrew & MacDiarmid 1991). Shears & Babcock (2002) found that the majority of wounds sustained by kina tethered in urchin barrens in two marine protected areas were consistent with those inflicted by lobsters. However, kina are not a preferred prey item of spiny lobsters and comprise only a small proportion of their diet. Kelly et al. (in prep) found the frequency of occurrence of kina in the guts of lobsters was fairly consistent among locations and times, being found in around 12% of lobsters with food in their guts and in 9% of all lobsters sampled. However, as red rock lobsters are gregarious and often occur in relatively high local densities (MacDiarmid 1994, Kelly et al. 1999, 2000) they have the potential to consume significant numbers of urchins in particular areas. Kelly et al. (in prep) found from gut clearance data that most food material passes through the foregut within 7-12 hours, so it is likely that urchins found in gut samples were consumed within 24 hours of sampling.

Kelly et al. (in prep) found no significant changes in diet composition in lobsters > 40 mm CL. Juveniles larger than this size have the same diet as described above for adults though there is evidence that the maximum size of a prey type able to be taken increases with lobster size (Andrew and MacDiarmid 1991, Langlois et al. 2006b). No New Zealand studies have examined the diet of very small juvenile rock lobsters. The same species occurs in southern Australia, however, where Edmonds (1995) found small molluscs (mainly gastropods), amphipods and small echinoderms comprised the majority of the diet of small juveniles. The diet of small juveniles in New Zealand is likely to be similar.

**Figure 3-1: A large male red rock lobster advances off the reef over the sand flats.** Photographer Alison MacDiarmid.

## 3.5 Connectivity with other populations

Red rock lobsters have a long pelagic larval phase lasting 1-2 years (Booth 1994). Over this period, while in the water column, larvae may be carried considerable distances (100s – 1000s of km) away from the parental reefs. In some places large offshore eddies may maintain the larvae close to their source populations The degree of connectivity between populations of red rock lobsters around New Zealand has been explored by Chiswell & Booth (2008) using satellite measured ocean currents to numerically model tracks of individual larva originating from different locations to build a statistical picture of both where larvae from a particular source settle (i.e. larval sinks), and conversely, where settlement at a particular location originated from (i.e. larval sources). Connectivity in this species has also been explored using genetic microsatellite markers (Thomas & Bell 2013).

The study by Chiswell & Booth (2008) indicated that red rock lobsters breeding in the CRA 9 area (this includes the STB as well as much of the west coasts of North Island and South Island) contribute substantially to populations around the rest of New Zealand. CRA 1 (the east and west coasts of the Northland peninsular) is particularly dependent on larvae originating from CRA 9 with 80% originating from this region. Importantly, only about 17% of larvae originating from within CRA 9 actually settle as juveniles somewhere in the same region. About 75% of lobster larvae settling in the CRA 9 area, including reefs in the STB, originate from CRA 8, which includes Fiordland, the Southland coast and Stewart Island.

## 3.6 Discussion

Red rock lobsters are typically the largest and most abundant invertebrate predator on coastal rocky reefs throughout New Zealand. At certain times of the year, particularly immediately after the mating and moulting in winter and summer respectively larger males may migrate offshore across sand flats to feed on shellfish. Egg-brooding females may also form offshore aggregations in areas of high water current in spring at the time of larval hatching. The limited available data from the STB suggests that this migration does not carry lobsters as far offshore as TTR's proposed project area.

Modelling by Chiswell & Booth (2008) indicated that that the STB lobster population is most dependent on larval supply from lobster stocks living around Fiordland, Southland and Stewart Island with only a minor component (17%) originating from adult lobsters in the CRA9 region of which the STB comprises about 10%. Although, the lobster stock in CRA 9 makes a very significant contribution of larvae to lobsters stocks in CRA 1, along the east and west coasts of the Northland peninsular, it is unclear what proportion comes from the STB region.

# 4 Demersal and pelagic fish distribution and abundance

## 4.1 Background

Demersal (bottom associated) and pelagic (open water) fish occur over a variety habitats in the region, including the inner harbour muds and harbour entrance sands and gravels. Some species support important commercial, recreational and/or customary fisheries in the region. We propose to summarise the information pertaining to the distribution and abundance of these fish species in Wellington Harbour, along Wellington's south coast, and in Cook Strait using existing research trawl information. We suggest this is more likely to yield dependable information than a modern one-off survey even if permission could be granted for a destructive trawl-survey in enclosed harbour waters. There have been many research bottom trawl surveys around New Zealand that have sought to determine fish distribution and abundance. Interpreting the raw abundance data from these surveys is difficult because they were collected using different vessels and fishing gear, in different seasons, and at different depths. Rather than providing the raw information from these surveys we propose to present the predicted distributions and catch levels from existing statistical models describing the relationships between environment variables and catch as recorded in data from 21 000 research trawls sampling demersal waters throughout New Zealand's EEZ from 1979-1997 (). We also propose to summarise the available data on the presence of spawning, egg-laying, pupping, or juvenile fish in the regions of interest drawing on a review undertaken by Hurst et al. (2000).

### 4.1.1 Adult fish

The biological data layers contained in this section describe the predicted distributions of 51 demersal fish species occurring in the region (Table 4-1). All layers were produced from statistical models describing the relationships between environment and catch as recorded in data from research bottom trawls from only three vessels; RVs *James Cook*, *Kaharoa* and *Tangaroa*. These predictions were derived using a statistical implementation of Boosted Regression Trees (BRTs), a recently developed technique that uses stochastic gradient boosting to fit a model (Friedman 2002), enabling sophisticated regression analyses of complex responses, optimised for high predictive performance (Elith et al. 2006; Leathwick et al. 2006a). This method differs from conventional regression in that rather than fitting a single "best" model, it fits an ensemble or "committee" of simple regression tree models that are then combined to form predictions.

Two statistical models were fitted for each species and combined to predict spatial variation in standardised catch; the first described the probability of a catch from presence/absence transformed data from all trawls; the second described the amount of fish caught conditional on a catch occurring, and used log-transformed catch data from only those trawls in which the species were caught. These models were then used to predict both the probability of capture and catch (kg/trawl) under standardised trawl conditions. Predictions were made for all 1 $km^2$ grid cells. Grids are defined within the Clarke 1866 Mercator projection, i.e. the same projection as used for Marine Environments Classification (MEC) (Snelder *et al.* 2007). Further details of the modelling methods are provided in Leathwick et al. (2006 a & b).

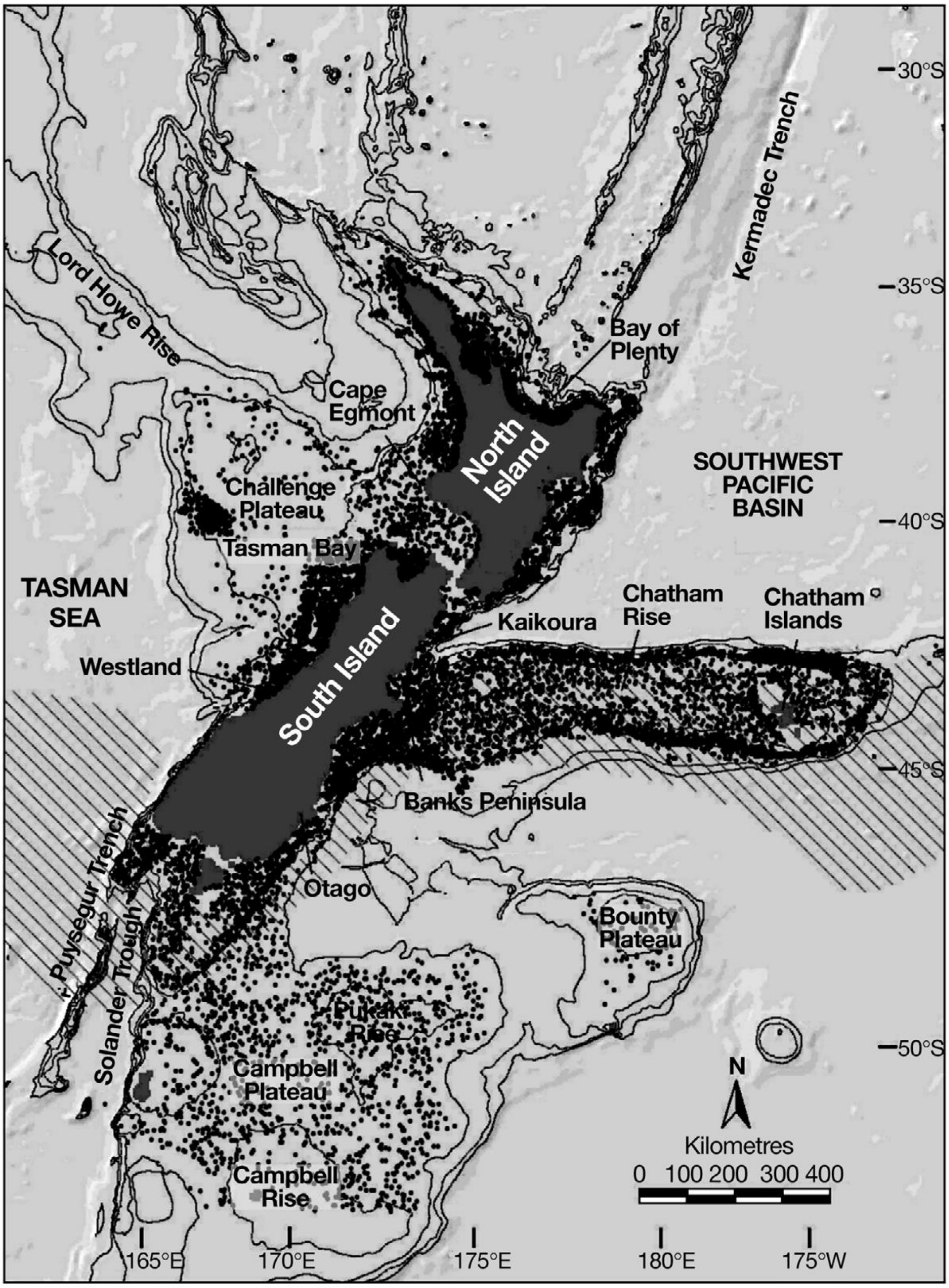


**Figure 4-1: Locations of existing bottom trawls that will be used in the analysis of demersal and pelagic fish distributions.** Bathymetric contours are shown only to a depth of 2000 m. The 500, 1000, 1500 and 2000 m isobaths are given. Locations of trawl sites are indicated by dots, and the approximate position of the subtropical front (STF) is shown by diagonal hatching. Figure from Leathwick et al. (2006a).

**Table 4-1: Species codes for 51 demersal and pelagic fish species, and their corresponding common and scientific names.**

| Code | Common name | Scientific name | Principal distribution |
|---|---|---|---|
| ANC | Anchovy | *Engraulis australis* | Pelagic |
| BAR | Barracouta | *Thyrsites atun* | Pelagic |
| BCO | Blue cod | *Parapercis colias* | Demersal |
| BRA | Short-tailed black ray | *Dasyatis brevicaudata* | Demersal |
| CAR | Carpet shark | *Cephaloscyllium isabellum* | Demersal |
| CBE | Crested bellowsfish | *Notopogon lillei* | Pelagic |
| CUC | Cucumber fish | *Chlorophthalmus nigripinnis* | Pelagic |
| EGR | Eagle ray | *Myliobatis tenuicaudatus* | Demersal |
| ELE | Elephant fish | *Callorhinchus milii* | Demersal |
| EMA | Blue mackerel | *Scomber australasicus* | Pelagic |
| ESO | N.Z. sole | *Peltorhamphus novaezeelandiae* | Demersal |
| FRO | Frostfish | *Lepidopus caudatus* | Pelagic |
| GSP | Pale ghost shark | *Hydrolagus bemisi* | Demersal |
| GUR | Gurnard | *Chelidonichthys kumu* | Demersal |
| HAK | Hake | *Merluccius australis* | Pelagic |
| HAP | Hapuka | *Polyprion oxygeneios* | Demersal |
| HOK | Hoki | *Macruronus novaezelandiae* | Demersal and pelagic |
| JDO | John dory | *Zeus faber* | Demersal |
| JMD | Horse mackerel | *Trachurus declivis* | Pelagic |
| JMM | Murphys mackerel | *Trachurus symmertricus murphyi* | Pelagic |
| JMN | Golden mackerel | *Trachurus novaezelandiae* | Pelagic |
| KAH | Kahawai | *Arripis trutta* | Pelagic |
| KIN | Kingfish | *Seriola lalandi* | Pelagic |
| LEA | Leatherjacket | *Parika scaber* | Demersal |
| LIN | Ling | *Genypterus blacodes* | Demersal |
| LSO | Lemon sole | *Pelotretis flavilatus* | Demersal |
| NSD | Northern spiny dogfish | *Squalus griffini* | Pelagic |
| PCO | Ahuru | *Auchenoceros punctatus* | Pelagic |
| POP | Porcupine fish | *Allomycterus jaculiferus* | Pelagic |
| RBM | Rays bream | *Brama brama* | Pelagic |
| RBT | Redbait | *Emmelichthys nitidus* | Pelagic |
| RCO | Red cod | *Pseudophycis bachus* | Demersal |
| RMU | Red mullet | *Upeneichthys lineatus* | Demersal |
| SCG | Scaly gurnard | *Lepidotrigla brachyoptera* | Demersal |
| SCH | School shark | *Galeorhinus galeus* | Pelagic |
| SDO | Silver dory | *Cyttus novaezealandiae* | Demersal |
| SFL | Sand flounder | *Phombosolea plebeia* | Demersal |
| SKI | Gemfish | *Rexea solandri* | Pelagic |
| SNA | Snapper | *Pagrus auratus* | Demersal |

| Code | Common name | Scientific name | Principal distribution |
|---|---|---|---|
| SPD | Spiny dogfish | *Squalus acanthias* | Pelagic |
| SPE | Sea perch | *Helicolenus spp.* | Demersal |
| SPO | Rig | *Mustelus lenticulatus* | Demersal |
| SPZ | Spotted stargazer | *Genyagnus monopterygius* | Demersal |
| SSI | Silverside | *Argentina elongate* | Pelagic |
| STY | Spotty | *Notolabrus celidotus* | Demersal |
| SWA | Silver warehou | *Seriolella punctata* | Pelagic |
| TAR | Tarakihi | *Nemadactylus macropterus* | Demersal and pelagic |
| TRE | Trevally | *Pseudocaranx dentex* | Demersal and pelagic |
| WAR | Common warehou | *Seriolella brama* | Pelagic |
| WIT | Witch | *Arnoglossus scapha* | Demersal |
| YBF | Yellow-belly flounder | *Rhombosolea leporina* | Demersal |

Environmental predictors used in this analysis (shown in Table 4-2) were based on those used by Leathwick et al. (2006a) with modifications as follows. Estimates of sea floor water temperature and salinity were derived from the World Oceans Atlas (Boyer et al. 2005) as described in Pinkerton et al. (2005). Estimates of suspended particulate matter and dissolved organic matter were derived from a case-2 analysis of satellite imagery (Pinkerton & Richardson 2005), and for consistency, estimates of chlorophyll-*a* concentration (a proxy for micro-algal biomass) were also derived from a case-2 analysis.

**Table 4-2: Environmental and trawl variables used in predicting the distribution of demersal fish species across New Zealand's Exclusive Economic Zone.**

| Variable | Details |
|---|---|
| AvgDepth | Average depth (m) |
| Temperature | Estimated temperature at the sea floor (°C) |
| Salinity | Estimated salinity at the seafloor (psu) |
| ChlaCase2 | Chlorophyll-a concentration – derived from case-2 algorithm (ppm) |
| SSTGrad | Sea surface temperature spatial gradient (°C $km^{-1}$) |
| TidalCurr | Depth averaged tidal currents ($ms^{-1}$) |
| Slope | Sea-floor slope (°) |
| SusPartMat | Suspended particulate matter (approximate to g $m^{-3}$) |
| OrbVel | Wave-induced orbital velocity at the seafloor (m $s^{-1}$) |
| DisOrgMat | Dissolved organic matter (dimensionless index) |
| CodendSize | Mesh-size of the trawl cod-end (mm) |
| Distance | Trawl distance (nm) |
| Pentade | Year of trawling grouped in five-year intervals |
| Speed | Trawl speed (kn.) |

### 4.1.2 Presence of spawning, egg-laying, pupping, or juvenile fish

A comprehensive New Zealand wide review of areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand coastal fish was carried out by Hurst at al. (2000) who examined published and unpublished literature, as well as the Ministry for Primary Industries fisheries research and commercial scientific observer databases. Some data were provided by research programmes funded by other providers. We drew upon this review to extract information relevant to the STB.

## 4.2 Results

### 4.2.1 Data coverage

A good representation of research trawls (666 trawls; ~3% of the NZ EEZ total) ranging in depth from 4-1410 m appears within the region of interest. In general, there is good spatial coverage throughout the region. The trawls span 18 years from 1979 to 1997.

### 4.2.2 Predicted fish distributions

The modelled distributions (probability of occurrence (%) in trawl catches) of the demersal fish species occurring in the STB region are provided as maps (on a 1-km grid) in Appendix B, and the main depth ranges of the modelled predictions for each species are summarised in Table 4-3. The distribution of leatherjacket is shown as an example in Figure 4-2. They are particularly common inshore on shallow reefs and in 20-50 m along the whole STB and also in Tasman Bay. There are similar distinct distributions for many of the species.

**Table 4-3: Main depth ranges for the predicted catch rates, by species.** Note that several species are not included in this table: for hake the predicted distribution was mainly concentrated in patches in 20–100 m in Tasman Bay and in Cook Strait; Murphy's mackerel was common only on the southern flanks of Cook Strait.

| Depth range | Species |
|---|---|
| < 50 m | anchovy, elephant fish, eagle ray, kahawai, kingfish, leather jacket, lemon sole, New Zealand sole, ahuru, sand flounder, snapper, spotted stargazer, spotty, short-tailed black ray, yellow-bellied flounder, red mullet, trevally, common warehou |
| < 100 m | blue cod, blue mackerel, cucumberfish, red gurnard, John dory, kingfish, porcupine fish |
| < 150 m | golden mackerel, rig, scaly gurnard |
| < 200 m | barracouta, ling, red cod, spiny dogfish, school shark, tarakihi |
| > 50-200 m | carpet shark, frostfish, hapuka, horse (greenback jack) mackerel and witch. |
| 100–150 m | gemfish, Murphy's mackerel, mirror dory, crested bellowsfish, redbait, and seal shark. |
| 100–200 m | hapuka, horse mackerel, common warehou, northern spiny dogfish, ray's bream, sea perch, silverside, spiny dogfish, |
| 150-200 m | bluenose, crested bellowsfish, gemfish, hoki, pale ghost shark, capro dory, silver warehou and silver dory |

For some species there are well-defined concentrations of higher predicted catch rates within the broad depth ranges given in Table 4-3; for example, leatherjacket, golden mackerel (*Trachurus novaezelandiae*), eagle ray (*Myliobatis tenuicaudatus*) and blue cod. Some species were particularly common through the whole region, particularly baracoutta

(*Thyrsites atun*) carpet shark (*Cephaloscyllium isabellum*), red gurnard (*Chelidonichthys kumu*), school shark (*Galeorhinus galeus*), spiny dogfish (*Squalus griffini*) and tarakihi.

Species such as elephant fish (*Callorhinchus milii*), New Zealand sole (*Peltorhamphus novaezeelandiae*), kahawai (*Arripis trutta*), kingfish (*Seriola lalandi*), ahuru (*Auchenoceros punctatus*), sand flounder (*Phombosolea plebeia*), snapper, rig, spotted stargazer (*Genyagnus monopterygius*), spotty, trevally (*Pseudocaranx dentex*), short-tailed black ray (*Dasyatis brevicaudata*), and yellow-bellied flounder (*Rhombosolea leporina*) showed distinct inshore distributions.

Species with a high probability of occurrence along the south Taranaki coastline coincidental with areas of interest to TTR include barracouta, blue cod, carpet shark, eagle ray, John dory (*Zeus faber*), golden mackerel, kahawai, leatherjacket, lemon sole (*Pelotretis flavilatus*), red cod (*Pseudophycis bachus*), red gurnard (*Chelidonichthys kumu*), rig, school shark, snapper, spiny dogfish, tarakihi, trevally, common warehou (*Seriolella brama*), and witch (*Arnoglossus scapha*).

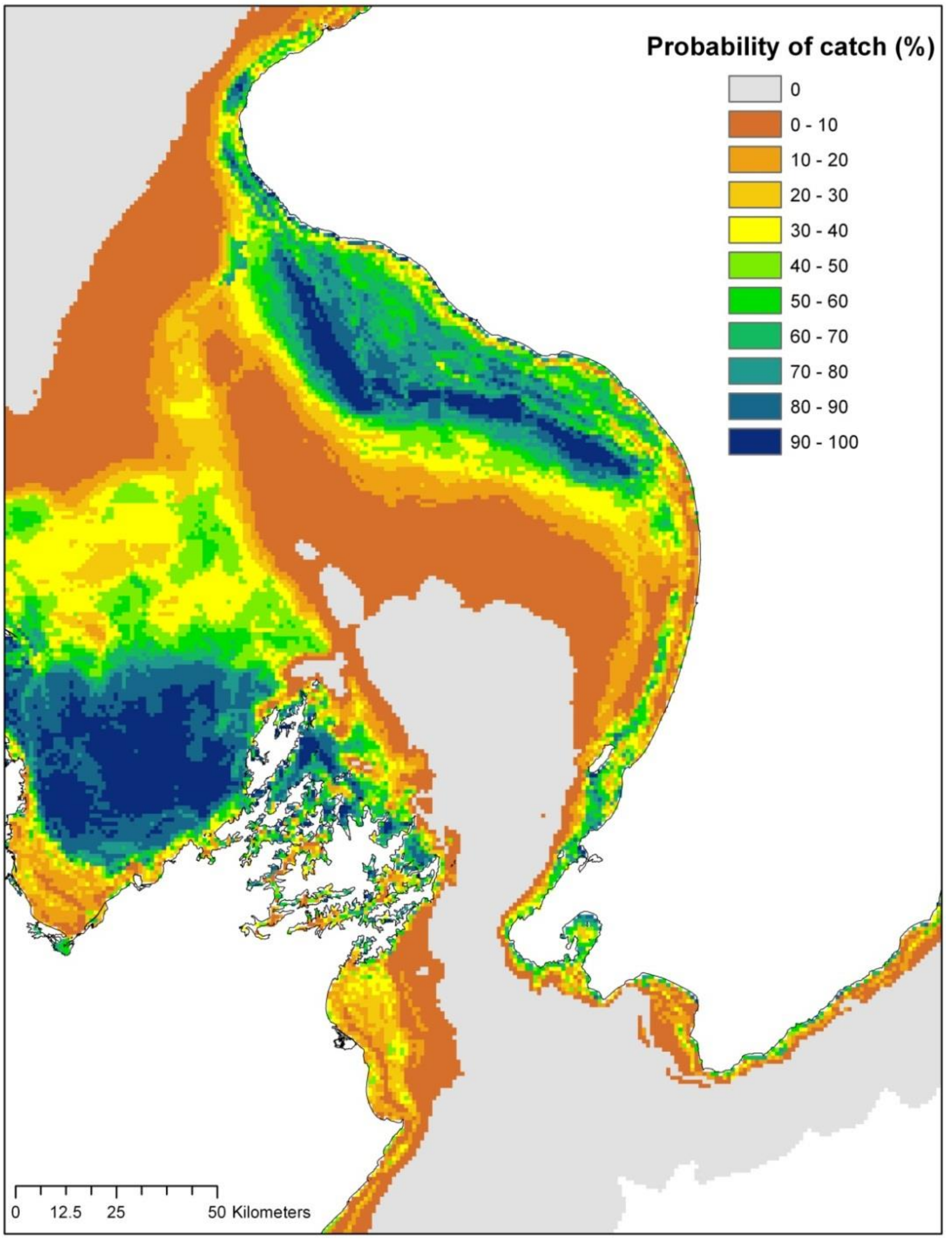


Figure 4-2: Probability of occurrence (%) of leatherjacket (*Parika scaber*) in a demersal trawl in the South Taranaki Bight region.

### 4.2.3 Predicted fish catch rates

Maps of the predicted maximum catch rates (kg per trawl) for each species are provided in Appendix C. The catch of leatherjacket is provided (Figure 4-3) for comparison with Figure 4-2. In the STB north of Cook Strait catch rates varied widely between species, with maximum catch rates for ten species less than 10 kg per trawl while others were caught at maximum rate of 1,000 – 10,000 kg per trawl (Table 4-4). Generally the distributions of catches of those species with low catch rates were very patchy, though exceptions include some shark species, soles, sea perch (*Helicolenus spp.*), redbait (*Emmelichthys nitidus*), and witch. Those species with higher maximum catch rates were more likely to have widespread distributions within their predicted depth ranges, but the concentration of higher catch rates was not necessarily uniform throughout their predicted range (e.g. barracouta, golden mackerel, and snapper). Barracouta, school shark and spiny dogfish were abundant throughout the region.

Species that were predicted to be particularly abundant (> 50 kg per trawl) in the areas of mining interest included barracouta, red gurnard, leatherjacket, school shark, snapper, spiny dogfish, rig, tarakihi, and trevally.

**Table 4-4: Distribution of maximum predicted catch rates (kg per trawl), by species.**

| Catch rate (kg per trawl) | Species |
|---|---|
| < 5 | anchovy, ahuru, short-tailed black ray, crested bellowsfish, hake, blue mackerel, pale ghost shark, silverside, spotted stargazer |
| 5–10 | witch |
| 10–50 | blue cod, cucumber fish, elephant fish, kingfish, New Zealand sole, lemon sole, ling, porcupine fish, Ray's bream, redbait, red mullet, scaly gurnard, spotty, yellow-bellied flounder |
| 50–100 | carpet shark, gemfish, John dory, kahawai, northern spiny dogfish, sea perch, silver warehou, common warehou |
| 100–500 | eagle ray, frostfish, hapuka, horse mackerel, Murphy's mackerel, golden mackerel, red gurnard, sand flounder, silver dory, snapper, rig, tarakihi, trevally, |
| 500–1,000 | red cod, school shark |
| 1000-10,000 | leatherjacket, spiny dogfish, barracouta, hoki |

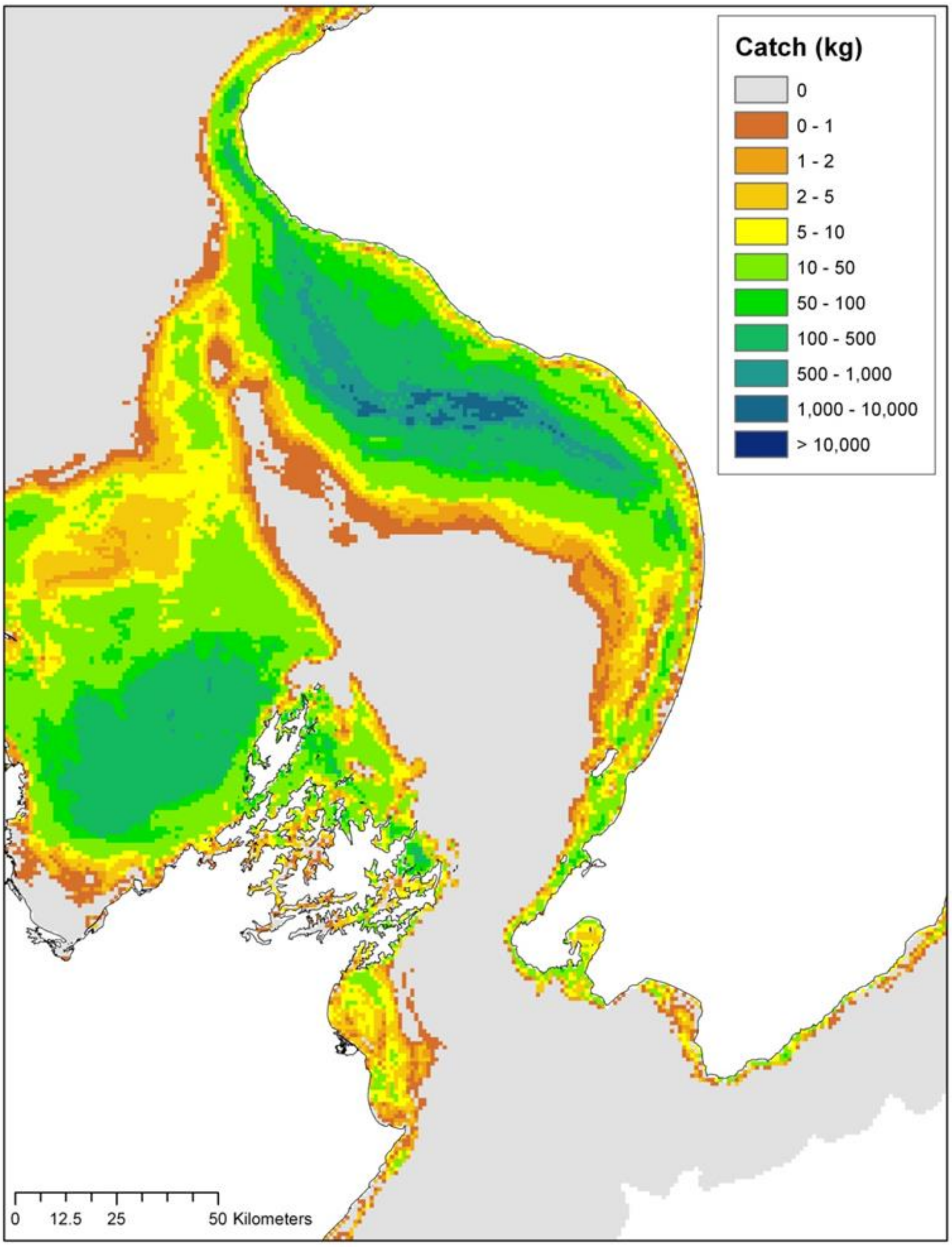


**Figure 4-3: Predicted catch (kg) of leatherjacket (*Parika scaber*) in a demersal trawl in the South Taranaki Bight region.**

### 4.2.4 Presence of spawning, egg-laying, pupping, or juvenile fish

Hurst et al. (2000) indicate that there is good evidence of spawning, pupping or egg-laying by the following six species along the shelf in the south-west of the North Island; lemon sole, New Zealand sole, rig, sand flounder, yellow-belly flounder, and yellow-eyed mullet. Probable spawning by golden mackerel is evidenced by the common occurrence in the region of fish with running-ripe gonads (Hurst et al. 2000). Blue mackerel with spent gonads also occur.

Hurst et al. (2000) also suggested the possible breeding of a further five species based on the presence of small juveniles in the region. These species included blue cod, John dory, kahawai, kingfish, and sea perch.

Hurst et al. (2000) report the relative abundance of larger juveniles along the shelf in the south-west of the North Island based on catches by the RV Kaharoa during research trawl surveys conducted in some years between 1992-2000. Low abundances of juveniles of the following species were present; arrow squid (*Nototodarus* sp.), barracouta, blue warehou, giant stargazer, Jack mackerel, John dory, kahawai, kingfish, red gurnard, rig, sea perch, school shark, snapper, spiny dogfish, terakihi, and trevally. Juveniles of eight other species are listed by Hurst et al. (2000) but no abundance estimate is provided because of insufficient data. These species included blue cod, grey mullet, horse mackerel, New Zealand sole, red cod, silver warehou, yellowbely flounder, and yellow-eyed mullet.

Hurst et al. (2000) provide maps showing the locations of catches of running ripe mature fish and juveniles in the STB. However, these should be interpreted cautiously as they indicate only where catches of these life stages took place on trawlable ground deeper than approximately 20 m. Shallow areas and areas with bottom features too rough to trawl were not sampled.

## 4.3 Discussion

Adults of fifty-one species of demersal fish are predicted to occur in the region. Leathwick et al. (2006a) indicated that over a broad region of the STB demersal fish species richness is predicted to be a moderate 12-16 species per standard research bottom trawl with 95% confidence limits ranging from ± 1-4 species (Figure 4-4). Similar levels of species richness occur over a broad area of the shelf of the west coasts of the North and South Islands (Figure 4-4). Within the STB slightly lower richness (8-12 species per standard research bottom trawl) occurred in depths <50 m off Patea and slightly higher richness (16-20 species) inshore in the south-east of the region north of Kapiti Island towards Whanganui (see Figure 4-4). This compares with the northern flank of the Chatham Rise and continental slopes along the north-eastern flank of South Island and south-eastern flank of North Island that have predicted richness in excess of 20 species per tow. Leathwick et al. (2006a) stated that depth, temperature, and salinity were the main predictors of species abundance, but noted that generally species richness also increased with increasing chlorophyll-*a* concentration. Thus, areas in the region subject to upwelling, such as north of Farewell Spit, may support more diverse demersal fish assemblages.

A few species were predicted to be very widespread and abundant but most species are common only within a restricted depth range. A few species had a very restricted distribution in the region.

There is some evidence for spawning activity by 13 demersal or pelagic fish species in the STB while larger juveniles of 24 species also occur in the region (Hurst et al. 2000). The maps provided by Hurst et al. (2000) showing the locations of catches of running ripe mature fish and juveniles in the South Taranaki Bight should be interpreted cautiously as they indicate only where trawls took place on trawlable ground deeper than approximately 20 m. Shallow areas and areas with bottom features too rough to trawl were not sampled.

Species with predicted adult distributions in the STB that particularly coincide with areas potentially affected by iron sand extraction operations (% occurrence > 50%) include barracouta, blue cod, carpet shark, eagle ray, John dory, golden mackerel, kahawai, leatherjacket, lemon sole, red cod, red gurnard, rig, school shark,  snapper, spiny dogfish, tarakihi, trevally, common warehou, and witch.

Species that were predicted to be particularly abundant (> 50 kg per hour) in TTR's proposed project area include barracouta, red gurnard, leatherjacket, school shark, snapper, spiny dogfish, rig, tarakihi, and trevally.

There are a number of strengths and limitations to these predicted distributions and abundances. The modelling is performed on research trawl data collected over a span of 26 years from 1979 to 2006 so that inter-annual variations or trends in demersal fish abundance and distributions are not apparent. Although effort from trawl surveys throughout the EEZ is included in the modelling, there are seasonal distribution biases that could confound the predictions, given that some species migrate. The predicted distributions and abundances only apply to habitats able to be bottom trawled; they do not apply to rocky reef habitats, for example. The strength of the predicted fish distributions and abundances is that they are based on an enormous data set, containing 21,000 research demersal trawls from throughout New Zealand, with 666 trawls from within the STB. This provides confidence that the model provides reliable long term patterns of demersal and pelagic fish distribution and abundance in the STB.

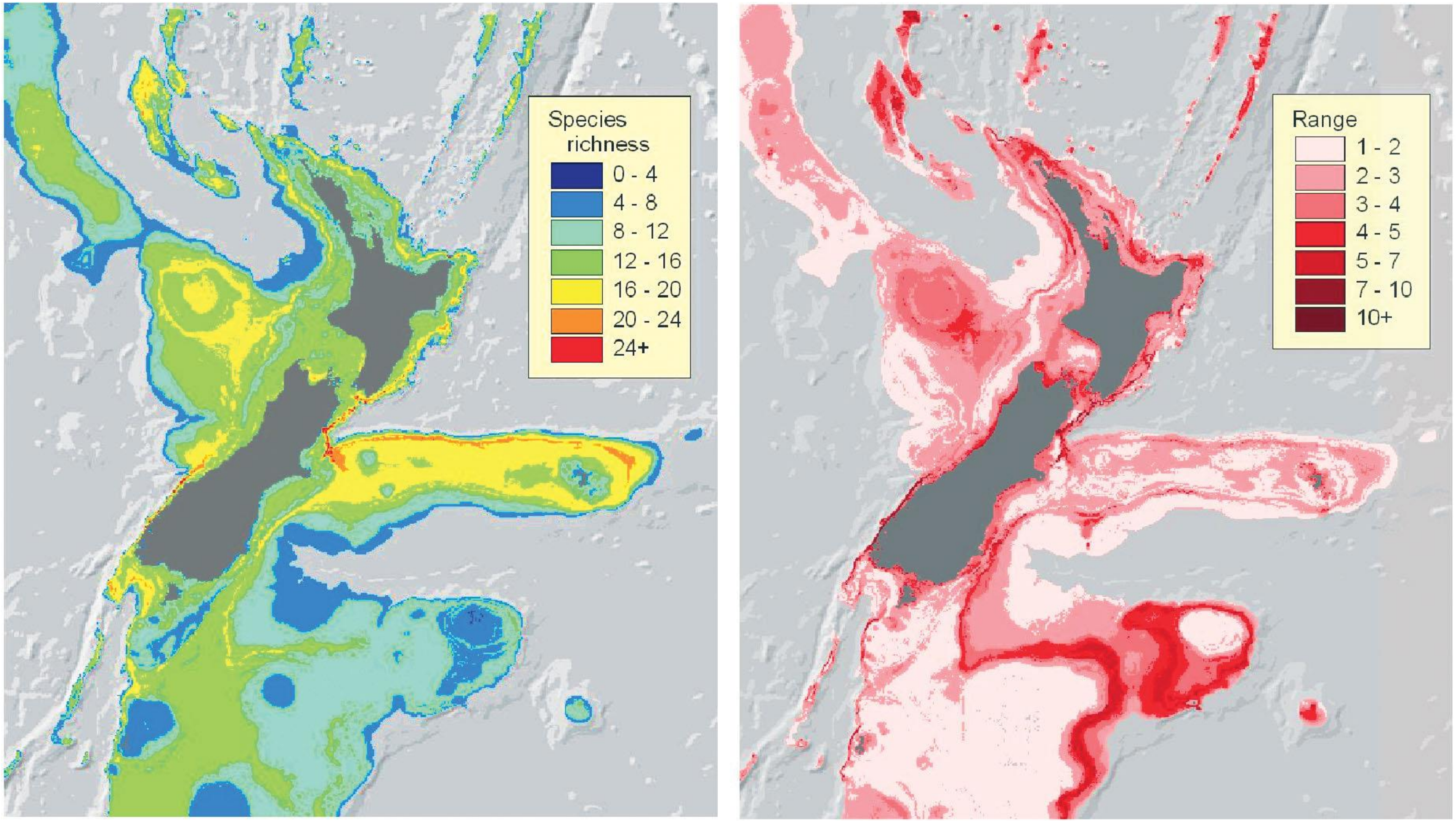


**Figure 4-4: Demersal fish species richness.** This was predicted from a Boosted Regression Tree model using environment and trawl characteristics as predictors, and fitted with a tree size of 5. Confidence intervals were estimated from predictions made from 1000 models fitted to bootstrap samples of the trawl dataset. Left panel: predicted species richness. Right panel: range of the 5 to 95% confidence interval (From Leathwick et al. 2006a).

# 5 Commercial Fisheries

## 5.1 Introduction

Commercial fisheries for fish and invertebrates occur in the STB region using a variety of methods including bottom trawling, mid-water trawling, set-netting, bottom long-lining, squid jigging, purse seining, trolling, potting or trapping, and drop lining. Iron sand extraction operations may overlap with, and thus directly or indirectly impact these fisheries.

In this section we summarise the effort and catch for each of these methods and for the principal methods of capture we indicate the spatial distribution of the fishery in the STB.

## 5.2 Methods

An extract of commercial fishing catch and effort data for fishing activities within the study area over the prior six fishing seasons was obtained from the Ministry of Fisheries in August 2010. The extract included all fishing events (trawl, set of a net or longline, pot drop etc.) for which the geographical coordinates were recorded by the fisher. The extract did not include any fishing events which were recorded without coordinates and instead assigned to broad “Statistical Areas” defined by the Ministry of Fisheries. These statistical areas mostly extend well beyond the study area boundaries and so are far less useful for assessing fishing activity within the area, but it should be noted that they were not used. Increasingly, fishers record their activities with coordinates taken from GPS devices, and the lack of data available for this analysis for some methods in the earlier years of this period may be partly due to this change in recording practice.

The catch effort data obtained were used to make summaries of fishing activity by fishing year (1 Oct–30 Sep) and fishing method except for 2009-10 which includes data only up until mid-July 2010.

## 5.3 Results

### 5.3.1 Fishing methods

Trawling was been the most common fishing method used over the five years of records sampled, split evenly (in terms of effort) between bottom and midwater trawling (Table 5-1). Levels of both have been variable, but there was a general increase in bottom trawling effort between 2004–05 and 2009–10, and fluctuating levels of midwater trawling during the same period. The total catch from midwater trawling was about ten times that from bottom trawling, due to the different species targeted and caught. Set netting was the next most common fishing method, although no set netting was recorded in 2004–05 or 2005–06, with 360–570 sets per year recorded in the last four years. Similarly, bottom longlining has only been recorded in the area from 2007/08, with 70–90 sets per year. Squid jigging was also recorded in the area, mainly in 2004–05, but this information appears unreliable, as no catch was recorded. Other fishing methods reported in the region, at low levels, were trolling, rock lobster potting, drop lining, and fish trapping.

**Table 5-1: Summary of fishing effort by fishing year (1 Oct–31 Sep) and fishing method, and total catch by method.** Pixels are 0.1° x 0.1° rectangles. The dashed line represents the 50 m contour.

| Fishing method | Number of fishing events per fishing year | | | | | | | Total catch (t) |
|---|---|---|---|---|---|---|---|---|
| | 2004–05 | 2005–06 | 2006–07 | 2007–08 | 2008–09 | 2009–10 | Total | |
| Bottom trawling | 410 | 438 | 376 | 1,026 | 1,108 | 802 | 4,160 | 6,653 |
| Midwater trawling | 338 | 824 | 676 | 435 | 529 | 890 | 3,692 | 66,410 |
| Set netting | 0 | 0 | 361 | 570 | 529 | 505 | 1,965 | 1,855 |
| Bottom longlining | 1 | 0 | 0 | 94 | 94 | 71 | 260 | 120 |
| Squid jigging | 127 | 8 | 3 | 1 | 3 | 1 | 143 | 0 |
| Purse seining | 16 | 7 | 8 | 11 | 9 | 0 | 51 | 1,879 |
| Trolling | 2 | 0 | 0 | 6 | 0 | 1 | 9 | <1 |
| Rock lobster potting | 0 | 0 | 0 | 2 | 1 | 5 | 8 | <1 |
| Drop lining | 0 | 0 | 0 | 1 | 0 | 0 | 1 | <1 |
| Fish traps | 0 | 0 | 0 | 0 | 0 | 1 | 1 | <1 |

The lowest levels of fishing effort in the region were in the central south sector, offshore of the coastline south of Whanganui, and also very close to the shore north of Opunake and north and south of Whanganui (Figure 5-1). The highest levels of effort were off the coastline between New Plymouth and Cape Egmont, between Hawera and Whanganui especially near the 50 m contour, and in some locations between the centre of the area and Tasman Bay in the South Island. The distribution of total catch was quite different to that of effort and was dominated by the large, offshore midwater trawl fishery for jack mackerel (*Trachurus spp.*), focussed on the western central and southern sectors of the study area.

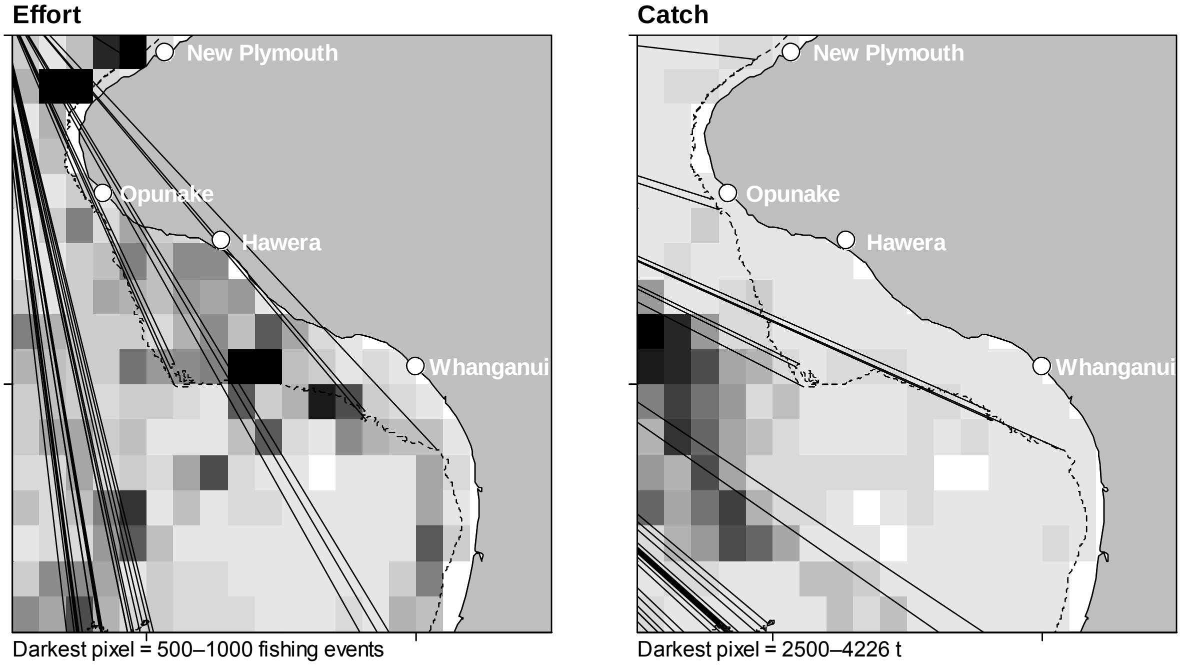


**Figure 5-1: All fishing methods - effort and catch.** Density plots showing the spread of fishing effort (number of fishing events) and total catch within the study area between 1 October 2004 and July 2010. Pixels are 0.1° x 0.1° rectangles. The dashed line represents the 50 m contour.Move up, probably caused by me.

## 5.3.2 Bottom trawling

The main species targeted by bottom trawling in most years was red gurnard, with 130–280 trawls per year and an average total catch (all species) of over 200 t per year for the period (Table 5-2). Several other species were consistently targeted, including tarakihi, trevally, barracouta, warehou (two species), flatfish (several species), leatherjacket, John dory, and snapper. Target trawling for jack mackerel, although less common than for these other species, produced the second largest total catch for the period. Bottom trawling occurs year round with no obvious seasonality in effort.

Bottom trawling was spread out over much of the study area, with the main areas of effort and catch being adjacent to New Plymouth, between Opunake and Hawera, south of Wanganui, and in the southwest corner of the area, to the north of Tasman Bay (Figure 5-2).

**Table 5-2: Bottom trawling.** Summary of fishing effort by target species and fishing year (1 Oct–31 Sep), and total catch by target species.

| | Number of trawls per fishing year | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| Target species | 2004–05 | 2005–06 | 2006–07 | 2007–08 | 2008–09 | 2009–10 | Total | catch (t) |
| Red gurnard | 178 | 156 | 133 | 166 | 283 | 248 | 1,164 | 1,550 |
| Tarakihi | 69 | 108 | 32 | 107 | 171 | 116 | 603 | 550 |
| Trevally | 45 | 90 | 44 | 67 | 79 | 98 | 423 | 841 |
| Flatfish | 22 | 6 | 12 | 155 | 171 | 33 | 399 | 233 |
| Barracouta | 12 | 6 | 29 | 223 | 71 | 41 | 382 | 832 |
| Warehou | 16 | 42 | 61 | 71 | 137 | 54 | 381 | 574 |
| Leatherjacket | 12 | 16 | 31 | 44 | 63 | 92 | 258 | 605 |
| John dory | 14 | 5 | 8 | 59 | 43 | 56 | 185 | 101 |
| Snapper | 14 | 1 | 2 | 51 | 47 | 54 | 169 | 119 |
| Jack mackerel | 16 | 0 | 23 | 67 | 15 | 1 | 122 | 1,194 |
| School shark | 11 | 8 | 1 | 5 | 12 | 2 | 39 | 39 |
| Dark ghost shark | 0 | 0 | 0 | 0 | 8 | 3 | 11 | 7 |
| Red cod | 0 | 0 | 0 | 5 | 2 | 1 | 8 | 3 |
| Hapuka and Bass | 0 | 0 | 0 | 4 | 2 | 1 | 7 | 3 |
| Rig | 1 | 0 | 0 | 1 | 2 | 1 | 5 | 2 |
| Moki | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 1 |
| Kahawai | 0 | 0 | 0 | 1 | 0 | 0 | 1 | <1 |

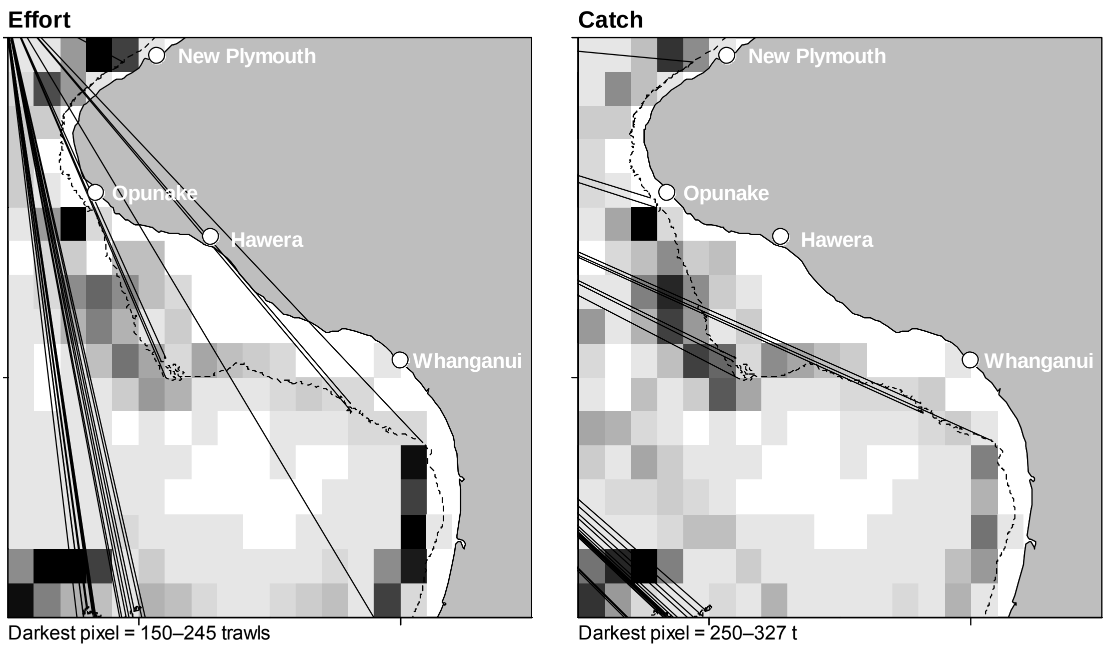


**Figure 5-2: Bottom trawling - effort and catch.** Density plots showing the spread of fishing effort and total catch within the study area between 1 October 2004 and July 2010. Pixels are 0.1° x 0.1° rectangles. The dashed line represents the 50 m contour.

### 5.3.3 Midwater trawling

Midwater trawling in the area mostly targeted jack mackerel, with a small amount of barracouta targeting, and a single trawl targeting hoki (*Macruronus novaezelandiae*) (Table 5-3). In terms of both effort and total catch, midwater trawling for jack mackerel has been the most important fishery in the area, with over 64,000 t caught during the period, from over 3500 trawls. Midwater trawling occurs year round, but there has been a concentration of effort in December and January.

Midwater trawling tends to be in deeper water with most reported trawls well beyond the 50 m depth contour and focussed on a region parallel to the coast between Opunake and Whanganui (Figure 5-3). Fishing effort and catch has been most intense in the northern part of this area.

**Table 5-3: Midwater trawling.** Summary of fishing effort by target species and fishing year (1 Oct–31 Sep), and total catch by target species.

| | Number of trawls per fishing year | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| Target species | 2004–05 | 2005–06 | 2006–07 | 2007–08 | 2008–09 | 2009–10 | Total | catch (t) |
| Jack mackerel | 332 | 803 | 635 | 433 | 505 | 869 | 3,577 | 64,243 |
| Barracouta | 6 | 21 | 41 | 1 | 24 | 21 | 114 | 2,159 |
| Hoki | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 8 |

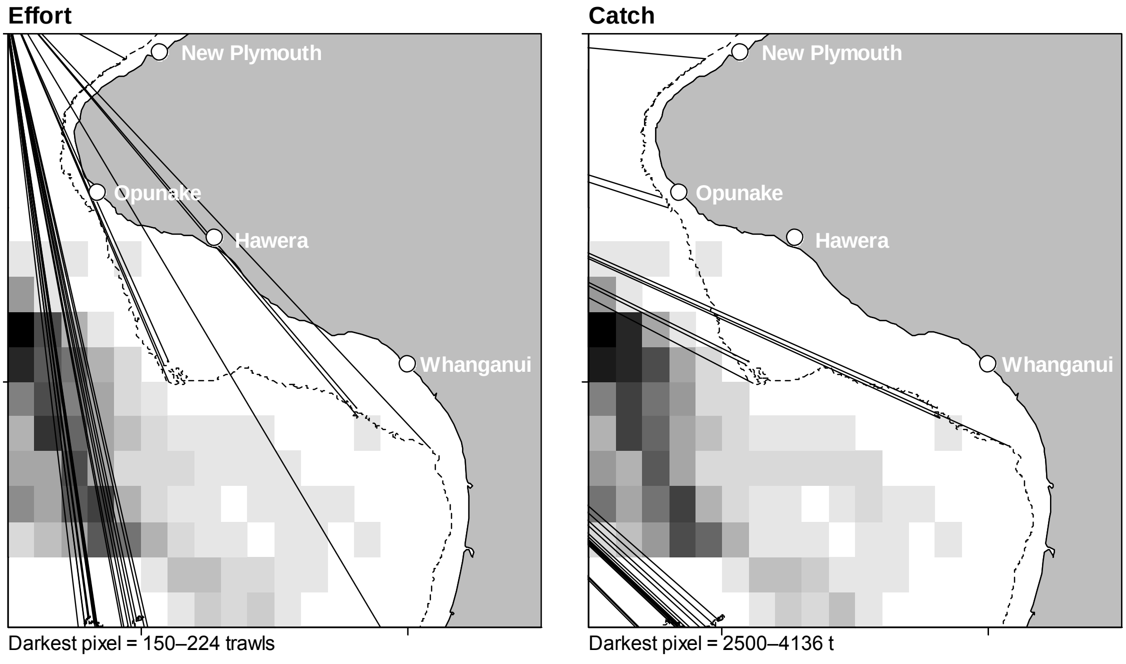


**Figure 5-3: Midwater trawling – effort and catch.** Density plots showing the spread of fishing effort and total catch within the study area between 1 October 2004 and July 2010. Pixels are 0.1° x 0.1° rectangles. The dashed line represents the 50 m contour.

### 5.3.4 Set netting

Set netting in the area targeted three main species, rig, warehou, and school shark, with a moderately consistent level of effort in each year after 2005–06 (Table 5-4). A small fraction of set netting effort targeted trevally (39 t of total catch), and several other species were occasionally targeted. The total catch for all set netting combined was about 1,800 t during the last four years reviewed (including the incomplete 2009/10 year) from about 2,000 sets. Set netting occurs year round with no obvious seasonality in effort.

**Table 5-4: Set-netting.** Summary of fishing effort by target species and fishing year (1 Oct–31 Sep), and total catch by target species.

| | Number of sets per fishing year | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| Target species | 2004–05 | 2005–06 | 2006–07 | 2007–08 | 2008–09 | 2009–10 | Total | catch (t) |
| Rig | – | – | 198 | 326 | 198 | 259 | 981 | 823 |
| Warehou | – | – | 96 | 114 | 171 | 127 | 508 | 351 |
| School shark | – | – | 58 | 125 | 135 | 85 | 403 | 634 |
| Trevally | – | – | 6 | 3 | 12 | 27 | 48 | 39 |
| Flatfish | – | – | 0 | 0 | 7 | 6 | 13 | 1.6 |
| Kahawai | – | – | 0 | 0 | 5 | 0 | 5 | 3.1 |
| Elephantfish | – | – | 1 | 0 | 0 | 0 | 1 | 0.0 |
| Red gurnard | – | – | 1 | 0 | 0 | 0 | 1 | 0.1 |
| Hapuka/Bass | – | – | 1 | 0 | 0 | 0 | 1 | 0.3 |
| John dory | – | – | 0 | 1 | 0 | 0 | 1 | 0.1 |
| Snapper | – | – | 0 | 1 | 0 | 0 | 1 | 1.8 |
| Spiny dogfish | – | – | 0 | 0 | 1 | 0 | 1 | 0.3 |
| Tarakihi | – | – | 0 | 0 | 0 | 1 | 1 | 1.0 |

Set netting was widespread throughout the study area, but with a focus on the coastline around New Plymouth and between Hawera and Whanganui, around or within the 50 m depth contour (Figure 5-4). There was a lower level of set netting effort recorded between this latter area and Tasman Bay and also along other parts of the coastline, but no effort or catch recorded in the central south region of the area.

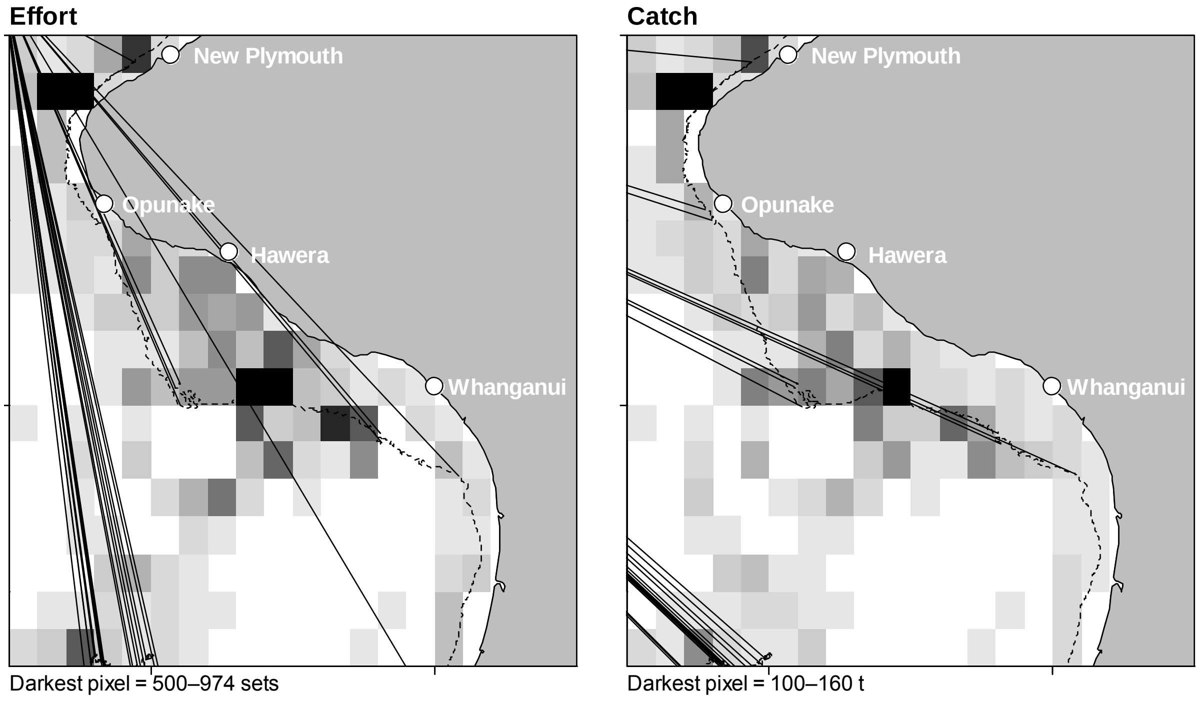


**Figure 5-4: Set netting - effort and catch.** Density plots showing the spread of fishing effort and total catch within the study area between 1 October 2004 and July 2010. Pixels are 0.1° x 0.1° rectangles. The dashed line represents the 50 m contour.

### 5.3.5 Bottom longlining

Several species were targeted by bottom longlining in the area during the past six years, but effort data are mainly for the most recent three years, and catches were mostly related to fishing for red gurnard, school shark, and hapuka and bass (*Polyprion americanus*) (Table 5-5). Little more than 100 t of total catch were recorded for this method for the period examined. Bottom longlining occurs year round but there has been less effort in these years in the winter months.

Longlining effort was strongly concentrated on the area of coastline from New Plymouth to Cape Egmont, and also in the southwestern sector north of Golden Bay/Tasman Bay. Some longlining took place along the coastline between Hawera and Whanganui, but both effort and catch were at comparatively low levels (Figure 5-5).

**Table 5-5: Bottom longlining.** Summary of fishing effort by target species and fishing year (1 Oct–31 Sep), and total catch by target species.

| | Number of sets | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| Target species | 2004–05 | 2005–06 | 2006–07 | 2007–08 | 2008–09 | 2009–10 | Total | catch (t) |
| Red gurnard | 0 | – | – | 34 | 44 | 27 | 105 | 29 |
| School shark | 0 | – | – | 14 | 21 | 27 | 62 | 56 |
| Hapuka/Bass | 0 | – | – | 24 | 11 | 7 | 42 | 20 |
| Snapper | 0 | – | – | 5 | 12 | 9 | 26 | 5 |
| Blue cod | 0 | – | – | 10 | 5 | 0 | 15 | 5 |
| Tarakihi | 0 | – | – | 7 | 0 | 1 | 8 | 2 |
| Ling | 1 | – | – | 0 | 1 | 0 | 2 | 3 |

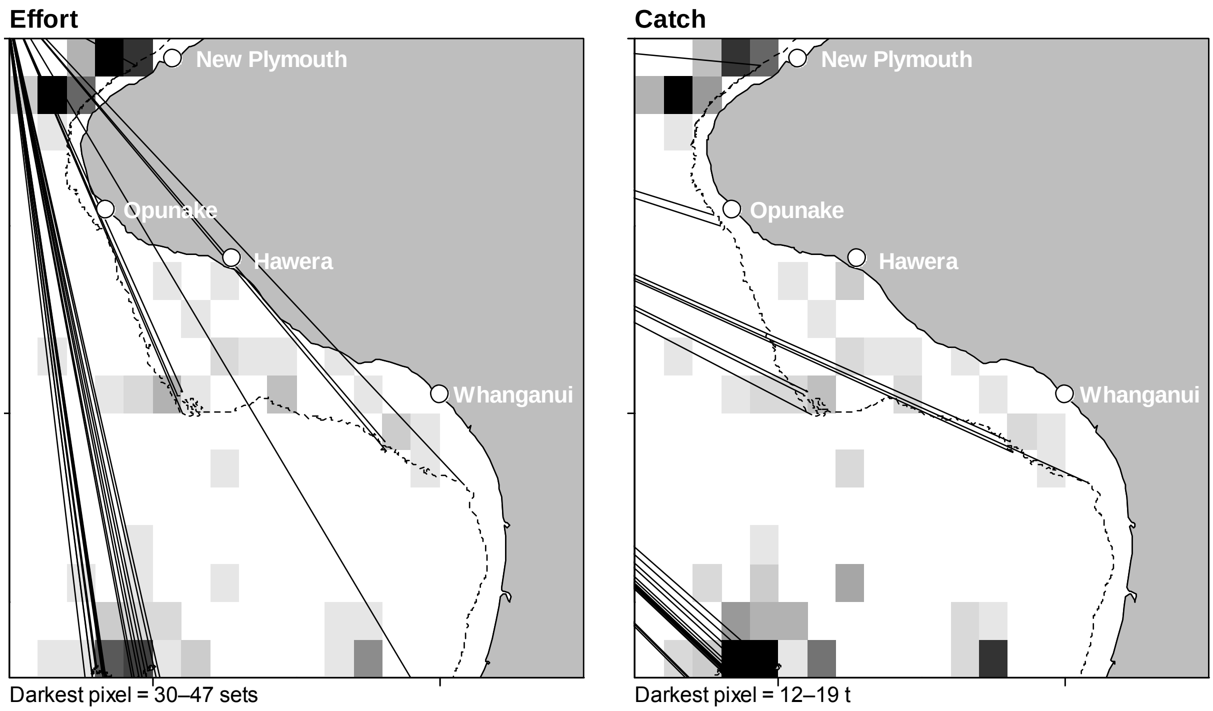


**Figure 5-5: Bottom longlining - effort and catch.** Density plots showing the spread of fishing effort and total catch within the study area between 1 October 2004 and July 2010. Pixels are 0.1° x 0.1° rectangles. The dashed line represents the 50 m contour.

### 5.3.6 Cray-fishing

Data are available only on a fishing statistical area basis, and as so few fishermen are involved in this commercial fishery the data cannot be partitioned on a smaller spatial scale. The relevant statistical unit is Area 935 that runs from just south of New Plymouth to near Bulls, a distance along the coast of about 240 km (Figure 5-6). The average total commercial catch of rock lobsters along this stretch of coast over the last six fishing years has been 23.6 t (Table 5-6). This is about 50% of the Total Allowable Commercial Catch (TACC) of rock lobsters (47 t) in the whole of the CRA9 Fisheries Management Area (FMA) that extends along the west coasts of the South and North Islands from Hokitika to the Kaipara Harbour (Ministry of Fisheries 2011).

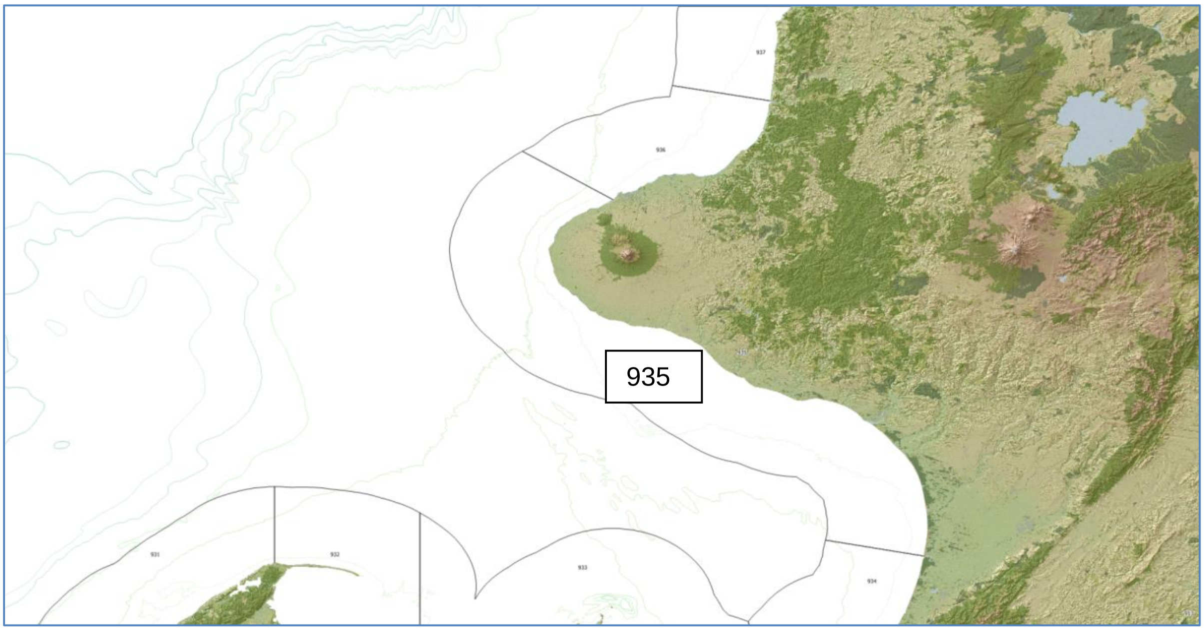


**Figure 5-6: Crayfishing statistical areas.** Rock lobster statistical area 935 runs from runs from just south of New Plymouth to near Foxton Beach.

**Table 5-6: Annual (fishing year 1 April – 30 March) commercial catch of rock lobsters from statistical area 935.** Data courtesy of the Ministry for Primary Industries.

| Fishing year | CRA estimated catch (kg) |
|---|---|
| 2005-06 | 27 589 |
| 2006-07 | 27 172 |
| 2007-08 | 26 050 |
| 2008-09 | 17 352 |
| 2009-10 | 14 658 |
| 2010-11 | 28 559 |

Because rock lobsters spend most of the year associated with subtidal reefs most of the commercial catch is likely to be taken at these localities (see Figure 1-2 for the regional distribution of subtidal reefs). However, in winter and summer larger (>1.5 kg) rock lobsters may move offshore to depths >25 m to feed on shellfish such as dog cockles (*Tucetona laticostata),* scallops (*Pectin novaezealandiae*) and horse mussels (*Atrina zelandica*) (Kelly et al. 1999, Kelly and MacDiarmid 2003, Langlois et al 2005. Commercial fishermen may seasonally target rock lobsters on these shellfish beds (e.g. Kelly et al. 2002).

## 5.4 Discussion

Commercial fishing operations within the study area have been dominated in recent years by three main fishing methods, bottom trawling (for a variety of species), midwater trawling (mainly for jack mackerel), and set netting (mainly for rig, warehou, and school shark). Together these methods have accounted for 95% of all fishing events recorded with position data, between 1 October 2004 and mid-July 2010. Bottom longlining, squid jigging, and purse seining account for most of the remaining fishing effort, and there has also been a very small amount of trolling, rock lobster potting, drop lining, and fish trapping.

The lowest levels of fishing effort were in the offshore, central-south regions of the study area and in the shallowest parts of the southern and western coastlines. The highest levels of fishing effort (mainly bottom trawling and set netting) were between New Plymouth and Cape Egmont, relatively close to the shore, and between Hawera and Whanganui near the 50 m contour.

Fishing effort of all methods occurred throughout the year, but there was a concentration of midwater trawling effort in early summer, and notably less bottom longlining effort during winter.

This analysis is based only on data for which there was position data recorded, and does not include variable amounts of fishing effort assigned only to broad statistical areas which overlap the study area. It is expected, however, that the available data is largely representative of the total commercial fishing activities in the study area.

The fisheries with the greatest overlap with the proposed iron sand extraction operations are the setnet fisheries for rig, warehou, and school shark. The greatest effort and catch in these fisheries in the STB is over and to the south and east of the banks where iron sand extraction is proposed.

# 6 Customary Fisheries

## 6.1 Background

Marine and freshwater fisheries have traditionally been a source of cultural and economic wealth for Māori. Provision of fish or shellfish to feed family or manuhiri (guests) has always been part of the cultural heritage for Māori and seafood played an important economic role in trading with inland iwi and with early European settlers (Leach 2006).

The iwi likely to be most affected by iron sand extraction in the STB are Nga Ruahine, Ngāti Ruanui, and Ngā Rauru (Figure 6-1).

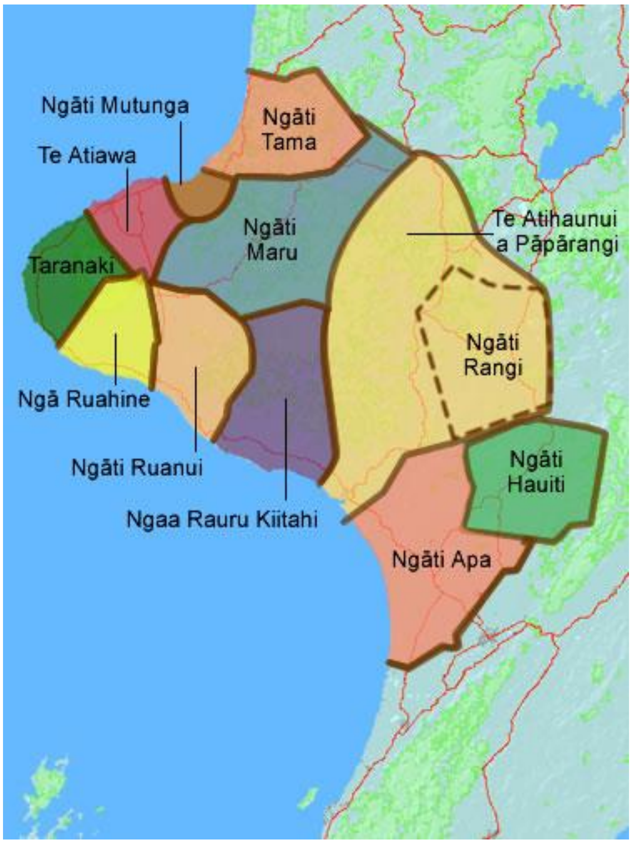


**Figure 6-1: Iwi rohe in Taranaki and northern Manawatu.**

## 6.2 Methods

TTR is engaged in an on-going consultation programme with South Taranaki iwi. This consultation will involve attention to tangata whenua fishing interests in the STB. This chapter is intended to provide a technical basis for this consultation and is based on a review of the available literature to determine the range of kaimoana species commonly utilised from along the STB and the likely collection method. The distribution and abundance of the reef, dermersal and pelagic fish species customarily fished was assessed from the model outputs described in sections 2.0 and 4.0. A brief review of freshwater fish species with a marine phase to the their lifecycle is also included as this phase has the potential to be impacted by the proposed offshore extraction of iron sand,

## 6.3 Results

At least forty species of invertebrates and fish are customarily gathered or fished from the STB (Table 6-1) (Patrick 2000, 2001, Ministry for the Environment 2003, Department of Conservation 2006, Taranaki Regional Council 2011). Harvesting sites vary from intertidal reefs to deep offshore areas and methods of collection vary from hand picking or gathering to specialised hook and line and potting techniques. The predicted distribution and abundance of the fish species are provided in maps in Appendices A, B and C. The modelling technique used to generate the distributional maps utilised data collected over many years and does not take into account seasonal or year to year variations so the maps should be used as a guide to general distributions only. At any particular point the abundance of a fish species may vary over a range of time scales.

**Table 6-1: Species commonly customarily harvested from the STB and the method used.**

| Māori name | Common name | Scientific name | Harvesting methods | Centre of abundance in the STB | Appendix Figure |
|---|---|---|---|---|---|
| Kina | sea urchin | *Evechinus chloroticus* | hand gathering, diving | Shallow coastal reefs | - |
| Pāua | paua, NZ abalone | *Haliotis iris* | hand gathering, diving | Shallow coastal reefs | - |
| Kuku, Kūtai | green-lipped mussel | *Perna canaliculus* | hand gathering, diving | Shallow coastal reefs | - |
| Rori | black sea slug | *Scutus breviculus* | hand gathering | Shallow coastal reefs | - |
| Weke | octopus | *Pinnoctopus cordiformis* | hand gathering, potting | Coastal reefs | - |
| Pupu | cats-eyes, top shells, turban shells and limpets | *Turbo smaragdus, Melagraphia aethiops , Cookia sulcata, Cellana ornata , C. radians and C. stellifera* | hand gathering | Shallow coastal reefs | - |
| Papaka | purple rock crab | *Leptograpsus variegatus* | hand gathering | Intertidal reefs | - |
| | paddle crab | *Ovalipes catharus* | potting | Shallow coastal zone | |
| Kōura | red rock lobster | *Jasus edwardsii* | potting, diving | Subtidal reefs to 50 m | - |
| Paeha | sweep | *Scorpis lineolatus* | lining, netting | Subtidal reefs to 30 m | 10-34 |
| Nanua | red moki | *Cheilodactylus spectabilis* | netting | Subtidal reefs to 30 m | 10-31 |
| Patote | butterfish | *Odax pullus* | netting | Subtidal reefs to 10 m | 10-27 |
| Kooriro | conger eel | *Conger verreauxi* | potting | Subtidal reefs | 10-2 |
| Rawaru | blue cod | *Parapercis colias* | Potting, lining | Subtidal reefs and shallow coastal zone to 30 m | 10-17, 11-3 |
| Haku | kingfish | *Seriola lalandi* | lining | Subtidal reefs | 10-24 |
| Arara | trevally | *Pseudocaranx georgianus* | lining, netting | Shallow coastal zone to 50 m | 10-3, 11-49 |
| Kuparu | John dory | *Zeus faber* | netting | Open ground and reefs > 25 m | 11-18 |
| Hiriri | leatherjacket | *Parika scaber* | lining, netting | Shallow coastal zone to 50 m | 10-22, 11-24 |
| Kahawai | kahawai | *Arripis trutta* | lining, netting | Shallow coastal zone to 15 m | 11-22 |
| Kumu | red gurnard | *Chelidonichthys kumu* | lining | Shallow coastal zone to 50 m | 11-14 |
| Mango | rig | *Mustelus lenticulatus* | netting | Shallow coastal zone to 35 m | 11-42 |
| Koheru | golden mackerel | *Trachurus novaezelandiae* | netting | Shallow coastal zone to 20 m | 11-21 |
| Koheru | horse mackerel | *Trachurus declivis* | netting | Offshore zone > 30 m | 11-19 |
| Porae | porae | *Nemadactylus douglasi* | netting | Subtidal reefs and adjacent sand flats | 10-4 |

| | | | | | |
|---|---|---|---|---|---|
| Reperepe | elephant fish | *Callorhinchus milii* | lining | Shallow coastal zone to 15 m | 11-9 |
| Tāmure | snapper | *Pagrus auratus* | lining | Coastal zone to 30 m | 11-39 |
| Pioke | northern spiny dogfish | *Squalus griffini* | netting | Deepwater west of Maui platform | 11-27 |
| Tuare | blind eel | *Eptatretus cirrhatus* | potting | Throughout the region | - |
| Tarakihi | tarakihi | *Nemadactylus macropterus* | lining | Subtidal reefs and offshore zone > 20 m | 10-14, 11-47 |
| Pātiki | lemon sole | *Pelotretis flavilatus* | netting | Coastal zone especially towards Whanganui | 11-26 |
| Maka, Makaa, Manga | barracouta | *Thyrsites atun* | lining | Throughout the region | 11-2 |
| Warehou | common warehou | *Seriolella brama* | lining | Shallow coastal zone to 20 m | 11-49 |
| Warehou | silver warehou | *Seriolella punctata* | lining | Off shore zone > 50 m | 11-46 |
| Hoka | red cod | *Pseudophycis bachus* | lining | Shallow coastal zone to 10 m | 11-32 |
| Paara | frostfish | *Lepidopus caudatus* | lining | Offshore zone > 100 m | 11-12 |
| Hapuka | Groper or bass | *Polyprion oxygeneios* | lining | Offshore reefs | 11-16 |

## 6.4 Reef based fisheries

### 6.4.1 Pupu

This is a collective term for several species of edible sea snails and limpets such as *Turbo smaragdus, Melagraphia aethiops, Cookia sulcata, Cellana ornata, C. radians and C. stellifera,* occurring on intertidal or shallow subtidal reef platforms. These are hand gathered.

### 6.4.2 Kina

Kina (*Evechinus chloroticus*) occur inter-tidally in rock pools and sub-tidally to about 15m. They are usually gathered by hand at low tide or by snorkelling in shallow water. Only mature individuals are gathered as the ripening roe is the prized target.

### 6.4.3 Paua

Paua (*Haliotis iris*) are restricted to rocky reefs that extend into shallow water which is where juvenile paua initial settle under boulders. Paua are usually absent from reefs that are deeper than 10-15 m.

Paua along the Taranaki coast attain a maximum size of about 90−100 mm which is less than the usual minimum legal size (MLS). Because of the small size of paua around Taranaki, the Ministry of Fisheries reduced the MLS for recreational fishers to 85 mm for the area between the Awakino and Wanganui rivers on the 1st of October 2009. There are no reliable estimates of recreational catch in the region and no commercial fisheries for paua in the region (Ministry of Fisheries 2011).

Lawful access to the Taranaki paua fishery is presently restricted to fishers operating under customary fishing authorisations and allows the collection of paua less than the 125 mm MLS. Tangata kaitiaki currently issue these authorisations under the amateur fishing regulations, and therefore paua can only be taken for hui and tangi purposes. Customary access is presently not allowed for any other purposes (including personal consumption). There are no reliable data to indicate the present level of authorised customary take of paua in the STB.

### 6.4.4 Kuku (green shell mussels)

Greenshell mussels (*Perna canaliculus*) occur on reefs at the low intertidal and shallow subtidal zones. They are usually gathered by hand at low tide or by snorkelling in shallow water. Typically the distribution of greenshell mussels along the coastline is highly patchy so gathering sites are highly regarded.

### 6.4.5 Koura (rock lobsters)

The common species in the STB is the red rock lobster or crayfish, though occasional specimens of the packhorse rock lobster are caught on the Taranaki coast (Booth 2011). In the STB rock lobsters are caught commercially (see Section 5.3.6) and recreationally, as well as customarily. The size of the customary fishery is not documented.

Legal size rock lobsters may occur on reefs from 1 to 50 m and occasionally in deeper water where they may occur on sand flats well away from reef structures. Historically, rock lobsters were customarily hand gathered in shallow water in other parts of New Zealand (MacDiarmid et al. in press). Presently, rock lobsters may be hand gathered by snorkelling or SCUBA diving, or by setting baited pots or traps.

### 6.4.6 Reef fish

A variety of reef associated fish species are targeted by customary fishers (Table 6-1), including butterfish, red moki, conger eel and kingfish. While butterfish is almost exclusively caught on shallow reefs to 15 m, and red moki to 25 m, conger eel may occur at all depths on the shelf and kingfish may be fished by bait line or by lure from the pelagic zone over and adjacent to reef structures.

## 6.5 Open water fisheries

A wide variety of open water fish may be targeted by customary fishers depending on their access to offshore areas (Table 6-1). The most important of these are likely to be trevally, kahawai, rig, snapper, tarakihi and barracouta.

## 6.6 Diadromous fishes

New Zealand has about 35 species of freshwater fish (McDowall 1990). Most are endemic and almost half are diadromous, spending part of their life cycle in the sea. Depending on the species, the marine component of the life cycle may be eggs and larvae, juveniles, or adults. Important customary fisheries exist for a number of diadromous fish including lampreys, short and long fined eels and whitebait (Galaxids). Below we review the information relevant to these species in the South Taranaki Bight.

### 6.6.1 Lampreys - piharau

New Zealand has one species of lamprey, *Geotria australis* which is also found in Australia and southern South America. They are widely distributed in New Zealand (Richardson 2005). The marine phase of this fish spends 3-4 years in the open ocean where it uses a circular sucker to attach itself to other animals and feeds by rasping a hole in their flesh (Richardson et al. 2007). According to James (2008) lampreys then enter freshwater and spend up to 16 months reaching sexual maturity and migrating upstream to small, shady, hard-bottomed streams where they spawn and die. Larvae spend around 4 years as filter feeders in freshwater buried in fine sediments before metamorphosing into miniatures of the marine phase that then migrate downstream to begin their 3-4 years of life in the ocean. Little is known of *G. australis* once it enters the ocean (Richardson et al. 2007, James 2008). Historically lampreys have great value as a food source for Maori (Richardson et al 2007). Extensive freshwater fisheries for lamprey once existed in the Whanganui and Taranaki regions (James 2008).

### 6.6.2 Freshwater eels - tuna

New Zealand has two species, the shortfin (Anguilla australis) and longfin eel (Anguilla dieffenbachii). The shortfin eel occurs throughout the South Pacific while the longfin eel is endemic to New Zealand (Richardson 2005). Adult eels are thought to breed in the deep ocean trenches north-east of New Zealand, near Tonga (McDowall 1990) though the migration routes are not understood. The transparent leaf like larvae, the leptocephalus, drift on ocean currents for over a year before reaching New Zealand coasts. Before entering freshwater the leptocephalus changes into the more familiar eel shape although they remain transparent for up to a week after leaving the ocean (Richardson et al. 2007). The two species frequently coexist, but the shortfin is principally a lowland species, dominating populations in lowland lakes, estuaries and the lower reaches of rivers, while longfins prefer flowing water and hence are found extensively in mainstem rivers, penetrating long distances upstream. Eels spend many years in stream, rivers and lakes (14-25 for male and female shortfins respectively; 25-40+ years for male and female longfins respectively) before migrating downstream to make their way their tropical spawning sites (Jellyman 2012).

Prior to European settlement, Maori had a highly developed fishery for freshwater eels (McDowall 2012). The extent of the present customary harvest is unknown (Jellyman 2012).

### 6.6.3 Whitebait - inanga

Whitebait or inanga is a general term applied to juvenile Galaxids of five different species; *Galaxias argentenus, G. brevipinnis, G. fasciatus, G. maculatus,* and *G. postvectis*. (McDowall 1990). All five species occur in the south Taranaki region (Richardson 2005) and have a similar life cycle. Newly hatched larvae are swept down river and out to sea where they spend their first six months feeding and growing. Where they live during this phase is unknown (Richardson et al 2007). Juvenile galaxids reenter streams and rivers in spring where they are harvested. Inanga were traditionally caught with similar methods used for tuna but adapted to suit their smaller body sizes. Today customary fisheries for inanga employ kupenga hao (long, rectangular nets) as well as large scoop nets.

## 6.7 Discussion

The available information describing the extent and magnitude of customary fishing and gathering in the STB is very limited. There is no comprehensive or systematic assessment of these fisheries though, without doubt, they are particularly important for coastal hapu. Moreover, there is little information to indicate how these fisheries may have trended over the last 100 years in relation to the development and growth of commercial and recreational fisheries, and changes to the land use patterns in the catchments that drain into the coastal zone.

The available information indicates that customary fishing likely occurs along most of the coast of the STB, especially where intertidal and shallow subtidal reefs occur as these harbour a variety of fish and invertebrate kaimoana species. Customary fishing farther offshore for a variety of finfish species is likely to vary depending on whānau access to suitable vessels and equipment and traditions of fishing for particular species.

The customary fisheries offshore that have the greatest overlap with TTRs proposed project area are those for species such as rig and leatherjacket which are abundant directly over the proposed extraction site. Few details are known about the marine phase of any diadromous fish such as lampreys, freshwater eels or galaxids (Richardson et al. 2007), so it is unknown whether any of these species occur in the vicinity of the proposed extraction site.

# 7 Summary and conclusions

A range of marine habitats occur in the STB that support a variety of organisms including reef fish and invertebrates, crayfish, demersal fish and pelagic fish species. The species richness of the reef fish, demersal fish and pelagic fish assemblages is moderate on a national scale (Leathwick et al. 2006a, Smith 2008). None of the strictly marine species reviewed in this report are nationally threatened (Hitchmough et al. 2007, Townsend et al. 2008), although several diadromous species are listed as 'at risk – declining', including the lamprey, longfin eel, and four of the five whitebait species occurring in the region (Allibone et al. 2010).

Some of the identified fish and invertebrate species support locally important commercial and customary fisheries. We did not investigate the extent or location of recreational fisheries.

The distribution of the marine life stages of diadromous fish in the STB is unknown.

There is some evidence for spawning activity by 13 demersal or pelagic fish species in the STB while larger juveniles of 24 species also occur in the region (Hurst et al. 2000). However, the distributions of spawning adults and juveniles are poorly defined and maps provided by Hurst et al. (2000) showing the locations of catches of running ripe mature fish and juveniles in the STB should be interpreted cautiously as they indicate only where catches of these life stages took place on trawlable ground deeper than approximately 20 m. Shallow areas and areas with bottom features too rough to trawl were not sampled.

Demersal and pelagic fish species with predicted adult distributions in the STB that particularly coincide with areas potentially affected by iron sand extraction operations (i.e. those species with % occurrence > 50%) include barracouta, blue cod, carpet shark, eagle ray, John dory, golden mackerel, kahawai, leatherjacket, lemon sole, red cod, red gurnard, rig, school shark, snapper, spiny dogfish, tarakihi, trevally, common warehou, and witch. Species that are predicted to be particularly abundant (> 50 kg per hour standard trawling) in the TTR proposed project area include barracouta, red gurnard, leatherjacket, school shark, snapper, spiny dogfish, rig, tarakihi, and trevally.

The fisheries that have the greatest overlap with TTRs proposed project area are the commercial set-net fisheries for rig, warehou, and school shark, and customary fisheries for rig and leather jackets. The greatest effort and catch in these commercial fisheries in the STB is located over and adjacent to the banks where the iron sand extraction operations will take place, while the greatest abundance of rig and leather jackets also occurs in this area.

Information relating to TTR's additional scientific work undertaken since 2014 has been provided and the conclusions is this report remain valid.

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# 9 References

Allibone, R.; David, B.; Hitchmough, R.; Jellyman, D.; Ling, N.; Ravenscroft, P.; Waters, J. (2010). Conservation status of New Zealand freshwater fish, 2009, *New Zealand Journal of Marine and Freshwater Research 44*: 271-287, DOI: 10.1080/00288330.2010.514346

Andrew, N.L.; MacDiarmid A.B. (1991). Interrelations between sea urchins (*Evechinus chloroticus*) and spiny lobsters (*Jasus edwardsii*) in north-eastern New Zealand. *Marine Ecology Progress Series* 70: 211-222.

Annala, J.H; Bycroft, B.L. (1984). Exploratory fishing for rock lobsters in offshore areas near Gisborne. *Fisheries Research Division Occasional Publication* 45.

Annala, J.H (1981). Movements of rock lobsters (*Jasus edwardsii*) tagged near Gisborne, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 15: 437-443.

Ayling, T.; Cox G.J. (1982). Collins Guide to the Sea Fishes of New Zealand. Collins Publishers, Auckland. 343pp.

Bassett, D.K.,;Jeffs, A.G.; Montgomery, J.C. (2008). Identification of predators using a novel photographic tethering device. *Marine and Freshwater Research* 59: 1079–1083

Beaumont, J.; Oliver, M.D.; MacDiarmid, A.B (2008). Mapping the Values of New Zealand's Coastal Waters. 1. Environmental Values. *Biosecurity New Zealand Technical Paper No: 2008/16*, 73 p.

Booth, J.D. (1994). *Jasus edwardsii* larval recruitment off the east coast of New Zealand. *Crustaceana* 66:295–317.

Booth, J.D. (1997). Long-distance movements in *Jasus* spp. and their role in larval recruitment. *Bulletin of Marine Science* 61: 111-128.

Booth, J.D. (2011). Spiny lobsters through the eyes of the giant packhorse. Victoria University Press, Wellington, 256 pp.

Boyer, T.; Levitus, S.; Garcia, H.; Locarnini, R.; Stephens, C.; Antonov, J. (2005), Objective analyses of annual, seasonal, and monthly temperature and salinity for the world ocean on a ¼ degree grid. International *Journal of Climatology* 25: 931-945.

Butler, M. J.; MacDiarmid, A.B.; Booth, J.D. (1999). The cause and consequence of ontogenetic changes in social aggregation in New Zealand spiny lobsters *Marine Ecology Progress Series* 188: 179-191.

Choat, J.H. (1982). Fish feeding and the structure of benthic communities in temperate waters. *Annual Review of Ecology and Systematics* 13:423-449.

Chiswell, S.M.; Booth, J.D. (2008). Sources and sinks of larval settlement in *Jasus edwardsii* around New Zealand: Where do larvae come from and where do they go? *Marine Ecology Progress Series* 354: 201–217.

Colman, J. A. (1972). Food of snapper, *Chrysophrys auratus* (Forster), in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 6:221-239

Department of Conservation (2006). Netting coastal knowledge: a report into what is known about the south Taranaki-Whanganui marine area. Department of Conservation, Whanganui Conservancy, 2006, 222 pp.

Denny, C.M.; Schiel, D.R. (2001). Feeding ecology of the banded wrasse *Notolabrus fucicola* (Labridae) in southern New Zealand: prey items, seasonal differences, and ontogenetic variation. *New Zealand Journal of Marine and Freshwater Research* 35:925-933.

Edmonds, M. (1995.). The ecology of juvenile spiny lobster *Jasus edwardsii*. PhD dissertation, University of Tasmania, 164 pp

Elith, J.; Graham, C.H.; Anderson, R.P.; Dudik, M.; Ferrier, S.; Hijmans, R.J.; Huettmann, F.; Leathwick, J.R.; Lehmann, A.; Li, J.; Lohmann, L.G.; Loiselle, B.A.; Manion, G.; Moritz, C.; Nakamura, M.; Nakazawa, Y.; Overton, J.M.; Peterson, A.T.; Phillips, S.J.; Richardson, K.S.; Scachetti-Pereira, R.; Schapire, R.E.; Soberon, J.; Williams, S.; Wisz, M.S. & Zimmermann, N.E. (2006). Novel methods improve prediction of species' distribution from occurrence data. *Ecography* 29: 129–151.

Elith, J.; Leathwick, J. R.; Hastie, T. (2008). A working guide to boosted regression trees. *Journal of Animal Ecology* 77: 802–813

Francis, M. (2001). Coastal fishes of New Zealand. Reed, Auckland. 103 pp.

Freeman, D.J. (2007). The ecology of spiny lobsters (*Jasus edwardsii*) on fished and unfished reefs. Unpublished PhD thesis, University of Auckland, 311 pp.

Freeman, D.J.; MacDiarmid, A.B.; Taylor, R.B. (2009). Habitat patches that cross marine reserve boundaries: consequences for the lobster *Jasus edwardsii*. *Marine Ecology Progress Series* 388:159-167

Freeman, D. J.; Alison B. MacDiarmid, Richard B. Taylor, Robert J. Davidson, Roger V. Grace, Tim R. Haggitt, Shane Kelly, Nick T. Shears (in press). Trajectories of spiny lobster *Jasus edwardsii* recovery in New Zealand marine reserves – is settlement a driver? *Environmental Conservation*.

Friedman, J.H. (2002) Stochastic gradient boosting. *Computational Statistics and Data Analysis* 38: 367-378.

Gillespie, J.L.; Nelson, C.S. (1996). Distribution and control of mixed terrigenous-carbonate surficial sediment facies, Wanganui shelf, New Zealand. *New Zealand Journal of Geology and Geophysics 39:* 533-549.

Gillespie, P. (2007). Potential effects of high sediment loads on the marine environment of the east coast of the North Island, East Cape - Hawke Bay: a review of existing information. Prepared for the Gisborne District Council. *Cawthorn Report* No. 1389, 9 p.

Godfriaux, B.L. (1969) Food of predatory demersal fish in Hauraki Gulf. 1: Food and feeding habits of snapper. *New Zealand Journal of Marine and Freshwater Research* 3: 518-544

Graham, D.H. (1957). A Treasury of New Zealand Fishes, 2nd ed. Reed, Wellington. 424 pp.

Hitchmough, R.; Bull, L.; Cromarty, P. (2007). New Zealand threat classification system lists 2005. Department of Conservation, Wellington New Zealand, 134 p.

Hurst, R.J.; Stevenson, M.L.; Bagley, N.W.; Griggs, L.H.; Morrison, M.A.; Francis, M.P. (2000). Areas of importance for spawning, pupping or egg laying, and juveniles of New Zealand coastal fish. Final Research Report for Ministry of Fisheries research Project ENV1999/03, Objective 1. NIWA, 200 p.

James, A. (2008). Ecology of the New Zealand Lamprey (*Geotria australis*): A literature review. *Te Tai Hauauru - Whanganui Conservancy Fauna Series 2008/1*, Published by Department of Conservation, 28 p.

Jellyman, D. (2012). The status of longfin eels in New Zealand - an overview of stocks and harvest. NIWA Client Report No: CHC2012-006 – revised, 78 p.

Kelly, S. (1999). Marine reserves and spiny lobster *Jasus edwardsii*. Unpublished PhD thesis, University of Auckland, New Zealand. 186 pp.

Kelly, S. (2001). Temporal variation in the movement of the spiny lobster *Jasus edwardsii*. *Marine and Freshwater Research* 52: 323–31

Kelly, S.; MacDiarmid, A.B.; & Babcock, R.C. (1999). Characteristics of spiny lobster, *Jasus edwardsii*, aggregations in exposed reef and sandy areas. *Marine and Freshwater Research* 50: 409-416.

Kelly, S.; Scott, D.; MacDiarmid, A.B.; and Babcock, R.C. (2000). Spiny lobster, *Jasus edwardsii*, recovery in New Zealand marine reserves. *Biological Conservation* 92: 359-369

Kelly, S.; Scott, D.; MacDiarmid, A.B. (2002). The value of a spill-over fishery for spiny lobsters around a marine reserve in northern New Zealand. *Coastal Management* 30: 153-166

Kelly, S.; MacDiarmid, A.B. (2003). Movement patterns of spiny lobsters, *Jasus edwardsii*, from a marine reserve. New Zealand Journal of Marine and Freshwater Research 37: 149 –158.

Kington, S.W. (1999). Factors influencing the on-growing and restocking of *Jasus edwardsii*. MSc thesis, University of Auckland. 78 pp.

Langlois, T. J.; Anderson, M.J.; Babcock, R.C. (2005). Reef-associated predators influence adjacent soft-sediment communities. *Ecology* 86: 1508-1519.

Langlois, T. J.; Anderson, M.J.; Babcock, R.C. (2006a). Inconsistent effects of reefs on different size classes of macrofauna in adjacent sand habitats. *Journal of Experimental Marine Biology and Ecology* 334: 269-282

Langlois, T.J.; Anderson, M.J.; Brock, M.; Murman, G. (2006b). Importance of rock lobster size–structure for trophic interactions: choice of soft-sediment bivalve prey. *Marine Biology* 149: 447–454

Langlois, T.J.; Anderson, M.J.; Babcock, R.C.; Kato, S. (2006c). Marine reserves demonstrate trophic interactions across habitats. *Oecologia* 147:134–140

Leach, B.F. (2006). Fishing in Pre-European New Zealand. *New Zealand Journal of Archaeology, and Archaeofauna*, Wellington. 359 p.

Leathwick, J.R.; Elith, J.; Francis, M.O.; Hastie, T.; Taylor, P. (2006a). Variation in demersal fish species richness in the oceans surrounding New Zealand: an analysis using boosted regression trees. *Marine Ecology Progress Series* 321: 267-281.

Leathwick, J.; Francis, M.; Julian, K. (2006b). Development of a demersal fish community map of New Zealand's Exclusive Economic Zone. NIWA Client Report: HAM2006–062. 38p.

Lohrer, A.M.; Hewett, J.E.; Thrush, S.F.(2006). Assessing far-field effects of terrigenous sediment loading in the coastal marine environment. *Marine Ecology Progress Series* 315: 13-16.

MacDiarmid, A.B. (1985). Sunrise release of larvae from the palinurid rock lobster *Jasus edwardsii*. *Marine Ecology Progress Series*. 21: 313-315.

MacDiarmid, A.B. (1989). Moulting and reproduction of the spiny lobster *Jasus edwardsii* (Decapoda, Palinuridae) in northern New Zealand. *Marine Biology* 103: 303-310

MacDiarmid, A.B. (1991). Seasonal changes in depth distribution, sex ratio and size frequency of spiny lobsters *Jasus edwardsii* (Decapoda, Palinuridae) on a coastal reef in northern New Zealand. *Marine Ecology Progress Series* 70: 129-141.

MacDiarmid, A.B. (1994) Cohabitation in the spiny lobster Jasus edwardsii (Hutton 1875). *Crustaceana* 66: 341-355

MacDiarmid, A.B.; Hickey, B.; Maller, R. A. (1991). Daily movement patterns of spiny lobster *Jasus edwardsii* (Hutton) on a shallow reef in northern New Zealand. *Journal of Experimental Marine Biology and Ecology* 147: 185-205.

MacDiarmid, A.B.; Stewart, R.; Oliver, M. (2000). Mate choice in rock lobsters. *SeaFood New Zealand* 8 (7), p. 38-39.

MacDiarmid, A.; Booth, J. (2003) Crayfish. In: The Living Reef: The Ecology of New Zealand's Rocky Reefs. Andrew, N., Francis, M. (eds). Craig Potton Publishing, Nelson, New Zealand. pp. 120-127

MacDiarmid, A.B; Sainte-Marie, B. (2006). Reproduction. In Lobsters: biology, management, aquaculture and fisheries. B.F. Phillips (ed) Blackwell Scientific Publications. Pp. 45-77

MacDiarmid, A.; Anderson, O.; Beaumont, J.; Gorman, R.; Hancock, N.; Julian, K.; Schwarz, J.; Stevens, S.; Sturman, J.; Thompson, D.; Torres, L. (2010). South Taranaki Bight iron sand mining baseline environmental study. *NIWA Client Report* WLG2010-46, 391 pp.

MacDiarmid, A. B.; Cleaver, P.; Stirling, B. (in press). Historical evidence for the state and exploitation of the marine environment in the Hauraki Gulf and along the Otago-Catlins shelf 1769 – 1950. *New Zealand Aquatic Environment and Biodiversity Report* No. XX, 600 pp.

McDowall, R.M. (1990). New Zealand Freshwater fishes: a natural history and guide. Heinemann Reed, Auckland, 553 p.

McDowall, R.M. (2011). Ikawai. Freshwater fishes in Maori culture and economy. Canterbury University Press.

McKoy, J.L. (1983). Movement of rock lobsters, *Jasus edwardsii* (Decapoda : Palinuridae), tagged near Stewart Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 17: 357-366.

McKoy, J. L.; Leachman, A. (1982). Aggregations of ovigerous female rock lobsters, *Jasus edwardsii* (Decapoda : Palinuridae). *New Zealand Journal of Marine and Freshwater Research* 16, 141.6.

Mills, D.J.; Gardner, C.; Johnson, C.R. (2006). Experimental reseeding of juvenile spiny lobsters (*Jasus edwardsii*): comparing survival and movement of wild and naïve lobsters at multiple sites. *Aquaculture* 254:256-268

Ministry for the Environment (2003). Kaimoana Survey Guidelines for Hapü and Iwi. Ministry for the Environment, Wellington, 79 p.

Ministry of Fisheries, Science (2010): Report from the Mid-Year Fishery Assessment Plenary, November 2010: stock assessments and yield estimates. 222p. (Unpublished report held in NIWA Greta Point library, Wellington.).

Ministry of Fisheries (2011). Report from the Fisheries Assessment Plenary, May 2011: stock assessments and yield estimates. Ministry of Fisheries, Wellington, New Zealand. 1178 p.

Oliver, M.D. (2007). Biological feasibility of spiny lobster *Jasus edwardsii* stock enhancement. Unpublished PhD thesis, University of Tasmania, Australia.

Oliver, M.D.; Stewart, R.; Mills, D.; MacDiarmid, A.B.; Gardner, C. (2005) Stock enhancement of rock lobsters (*Jasus edwardsii*): timing of predation on naïve juvenile lobsters immediately after release. *New Zealand Journal of Marine and Freshwater Research* 39:391-397.

Partrick, M. (2000). Kaimoana Survey 2000/2001 Phase 1 Report. Unpublished Report available on the Taranaki Regional Council website.

Partrick, M. (2001). Kaimoana Survey 2000/2001 Phase 3 North Taranaki Coastal Seafood Resources – Summary of Findings, and Recommendations. Unpublished Report available on the Taranaki Regional Council website.

Pinkerton, M.; Hadfield, M.; Hunter, K.; MaCaskill, B. (2005). Three additional layers for Marine Environment Classification: (1) Sea bed temperature; (2) Calcium compensation depth; (3) Sea-bed light levels. *NIWA Client Report* WLG2005-50. 40pp.

Pinkerton, M.H.; Richardson, K.R. (2005). Case 2 Climatology of New Zealand: Final report. *NIWA Client Report* WLG2005-49.16pp.

Pinkerton, M.H.; Lundquist, C.J.; Duffy, C.A.J.; Freeman, D.J. (2010) Trophic modelling of a New Zealand rocky reef ecosystem using simultaneous adjustment of diet, biomass and energetic parameters. *Journal of Experimental Marine Biology and Ecology* 367: 189–203

Richardson, J. (2005). NIWA atlas of New Zealand freshwater fishes. http:/www.niwascience.co.nz/rc/freshwater/fishatlas

Richardson, J.; McDowall, R.; Patuawa,T. (2007). Diadromous freshwater fishes (Families Geotiidae, Anguillidae, Galaxidae, Retropinnidae, Eleotridae, Pinguipedidae, and Pleuronectidae). In MacDiarmid, A. (editor) The Treasures of the Sea Nga Toanga a Tangaroa: a summary of the biodiversity in the New Zealand marine ecoregion. WWF-New Zealand, Wellington.

Ritchie, L.D. (1972). Octopus predation on pot-caught rock lobster, Hokianga area, New Zealand. *Fisheries Technical Report* 81. 44pp.

Russell, B.C. (1983). The food and feeding habits of rocky reef fish of north-eastern New Zealand.  *New Zealand Journal of Marine and Freshwater Research* 17: 121-145

Schiel, D.R.; Wood, S.A.; Dunmore, R.A.; Taylor, D.I. (2006). Sediment on rocky intertidal reefs: Effects on early post-settlement stages of habitat-forming seaweeds. *Journal of Experimental Marine Biology and Ecology* 331: 158-172.

Shears, N.T.; Babcock, R.C. (2002) Marine reserves demonstrate top-down control of community structure on temperate reefs. *Oecologia* 132: 131-142

Smith, A.N.H. (2008). Predicting the distribution and relative abundance of fishes on shallow subtidal reefs around New Zealand. *NIWA Client Report* WLG2008-9, 175 pp.

Snelder, T.H.; Leathwick, J.R.; Dey, K.L.; Rowden, A.A.; Weatherhead, M.A.; Fenwick, G.D.; Francis, M.P.; Gorman, R.M.; Grieve, J.M.; Hadfield, M.G.; Hewitt, J.E.; Richardson, K.M.; Uddstrom, M.J.; Zeldis, J.R. (2007). Development of an ecologic marine classification in the New Zealand region. *Environmental Management* 39:12-29

Street, R.J. (1969). The New Zealand crayfish, *Jasus edwardsii* (Hutton). *Fisheries Technical Report* New Zealand Marine Department 30: 1-24.

Taranaki Regional Council (2011). Regional air quality plan for Taranaki. Taranaki Regional Council, Document # 920197, 266 p.

Technip Mines (2012a). Prefeasibility Study of Tangaroa Project. Report reference 0061 004 Rev C. 304 pp.

Technip Mines (2012b). Executive Summary, Prefeasibility Study on TTR Offshore Ironsands Project Tangaroa. Report reference 0061 005 Rev C. 55 pp

Technip Mines (2012c). Discharge streams, Project Tangaroa Prefeasibility Study. File Discharge_Streams_P1.xlsx.

Thomas, L.; Bell, J.J. (2013). Testing the consistency of connectivity patterns for a widely dispersing marine species. Heredity (2013), 1–10.

Thomson, G.M.  (1892). Notes on sea-fishes.  *Transactions and Proceedings of the New Zealand Institute* 24:202-215

Booth, J.D. (2011). Spiny lobsters through the eyes of the giant packhorse. Victoria University Press, Wellington, 256 pp.

Thrush, S.F.; Hewett, J.E.; Cummings, V.J.; Ellis, J.I.; Hatton, C.; Lohrer, A.; Norkko, A. (2004). Muddy waters: elevating sediment input to coastal and estuarine habitats.  *Frontiers in Ecology and the Environment* 2: 299-306.

Townsend A.J.; de Lange, P.J.; Duffy, C.A.J.; Miskelly, C.M.; Molloy, J.; Norton, D.A. (2008). New Zealand threat classification system manual, Wellington, Department of Conservation.

Vermeulen, P. (2012). Trans-Tasman Resources reefs/rocks verification report. 11 pp.

Williams, B.G.; Dean, I.C. (1989). Timing of locomotor activity in the New Zealand rock lobster, *Jasus edwardsii*. *New Zealand Journal of Marine and Freshwater Research* 23: 215-224.

Willis, T.J.; Anderson, M.J. (2003). Structure of cryptic reef fish assemblages: relationships with habitat characteristics and predator density. *Marine Ecology Progress Series* 257: 209–221.

# 10 Appendix A: Modelled reef fish abundance and distribution

See separate file for this appendix

# 11 Appendix B: Modelled demersal fish distribution (% occurrence)

See separate file for this appendix

# 12 Appendix C: Modelled demersal and pelagic fish abundance (catch rate)

See separate file for this appendix

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