Fish assemblages of Moutere and Waimea inlets, Nelson

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Executive summary

Tasman District Council and Nelson City Council contracted NIWA to conduct research on Moutere Inlet and Waimea inlets, with the objective being " *to quantify what fish species live in these two estuaries, their habitat associations, and a brief interpretation of what the relative importance of these two estuaries are for the fish populations of this region*". An initial hui was held at NIWA Nelson on the 24th of November 2020, attended by iwi (Ngati Koata, Ngati Tama, Te Ātiawa), Manawhenua Ki Mohua (an iwi mandated organisation representing Ngati Tama, Ngati Rārua and Te Ātiawa), the two Councils, and several other interested organisations. The proposed survey and its objectives were presented and discussed, and the feedback incorporated into the projects approach, such as the need to release as many fish alive as possible.

Moutere Inlet and Waimea Inlet were subsequently sampled for their fish assemblages in February 2021, using 32 beach seine stations, 31 beam trawl stations, and 10 multi-panel gillnets (Waimea Inlet only). Sampling effort was spread across the subtidal channel areas of the two inlets. Two known areas of sponge garden were excluded from sampling. Twenty-one fish species were captured. Beach seine samples were taken around low tides, when fish were forced to migrate off the intertidal flats to the adjacent subtidal channels. Catches were dominated by juvenile yellow-eyed mullet and to a lesser degree spotties (a wrasse), along with low densities of triplefins, garfish/piper, speckled sole, yellow-belly and sand flounder. One station on a narrow subtidal seagrass fringe on the edge of an intertidal seagrass meadow notably returned the highest densities seen for spotties and triplefin, in line with the high value that subtidal seagrass is known to provide for these and other small-bodied fish species. No significant statistical difference in the fish assemblages was found between inlets, water depths (0 to 2 metre range), or for sediment type.

Beam trawling in the subtidal channels returned catches of spotties and triplefins, and other small fish including low numbers of juvenile yellow-belly and sand flounder. Several 0+ (young-of-the-year) snapper were caught in Waimea Inlet, although densities were too low to call the inlet a juvenile snapper nursery. A significant statistical difference was found between the fish assemblages sampled by beam trawl at the two inlets, though this was driven by small differences in spotty and triplefin densities, and unlikely to be ecologically important. No difference was found between different water depths (1 to 10 metre range). No biogenic-habitat forming species (e.g., sponges, calcareous tubeworm clumps) were caught as bycatch in the beam trawl (excepting two dead horse mussels), suggesting a largely bare seafloor composed of soft sediments.

Multi-panel nets set in Waimea Inlet returned catches of larger yellow-eyed mullet, kahawai, snapper, rig (spotted dogfish), and eagle rays; along with lesser numbers of trevally, spotties and other species. The catch included a low number of rig (a shark species) and school shark pups. A significant statistical difference was found between fish assemblages of Waimea Inlet's northern and southern areas, driven by higher yellow-eyed mullet and kahawai catches in the north, and higher snapper and rig catches in the south.

To help set the 2021 Moutere and Waimea inlet fish sampling result in a wider regional context, these data were compared to previous 2006 beach seine sampling of six estuaries located at the top of the South Island. Of note was Moutere Inlet having the second highest yellow-eyed mullet densities across the eight estuaries compared, after Port Underwood. Comparisons and links were also made to the fish assemblages of Tasman and Golden bays, as sampled by trawl surveys since 1986/1992. One beach seine site over subtidal seagrass fringe reinforced the value of subtidal

seagrass meadows as juvenile fish nursery habitat, with this habitat type being functionally (and largely physically) extinct across the entire top of the South Island (excepting eastern Tory Channel).

One of the council's most basic functions for these inlets is to protect important fish habitats. Recommendations are made on maintaining and protecting such habitats still present in the inlets from both direct and indirect human-driven disturbances. The potential for recovery/restoration of inferred extensive subtidal seagrass meadows in the past is also discussed, through improving environmental conditions (passive restoration).

1 Introduction

Waimea (3,445 ha) and Moutere inlets (764ha) are two of the largest estuaries in the Tasman / Golden Bay region, but their fish assemblages have received little to no attention from the scientific community. Both sit at the bottom of watersheds heavily modified by human activities and have long histories of adjacent human settlement and associated harbour use. The Tasman District Council (TDC) and Nelson City Council (NCC) sought to better understand the relative importance of these two estuaries for the fish population of this region. The objective was to quantify what fish species live in these two estuaries, their habitat associations, and a brief interpretation of what the relative importance of these two estuaries are for the fish populations of this region.

An initial hui was held at NIWA Nelson on the 24th of November 2020, attended by iwi (Ngati Koata, Ngati Tama, Te Ātiawa), Manawhenua Ki Mohua (an iwi mandated organisation representing Ngati Tama, Ngati Rārua and Te Ātiawa), the two Councils, and several other interested organisations. The proposed survey and its objectives were presented and discussed, and the feedback incorporated into the projects approach, such as iwi wishes that as many fish as possible were released alive.

The two inlets were surveyed in March–April 2021 using three fish sampling methods that collectively provide a good understanding of the fish populations and assemblages present. This report documents the findings of that survey and sets them within a wider regional context of fish assemblages. Some recommendations are also made on how fish monitoring might be progressed into the future, to assess potential shifts over time, in response to ongoing land-use changes in the inlets surrounding catchments.

1.1 Existing background knowledge of Waimea and Moutere inlets

1.1.1 Waimea Inlet

Waimea Inlet is a large (3,462 ha), shallow, well-flushed tidal lagoon type estuary (Stevens et al. 2020a). It is composed of two main subtidal basins, each with its own entrance and large extents of intertidal flats; with the two basins connected by north-west/south-east shallow tidal channels (Figure 1). The Waimea River empties into this intermediate connecting channel area, between Rough Island and Best Island. Various islands add complexity, with the largest, Moturoa (Rabbit) Island, forming most of the estuary's seaward boundary. Water residence time is low (less than one day), with most of the estuary draining on low tides, with 81% of the estuary being intertidal flats.

Davidson & Moffat (1990) undertook a review of the ecology of Waimea Inlet. Maori have been present in the area since the 1500s, with extensive gardens being created and used near Appleby in past times. With the arrival of Europeans in the 1840s, coastal forests were burnt and lost (converted to farmland or pine plantation forest), swamps drained, and more intensive human occupation occurred. About 200 hectares of the estuary margins were lost to reclamation, and transformed by industry, farms, stop banks and rubbish tips. Habitat mapping of the intertidal habitats of Waimea Inlet identified ten broad habitat classes: mobile sand, fine sand, eelgrass, mudflat, high-shore flat, *Sarcocornia* (salt-marsh), pebble and cobble, native rush-sedge, and *Spartina*. The invertebrate infauna was sampled with corers, and described qualitatively, with each habitat type varying in its associated invertebrate assemblage (Davidson & Moffat 1990).

Zostera (seagrass/eelgrass) was found to cover 58 hectares (1.7%) of the estuary, and it was stated that "*eelgrass grows below the mid-tide level and dies off in the winter months*". Most beds were located adjacent to the Nelson Airport Peninsula, and Saxton and Bell Islands. Two beds were also found in the northern inlet, adjacent to No Mans Island.

Since the original intertidal habitat mapping of Waimea Inlet (Davidson & Moffat 1990), the estuary has been mapped over time using the National Estuary Monitoring Protocol (NEMP, Robertson et al. 2002). NEMP fine scale surveys were conducted in 2001 (Robertson et. al 2002), 2006 (Gillespie et al. 2007), 2014 (Robertson & Robertson 2014), and most recently, in 2020 (Stevens et al. 2020a). All habitat mapping was for the intertidal zone only.

Stevens et al. (2020a) compared their findings with the earlier intertidal NEMP broad scale surveys and discussed status and trends in estuary health. Briefly, they used aerial colour photography for habitat mapping, with a pixel resolution of 0.075 to 0.3 m (depending on source), flown over the 2017–2019 period. Ground-truthing was carried out in May 2020. Both geological substrate (e.g., muds, sands, gravels, cobbles) and overlying vegetation (e.g., saltmarsh, seagrass, macroalgae) were mapped. Seagrass was assessed for mean-percent cover, to the nearest 10 % using a 6-category percent cover scale. Figure 1 shows the intertidal map produced.

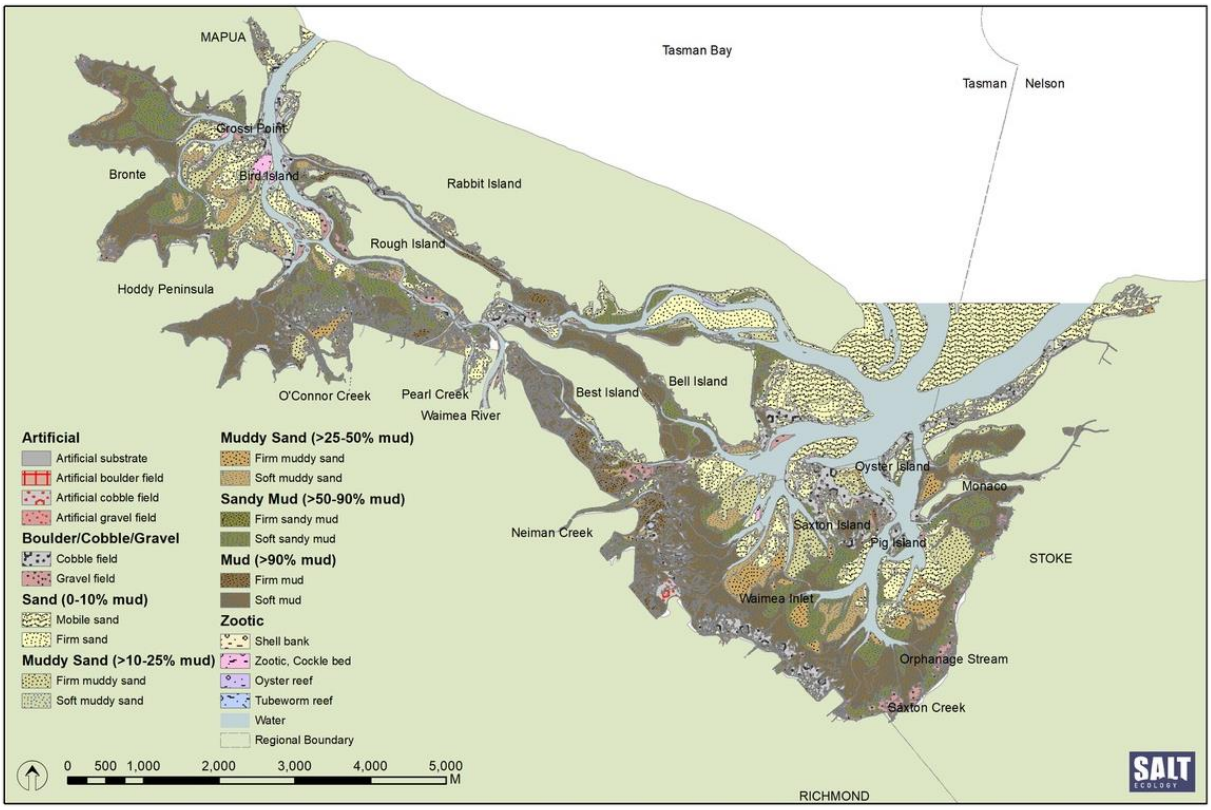

Figure 1: Intertidal habitat of Waimea as mapped using 2017–2019 high resolution aerial colour photography. (Source: figure 4 of Stevens et al. 2020).

An increase in muddiness in the inlet is one of the key management issues of concern, along with nutrient enrichment and associated nuisance intertidal macroalgae. Stevens et al. (2020) mapped out the percentage of mud in the sediments in May 2020, as well as calculating spatial extent changes in mud-dominated intertidal habitat over the five habitat mapping surveys (Figure 2). Mud-dominated areas were concentrated in the upper estuary intertidal zone, where low tide channels were very shallow and limited in extent.

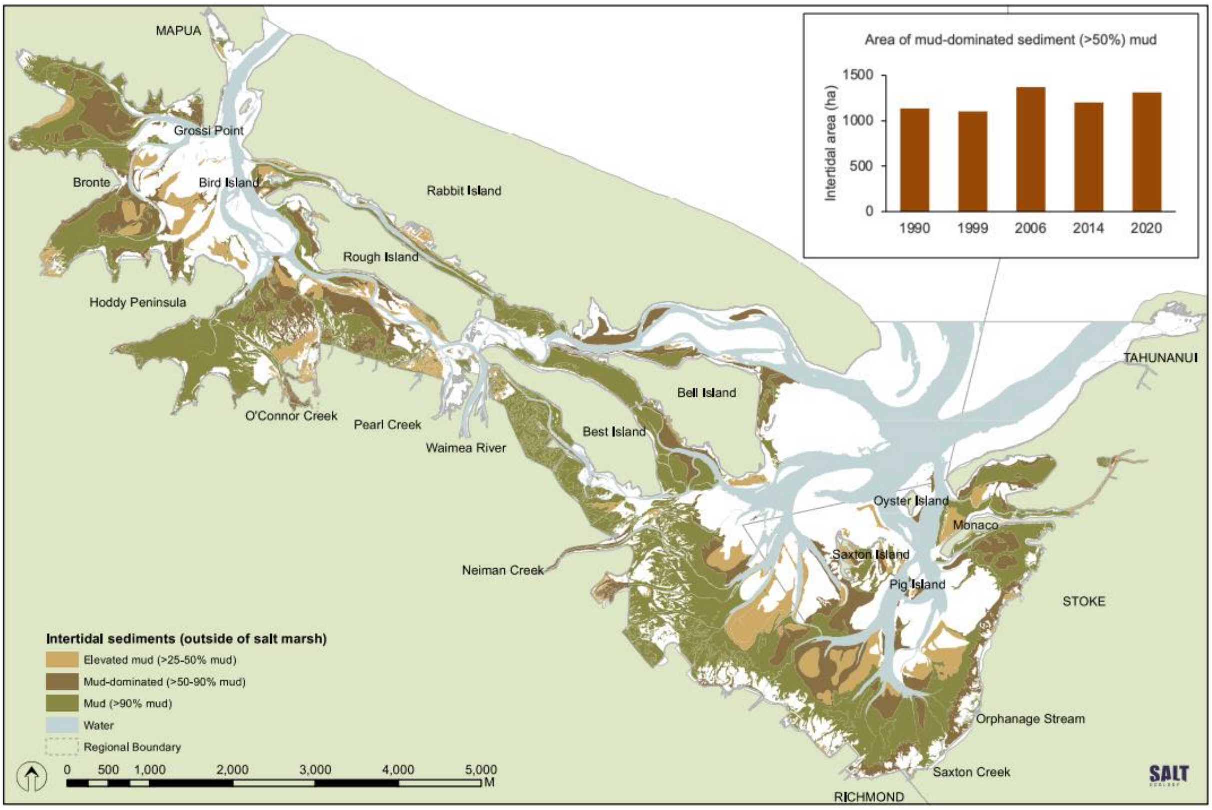

Figure 2: **Areas of mud-elevated (>25–50 % mud) and mud-dominated (>50% mud) sediment areas.** (in situ ground-truthing done May 2020). (Source: figure 5 of Stevens et al. 2020).

Stevens et al. (2020a) concluded that the source of the mud-dominated sediments was largely historic. Tasman District Council monitoring of sediment deposition over the last decade returned very low net sediment accumulation rates (average 0.1 mm yr^{-1}). Deep sediment cores (two sites) taken and dated for sediment deposition also showed low sedimentation rates (1.3–1.5 mm yr^{-1}) since ~1964, but with higher earlier (~1953 to 1964) inputs of 12.7 mm yr^{-1}. These higher rates matched anecdotal reports of orchard development in the 1950's and 1960's generating sediment inputs (Stevens & Robertson 2011). Beneath these mud-dominated layers were older sand-dominated sediments, with many intact shells, indicating a very different estuary ecosystem prior to large-scale catchment development by humans.

Seagrass meadows were present in the eastern area of the Waimea Inlet in the 2017–2019 imagery and mapped in fine detail by Stevens et al. (2020) (Figure 3). Most of the meadows were intertidal, but subtidal fringes appear present (current authors view) along the southern side of the main subtidal channel west of Nelson Airport. It was estimated that 2.3 % (68.3 ha) of the intertidal area held 1 % or higher seagrass cover, and within that some areas of >50 % seagrass cover (21.6 ha). This contrasted with 58 ha of >50 % seagrass cover present in 1990 (Davidson & Moffat 1990), and indicated a 63 % spatial extent reduction, with most loss thought to have occurred between 1990–1999. It was noted that "*the estuary had been significantly modified by 1990, and it is likely seagrass beds were far more extensive in their natural state*". From a fish habitat perspective, subtidal seagrass provides highly valued habitat for a range of fish species especially as juvenile nursey habitats, while intertidal seagrass is of little direct utility for fish in New Zealand (Morrison et al. 2014a–d).

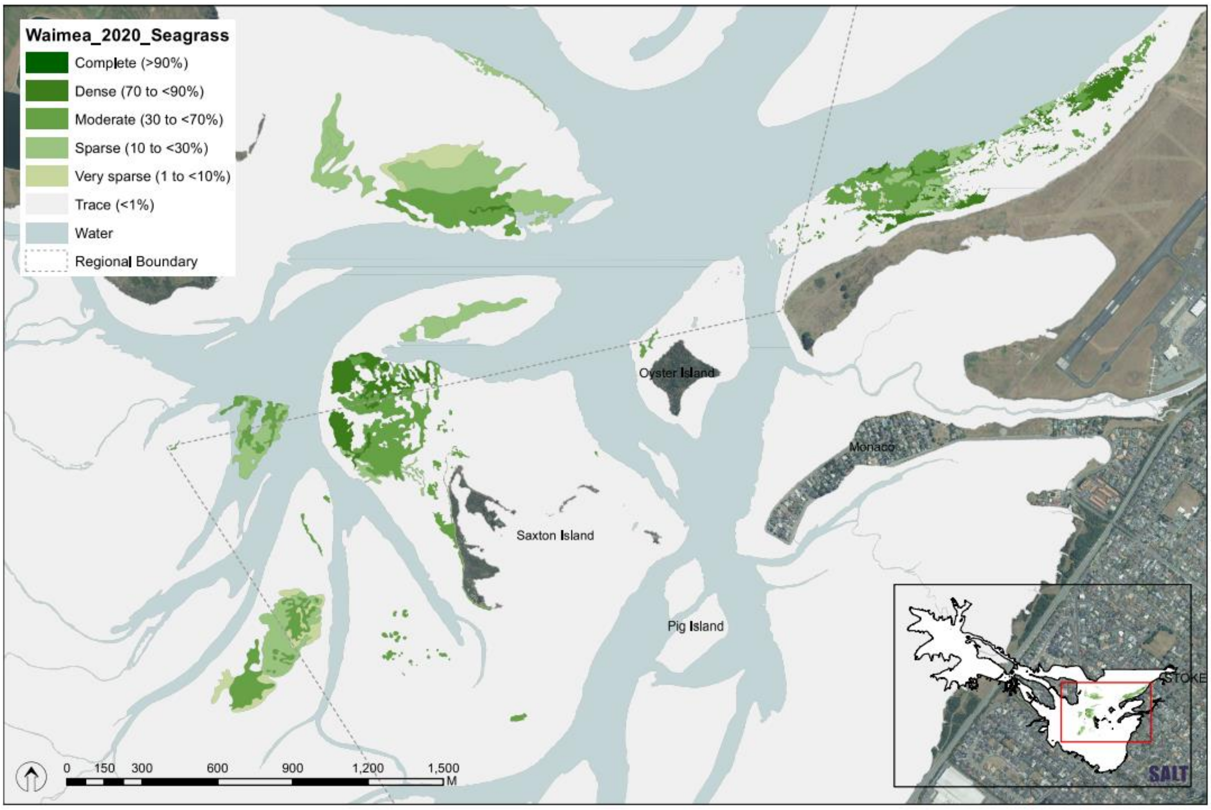

Figure 3: **Seagrass areas in Waimea Inlet south** (Source: figure 10 of Stevens et al. 2020).

Stevens et al. (2020a) also mapped small areas of low intertidal calcareous sabellid worm tube mounds (species unknown), occurring in the lower estuary areas (Figure 1), estimated to cover 1.2 hectares (0.04 % of the intertidal flats). Little is known about this biogenic habitat type, which appears rare in mound form (most mound-forming species can also occur as solitary individuals) in New Zealand. Tubeworm (*Spirobranchus cariniferus*) reef mounds have also been observed in the low tide fringe of Onepoto Inlet, Porirua (pers. comm., Leigh Stevens, marine ecologist, Salt Ecology Ltd). In the 1920s, prominent areas of intertidal tubeworm (or possibly gastropod) mounds were also present on Meola Reef in Auckland's Waitemata Harbour; these had vanished by the early 1980s (see figure 3 of Morrison et al. 2014b for historical images and the changes over time).

Figure 4: Sabellid (calcareous tubeworm) mounds at Grossi Point, 2011. (Source: Trevor James, coastal scientist, Tasman District Council).

Other biogenic habitats are also present in Waimea Inlet. Asher et al. (2008) described a sponge garden/assemblage that had developed in the narrow tidal channel between Rabbit Island and Rough Island (known as 'the Traverse', Figure 5) following the removal of pipe culverts at each end that strongly restricted tidal currents. In late 1998, the causeway across the western end of the Traverse was removed, which allowed greater tidal flows, although a raised entrance sill of single and firm mud remained. Ten years after the causeway removal, the Traverse exit channel area "*had changed from an anoxic soft sediment habitat with low species richness to a diverse sponge-associated biotic community*". This subtidal sponge garden extended over approximately 1.2 ha, with the faunal cover dominated by the sponge *Mycale* (*Carmia*) *tasmani* and associated biota, attached to a cobble/shingle seafloor. Water depth was less than 50 cm at low tide (as determined from photographs in Asher et al. 2008). This sponge species has two different morphological forms; a thick encrusting fibrous form with a smooth fleshy surface (found mainly in higher current areas), and an erect foliose 'finger-sponge' form (found in slower current flow areas) (Figure 5). The encrusting form dominated in the Traverse. Lesser densities of the sponge *Hymeniacidon perleve* were present near the western exit. At the eastern end, sponges were smaller, and interspersed with high macroalgal cover, including *Ulva* sp., *Ceramium apiculatum*, *Gigartina circumcincta*, *Gelidium caulacantheum*, and *Gracilaria* sp. Ecological sampling of the sponge assemblage recorded 114 associated taxa (invertebrates and macroalgae) (Asher et al. 2008).

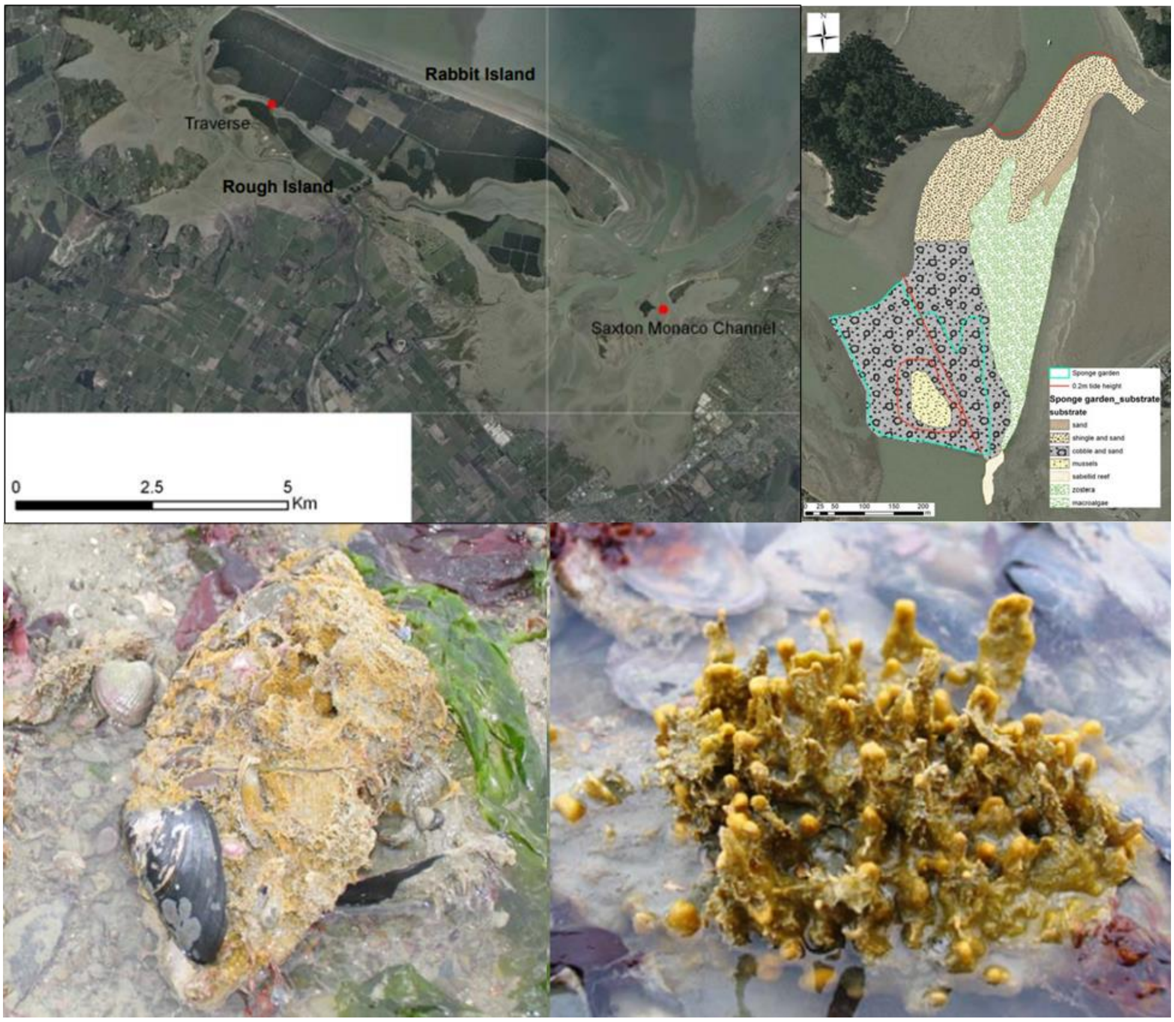

Figure 5: **Top left) locations of two sponge gardens within Waimea Inlet; top right) extent of Saxton Monaco sponge bed; lower panel), and the two growth forms of the sponge *Mycale* (*Carmia*) *tasmani*.** (Source: figures 1, 8, 10 of Asher et al. 2008).

A larger sponge garden (4.8 ha) was also investigated south of Oyster Island, in the eastern inlet (Figure 5). Known as the Saxton Monaco channel sponge garden, this habitat was described as usually subtidal, with approximately 50 % of the habitat becoming exposed during very low tides (<0.2 m chart datum). The sponge *M. tasmani* dominated, with both growth forms present, varying in dominance with tidal velocities (the finger-sponge form in the central channel, the encrusting form on the channel sides). The sponge *H. perleve* was absent. Ecological sampling found 69 taxa in association with the sponge garden, with sixteen of these not seen in the Traverse sampling (Asher et al. 2008).

1.2 Moutere Inlet

Moutere Inlet is a moderate-sized (764 ha), shallow, well-flushed, intertidally dominated estuary (Stevens et al. 2020b). It is composed of two small subtidal basins, each with its own entrance. Large extents of intertidal flat merge together west of Jacket Island, which forms much of the estuary's seaward boundary. The estuary is very shallow (mean depth ~2 m) and largely drains at low tide.

The intertidal portion of this inlet was recently broad-scale habitat mapped in 2019 by Stevens et al. (2020b) (Figure 6). The methodology followed that used for Waimea Inlet (Stevens et al. 2020a). As with Waimea, a key concern was the issue of sedimentation (along with nutrient enrichment and associated nuisance intertidal macroalgae), and changes in mud cover over time were assessed by comparing the 2109 survey with previous similar surveys in 2004 (Clark et al. 2006) and 2013 (Robertson & Stevens 2013). While the spatial extent of mud was rated as high in both a regional and national context, an encouraging reduction in mud spatial extent of 22 ha (9 % decrease) since 2012 was observed, along with "*an obvious decrease in sediment volume in certain parts of the estuary, most particularly the central basin*".

Figure 6 shows the extent of the different seafloor sediments and biological cover classes. As noted for Waimea Inlet, mud was dominant in the upper intertidal estuary areas, where the low tide channels were very shallow and generally limited in extent.

Seagrass meadows were present in the southern Moutere Inlet in 2019 and were mapped in fine detail by Stevens et al. (2020b), covering 3.12 ha (Figure 6). All these meadows occurred on the lower intertidal sandflats running along the east side of the Kina Peninsula channel. Most of the seagrass extent (>99 %) held dense blade cover (70–90 % cover) and appeared "*in a healthy and luxuriant condition*".

An earlier survey in 2004 recorded only 0.9 ha in seagrass cover (Clark et al. 2006). The 2019 survey estimate of 3.12 ha represented a 347 % spatial increase since 2004 – but from a very low baseline of 0.9 ha. The percent cover of seagrass recorded in 2019 was noted to be in the same range as for other estuaries in the region (e.g., Waimea, Motupipi, Ruataniwha, Motueka), but significantly less than the nearby, similar sized but less muddy, Nelson Haven (15 % of its 135-ha extent) (Stevens et al. 2020b). Clark & Gillespie (2007) examined historical aerial imagery and reported no seagrass in Moutere Inlet in 1947, and only 0.2 ha in 1988. However, Stevens et al. (2020b) examined the same 1947 images and observed that seagrass was in fact present at many of the same locations as seen in 2019, despite not being identified by Clark & Gillespie (2007). They also suggested that as the estuary had already been significantly modified by 1947, seagrass beds were likely to have been far more extensive historically. A small area of sabellid tubeworm mounds was present near the northern entrance (0.7 ha, 0.1 % of the intertidal).

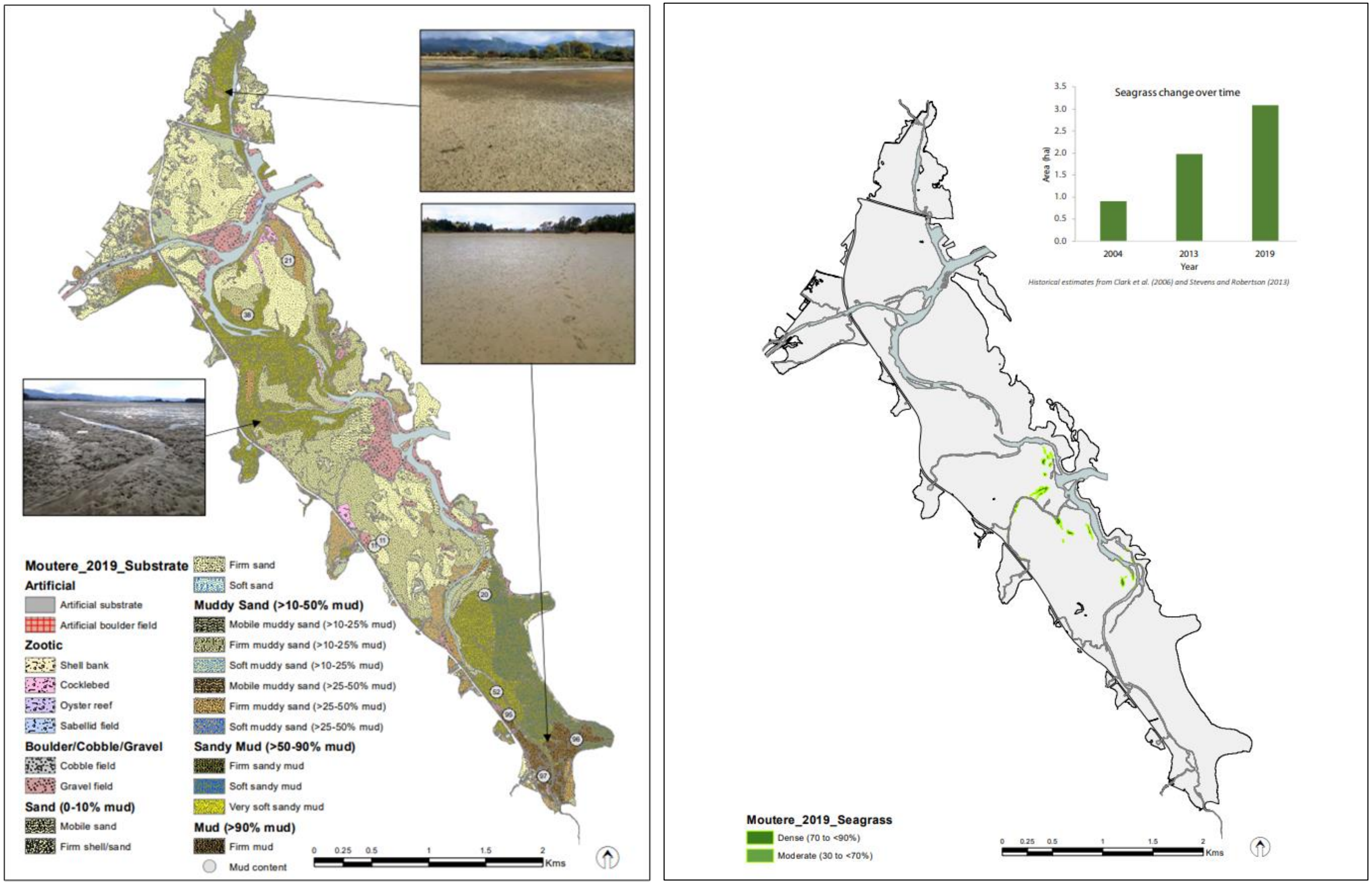

Figure 6: **Left) Moutere Inlet dominant intertidal substrate types; right) percent cover of seagrass.** Inset bar graph shows the area of >50 % seagrass cover in 2004, 2013 and 2019. (Source: figures 4 and 8 of Stevens et al. 2020b).

1.3 Estuarine fish knowledge in the region

There has been no previous sampling of fish assemblages in Moutere and Waimea inlets.

Davidson & Moffat (1990) assembled a list of 31 fish species that had been seen/caught in Waimea Inlet, based on liaison with local recreational fishers (Table 1). This list includes both species stated to be common and abundant such as yellow-eyed mullet, and other species that were probably only occasional transient visitors such as blue sharks (an oceanic water species). No estimates of abundance were recorded. It was noted that kahawai migrated into the inlet in spring and summer to feed on mullet, anchovy, and sprats; while grey mullet were commonly recreationally netted in the Traverse (Rabbit Island) and in the main channel adjacent to Bells Island. It was concluded that "*Waimea Estuary serves as a nursery for young flatfish, yellow-eyed mullet, grey mullet, stargazer, and rig*".

Table 1: Waimea Inlet list of fish species, as assembled by Davidson & Moffat (1990). Comments are by the present report authors. (Source: table 10 of Davidson & Moffat 1990).

Common name	Scientific name	Sampled in present study?	Comment
Blue shark	*Prionace glauca*		Likely occasional transients
Bronze whaler shark	*Carcharhinus brachyurus*		
Hammerhead shark	*Sphyrna zygaena*		Likely occasional transients
Spiny dogfish	*Squalus* sp.		Probably *Squalus acanthius*
Rig	*Mustelus lenticulatus*	Y	
Eagle ray	*Myliobatis tenuicaudatus*	Y	
Pilchard	*Sardinops neopilchardus*	Y	
Anchovy	*Engraulis australis*	Y	
Red cod	*Pseudophycis bacchus*		
Garfish	*Reporhamphus ihi*	Y	
Seahorse	*Hippocampus abdominalis*		
Gurnard	*Chelidonichthys kumu*	Y	Red gurnard
Rockfish	*Acanthoclinus fuscus*		Associated with/under rocks
Trevally	*Caranx lutescens*	Y	Now *Pseudocaranx dentex*
Kahawai	*Arripis trutta*	Y	
Kingfish	*Seriola grandis*		Now *Seriola lalandi*
Snapper	*Chrysophrys auratus*	Y	
Tarakihi	*Nemadactylus macropterus*		
Yellow-eyed mullet	*Aldrichetta forsteri*	Y	
Grey mullet	*Mugil cephalus*		One caught in targeted gillnet 2017
Barracouta	*Thyrsites atun*	Y	
Spotty	*Pseudolabrus celidotus*	Y	Now *Notolabrus celidotus*

Common name	Scientific name	Sampled in present study?	Comment
Stargazer	*Leptoscopus macropygus*		Estuarine stargazer
Cockabully (triplefins)	Tripterygion sp.	Y	
Jack mackerel	*Trachurus novaezealandiae*	Y	
Blue mackerel	*Scomber australasicus*		
Yellow-belly flounder	*Rhombosolea leporina*	Y	
Sand flounder	*Rhombosolea plebeia*	Y	
Common sole	*Peltorhamphus novaezelandiae*	Y	
Witch	*Arnoglossus scapha*		
Pufferfish	*Contusus richei*		

1.3.1 Past beach seine sampling (regional)

Broad surveys

As part of a nation-wide survey of juvenile and small fish in 68 estuaries around New Zealand, six upper South Island region estuaries were sampled using a beach seine in 2006 (Whanganui Inlet, Ruataniwha Inlet, Nelson Haven, Havelock (Upper Pelorus Sound), upper Queen Charlotte Sound, and Port Underwood, Francis et al. 2011). Fish species diversity was relatively modest, ranging from eight species in Havelock, to 15 species in Whanganui Inlet. Modelling of the national scale dataset found that an asymptote in species richness was reached with sampling intensity of sixteen beach seine tows spread across the estuary extent.

As a general pattern, species richness in estuaries increased along the gradient from harbour entrances to the head as water clarity declined and substratum sediments became muddier. However, more economically valuable species such as juvenile snapper and trevally quickly disappeared from the species assemblages along this gradient. The cause of this general increase in fish species richness was unknown but thought to relate to greater invertebrate food availability in the muddier upper reaches of the harbours and/or reduced predation on juvenile and small fishes by visual predators as water turbidity increased. Such spatial gradients have undoubtedly steepened in New Zealand estuaries following deforestation, and agricultural and urban development; historically, many estuaries would have been clearer with sandy rather than muddy substrata, particularly in their upper reaches. The models of Francis et al. (2011) suggested that those previous, more natural, conditions may have supported a reduced suite of species – but probably favoured economically valued fisheries species.

The triplefin *Grahamina nigripenne* and the galaxiid *Galaxias maculatus* (the dominant species in whitebait catches) showed steady and rapid declines in their occurrence with increasing catchment development. In contrast, yellow-eyed mullet (*Aldrichetta forsteri*), speckled sole (*Peltorhamphus latus*), spotted stargazer (*Genyagnus monopterygius*) and sprat (*Sprattus muelleri*) showed positive correlations with catchment development (Francis et al. 2011).

In a separate project assessing seagrass meadows across New Zealand, the seagrass meadows and adjacent bare sediments of the Whanganui Inlet and Farewell Spit were sampled by beach seines in

2006 (Morrison et al. 2014a). Whanganui Inlet catches (15 species from 8 beach seine tows) were dominated by yellow-eyed mullet (116 fish per 100 m^2), smelt (14.94/100 m^2), garfish/piper (10.39/100 m^2), and juvenile sand flounder (5.3 fish/100 m^2), with low densities (<0.7 fish/100 m^2) for estuarine triplefins, spotties, speckled sole, red gurnard, estuarine/slender/sand/spotted stargazers (four different species), and leatherjackets. Mid-Farewell Spit sampling (16 beach seine tows) returned a much sparser fish assemblage, with 8 species caught, dominated by yellow-eyed mullet (23 fish/100 m^2) and garfish/piper (23 fish/100 m^2), with low densities (<0.6 fish/100 m^2) for specked sole, sand flounder, slender sprat, mottled triplefin, and smooth pipefish. Spotties were absent.

Subtidal seagrass habitat

New Zealand's seagrass species, *Zostera muelleri*, is largely an intertidal species, but can extend down into the subtidal to 3 metres depth or more when water clarity conditions are good (maximum recorded depth is around eight to nine metres in very clear waters). Subtidal beds can occur as both discrete meadows unconnected to the intertidal, and as fringes extending down from areas of intertidal seagrass. Blade lengths elongate as a response to the lower light levels available when permanently submerged, and subtidal beds provide valuable habitat for juvenile and small fish, with blade density being a strong driver of fish densities (Morrison et al 2014a–c). Unfortunately, *Z. muelleri* is a light-sensitive plant, and as water clarity decreases (and/or plants experience direct sedimentation on their surfaces), subtidal seagrass areas are the first to disappear, with the plant's depth distribution contracting up to the intertidal. Many areas around New Zealand have suffered large-scale seagrass meadow loss, especially of the subtidal components, with the true loss probably strongly under-estimated.

Sampling of seagrass meadows across New Zealand, from Parengarenga Harbour in the far north to Cooks Inlet on Stewart Island, has found strong positive associations of several juvenile fish species with subtidal seagrass (Francis et al. 2005, 2011, Morrison et al 2014a, 2019). In northern New Zealand, 0+ snapper, trevally, spotties, parore, triplefins, pipefish and other species can reach very high densities in subtidal seagrass meadows. Further south, in the lower North Island and the South Island, economically valuable/fished fish species (juvenile snapper, trevally, and parore) disappear from subtidal seagrass fish assemblages, while high densities of spotties, triplefins, and pipefish continue to be present. However, the situation for upper South Island estuaries is unclear, as subtidal seagrass habitat is functionally extinct (and completely missing) from the regions estuaries. Only one small subtidal seagrass patch has been encountered across multiple sampling trips in the region, despite targeted searches. That subtidal seagrass patch was located on a small subtidal sandbar at the entrance to Mahakipawa Arm, one bay north of Havelock Estuary, in 2006. A very short beach seine tow on that patch returned high densities of spotties and triplefins. No juvenile 0+ snapper were caught, but the timing of sampling was in the early 2000s (2006) when the SNA7 snapper stock had completely collapsed, and the MPI trawl surveys of Golden and Tasman Bays were devoid of juvenile snapper catches (see later sections).

The recent and ongoing recovery of the SNA7 stock suggests that 0+ juvenile snapper are likely to be much more abundant now than 15+ years ago, and that any estuarine subtidal seagrass in the upper South Island may provide high fisheries support values. Encouragingly, healthy subtidal beds have recently been discovered in several northern bays just inside Tory Channel, eastern Queen Charlotte Sound (Davidson et al. 2020), though it is unknown whether these have always existed or if they represent seagrass recovery. Subtidal seagrass was probably common historically in upper South Island estuaries prior to large-scale land clearances, and likely to have disappeared in the earlier days of European settlement, prior to the advent of aerial photography from the 1940s onwards. This inference is based on subtidal seagrass occurring in the present day to the north (e.g., Pautahanui Inlet, Wellington), south (e.g., Waikawa and Bluff estuaries, lower South Island) and east (Tory Channel, Marlborough Sounds) of the Tasman region (Morrison et al. 2014, Davidson et al. 2020) where environmental conditions still allow it. Extensive seagrass loss has also likely occurred across many southern estuaries, e.g., from Avon-Heathcote Estuary, Christchurch (Inglis 2003).

Recovery/restoration of subtidal seagrass for both fisheries and biodiversity values would be a very valuable objective (Morrison 2021). Subtidal seagrass has the potential to recover when the stressors that caused its loss are removed, albeit with temporal lags.

A good example is Whangarei Harbour, where extensive intertidal and subtidal seagrass meadows disappeared in the 1960s (Morrison 2003). From the 1920s through the end of the 1970s, nearly 3 x 10^6 m^3 of sediment fines (‘rejects’) were pumped into the harbour by the Wilsons (NZ) Portland Cement Works Company, of which 90 % were sediment under 10 microns in diameter (Millar 1980). Between 1958 and 1980, the supply of artificial fine sediments from Portland was estimated to be around 20 times that of natural inputs (Millar 1980). A further 2 x 10^6 m^3 of sediments from the Northland Harbour Board’s capital dredging programme (to improve shipping access) was dumped into different areas of the harbour during the 1960s (Dickie 1984). This included 754,000 m^3 of sediment from the main harbour channel dredging operations being pumped onto Snake bank and the Takahiwai shoreline about the 1 fathom line (~ 2m depth). Unsurprisingly, virtually all seagrass disappeared from Whangarei Harbour, along with all of the juvenile fish production and values associated with it, as well as seagrass associated scallop beds. By 1982, Portland Cement Works had moved to a ‘dry’ manufacturing process that did not require dumping fines into the harbour. Similarly, the port dredging reduced to maintenance levels. Sediment inputs fell away accordingly.

Some forty years after disappearing in the 1960s, seagrass ‘returned’ in the early 2000s, presumably due to environmental conditions having improved sufficiently over time to allow it to recolonise the harbour. With it came the return of the associated juvenile fish habitat values, especially for 0+ snapper. Subtidal seagrass is now widely present in areas of the lower harbour, with the most extensive area/s (which extend out from extensive intertidal seagrass) seen along the Takahiwai shoreline, spanning several kilometres. As of 2023, seagrass (intertidal and subtidal combined) cover has not yet recovered to its historical pre-1960s extent of at least 12 km^2, at present covering perhaps a third of that area. It is quite likely that additional large-scale undocumented seagrass meadow loss may have occurred well before the initial 1966 aerial mapping of Whangarei Harbour seagrass, in association with the clearance and development of the harbours land catchments by European colonists.

Grey mullet (*Mugil cephalus*) nurseries

Grey mullet adults occur around the top of the South Island and lower North Island in marine, estuarine, and freshwater environments. At the top of the South Island, they are caught seasonally in the warmer summer months by some knowledgeable recreational fishers, at discrete locations including outer Farewell Spit, Waimea Inlet, the lower Pelorus River, and Wairau River (Blenheim). These locations collectively represent the southern-most limit of this globally distributed species.

Despite the presence of adult populations, previous estuarine fish sampling found no juvenile grey mullet in either the South Island or lower North Island (Francis et al. 2011, Morrison et al. 2014c). Juvenile grey mullet are obligate on estuaries as juveniles (Morrison et al 2014c). Based on this, it was suspected that grey mullet populations in those regions were being supported by the movement of fish southwards originating from northern North Island estuarine nurseries, several hundred kilometres to the north. It was also suspected that as global climate change progressed, entirely new grey mullet nurseries might establish in these more southern regions as estuarine environments warmed, with concurrent fundamental increases in adult grey mullet abundance, with the potential to support new associated fisheries.

To test the assumption that no grey mullet nurseries were present in these regions, and to set a baseline against which future changes in juvenile grey mullet occurrence and abundances could be assessed, detailed searches for juvenile grey mullet were made in 2015 at eight South Island (Whanganui Inlet, Aorere River entrance, Ruataniwha Estuary, Parapara Inlet, Otere Inlet, Waimea Inlet, Takaka River east, Havelock River Estuary) and three lower North Island estuaries (Pāuatahanui Inlet, Hutt River estuarine area, Lake Ferry/Onoke). Based on earlier northern estuary survey work in 2010 (69 northern estuaries systematically sampled to identify juvenile grey mullet nurseries, see Morrison et al. 2016), the upper estuarine habitat reaches of these eight estuaries were systematically and comprehensively searched by field teams using beach seining, along with watching for surface sign of juvenile grey mullet (small dimples and v-patterns on the water surface from feeding and movements). No juvenile grey mullet were encountered at all, suggesting that there were no grey mullet nursery habitats/areas present in the lower North Island or South Island. As global climate change continues, this situation may change, and new surveys decades hence are proposed to quantify such potential climate-based distributional shifts.

2 Methods: 2021 fish survey

Fish sampling of Moutere and Waimea inlets was undertaken in 2021, using three different sampling methodologies: beach seine, beam trawl and gillnetting.

2.1 Sampling gear

2.1.1 Beach seine

Fine-mesh beach seines were used to quantify small benthic/semi-pelagic fish of intertidal flats and subtidal channel edges. These were deployed during low tide (2.5 hours either side of the low) to sample juvenile and small fish (as per Morrison et al. 2002). This method targets small fish that must move off the intertidal flats during periods of low water, as well as fish living on the edges of subtidal channels. The net tow speed is too slow to efficiently capture larger fish, except for flounders and other flatfish that may be herded and do not flee around or over the net. The beach seine net was 11 metres wide, and composed of 9 mm coarse braid mesh, with a 2.3 m height, and a 4-m long codend. Two people deployed and retrieved the net, which fished a width of around 9 m when being towed. Each tow commenced in waist deep water (maximum circa 1.2 m), where the net was set out perpendicular to the shore, and then towed directly to the low-tide shoreline at a slow walking speed. For deeper water stations (>1.2 m), one person held the first tow warp on the shore and a small boat reversed out from the shore while paying out the second tow warp. The net was set parallel to the shore, and then the boat driven into shore paying out the second tow warp. The net was then pulled to the shore by hand-hauling both tow warps (Figure 7).

Figure 7: The beach seine being retrieved at a Moutere Inlet site.

A GPS was used to record the start and end position of each tow, and the area-swept calculated as the distance travelled (in metres), multiplied by an assumed net width of nine metres.

Following TDC/NCC's direction that all fish be released alive if possible; the fish catch was sorted from general debris in the net and held in water-filled bins. Measuring large numbers of small live fish in the field accurately (down to the nearest mm), especially of species such as yellow-eyed mullet which do not survive handling well, is difficult both logistically and for fish survival. To address this, each individual fish was identified to species level, assigned by eye to a 5 cm size bin (using a ruler for reference), and released. Triplefins, a species group that can be hard to separate to species without specialist knowledge, were assigned to a generic 'triplefin' code. Fish catches were standardised to fish density per 100 m^2 swept area.

The field team kept general notes of each site, including observations of seafloor sediment types including cobble, gravel, sand, sandy-mud, muddy-sand, and mud.

2.1.2 Beam trawl

To quantify small benthic fish within deeper subtidal channel areas away from the shore, a small beam trawl was used to sample small benthic associated fishes, based on the design of Hamer et al. (1998) (Figure 8). This net consisted of a 3 m steel beam, from which was suspended a trawl net with a 6 m deep cod-end, composed of 9 mm mesh (the same material as the beach seine). The restricted nature of the subtidal channels of the two estuaries limited survey vessel navigation and station placement. Sampling stations were placed so that each 200 m long tow ran parallel with the channel axes, while allowing sufficient room before and after the tow to allow for safe gear setting and retrieval. Tow sampling distance was measured from when the tow warp came up hard on the trawl (when the net started fishing), to when hauling commenced, using GPS. A 5–1 warp-to-depth ratio was used, as all water depths were less than 10 m. Tow speed was kept between 1.5 to 2 knots; to prevent the net from 'flying' (e.g., Morrison & Carbines 2006). As catch volumes were much smaller than those of the beach seines, fish were kept alive in water-filled bins, and sorted, identified to species level, and measured down to the nearest mm fork or total length. Fish catches were subsequently standardised to fish density per 100 m^2 swept area, using a net width sweep assumption of 2.3 m.

Catch of non-fish species (invertebrates, macroalgae) and debris (e.g., sticks, stones) was quantified as visually estimated volumes, using bins marked with graduated volume lines as guides. These are not reported on further, but Appendix A shows maps of macro-algae catch (litres per 200 metres tow) contrasted against the biogenic habitats mapped by Stevens et al. (2020). Go-Pro cameras were attached to the net to gather information on seafloor habitat types, but turbid water conditions prevented useful footage being collected.

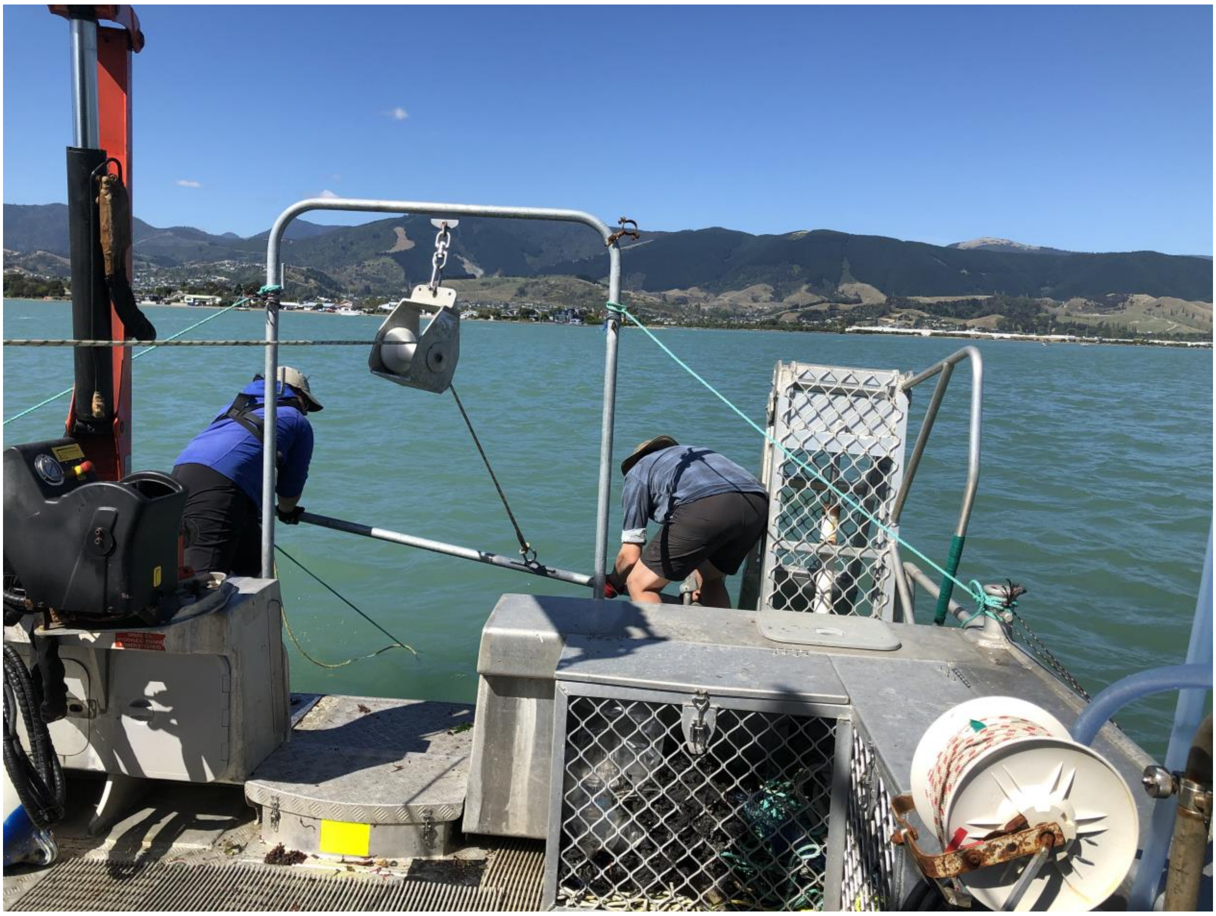

Figure 8: The beam trawl being deployed. The three-metre bar is being handled by two field staff, with the net itself being submerged behind the survey vessel.

2.1.3 Gillnets

Larger fish such as adult kahawai, snapper, and elasmobranchs (sharks, rays) are too fast and wary to be captured by fine-mesh beach seines and beam trawls, which can only be towed at slow speeds. To quantify these larger-bodied fish in subtidal channels, multi-panel gillnets were set overnight, when they are less able to be detected by fish. Gillnet mesh size is a strong determinant of what fish species are caught, as well as selecting for size ranges within species (e.g., smaller meshes allow larger fish to 'bounce' off the nets; while larger meshes allow smaller fish to swim straight through the nets). To reduce these effects and sample as wide a range of larger fish as practical, custom-built nets were used, each consisting of four joined mesh panels of 12 m (mesh size 1.5, 2.5, 3.5, and 4.5 inches), with a drop (net height) of ~2–2.5 m (Figure 9). Gillnet catches are presented as summed catch across the four panels.

These nets were set on high tides just before darkness, left to fish overnight, and retrieved on the next morning's high tide during daylight hours. Their catch was representative of fish passing through the sampling site over a full tidal cycle, as they fished a 12-to-14-hour time span. On net retrieval, any fish alive and in a condition likely to survive were released back into the sea, while dead fish were kept for later disposal as per the conditions of NIWA's MPI Special Permit. All fish were identified to species and measured down to the nearest mm fork or total length.

Figure 9: **Setting of a multi-panel net in Waimea Inlet.**

2.2 Sampling design

Our goal was to comprehensively quantify the fish fauna of the two estuaries by deploying the three fish sampling methods across the available estuarine areas. Available recent low tide aerial imagery on Google Earth was used to assign sampling effort. Sampling sites were assigned haphazardly, using depth and distance from estuary mouth as proxies for the environmental gradients present. The spatial distribution of all three sampling methods (beach seine, beam trawl, gillnet) are shown in Figure 10, Figure 11) Low tide aerial imagery is used as a backdrop, to show the available subtidal sampling area.

2.2.1 Beach seine – 32 stations

Thirty-two beach seine stations were conducted between 11 March and 27 March 2021, with sixteen stations in each estuary, split equally across the western and eastern areas (Figure 10, Figure 11). Each eight-station grouping required one day to sample. Sampling locations were placed broadly equidistant along the low-tide channel edges of the lower estuary areas, working up into the estuary until the point where low-tide channel water depths were estimated to be 20 cm or less. Post-sampling, each station was assigned to a depth band class: <0.5 m, 0.5–1.0 m, or >1 m water depth. Observations of the sediment types of present were also made, and later classed into one of the following six categories based on the dominant substrate present at each station: Mud, muddy sand, sandy mud, sand, gravel, and cobble.

2.2.2 Beam trawl – 33 stations

Thirty-one successful beam trawls were deployed across the two estuaries between 15 and 18 March 2021 (Figure 10, Figure 11). Beam trawl stations were allocated to the subtidal channel areas, with the constraint that sufficient straight distance space was required for each station to allow for both the 200-metre-long tow, and the vessel setting and retrieval processes. Beam trawls were conducted across three sampling days, with a target of eleven stations per day, with each sampling day centred on a high tide to maximise vessel access and ability to manoeuvre. Two days were spent sampling the larger Waimea Estuary (one day west, one day east), and one day at the smaller Moutere Estuary (encompassing both west and east areas). Post-sampling, each station was assigned to a depth band class: <2.5 m, 2.5–5 m, 5–7.5 m, 7.5–10 m water depth.

2.2.3 Multi-panel gillnets – 10 stations

Ten gillnet deployments were made within the Waimea estuary between 8 to 10 March 2021 (Figure 11). Gillnet sites were deployed around the subtidal channel areas, with the constraint of avoiding navigation ways likely to be used by vessels (harbour entrances). Three nights of gillnet sampling were originally planned; one for Moutere Inlet, and two for Waimea Inlet, with a target of five nets deployed per night. However, the relatively recent closure of the survey area to static nets to protect Hectors dolphins was not realised in the MPI Special Permit and its associated use conditions. Following the Waimea Inlet gillnet sampling, locals communicated this gillnet ban, and the Moutere Inlet gillnet sampling was dropped. Some of the gillnet sets were retrieved with heavy macroalgae entanglement, and some parts of the nets were rolled into a tight bundle; a result of high currents and drifting macroalgae. We assume that these nets fished for some time before being partially compromised; there was no way to tell when their fishing power started to drop. No depth divisions were assigned.

Figure 10: Sampling sites at Moutere Inlet: beach seine (B) and beam trawl (M). No gillnet deployments were made at Moutere Inlet. For beach seine and beam trawl, the approximate tow path is shown as a line between the start and end positions.

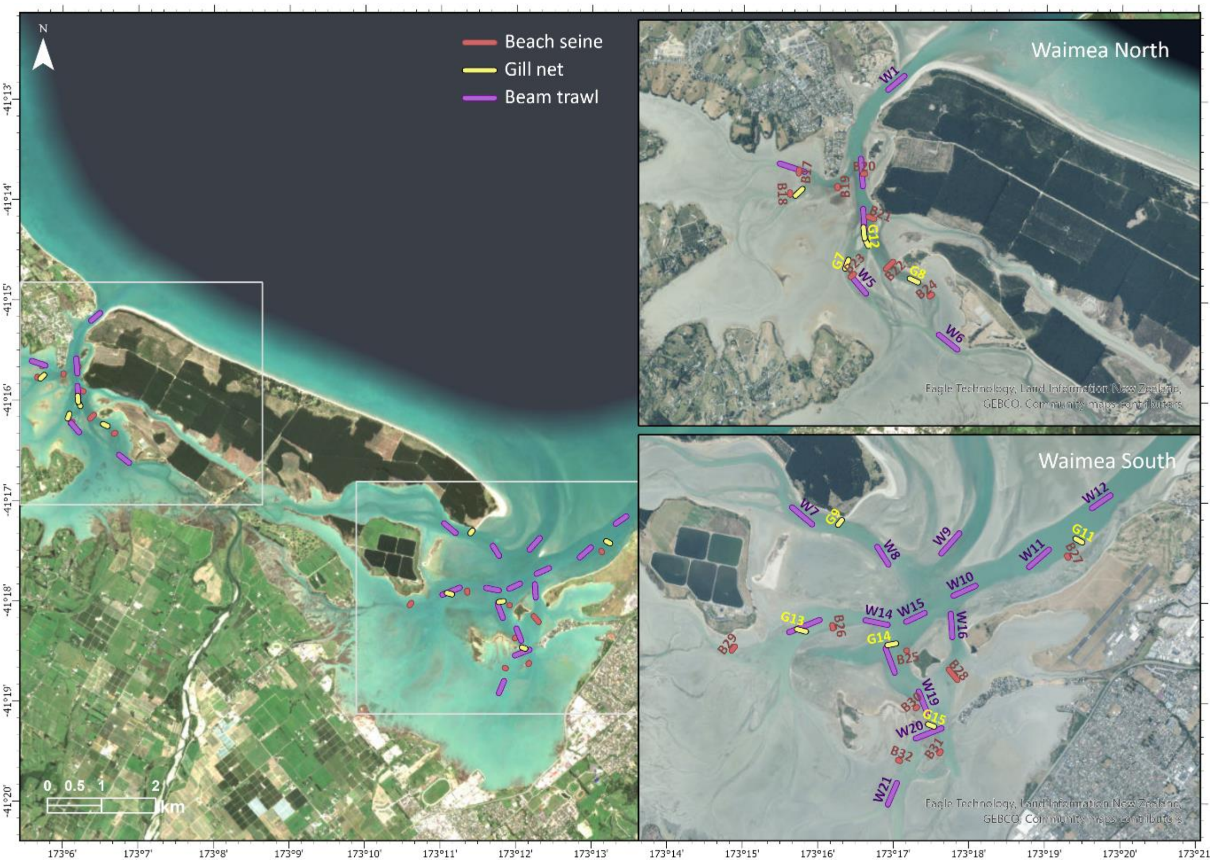

Figure 11: Sampling sites within Waimea Inlet: beach seine (B), beam trawl (W), and multi-panel gillnets (G). For beach seine and beam trawl, the approximate tow path is shown as a line between the start and end positions. Gill net sets were static, shown are the net start and end positions at the time of setting.

2.2.4 Data analysis

Fish catches (by species) are presented as fish counts, size frequencies, and individuals per 100 m^2.

The software packages PRIMER (Clarke and Gorley 2006) and PERMANOVA+ for PRIMER (Anderson et al 2008) were used to assess fish assemblage patterns. Fish densities were fourth root transformed to down-weight the contribution of abundant species (notably yellow-eyed mullet) and a similarity matrix created. Non-Metric Multi-Dimensional Scaling (nMDS), based on a matrix of Bray-Curtis similarities, was used to visually assess community similarities. Permutational Analysis of Variance (PERMANOVA) routines were used to formally test for significant differences, for each of the three sampling methods. Full crossed factor models were run for each of the three gear types. Where a significant difference was found in one or more of the main terms, and there were no significant differences in the interaction terms, the Similarity Percentage (SIMPER) routine was used to determine which species were driving the differences.

Beach seine

Model 1: tested for differences between three factors: Estuary (Fixed, 2 levels), Substrate (Fixed, 6 levels), and depth (Fixed, 3 levels). Not all the interaction term cells were able to be populated with data (i.e., not all of the substrate classes were present at all ‘depths’, and in both estuaries). Depth for this gear type was taken as the depth at the start of the tow, with end depth always being zero, as the net was dragged onto the intertidal. This means that depth was not a discrete separate band between each of the depth classes as tows starting in deeper water still traversed and sampled the shallow depth bands as part of the tow.

Beam trawl

Model 1: tested for differences between two factors: Estuary (Fixed, 2 levels), and Depth (Fixed, 4 levels).

Gill nets

Model 1: tested for differences between two factors: Estuary (Fixed, 2 levels), and Depth (Fixed, 4 levels).

3 Results

Across the three sampling methods, 5,811 individual fish were caught from twenty-one fish species (Table 2). Yellow-eyed mullet dominated the fish assemblage, contributing 83.5 % of the fish catch (4,896 individuals), followed by spotties (394, 6.7 %), and triplefins (101, 1.7 %). A further eight species contributed 25 or more individuals (kahawai, snapper, garfish/piper, speckled sole, rig, yellow-bellied flounder, sand flounder, and eagle rays). The remaining nine species were represented by less than 10 individuals. Note that while 53 anchovies were caught in beam trawls, these were not included in Table 2, or in analyses, as juvenile anchovy are known to easily pass through the 9 mm beach seine and beam trawl mesh and so are likely to be strongly underrepresented.

Table 2: Species catch summary across the three sampling methods.; Beach seine (Beach), beam trawl (Beam) and multi-panel gillnet (Gillnet). Data are from both estuaries combined. Fifty-three anchovies caught in the beam trawl have not been included.

Common name	Scientific name	Beach	Beam	Gillnet	Total
Yellow-eyed mullet	*Aldrichetta forsteri*	4776		120	4,896
Spotty	*Notolabrus celidotus*	140	228	26	394
Triplefin	Several species present	24	77		101
Kahawai	*Arripis trutta*			79	79
Snapper	*Pagrus auratus*	1	6	58	65
Garfish/piper	*Hyporhamphus ihi*	59			59
Speckled sole	*Peltorhamphus latus*	56			56
Rig	*Mustelus lenticulatus*			45	45
Yellow-bellied flounder	*Rhombosolea leporina*	27	2	5	34
Sand flounder	*Rhombosolea plebeia*	22	8	2	32
Eagle ray	*Myliobatus tenuicaudatus*	1		24	25
Pilchard	*Sardinia neopilchardus*	12			
Trevally	*Pseudocaranx dentex*		1	8	9
Clingfish			4		4
School shark	*Galeorhinus galeus*			3	3
Red mullet	*Upeneichthys lineatus*		2		2
Green backed flounder	*Rhombosolea taperina*	2			2
Red gurnard	*Chelidonichthys kumu*	2			2
Jack mackerel	*Trachurus novaezelandiae*			1	1
Jack mackerel	*Trachurus* sp.		1		1
Leatherjacket	*Parika scaber*	1			1
Barracouta	*Thyrsites atun*	1			
	Totals	5,111	329	371	5,811

3.1 Individual species

3.1.1 Yellow-eyed mullet Aldrichetta forsteri

Yellow-eyed mullet dominated the fish assemblage sampled (Table 2) with a total of 4,896 individuals sampled across both estuaries. This semi-pelagic species occurs as schools, with fish within any given school tending to be similar-sized fish (fish of the same size school together). Most fish were caught with the low-tide beach seines, which sampled both fish forced to migrate off the tidal flats with the tide, and potentially resident fish on the edge of the sub-tidal channels. Yellow-eyed mullet were caught at all thirty-two beach seine stations and at eight of the 10 gillnet stations. None were caught with beam trawl, consistent with this method seldom capturing this species.

In Moutere Inlet, a juvenile cohort of small 0+ individuals (<5 cm) dominated the population, along with a second less abundant cohort of older, larger 1+ juveniles (10–15 cm) (Figure 12). Both 0+ and 1+ fish probably contributed to the intermediate 5–10 cm length bin. Older fish in the 15–20 cm size range were also present. Waimea Inlet returned the same overall size range of yellow-eyed mullet, but with the 1+ cohort mode dominant, rather than the 0+ cohort. The multi-panel gillnets (Waimea Inlet only) caught larger adults, ranging from 14 to 30 cm, with a mode at 17 cm (Figure 12).

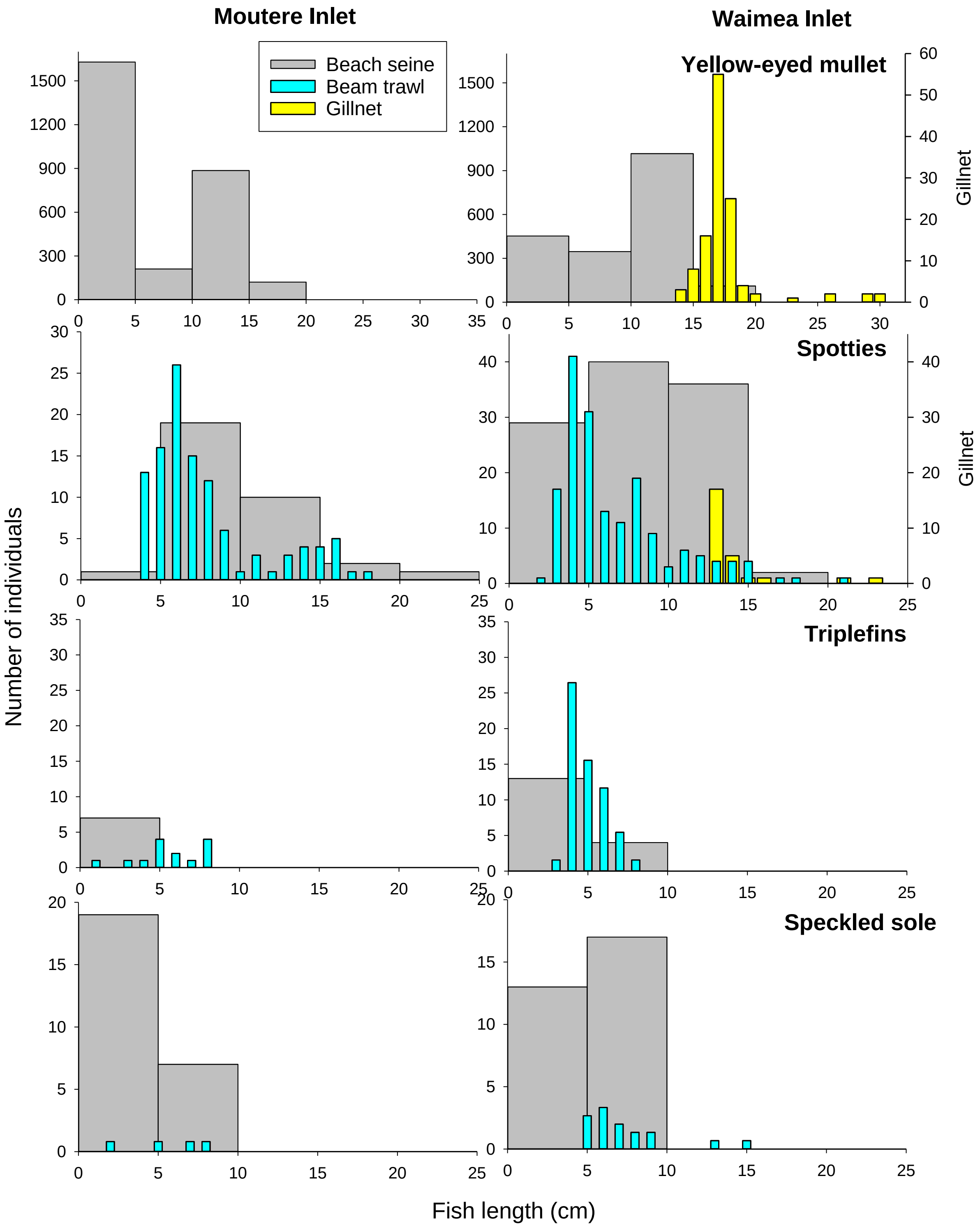

Figure 12: Length frequencies of yellow-eyed mullet, spotty, triplefins, and speckled sole, from Moutere and Waimea inlets. Fish caught by beach seine were assigned to 5 cm length bins, while fish caught by beam trawl and gillnet were measured down to the nearest millimetre. Note that the gillnet catches of yellow-eyed mullet and spotties from Waimea Estuary have a separate y-axis.

Yellow-eyed mullet densities across the four sub-areas of the two inlets ranged from 13 to 53 individuals per 100 m^2 for fish less than 11 cm, and from 10 to 39 individual per 100 m^2 for fish greater than 10 cm. Roughly twice the number of yellow-eyed mullet per 100 m^2 were caught at Waimea Inlet compared to Moutere Inlet, except for fish greater than 10 cm in Waimea Inlet north, which occurred at a similar density to those of Moutere Inlet (Figure 13).

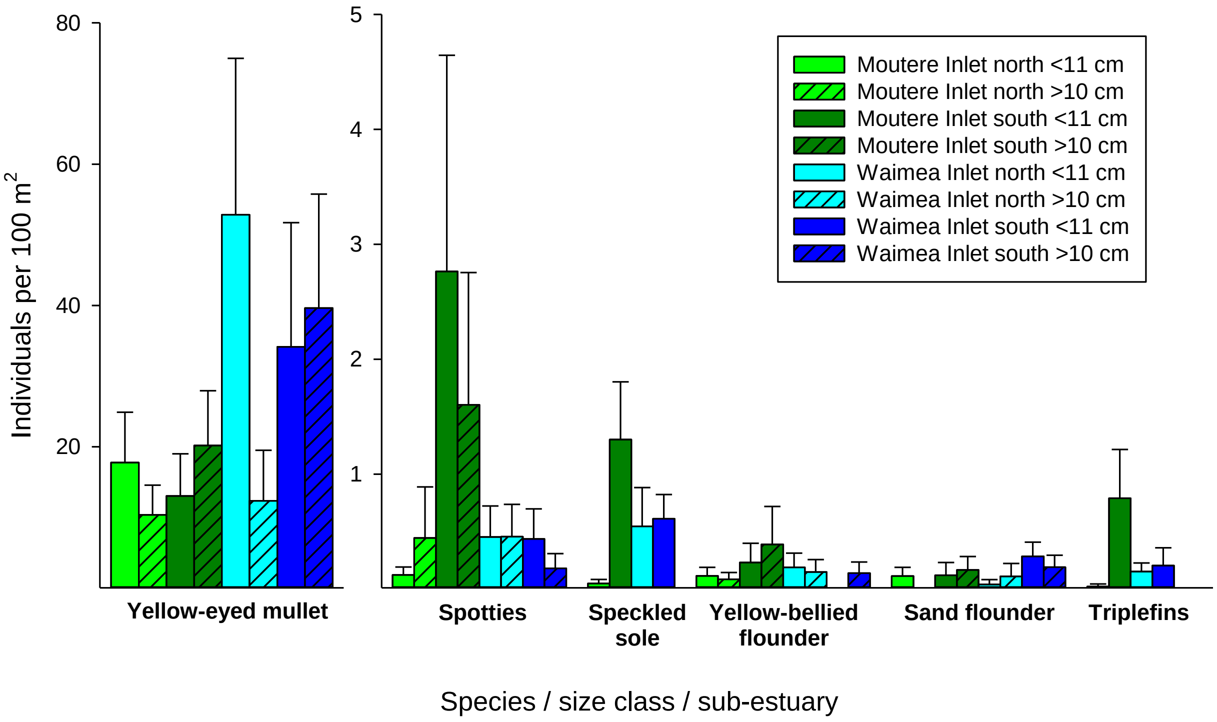

Figure 13: Beach seine catch species densities (+/- standard error), by size class and sub-estuary. Where fish were present as both larger than 10 cm, and smaller than 11 cm sized individuals, both size classes are presented.

In Moutere Inlet north, there were no obvious spatial patterns with distance from the estuary mouths (Figure 14) and catch rates. The largest catch of small fish (<11 cm) came from station B2 on the northern end of Jackett Island (189.3 fish/100 m^2), followed by stations B5 and B7 along the south side of the main channel (70–89.9 fish/100 m^2). Larger fish (>10 cm) were concentrated at stations B1 and B2 (47.1, 42.3 fish/100 m^2) on the northern side of the channel. In Moutere Inlet south, smaller fish were concentrated along the southern subtidal channel, adjacent to Kina Peninsula (maximum density station B14, 146.2 fish/100 m^2). Larger fish (>10 cm) were concentrated along the western side of the main channel, with the highest densities at stations B11 and B13 (126.3, 85.2 fish/100 m^2). Lower abundances of both size classes were present at the two northern channel stations (Figure 14).

In Waimea Inlet, smaller fish (<10 cm) were more abundant further up the estuary arms, and larger fish (>10 cm) more widely spread, for both the north and south areas (Figure 14). In Waimea Inlet north, small fish (<10 cm) were concentrated at upper south channel stations B23 and B24 (38–53 fish/100 m^2). Larger fish (>10 cm) were less abundant, with a maximum density at station B19 of 18 fish/100 m^2 (west of Rabbit Island). Most of the gillnet catch of bigger, yellow-eyed mullet (14–30 cm) also came from the upper south channel area, dominated by station G8 (63 fish caught) on the east side of the channel. In Waimea Inlet south, both size classes were more abundant (albeit patchily) on the eastern side of the estuary (Figure 14).

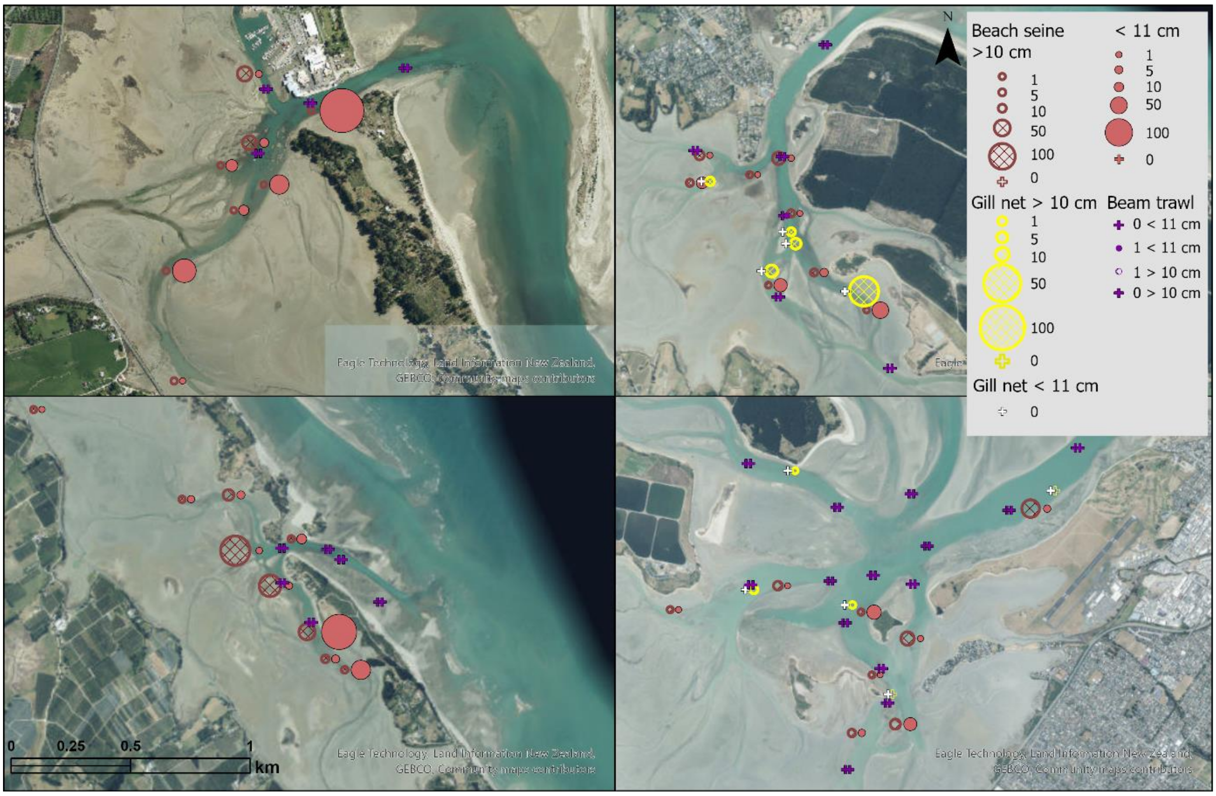

Figure 14: Catch rates of yellow-eyed mullet per 100 m^2 (beach seine and beam trawl) or per gillnet. Left) Moutere Inlet north and south; right) Waimea Inlet north and south. Both fish classes of <11 cm and >10 cm are shown, side-by-side, centred on the station sampled. Gillnet sampling was restricted to Waimea Inlet.

The largest catches of smaller fish (<10 cm) came from stations B25 (43 fish/100 m^2, east of Saxton Island) and B31 (36 fish/100 m^2, south-west of Monaco Peninsula). Highest density of larger fish (>10 cm) occurred at stations B27 and B28 (63 fish/100 m^2, north-west of Nelson Airport 40 fish/100 m^2, east of Saxton Island, respectively). Station B27 had the highest density of larger (>10 cm fish) and fell over patchy subtidal/intertidal seagrass meadow (the only seagrass encountered). Gillnet catches of yellow-eyed mullet at Waimea Inlet south were considerably lower than those of Waimea Inlet north (Figure 15).

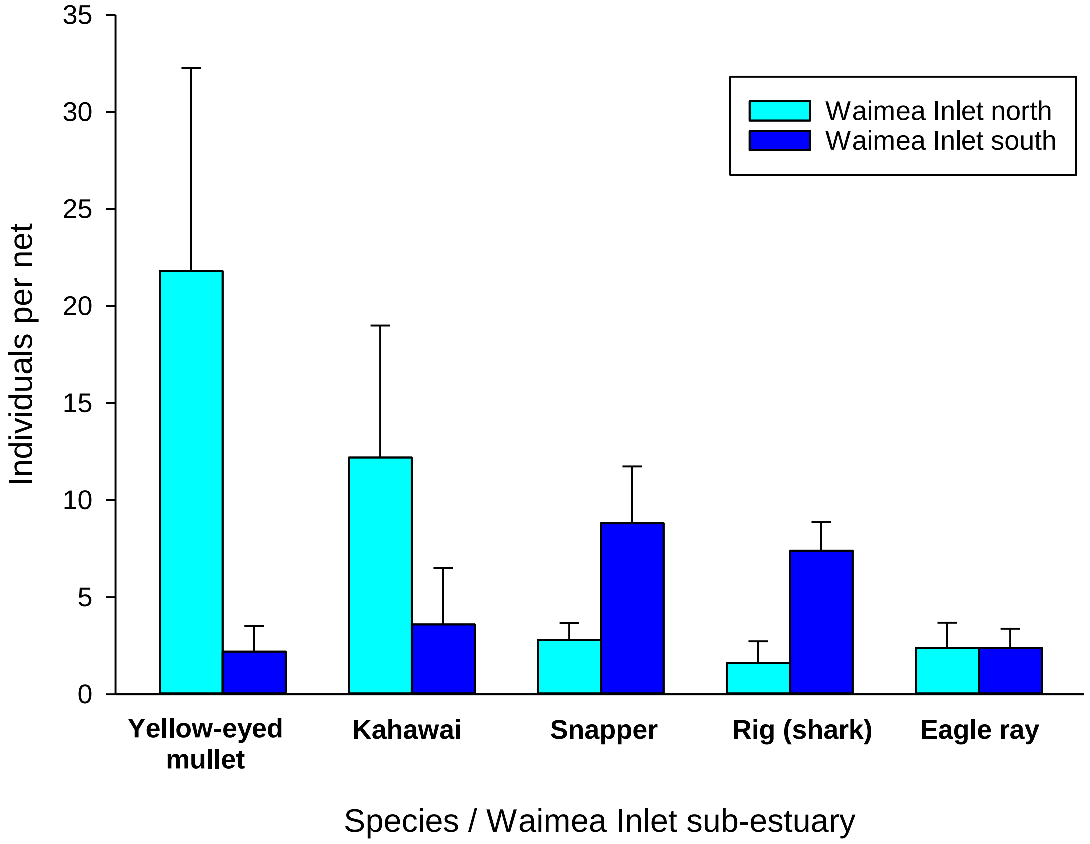

Figure 15: Gillnet catch species densities (individuals per net, +/- standard error) for Waimea Inlet north and south(Moutere Inlet not sampled).

3.1.2 Spotties *Notolabrus celidotus*

Spotties, a species of wrasse, were the 2nd most abundant species, with a total of 394 individuals sampled (Table 2) across both inlets. The beach seine and beam trawl caught over 100 and 200 fish respectively, while the gillnets caught a lesser number of large individuals. Seventeen of the thirty-two beach seines, eighteen of the thirty-one beam trawls, and seven of the ten gillnet stations returned spotties.

In the Moutere Inlet beam trawl seine catches, a 0+ juvenile cohort (4 to 9 cm, mode 6 cm) dominated the population, along with a less abundant cohort of 11–16 cm fish (Figure 12). Beach seine catches showed a similar fish size distribution, with the 5–10 and 10–15 cm size bins being dominant. Beam trawl catches from Waimea Inlet returned the same overall spotty size range, but the 0+ juvenile fish population was composed of on-average slightly smaller individuals (2 to 9 cm, mode 4 cm), with the separation from larger/older fish less apparent (Figure 12). In contrast to Moutere Inlet, the Waimea Inlet beach seine samples returned many individuals in the 1–5 cm size bin, matching the fish size distribution caught in the beam trawl. Gillnet sampling (Waimea Inlet only) caught larger-sized spotties from 13 to 23 cm, with a mode of 13 cm (Figure 12).

Average spotty densities from both beam trawl and beach seine, across the four sub-areas, never exceeded more than 2 and 3 fish per 100 m^2, respectively (Figure 13, Figure 16). Beam trawl catches at Moutere Inlet had slightly higher average fish densities relative to Waimea Inlet (Figure 16). This difference was much stronger for the beach seine samples, with spotty densities 3 to 6 times higher at Moutere Inlet south than the other three sub-areas (Moutere Inlet north, Waimea Inlet north, Waimea Inlet south) (Figure 16).

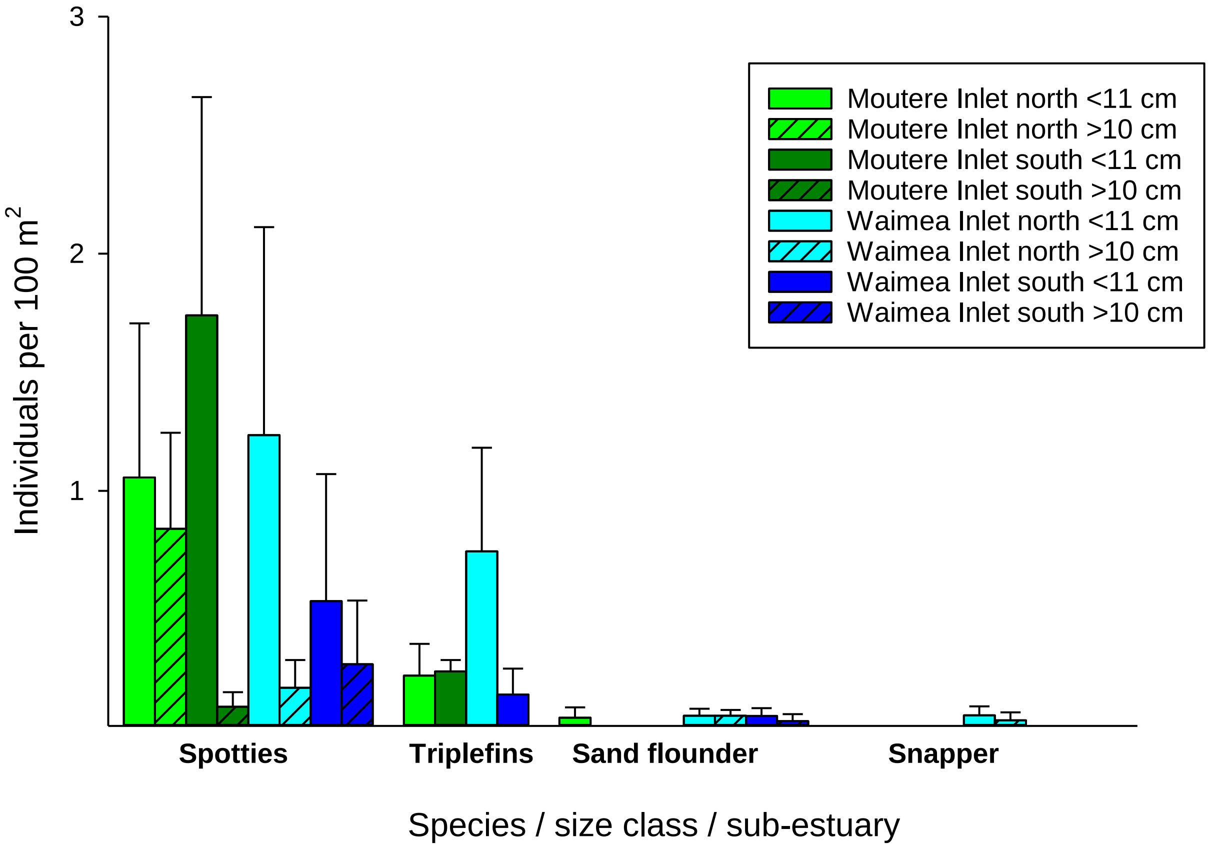

Figure 16: Beam trawl catch species densities (+/- standard error), for spotties, triplefins, sand flounder and snapper. by size class and sub-estuary.

In Moutere Inlet north, three of the eight beach seine stations (B1, B5, B7) returned <11 cm spotty abundances of (0.33–2 fish/100 m^2), while two of these same stations (B1, B7) along with station B2 also held >10 cm spotties (0.4–2.2 fish/100 m^2) (Figure 17). In Moutere Inlet south, spotties <11 cm occurred at stations B9, B13 and B15 (0.3–2 fish/100 m^2) which spanned both channel arms, while spotties >10 cm were restricted to the northern channel arm (stations B9–B10, 0.5–1 fish/100 m^2).

Moutere Inlet beam trawl spotty catches were largely confined to the entrance channel areas (Figure 17). In Moutere Inlet north, spotties <11 cm were present at three of the four beam trawl stations (0.2–2.8 fish/100 m^2), spotties >10 cm were present at all four stations (0.2–2 fish/100 m^2). In Moutere Inlet south, four of the six beam trawl stations held spotties <11 cm (0.4–4.8 fish/100 m^2), while two stations of the same stations (M7, M9) also held spotties >10 cm (0.1–1.4 fish/100 m^2).

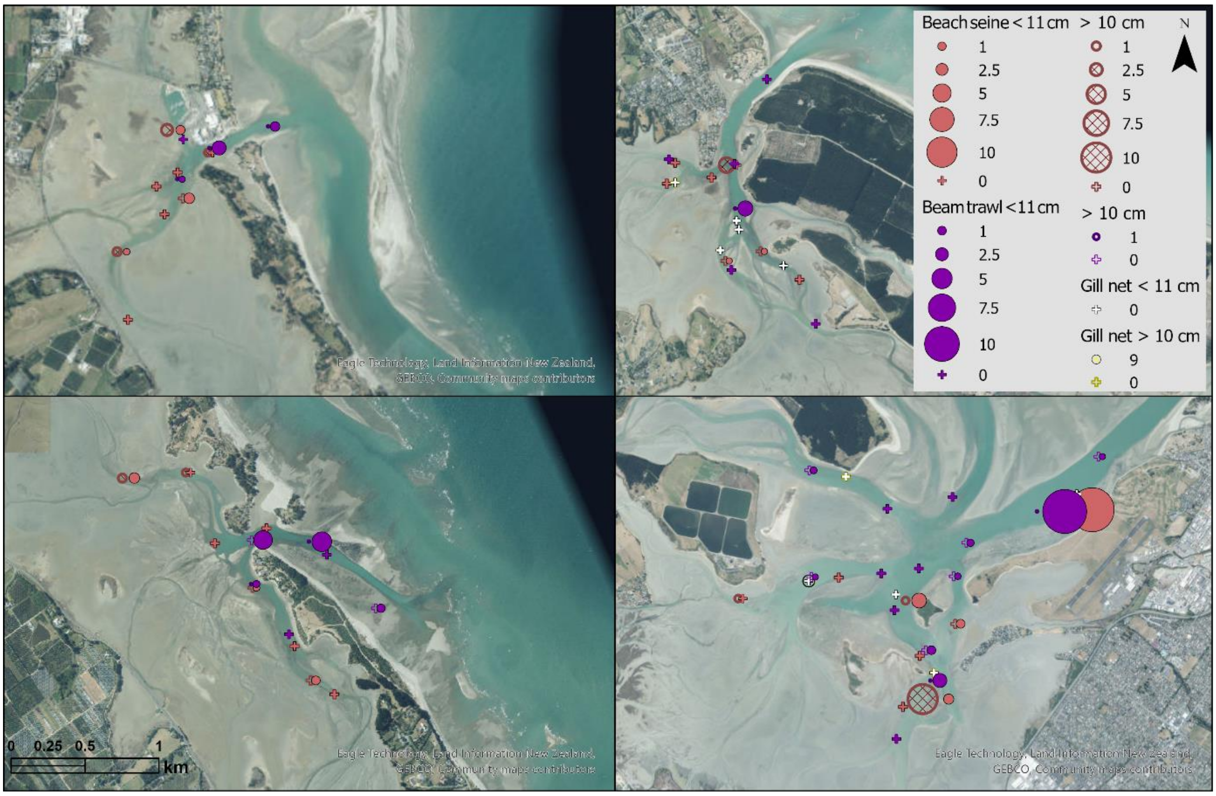

Figure 17: Catch rates of spotties per 100 m^2 (beach seine and beam trawl) or per gillnet. Left) Moutere Inlet north and south; right) Waimea Inlet north and south. Both fish classes of <11 cm and >10 cm are shown, side-by-side, centred on the station sampled. Gillnet sampling was restricted to Waimea Inlet.

In Waimea Inlet, spotties were caught at nine of the sixteen beach seine stations. In Waimea Inlet north, stations B21 to B23 held <11 cm spotties (0.2–0.5 fish/100 m^2), and one station (B20) held >10 cm spotties (3.6 fish/100 m^2). In Waimea Inlet south, four beach seine stations returned <11 cm spotties (B25, B27, B28, B31; 1.2–15.6 fish/100 m^2). The highest density of 15.6 fish/100 m^2 was caught at site B27 and was associated with a sand and subtidal/intertidal seagrass meadow mosaic (the only subtidal seagrass fringe encountered). Juvenile spotties known to have a positive density response to subtidal seagrass in estuaries (Morrison et al 2014). Larger >10 cm spotties were present at three of the four stations where smaller fish were present, as well as station B29 (0.4–9.3 fish/100 m^2). The highest density of 9.3 fish/100 m^2 was caught at station B31, composed of mud and cockle shell seafloor, with small black mussels and stones nearby. Several other beach stations across both Moutere and Waimea inlets held similar habitat but had no/very low spotty densities.

In Waimea Inlet north, spotties were caught at only one (W4) of the six beam trawl stations, with both <11 cm (3.2 fish/100 m^2) and >10 cm (1.6 fish/100 m^2) size classes present. In Waimea Inlet south, seven of the fifteen beam trawl stations held <10 cm spotties, with six of those stations having densities from 0.1–2.8 fish/100 m^2. The highest density of fish (13.2 fish/100 m^2) was caught at station W11 and was located immediately adjacent to the beach seine station that returned the highest <10 cm spotty density (B27, 15.6 fish/100 m^2). This suggests a hotspot for <10 cm juvenile spotties in this sub-area, north-west of Nelson Airport. Larger spotties (>10 cm) were uncommon, and occurred at only two stations (W11, W20; 0.9–1.6 fish/100 m^2). Four of the five gillnet stations in Waimea Inlet north returned from 1 to 2 spotties each, while three of the five Waimea Inlet south stations returned between1 and 16 spotties (fish size range 13–23 cm).

3.1.3 Triplefins

Triplefins, probably dominated by the estuarine triplefin (*Grahamina nigripenne*) and the mottled triplefin (*Grahamina capito*), were the 3rd most abundant taxa, with 101 individuals sampled across both inlets (Table 2, 24 by beach seine, 77 by beam trawl). Twelve of the thirty-two beach seines, and eighteen of the thirty-one beam trawls returned triplefins. All fish were less than 11 cm in length, with both juvenile and adults present (Figure 12, Figure 15). Densities were low, averaging less than one fish/100 m^2 from both beach seine and beam trawl, across the four inlet sub-areas (Figure 13, Figure 16). Beach seine densities of triplefin were highest at Moutere Inlet south (Figure 13), while beam trawl average densities were highest at Waimea Inlet north (Figure 16). However, both the highest density beach seine (3.6 fish/100 m^2, station B27) and beam trawl (6.7 fish/100 m^2, station W11) catches were made in Waimea Inlet south (Figure 18). These two stations were also those where the highest density of spotties <11 cm was recorded. The beach seine tow was over intertidal/subtidal seagrass (triplefins show strong positive density responses to subtidal seagrass), with the beam trawl station nearby.

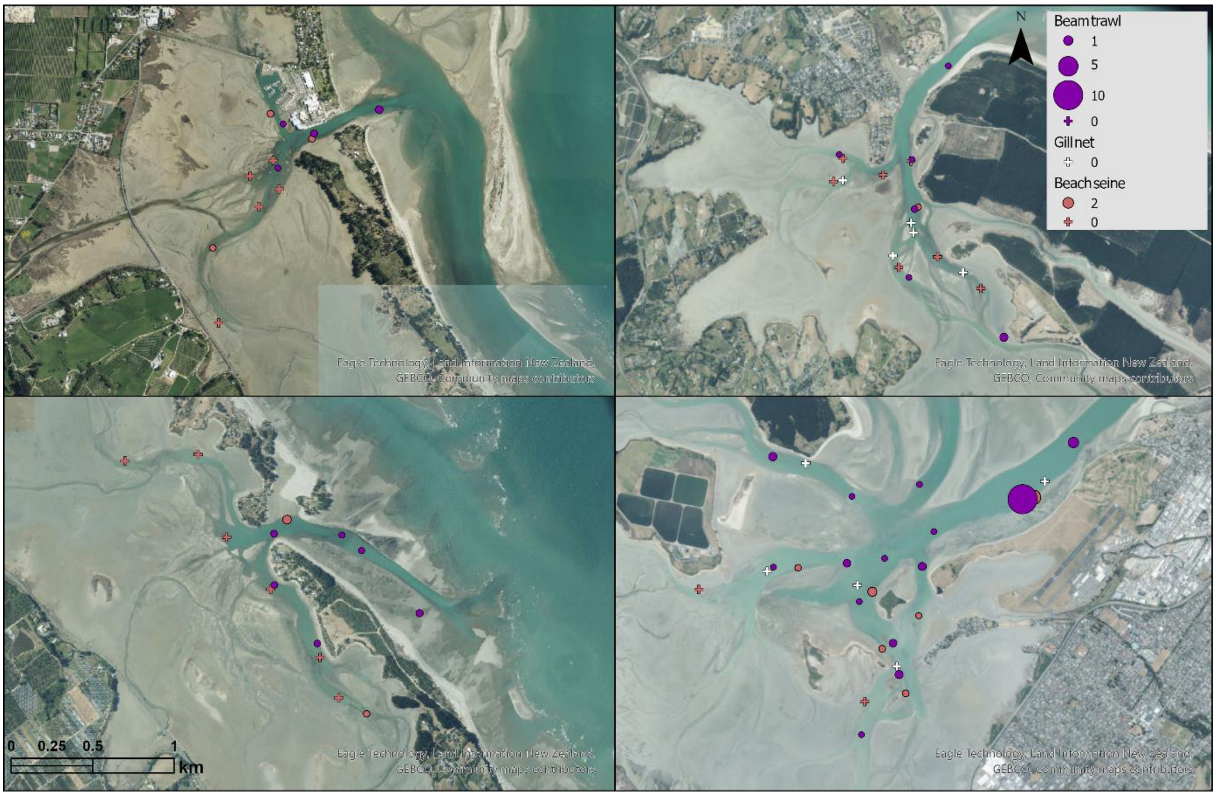

Figure 18: Catch rates of triplefin per 100 m^2 (beach seine and beam trawl). Left) Moutere Inlet north and south; right) Waimea Inlet north and south.

3.1.4 Kahawai *Arripis trutta*

This species was the 4th most abundant caught with 79 individuals being sampled, all captured by gillnet within the Waimea Inlet (Table 2). Fish ranged from 15 to 57 cm in length, with four peaks in the length frequency, with respective modes at 15–16, 22, 31, and 39 cm (Figure 19). These may represent age classes, with the first two probably corresponding to 1+ and 2+ age cohorts. Sixty-one of the 79 fish caught were from Waimea Inlet North, where kahawai was caught in all five gillnet stations (average catch 12.2 kahawai, Figure 15), with the highest catch at G8 with thirty-nine fish sampled (Figure 20). Waimea Inlet south returned eighteen fish from two of the five gillnet stations (average catch 3.6 kahawai), with fifteen of these fish caught at station G9.

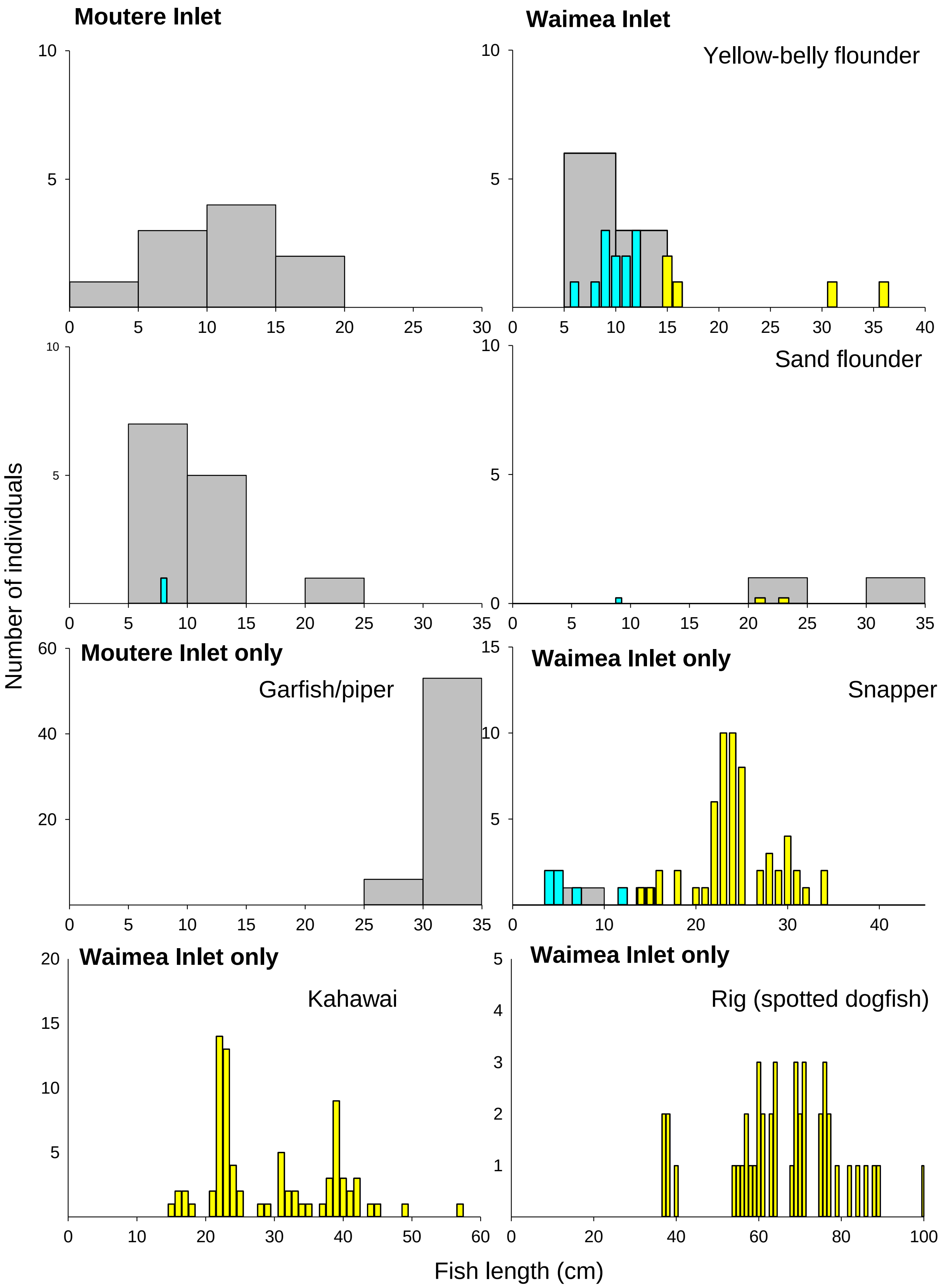

Figure 19: Length frequencies of yellow-belly flounder, sand flounder, garfish/piper, snapper, kahawai, and rig (spotted dogfish), from Moutere and Waimea inlets. Fish caught by beach seine were assigned to 5 cm length bins, while fish caught by beam trawl and gillnet were measured down to the nearest millimetre. Where a species was only sampled from one of the two inlets, the inlet with no catch is not shown.

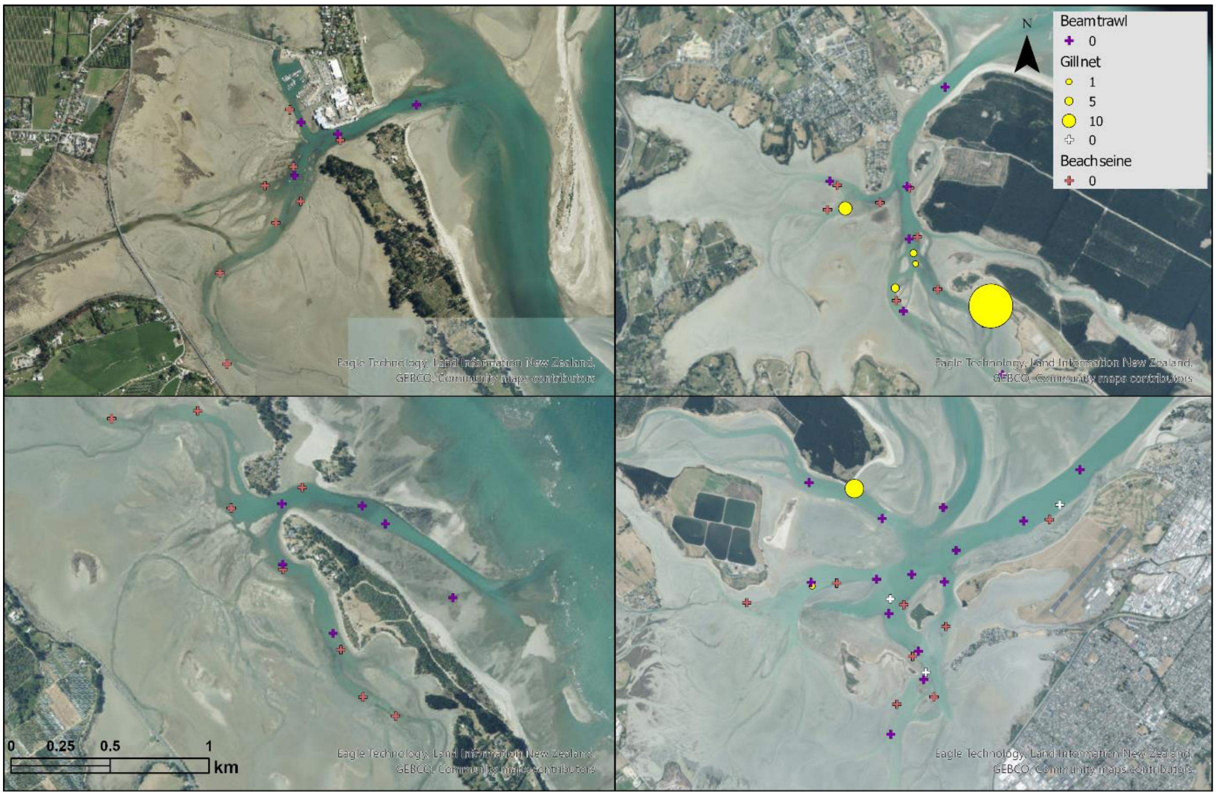

Figure 20: **Catch rates of kahawai by gillnet.** (no fish caught by beach seine or beam trawl). Left) Moutere Inlet north and south; right) Waimea Inlet north and south. Only Waimea Inlet was sampled by gillnet.

3.1.5 Snapper *Pagrus auratus*

This species was the 5th most abundant caught with 65 individuals sampled, mainly by gillnet (58 individuals) (Table 2). No snapper were caught in Moutere Inlet. Fish sizes ranged from 4 to 34 cm (Figure 16). A single 0+ snapper (5–10 cm length) was caught by beach seine at station B28, while five 0+ snapper (<11 cm) were caught by beam trawling at south stations W12 and W20 (0.3–0.5 fish/100 m^2), with station W12 also returning a single 1+ fish (0.5 fish/100 m^2). Note snapper >9 cm are seldom caught by beam trawl (Morrison & Carbines 2006). Gillnet sampled snapper ranged from 14 to 34 cm, with a clear peak at 22–25 cm, and a lesser peak at 27–32 cm (mode 30 cm) (Figure 19). In Waimea Inlet north, four of the five gillnet stations caught snapper (2–5 fish per net when present, with a five net average of 2.8 fish), as did four of the five gillnets at Waimea Inlet south (4–16 fish per net when present, average of all five nets 8.8) (Figure 15, Figure 21).

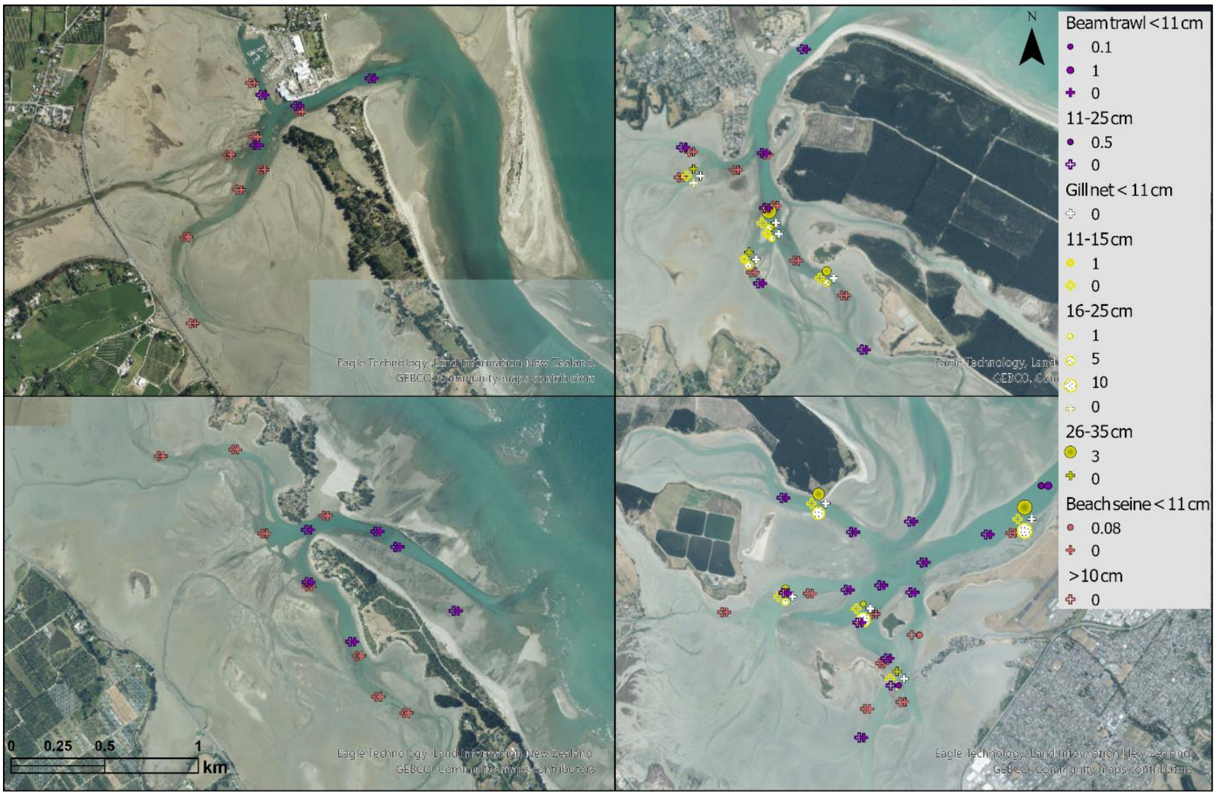

Figure 21: Catch rates of snapper per 100 m2 (beach seine and beam trawl) or per gillnet. Left) Moutere Inlet north and south; right) Waimea Inlet north and south. Size classes of <11, 11–15, 16–25, and 26–35 cm are displayed, to allow comparison with Golden/Tasman Bay snapper trawl survey catches. Gillnet sampling restricted to Waimea Inlet. No snapper caught in Moutere Inlet.

3.1.6 Garfish/piper *Hyporhamphus ihi*

This species was the 6th most abundant fish caught, with all 59 individuals caught at one Moutere Inlet south beach seine station (B11, Table 2). All fish caught were adults, ranging from 20 to 30 cm long (Figure 15), with a station density of 29.8 fish/100 m^2. This semi-pelagic species occurs as schools of similar-sized fish. No associated catch map is given.

3.1.7 Speckled sole *Peltorhamphus latus*

This species was the 7th most abundant fish, with 56 individuals recorded, all caught by beach seining (Table 2). It was present in 15 of the 32 beach seine stations. This species is known to migrate out from estuaries before it reaches adult maturity and all but two fish were juveniles (<11 cm) (Figure 12). Beach seine densities were low (Figure 13), with Moutere Inlet south having the highest average densities (1.3 fish per 100 m^2), Waimea Inlet north and south had intermediate densities (0.54–0.61 fish per 100 m^2), and Moutere Inlet north the lowest density (0.05 per 100 m^2) (Figure 22).

Figure 22: Catch rates of specked sole per 100 m^2 caught by beach seine. Left) Moutere Inlet north and south; right) Waimea Inlet north and south.

3.1.8 Rig (spotted dogfish) *Mustelus lenticulatus*

This species was the 8th most abundant fish, with 45 individuals recorded in gillnets at Waimea Inlet (Table 2). Fish lengths ranged from 37 to 99 cm (Figure 16), with 36 female, 7 male, and 3 un-sexed fish. A mode of smaller fish at 37–41 cm (5 individuals) was likely to have been young-of-the-year ‘pups’; while most of the larger fish ranged from 60 to 80 cm in length. Rig were caught at eight of the ten gillnet stations (Figure 23), suggesting that this species was relatively widespread across Waimea Inlet. Three north stations returned 1–6 fish per net when present (average of all nets 2.6 fish); along with five south stations with 5–13 fish per net when present (average of all nets 8.8 fish) (Figure 15).

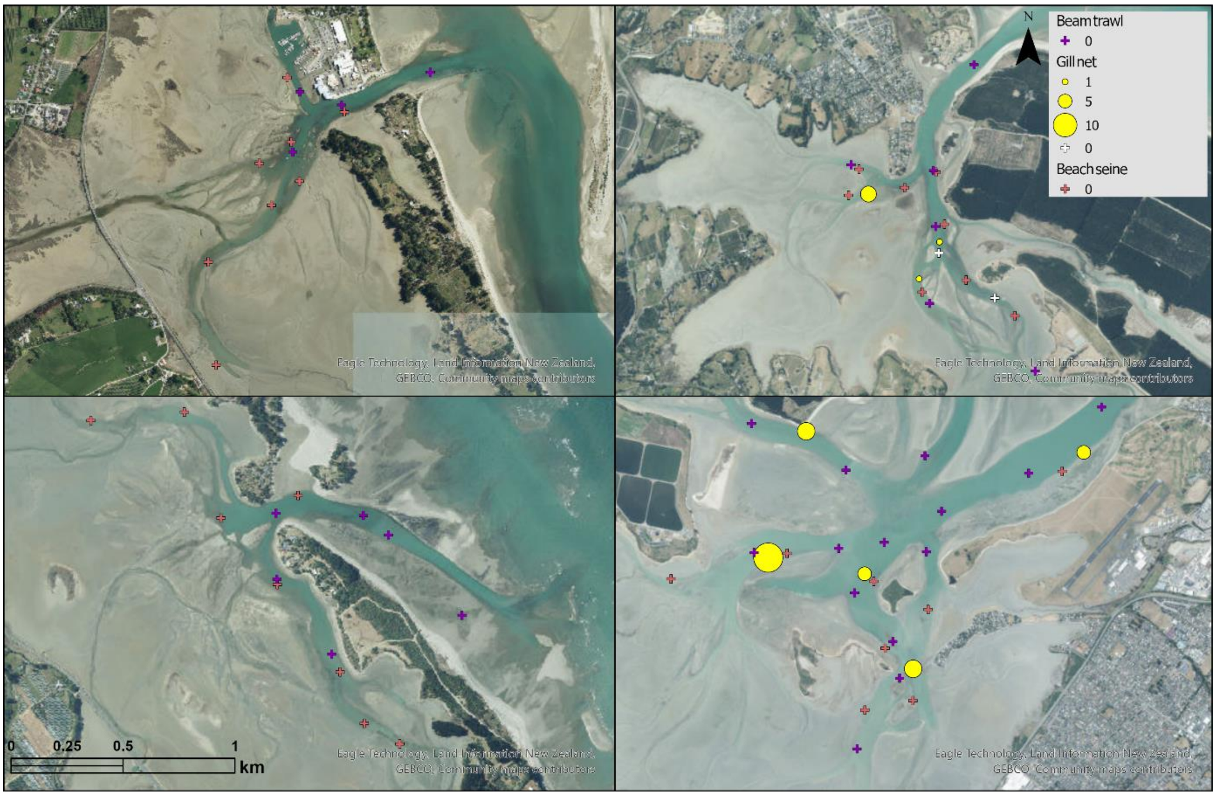

Figure 23: Catch rates of rig (spotted dogfish) by gillnet(no fish caught by beach seine or beam trawl). Left) Moutere Inlet north and south; right) Waimea Inlet north and south. Only Waimea Inlet was sampled by gillnet.

3.1.9 Yellow-belly flounder *Rhombosolea leporina*

This species was the 9th most abundant fish, with 34 individuals sampled across both estuaries and all three fish sampling methods (Table 2). Yellow-belly flounder were caught at eleven of the thirty-two beach seines, nine of the thirty-one beam trawl, and three of the ten gillnet stations. In Moutere Inlet, yellow-belly flounder was only captured by beach seining, where fish ranging in size from 1–5 cm through to 15–20 cm were sampled (Figure 19). In Waimea Inlet, all three sampling methods caught yellow-bellied flounder. Beach seine caught fish were in the 5–10 and 11–15 cm length size classes, while beam trawling caught fish ranged from 6–12 cm in length (Figure 19). The five fish caught in gillnets ranged from 15 to 36 cm in length.

Densities of yellow-belly flounder were very low across all four inlet sub-areas, for both beach seine (Figure 10) and beam trawl (not plotted). In Moutere Inlet north, two beach seine stations held fish <11 cm (0.7–0.9 fish/100 m^2), while one of these stations along with another held fish >10 cm (0.3–0.9 fish/100 m^2). In Moutere Inlet south, no fish <11 cm were sampled, while two stations held fish >10 cm (0.4–0.7 fish/100 m^2) (Figure 24).

In Waimea Inlet north, only one beach seine station returned yellow-belly flounder (<11 cm, 0.5 fish/100 m^2; >10 cm, 0.3 fish/100 m^2), while two beam trawl stations returned fish <11 cm (0.1–0.2 fish/100 m^2), and a third station fish >10 cm (0.2 fish/100 m^2). Gillnet caught yellow-belly flounder were restricted to three Waimea Inlet north stations, with 1–3 fish per net (Figure 24).

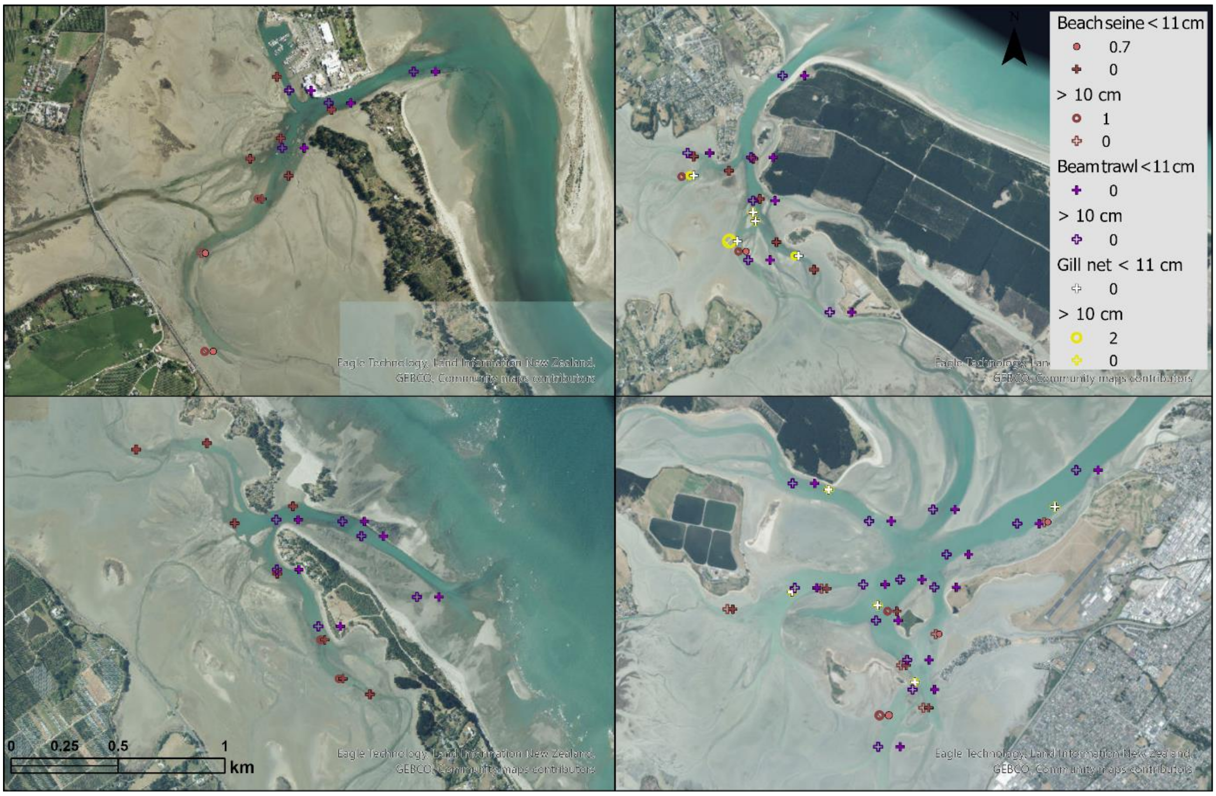

Figure 24: Catch rates of yellow-belly flounder per 100 m^2 of all three gear types.(beach seine, beam trawl and gillnet). Left) Moutere Inlet north and south; right) Waimea Inlet north and south.

3.1.10 Sand flounder *Rhombosolea plebeia*

This species was the 10th most abundant fish, with 32 individuals sampled across both inlets and all three fish sampling methods (Table 2). Sand flounder were caught at eleven of the thirty-two beach seines, seven of the thirty-one beam trawl, and two of the ten gillnet stations. In Moutere Inlet, most fish caught by beach seine fell in the 5–10 and 10–15 cm length bins, along with one fish in the 20–25 cm bin (Figure 19). In Waimea Inlet, only five sand flounder were caught, one 9 cm fish (beam trawl caught) and four larger 20–35 cm length fish (beach seine and gillnet caught).

Beach seine and beam trawl yellow-belly flounder densities were very low (Figure 13, Figure 16). In Moutere Inlet north, all beach-seine caught fish <11 cm were from one station (0.3 fish/100 m^2), and all fish >10 cm from another single station (0.9 fish/100 m^2) (Figure 25). One beam trawl station returned fish <10 cm (0.2 fish/100 m^2), with no larger sand flounder caught in beam trawls. In Moutere Inlet south, fish <10 cm were caught at four of the eight beach seine stations (0.3–0.8 fish/100 m^2), and fish >10 cm at three of these same stations (0.4–0.8 fish/100 m^2) (Figure 25). No sand flounder were caught by beam trawl.

In Waimea Inlet north, two beach seine stations held fish <11 cm (0.3–0.6 fish/100 m^2), with no larger individuals caught (Figure 19). Two of the six beam trawl stations held fish <11 cm (0.1–0.2 fish/100 m^2), and one other station held fish >10 cm (0.2 fish/100 m^2). Two of the gillnet stations returned sand flounder (1–3 fish per net). In Waimea Inlet south, two beach seine stations held fish <11 cm (0.1–0.9 fish/100 m^2), and one of these stations plus one other held fish >10 cm (0.4–0.9 fish/100 m^2). Two beam trawl stations held fish <11 cm (0.3–0.6 fish/100 m^2), with no larger sand flounder caught. No sand flounder were caught in any of the five gillnet stations.

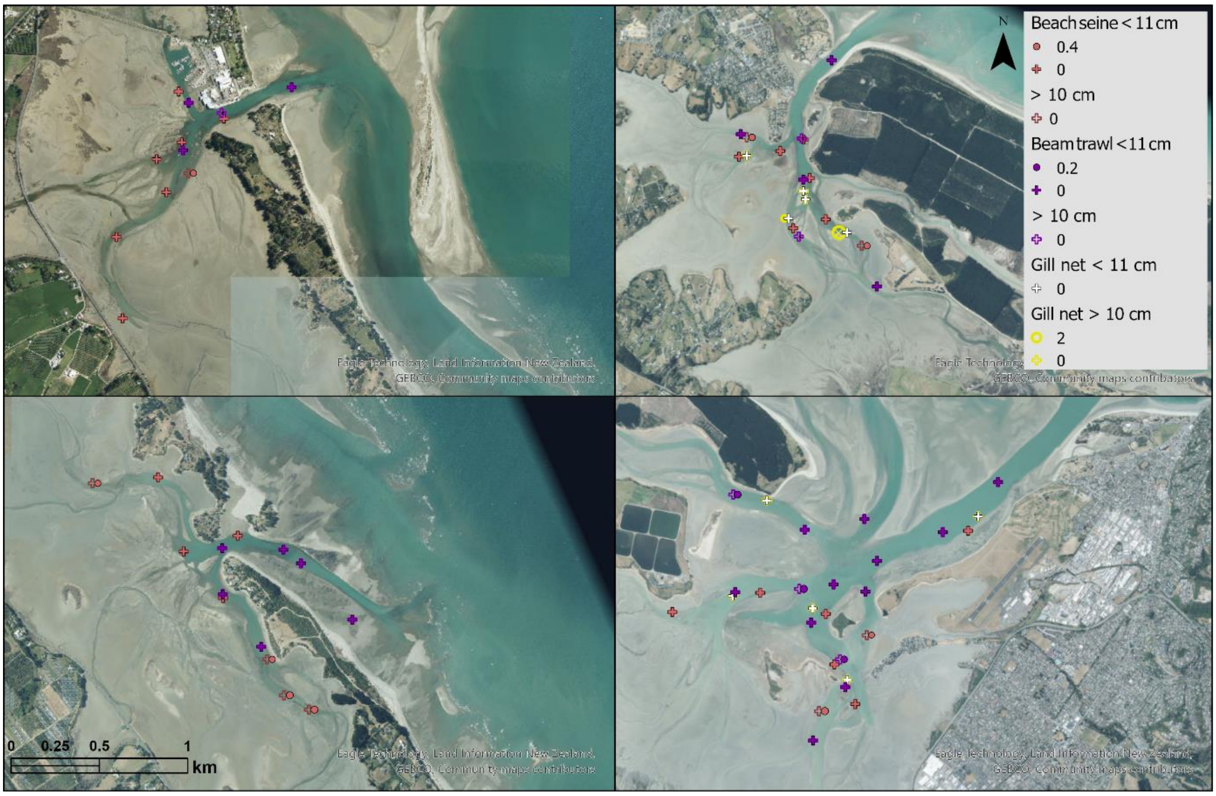

Figure 25: **Catch rates of sand flounder per 100 m² of all three gear types**(beach seine, beam trawl, and gillnet). Left) Moutere Inlet north and south; right) Waimea Inlet north and south.

3.1.11 Eagle rays *Myliobatus tenuicaudatus*

This species was the 11th most abundant fish, with a total of 25 individuals caught across both inlets (24 by gillnet, one by beach seine, Table 2). No rays were caught in beam trawls. Rays ranged from 35 to 100 cm (measured from wingtip to wingtip), with most fish in the 35 to 60 cm range, representing both larger juveniles and adults (Figure 26). Fourteen fish were female, 8 were male, and 3 were un-sexed fish. The single fish caught in a beach seine (100 cm width) was at station B8 in Moutere Inlet north (Figure 27). Gillnet sampling was restricted to Waimea Inlet, with rays caught at eight of the ten gillnet stations (12 rays in the north, 12 rays in the south) suggesting that eagle rays are widely distributed in this inlet (Figure 27). Three stations in Waimea Inlet north returned fish (1–2 fish per net when present, average of all nets 2.4 fish), while all five of the gillnet stations in Waimea Inlet south returned fish (1–6 fish per net, average 2.4 fish).

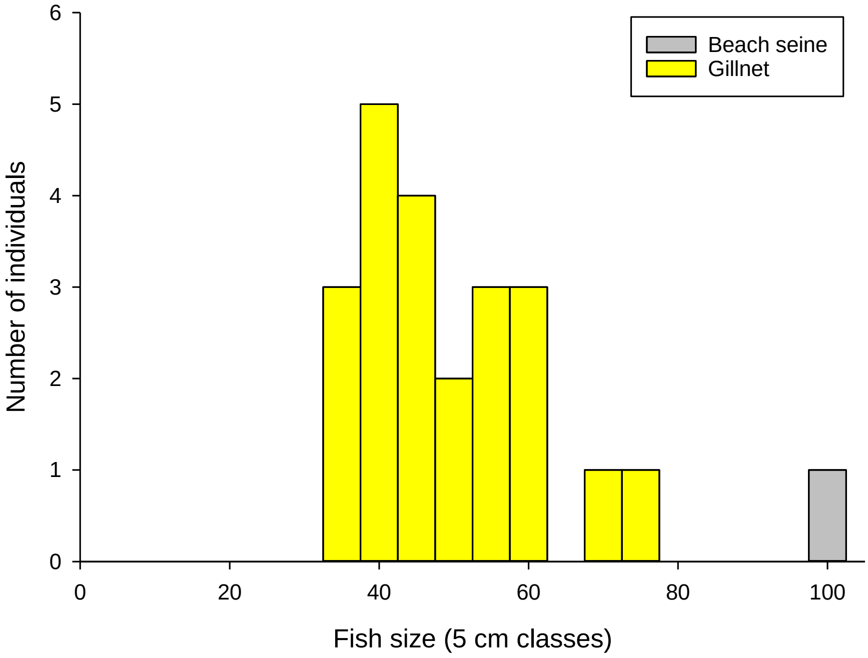

Figure 26: **Length frequency of eagle rays**from Moutere and Waimea inlets. Only Waimea Inlet was sampled by gillnets. The single individual caught by beach seine was in Moutere Inlet.

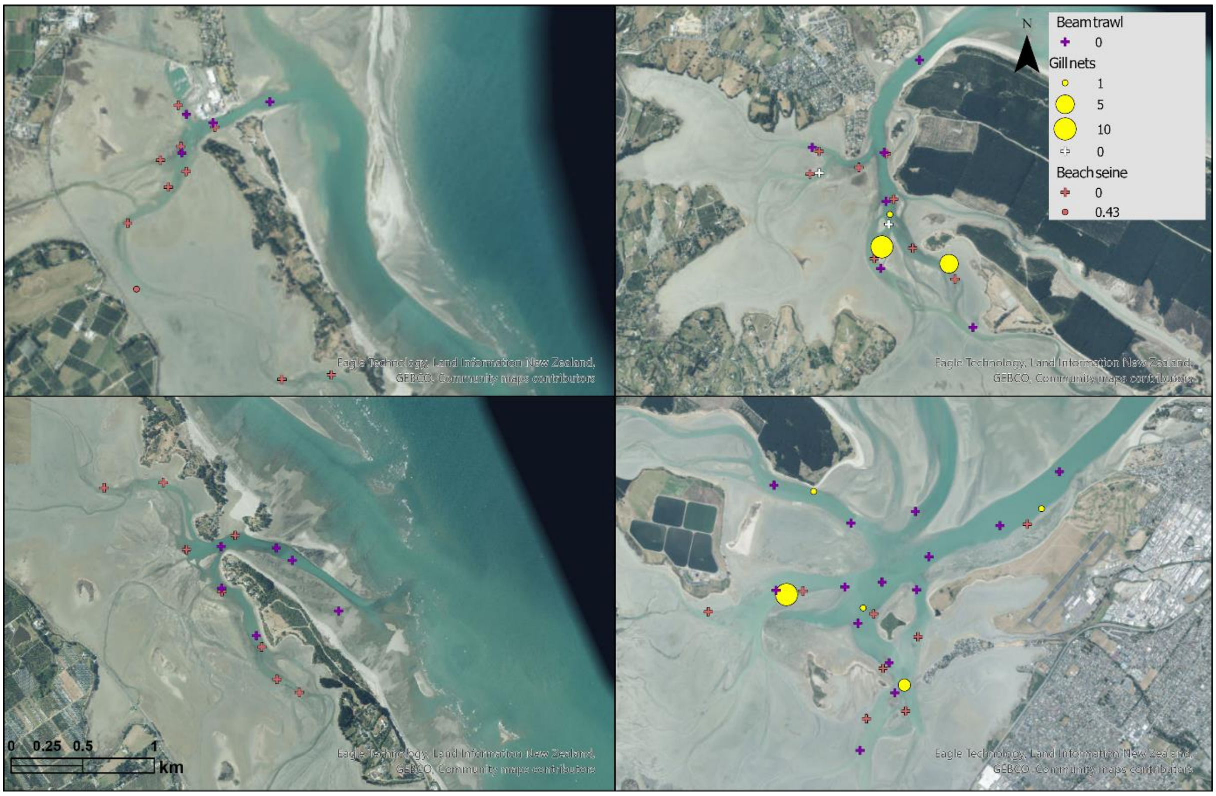

Figure 27: **Catch rates of eagle rays (beach seine and gillnet)** Left) Moutere Inlet north and south; right) Waimea Inlet north and south. Only Waimea Inlet was sampled with gillnets. No eagle rays were caught in beam trawls.

3.1.12 Fish species with less than twenty individuals sampled

There were nine fish species with total catches of less than 20 individuals. These are briefly described below:

Pilchard *Sardinia neopilchardus*

Twelve pilchards were caught in Waimea South, at station W21. These were initially misidentified in the field as anchovies and not measured; using a field photograph they were re-assigned to their correct species and estimated to be on average 7–8 cm long.

Trevally *Pseudocaranx dentex*

Three very small 0+ juvenile trevally (26–38 mm length) were caught by beam trawl in Waimea Inlet south, at stations W7 and W20. Eight larger juvenile trevally (190–279 mm, average 217 mm) were caught by gillnet in Waimea Inlet north (seven at station G8, one at G10).

Clingfish

Four fish were caught by beam trawl (fish length 27–43 mm) across Moutere Inlet south (stations M7, M8) and Waimea Inlet south (station W9).

School shark *Galeorhinus galeus*

Three fish were caught by gillnet in Waimea Inlet south at station G11. Fish length ranged from 381 to 393 mm (all females); these were small juvenile pups.

Red mullet *Upeneichthys lineatus*

Two juvenile 0+ fish (40–44 mm) were caught by beam trawl in Waimea Inlet south, at station W11.

Green-backed flounder *Rhombosolea taperina*

Two adult fish (31–35 cm length bin) were caught in Waimea Inlet north by beach seine, at station B23.

Jack mackerel *Trachurus* sp.

One jack mackerel (*Trachurus novaezealandiae*), 202 mm long, was caught by gillnet in Waimea Inlet south, at station G13. A second *T. novaezealandiae* individual was also caught in this area by beam trawl (140 mm, station W16) (note: beam trawling seldom catches jack mackerel >5 cm), as well as a third jack mackerel individual (57 mm, station W12) identifiable only to genus (*Trachurus* sp.).

Red gurnard *Chelidonichthys kumu*

One juvenile 0+ red gurnard (1–5 cm length bin) was caught by beach seine in Moutere Inlet north, at station B5.

Leatherjacket *Parika scaber*

One juvenile 0+ leatherjacket (1–5 cm length bin) was caught by beach seine in Waimea Inlet north, at station B31.

Barracouta *Thyrsites atun*

One juvenile 0+ barracouta (50 mm) was caught by beam trawl beach seine in Waimea Inlet south, at station W21.

3.2 Species richness

All 32 beach seine stations caught between 1 and 8 species (average 3.3, species pool of 11, Figure 28). Of the 31 beam trawl stations, four returned no fish. The remaining 27 beam trawl stations caught between 1 and 6 species (average 2.3 species across all 31 stations, species pool of 12). All 10 gillnet stations returned fish, with a range of 2 to 8 species (average 5.4, from species pool of 10).

Across Moutere Inlet, there were no obvious spatial patterns in species richness (Figure 28). Waimea Inlet in contrast showed a reduction in species richness for some of the beam trawl stations located in the mid to outer subtidal channel areas. No strong spatial patterns in species richness were apparent for the other two fish sampling methods (Figure 28).

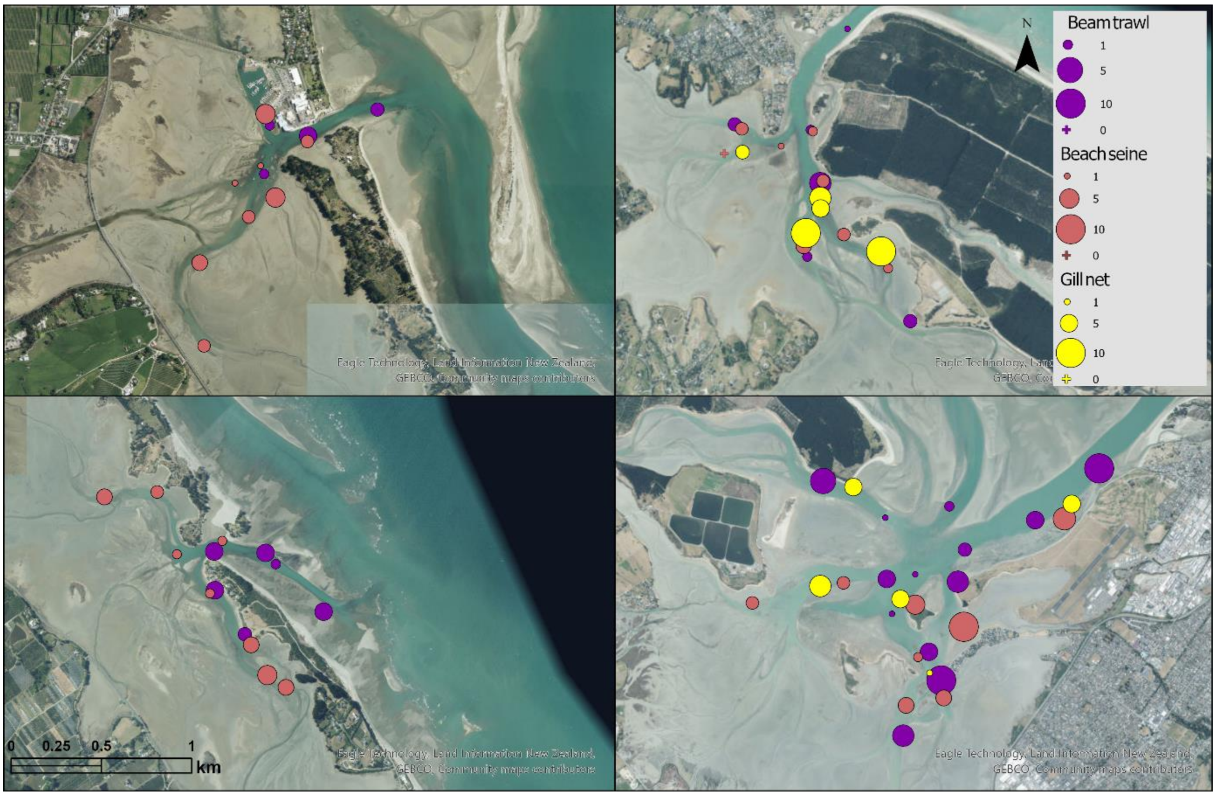

Figure 28: Species richness caught using the three gear types. Left) Moutere Inlet north and south; right) Waimea Inlet north and south. Only Waimea Inlet was sampled with gillnets.

3.3 Multivariate analysis of community structure

3.3.1 Beach seine

An nMDS of the thirty-two beach stations showed no evidence of different fish assemblages between Moutere and Waimea inlets (Figure 29). PERMANOVA analysis found no significant differences ($p < 0.05$) between beach seine fish assemblages across the two inlets, sediment types, or depth classes (see Appendix B).

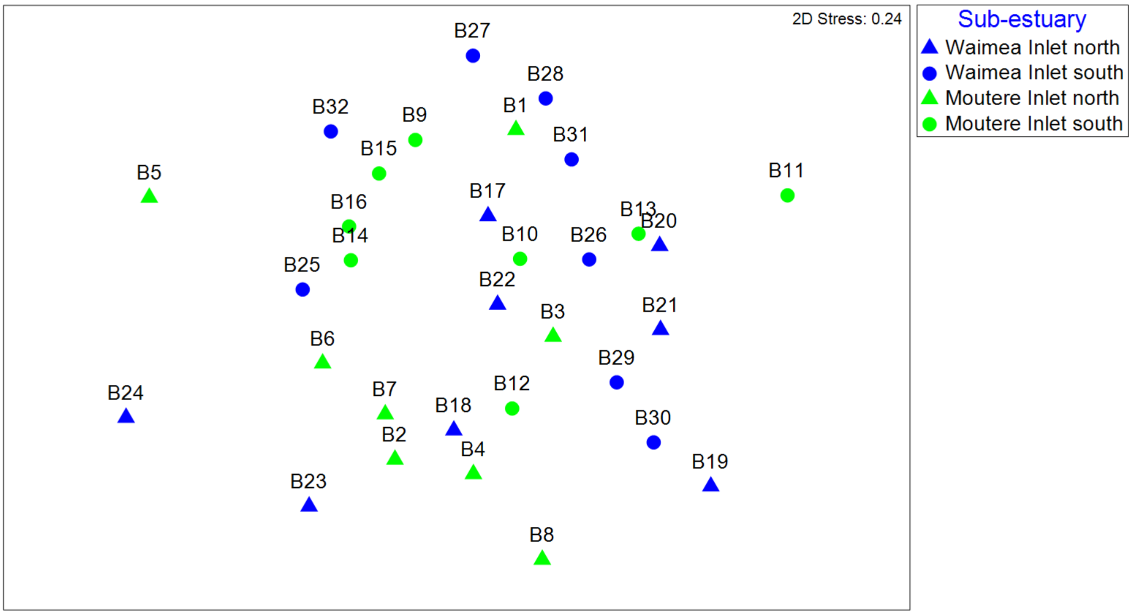

Figure 29: Beach seine station nMDS of Moutere and Waimea inlet stations. Note that the stress value of 0.24 is high, meaning that the MDS has not performed very well in 2D space.

3.3.2 Beam trawl

An nMDS of the thirty-one beam stations showed separation in fish assemblages between Moutere and Waimea inlets, although some stations overlapped (Figure 30). PERMANOVA analysis confirmed the fish assemblages of the two inlets (as sampled by beam trawl), to be significantly different ($p < 0.05$) from each other (Appendix B). A SIMPER analysis showed this was driven by small differences in spotty (mean density 1.85 vs 1.52 fish/100m^2) and triplefin densities (0.23 vs 0.71 fish/100m^2), with these two species contributing 93% of all beam trawl caught fish. There was no significant differences between water depths (Appendix B).

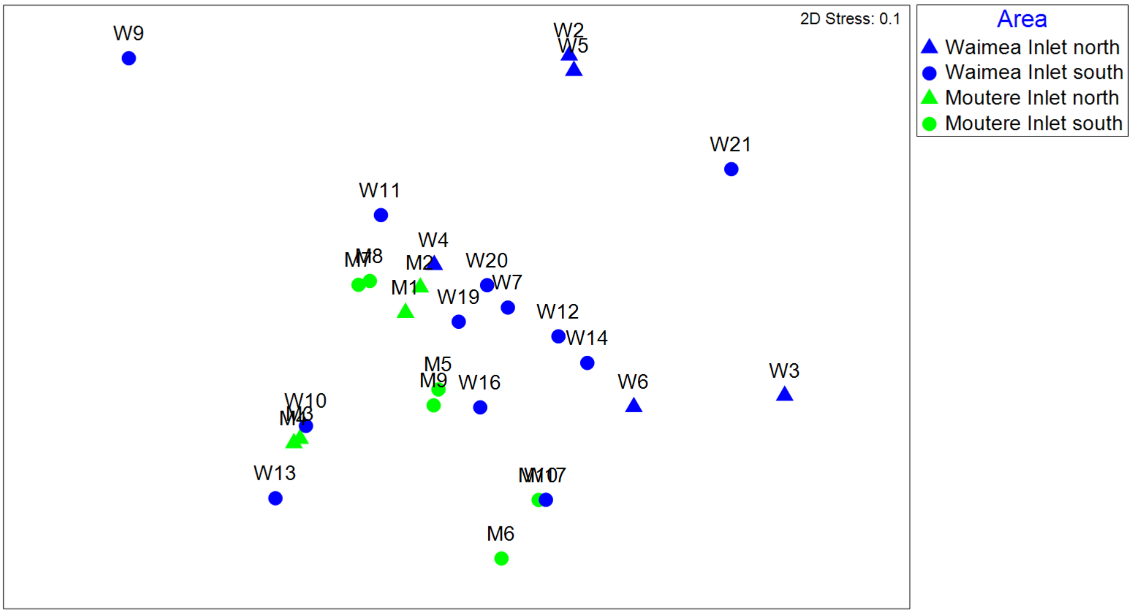

Figure 30: Beam trawl station nMDS of Moutere and Waimea inlet stations. The stress value of 0.1 shows a relatively good fit in 2D space.

3.3.3 Gillnet

An nMDS of the gillnet stations showed clear separation in fish assemblages between Waimea Inlet north and south (no gillnetting sampling done in Moutere Inlet) (Figure 31). PERMANOVA found a significant difference ($p < 0.05$, Appendix B) between fish assemblages at the two sub-inlets. A SIMPER analysis showed that this difference was driven by higher yellow-eyed mullet and kahawai catches in the north area, and higher snapper and rig (spotted dogfish) catches in the south area.

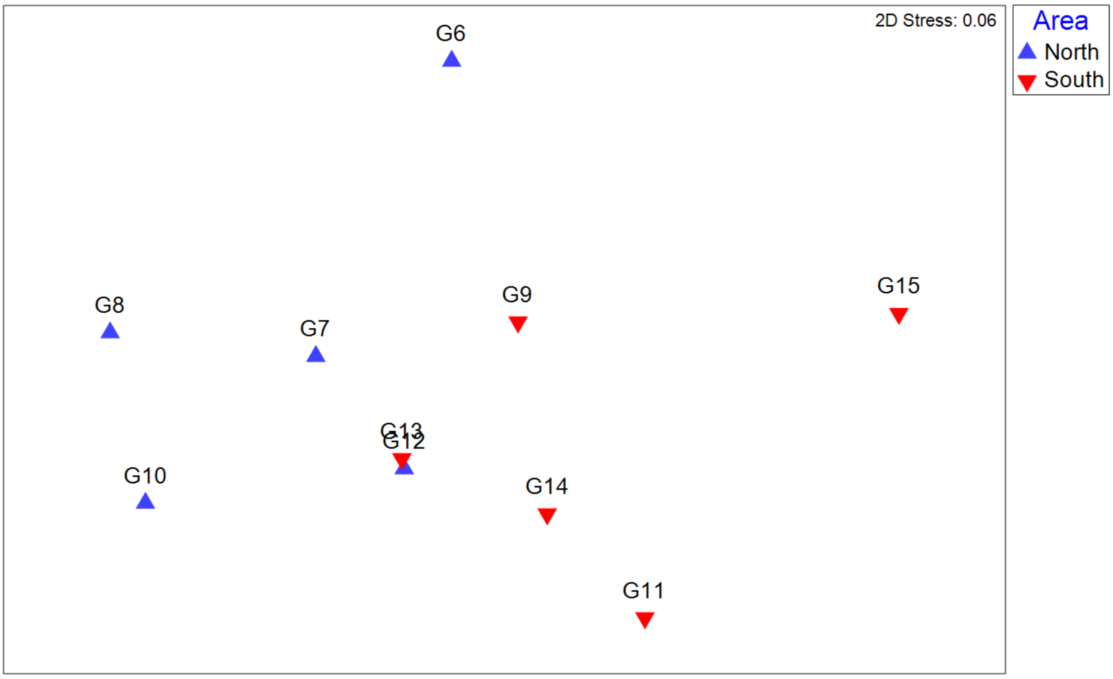

Figure 31: Gillnet station nMDS of Waimea Inlet stations. The stress value of 0.06 shows a good fit.

4 Setting Moutere and Waimea inlets in a wider regional context

As part of a nation-wide assessment of juvenile and small fish in estuaries, a beach seine survey of six upper South Island estuaries was competed in February-March 2006 (Moutere and Waimea inlets not sampled) (Francis et al. 2011). These six estuaries (Whanganui Inlet, Ruataniwha Inlet, Nelson Haven, Havelock Estuary (upper Pelorus Sound), upper Queen Charlotte Sound, Port Underwood) were sampled using the same beach seines and approach as the present study, with eight low-tide beach seine tows per estuary (six in Ruataniwha Inlet). These 2006 data are compared to the present 2021 data, with the caveat that temporal variations in juvenile recruitment numbers are likely.

The combined size frequencies of the most eight abundant species (and snapper), summed across the six estuaries sampled in 2006, are shown in Figure 32.

In the 2006 survey, yellow-eyed mullet showed a dominant 0+ juvenile class peak from 50 to 75 mm, with lesser peaks of fish from 75 to 90 mm, and 90 to 110 mm: with a low tail of larger fish extending to 150 mm and more in length. This dominance of small juvenile yellow-eyed mullet was consistent with the pattern seen in Moutere and Waimea inlets in 2021 (Figure 12).

Spotties ranged from <20 to 240 mm in length in 2006, with dominant peaks present around 30 to 40 mm, 60 to 80 mm, and 100 to 125 mm (Figure 32). This general pattern was also present in Moutere and Waimea inlets in 2021 (Figure 12). Triplefins (estuarine triplefin *G. nigripenne* and mottled triplefin *G. capito*) were present as broad size peaks spanning the 30 to 80 mm range, also consistent with Moutere and Waimea Inlets. Kahawai (only sampled in Port Underwood), in contrast, were dominated by a 0+ juvenile peak of fish around 40–50 mm long, with a much lesser peak of fish 80 to 120 mm long (Figure 32); Moutere and Waimea inlets returned no kahawai from the 32 beach seine stations sampled in 2021. Snapper were rare in the 2006 beach seine samples, with only two 0+ juveniles sampled, comparable to the single 0+ snapper sampled in Waimea Inlet (by beach seine) in 2021. Garfish/piper were present in the 2006 samples with two size peaks, centred around 80 to 120 mm (juvenile fish), and 150 to 250 mm (larger juveniles and adults). In 2021, adult fish (250 to 350 mm size bins) only were sampled from a single Moutere Inlet station (Figure 19). Specked sole caught in 2006 ranged in size from 25 to 110 mm, with a similar size range seen in Moutere and Waimea inlets in 2021 (Figure 12). Yellow-belly flounder sampled in 2006 ranged from 20 to more than 400 mm in length, with most less than 100 mm long. Sand flounder sampled in 2006 ranged in length from 15 to 245 mm, with a broad concentration of fish from 40 to 100 mm long. Beach seine catches of these two species in Moutere and Waimea inlets broadly showed similar length compositions in 2021 (Figure 19).

Average fish density (all fish sizes included), by species and harbour, from the 2006 beach seine survey, and the 2021 Moutere and Waimea inlet survey, are given in Figure 33. Yellow-eyed mullet densities were considerably greater in Port Underwood (210 fish/100 m^2) compared to all the other estuaries (<100 fish/100 m^2). Of the remaining seven estuaries, Moutere Inlet had the highest average (69 fish/100 m^2) densities, with the other six estuaries ranging from 24 to 42 fish/100 m^2 (Figure 33). Triplefin densities were highest in inner Pelorus Sound, with 28 fish/100 m^2, with the two beach seine stations that contributed the most fish situated over a subtidal seagrass patch on a bank at the entrance to Mahakipara Arm, and a very soft mud at the head of Mahakipara Arm.

Kahawai were restricted to Port Underwood, where juvenile fish densities averaged 8.5 fish/100 m^2. Snapper (0+) were largely absent from beach seine samples in both 2006 and 2021, with two fish captured in 2006 in Nelson Haven (one adjacent to intertidal seagrass, one adjacent to bare sandflat), and one in Waimea Inlet in 2021. Garfish/piper were present in low densities in Ruataniwha, inner

Charlotte Sound, and Port Underwood in 2006 (2.4–3.3 fish/100 m^2), occurring as occasional schools at a few sites (shown by the large standard error bars, Figure 33), and largely missing from the other three estuaries. Similarly, only one Moutere Inlet station held garfish/piper in 2021, with no fish captured from Waimea Inlet.

Speckled sole were uniformly and widely spead across all eight estuaries, although densities were low, with Port Underwood holding the highest average density (1.5 fish/100 m^2) and inner Pelorus Sound none. Yellow-belly flounder were present in low densities (0.06–0.66 fish/100 m^2) across six of the estuaries, with Havelock having the highest density (1.5 fish/100 m^2), and no fish from inner Queen Charlotte Sound. Sand flounder had the lowest densities within Moutere and Waimea estuaries (0.2–0.3 fish/100 m^2) (Figure 33).

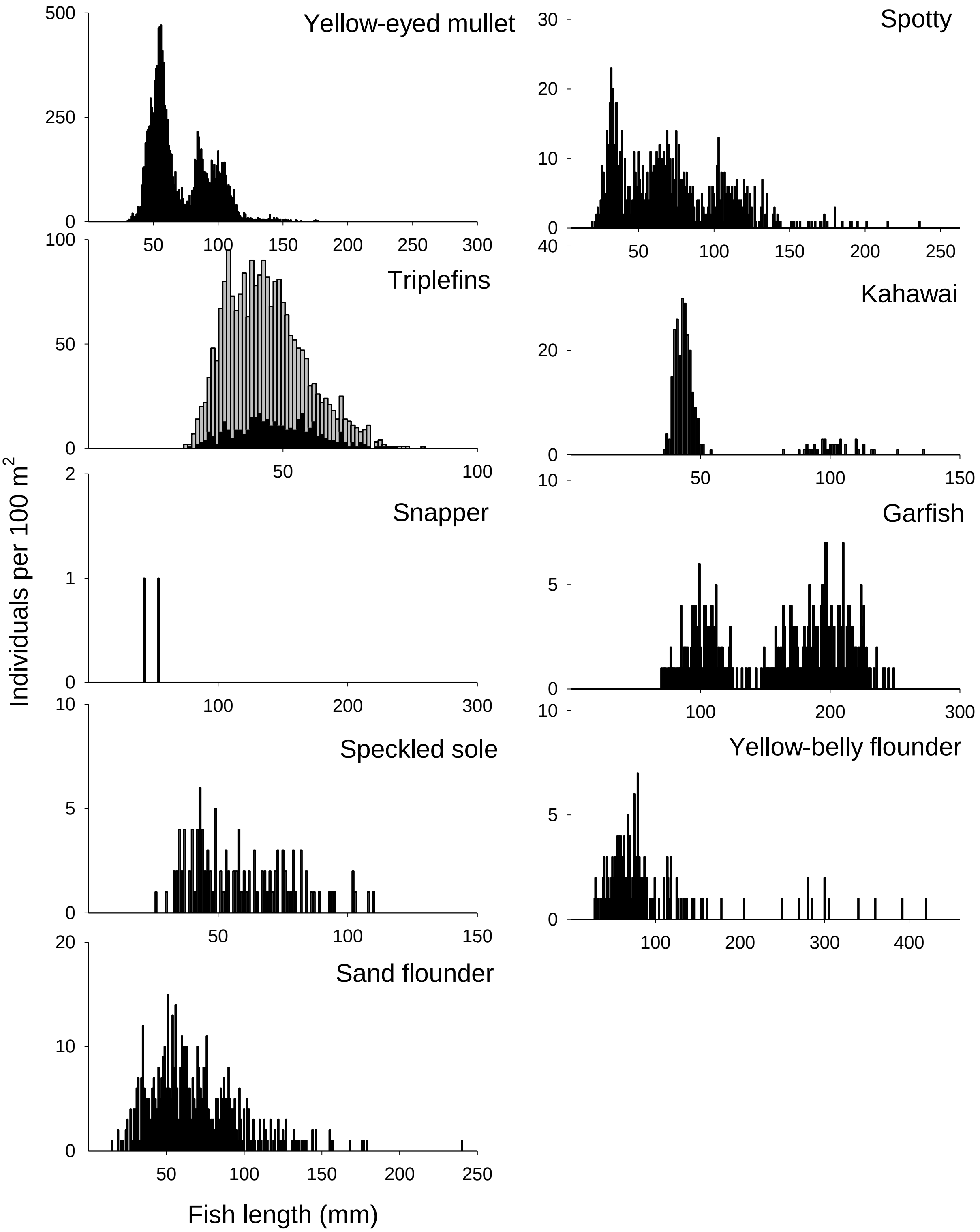

Figure 32: Length frequencies of 2006 beach seine survey more abundant fish species from six upper South Island estuaries(from data collected by Francis *et al.* 2011). Triplefins are represented by the estuarine triplefin *G. nigripenne* (light bars) and the mottled triplefin *G. capito* (dark bars). Fish length frequencies from the 2021 beach seine survey of Moutere and Waimea inlets are given in Figures 9 and 16.

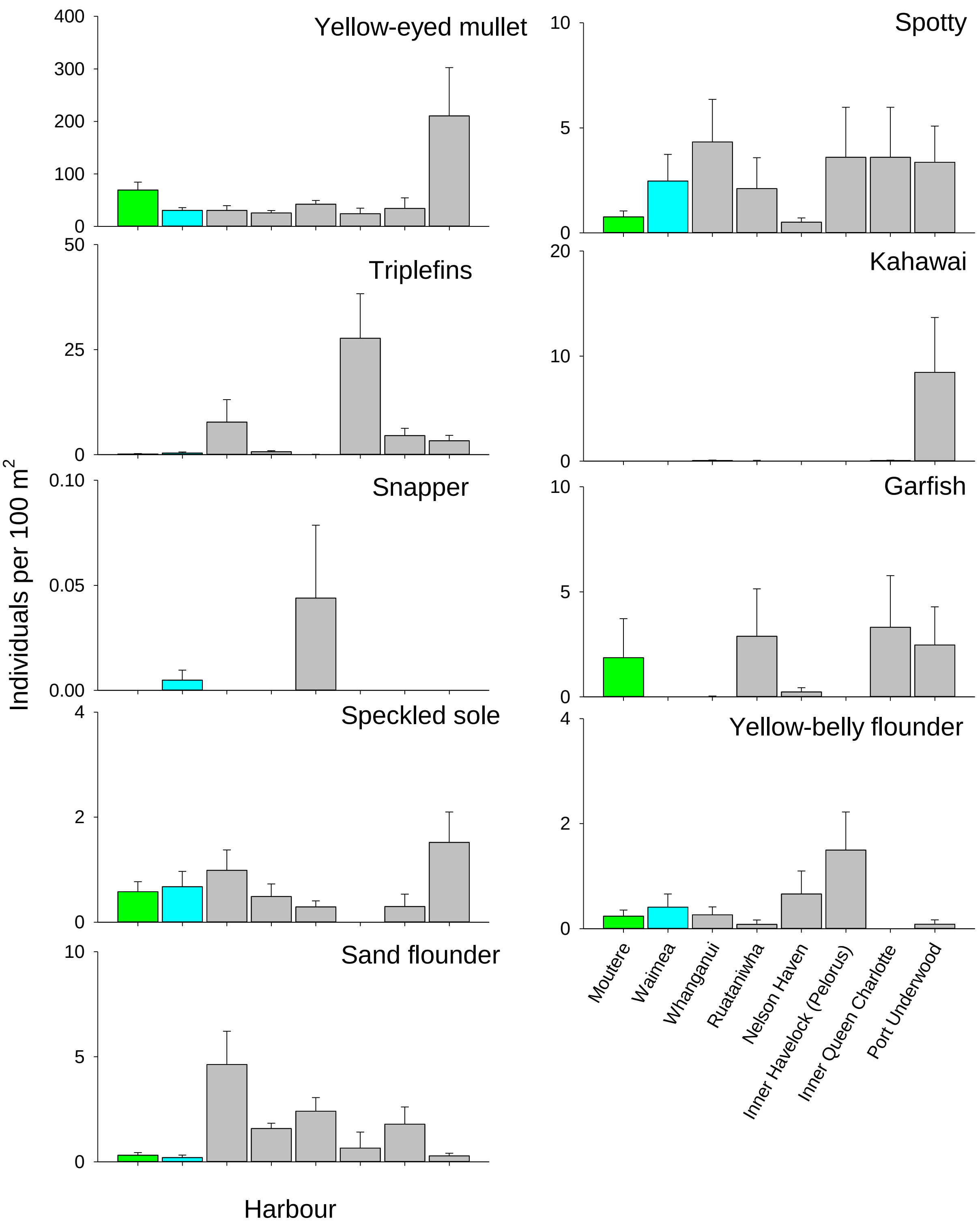

Figure 33: **Average beach seine fish densities per 100 m2, from the 2006 survey of six upper South Island estuaries (grey shading), and the 2021 Moutere (yellow s shading) and Waimea inlet (green shading) survey.**

5 Adjacent coastal zone fish catches from research trawl surveys.

Research trawl survey catches from sampling in the adjacent Golden Bay and Tasman Bay were assessed for those species that also occurred in Moutere and Waimea inlets. These data were used to place the two estuaries fish populations in the context of the wider local areas fish populations. As this was not directly focussed on the project's objective, these descriptions and contrasts are provided in Appendix C.

6 Local knowledge of historical change

Several long-term Nelson residents with many years of experience interacting with the inlets were informally interviewed, to learn more about past environmental change. As most observations were not about fish, but rather birds, plants and general changes, a summary of these observations is provided in Appendix D.

7 Conclusions and recommendations

Sampling of Moutere and Waimea inlets, using three different sampling methodologies, has quantified the associated fish assemblages. Species richness and abundance of small and juvenile fishes were similar to other upper South Island estuaries, and dominated in particular by yellow-eyed mullet, and, to a lesser extent, spotties and triplefins. The larger sized (greater than 10 cm length) fish assemblage included snapper, kahawai, rig, and eagle rays.

Juvenile snapper, rig, school shark, trevally, yellow-belly flounder, and sand flounder were present in low numbers, suggesting that at the present time, the two estuaries do not provide significant nursery functions for these QMS species. For snapper however, local knowledge reports of Waimea Inlet at times 'being full of juvenile snapper' suggests that this inlet may play a larger nursery role in some years for this species. The sizes of those juveniles were not given, but to be caught by fishing gears were likely to have been circa 150 mm and larger (1+ and older in age). Snapper are well known for large inter-annual variations in juvenile year class strengths. The SNA7 fishery, which includes Tasman and Golden Bays, is in ongoing recovery from being a collapsed fishery stock. These dynamics mean that Waimea Inlet may at times be of greater importance to juvenile snapper. In contrast, the very limited subtidal spatial extent of Moutere Inlet fundamentally limits its ability to play a more significant role.

In terms of potential ongoing monitoring of the two inlets fish assemblages, beach seining provides the most cost-effective method for quantifying small and juvenile fish. The main target species of the methods used in the two inlets were yellow-eyed mullet, spotties, triplefins and flatfish on bare sediments; and where subtidal seagrass was present, spotties and triplefins, and possibly 0+ snapper, trevally, and pipefish. With the progression of climate change, warmer water temperate species may also start to appear in the Nelson region as their distribution expands southwards. For example, the parore *Girella tricuspidata* is abundant in northern New Zealand estuaries and on shallow coastal reefs, with juveniles using subtidal seagrass as a key nursery habitat. A southwards expansion of this species, assuming that adult breeding population/s were established, would see 0+ juveniles using what subtidal seagrass that exists in the upper South Island as nursery habitat. Similarly, bare sediment associated species such as the gobies *Favonigobius exquisitus* and *Favonigobius lentiginosus*, might also expand southwards as the climate warms.

Assessing the statistical power of beach seine data for detecting large-scale temporal changes in fish densities was outside the scope of this project but given the current low densities of most species (excluding yellow-eyed mullet) as a starting point, any large scale increases in densities in the future would be readily apparent in any time series. The current allocation of 16 beach seine stations (achievable in two field days), is suggested to be sufficient for an individual estuary; although the assignment of additional stations to target subtidal seagrass habitat (if any can be found) would be of high monitoring value.

On-going sampling for 0+ snapper in the subtidal channels would be more involved, with beam trawling being the best method, requiring the use of a survey vessel with a winch. Rather than sampling of just Waimea Inlet, a more informative approach would be to undertake a systematic survey of inner Golden and Tasman bays (including estuaries), to identify where the important snapper nurseries are located, and which habitat types they are associated with (as has been done for East Northland and the Hauraki Gulf, Morrison et al. 2019). This would allow the relative importance of Waimea Inlet as a 0+ snapper nursery to be assessed.

Juveniles of larger-bodied species, such as rig and school-shark, and larger-sized adult fish in general, are not amenable to sampling by beach seine or beam trawl. Gill-netting is now banned in upper South Island estuaries, given the formal exclusion zone to protect Hectors dolphins. One possible solution is the use of towed video camera during the hours of darkness, when many fish species sleep on the seafloor (including snapper) and can be counted and measured (Morrison & Carbines 2006, Compton et al. 2012). While water clarity can be limiting in more turbid areas, careful selection of periods of calm weather, and sampling over high tides, can help mitigate this issue. Towed video has the added advantage of being able to be deployed benignly over sensitive habitats such as sponge gardens and reefs, as well as higher human use areas such as harbour entrances. Critically, it also provides detailed information on seafloor habitats as well as fish, as geo-referenced video records that can be archived and revisited as needed if new analyses are needed. Current towed video systems are limited to a field of view of 0.5 to 2 metres, depending on water visibility conditions. NIWA is building a new multiple-camera towed system, that will be able to image a 10-metre-wide swath in good visibility conditions; that system will initially be limited to large survey vessels not suitable for estuary sampling but will likely be eventually portable to smaller survey vessels that are suitable for estuaries.

Based on beam trawl bycatch, little biogenic (living) habitat structure was present on the subtidal channel seafloors, aside from the two known sponge gardens (not sampled). Non-fish catch was dominated by low volumes of macro-algae, likely to be drift from large areas of macroalgae further up the inlets growing on the intertidal mudflats (see Appendix A). Those macroalgae areas are considered to be a nuisance, and a result of human-driven increases in nutrient inputs to the inlets. Two small dead horse mussels were caught in one beam trawl; the complete lack of live bycatch of this species suggests horse mussel habitats, an important biogenic habitat for some fish species juveniles (e.g., 0+ snapper, trevally, and spotties) are effectively absent from the inlets. One beach-seine station that passed over a limited subtidal fringe of an intertidal seagrass meadow returned the highest densities of spotties and triplefins, consistent with the high value this habitat type provides to these and other fish species (Morrison et al. 2014a).

The survey results show that the two inlets are subtidally dominated by bare sediments (shell, sand, mud) with little three-dimensional seafloor structure such as horse mussel beds, subtidal seagrass meadows, and other biogenic habitat formers. While suspended sediment in the water column was not measured in this study (and no previous measures appear to have been made), the waters are relatively turbid, which limits the ability of seagrass and other plants to grow subtidally, and the ability of filter feeding animals such as horse mussels to feed (Morrison et al. 2009, 2023). Fish can also be negatively impacted by higher suspended sediment concentrations, e.g., 0+ snapper experience reduced foraging success, lower body weights at length, higher disease loads, and altered behaviour (Lowe et al. 2015).

There is little knowledge of what the two estuaries looked like before large scale clearances of their land catchments. For Waimea Inlet, evidence from intertidal sediment cores shows that beneath the mud-dominated layers generated by human activities, are older sand-dominated sediments, with many intact shells, indicating a very different estuary ecosystem before large-scale catchment development. In the present day, increasing muddiness is a key management concern, though much of this appears to be a legacy of historical land uses. Tasman District Council monitoring of sediment deposition over the last decade has returned very low net sediment accumulation rates (average 0.1 mm yr^{-1}).

No suspended sediment measurements have been made for the inlets, but it is probable that weather events often re-suspend some of the muds held on the intertidal flats, which then spends time in the water column as suspended sediments and may be transported around the inlets. These fine muds might end up back where they originated from, be deposited elsewhere in the inlet, or exported out to the coast. There is no sediment transport model for either of the inlets to assess such dynamics. Water turbidity can also be driven by factors other than suspended sediment. For instance, high phytoplankton abundance can play a role. With the two inlets known to be nutrient enriched from land catchment uses, increased phytoplankton abundance might also play a role (although no phytoplankton abundance estimates exist).

Remaining fish/habitat information gaps

In Waimea Inlet the sixteen beam trawl stations did not locate any new biogenic habitat areas. However, such habitats often occur as small discrete patches (e.g., horse mussel beds, sponge gardens, bryozoan mound fields) against a wider background of 'bare' sediments. Low intensity random sampling has a high probability of missing such small habitat areas. The ideal approach for finding such habitats is to use remote sensing tools (e.g., multibeam sonar, side-scan sonar, aerial/satellite imagery where water clarity allows) that can detect and map out such habitats. Such approaches are expensive and can be constrained by limited water clarity (image-based methods) and shallow water depths (acoustic methods). Given Waimea Inlet's relatively small subtidal extent, a pragmatic and cost-effective approach would be to systematically search the subtidal area using oblique cross-channel towed video transects. As well as systematic searching, more intensive localised sampling could be focussed in sub-areas most likely to hold new habitat areas, e.g., the channels around Oyster Island, with the Saxton-Monaco sponge garden on its south side. Given the usually low visibility conditions in the inlet, such work would need to coincide with the clearest water conditions (e.g., after an extended period of no rain and calm seas). Relatively low cost underwater cameras are now widely available, and such work could be done by councils themselves, using the harbour masters vessel.

The two known sponge gardens (Traverse, Saxton Monaco), and the Sabellid tubeworm mound fields, as well as any new significant biogenic habitat discoveries, remain to be quantified for their fish-habitat relationships. Benign sampling tools can be used to prevent damage to the habitats (Morrison 2010). As times of higher water clarity permit, static drop cameras can be deployed to quantify what fish species and sizes are present within these habitats, and their relative abundances. Baited Underwater Video (BUV) is a well-established method in New Zealand, e.g., the Department of Conservation uses BUV for ongoing monitoring of marine reserve fish populations. Unbaited cameras can also be used, providing a better view of fish interactions with their habitat, with the trade-off of fewer fish being seen (sometimes none). Towed camera systems can also be deployed (as described above) over such habitats during darkness, to quantify the spatial associations between fish and habitat, and how that varies with different habitat configurations/qualities.

If water clarity conditions never allow the use of cameras, static fish capture methods such as baited fish traps and fyke nets could be used. Baited fish traps can be deployed both subtidally, and in the intertidal when the tide is in (retrieved before the water level drops too low to keep trapped fish alive). For intertidal habitats such as the Sabellid mound field/s patches, where fish are forced to retreat to the adjacent subtidal channels when the tide is out, an alternative method would be to deploy fine mesh fyke nets with wings during the high tide across the path of their retreat. This approach has been effectively used in northern New Zealand to sample the small fish assemblages of mangrove forests (Morrisey et al. 2007, 2010, Morrison et al 2014b, c). The Sabellid mound habitats in the two inlets sit adjacent to subtidal channels, allowing fyke nets to be set with the wings in the intertidal, while the fyke proper remains submerged in the subtidal, keeping the fish caught alive.

What can councils do to maintain and improve the fish habitats of Waimea and Waimea Inlets

Protect biogenic habitats present in the two inlets from direct disturbance. It is much harder to restore habitats, versus protecting what still exists. So, the highest priority management action is to pro-actively avoid/limit human activities that adversely impact on existing biogenic habitats. As of 2023, from a fish-habitat value perspective, the key biogenic habitat for fish is subtidal seagrass (i.e., the limited subtidal fringes, eastern side of Waimea Inlet) and indirectly, intertidal seagrass. While intertidal seagrass does not directly provide important fish habitat, it is the foundation from which subtidal seagrass can establish though vegetative expansions out into the subtidal from lower intertidal meadow edges; or become established independently in the subtidal from drift of seagrass rhizome/leaf fragments (or possibly reproductively through actual seagrass seed dispersal). Other likely important biogenic habitats (for fish) include the two known sponge gardens (especially at Oyster Island), and to a lesser extent, the intertidal Sabellid tubeworm mound field/s, though the value of these habitats to fish remains to be quantified.

Direct disturbance to these habitats from infrastructure development, such as the placing of sewer lines, should be actively avoided. Nearby land-based activities that may discharge large sediment and/or nutrient loads into the inlets, such as land development projects, should also be actively managed to minimise such inputs. Human recreational activities that can damage such habitats, such as recreational vessels leaving propeller trails through seagrass meadows, and recreational 4WD vehicles accessing the intertidal and running over seagrass habitat, should also be minimised. Ideally this would be through increasing public awareness of the need to protect these habitats, so that the 'social licence' towards allowing such impacts fundamentally shifts.

Protect biogenic habitats present in the two inlets from broader environmental degradation. Water clarity and associated suspended sediment (and potentially phytoplankton) loads are key drivers of what can exist in estuaries. For subtidal seagrass, the dominant driver of loss around New Zealand is strongly inferred to be declining water clarity, which particularly reduces light levels for permanently submerged plants (intertidal seagrass can continue to photosynthesise to some extent when the tide is out). Similarly, filter feeding species such as horse mussels and sponges are negatively impacted by increased suspended loads, though some sponges species appear sediment tolerant. Efforts should continue to be made to limit, and ideally reduce, ongoing sediment inputs to the inlets from the adjacent catchments. That includes appropriate land use management, and mitigation activities such as the planting of riparian corridors for rivers and streams and establishing wetlands to slow down water run-off and allow fine sediments to settle out before reaching the inlets.

Seek a better understanding of the inlets original state. There is very little documented information of what the inlets looked like before large-scale human impacts. While the inlets will never be able to be restored to their original state, it would be very useful to understand their original condition. Management actions and frameworks can then use that knowledge in working to move the inlets some way towards that original state (while accepting new realities such as climate change). A fundamental knowledge base that could help in understanding that original state is Mātauranga Māori, including iwi's oral histories of the inlets. Through an iwi led project with appropriate tikanga, a better understanding could emerge of what fish and other species were once abundant, what habitats were present, and how the inlets 'worked'.

Historical European accounts of the inlets, both direct and indirect, could also be explored through targeted searches through historical documents, photographs, and sketches, held in libraries, national archives, and by long-established local families. As an example, even simple potential historical observations such as being able to see the seafloor in the inlets entrance would provide fundamental insight on past environmental conditions.

Monitor key biogenic habitats spatial extents and health/quality. The Tasman District Council currently monitors the two inlets through occasional intertidal habitat surveys over time. Those surveys use aerial photography to map out the intertidal habitats, and ground-truthing on foot, to assess changes over time. That includes intertidal seagrass, and though not separated out, any subtidal seagrass fringes associated with the intertidal seagrass. Future monitoring surveys could explicitly separate out those subtidal fringes (both currently existing, and where new fringes appear), so that they can be monitored for spatial change over time. Associated water depths are a key variable to measure, in particular the maximum water depth at which subtidal seagrass grows.

As water clarity is likely to be key limiter of subtidal seagrass presence, it would be useful to also deploy suitable subtidal in-situ sensors to quantify water turbidity, and the light levels reaching the seafloor. Such sensors would need to be deployed for periods of weeks to months or longer to get good measures of average water column conditions, and the variation around those averages. Water samples could also be taken and quantified for suspended sediment and phytoplankton concentrations, as well as for any other variables likely to be drivers of water clarity.

Combined, the subtidal seagrass mapping and water column monitoring would provide a baseline of present day dynamics of subtidal seagrass fringe habitats and their environmental conditions in Waimea Inlet. This baseline could be compared with seagrass research findings (present and ongoing) from sites in other regions of New Zealand where subtidal seagrass is still present and thriving, to assess the change through passive restoration (improving environmental conditions) that would be needed for subtidal seagrass to potentially return (with the key assumption of it once being spatially significant habitat). Whangarei Harbour is an example of subtidal seagrass recovery being possible, where large sediment inputs to the harbour from human infrastructure development and industry eliminated around 12 km^2 of intertidal and subtidal seagrass; following cessation of those large sediment inputs the seagrass returned, albeit with a temporal lag of several decades, and not yet having regained its full historical extent. Unlike Whangarei Harbour’s pre-recovery state, Waimea (and Moutere) inlets have an advantage in that good intertidal seagrass meadows are still present, as source populations. If the adverse environmental conditions that drove the suspected large-scale loss of subtidal seagrass can be removed, then the restoration of subtidal seagrass meadows would be of great value for both fisheries productivity, and biodiversity and seafloor productivity more broadly (Morrison 2021). Other important biogenic habitats such as horse mussel beds would also be more likely to become established with improved environmental conditions.

The sponge gardens and Sabellid mound field/s should also be monitored over time, if the proposed quantification of their fish-habitat relationships shows that they provide important habitat for fish. The two sponge gardens are in very shallow water, with low tide depths of around 50 cm in the Traverse, while for the Saxton/Monico one half the garden may be exposed for up to half an hour during spring tide (<0.2 m chart datum) Targeting periods of higher water clarity, in associations with spring tides, a drone could be used to map these habitats using georeferenced photography, and associated ground-truthing be done on foot.

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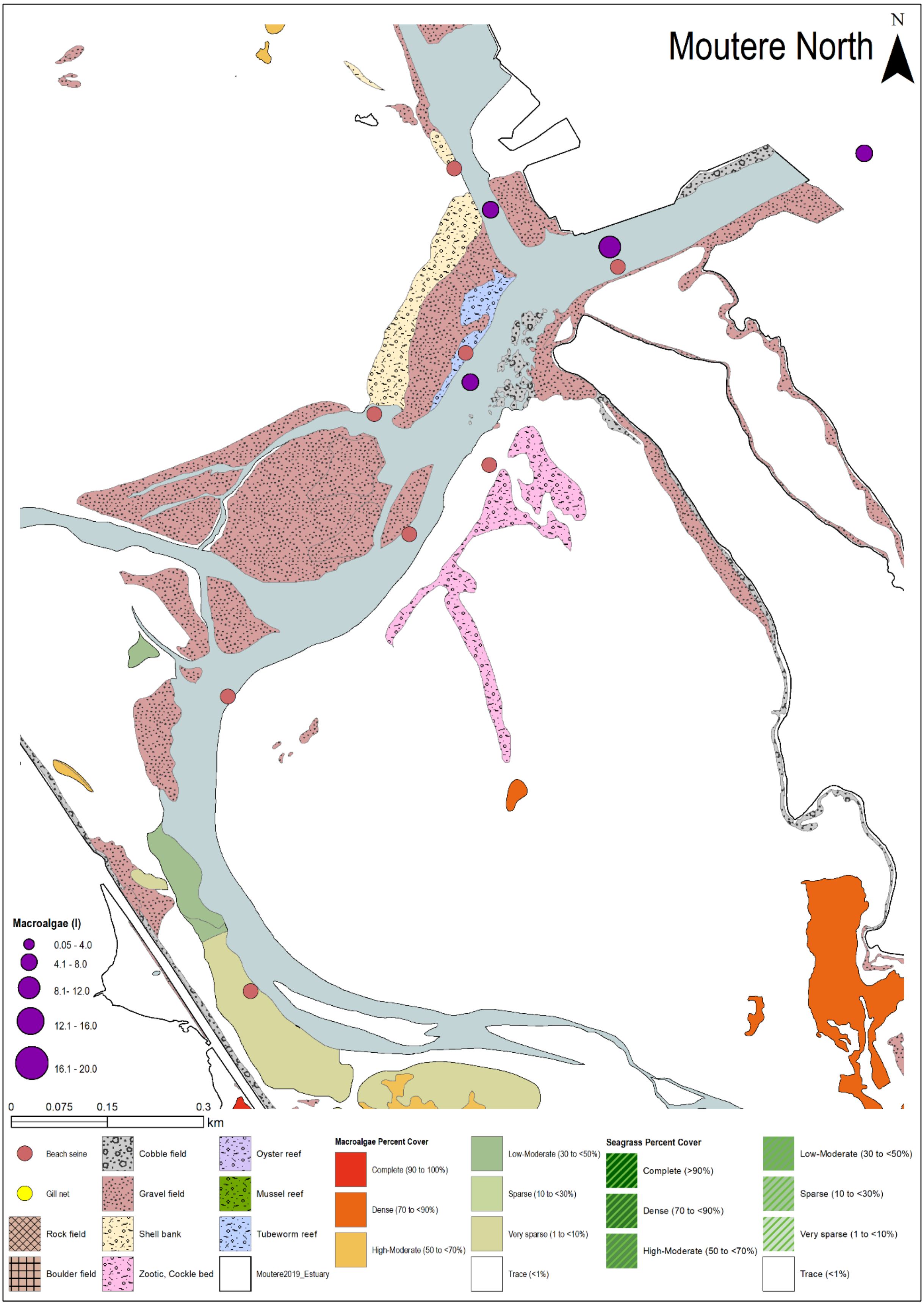
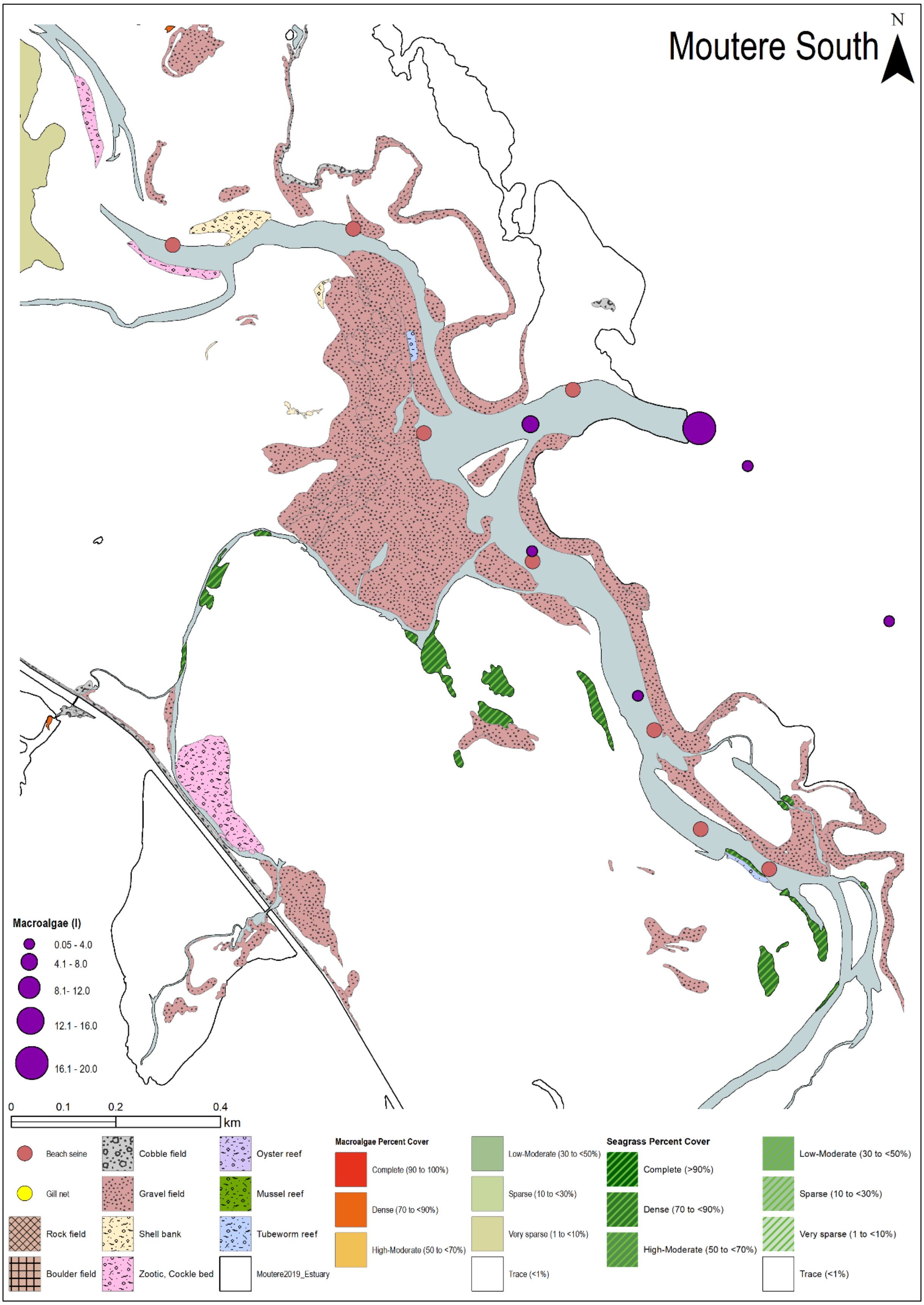
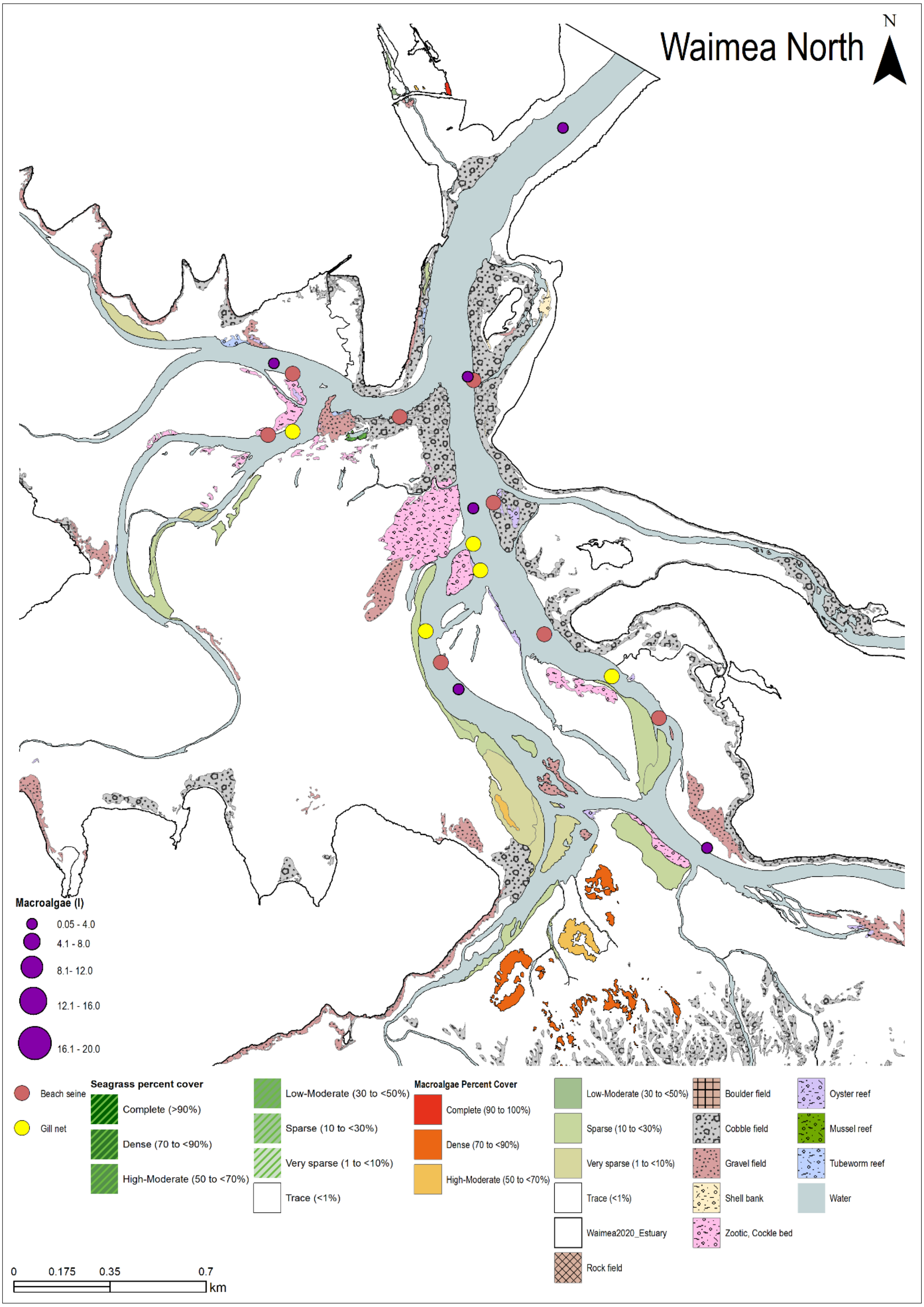
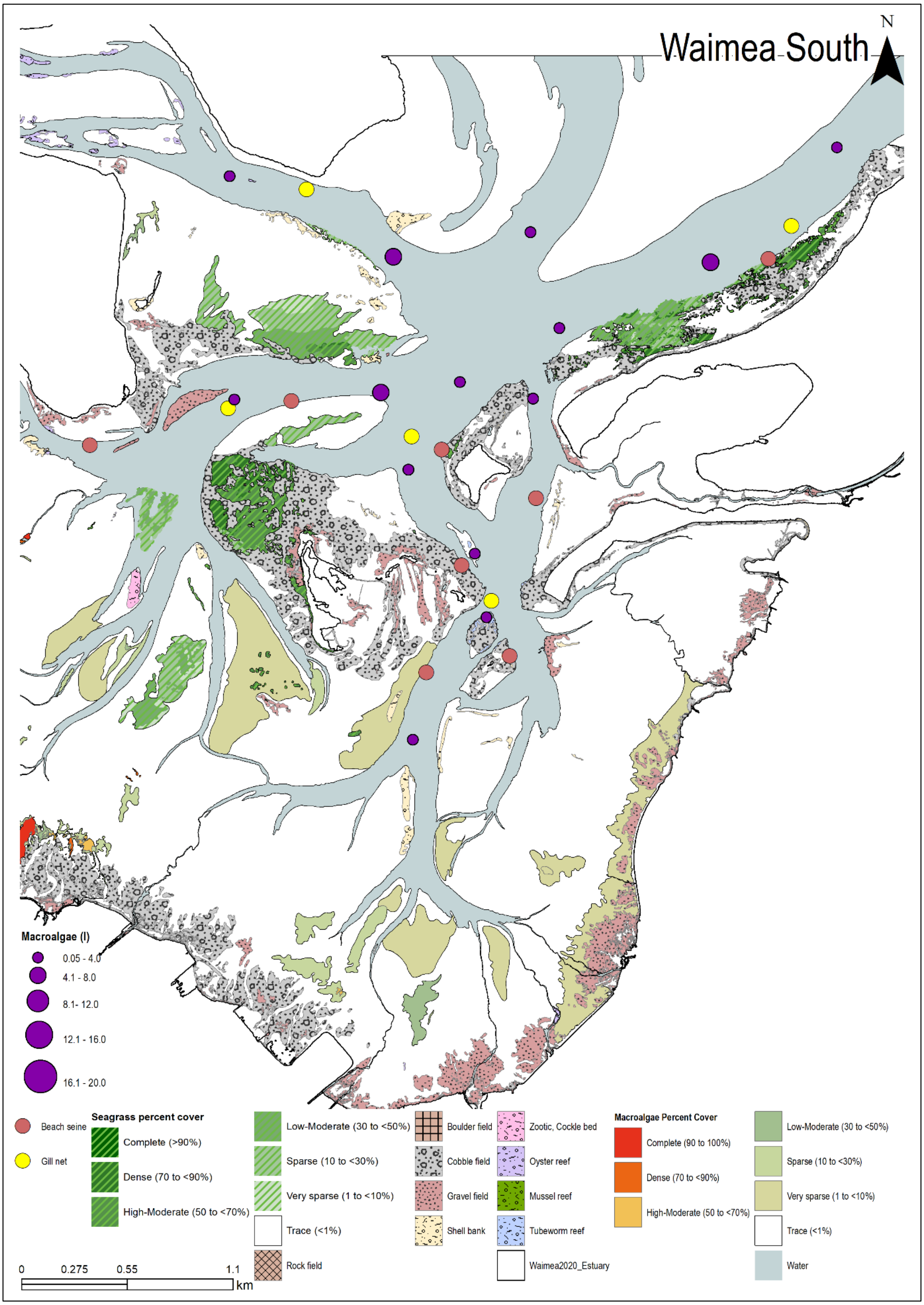
Appendix A Intertidal habitat maps with 2021 fish sampling stations shown.

For beam trawling, catch volumes of macroalgae are plotted (litres per 200 metre tow). Intertidal substrate, seagrass and macroalgae data and map styles sourced from Stevens et al. 2020a, b, and used with the approval of TDC and NCC. Unconsolidated soft sediment layers (sands and muds) have been deliberately excluded to emphasise the highlighting of the biogenic/hard substrates.


Moutere North
N
Macroalgae (l)
0.05 - 4.0
4.1 - 8.0
8.1- 12.0
12.1 - 16.0
16.1 - 20.0
0
0.075
0.15
0.3
km
Beach seine
Gill net
Rock field
Boulder field
Cobble field
Gravel field
Shell bank
Zootic, Cockle bed
Oyster reef
Mussel reef
Tubeworm reef
Moutere2019_Estuary
Macroalgae Percent Cover
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Trace (<1%)
Seagrass Percent Cover
Complete (>90%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Trace (<1%)


Moutere South
N
Macroalgae (l)
0.05 - 4.0
4.1 - 8.0
8.1- 12.0
12.1 - 16.0
16.1 - 20.0
0
0.1
0.2
0.4
km
Beach seine
Gill net
Rock field
Boulder field
Cobble field
Gravel field
Shell bank
Zootic, Cockle bed
Oyster reef
Mussel reef
Tubeworm reef
Moutere2019_Estuary
Macroalgae Percent Cover
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Trace (<1%)
Seagrass Percent Cover
Complete (>90%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Trace (<1%)


Waimea North
N
Macroalgae (l)
0.05 - 4.0
4.1 - 8.0
8.1- 12.0
12.1 - 16.0
16.1 - 20.0
Beach seine
Gill net
Seagrass percent cover
Complete (>90%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Trace (<1%)
Macroalgae Percent Cover
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Trace (<1%)
Waimea2020_Estuary
Rock field
Boulder field
Cobble field
Gravel field
Shell bank
Zootic, Cockle bed
Oyster reef
Mussel reef
Tubeworm reef
Water
0
0.175
0.35
0.7
km


Waimea South
N
Macroalgae (l)
0.05 - 4.0
4.1 - 8.0
8.1- 12.0
12.1 - 16.0
16.1 - 20.0
Beach seine
Gill net
Seagrass percent cover
Complete (>90%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Trace (<1%)
Rock field
Boulder field
Cobble field
Gravel field
Shell bank
Zootic, Cockle bed
Oyster reef
Mussel reef
Tubeworm reef
Waimea2020_Estuary
Macroalgae Percent Cover
Complete (90 to 100%)
Dense (70 to <90%)
High-Moderate (50 to <70%)
Low-Moderate (30 to <50%)
Sparse (10 to <30%)
Very sparse (1 to <10%)
Trace (<1%)
Water
0
0.275
0.55
1.1
km

Appendix B Statistical tables

Beach seine – PERMANOVA, factors of inlets, sediment types, and depths

Factors

Name	Abbrev.	Type	Levels
Estuary1	Es	Fixed	2
Substrate	Su	Fixed	6
Depth-band	De	Fixed	3

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Estuary	1	1348.5	1348.5	1.2387	0.335	999
Substate	5	6194.9	1239	1.1381	0.365	998
Depth-band	2	2429.8	1214.9	1.116	0.37	998
EsxSu**	4	5341.8	1335.4	1.2267	0.315	999
EsxDe	2	3919.8	1959.9	1.8003	0.115	999
SuxDe**	5	4234.5	846.9	0.77793	0.694	998
EsxSuxDe**	1	1629.7	1629.7	1.497	0.247	998
Res	11	11975	1088.6			
Total	31	33398				

** Term has one or more empty cells

Beam trawl – PERMANOVA; factors of inlets and depths

Factors

Name	Abbrev.	Type	Levels
Area	Ar	Fixed	4
Depth	De	Fixed	4

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Area	3	14916	4971.9	1.8057	**0.042**	996
Depth	3	7025.2	2341.7	0.85047	0.626	998
ArxDe**	4	7657.8	1914.4	0.69528	0.855	999
Res	16	44055	2753.5			
Total	26	77070				

** Term has one or more empty cells

SIMPER between Moutere and Waimea Inlets

Similarity Percentages - species contributions

One-Way Analysis

Group Moutere

Average similarity: 32.36

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.
Spotty	1.85	24.42	0.86	75.46	75.46

Group Waimea

Average similarity: 13.89

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Triplefin	0.71	5.32	0.51	38.31	38.31
Spotty	1.52	4.26	0.42	30.63	68.94
Sand flounder	0.12	2.5	0.3	18.02	86.95

Groups Moutere & Waimea

Average dissimilarity = 80.93

Species	Moutere Av.Abund	Waimea Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Spotty	1.85	1.52	43.26	1.51	53.45	53.45
Triplefin	0.23	0.71	13.62	1.02	16.83	70.28

Gill nets – PERMANOVA between Waimea Inlet north and south

PERMANOVA

Permutational MANOVA

Factors

Name	Abbrev.	Type	Levels
Area	Ar	Fixed	2

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Ar	1	7007.7	7007.7	4.3634	**0.007**	126
Res	8	12848	1606			
Total	9	19856				

Gillnets – SIMPER

SIMPER

Similarity Percentages - species contributions

One-Way Analysis

Group North

Average similarity: 46.13

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Yellow-eyed mullet	21.8	25.69	2.27	55.69	55.69
Kahawai	12.2	11.43	2.45	24.78	80.47

Group South

Average similarity: 44.64

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Spotted dogfish	7.4	20.81	3.1	46.63	46.63
Snapper	8.8	15.79	0.83	35.38	82.01

Groups North & South

Average dissimilarity = 71.60

Species	North Av.Abund	South Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Yellow-eyed mullet	21.8	2.2	22.83	1.68	31.89	31.89
Kahawai	12.2	3.6	13.71	1.59	19.15	51.04
Snapper	2.8	8.8	12.12	1.3	16.93	67.96
Spotted dogfish	1.6	7.4	9.19	1.57	12.83	80.8

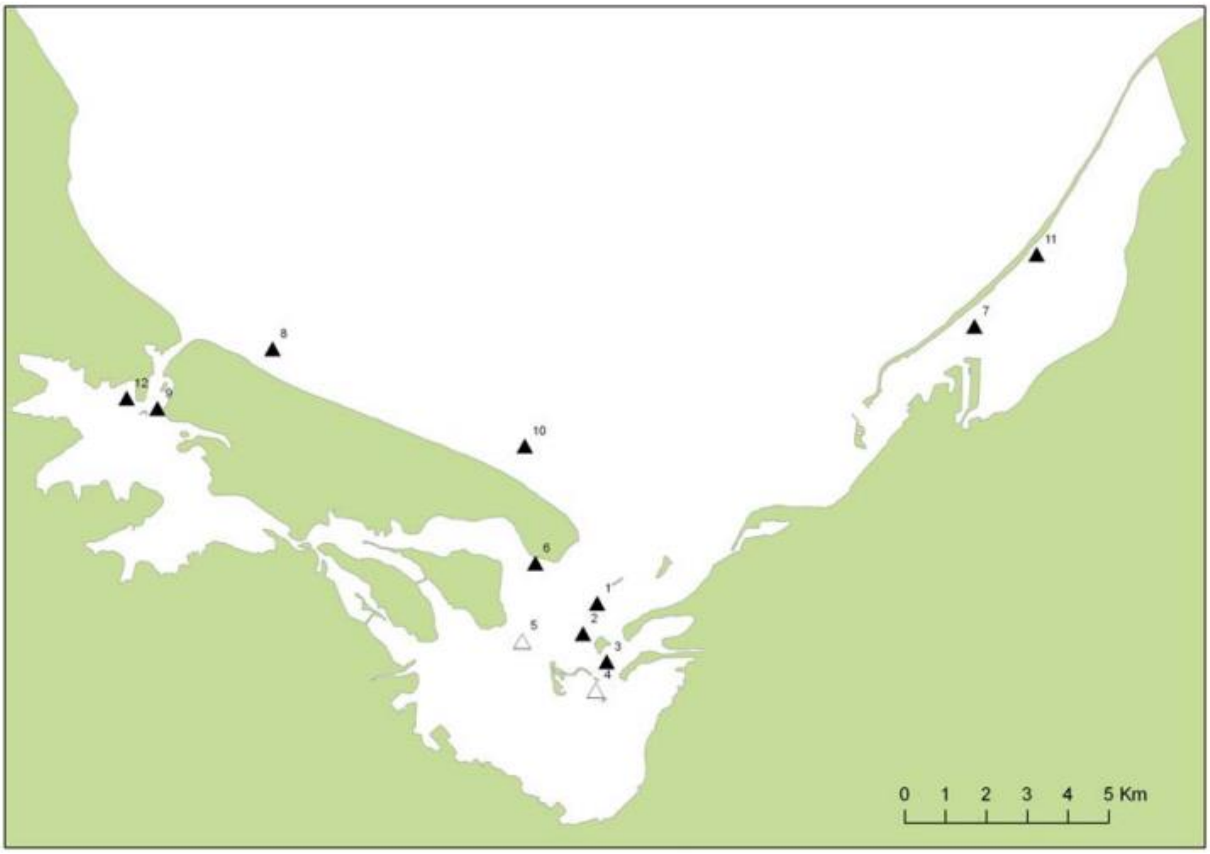


Figure B-1: Nelson area gillnet stations of Francis et al. (2012) targeting 0+ rig (none caught). White symbols indicate 'foul' sets where the net did not function well.

Appendix C Trawl survey catches in the adjacent coastal zone

The adjacent coastal zone

Research trawl fish catches were available from Tasman and Golden bays. In 1986 a trawl survey targeting juvenile snapper (<25 cm) was undertaken using two commercial pair trawlers, towing a net with the codend lined with 20 mm mesh to retain smaller fish (Drummond & Kirk 1986). Sampling was restricted to less than 10 m water depth in the two bays. Snapper catch was reported as size frequencies and number caught. Bycatch species were dominated by jack mackerel, red gurnard, trevally, ’flatfish’, and spotties. Fishing effort was recorded as the number of minutes towed at each station; no indication of net dimensions or area swept were given. For the purposes of this report, snapper catch rates were standardised to fish caught per 10 minutes of fishing.

In 1992, the R.V. Kaharoa west coast South Island Ministry of Primary Industries (MPI) research trawl survey series commenced, covering Tasman Bay, Golden Bay, and the upper west coast of the South Island. Surveys have since been completed in 1994, 1995, 1997, 2000, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, and 2021 (McGibbon et al. 2022), with a further survey scheduled for 2023. The trawl net is fitted with a 60 mm knotless codend, which limits the number of small fish caught. Prior to 2017, the shallowest sampling strata only extended in to 20 metres, from 2017 onwards two shallower strata of 10–20 m water depth for Golden and Tasman bays. For this report, fish catches from those two shallow strata (for the years 2017, 2019, and 2021) were standardised to fish/km^2, for species relevant to the Moutere and Waimea inlet fish assemblages.

Yellow-eyed mullet

Only adult, yellow-eyed mullet were captured by the MPI surveys, with fish ranging from 20–30 cm in length (Figure C1). Trawl surveys are generally poor at catching this species, with most fish likely to be near the sea surface and less vulnerable to bottom trawl. Relatively few fish were sampled, from a small number of stations (Figure C2). These larger adult, yellow-eyed mullet are not often caught/observed in estuaries. Available evidence points to estuaries and sheltered shallow coastal bay fringes proving nursery areas for smaller juvenile, yellow-eyed mullet (Morrison et al. 2002, Francis et al. 2005, 2011) which move with increasing size and age out to more open coastal areas, where large adult populations are likely (very limited empirical data is available). Here they provide forage for larger fish, birds, and mammals such as dolphins, though there is very little understanding of the role this abundant species plays in shallow coastal ecosystems. The juvenile, yellow-eyed mullet contribution provided by Moutere and Waimea inlets may be locally important; but without knowledge of how many juveniles are provided by potential alternative coastal nursery areas (e.g., the shallow fringes of Tasman and Golden Bays), no ranking of importance is possible. This issue of not having any estimates of the relative proportions of overall juvenile recruitment provided by different habitats, areas, and coastal features, is true for all New Zealand’s coastal fish species (Morrison et al. 2014c). The related issue of how the different populations are connected also remains largely known, beyond (nominally) key Quota Management System (QMS) fish stocks (yellow-eyed mullet are a QMS species, but of low commercial value).

Kahawai

Two size peaks were apparent in the trawl caught kahawai, at 14–19 cm, and 20–26 cm (Figure C1). Kahawai in general are poorly sampled by trawl, due at least in part to their often semi-pelagic nature. Most fish were from a few stations (Figure C2). Fewer fish were caught in 2021 relative to the other two years, with a size peak around 17–18 cm (six fish of this size were present in the 2021 Waimea Inlet gillnet catches. Larger kahawai >25 cm were present in the Waimea Inlet gillnet catches, but not the MPI trawl catches, likely to have been a gear effect. Kahawai schools are known to be mobile, and seasonal abundance cycles have been observed in shallow northern New Zealand estuaries, where kahawai become more common from April onwards as water temperatures drop (M. Morrison, pers. obs.). The kahawai sampled in Waimea Inlet were part of the larger population occupying Tasman and Golden Bays (or wider area), that extends into the estuaries depending on season and environmental conditions (as noted by Davidson & Moffat 1990 for Waimea Inlet). Juvenile 0+ kahawai (<10 cm length) were not sampled in Moutere or Waimea inlets, nor any of the estuaries sampled in 2006, with the stark exception of Port Underwood (see previous section). Alternative coastal 0+ kahawai nursery habitats/areas may exist along the relatively sheltered shallow coastal beaches of Tasman and Golden bays, which remain to be investigated. In north-eastern New Zealand, 0+ and 1+ kahawai have been caught using small hooks off central Bay of Plenty beaches, by recreational beach seine on some southern Bay of Islands beaches (M. Morrison pers. obs.), and on beaches within large estuaries (e.g., Manukau Harbour, Francis et al 2005).

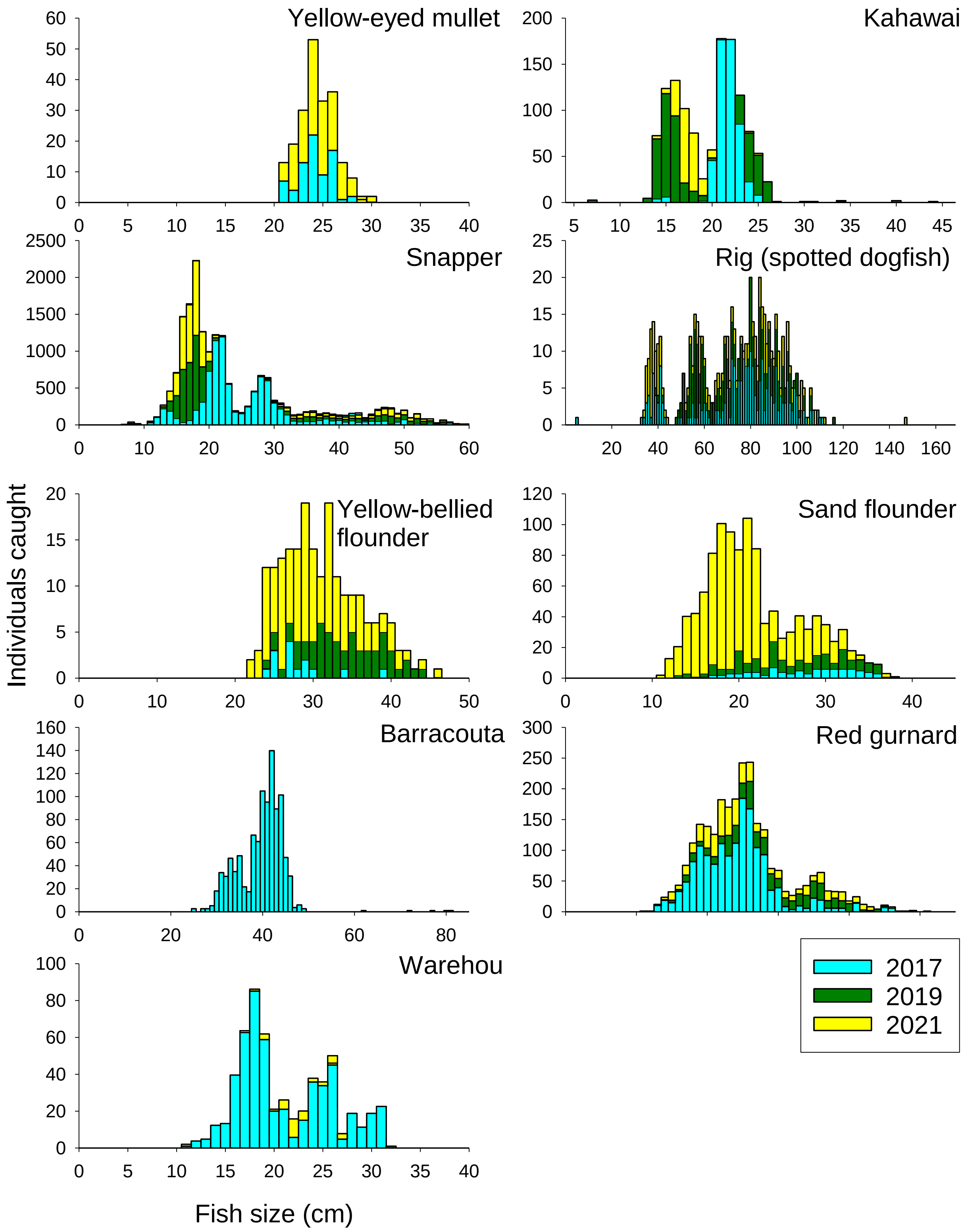


Figure C1: Summed raw length frequencies of selected MPI trawl survey species. Data from recent MPI R.V. Kaharoa trawl surveys of Tasman and Golden bays (2017, 2019, and 2021 years) (bars are stacked).

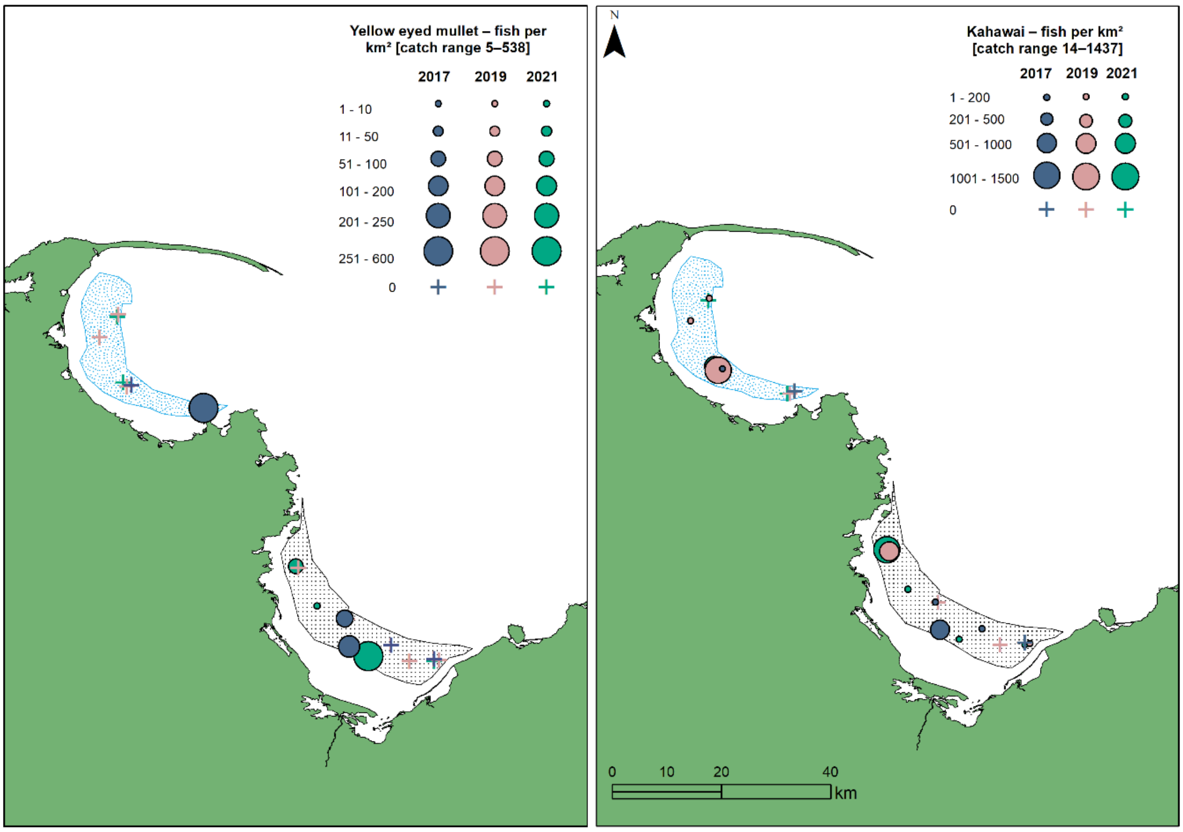


Figure C2: Catch rates (individuals per km^2) from R.V. Kaharoa research trawls in 2017, 2019, and 2021: left) yellow-eyed mullet, right) kahawai. Shaded polygons show the MPI trawl survey 10–20 metre water depth sampling strata.

Snapper

Snapper was a dominant species caught in both Drummond & Kirks 1986 survey, and the MPI trawl survey series. Drummond & Kirk (1986) sampled six stations in Golden Bay, and fifteen in Tasman Bay. Drummond & Kirk's report did not include full snapper length frequencies, but their plots of the higher catch station size frequencies showed a dominant snapper size class from 11–16 cm, along with numbers of adult fish at some stations, dominated by fish 25–35 cm in length (Figure C3).

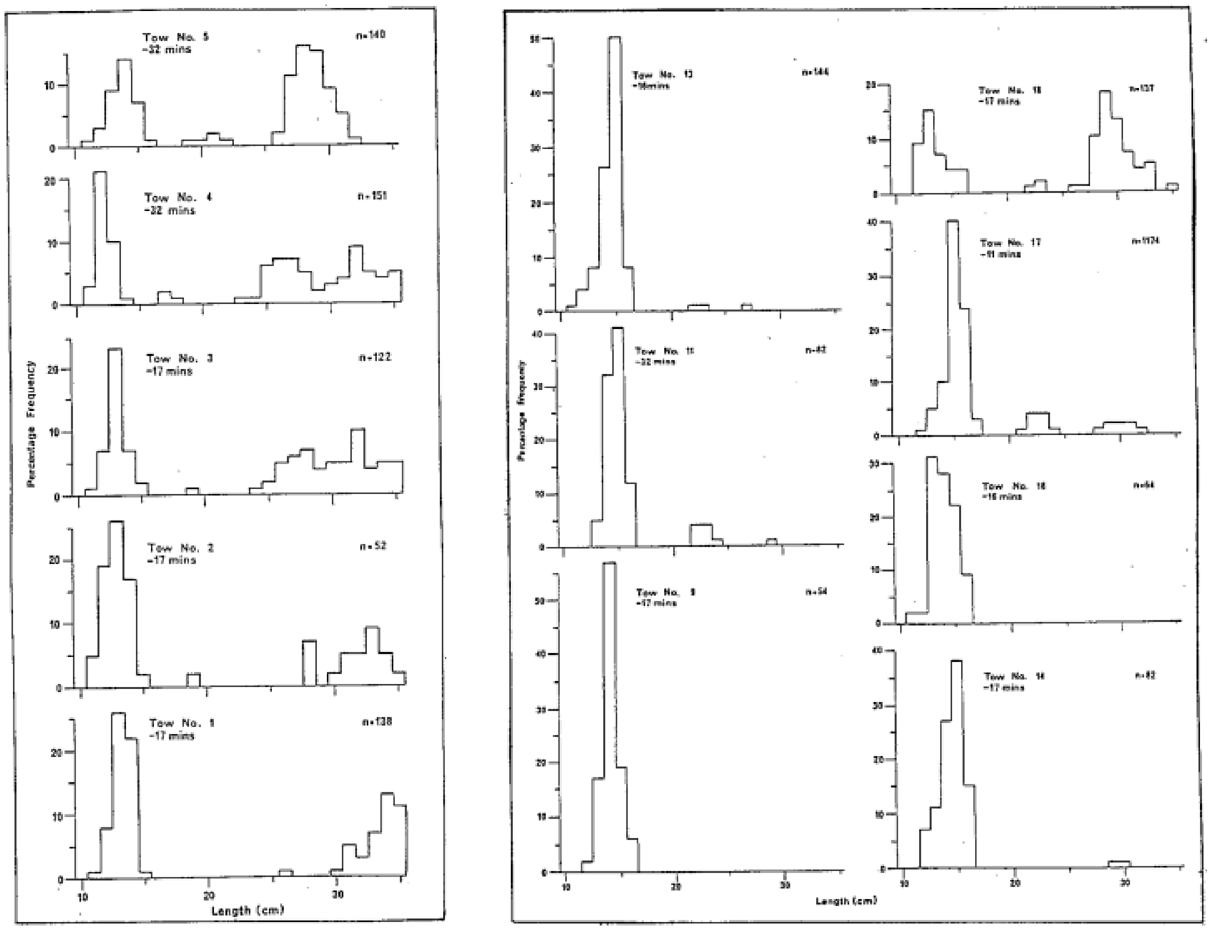


Figure C3: Snapper length frequencies of snapper from the highest catch stations of Drummond & Kirk (1986). Left) the five Golden Bay stations where snapper were caught, running from south to north; right) the seven highest snapper catch stations of Tasman Bay.

Drummond & Kirk (1986) provided snapper catch rates per station in length bins of <15, 16–25, 26–35, and >35 cm. Examination of the length frequencies plots (Figure C4) suggested no snapper <11 cm (0+ snapper) were sampled, which was unsurprising given the 20 mm cod-end liner, and sampling in February, when 0+ snapper would have been 1–6 cm long (Morrison et al 2014a). Snapper catch rates by size bin are given in Figures C5 and C6 (<15 cm and 16–25 cm size bins combined).

Eleven to sixteen cm long snapper (age 1+) dominated the 1986 catch, with this size/age class present in all of the Tasman Bay stations aside from the most eastern (in Wainui Bay), and all the Golden Bay stations, aside from the most northern and eastern stations. Notably, a particularly large catch of 1+ snapper was made just outside Waimea Inlet south, with 1,080 1+ snapper caught in a 11.5 minute tow (Figure C5). These results indicate that the shallow areas of both Tasman and Golden bays provide important juvenile snapper nursery habitat.

Subsequent to Drummond & Kirks's 1986 work, the SNA7 snapper stock (which includes Tasman and Golden bays) completely collapsed. The R.V. Kaharoa research trawl survey series started in 1992, with sampling strata from 20 m water depth to deeper depths (snapper was not a target species). In that intial survey, only 44 snapper in total were caught, including a few juveniles in the 18 to 25 cm length range. The following seven surveys from 1994 to 2007 caught no or only single digit numbers of snapper <25 cm; the 2009 survey revealed a juvenile size cohort in the 14–19 cm size range; while the 2011, 2013, and 2015 surveys returned no snapper at all <21 cm long, though numbers of adult snapper had started to increase (McGibbon et al. 2022). For the 2017 survey, two new shallow 10–20 m water depth sampling strata were added in Golden and Tasman bays (see shaded polygons in Figure 34) to explicitly target snapper. In 2017 a few small juveniles <21 cm were caught, followed in the 2019 survey by a relatively large number of juvenile 1+ snapper in the 12–20 cm size range, which was re-sampled as a strong 3+ cohort in the 2021 survey, two years later (Figure C4). The subsequent 2021 survey then returned a much smaller cohort of 1+ juveniles.

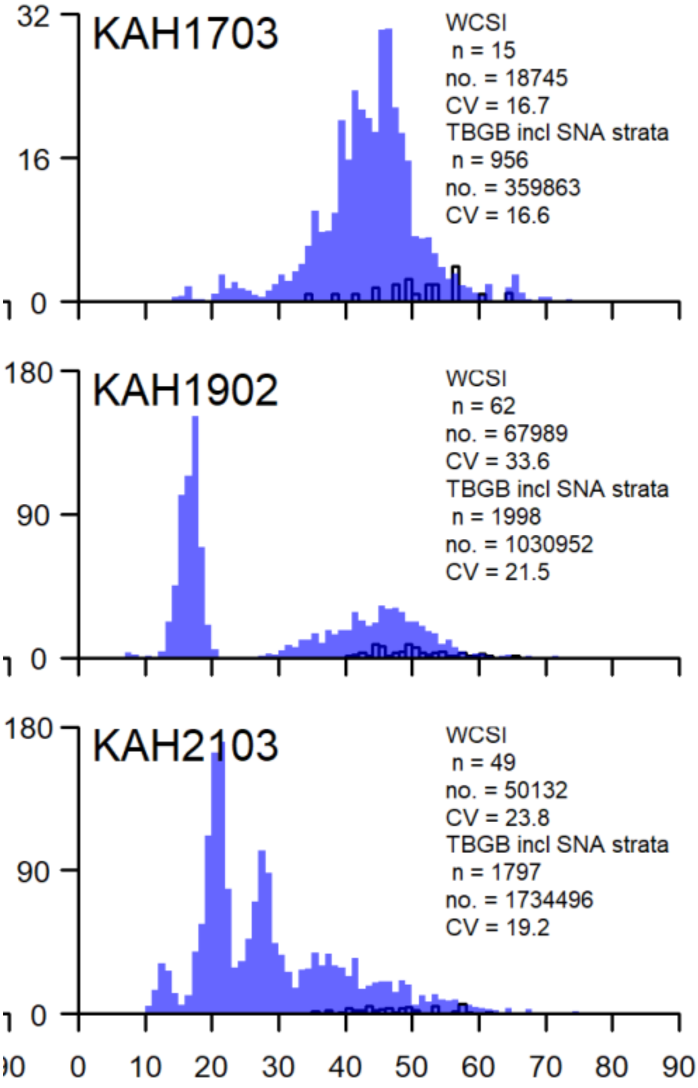


Figure C4: Scaled length frequencies of snapper catch (blue bars) from Golden and Tasman bays, from R.V. Kaharoa research trawl surveys in 2017 (voyage KAH1703), 2019 (voyage KAH1902), and 2021 (voyage KAH2103), for the two 10–20 m water depth sampling strata. Centimetre length bins are used. TBGB, Tasman Bay Golden Bay. (Source: figure 51 of McGibbon et al. 2022).

Low numbers of <11 cm snapper were caught in the 2019 survey at several stations (none caught in 2017 or 2021), with the largest catch (81 fish per km^2) in eastern Tasman Bay (Figure C5). Larger juveniles (11–25 cm) were rare in 2017, but appeared in the 2019 and 2021 surveys, where they were found across stations in both bays. The highest catch rate (8,242 fish per km^2) was taken north of Waimea Inlet south, in slightly over 20 metres water depth (Figure C5). Catch rates of larger snapper (25–35 cm, >3 cm) are shown in Figure 36.

Drummond & Kirks (1986) and the MPI trawl series are not directly comparable, as different trawl gear configurations were used; and the area swept by the Drummond & Kirk net was not recorded, with their tow effort measured by time rather than area-swept (in a pre-GPS era). An important caveat for the MPI trawl snapper data is that as a rebuilding stock is being sampled; so juvenile densities may not yet have increased/retuned to those representative of a healthy stock. Large inter-annual variations in recruitment strength are also common for snapper stocks.

Never-the-less, collectively these data clearly show that the inner areas (<20 m) of Golden and Tasman bays support juvenile 1+ snapper nurseries. Smaller 0+ snapper (<11 cm) are likely to be present also, although this remains to be empirically shown by survey. Work in the inner Hauraki Gulf has shown that 0+ and 1+ snapper co-occur (Compton et al. 2012); more broadly, Hauraki Gulf and East Northland 0+ snapper are concentrated in nursery habitat areas generally less than 20 metres deep (though they can extend to 30 m) (Morrison et al. 2019).

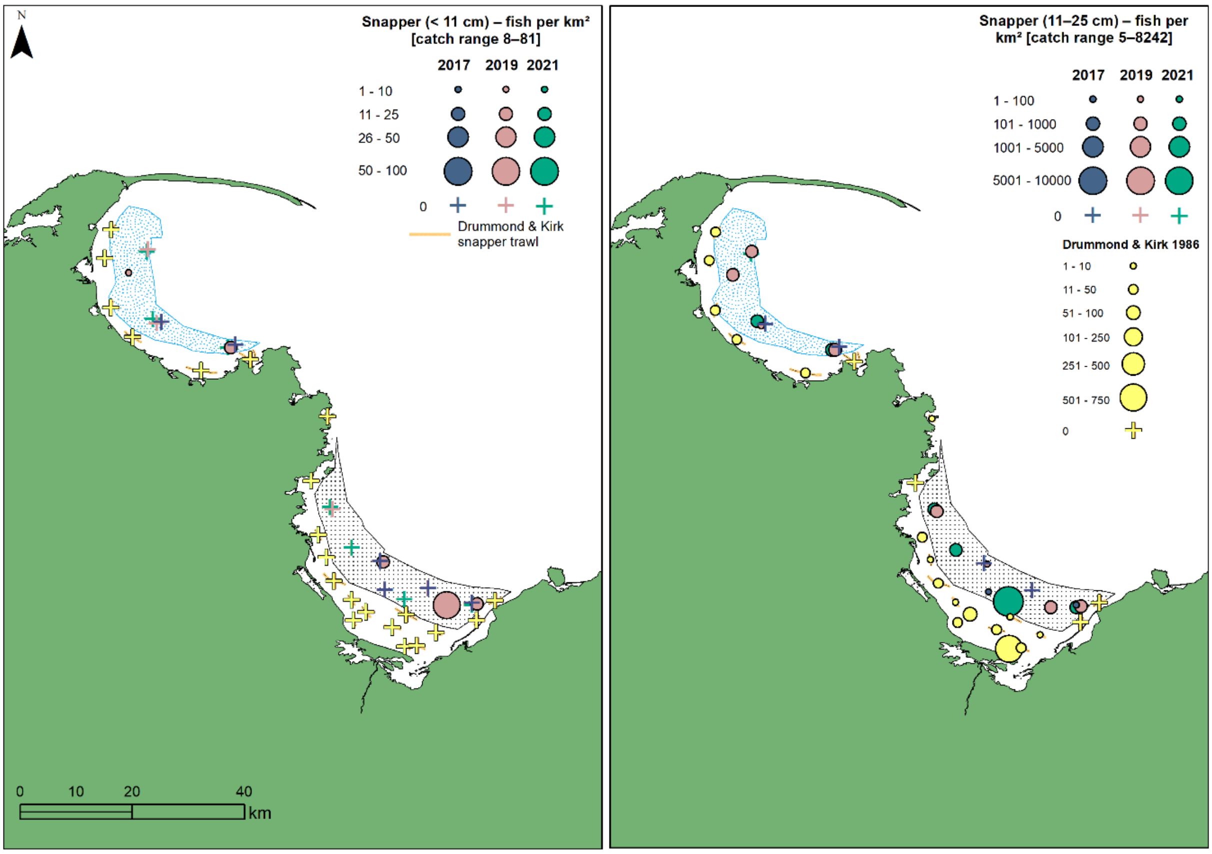


Figure C5: Snapper catch rates from Drummond & Kirk (1986) (fish per minute towed) and R.V. Kaharoa research trawls in 2017, 2019, and 2021 (individuals per km^2): left) snapper <11 cm; right) snapper 11–25 cm). Shaded polygons show the MPI trawl survey 10–20 metre water depth sampling strata.

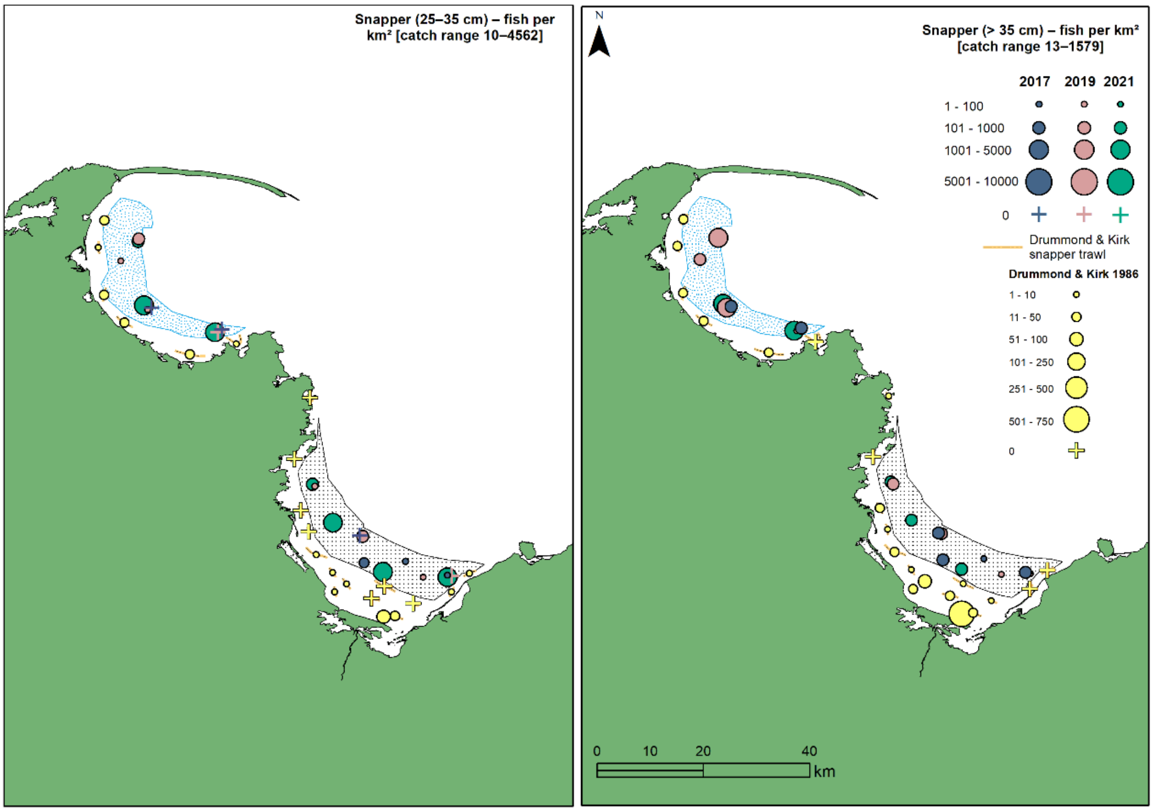


Figure C6: Left) snapper catch rates from Drummond & Kirk (1986) (fish per minute towed) and R.V. Kaharoa research trawls in 2017, 2019, and 2021 (individuals per km^2). Left) for snapper 25–35 cm; right) for snapper >35 cm. Shaded polygons show the MPI trawl survey 10–20 metre water depth sampling strata.

The Waimea Inlet 2021 gillnetting (10 stations) and the MPI 2021 trawl survey were completed in the same late summer period and are broadly comparable. The strong 2+ snapper cohort (centred around 21 cm) seen in the MPI survey (Figure C4) was also apparent in the gillnet catches of Waimea Inlet. While the age/length cohorts to either side of this strong 2+ cohort were clear in the trawl survey too few fish were caught in gillnets to define these clearly in the Waimea inlet data. The authors of this report have no local knowledge of seasonal snapper movements in the bays. However, in the NE of NZ, large snapper move seasonally into shallow waters including estuaries in the warmer summer months and move off to deeper water in the cooler part of the year.

Six small 0+ snapper were caught in Waimea Inlet (five by beam trawl, one by beach seine) which indicate that this estuary is likely to provide some nursery value for young-of-the-year (0+) snapper. Some 1+ snapper were also caught (six by gill-net, one by beam trawl), although these two methods are poor at catching snapper in this size range. Knowledgeable locals mentioned that the estuaries were at times ‘full of juvenile snapper’ (sizes not mentioned), suggesting that at times these estuaries do support large abundances of juvenile fish. It is important to note, as mentioned previously, that snapper year class recruitment strengths can vary strongly from year-to-year, and correspondingly, nursery habitats/areas may hold high abundances of fish in some years, but not in others.

Moutere Inlet, with its small and very shallow subtidal area, precludes it from providing a significant juvenile snapper nursery function. Waimea Inlet, with its larger and deeper subtidal habitat extent, is a more suitable location for supporting a juvenile snapper nursery. The 2021 fish sampling data suggests that it does not (only five 0+ snapper caught), but this may simply be the result of low snapper recruitment in 2021. Whether that is so will not be known until at least 2026 or later, when the 2021 snapper year class recruits into the adult fished population and starts to appear in MPI's ongoing commercial fish shed catch sampling (snapper catches are measured for length, aged, and the data to estimate the size/age structure of the snapper stock). The MPI trawl survey series is also continuing, with a survey scheduled for February/March 2023.

Rig (spotted dogfish)

Two clear smaller-sized fish peaks were apparent in the coastal trawl caught fish at centred around 40 and 58 cm, another at around 70 cm, and a broader range from 75 to 115 cm (Figure C1). Fish were caught in both bays but occurred at higher densities in Golden Bay (Figure C1). More fish were caught in the later 2019 and 2022 surveys. The Waimea Inlet gillnets caught 45 rig, too few fish to make out clear length modes, although a small group of five fish around 40 cm suggested a 0+ cohort, and larger fish spanned most of the size range seen in the trawl caught fish. Fish less than 46 cm are classed as 0+ pups (rig are live-bearers) (Francis et al. 2012), born in harbours in spring following a migration of adult females into the harbours, and then moving out to the open coast from February until May–June.

Francis et al. (2012) undertook a national survey of 14 estuaries in the North and South islands, searching for 0+ rig nurseries. Gillnets composed of 3 inch (76 mm) mesh, each 60 metres long, were set and left to fish overnight, in the same fashion as in this report. Around the top of the South Island, nets were deployed in Whanganui Inlet (7 nets), Farewell Spit and Golden Bay north (10 nets), Nelson (2 in Waimea Inlet north, 4 in Waimea Inlet south, 2 in Nelson Haven, 2 offshore of Rabbit Island), and Pelorus and Kenepuru Sounds (12 nets) (see Appendix B for the Nelson area net station locations). Only two 0+ rig were caught, from one net in upper Kenepuru Sound. Most 0+ rig were caught in the North Island estuaries. Based on these results, and a comprehensive review of all reports of 0+ rig in the literature, Francis et al (2012) concluded that "*There is no good evidence that any of the South Island harbours are important rig nurseries and it is not known where South Island recruits come from. Bays around the southern South Island, surf beaches and open coastlines less than 10 m deep warrant further study to determine if they are functioning as South Island nurseries*". They also suggested that "*an alternative hypothesis is that South Island recruits migrate south from the main North Island nurseries over their first few years of life*". The R.V. Kaharoa Golden/Tasman bays trawl survey series from 1992 to 2007 caught only a few 0+ rig. However, the surveys from 2011 onwards (after Francis et al.'s data collation) generally caught larger numbers of 0+ rig, suggesting localised nurseries in the bays (Figure C7).

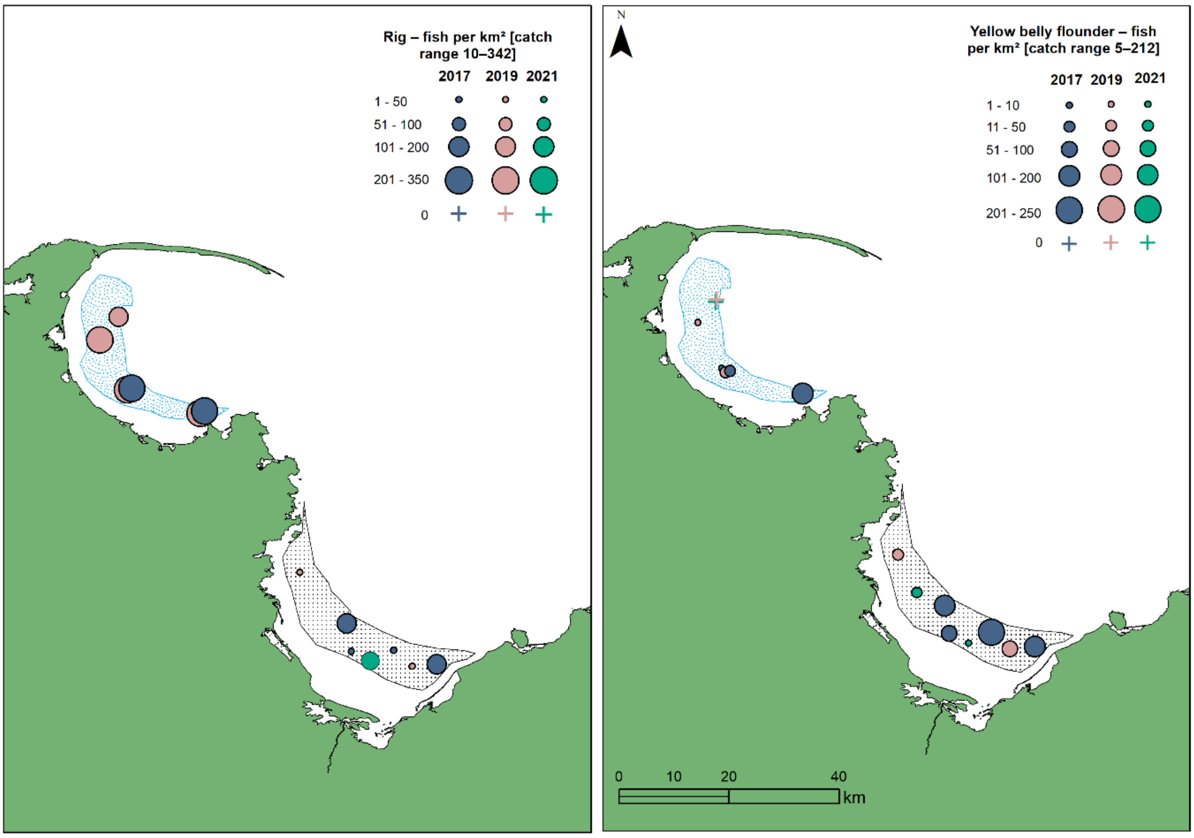


Figure C7: Catch rates (individuals per km^2) from R.V. Kaharoa research trawls in 2017, 2019, and 2021: left) rig (spotted dogfish), right) yellow-belly flounder. Shaded polygons show the MPI trawl survey 10–20 metre water depth sampling strata.

Although only five 0+ rig were caught in Waimea Inlet, it is considered likely to contribute to the spatial area of these possible rig nurseries. These five fish (371–400 mm long) were caught across three stations, with four of the fish caught in the ‘medium’ mesh panels (3.5 inches) and one in the ‘large’ mesh panels (4.5 inches). If the assumption is made that the 3.5 inch mesh (also used by Francis et al. 2012) was the best size mesh for capturing 0+ rig, and that 0+ rig are much less vulnerable to capture by the larger and smaller meshes; then the 48 metre long nets used were effectively only fishing for 0+ rig for twelve metres out of their 48 metres. If true, then 0+ rig abundances in Waimea Inlet may be higher than indicated. Francis et al. (2012) also cautioned (based on acoustic tagging work in Porirua Harbour, north of Wellington) that “*the availability and/or catchability of 0+ rig may fluctuate as a result of seasonal changes in abundance, movement of rig within and out of estuaries (perhaps in response to periods of heavy rainfall and reduced salinity (M. Francis, unpubl. data)), changes in water clarity, and changes in tide range (which impacts on current speeds and probably net efficiency)*”.

Yellow-bellied flounder

Yellow-bellied flounder were present in the coastal trawl catches as individuals 22 cm long and larger, with most fish falling in the 24 to 46 cm range (Figure C1). Most fish were caught in Tasman Bay (Figure C8) This species favours mud seafloors (though strangely they can also occur on surf beaches), in contrast to sand flounders, which range across a broader range of soft sediment types (Morrison et al 2014c). Juveniles <10 cm are abundant in estuaries around New Zealand, where they are found in upper estuary areas in close association with mud habitats (Morrison et al. 2002, 2014c, Francis et al 2005, 2011). Larger estuaries that have extensive intertidal mudflat extents (e.g., the

Kaipara and Manukau harbours) support large numbers of juvenile fish, in contrast to estuaries that are sand and shell seafloor dominated (e.g., Parengarenga and Rangaunu harbours, East Northland). Juvenile yellow-bellied flounder were present in both Moutere and Waimea inlets, but in low abundances only. In Moutere Inlet, the beach seine sampling covered almost all the low water areas available at low tide; similarly, most of Waimea Inlet was covered. Moutere and Waimea inlets do not hold higher density juvenile yellow-bellied flounder nursery areas (noting that as with other species, flounder year class recruitment strengths can vary from year to year).

Most yellow-belly flounder remain in estuaries into adulthood, although some move out into muddy coastal areas such as Tasman Bay and the Firth of Thames (Auckland region). Few adult yellow-bellied were sampled from Moutere and Waimea inlets. However, a caveat to this finding was the gillnets were set to sample the general fish assemblage rather than flounders per se. When explicitly targeting flounders, gillnets are ‘tied down’ to form a series of low-height pockets along the net; with ties used to bring the head-line and ground-line close together at intervals, so that net only fishes to around 30–40 cm in height, and forms pockets along its length. These nets are set on the edge of tidal flats, facing the direction in which flounder will be travelling (coming off the intertidal flats during the falling tide, or moving onto the tidal flats with incoming tides). Flounder are herded into the pockets, and ‘trapped’ there (often without being meshed), with the nets being retrieved so that the fish remain in the pockets during net hauling. If the net is not retrieved before the tide turns, most fish will simply swim out of the net with the reversed tide. In this study, the nets were not tied down, and were set out across the subtidal channels proper rather than parallel to the intertidal flats; to capture as wide a range of fish species as possible. They were not optimised to target flounders.

Sand flounder

Sand flounder were caught in the coastal trawl surveys in higher numbers than yellow-belly flounders (Figure C9) and ranged in size from 10 to 38 cm (Figure C1). Most individuals were caught in the 2021 survey, with a dominance of fish from 14 to 24 cm, and lesser numbers from 25 to 36 cm. This species inhabits a broader range of seafloor types than yellow-belly flounder, and its name implies, is often found on sand habitats. As with yellow-belly flounder, juveniles <10 cm are abundant in estuaries around New Zealand, co-occurring with yellow-belly juveniles in upper muddy areas. With increasing size and age, they move down into the estuary channels, and then eventually out to the open coast. Extensive tagging of large sand flounder juveniles in the three main estuaries around Banks Peninsula (Avon-Heathcote, Lyttelton, Akaroa), and subsequent tagged fish recapture in the commercial fisheries along the Canterbury coast, has clearly shown the connectivity between estuarine nurseries, and open coast adult stocks (Coleman 1978). However, it is unclear to what degree alternative coastal nurseries, if they exist, might also be contributing. Juvenile sand flounders are also caught on sheltered sandy beaches, and in beam trawl catches in deeper waters (<20 m).

Only low numbers of juveniles were caught in Moutere Inlet (12 by beach seine, one by beam trawl), while Waimea returned only one juvenile. Moutere and Waimea inlets do not hold high density juvenile sand flounder nursery areas (noting that as with other species, flounder year class recruitment strengths can vary from year to year).

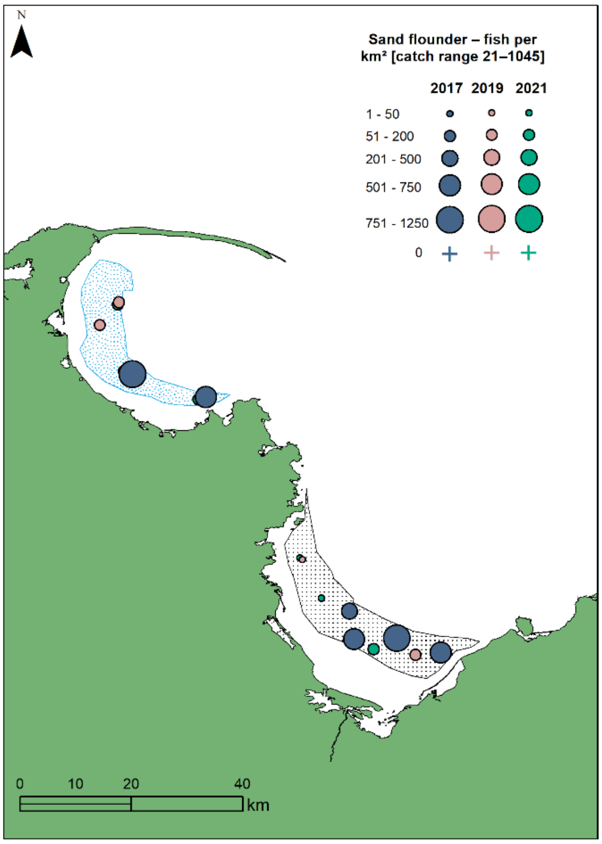


Figure C8: Catch rates (individuals per km^2) from R.V. Kaharoa research trawls in 2017, 2019, and 2021 of sand flounder for the inner shallow strata. Shaded polygons show the MPI trawl survey 10–20 metre water depth sampling strata.

Eagle rays

Eagle rays are usually not measured in trawl surveys, as they are not a commercial QMS species. However, they were included in the 2019 MPI trawl survey, with 21 fish from 15 to 35 cm captured. Most fell between 19 to 28 cm in length (measured from the snout to the end of the body proper)

Gillnet sampling in Waimea Inlet (2021) caught 24 eagle rays, from 35 to 60 cm (measured wingtip to wingtip), while one larger individual of 1 metre was caught by beach seine. No conversation factor is available to translate width measures to length measures. Regardless, most of these fish (both trawl and harbour) were larger juveniles and small adults. Eagle rays are live born, at sizes of 20–30 cm width.

Other species – trevally, school shark, red gurnard, blue warehou, barracouta

Several other fish species were abundant as adults in the Golden/Tasman Bay MPI trawl series but were only caught in Moutere and Waimea inlets (2021 survey) in low density or not at all. For completeness, these are briefly covered here.

Trevally

In the MPI trawl surveys, the 2019 survey caught 700 trevally ranging in size from 17–23 cm; while the present 2021 harbour survey caught 22 trevally, most 31–36 cm in length, with two at 21–22 cm. Coastal trawl catch rates ranged from 4 to 2,667 fish per km^2.

The 2021 estuary sampling caught three 0+ (26–38 mm length), and eight larger juvenile (190–279 mm, average 217 mm) trevally. This species is hard to sample well, as fish are semi-pelagic (occur as schools in the water column). They are sporadically caught in low numbers (single to several individuals) in beam trawl and beach seine surveys in northern North Island estuaries and sheltered coastal bays. Occasional larger catches (tens of individuals) (along with 0+ snapper) are made by beam trawl when a tow has inadvertently passed over a small patch reef in high current areas, often with significant net damage (e.g., in Kaipara and Aotea harbours). Larger single catches (100–200+ fish) have been made by beam trawl in some East Coromandel harbour entrances (e.g., Whangamata Harbour), associated with high tidal current speeds and periods of higher water turbidity. In these situations, the net is probably hard to visually detect, and fish are occasionally caught in large numbers. The capture of three 0+ trevally in Waimea Inlet hints at the possibility of larger numbers of 0+ fish associated with the reef/cobble habitats at the inlet entrances, and in the multiple high current channels connecting south Waimea Inlet to the open coast. The eight larger juvenile caught by gillnet further suggest a possible juvenile nursery function.

School shark

School shark were caught in low numbers in the MPI trawl surveys shallow strata with 39, 1 and 7 individuals caught in 2017, 2019 and 2021 respectively. Most of those animals were 0+ pups in their first year of life. Similarly, three 0+ school sharks (38–39 cm) were caught by gillnet in Waimea Inlet in 2021. Like rig, two of these three fish were caught in the medium mesh size, and one in the large mesh size; the same arguments about what part of the gillnet was able to capture small pups holds as for rig. Young-of-the-year school shark nursery areas are very poorly known for New Zealand.

Red gurnard

Red gurnard occurred in relatively high abundance in the MPI trawl surveys, with fish size ranging from 11 to 51 cm long, with most fish between 18 and 28 cm. Only one very small (1–5 cm) 0+ red gurnard was caught in Moutere Inlet by beach seine. Juvenile red gurnard are seldom sampled in estuaries, and when present are caught as sparse low occasional catches of one to several individuals (Morrison et al 2002, Francis et al. 2005, 2011). Estuaries are not a nursery habitat for this species; 0+ nurseries must exist somewhere along the open coasts around New Zealand but have yet to be discovered using appropriate methodologies.

Appendix D Long term observations by local residents

Taken from recorded interviews, edited/modified to remove less relevant material.

Interviewee A (born 1945) and their family has lived in the Waimea area for 165 years, on a family farm near Waimea Estuary by Pearl Creek. Land reclamation in the 1950s and onwards reduced the size of the mudflats in the area. Manuka Island was harvested in the early days for Red Manuka for fencing, in the 1950s it was all cut stamps, and only the slightly higher ground areas recovered. Interviewee A suggested that slow sea-level rise over 100-200 years had affected the lower lying areas, and that the big trees were able to withstand occasional inundation by big tides. Though once the big trees were cut down the Manuka never came back and was replaced by 'fine plant with white flowers'. With the arrival of Manuka blight into the country, it ruined all the manuka, which never grows to any size now.

Big flocks of birds seen in the past seem to have disappeared, they used to sit on the power lines on the farm. Australasian Bittern have become rare, although quite a bit of bittern habitat is re-establishing around the mouth of the estuary, now that the area has been fenced off to keep stock out. Marsh crake are present in Pearl Creek, along with the odd Banded Rail. There has been an increase in teal, with quite a few around, but not as many grey ducks as they have been shot out, mostly mallard ducks now. There are a phenomenal number of pukeko around now, attributed to the success of the trapping being done around here for stoats, and sometimes cats. O'Connor's/Eves Valley Stream has been modified and ruined. In early 1950s the creek had cock-a-bullies, koura, dozens of big eels (would tear up sheep if they got in there). Creek was ruined by the development of transport holdings up in the hills, used to be red manuka with sphagnum moss on ground, all through summer there were trickling streams and the creek was always running. Used to irrigate out of it. When they cleared for transport holding and put into pasture, it modified the creeks to the extent that when a flash flood occurred the level of water came up and went down fast. As compared to when sphagnum moss was there, when the creek would slowly come up and stay up for couple weeks before it went down again. One day (late 60's-early 70s) rained up on the hill where they'd just planted turnips, creek was brown water, eels trying to get away, wiped things out with all the fertiliser and soil coming down, knocked the creek right back and cleaned out a lot of the fish, then year or too later it went dry, with a dry summer, and that was the finish of the creek. Used to be freshwater mussels in that creek that were harvested by Maori, and flax was all up there too. When it dried out it stunk, everything was dead, it never recovered, it flows most of the year now but there's nothing much in it. The creek used to have meanders in it, but the catchment board bulldozed a straight track through, increased the slope of the water, undermined the banks, and degraded the creek. Pearl Creek used to flood, so they put in a causeway with a culvert and flood gate.

The establishment of causeways (Rabbit Island, Bells Island, Best Island) caused issues, family farm was getting flooded out, they modified the mouth of the river. Causeway restricted outflow; were flooded out three times in four years.

Saw a seal on Rabbit Island beach one day. Orca's come into the Nelson haven, and in behind the freezing works that are part of the estuary. Heard someone saw a school of barracouta (10-15 years ago), quite likely as the beach channel comes in.

Men that used to work for his father used to catch fish between Rough & Rabbit Island on an 11 o'clock tide "you couldn't miss" they said. They'd come tumbling through there and they'd catch them, big snapper, I think there were more around in those days. In the early days on Rabbit island, way back, when his mother first married, she'd look down the island and see black clouds appear and disappear, father said they were flocks of birds (I guess starlings or something), don't seem to get big flocks of birds like we used to get the odd one.

Definitely sharks in here in the early days, used to have an old hook over in the shed, father told me he used to put a bullocks heart on it and set it over on the mud flat. One of the men working with his father was fishing, water was clear and he wished he'd brought togs, until a shark came from upstream and ripped a great hole in his net.

I don't think it's changed much personally [the estuary] and I haven't heard them [parents/ancestors] say it's (mud flats) have degraded in any way. There's crab holes out there and to me it looks just the same except for pacific oysters, they've ruined the place can't go out bare foot now. Old people used to go to Mapua to catch rock oysters, still a few down there. Always been big floods come down. Mud flats never suffered contamination from logging. Maybe from chemicals from effluent or from urban areas. Freezing works used to dump blood and stuff; sharks used to come in (about 1940s). I have modified [my] fertiliser application. Nitrification of the water is a big worry, there's been some comment in paper, council is monitoring levels and they're going up. It's a big concern and something we're going to have to deal with.

Rough Island was covered in red manuka and some scrub-totara, that's been modified in my lifetime, broken in, manuka flattened and pine planted. Manuka compromised because of blight anyway, that's been a big change on Rough Island. Probably same on Best [Island]. Used to get big manuka on Bells [Island], unless it was kanuka. There wasn't a lot of kanuka around, mostly red manuka that was the prevailing cover around the edge of the estuary. Manuka Island was thick manuka and healthy, no black crap on it. To my thinking one of the big tragedies of the area is the deterioration of manuka due to blight (from 1950s on).

Rabbit Island. I guess was manuka and other native stuff, I think they planted a lot of the trees [pine] during the depression. used as a quarantine island in early days. Home guard and mounted troops were there and used to pinch fathers geese.

The [Waimea] River has chopped and changed a bit over the year, degraded from early days. Steamer ran from Nelson up to Brightwater. Rivers degraded and gravels built up. Big stop-banks have stopped the rivers coming through. Waiti River used to roar right through here. Flooded right through here. Flood situation for us has improved a lot over time. Big tide flooded farm in 1908, 1953 & 54 (tidal flood usually every 50 years, except happened again '54), again couple of years back, salt water flowed in. Get the odd tide like that about once every 50 years.

Interviewee B has had an association with Moutere Inlet for twenty years.

White-baiting down there in the whitebait season. Usually fish [whitebait] on the Motueka River, not the prettiest spot. Sometimes go to the Moutere River for a whitebait if Motueka is flooded. Only fishing a small piece of the whole estuary at the mouth of the Moutere Creek [River]. I don't fish it too much anymore, not very often, I'm not down there every day. Also flounders and duck-shoots. Sees herring [likely, yellow-eyed mullet] and garfish when floundering.

It's pretty much stayed the same. Where we whitebait has changed a little bit from flooding (just gravel movement). River changes a little from gravel moving and floods. It's probably more siltier down there now [at the Motueka River], possibly in the Moutere as well there's probably more mud and silt getting left behind after big flood events, whether that's from forestry or run off, river seems to run dirtier nowadays when we have rain. Seems to be more mud and silt out there in the estuaries rather than [the] sand and rocks that there used to be.

Motueka River mouth - big changes with flooding. A lot of gravel loss out the river, out the mouth. Used to be big rush beds out the front that have all disappeared. And big gravel banks that have disappeared. Over the last 5–6 years. Last big flood done a lot of damage. Washing away gravels bars and rushes. Noted the river flow seems to get down the river quicker with getting rid of trees that used to slow the river up, now rock walls/big boulders which speed the river up, could be part of the problem, whether that's having an effect?

White-baiting and floundering (has been same over time), we have good years and bad years but a lot of that's climate. If we have a good wet spring we have good whitebait, if we have a real dry spring it's not as good. Wouldn't want to see it [the estuary] get degraded anymore. Good to see native tree planting at sides of creeks at head of Estuary.

Interviewee C has had an association with the Moutere Inlet for 30+ years, starting as a child; their father also lived in the area.

Looks like its silting up from what it was. Flock of spoonbills turn up that didn't use to be there when younger, on north side Wharf Road. Jackett Island is eroding away on the outside, over last 10 years, front edge. Sand bar out front has moved along. Down Kina Peninsula that whole end has taken a hiding over last few years.

In father's time the tide used to do [go] further up, right up to High St, Road put across [the coastal highway, built when he was a kid], on inside has been drained and turned into paddocks [during father times], clinker boats use to get up to back door when living on High St south, before that.

Still seeing plenty of herrings [probably yellow-eyed mullet] in the estuary.

Interviewee D. Involved with Moutere Inlet since the 1960s, grandparents lived up road as well. Mainly duck shooting and a bit of fishing.

Since the chip mill, fertiliser works and the sewage plant went into the Inlet, its changed the whole environment, a lot of silt coming down. Used to be able to walk over, can't now there's that much silt build up. [Sediment] used to be firm but now there's that much silt you'd be up to your knees.

Destroyed the shellfish out in the bay. Used to fish for oysters out there.

Ducks was thousands of ducks in the inlet. Everyone had wheat crops and food growing, ducks everywhere. Totally different place to what it is today, mind you there's more people [now].

More people encroaching on the edges of it everywhere and that changes it.

Habitat of rabbit and hares that used to live on the edges is disappearing.

Subdivision Queen St, Richmond, used to be farmland [modification of land around estuary]. Farmland now houses so going to be an increase of water come down those creeks.

Not so many fish around now, they don't seem to come in here. In the old days they did, used to get the biggest snapper in there. Used to catch lovely herrings that you could eat, wouldn't eat them now. Looks clean when the tide comes in but when it goes out it ain't.

Plenty of flounders. Father and I, used to go to out and catch half a dozen great big snapper.

Was a nice place, had rushes, the whole foreshore had macrocarpa trees right round it, from freezing works to the island was macrocarpa trees right round the edge, was a lovely place.

Quite a lot for the fish [natural values the estuary provides], going in there to spawn, flounders whitebait, the whole lot go in there and use it. Pretty important place.

I rate it pretty top. Would like to see it get looked after

One thing you can tell about the Inlet, if it’s healthy there’s always that lovely green lettuce grass in there (can see from the motorway).