Table 8:

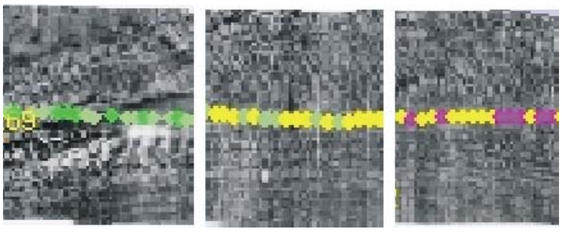
Subtidal epibenthic habitats (derived from video and dredge) and ecological communities (derived from grab sampling) observed in the different side-scan derived seafloor types.

Side-scan seafloor type	Epibenthic habitat	Ecological community
1. Sand waves	Mainly bare, *Fellaster*, *Fellaster*/gastropod, Gastropod	Epibenthos, *Fellaster*, Bivalve-suspension feeders
2. Mega ripples	Mainly bare, *Fellaster*, *Fellaster*/gastropod, Filamentous weed, Hydroids (only in sheltered areas, with smaller ripples)	*Fellaster*, Large animals, Bivalve-deposit feeders, Bivalve-suspension feeders, Surface bioturbators, Sedentary epibenthos, Polychaete- deposit feeders
3. Small wave ripples	Hydroids, *Fellaster*/gastropod, Gastropods, Mainly bare	*Fellaster*, Surface bioturbators, *Musculista* , Bivalve- suspension feeders, Bivalve-deposit feeders, Epibenthos
4. Confused ripples	*Fellaster*, *Fellaster*/gastropod , Gastropod, Hydroids, *Zostera*, Filamentous weed,	*Fellaster*, Large animals, Bivalve-deposit feeders, High diversity-surface bioturbators, Surface bioturbators, Burrowers
5. Channel banks	*Fellaster,* Hydroids, Sponge-weed	*Fellaster,* Bivalve- suspension feeders
6. Rubble	Rubble, Mainly bare	*Atrina*, Sponges, High diversity-large animals
7. Shell lag	Fellaster, Musculista	Fellaster, Musculista
8. Flat mud/sand	Gastropod, Epifauna complex, Hydroids, Sponge-weed, *Musculista* , Burrows, *Atrina*	Bivalve- deposit feeders, *Fellaster*, All high diversity community types, Sponges, Large animals, Sedentary epibenthos, Tube-dwellers, Surface bioturbators
9. Smooth sand with sparse dark spots	Mainly bare with high density patches of *Fellaster* and dead gastropod shells	Fellaster
10. Potential artefacts	*Fellaster*, *Fellaster*/gastropod, Sponge-weed, Hydroids	*Fellaster*, Large animals, Sedentary epibenthos, Polychaete predators/scavengers, Surface bioturbators

Examination of the video and dredge samples suggested shell lag areas could be comprised of broken shells, Umbonium shells and, sometimes, live *Fellaster*. The occasional dark spots observed in the side-scan data area in the central harbour seemed likely to be composed of patches of dense *Fellaster* or dead gastropods. Areas of potential artefacts in the side-scan image harboured a range of epibenthic habitat types (*Fellaster*, Gastropods, Sponges and Hydroids), which may well have been being picked up by the side-scan. Ecological communities found in the different seafloor types were equally varied (Table 8). Comparisons made between the seafloor types, and the count data for all taxa derived from the grab samples revealed that none of the seafloor types exhibited a significantly different community ($p > 0.05$). Furthermore, there were no significant differences in the numbers of taxa found in different side-scan seafloor types. However, while the side-scan seafloor types could not discriminate ecological communities, some taxa and ecological information were well related. Discriminant analysis between the side-scan seafloor types and the video and dredge data revealed that, with a spatial component (Easting) built in, % of coarse sediment, degree of bioturbation and rank abundance of *Musculista* and sponges were related to some of the seafloor types (1,3,5,7,8,9). A further attempt was made to link the side-scan data to the ecological data using the size of the ripples recorded in the side-scan as a predictor. However, no significant relationships were observed for any of the widespread taxa.

Visual inspection of the QTC data revealed that, while frequently a single class covered an extensive area, some areas were comprised of a mix of two QTC classes (Figure 15). This led to an extension of the QTC classes to 9. The extended classes comprised: a mix of class 2 and 4; a mix of class 4 and 5; a mix of class 3 and 5; and a mix of class 1 and 5. Comparison of the QTC classes with the count data from the grab samples revealed that no significant difference was apparent between communities in the different classes. While the p-value for this was barely nonsignificant ($p = 0.056$), pairwise comparisons revealed only two comparisons significant at the 0.1 level (differences between classes 4 and 1, and between classes 5 and 6). There was also no significant differences between different QTC classes In terms of number of taxa, number of orders or total number of individuals ($p > 0.05$).

Figure 15:
Sections of side-scan with mixed classes of QTC data superimposed. Different QTC classes are displayed with different colours. Mixed colours over a small area suggest a different habitat than an area with only one colour.



Nor was there a better relationship between the QTC classes and the epibenthic habitats derived from the video and dredge data, or the ecological communities derived from the grab sampling (Table 9). Although there were some habitats and communities that only occurred in certain classes (e.g., class 5 had a number of the large epifauna communities), there was also considerable overlap. Similar to the side-scan data, however, while the QTC classes could not discriminate ecological communities, some taxa and ecological information was well related. Discriminant analysis between the QTC classes and the video and dredge data revealed that depth and rank abundance of *Fellaster* and gastropods were related to the QTC classes. When depth was removed, bioturbation, and rank abundance of seaweed and *Zostera* became important, but the relationship decreased to an association with classes 4 and 5 only.

The original five QTC classes all overlapped a number of side-scan seafloor types (see Table 9, Figure 16). However, 2 of the 4 derived classes were comprised of a single side-scan seafloor habitat. In both cases these habitats were not spatially extensive nor did the side-scan seafloor type they represented occur only in that QTC class.

Figure 16:
A QTC class (yellow dots) overlapping a number of different seafloor types observed with side-scan data.

Table 9:

Side-scan derived seafloor types, subtidal epibenthic habitats and ecological communities observed in the different QTC-derived classes.

QTC class	Sediment type	Epibenthic habitat	Ecological community	Seafloor type
1	Fine to medium sand	Only one sample 9	1,2,3	3,8,9,
2	Mud to medium sand and coarse, sandy muds	2,4,5,6,9,10	8,9,1,6,7,5,11	5,4,2,8,1
3	Mud to medium sands	7,11,9,8,6,10,5	9,10,3,6,7,12,11 ,15,4	5,4,7,2,8,10,3,1
4	Fine to coarse sands	8,10,5,3,4	1,3,6,5,15,4	5,9,10,1,2,3
5	Fine to sandy muds	2,8,10	1,3,5,4,2	2,8,10,3,4
6	Fine to medium sands	3,4,6,8,9	10,3,7,11,14	4,2
7	No samples	No samples	No samples	2, 4
8	Fine to medium sands	1	2,3,6,8,11	6
9	No samples	No samples	No samples	3

Past research has demonstrated that difficulties in linking acoustic data to ecological data is frequently due to: variability in ecological data at a scale below that of the resolution of the acoustic data (Thrush et al. 2003a); a heterogeneous but not strongly differentiated substrate to which the ecology responds in a variable way (Hewitt et al. 2004a); or ecological responses that are not completely driven by the environmental factors that the acoustic data reflect (e.g., predation, recruitment). With the strongly rippled surface that comprises much of the surface of the Southern Kaipara seafloor, it is not surprisingly that the ability of acoustic data to detect smaller relief features such as bioturbated areas, sponges or *Atrina* is limited. Furthermore, it is important to remember that associations between environmental factors (e.g., depth, sediment type, current speed) and ecology only represent what may be found, assuming other factors do not compromise the relationship (e.g., over fishing, water clarity, chemical contamination).

The variable epibenthic habitats and subtidal communities found in the side-scan seafloor habitats and the QTC classes make it difficult to use these data to generate ecologically significant habitat maps. For this reason, we have provided these data as GIS layers but have not produced a habitat map from them.

Over the range in depths sampled in the Southern Kaipara, only three depth classes contained significantly different communities (the intertidal, the shallow subtidal and the > 3 m), although a number of taxa also demonstrated a preference for > 15 m. Generally, large-scale features did not prove particularly useful for the mapping of either sediment particle size or ecological characteristics. As expected from previous work, the flora and fauna of both the intertidal and subtidal areas of the harbour displayed the ability to occupy a number of different sediment types and physical environments. Even *Zostera* beds did not contain distinctly different communities overall. The one large-scale feature that did have a distinctly different community was the mangroves (> 50 % cover), with community change gradually occurring from this habitat to low density mangroves and non-vegetated mudflats through to areas with coarser sediments.

5.5.2 Final habitat and ecological descriptions of the Southern Kaipara

There were distinct differences between the types of fauna and communities found in some areas of the harbour. Prompted by the obvious spatial differences observed in the widepread taxa (Tables 4 and 7), the Southern Kaipara was divided into 7 intertidal and 8 subtidal areas (Figure 17). The 7 intertidal areas were the Oruawharo (O) and Tauhoa arms (T), the upper part of the Kaipara River arm (U), the eastern and western areas of the outer Kaipara River arm (E and W), the area of sand dune areas oppposite the mouth (Ex), and Waonui Inlet (I). The 8 subtidal areas were the Oruawharo (O) and upper Tauhoa arms (UT), the upper and middle area of the Kaipara River arm (U and M), the high current area near South head (H), the shallow subtidal area between the Kaipara River and Tauhoa arm (S), the exposed deep area in the mouth (Ex) and the outer area of the Tauhoa arm (OT).

These splits were confirmed by analysis of dissimilarlities between the species found in areas, with all areas being different from at least one other area ($p < 0.05$ ANOSIM). In the subtidal area, the high current (H) and shallow subtidal areas (S) were different to all other areas. Other differences were UT compared to Ex and M, Ex compared to M, O and UT, M compared to O, OT and UT, and O compared to OT and UT. There were differences within these areas driven by sediment characteristics. There were more overlaps between areas intertidally but a number of differences still occurred: W compared to W and I, U compared to E, O compared to T, Ex, E and I, T compared to Ex and I, Ex compared to E and E compared to I. The strong differences found between species observed in sand, mud, mangroves and Zostera habitats led to each intertidal areas being further subdivided on this basis.

Area U (the upper area of the Kaipara River arm) had five main habitat types: mangroves of varying densities, unvegetated intertidal mudflats ranging from muddy to very muddy (>50% mud) and sandflats; a small area of intertidal *Zostera* and subtidal muds. The mangrove communities were all dominated by burrowing animals, while the communities in the mud were more variable, comprised of deposit-feeding bivalves and polychaetes, surface bioturbators, tube dwellers and polychaete predators/scavengers. The *Zostera* supported a *Macomona* community, the unvegetated sand areas also had *Macomona* dominated comunities, as well as deposit-feeding polychaetes, suspension-feeding bivalves, *Austrovenus* and tube dwellers[2]. The subtidal area was composed of 4 ecological community types: deposit-feeding bivalves, tube dwellers, sedentary epifauna and surface bioturbators.

The Tauhoa arm had a similar range of intertidal habitat types. Similar to the upper area of the Kaipara River arm, the mangrove and *Zostera* communities were predominantly

[2] The presence of invasive communities is discussed in a separate section

burrowers and *Macomona*-dominated respectively. However, in the low density mangroves some *Macomona* were also observed. In the sandy areas deposit-feeding polychaetes, *Macomona* and tube-dwellers were dominant. The subtidal area was divided into an upper and outer area, although these were not statistically significant from each other. The upper area was generally comprised of finer sediments and was shallower (< 7 m) with a more diverse range of ecological communities (deposit-feeding bivalves, surface bioturbators, tube-dwellers, predatory/scavenging polychaetes, large fauna and invasives). The outer area displayed burrowing, tube dweller and large fauna communities. Both areas frequently had high order diversity.

Area S (the shallow subtidal area between the Kaipara River and Tauhoa arms) was one of the most diverse areas. The sediments were predominantly fine sand and a number of ecological communities were observed (deposit-feeding bivalves, sedentary epibenthos, sponges, tube-dweller, large fauna, surface bioturbators and invasives).

Although mangroves on the eastern side of the Kaipara River arm were not sampled, the overall similarity in communities found in the mangroves across the Southern Kaipara suggest they are dominated by burrowing animals. The muddy areas were dominated by tube dwellers. The *Zostera* communities were very variable; dominated by *Austrovenus*, *Macomona*, deposit-feeding polychaetes, tube dwellers, polychaete predators/scavengers or surface bioturbators and varying from high to moderate diversity. Sandy areas were also variable in fauna, varying from *Austrovenus*, *Macomona*, deposit-feeding polychaetes, tube dwellers to surface bioturbators, although diversity was generally lower than in the seagrass.

Mangroves on the western side of the Kaipara River arm again were dominated by burrowers, although in lower density areas an *Austrovenus*- *Macomona* community was observed. Muddy areas supported *Austrovenus*, *Macomona* and tube-dweller communities. *Zostera* communities were dominated by *Austrovenus* and *Macomona*, while the unvegetated sand supported a number of different communities (suspension-feeding bivalves, deposit-feeding polychaetes, tube-dwellers, polychaete predators/scavengers, surface bioturbators and *Macomona* dominated); frequently of high diversity.

Area M (the middle subtidal area of the Kaipara River arm) was generally of low diversity with sandy muds to fine sands. Ecological communities varied from suspension-feeding bivalves, tube-dwellers, surface bioturbators, large fauna and *Fellaster* dominated.

The high current area by South Head was another very diverse area, comprising the steep rock walls, the rubble habitat and the sandy channel bottom. Apart from the highly diverse communities on the rock walls and rubble, Fellaster, surface bioturbators, sedentary epifaunal communities were common.

Waionui Inlet had no *Zostera* and the mangoves were not sampled. Unvegetated mud communities were dominated by deposit-feeding polychaetes; these were also found in the sandy areas. Other sandy communities were dominated by *Austrovenus* and surface bioturbators.

Zostera was also not observed in the Oruawharo arm. Mangrove communities in this arm were different to those in other mangrove areas, often having the small deposit-feeding bivalve (*Arthritica*) and polychaete predators/scavengers as well as burrowers. The muddy areas were dominated by either polychaete predators/scavengers or deposit-feeding bivalves. The sandy areas were usually sandy mud and were dominated by *Austrovenus*, often with *Macomona*. Subtidal areas in this arm were mainly muddy comprised of deposit-feeding bivalves, sedentary epifauna and *Fellaster*-dominated communities. Further towards the mouth, more surface bioturbators, tube-dwellers and communities dominated by large fauna were found.

The three main habitats opposite the mouth were intertidal *Zostera* and sand and subtidal sand. *Zostera* communities were dominated by a mix of large animals and dead cockle shells were common. The intertidal sand area communities were variable with *Macomona*, tube-dwelllers, surface bioturbators, deposit-feeding bivalves and polychaete predators/scavengers dominated communities found. Subtidal communities were predominantly *Fellaster* and surface bioturbating gastropods.

Figure 17:
General habitat areas of the Southern Kaipara.

6 Conclusions

6.1 Tier II monitoring design guidelines

This project is an ambitious survey of half of the largest harbour in the southern hemisphere. Although in recent years we have begun to research methods for integrating new acoustic techniques with traditional biological sampling to provide ecologically relevant maps, this is ground-breaking research and there is no simple way forward. This section will discuss the philosophy of the Tier II monitoring design, information requirements, the cost-effectiveness of various sampling methods and the use of various analytical techniques. The Tier II section of ARC's regional monitoring network focuses on providing resource information (i.e., spatial patterns of habitats and descriptions of ecological communities). This information has to be both extensive enough and precise enough to enable assessments of major change over a 10 – 15 yr time scale.

Sampling large-scale habitat features

A first step in habitat surveys is generally to focus on large-scale habitat features that can be sampled continuously (or nearly so) in a cost-effective fashion.

Intertidal

Intertidally, such features are generally sampled by aerial photography. However, extensive aerial photographs covering the whole of the intertidal that are not compromised by cloud cover and actually have been taken at dead low water are difficult and frequently expensive to achieve. The larger the area, the more difficult and expensive. Furthermore, frequently the aerial photographs are not taken in the same year as the other sampling (as in this project). While effort should be placed into gaining aerial photographs, it is important that the effort is only proportional to the information they provide (i.e., estimates of mangrove, *Spartina*, *Zostera* and non-vegetated areas). This information, while important in providing a map of ecological resources, is not information that will reveal vulnerabilities to many anthropogenic impacts or provide a strong base from which to describe ecological values at a less general level (e.g., biodiversity, shellfish distribution and abundance). Our work in this project using a helicopter suggests that video transects run from a helicopter can be useful in (a) quickly ground truthing aerial photographs and determining whether old photographs are still useful, (b) providing more information on sediment type and (c) replacing aerial photography when weather and/or size of the area makes aerial photography[3] excessively costly. In future, if increases in satellite coverage continue, satellite imagery may prove to be a useful alternative for characterising broad-scale features. At present, lack of tidal height data is a difficulty, particularly for smaller estuaries where even the limited chart data available for the Southern Kaipara is non-

[3] Infra-red aerial photography that allows better definition between vegetation types and vegetated and non-vegetated areas should be used whenever possible.

existent. However, in future bathymetric information may be more readily available as the necessity for assessing risks associated with storms and tsunamis becomes more accepted.

Subtidal

Subtidally, the usefulness of collecting continuous large-scale data is less clear. Increasingly in subtidal areas continuous large-scale data is becoming synonymous with acoustic data. In the methods section, three available tools and the rationale for selecting side-scan for use in this project are discussed. To recap, in water depths < 30 m (which the majority of the Southern Kaipara is), side-scan is the most cost effective tool. There are a number of problems associated with the use of acoustic techniques.

(1) Technically multibeam and QTC can be used in shallower waters than can side-scan (i.e., < 7 m), but in reality the low coverage and the loss of signal clarity generated by small waves, and vessel safety issues, mean that regardless of the acoustic tool used, this depth range is difficult to sample.

(2) Acoustic data is expensive to collect over large areas, for example collecting and analysing the data in the Southern Kaipara (which excluded both the shallow subtidal and the extensive area near the mouth) took 40% of the study cost. An area the size of Kawau Bay would cost much more, resulting in the necessity to take a transect approach with all the resultant errors associated with interpolation between transects.

(3) A final problem, well demonstrated in this project, is the ability to separate the acoustic data into physical or ecological habitats. In this project, neither the side-scan nor QTC data were well related to ecological habitats, although the side-scan did represented a number of distinctive physical features. This finding is location specific and probably related to the strong tidal currents and wave energy in the harbour; side-scan data in other locations has related well to ecological habitats. Most of the area in the Southern Kaipara, deep enough to be acoustically surveyed, is predominantly sand disturbed by waves or currents. Importantly, the high degree of small-scale variability such as has been found in the Southern Kaipara has always proven to be difficult to capture using acoustic techniques (Thrush et al. 2003a, Hewitt et al. 2004a).

At the heart of the problem of linking ecology and acoustic techniques are two factors. (i) Some areas have high small-scale ecological variability, which can not always be resolved with increased sample replication. If these areas have ecological communities that, although highly variable, do not occur elsewhere then they may be identified and separated out, although their descriptions may be of little use to someone attempting to monitor changes. If, however, as often occurs, some of these communities also occur in other areas, this may prove to be an untractable problem. (ii) However, the analytical tools for analysing acoustic information in relation to ecology is still in its infancy. It is now recognised that advances can only occur as analytical techniques are tested and developed over a number of different areas; fortunately the acoustic information gathered in the Southern Kaipara can be re-analysed as new techniques became available.

All these problems mean that it is important that acoustic imagery is not seen as a panacea. It is expensive to collect over large areas and, until a very good integration over all sedimentary and ecological habitat types has been established, an equal effort needs to be placed into collecting ecological data. Thus, subtidal surveys will continue to be expensive and, for large areas such as the Southern Kaipara and Kawau Bay, best done utilising transects rather that fully covering the area.

This has important implications for the Tier III monitoring, which is focused on collecting large-scale acoustic data with a small amount of ecological data for ground truth purposes. It suggests that, if ecological information rather than purely physical habitat descriptions is an important focus of the Tier III monitoring, Tier III monitoring should be implemented in stages, with the effectiveness of the results carefully monitored.

Less continuous subtidal information can be collected by video. The video information collected by this project proved useful in determining epibenthic habitats that were driven by both physical environments and ecology, and in reflecting ecological community characteristics of the infauna. In areas too turbid for video to be of use, dredge data was successfully collected and integrated with the video data. There are a number of problems with dredging: the dredge could fill before the dredge is pulled up; the dredge may not dredge to a consistent depth; the area covered may be very heterogeneous. However, if dredging is done carefully and grab sampling is used to investigate variability, dredging can be a useful technique for broad-scale ecological mapping. To conclude, in small areas, video/dredging is likely to be cost-effective and information rich compared with acoustic techniques. In larger areas, use of an acoustic device (either side-scan or multibeam) to help interpret and interpolate the video data is still recommended, although continuous coverage is probably not cost-effective.

Point sampling

To collect information on which to base ecological descriptions or ground truth acoustic habitats, point sampling is the standard technique, but the sampling device, size and resolution of sample, and the allocation of effort into replicates or sites varies depending on substrate type and study focus:

- In this project, the sampling device and its size was chosen to be consistent with other studies carried out for ARC and in other areas of New Zealand. Thus, a 13 cm diam x 15 cm deep core was used in the intertidal soft-sediment areas, a 0.1 m^2 grab in the subtidal soft sediment areas and a 0.25 m^2 quadrat in intertidal rocky areas. The subtidal rocky sampling was not consistent with other ARC sampling as no rocky reefs were encountered, rather cliff faces were surveyed using an ROV. For the soft-sediment sampling, a 1 mm mesh sieve was used. This worked well to remove recently settled juveniles from the analysis; a valid precaution when deriving a description that will be able to be compared with another one-off sampling occasion in 10 –1 5 yrs. This is also likely to be a cost-effective choice in East Coast areas of the Auckland Region, where the average sediment particle size is coarser.

- Most of the sampling effort was placed into spatial coverage with a maximum of three replicates collected at each site. This was consistent with other large-scale surveys carried out for ARC. The number of sites able to be sampled was increased by using a two-Tier approach based on analysing the similarity of the area (in terms of surface evidence of fauna and flora) to nearby areas before committing to sampling. In low visibility subtidal areas, a single grab was used to determine whether three replicates would be taken. Sampling locations were chosen to represent a range of environmental factors (wave exposure, currents, vegetation cover, depth, sediment types) as well as providing a good spatial coverage. In particular, areas of transition between habitats were sampled (e.g., low density mangroves, patchy *Zostera*, channel banks). We recommend that this continues to be a focus of the Tier II monitoring.

Linking intertidal and subtidal sampling

A major problem in mapping any area that incorporates both intertidal and subtidal is the interface between these two. In this project, we have left these areas separate for two reasons. (1) Lacking detailed depth and tidal information it was difficult to exactly define the interface as intertidal flats slope gently into the subtidal. (2) There was not a large overlap between the taxa found in the two areas. Large epibenthic animals primarily live in subtidal areas and the dominant bivalves frequently differ (as they did here). Polychaetes and amphipods are generally less specific but even so there are frequent differences in dominance.

Describing ecological communities

A major focus of the Tier II monitoring is the description of ecological communities, in particular the identification of vulnerable or unique communities. There are a number of methods for determining community associations from biological data. Generally methods for determining community associations revolve around different statistical techniques for determining clusters of like communities. Such techniques were not found to be suitable for this project, as distinct clusters containing a high self-similarity were generally not found. Also, such techniques frequently do not come up with associations with high ecological or social values, or that are easily assessed for vulnerability to anthropogenic threats (which is generally associated with functional characteristics displayed by the community such as mobility, feeding mode and position within the sediment). Therefore, this project used an ecological rules based approach for determining communities. It worked well and we would suggest its continuance in the Tier II monitoring.

Analysing temporal changes after a return survey

While this report concentrates on descriptions of the general habitats and communities found in the Southern Kaipara, there are two ways by which changes over time could be identified, if a return visit was made in 10-15 yrs time as part of ongoing Tier II monitoring in the ARC region. (i) Site differences can be calculated for both individual taxa and for the community, and any resultant change in ecological community description (e.g., from a bivalve-deposit feeding community to a surface-burrowing community determined. As samples were taken over a 10 m area, but were representative of a larger area; returning to within 50 m is likely to be sufficiently accurate. A GIS layer that associates distance from sampled areas to certainty is supplied to help interpret certainty. (ii) Changes to the number of and variability in ecological communities within the bounds of the general habitats described in section 5.2.2 can be assessed statistically.

The ability to detect comparatively small or subtle changes between surveys reduced when the decision to increase the number of sites (and decrease site replication and remove the 1 year repeat sampling) was taken. This does not mean, however, that only catastrophic changes can be detected by the sampling. While the low replication at a site does limit ability to detect small changes, community level analysis will act in part to increase detection ability. This will be increased further by being able to summarise changes operating over a large area (or multiple habitats).

Natural temporal variability apparent from the sentinel monitoring sites in the region (Tier I) will need to be used to set the limit on the magnitude of effects able to be detected in the Tier II temporal comparisons. This information, combined with experimental work that provides information on the taxa expected to show changes in response to specific anthropogenic impacts, and the direction and magnitude of such changes, give us confidence in our ability to separate natural variability in the Kaipara from potential anthropogenic changes. However, it is assumed that within the broad-scale assessment conducted under Tier II, more detailed impact assessments (for example, those concerned with the effect of specific marine farm or urbanisation) would be conducted at specific sites and times.

6.2 General description of ecological values of Southern Kaipara

The Southern Kaipara is a unique harbour. It is not only large, but it has high diversity of habitats: extensive fringing mangroves and salt marshes; *Zostera* meadows and patches; non-vegetated mud and sand intertidal flats and shallow subtidal flats, as well as small areas of steep banks, deep high-flow channels and intertidal rocky reefs and subtidal cliffs. Despite the high flow and potential for wind and ocean swell generated waves, many areas of the Southern Kaipara displayed high taxonomic diversity at both a species and order level, and a number of the taxa are large and long-lived. A number of species commonly associated with pristine environments (sponges, ascidians, bryozoans, hydroids, echinoderms and pipis) were found in the harbour. The harbour is ranked by the Department of Conservation as one of international significance due to its value as a feeding and roosting area of migratory birds and of national significance for its fisheries value.

Subtidally, the most common community type was dominated by varying densities of the sand dollar (*Fellaster*), or a *Fellaster*/gastropod mix. Areas of rich epifauna (sponges, ascidians, bryozoans, mussels) are more confined, occurring mainly in the central moderate-depth subtidal, along the channel banks and in the main channel near South Head, although hydroid habitats are found considerable distances up the Oruawharo, Tauhoa and Kaipara River arms. Intertidally, the most common communities were those dominated by deposit-feeding polychaetes. However, a number of bivalve and gastropod dominated communities occur as well. Moderate to dense mangrove areas (> 50% cover) were low in benthic diversity supporting communities that were distinctly different, though variable, from other intertidal areas.

There were distinct differences between the types of fauna and communities found in some areas of the harbour. Prompted by the obvious spatial differences observed in the widepread taxa, the Southern Kaipara was divided into 7 intertidal and 8 subtidal areas. The 7 intertidal areas were the Oruawharo and Tauhoa arms, the upper part of the Kaipara River arm, the eastern and western areas of the outer Kaipara River arm, the area sand dune areas opposite the mouth, and Waonui Inlet. The 8 subtidal areas were the Oruawharo and upper Tauhoa arms, the upper and middle area of the Kaipara River arm, the high current area near South head, the shallow subtidal area between the Kaipara River and Tauhoa arm, the exposed deep area in the mouth and the outer area of the Tauhoa arm. The strong differences found between species observed in sand, mud, mangroves and *Zostera* habitats led to each intertidal areas being further subdivided on this basis.

While many of the taxa and habitats found in the Southern Kaipara occur elsewhere, some are unique (at least in our present state of knowledge). In particular, a subtidal association of tube-building worms was found in the shallow subtidal area of the main harbour comprised of high numbers of *Owenia*, *Macroclymenella*, *Euchone* and Phoronids. Although these taxa occur in other areas (e.g., they have all been observed in the Tier I monitoring), either singly or together, rarely do they reach the densities observed here. Subtidal *Zostera* is also relatively unique in New Zealand; only a few areas have been recorded. Strong differences were also recorded from different parts of the harbour; the Oruawharo Arm and Waionui Inlet both had distinctly different taxa than the main harbour. The *Atrina* beds of the Kaipara, while not unique, *Atrina* being found in many areas of New Zealand, are particularly important for juvenile snapper. Recent research has suggested that in 2003 the Kaipara Harbour alone may have provided almost three-quarters of overall estuarine-based recruitment of snapper on the northeast coast (Morrison pers. obs.).

We have described the current ecological status of the Southern Kaipara, but it is important to note that significant changes have already occurred in the harbour. For example, a commercial dredge fishery for green-lipped mussel beds used to exist in the Kaipara, suggesting that relatively extensive beds once existed. These were not found, although patches were observed in the rocky areas near the South Head cliffs. Substantial native oyster (*Saccostrea glomerata*) beds were previously reported; these were badly depleted from commercial fishing by 1910 (Waitangi Tribunal 1988). Concern over decreases in snapper, scallops and, to a lesser extent, cockles and pipis have been documented (Fishing for the future: a strategy for the fisheries of the Kaipara Harbour). Invasive bivalve species were observed in the harbour in our 2003 – 5 sampling, frequently in high-density patches. These patches were relatively small, never stretching from one sampling location to the next. Species found were the Pacific oyster (*Crassostera gigas*), the Asian mussel (*Musculista senhousia*) and a small bivalve *Theora lubrica. Theora* is found in many areas (e.g., Mahurangi, Manukau) but seems to occur only in low numbers. *Crassostera* is found in many areas (e.g., Manukau), often replacing the native oyster, although it can grow in much muddier areas than *Saccostrea* could. *Musculista* is found in many areas as well, growing densely (e.g., Tamaki Inlet) and often excluding other animals, though this does not yet seem to be the case here. However, *Musculista* patches were widespread occurring in all areas of the harbour with the exception of Waionui Inlet. It appears possible that tube-dwelling communities are particularly susceptible to *Musculista* settlement and growth as frequently less dense patches were found in these communities with *Musculista* adhering to the tubes.

While the harbour may have suffered from overfishing (Fishing for the future: a strategy for the fisheries of the Kaipara Harbour), many areas within the harbour have been protected in the past from the changes in land use that result in increased delivery of terrestrial sediment to the harbour. Most harbours are usually sheltered from ocean swells by headlands and shallow entrances, but in the Kaipara, the ocean swells can enter the harbour. Furthermore the size of the inlet means that there is sufficient fetch for sizeable wind-waves to develop and affect the intertidal areas. This combined with the strong tidal currents presents many opportunities for seabed reworking, resulting in mud being winnowed away, either back into the upper arms or out to sea. This may account for the number of taxa that would be expected to be sensitive to elevated sediment (e.g., cockles, *Atrina*, sponges, *Perna* and other suspension-feeding bivalves) found in many areas of the Southern Kaipara.

6.3 Likely impacts of habitat changes

Likely impacts on habitats in the Southern Kaipara include:

- spread of mangrove cover, as mangroves trap increased amounts of sediment input associated with climatic and land use changes;
- increased muddiness of the sediment and spread of the mud areas into presently sandy habitats and decrease in water clarity again associated with climatic and land use changes;
- decreased *Zostera* cover associated with decreased water clarity or, potentially the periodic loss of *Zostera* that occasionally occurs in New Zealand, the cause of which is not known;
- changes associated with marine farms (discussed in the next section).

6.3.1 Spread of mangrove cover.

Communities found in dense mangroves were dominated by the mud crab (*Helice crassa*), with low numbers of Nereids and *Arthritica* and were different to those found in all but sparse mangrove areas. As the mangroves prograded therefore, we would expect to lose the more diverse mud communities as they became more like the low density mangrove areas, followed by more loss in diversity as the low density mangrove areas became high density areas. It is important to realise that mangrove areas in New Zealand are different to those described from tropical or sub-tropical areas. In these areas, diverse communities are usually described with mangroves being highly productive both for the rest of the ecosystem (nursery areas, production of organics) and commercially (wood and edible crab species). In New Zealand, mangroves are not commercially important, and the few ecological community studies that have been done suggest low diversity (Ellis et al. 2004). Their role in the estuarine ecosystem is still under study; Morrisey et al. (2003) suggests that export of organics is not as important as else where in the world. A study on fish species associated with mangroves in a few areas do, however, suggest that they may have a role as a nursery for some species (Morrison pers. comm.).

6.3.2 Increased muddiness.

Communities observed in the mud areas formed part of a gradient of change between mangrove habitats and exposed sand habitats. As Lundquist et al. (2003) demonstrate, muddy habitats do not necessarily exhibit low diversity and functionality. They describe a gradient of decreasing numbers of taxa, functions and large animals with increasing sedimentation rates, and muddy communities from different types of estuaries and harbours becoming more similar. Muddy habitats of the Southern Kaipara presently fit into the medium area of the Lundquist model. Increased sedimentation, even if the hydrodynamics of the Southern Kaipara prevented spread of muddy areas on to presently sandy areas, would therefore result in changes to the animals inhabiting the muddy areas, with decreased diversity and mainly mobile surface dwelling species such as corophid amphipods and the mud crab (*Helice crassa*).

If the mud habitats did spread, the taxa most likely to exhibit changes in intertidal areas can be determined using Gibbs and Hewitt (2004). Many of the taxa summarised as sensitive (SS by Gibbs et al. 2004), are widespread in the Southern Kaipara i.e., *Notoacmea helmsi*, *Asychis*, *Cominella glandiformis*, *Diloma subrostrata*). These taxa would be expected to decrease first, followed by less sensitive taxa (those designated S by Gibbs and Hewitt (2004); Lysianassid and Phoxocephalid amphipods, orbinid polychaetes, *Aonides oxycephala*, *Macomona liliana*. Finally, those preferring intermediate amounts of mud could also decrease (*Austrovenus stutchburyi* , *Arthritica bifurca*, *Aquilaspio aucklandica*, Glycerid and Syllid polychaetes, *Heteromastus filiformis*, *Macroclymenella stewartensis*, *Boccardia* spp., *Cossura consimilis* , *Aricidea* sp., and *Macropthalmus hirtipes*).

Determining likely changes in the subtidal is more difficult as less work has been done on these taxa. However, with increasing turbidity, suspension feeders (such as sponges, *Atrina*) would be likely to decrease (Ellis et al. 1999, Ellis et al. 2002, Lohrer et al. 2003). Some suspension feeders (*Crassostera*, *Perna*) are not so susceptible and would require much higher levels of elevated turbidity before exhibiting reductions (Hawkins et al. 1999). The response of grazers (such as *Fellaster* and the gastropods that comprise much of the subtidal habitat) is difficult to determine as many grazers can switch from grazing on algal species to detritus, although *Fellaster* is recorded as being sensitive to sedimentation (Gibbs and Hewitt 2004). If, as well as increased turbidity, increased sedimentation occurred (given the dynamics of the Southern Kaipara this would only be likely to occur in sheltered, low flow areas) taxa likely to exhibit changes can be determined using the field experimental results of (Lohrer et al. 2003): Sponges, asciidians, scallops, *Atrina*, Lysianassid and Phoxocephalid amphipods, orbinid polychaetes, *Fellaster*, *Echinocardium australis*, *Boccardia* spp., Glycerid and Syllid polychaetes, *Heteromastus filiformis*, *Macroclymenella* *stewartensis*, *Cossura consimilis* , *Aricidea* sp., and *Macropthalmus hirtipes*. It is likely that the unique tube-dwelling community would be affected, as *Macroclymenella* is known to prefer sand, athough no information is available for the preferences of *Euchone*, *Owenia* or Phoronids.

6.3.3 Decreased *Zostera* cover.

While research indicates that differences between communities living in *Zostera* beds and adjacent un-vegetated areas occur, these differences are not consistent between locations. As a result, there are no published studies that list taxa found primarily in *Zostera*, for example cockles may be found in higher densities in *Zostera* beds that outside in one area, but not in others. However, reduction or break-up of the extensive Southern Kaipara meadows would be expected to result in changes to the ecological communities, as Hewitt et al. (2003) suggests that the effect of *Zostera* is likely to be dependent on size of area with greater effects on community structure and diversity in large meadows than in small meadows or patches. The presence of *Zostera* also has implications to the rest of the estuarine ecosystem beyond the benthic communities. Vegetated areas are generally expected to affect organic, sediment and nutrient fluxes, trapping sediment and exporting organics and nutrients to the rest of the ecosystem, thus increasing productivity. Recent research in New Zealand, however, has demonstrated that some key species in non-vegetated areas can also enhance productivity and alter nutrient fluxes (*Atrina* (Gibbs et al. 2005), *Echinocardium* (Lohrer et al. 2004), *Macomona* and *Austrovenus* (Thrush et al. in prep)) to a similar extent as has been demonstrated for vegetated areas in other parts of the world. Similar to mangroves, *Zostera* meadows are reported internationally to be important for various fish species. In New Zealand early results reported by Morrison and Francis (2002) suggest that beds are important for juvenile snapper, trevally, parore, spotties and pipefish.

6.4 Implications of the locations of selected Aquaculture Management Areas

This section is an assessment of the vulnerability and uniqueness of the benthic communities under the AMAs to mussel and oyster farming (as these are types of aquaculture considered for the areas (D. McCarthy pers. comm)). It does not contain a review of studies investigating impacts of different aquaculture techniques as does, for example Hatton et al. (2003) or Kaspar et al. (1985).

The AMAs intended for the Southern Kaipara fall across three types of habitats.

AMA D and E are located in the sheltered shallow subtidal area of the main harbour. They lie across an area of subtidal *Zostera* and high diversity patches of sponges, suspension-feeding bivalves, filamentous seaweeds and the unique tube-dominated community discussed in the previous section. The *Zostera* is not continuous meadow, rather a number of patches of varying size and density occur over a wide area. No significant differences were observed between the samples taken within these AMAs and the samples immediately adjacent to them, or between the two AMAs, although the prevalence of tube-dominated community does decrease southwards through AMA E. Some dense areas of *Musculista* were found in these AMAs. The nearby intertidal area is a mix of *Zostera* (meadows and patches) and sandflats containing crabs, amphipods, small deposit-feeding bivalves and polychaetes. Some areas of tube-dwellers and a high-density patch of the gastropod *Umbonium* were observed.

Marine farming, particularly rack farming, is likely to cause changes in water flow. The flora and fauna of these areas are likely to be sensitive to such changes in water flow, due to both direct effects on food, oxygen and nutrient fluxes and indirect effects on rates of sedimentation of fine particles causing smothering and interfering with feeding by suspension feeders. Depending on the locality and the nature of the marine farming, marine farms may, however, provide an extra food source for the mainly deposit-feeding tube-dwellers found in this area and feeding by the farmed suspension-feeders may remove sediment from the water column, increasing water clarity around farms. Changes to sediment characteristics by deposition of shell hash underneath the farm would also be likely to affect the communities living in these areas. Affects on taxa due to phytoplankton removal are likely to occur over a larger area than the AMAs themselves and will depend on stock density and water column productivity and exchange rates; none of which are presently known. However, these likely effects need to be balanced against the areas of sensitive habitats covered by the proposed AMAs. AMA D and E occupy an area of about 200 ha which is approximately 16% of the sheltered shallow subtidal area. The percentage of the sheltered shallow subtidal area that contains *Zostera* is 33% (approximately 940 ha), of which 21% of the subtidal seagrass falls within the boundaries of AMA D and E[4] .

AMA C lies in a channel area, with *Fellaster* or *Fellaster*/gastropod dominated communities, offshore from some intertidal *Zostera* beds. The *Fellaster* and *Fellaster*/gastropod dominated communities are the least diverse and most common subtidal habitats observed in the Southern Kaipara and AMA C covers only a small proportion of this habitat type (< 5%). The currents in this area suggest that build up of fine organic material below farms is unlikely, thus the major effects of farms is likely to come from deposition of shell material or depletion of phytoplankton. While the gastropods and *Fellaster* are expected to be grazers, *Fellaster* may also be a filter feeder. Similar taxa in other parts of the world are known to raise themselves into the water column, by tilting their bodies into the flow, and intercept plankton flowing past. The density reached by *Fellaster* in many areas of the Southern Kaipara suggests that they may behave similarly.

While a section of both AMAs A and B lies in sandy channel areas similar to AMA C, a section of both encompasses the highly diverse and encrusted rubble and rock wall habitats. These habitats are dominated mainly by fauna (sponges, bryozoans and mussels) and deep channel areas containing sponges. A patch of *Zostera* was observed in AMA B, which was sandier with gently sloping walls. Generally areas sampled in the AMAs A and B had lesser slopes than the areas outside, resulting in slightly less diverse and rich communities on the cliff walls. Similar to AMA C, the currents in these areas suggest that build up of fine organic material below farms is

[4] Note that the depth information is based on sparse sampling and the *Zostera* cover is based on interpolations between data from helicopter and boat transects (the latter provided by Dollimore). This affects the confidence with which we can view these estimates

unlikely, and the major effects of farms is likely to come from deposition of shell material in flat or gently sloping areas, or depletion of phytoplankton. The benthic communities in these AMAs are likely to be particularly sensitive to depletion of phytoplankton due to the number of suspension-feeding taxa inhabiting them. The two AMAs together cover approximately 29% of the highly diverse and encrusted rubble and rock wall habitats. The high currents are likely to reduce the possibility of phytoplankton depletion becoming an issue (see NIWA current data and Gibbs et al. 2005). However, as noted previously, whether phytoplankton depletion occurs will depend on stock density, water column productivity and exchange rates. Given the diversity of the benthic habitats and taxa encompassed by these AMA's, a detailed assessment of the risks is warranted.

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