Marine Monitoring Plan

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Research, Investigations and Monitoring Unit
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Executive summary

The Research, Investigations and Monitoring Unit leads the evidence gathering functions of the Auckland Council to ensure that policy development and implementation is based on sound evidential principles; promoting systems that are informed by evidence at each stage of the policy development process; from issue identification, to development of response options, and subsequent evaluation of effectiveness. The foundation of the evidence base is the broad data obtained through systematic, comprehensive and long-term monitoring programmes established across the four domains of social, economic, cultural and environment.

While there is a legislative requirement for monitoring, it is also good business practice and an essential component of the wider strategic planning and operational framework. The true value of monitoring is in the information generated that can be used to evaluate and report on performance and progress, demonstrate accountability and support good decision-making.

This marine monitoring plan is designed to provide a high-level outline of the council's monitoring of the marine environment for the Auckland region. The plan sets out what monitoring is being carried out, explaining the links between the various programmes, both in terms of information exchange (feedbacks and links) and also in terms of spatial relationships (efficiency of programme design).

The region's coastal marine area is very large and highly variable, with two very different coast lines, a strong exposure gradient from the inner to outer Hauraki Gulf, three large harbours (including Kaipara Harbour, the largest harbour in New Zealand and often reported as the largest in the Southern Hemisphere), as well as many estuaries and embayments. The inherent complexity of Auckland's marine environment makes it very difficult to generalise across the region so a comprehensive monitoring programme is required that covers the range of habitats and exposure gradients.

1.0 Introduction

1.1 Objective of this plan

The Research Investigations and Monitoring Unit of Auckland Council, monitors environmental quality across five resource classes; air, land, terrestrial biodiversity, freshwater and marine. An integrated monitoring plan (in prep) will broadly outline these and integrate across resource classes in terms of data management, reporting and review. For each resource class there is a monitoring plan.

This marine monitoring plan is designed to provide a high-level outline of the council's monitoring of the marine environment for the Auckland region. The plan sets out what monitoring is being carried out, explaining the links between the various programmes, both in terms of information exchange (feedbacks and links) and also in terms of spatial relationships (efficiency of programme design). The objective is to integrate the various marine programmes and improve the interoperability of the programmes and information they produce.

1.2 Requirements for marine monitoring

Section 35 of the RMA specifies the duty to gather information, monitor and keep records in order to monitor the state of the environment and policy effectiveness and to take appropriate action when monitoring indicates that this is necessary.

There are a number of plans that make up Auckland Council's strategic framework. Some plans such as the Unitary Plan have a statutory basis, while others like strategies are developed to help achieve the council's vision. Each plan or strategy has a specific role and objective and each require monitoring to ensure those objectives are achieved.

The Auckland Plan (spatial plan) is a long-term (30-year) strategy that contributes to Auckland's social, economic, environmental and cultural wellbeing, and shows how Auckland will change, grow and develop in the future. The Auckland Plan calls for a quality compact city with more affordable housing, a stronger economy and protection of the city's environment, heritage and character.

The Unitary Plan is the council's key land use planning document and its principal means of applying the Resource Management Act. The Unitary Plan will replace the existing district and some regional plans from the former city, district and regional councils including the Coastal Plan, Air, Land and Water Plan and the Sediment Plan, all of which controlled activities affecting the marine environment. With respect to the marine environment, the Unitary Plan will also need to take account of the New Zealand Coastal Policy Statement (NZCPS).

A key requirement of the Unitary Plan will be to monitor specific aspects of the environment in order to provide council with the information required to assess its effectiveness in managing resource use.

1.3 Monitoring in the context of Auckland's marine environment

Auckland's marine environment is highly complex and ecologically valuable for the range of habitats available that support a diverse range of species. The Auckland marine environment also provides a range of ecosystem services and functions of great significance to the region. These can be broadly categorised to include: cultural values, recreational opportunities, quantity and quality of food resources,

shoreline protection, climate change mitigation, nutrient cycling, contaminant processing, sediment stability, resilience and biodiversity, mitigation of harmful algal blooms, supporting science and education and underpinning natural aesthetic values and tourism.

The region's coastal marine area is very large and highly variable, with two very different coast lines, a strong exposure gradient from the inner to outer Hauraki Gulf, three large harbours (including Kaipara Harbour, the largest harbour in New Zealand and often reported as the largest in the Southern Hemisphere), as well as many estuaries and embayments. The inherent complexity of Auckland's marine environment makes it very difficult to generalise across the region so a comprehensive monitoring programme is required that covers the range of habitats and exposure gradients within Auckland's marine environment.

Programmes like water and sediment quality and coastal profiles take a regional approach, but the marine ecology programme is structured into harbours, estuaries and reefs to reflect the inherent differences in these environments. Even within these environments, there can be major differences between locations such as harbours on the east and west coast, so the ecology programme is generally specific to a particular receiving environment. Work is underway to develop regional reporting indicators that can be used across these spatially specific ecology monitoring programmes.

Differences in exposure gradient and receiving environment type also need to be accounted for in reporting information from marine programmes with a regional approach such as the water quality programme as inherent differences in these will influence the expected results. For example, inner harbour sites are always going to have different (generally lower) water quality than more flushed outer harbour sites. So while regional comparisons are made, the receiving environment type must also be included in the analysis and interpretation.

The marine environment is extremely variable and, in order to try to determine whether changes in species, habitats or environmental quality (e.g. sediment contaminant levels are due to human-induced activities, natural processes or climatic variation, we need to understand this natural variability. Therefore, it is important for monitoring programmes to use a consistent, long-term monitoring method so that natural biological and climatic variations can be filtered out. For example, many marine species naturally vary in abundance on a five to seven year cycle so it is important that the monitoring programme can separate these natural cycles from any other change that might be due to anthropogenic influences.

2.0 Background

2.1 Origin and design of monitoring programmes

Monitoring of Auckland's marine environment has evolved through time with a variety of progenitor programmes and founding reports. The genesis of many of the environmental monitoring programme was the Manukau Harbour Action Plan (MHAP). The stated aim of the MHAP was to set up a comprehensive water quality management framework for the Manukau Harbour and catchment to ensure the quality of the harbour and its tributaries were suitable for wide variety of uses for present and future generations (ARWB 1990).

A key outcome of the MHAP was the establishment of coordinated research and monitoring programmes for the harbour including:

- Saline water quality monitoring
- Biological monitoring
- Shellfish/finfish quality surveys
- Detection of sub-lethal stress in shellfish
- Bathing beach surveys
- Stormwater quality run-off evaluation

Of these programmes, the saline water quality, biological monitoring (of marine benthic fauna) and shellfish quality surveys continue today, resulting in a 22 year data set for the Manukau Harbour. These surveys have since been extended to cover the region.

In 2000, a State of the Environment marine ecology monitoring programme was designed and prepared for ARC. The programme was designed by NIWA as the result of discussions with ARC and a work shop with ARC staff and relevant NIWA and University of Auckland staff.

The programme was designed to focus monitoring on:

- The ecological status and trends of change in macrobenthic communities in marine habitats representative of the region
- Habitats affected by identified ARC priority issues of sedimentation and pollution while also providing feedback relevant to other issues as far as practicable.

The design built on existing SOE programmes and land development effects programmes to give comprehensive coverage of the Auckland region. The design is outlined in ARC Technical Publication 271 (Hewitt 2000).

2.2 Previous structure

The marine monitoring programme was structured into two components, Regional Status and Trends and Strategy and Policy. The Regional Status and Trends programme fulfilled the State of the Environment monitoring role with long term regionally representative monitoring programmes across a number of parameters, while Strategy and Policy monitoring addressed specific policy requirements or changes, e.g. the effectiveness of land use zoning changes.

2.2.1 State of the Environment Monitoring Programmes

The quality of the marine environment was monitored through five State of the Environment (SOE) monitoring programmes. Together they provided consistent, long-term information on the environmental quality of Auckland's marine environment, and in particular the: water column (i.e. pelagic environment); sea-bed (i.e. benthic environment); and, foreshore. The five monitoring programmes were:

- Coastal Water Quality
- Shellfish Contaminant Monitoring
- Sediment Contaminant Monitoring
- Benthic Ecology Programme
- Beach Profile Programme

2.2.2 Strategy and policy monitoring programmes

The value of these SOE programmes has in the past been greatly enhanced through linkages to other marine monitoring carried out under the Strategy and Policy monitoring programme to address particular information requirements. These programmes were primarily focused on the effects of sediment and contaminant generation due to land use, development and stormwater and include:

- Land Development Affects Programmes at
    - Long Bay
    - Okura and Whitford
    - Upper Waitemata Harbour
- Regional Discharge Programme

These programmes were to a large extent interoperable with the SOE programmes and greatly extended the regional coverage of environmental data and employ methods and analysis aligned to those used in SOE programmes, having followed the same monitoring designs. The land development effects programme and the regional discharge programme align closely with the Benthic Ecology SOE programme and the Sediment Chemistry SOE programme in particular.

3.0 Marine Monitoring Programme

3.1 Introduction

As outlined in Section 3 above marine monitoring has previously been divided across a number of segregated programmes which has lead to some duplication and has not maximized the valuable information collected.

The marine monitoring programmes described below, follows the precedent set in Hewitt 2000 (ARC TP271) of combining information across programmes to provide comprehensive coverage of regional variation in habitat types, gradients of exposure and land use and environmental issues. The result is a comprehensive state of the environment monitoring programme which is outlined in section 4.2, which enable us to track whether things are getting better or worse or remaining stable and therefore to report on the effectiveness of policies and plans. In addition to providing information on the state of environment, data from these programmes can be used to address particular questions arising as a consequence of proposed changes in land use, including input to and validation of modelling and environmental risk predictions used to underpin development-planning decisions. In a number of cases, monitoring is designed to answer additional questions related to specific issues as outlined in Section 4.3.

The contribution of each programme to state of the environment reporting and specific issues is summarised in Table 1.

3.2 Baseline state of the environment monitoring

SOE monitoring provides a stock-take of baseline data on the status (quality and quantity) and trends of change over time of environmental resources at representative locations around the region. SOE monitoring comprises baseline and event based monitoring programmes, both of which also encompass the ability to investigate specific issues

We monitor coastal water quality as a broad indicator of what is going on in the environment, chemicals in sediment and shellfish as a specific indicator of pollution levels in the environment and the ecology of harbours, estuaries and reefs as an indicator of the overall health of our marine ecosystems (See Figure 1). These programmes focus on detecting the effects of the key stressors generated by land based activities sediments and contaminants (chemical, nutrient and faecal). Coastal profiles are monitored as a measure of beach dynamics and erosion. Together these monitoring programmes provide consistent, long-term information on the environmental quality of Auckland's marine environment, covering the water column (i.e. pelagic environment), sea-bed (i.e. benthic environment), and foreshore.

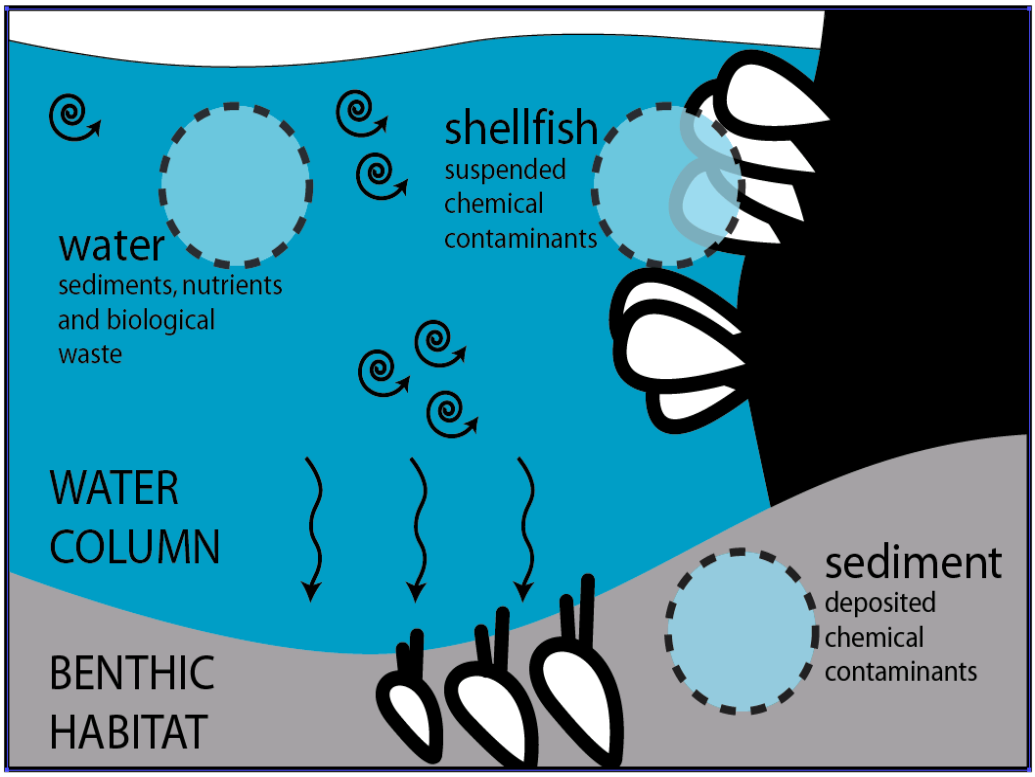

Figure 1: The marine monitoring programme focuses on detecting the effects of key land derived contaminants across pelagic (water column) and benthic (bottom) habitats

There are six key marine programmes:

- Coastal Water Quality - This programme monitors contaminants associated with erosion, nutrients and biological wastes (organic material and faecal contaminants) in the water column and provides a useful measure of broad scale patterns associated with discharges from land and climatic variables across the region.
- Marine Ecology (Harbours, Estuaries and Reefs) - The abundance and composition of benthic organisms found in coastal ecosystems provides a sensitive measure of ecosystem condition or health. Organisms in these communities form a significant component of our regional biodiversity and also provide an important food source for birds, fish, and people. Their low mobility can also make them representative of local conditions.
- Sediment Chemistry - Many contaminants attach to particulate material which settles out of the water column and accumulates in depositional zones. These contaminants can be toxic to the organisms that live on and in the sediments. There are established guidelines for levels of contaminants in sediment, so monitoring sediment chemistry provides a useful measure of the marine sediment quality across the region
- Shellfish Contaminants - Direct measurement of chemical contaminants in the water column can be unreliable because concentrations are commonly below analytical detection limits, and they vary widely due to water movement and the patchy nature of inputs. However, plants and animals accumulate contaminants over time, even when ambient levels in the water column are relatively low. The tissues of sedentary, filter-feeding shellfish therefore provide an integrated measure of ambient chemical contaminant levels in the water column.

- Beach Profiles - The programme provides information on beach dynamics, coastal hazards and changes that can potentially be linked to changes in climatic patterns and provides information on coastal erosion and storm impacts.
- Benthic Health – this programme integrates marine ecological and sediment contaminant data to report on the ecological health of our harbours and estuaries on a regional scale in relation to sediment and contaminant effects.

The following is a description of the spatial coverage of the marine monitoring programme and a brief description of each programme. The specific details (sites and methods etc) are summarised in Appendix 1 and covered fully in the project histories and protocol documents.

3.2.1 Spatial coverage

The spatial coverage of the marine monitoring programme is shown in Figure 2.

The intensity and spatial distribution of sampling is concentrated in areas that have historically been viewed as being particularly vulnerable to the impacts of surrounding land use. Effort is largely focused on marine receiving environments affected by the major population centres i.e. Manukau Harbour, Tamaki Estuary, Waitemata Harbour and Mahurangi Harbour, with a strong emphasis on monitoring the effects of urban contaminants. These areas are well covered for water quality, and shellfish and sediment contaminants.

Progressive inclusion of the east coast estuaries and reefs and the Upper Waitemata Harbour has increased the regional ecological coverage and representativeness of the programme by including estuaries as well as the large harbours and extending monitoring to reef habitats as well as soft sediment habitats.

Development of the current coverage also recognised that a number of the region's highest value areas were not monitored (e.g. Kaipara Harbour, Whangateau, Kawau Bay). Surrounding land use practices suggest that these areas are likely to be under significant pressure and there was a risk that the lack of environmental monitoring would mean that degradation in environmental quality would not be detected in time for an effective management response to be developed and implemented. In order to address this, two new monitoring programmes were established in the 2009/10 year in the Kaipara and Whangateau Harbours. The Kaipara Harbour monitoring is aligned with our other harbour monitoring programmes while the Whangateau Harbour monitoring has been integrated with the East Coast Estuaries monitoring programme.

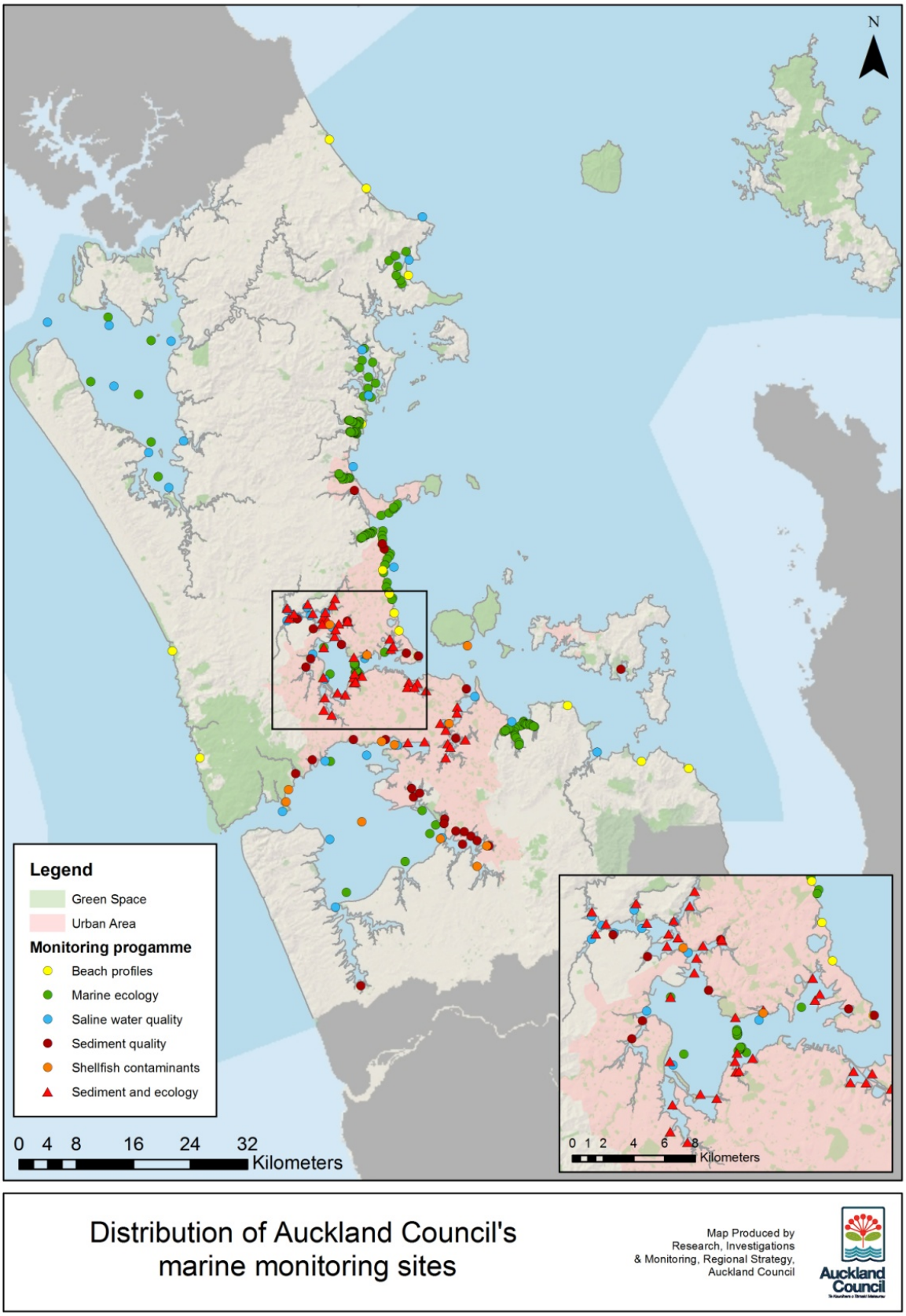

Figure 2: The distribution of Auckland Council's marine monitoring sites.

3.2.2 Coastal water quality

This programme monitors contaminants associated with erosion, nutrients and biological wastes (organic material and faecal contaminants) in the water column and provides regionally representative baseline monitoring.

In 1977/78, a preliminary study of twelve areas subject to environmental pressure was carried out (ARWB 1977 - TP 5). Following this a ten-year programme (1977-1987) of water quality sampling of representative baseline sites was established (ARWB 1982 - TP 22). The current monitoring network was established in 1987 to monitor the state of the Manukau Harbour (ARWB 1990) and subsequently extended to the Waitamata, Hauraki Gulf (ARC 1993a - TP 30) and Kaipara Harbours (one site only) (ARC 1994 - TP42). Special sites in the Tamaki Estuary were added in 1992 and in Mahurang Estuary and Upper Waitemata Harbour in 1993 and have subsequently been added to the regional programme. More recently, 2009, additional sites have been established in the Kaipara Harbour (six additional sites) the Manukau Harbour (1 additional site), Turanga estuary (1 new site) and the Wairoa River (1 new site). Sites have been selected which provided information on:

- coastal water quality ranging from very high to degraded,
- a range of exposure levels including open coast, sheltered coast, harbours, large estuaries and tidal creeks,
- the main harbours and large estuaries,
- areas with a variety of adjacent land uses ranging from urban/industrial to rural, and
- regional variation in water quality.

A standard set of parameters are used as indicators of sediment, nutrients and biological contaminants. In addition, a number of environmental parameters (e.g. temperature) are measured to provide information on ambient coastal water conditions and/or because they effect the toxicity of contaminants such as ammonia. Samples are collected monthly and collection is predominately by helicopter due to the wide geographic area covered.

3.2.3 Marine ecology

We monitor marine ecology in different environments, and in relation to different potential environmental pressures. It is not possible to monitor the full component of biodiversity present in our region. Instead the abundance and composition of benthic organisms found in coastal ecosystems provides a sensitive measure of ecosystem condition or health. Organisms in these communities form a significant component of our regional biodiversity and also provide an important food source for birds, fish, and people. Their low mobility can also make them representative of local conditions.

Roughly 70% of the total region is coastal and marine. The Auckland mainland is surrounded by approximately 1,800 km of coastline (excluding islands) split nearly equally between the east and west coasts. While most of the marine habitats are in water >20m deep, there is approximately 2400km^2 of marine area 0-20 m deep and over 600km^2 of intertidal area. As, obviously all of this area cannot be monitored in detail, we have a monitoring programme with three levels (tiers) of effort which will result in comprehensive coverage of the Auckland region. The design of this programme is outlined in Hewitt 2000 (ARC TP271), which sets out a plan for monitoring marine ecology which is being progressively implemented.

The network design aims to provide both spatially and temporally relevant feedback on the condition of marine ecology. Temporal accuracy (trend detection) requires intensive sampling, which places practical limits on the area that can be covered. Methods that provide broad spatial coverage generally cannot provide detailed biological information necessary to reliably distinguish trends in marine ecology from natural variability. Consequently the regional network design incorporates three nested tiers with different monitoring methods designed to meet the two objectives. Tier I involves 'sentinel' monitoring which aims to meet temporal objectives. Tiers II (habitat mapping and ecological community) and III (broad habitat mapping) aim to meet spatial objectives.

The objectives for Tier I sentinel monitoring programmes are:

- To provide a stock-take and baseline data on the status of seabed dwelling marine ecology at representative locations around the region, against which future cause-effect or impact studies could be conducted.
- Identification of long-term trends, cyclic temporal variability and spatial variability in benthic communities.
- Reliable and technically robust detection of trends of change in the status of these resources overtime.
- To provide feedback on harbour management activities, for example pollution control.
- Through an understanding of the sensitivity of organisms monitored to various stressors, identification of sources of stress and pressure likely to be causing observed biological trends.
- To distinguish between trends of change associated with human sources of stress and those caused by natural processes.

The objectives of the Tier II and III monitoring programmes are:

- Providing baseline data on the spatial distribution of physical and biological habitats and the communities of seabed-dwelling organisms they support across large areas of the coastal near-shore (<30m depth) environment.
- Broad scale habitat mapping to progressively identify the variety of habitats present within the region's CMA, and their patterns of distribution.
- Identification of habitats and biological communities of environmental importance or those that are particularly vulnerable to stressors.
- Provide an inventory of benthic organisms' characteristic of the habitats identified.
- Detection of broad changes in patterns of habitat distribution and the status of these resources over time through repeating surveys every 10-15 years.
- Place tier one marine monitoring results into context.
- Identify additional areas of importance that should be included in tier one monitoring.

3.2.3.1 Tier I marine ecology monitoring

The Tier I programme monitors temporal changes in specific benthic communities in harbours, estuaries and reefs across the region. The information is primarily used for determining trends of community change therefore the monitoring under this tier is the most temporally intense. Tier I provides for intensive monitoring of sentinel locations and is designed to give information on representative areas.

This first tier focuses upon robust and environmentally significant trend detection (change in condition over time) in priority habitats. This involves intensive monitoring of comparatively small (~ 1 ha) representative sites within a number of key regional locations, including intertidal and subtidal soft

sediment and rocky habitats. Temporal changes in specific benthic communities are monitored in the following locations:

- Harbours (soft sediment): Manukau, Mahurangi, Central Waitemata, Upper Waitemata and Kaipara (each of these locations are managed as sub-programmes)
- Estuaries (soft sediment): Whangateau, Puhoi, Waiwera, Orewa, Okura, Mangemangeroa, Waikopua, Turanga (all East Coast)
- Subtidal Reefs: Meola Reef (Waitemata Harbour) and Waiwera, Stanmore, Manly, Long Bay, Torbay, Campbells Bay (all East Coast)

While the Tier I monitoring programme is temporarily intense in terms of frequency of sampling, efficiencies have been made in the harbours and estuaries sub-programme by introducing temporally and spatially nested sampling designs for those with greater than five years of monitoring data. The number of sites for each harbour or estuary sampled continuously and the remainder are sampled on a rotational basis. For example there are six sites in the Manukau Harbour, only two are monitored continuously and the remainder are monitored for two years every five years. The sampling has been programmed so that only one harbour or estuary in each sub-programme is monitored in full at any one time, thereby reducing the overall sampling effort and therefore cost. This approach also maintains the budget at a stable level with no fluctuations for years with full sampling. The schedule for rotational site sampling is provided in Appendix 2. The reduced sampling approach needs to be continually reviewed in light of any changes in catchment development plans, or any other arising issues or concerns that might warrant a return to full sampling. All sites in Upper Waitemata Harbour are currently monitored as changes are expected in this receiving environment as a result of ongoing development in the catchment. However the frequency at which sites are monitored has been reduced for some sites within this sub-programme.

3.2.3.2 Tier II and III marine ecology monitoring

Tiers II and III provide information that covers a broader spatial context than Tier I monitoring. Tier II monitors broad scale habitat and ecological communities for more accessible and higher priority near-shore ecosystems while Tier III is designed to map broad-scale habitats in deeper waters (>20m). For Tier II monitoring, sampling is carried out in a new location every two years, with each survey taking two years to complete. Surveys are to be repeated on a 10-15 year rotational basis to allow for detection of any major changes. Tier II has so far been implemented in Kaipara Harbour (Hewitt and Funnel 2005 - TP275), Kawau Bay (Chiaroni et al. 2008, TP362) and Tamaki Strait (Chiaroni et al. 2010 - TR2010/038) and on a smaller scale in Whangateau Estuary (Townsend et al. 2010 - TR2010/057) and Wairoa Estuary (Lohrer et al. 2012 - TR2012/028). Tier III has yet to be implemented.

3.2.4 Sediment chemistry

In 1998, the ARC initiated a sediment contaminant monitoring programme aimed at assessing the spatial distribution and temporal trends in key chemical contaminants in near-shore sediments across the regions urban estuaries, harbours and beaches as well as monitoring some reference sites (Williamson et al. 1999 - ARC TP 107).

Many contaminants attach to particulate material which settles out of the water column and accumulates in depositional zones. These contaminants can be toxic to the organisms that live on and in the sediments. The sediment chemistry monitoring programme combines a baseline state of the environment monitoring programme with the Regional Discharge Programme (ARC 2004). In addition to the regionally representative sites sampled as part of the baseline programme, the Regional Discharge Programme samples additional sites subject to stormwater inputs, increasing the spatial coverage of the baseline

programme and the programmes ability to report on stormwater outcomes. All of the urban sites included in the baseline sediment chemistry monitoring programme are also RDP monitoring sites hence these two sub-programmes are closely aligned and the results for the sediment chemistry can be reported as one.

Sites were selected to cover a range of land use categories and to be representative of the region as whole, including sites with sediment contaminant levels ranging from background levels to relatively high concentrations. This was achieved by including:

- Sites with sediment contaminant levels ranging from background levels to relatively high concentrations and including reference sites.
- Sites covering a range of receiving environments from estuarine to semi-exposed coastal.
- Sites with a variety of adjacent land uses, ranging from urban/industrial to rural.
- Sites which represented a range of stormwater quality entering the receiving environment.

The programme was reviewed in 2002 on the basis of the first three years of data (Timperely and Mathieson 2002 - ARC TP193). The programme is currently under review based on the results of long term trend analysis.

3.2.5 Benthic health programme

The benthic health programme is based on the benthic health model which provides a means to assess on a regional basis the ecological health of our harbours and estuaries.

The benthic health model was developed by the ARC to provide a tool for classifying intertidal sites within the region according to categories of relative ecosystem health, based on its community composition and predicted responses to storm-water contamination (Anderson et al. 2006 – TP317). The model is a multivariate analysis (CAP) of macrobenthic community composition backed by information on sediment copper, lead and zinc concentrations. Recently the model has been further developed to incorporate community responses to a mud gradient and this will extend the usefulness of the BHM as a SOE indicator (van Houte-Howes and Lohrer 2010 - TR2010/035, Lohrer and Rodil 2011 - TR2011/004). As well as core benthic health sites, the programme integrates data from the sediment chemistry and various marine ecology programmes providing wide regional coverage.

The Traits Based Indicator (TBI) was developed based on the richness of species in 7 functional groupings, with changes in index values reflecting potential shifts in ecological resilience (van Houte-Howes and Lohrer 2010 - TR2010/035, Lohrer and Rodil 2011 - TR2011/004). In conjunction with the Benthic Health Model, the TBI offers a useful way of assessing some of the elements of ecosystem health in our harbours and estuaries. As this functional indicator is developed it will be incorporated into reporting on benthic health.

3.2.6 Shellfish contaminant monitoring

Direct measurement of chemical contaminants in the water column can be unreliable because concentrations are commonly below analytical detection limits, and they vary widely due to water movement and the patchy nature of inputs. However, plants and animals accumulate contaminants over time, even when ambient levels in the water column are relatively low. The tissues of sedentary, filter-feeding shellfish therefore provide an integrated measure of ambient chemical contaminant levels in the water column.

The Manukau Oyster Monitoring Programme was initiated as part of the Manukau Harbour Action Plan (1987), following concerns over the environmental condition of the harbour (ARWB 1988). Initially 11 sites were monitored, however, following a programme review and assessment of 5 years of data by NIWA,

the number of sites was reduced to 4 in 1992 (ARC 1993b). The catchments adjoining the remaining sites were selected to represent different land uses ranging from highly urbanised to those dominated by rural activity and/or bush.

The use of oysters as a region wide monitoring tool is constrained by the lack of widespread “natural” populations, particularly at east coast locations. This method relies on the persistence of oyster populations at the monitoring sites. The intertidal habit of oysters also limits monitoring to the intertidal zone. Consequently, the Shellfish Contaminant Monitoring Programme was expanded by adding a mussel monitoring component. Method development and site selection was carried out in the Waitemata Harbour and Tamaki estuary between 1990 and 1996 and consistent sites and methods have been used in the Waitemata and Tamaki since 1999 following a programme review by NIWA in 1998 (Mills, 1998). Mussel sites were also added in the Manukau Harbour in 2000. Mussels are obtained from Coromandel, attached to mussel ropes and set at AC monitoring sites. Occasional sampling of shellfish from other locations has also been carried out, such as oyster sampling from Hobson Bay and the Waitemata Harbour in 1998.

Shellfish are analysed for chemical contaminants and general condition. The contaminants measured include heavy metals, PAHs, PCBs, and persistent pesticides (lindane, chlordane, dieldrin and DDT). The programme was primarily established to track the level of urban contaminants, but reference sites included in the programme also provide information from areas beyond the urban fringe. Samples are also analysed for some contaminants, such as persistent pesticides, which may originate from agricultural areas.

3.2.7 Beach profile monitoring

This programme monitors long-term changes in the landward position of the beach, changes in volume of sand stored within the beach, changes in beach width, and determination of the envelope of beach change for the entire dataset for each beach. The programme provides information on beach dynamics, coastal hazards and changes that can potentially be linked to changes in climatic patterns.

Following a programme review by Kench (2008), three clear objectives have been set in place:

- Recreational amenity value of beaches
- Monitoring coastal erosion
- Assessing storm impacts

Since the start of this programme there have been 16 beaches included in this study, providing regional coverage. The time-span of the profile datasets varies from site to site, with some site records dating back to 1978, and in the case of Omaha to1965, to more recent site records established in 1998.

3.3 Issue specific monitoring

As well as providing regionally representative coverage of temporal change, monitoring carried out at a number of locations is designed to answer additional questions related to specific issues. These issue specific programmes may be spatially specific or temporally intensive in specific locations or may measure a selected suite of parameters additional to those monitored in the core monitoring programme.

3.3.1.1 Upper Waitemata Harbour

In November 2005, a long term monitoring programme was established in the Upper Waitemata Harbour, to monitor the ecological status of benthic macrofauna in habitats that have the potential to be affected by

development of the surrounding catchments (Hewitt et al. 2006 – TP331). The core monitoring is aligned to the marine ecology programme and contributes to regional coverage. In addition concurrent sampling of sediment characteristics and chemical contaminants was initiated to provide the ability to correlate macrofaunal information with predictions from catchment and hydrodynamic models developed for the Upper Waitemata Harbour (see Green et al. 2004 – TP250 and associated reports). Cummings et al. 2002 (TP219) describes the results of a survey of 74 sites, conducted to quantify the existing intertidal and subtidal benthic communities of UWH. It also includes a qualitative assessment of the potential effect on these communities of long-term habitat change due to increased sediment muddiness.

3.3.1.2 Estuaries

In addition to providing information on the state of marine ecology in east coast estuaries, the Estuaries Monitoring Programme was also established to address particular questions that arose as a consequence of proposed changes in land use. The objective of the Estuaries Monitoring Programme is therefore also to determine whether land disturbance associated with varying degrees of urbanisation in the surrounding catchment causes ecologically damaging sedimentation to the intertidal soft-sediment infauna in the estuary, and in this way to verify modelling and environmental risk predictions used to underpin development-planning decisions. Sediment accumulation and input is monitored across all seven east coast estuaries.

Permissible development (rural intensification) in the Okura catchment has been guided by comprehensive environmental risk assessment of the marine receiving ecosystem. The risk assessment methodology employed detailed numerical modelling. This technique is being used to guide major planning decisions across the region. Monitoring of the accuracy of the model and risk-assessment predictions is critical to complete verification of the continued utility of the detailed modelling method, and of the fundamental strategic planning policies currently being applied by ARC which are based on this modelling. This verification has particularly strong linkages to sediment control policies and application of sustainable urban and rural land clearance and development practices.

The catchments surrounding the Whitford embayment in the south are designated for rural residential development and comprehensive risk assessment modelling has been carried out for a range of land use scenarios. As in Okura, the objective of monitoring in the Whitford Embayment is also to test the predictions of sediment run-off and ecological response assessments for Whitford.

Following pilot studies in 1999/2000, a monitoring programme was established the following year within the Okura Estuary (Anderson et al. 2001a, Anderson et al. 2001b). This program was established to detect any significant benthic ecological changes within the estuary as development proceeded. In August 2002, four other estuaries were added to the monitoring programme (Puhoi, Waiwera, Orewa and Mangemangeroa) in order to place any potential changes through time at Okura within a broader regional context (Ford et al. 2004 – TP216). In August 2004, Turanga and Waikopua were added to the programme (Ford and Anderson 2005 – TP287). In 2009 Whangateau was added to the programme as a reference estuary and also as one where there was potential for catchment development in the future (Townsend et al. 2001 – TR2010/057).

It is important to note that while Orewa, Puhoi and Waiwera were added as reference estuaries for the monitoring the effects of development in Okura, each of these estuaries is also now subject to a number of potential impacts associated with land use.

3.3.1.3 Long Bay

The Long Bay Monitoring Programme was established in 1998 following an Environmental court ruling (1995) allowing development of the Long Bay catchment (Babcock et al. 1999a, Babcock et al. 1999b). The decision to allow development was based upon the conclusion that the catchment was already partially urbanised and little undisturbed freshwater habitat remained. The court also accepted expert advice suggesting the effects on the semi-exposed coastal habitats of the Long Bay receiving environment would be minor. The ARC implemented this monitoring programme to verify whether the rationale upon which the Environmental court based its ruling was sound.

Monitoring was therefore initiated to determine whether the adverse effects of urban “green-field” development on coastal and freshwater environments were more than minor. Changes in the health of marine communities on subtidal reefs are being monitored. Several control sites are also included in the programme to ensure that any changes detected can be attributed to land based activity rather than natural processes. These control sites form the basis of the Reefs SOE monitoring programme. In addition to ecological monitoring, at all sites, sedimentation is measured using sediment traps and percent cover of sediment on the reef to link changes in the ecology to changes in sedimentation levels resulting from land use change in the surrounding catchments (see Shears 2010 -TR2010/032).

3.3.1.4 Stormwater

Stormwater and its effects is a key issue for the Auckland region. By incorporating spatially intense sampling within the sediment chemistry and benthic health programmes, in urban areas affected by stormwater, we can assess the level of stormwater contaminants in marine receiving environments (through monitoring sediment chemistry) and the ecological health of benthic communities (through the benthic health model) in relation to those stormwater contaminants. This programme was originally set up as the Regional Discharges Programme in order to inform the network consent process and the methodologies are outlined in ARC 2004 (TP168) and Anderson et al. 2006 (TP317).

Several of the marine ecology (harbours and estuaries) and sediment chemistry sites are used as Benthic Health Programme BHP sites, with the information collected once and used for two reporting purposes. The additional sites monitored as part of the BHP provide more spatially intense information on benthic ecology and sediment chemistry in urban areas affected by stormwater.

3.4.1 Event monitoring

The baseline monitoring programme monitors variables at regular intervals in order to build a consistent dataset. However, this regular monitoring structure means that important climatic and anthropogenic events may be missed, for example flood events that may deliver large sediment loads to the marine environment. Currently event based monitoring is only carried out as part of one programme, the estuaries monitoring programme. Event based sampling is under development for the coastal water quality monitoring and will be progressively added to the marine ecology programme following the establishment of sediment monitoring in adjoining catchments.

3.4.1.1 Estuaries

Sampling of marine ecology in estuaries incorporates event based sampling timed to occur when increases in sediment inputs from the surrounding catchment occur due to heavy rainfall (particularly with

the advent of land-use changes and development) might be expected. Sampling occurred twice (after rain, and after a dry period) within each of two discrete seasonal three-month blocks (winter/spring: August – October and summer/autumn: February – April), yielding four sampling times per year. Sampling after rainfall focuses on three of the seven estuaries (Okura, Orewa and Mangemangeroa) where a greater number of relevant environmental parameters can be measured for monitoring (including quick-flow volume, peak flow and suspended sediment yield). This provides for the establishment of stronger physical causative links and inferences in the event of future impacts. An individual rain fall trigger has been developed for each of these estuaries based on long term records recognizing the regional variation in rainfall intensity. Rainfall is monitored in each of the three catchments and an alert sent via text message when a rainfall trigger event occurs. Sampling then occurs in the estuary or estuaries where an alert was triggered within 7-10 days of the rainfall event. Sampling after rainfall occurs up to three times per year in each of Mangemangeroa, Okura and Orewa estuaries and does not occur if the rainfall trigger is not meet during the year. Sampling continues to be done across all seven estuaries, once in each season after relatively dry conditions (no greater than 15 mm of rainfall in 24 hours in the previous 10 days).

Table 1: Summary of marine monitoring programmes showing their contribution to baseline and issue monitoring and components of event monitoring.

Programme	Sub-programmes	Baseline	Issue	Event	Record beginning
Saline water quality		Regionally representative			1986 to 2009
Shellfish contaminants		Manukau and Waitemata Habours, Tamaki Estuary			1987 (oysters). 1999 (mussels)
Sediment Chemistry		Regionally representative	Urban stormwater sites		1998 (SOE). 2002 (Stormwater)
Benthic Health (ecology and contaminants)		Regionally representative	Urban stormwater sites		2002
Harbour marine ecology (Tier I)	Manukau	Temporally intense			1987
	Mahurangi	Temporally intense			1994
	Central Waitemata	Temporally intense			2000
	Upper Waitemata	Temporally intense	Contaminants to look at development effects		2005
	Kaipara Harbour	Temporally intense			2009
Estuaries marine ecology (Tier I)		Regionally representative of estuaries	Sediment accumulation and sediment input	Sediment input in relation to rainfall	2000

Programme	Sub-programmes	Baseline	Issue	Event	Record beginning
Reefs marine ecology (Tier I)	Subtidal	Representative of east coast reefs	Tracks changes in relation to Long Bay development. Sediment accumulation using sediment traps and percent sediment cover		1998
	Intertidal	Currently only Meola reef, regional pilot	Includes sediment accumulation		2000
Habitat Monitoring (Tier II)		Regionally representative			2003 (Kaipara)
Coastal Profiles		Regionally representative			1978-1998

4.0 Information Management

4.1 Data collection and management

Data is collected at regular time periods and is carried out by both internal staff (Environmental Services) and external providers (Table 2). For all programmes there are protocol documents which set out the methods for collecting the data, entering and checking data to databases. Where data is collected by external providers it is generally provided at the end of each financial year in agreed formats using a template supplied to them by the council.

Table 2: Sampling details for marine monitoring programmes. See Appendix 3 for database descriptions

Programme	Sub-programme	Sampling Interval	Sampled by	Data entry	Database
Water quality		Monthly	Auckland Council. Water samples sent to Watercare Laboratories.	Data from probes entered directly, data from lab received in template.	Hydstra
Shellfish Contaminants		Annual (oysters: Nov/Dec, mussels: Sep to Dec)	Auckland Council - samples sent to external labs for analysis	Data received from lab and entered.	Hydstra
Sediment Contaminants	SOE	Biennial (Oct/Nov)	Diffuse Sources Ltd – samples sent to external labs for analysis	Data received from lab and entered.	Hydstra
	RDP	Annual (Oct/Nov) but sampled sites rotate (2-5 yearly) depending on level of contaminants.	Diffuse Sources Ltd – samples sent to external labs for analysis	Data received from lab and entered.	Hydstra
Marine Ecology	Manukau	bimonthly (Feb, Apr, Jun, Aug, Oct, Dec)	Cores collected by Auckland Council, sorted and ID by NIWA	Data received from providers on yearly basis and entered.	EcoBase
	Central Waitemata	Bimonthly (Feb, Apr, Jun, Aug, Oct, Dec)	Cores collected by Auckland Council, sorted and ID by NIWA	Data received from providers on yearly basis and entered.	EcoBase
	Mahurangi	Trimonthly (Jan, Apr, Jul, Oct)	Cores collected by NIWA plus AC, sorted and ID by NIWA	Data received from providers on yearly basis and entered.	EcoBase
	Upper Waitemata Harbour	Trimonthly (Feb, May, Aug, Nov) for some sites and annually for some muddy sites to avoid disturbance.	Cores collected by NIWA, sorted and ID by NIWA	Data received from providers on yearly basis and entered.	EcoBase

Programme	Sub-programme	Sampling Interval	Sampled by	Data entry	Database
	Estuaries	Biannual October and April plus events	Cores collected by NIWA, sorted and ID by NIWA	Data received from providers on yearly basis and entered.	EcoBase
	Reefs	Annual (Subtidal in Feb/April, Meola intertidal in Oct) 6 weekly for sediment traps	University of Auckland	Data received from providers on yearly basis and entered.	EcoBase
Habitats (Tier II)		Usually a 2 year programme for each site, not currently programmed	Tendered	Data received from providers	EcoBase for ecology data. GIS for habitat data.
Benthic Health (ecology)		Annual (Oct/Nov) but sampled sites rotate (2-5 yearly) depending on level of contaminants. 2 yearly for most contaminated suites, 5 yearly for rest	Diffuse Sources Ltd	Data received from providers on yearly basis and entered.	EcoBase
Beach Profiles		Annual (Tidally-dependant sampling; beginning and end of summer (Apr-May, then Oct-Nov)	Auckland Council	Data entered directly	RMap

5.0 Reporting

Data collected by monitoring programmes is disseminated by a variety of formal and informal means. Formal reporting ensures that the information is made publicly available in a variety of formats, suitable for the audience. Informal methods ensure that data is used to: inform council policy, planning and consenting processes, and non-statutory initiatives; educate council staff and community stakeholders; and improve the councils understanding of environmental processes. The various methods of data dissemination are summarized below.

5.1 Data reporting

All raw data is held in council databases and can be accessed to provide data for specific requests (time period and sites can be specified).

Raw data for some programmes is reported directly via the Auckland Council GIS viewer (http://maps.aucklandcouncil.govt.nz/aucklandcouncilviewer/ Environmental Data Online), while others are reported in data reports (raw data only no interpretation) or included as data table appendices in interpretative technical reports (see 6.2 below). As web based reporting of data improves the inclusion of data tables in technical reports will cease.

5.2 Technical reports

Technical reports are produced for each of the monitoring programmes/sub-programmes on a regular basis (Table 3) and published on the Auckland Council website at http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/reports/technicalpublications/Pages/home.aspx. The purpose of these reports is to make detailed monitoring results publicly available and provide a technical interpretation of the findings. The reporting frequency is designed to allow enough data to be gathered for trend detection, but also to allow a check on sampling and data accuracy before deficiencies in these, impact on the data set. Also if a real change is suspected, early detection will allow closer monitoring to determine if the trend is real and potentially investigative studies to determine the cause.

Table 3: Data reporting format for marine monitoring programmes. Year/number of last report is given.

Programme	Sub-programme	Current data reporting	Technical reporting (basic trends)	Technical reporting (review)
Saline water quality		Online, yearly data reports,	3 yearly TR 2008/005	6 yearly TR 2008/005
Shellfish contaminants		Yearly data reports	5 yearly 2012 (report pending)	5 yearly 2012 (report pending)
Sediment Chemistry		Yearly data reports	3 yearly 2012 (report on data up to 2010)	6 yearly 2012 (report pending)
Benthic Health			3 yearly 2012 (report pending)	6 yearly 2012 (report pending)

Programme	Sub-programme	Current data reporting	Technical reporting (basic trends)	Technical reporting (review)
Marine Ecology (Tier I) - Harbours	Manukau	Appendices in technical report	2 yearly 2011 (TR2012/004)	6 yearly Planned for 2013/14
	Mahurangi	Appendices in technical report	2 yearly 2011 (TR2012/003)	6 yearly Planned for 2013/14
	Central Waitemata	Appendices in technical report	2 yearly 2012 (report number pending)	6 yearly Planned for 2013/14
	Upper Waitemata	Appendices in technical report	2 yearly 2012 (TR2012/027)	6 yearly Planned for 2013/14
	Kaipara Harbour	Appendices in technical report	2 yearly 2012 (TR2012/026))	6 yearly Planned for 2013/14
Marine Ecology (Tier I) - Estuaries	including Whanngateau	Appendices in technical report	2 yearly 2012 (TR2012/005)	6 yearly Planned for 2013/14
Marine Ecology (Tier I) - Reefs	Subtidal	Appendices in technical report	2 yearly (TR 2010/032)	6 yearly WR132 (2006)
	Intertidal	Appendices in technical report	2 yearly (TR 2010/031)	6 yearly WR132 (2006)
Habitat monitoring (Tier II)		Appendices in technical report	Not applicable	Aim is to return to sites within 10 years
Coastal Profiles		Appendices in technical report	3 yearly (TR2008/015)	6 yearly (IR2008/004)

5.3 Spatial and web based reporting

The detailed results of monitoring programmes are published as technical reports but these tend to be highly specific and quite complex and as a result, the information is not accessible to all audiences. To help address this issue, a range of spatial and web based reporting mechanisms are being implemented which utilize reporting indicators. These are discussed below.

5.4 Indicator Implementation

Most definitions of ecological health include concepts of the structure and function of the biological assemblages that comprise a particular ecosystem. Indicators should reflect both of these attributes

Marine environments are characterised by large variations in the spatial and temporal patterns of biodiversity driven by variability in factors such as habitat availability, levels of recruitment, regional oceanography, climatic cycles and the ecological interactions among marine species (e.g. competition and predation). Spatial and temporal variation in human impacts adds extra complexity to an already difficult task of assessing variable marine environments. Impacts may be sustained (long term) or

episodic (short-lived), operate over small scales or hundreds of kilometres, and affect ecosystems in ways that are difficult to predict or detect. Incorporating an understanding of this variation into monitoring programmes is difficult, yet important.

Given the limited resources available for effective monitoring of biodiversity and environmental quality, it is important to identify surrogate (indicator) measures that reflect patterns of biodiversity over large, continuous areas. In identifying suitable indicators, it will be crucial to examine the inertia, resilience and stability of natural populations and to find out more about ecosystems, habitats and species within the marine ecosystems of Auckland.

Reporting Indicators

While we monitor a very wide range of parameters and variables that allow us to monitor changes in biodiversity and environmental quality, it can be very difficult to communicate this in a meaningful way, particularly to a non-specialist audience. In addition tracking changes over time can be very complicated if there are multiple variables to compare. In order to simplify the communication of results and changes over time and to place local areas in a regional context, a number of reporting indicators have been developed for the marine monitoring programme.

For water quality, we monitor up to 27 key parameters that serve as indicators of sediment, nutrient and biological waste input and changes in the physical environment. On their own, each of these parameters can provide important information, such as a change in temperature (which long term might be related to climate change) or an increase in selected nutrients (which might suggest increased inputs due to land management purposes). Reporting on 27 individual parameters can be confusing.

Four indices are used to assess the water quality for marine water and assessed across seven water quality variables.

- Scope: represents the percentage of parameters that failed to meet the compliance thresholds at least once (the lower the index the better).

- Frequency: represents the percentage of all individual tests that failed to meet the compliance thresholds (the lower this index the better).

- Magnitude: represents the amount by which failed tests exceeded the compliance thresholds (the lower this index the better).

- An overall Water Quality Index for ecological health based on a combines the three indices described above (the higher this index the better).

This WQI enables us to assign an overall water quality class using the following ranges:

- Greater than 90 = Excellent water quality,
- Between 70 and 90 = Good water quality,
- Between 60 and 70 = Fair water quality,
- Lower than 60 = Poor water quality.

The level of contaminants in sediments is reported in relation to sediment quality guidelines and this allows us to report the proportion of monitored sites above or below guidelines. Because the programme has a reasonable coverage of the region, we can compare the proportion of sites above guideline values between different areas. The contaminants selected for monitoring represent those most commonly found in stormwater and ubiquitous with urban environments (Cu, Pb and Zn) and a number of organic contaminants that can be of concern. We acknowledge that there are emerging contaminants of concern

mainly of the persistent organic nature. National standards for the analysis and effects of these contaminants need to be developed.

There are no established guidelines for ecological effects of contaminants in shellfish, therefore we analyse and report these in relation to figures from international literature and look at spatial and temporal changes. Contaminants in shellfish are not monitored in relation to food safety standards, which is the responsibility of the New Zealand Food Safety Authority.

Standardised indicators for marine ecological health are more difficult due to the different species present and the different conditions among and within harbours, estuaries, open coasts and reefs. That is, in most cases you would expect differences in composition, abundance and diversity of species between different habitat types.

The Benthic Health Index (BHI) describes the health of estuaries and harbours based on the types of animals and the levels of heavy metals (copper, lead and zinc) found in the sediment. The indicator uses a 1 to 5 scale with 1 meaning the environment is a healthy one while 5 means it is unhealthy.

The Traits Based Indicator (TBI) was developed based on the richness of species in 7 functional groupings, with changes in index values reflecting potential shifts in ecological resilience. In conjunction with the Benthic Health Index, it offers a useful way of assessing the functional health in our harbours and estuaries.

Changes in Soft Sediment Communities monitors changes over time, in the numbers and types of organisms, which live in and on muddy and sandy sediments that represent harbours and estuaries of the Auckland region.

Changes in Reef Communities monitors changes over time, in the numbers and types of organisms, which live on intertidal and shallow subtidal reef habitats.

5.5 Reporting of performance monitoring

If we revisit the Driving Force, Pressure, State, Impact, Response (DPSIR) model (see Integrated Monitoring Plan) it can be seen that the monitoring and reporting framework is circular and inter-linked and that the outcomes of responses (changes in policies or behaviours) can be followed by monitoring changes in pressure, state or impacts.

5.5.1 Policy effectiveness monitoring

Monitoring the effectiveness of policy and plans in achieving environmental outcomes, essentially involves integrating and reporting the appropriate information gathered under state of the environment monitoring programmes. In some cases, issue specific information will be gathered to determine the effectiveness of a particular plan. Examples of specific policy effectiveness monitoring programmes are given in Table 4. Specific research programmes may also be initiated to answer questions of policy effectiveness but are not the subject of this monitoring plan.

In other cases, the issue will be more broadly based and a broader information source is required. For example, many of our monitoring programmes gather information on the effects of sediment delivered to aquatic environments. The information from these programmes can be integrated and reported together to provide a regional picture on how our policy and plans in general are addressing the issue of sedimentation in aquatic environments, it does not relate changes to any specific policy or plan.

Table 4: Marine monitoring programme contribution to specific policy initiatives

Policy Issue	Specific programme	How is it reported
Weiti Forest	Weiti Forest Monitoring (currently being designed)	In design phase
Whitford Plan Change	Estuaries programme	In estuaries technical report
Long Bay Plan Change	Reefs programme	In reefs technical report
Okura Plan Change	Estuaries programme	In estuaries technical report
Stormwater	Sediment chemistry and benthic health programmes	In sediment chemistry and benthic health technical reports

6.0 Programme Reviews

Individual programmes are reviewed internally with the preparation of every technical report to ensure programme efficiencies. For example, site redundancy is reviewed. Marine monitoring programmes are reviewed more comprehensively at 5 to 6 year intervals. Techniques in these areas are continually developing. While it is necessary to keep continuity of methods, it is often possible to reanalyse old data using new techniques that are more appropriate and sensitive. Also, if research identifies appropriate indices, these should be included in the monitoring. Furthermore, the relative merits of effort put into spatial and temporal information is investigated.

Details of the components of the review (technical review and audit) are covered in the Integrated Environmental Monitoring Plan. Examples of recent reviews and their outcomes are:

Long Bay Land Development Effects monitoring programme and Meola Reef SOE monitoring programme (now combined and referred to as Reefs programme).

An independent audit of these two monitoring programmes was carried out in September 2006 by Dr. Tim Haggitt of Coastal and Aquatic Systems Ltd and Dr. Shaw Mead of ASR Marine Consulting and Research. The audit and review highlighted a number of deficiencies and concerns primarily related to project management by the research provider (Haggitt and Mead 2006 – WR132 and Haggitt and Mead 2007). We worked closely with the provider to rectify these matters and ultimately this has resulted in substantial changes in the key external personnel working on this programme. We now have one of New Zealand's top reef ecologists with substantial international experience, Dr Nick Shears, leading this programme.

Estuaries Monitoring Programme

This programme was independently peer reviewed for technical robustness by an expert of international standing in their field, Dr. Conrad Pilditch (University of Waikato) during 2006. General findings from this review were that, "… the overall sampling design analysis and interpretation is of a high standard. The conclusions drawn are sound and consistent with the data presented and I have no fundamental criticisms of the study." An independent audit by Dr. Tim Haggitt of Coastal and Aquatic Systems Ltd and Dr. Shaw Mead of ASR Marine Consulting and Research also found no areas of concern in the data management or quality. Results of both of these reviews is provided in Working Report 129 (ARC 2007)

As a result of the review we consolidated the number of sampling sites and the savings resulting from this are now being used to provide better data on the flow of catchment derived sediment to the estuary which will allow us to better target the question of cause and effect by generating robust data. This data collection is being undertaken by Auckland Council staff (Environmental Monitoring).

In addition, the quality of the programme was largely attributed to key technical staff employed by research provider. With the departure of the key staff member, we took the opportunity to review the programme further and to externally tender the project to see what efficiencies could be achieved. Substantial cost savings ($81,540) were achieved by a rationalisation of sites, improved methodology and through leverage with NIWA existing research activities and expertise. An additional series of experiments will be introduced to drive further methodological improvements.

Shellfish Contaminant Monitoring Programme

A review and audit of the shellfish monitoring programme was carried out by Dr. Geoff Mills in 2007 (WR131, Mills 2007). The review found that programme provided a high quality information resource of local, regional and national significance. The programme was well designed and run and the data analysis and reporting were of a high standard. The review strongly recommended that the programme continue for at least another five years and that any changes should be made in parallel with the existing programme. Recommendations were made for areas to investigate to maximise the information obtained from the programme, such as integration of land use pressure data. This programme is currently undergoing a further independent peer review (being carried out by NIWA).

7.0 Linkages to other monitoring programmes

7.1 Linkages to other environmental monitoring and research programmes

There is an integral link between what happens on land, what flows down streams and what ends up in the sea. For example, contaminants originating from a range of land uses (e.g. forestry or industrial land use) enter freshwater rivers and streams and eventually discharge into the marine environment.

The Auckland Council maintains rainfall and stream-flow monitoring sites throughout the Region. Information collected from a number of these sites has been particularly useful for generating direct estimates of sediment run-off into the coastal environment, and for providing data for the development of sediment run-off models. This type of information is becoming increasingly valuable for the interpretation of marine monitoring results. Currently sediment loads are available from only a limited number of flow monitoring sites. A programme for increasing the coverage of these data is currently being implemented.

The marine monitoring programmes are also complimented by the Regional Stream Monitoring Programme which provides information on the quality freshwater receiving environments. Eight water quality parameters are common across both water quality monitoring programmes and were used in the 2009 State of The Auckland Environment report (ARC 2009b) to compare trends in water quality. Results of the regional scale assessment of marine water quality were found to closely mirror results observed for the freshwater quality monitoring programme.

Across the Auckland region, during the period from the early 1990s until the mid 2000s, there was a significant decrease in the concentrations of some sediment related variables, such as suspended sediment and total phosphorous, at most monitored freshwater and marine sites. Concentrations of faecal coliforms, nitrate, and soluble reactive phosphorous also decreased in both environments. Trends in ammonicial nitrogen were more variable with some sites decreasing and some sites increasing. Turbidity (water clarity) also displayed varied results with decreases in freshwater environments while marine sites showed no consistent trend. In addition, there was a region wide increase in water temperature at both marine and freshwater sites.

A specific example of this link is the comparison of freshwater and marine water quality for Rangitopuni creek located in the upper Waitemata harbour. Both freshwater and marine water quality parameters are sampled at differing locations of the Rangitopuni creek. Both monitoring programmes revealed improving water quality between the early 1990s to mid 2000s. In particular, a reduction (indicating improving water quality) in the concentrations of faecal coliforms, the two phosphorous species (total and soluble), suspended sediment and turbidity (or water clarity) was observed. It is difficult to determine the cause of water quality changes due to the complexity of the relationship between water quality, climate and human activities. However, the observed improvements are likely a result, in part, of improvements in land and waste management.

With both the sediment and stream monitoring programmes, efforts are being made to integrate the establishment of new sites with existing monitoring sites in the marine receiving environment.

7.2 Linkages to external monitoring and research programmes

Given the importance of the marine environment and its ecosystems, it is vital to understand as much as possible about this complex natural resource. It is important to try and understand how these ecosystems are structured (e.g. the distribution of habitats) and how they work in relation to physical processes such as tides and waves and their biological processes such as competition and predation. Much of this is

beyond the capacity of a regional agency, which is why, as well as undertaking and commissioning research, we work cooperatively with crown funded agencies, universities and research providers.

Our monitoring programmes derive significant leverage from Ministry of Business and Innovation (MBIE – previously Foundation for Research, Science and Technology (FRST)) funded research. Analysis of long term data in relation to climate variability has been carried out by NIWA under FRST funding utilising our long term ecological data set and has allowed natural variability to be taken out of an analysis and to identify the remaining anthropogenic related variability. Many of NIWA's core and MBIE funded research programmes looking at disturbance effects, resilience and recovery dynamics are embedded within locations with long term benthic ecology monitoring.

8.0 Moving monitoring forward

A formal comprehensive gap analysis is required. What is presented here are simply some preliminary ideas.

Now that the marine monitoring programmes are working together to provide integrated information the priority is to integrate the marine programme with other environmental monitoring programmes. A catchment based approach would provide the best way to achieve this. Efforts are currently being made to retro-fit existing programmes. That is stocktaking what information is available for each catchment and deciding if new sites or variables can be added to provide a more complete picture of what is happening in the marine receiving environment. For example establishment of sediment monitoring flow stations on key riverine inputs to marine receiving environments.

More information on changes in land use is required to interpret changes in ecological communities in marine receiving environments and this information needs to be integrated, in that it comes from relevant areas and is captured at a time scale relative to the ecological changes observed. Information is also required on pressures such as the quality of stormwater and waste water inputs and river discharges.

The current monitoring programme is designed to be flexible, to allow for the programme to respond to the identification of new issues. The following recommendations may help better define priority issues.

- More frequent risk assessment of a variety of issues based on actual data as opposed to desktop exercises.
- Research into risk assessment procedures.
- Integration consent/compliance monitoring methods with state of the environment monitoring to produce comparable data. This can be done by using similar core sizes and number of samples to those used in similar habitats by the monitoring programme, by having sampling times in common, by measuring common parameters and utilise standardised analytical procedures, or by using nearby monitored sites as controls. This would allow us to more closely investigate causal relationships and expand the spatial coverage of the monitoring programme.

The marine ecology programme focuses on macrobenthos, because they are relatively immobile and therefore represent local conditions. Depending on the species, they act as a food source for other organisms (e.g., fish, birds and people); they play an important part in nutrient cycling and carbon fluxes between the water and the sediment; they affect water clarity and algal blooms; they stabilise sediment; they may concentrate / accumulate some contaminants in their tissues; and a large number of potential invasive species are benthic. While these reasons suggest macrobenthos as the best indicator to monitor for determining stress and/or health of the marine ecosystem, there are a number of other species/factors that could be investigated such as fish. However, there are difficulties in monitoring such motile species and relating changes in these to spatial impacts.

Extending the programme to include monitoring of phytoplankton and zooplankton would provide information on blooms and eutrophication. Problems involve, mobility, extreme temporal and spatial variability (meaning blooms are not likely to be detected), need for large-scale sampling balanced against fine-scale detail of species (especially for toxic blooms and determination of invasive species).

Monitoring should be constantly reviewed to integrate developments in our understanding of the sensitivity of organisms to particular pressures such as sediment and toxicity.

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10.0 Appendix 1: Marine monitoring programmes descriptions

Table 5: Description and sampling details of marine monitoring programmes and sub-programmes.

Programme	Description and sampling details
Marine Ecology – Estuaries (soft-shore)	Physical and biological monitoring of estuaries within the Auckland region. **Sampling sites** are located in the Whangateau, Puhoi, Waiwera, Orewa, Okura, Mangemangeroa, Waikopua and Turanga estuaries. **Sampling frequency** = biannual (Apr and Oct). In addition, event based sampling (rainfall threshold) may also be conducted. **Sampling began** in 2001 (not at all sites) and is ongoing. **Number of sites** = 80 total (10 sites per estuary). Sites marked by GPS and special purpose navigational markers. **Extent of site** = 1250m^2 (50m x 25m). **Number of replicates** = 6 per site. **Measured variables** = Infaunal communities using 500µm mesh (species identified to lowest taxonomic level possible and enumerated, key bivalves measured). Sediment characteristics (grain size, TOC and chlorophyll a). **Sampling protocol and QA** = Internal, NIWA laboratories.
Marine Ecology – Harbours (soft-shore)	Physical and biological monitoring of harbours within the Auckland region. **Sampling sites** are located in the Central Waitemata Harbour (CWH), Manukau, Mahurangi, Kaipara, Upper Waitemata Harbour (UWH). **Sampling frequency** = bimonthly in CWH (Feb, Apr, Jun, Aug, Oct, Dec), trimontly in Mahurangi (Jan, Apr, Jul, Oct) and UWH (Feb, May, Aug, Nov) for some sites and annually for some muddy sites to avoid disturbance. **Sampling began** in 1987 (not at all sites) and is ongoing. Number of sites = 33 total (note some sites monitored on rotational basis, 2 years on and 5 years off). Extent of site = 9000m^2. **Number of replicates** = 12 per site. **Measured variables** = Infaunal communities using 500µm mesh (species identified to lowest taxonomic level possible and enumerated, key bivalves measured). Sediment characteristics (grain size, TOC and chlorophyll a). **Sampling protocol and QA** = Internal, NIWA laboratories.

Programme	Description and sampling details
Marine Ecology - Reefs	Physical and biological monitoring of rocky reefs within the Auckland region. **Sampling sites** are located in Waitemata Harbour (Meola Reef), East Coast Bays, Leigh, Tawharanui and Mokohinau Islands. **Sampling frequency** = annual for ecology (Meola intertidal in Oct, all subtidal reefs in Feb/Mar) and 6 weekly for sediment. **Sampling began** in 1998 (not at all sites) and is ongoing (Leigh and Mokohinau Islands not sampled since 2010). **Number of sites** = Meola subtidal (6), intertidal (5), Little Manly, Long Bay, Torbay, Campbells Bay (5 each), Leigh, Tawharanui, Mokohinau Islands (1 each). **Number of replicates** = Varies depending on location; Meola, Little Manly, Long Bay, Torbay and Campbells Bay subtidal (7 quadrats + 1 sediment trap per site), Meola intertidal (10 permanent quadrat locations per site). Leigh, Tawharanui, Mokohinau Islands (5 quadrats at 2-4 depth strata (0-3, 4-6, 7-9, 10-15m). **Measured variables** = Macrofaunal communities (visual observer counts and measures using $1m^2$ quadrat). Sediment characteristics. **Sampling protocol and QA** = Internal sampling protocol, University of Auckland laboratories. Uniservices internal QA procedures
Marine Ecology – Habitats and Communities	Tier II monitors broad scale habitat and ecological communities for more accessible and higher priority near-shore ecosystems within the Auckland region. **Programme locations** = so far include Kaipara Harbour, Kawau Bay, Tamaki Strait and Wiaroa. **Sampling frequency** = Surveys are to be repeated on a 10-15 year rotational basis to allow for detection of any major changes. **Sampling began** in 2003 (Kaipara) and is ongoing. **Number of sites** = Sampling is carried out in a new location every two years, with each survey taking two years to complete. **Extent of site** = Varies. **Number of replicates** = Varies depending on location. **Measured variables** = This vast programme integrates helicopter video transects, ground transects, quadrats, cores, single beam QTC and side-scan sonar transects, underwater video transects, dredge transects, and also measures algae, sediment grain size, Chlorophyll a and organics. The methods employed depend on location specific conditions. **Sampling protocol and QA** = Internal sampling protocol, NIWA internal QA procedures. Sampling protocol depends on the location being sampled and the aspects of interest. A range of broad scale sampling devices may be employed along with more detailed core and diver sampling where appropriate.

Programme	Description and sampling details
Benthic Health	Physical and biological monitoring of estuaries and harbours within the Auckland region. The benthic health model was developed to provide a tool for classifying intertidal sites within the region according to categories of relative ecosystem health, based on its community composition and predicted responses to storm-water contamination. **Sampling frequency** = annual (Oct/Nov) but sampled sites rotate (2-5 yearly) depending on level of contaminants. **Sampling began** in 2002 (not at all sites) and is ongoing. **Number of sites** = 53 total, ecology is monitored at 32 sites along with sediment chemistry (contaminants) to give an overall picture of benthic ecosystem health. Sediment chemistry is monitored at a further 21sites. **Extent of site** = 9000m^2. **Number of replicates** = 10 per site. **Measured variables** = Infaunal communities using 500µm mesh (species identified to lowest taxonomic level possible and enumerated, key bivalves measured). Sediment characteristics (grain size, TOC and chlorophyll a). **Sampling protocol and QA** = Internal, NIWA laboratories.
Sediment	Chemical monitoring of sediments in estuaries within the Auckland region. **Sampling frequency** = annually (Oct/Nov); monitored sites rotate with a 2-5 year return period depending on the level of contamination. **Sampling began** in 1998 (not at all sites) and is ongoing. Number of sites = Approximately 80 sites in total. **Extent of site** = Varies; some sites are 1000m^2 (50m x 20m) and some are sub-sampled within 10,000m^2 (100m x 100m) plots. **Number of replicates** = 5 composite replicates per site (3 analysed, 2 kept for long-term storage and reanalysis if needed). **Measured variables** = Generally samples (scoop) collected every 2m along a pair of 50m 'runways'. Sediment characteristics (grain size, chlorophyll a, TOC, cadmium, nickel, lead, zinc, chromium, copper, arsenic, organics. **Sampling protocol and QA** = Internal sampling protocol based on the former SOE programme and the Regional Discharges Programme (RDP). Sediment analysis external (Malvern Particle Analyser: pre-2010, wet sieving: post-2010).

Programme	Description and sampling details
Shellfish	Physical, biological and chemical monitoring of shellfish within the Auckland region. The objective is to identify contaminants with abnormally high concentrations in shellfish, detect changes in contaminant levels over time, detect differences in contaminant levels between locations, and evaluate the effectiveness of measures aimed at reducing contaminant loads. **Sampling sites** are located in Tamaki Estuary, Waitemata Harbour and Manukau Harbour. **Sampling frequency** = annual (oysters: Nov/Dec, mussels: Sep to Dec). **Sampling began** in 1987 for oysters and 1999 for mussels (not at all sites) and is ongoing. **Number of sites** = 11 total: 4 wild-caught sites (oysters) and 7 'deployment' sites (mussels). **Extent of site** = varies. **Number of replicates** = 5 oyster or 5 mussel samples per site, pre-deployment samples are also taken for mussel sites. Measured variables = Shellfish analysed for metals (regular suite of 6 metals analysed), organics (including PAHs, PCBs and OCPs), condition index. **Sampling protocol and QA** = Internal monitoring protocol, has two sections: wild-caught oyster samples, and farmed mussels (sourced from the Coromandel, assembled on rigs in Kelly Tarlton's Sea Life Aquarium, deployed on site and then retrieved 3 months later by the AC dive team by boat. QA = Internal, a bulk reference sample is analyzed by the organics lab.

Programme	Description and sampling details
Beach Profiles	Profile monitoring of beaches of interest (e.g. those with high ecological values or planned development) within the Auckland region. **Sampling sites** are located at; Long Bay, Browns Bay, Campbells Bay, Milford, Cheltenham, Takapuna, Maraetai, Kawakawa Bay, Piha, Muriwai, Mangawhai, Pakiri and Omaha. **Sampling frequency** = annual (Tidally-dependant sampling; beginning and end of summer (Apr-May, then Oct-Nov). **Records start in** 1965 (Omaha) but most site records are more recent (starting in 1998). Sampling is ongoing. **Number of sites** = 13 total. **Extent of site** = transects span from dune to low water (length of transect varies depending on site). **Number of replicates** = 2-11 (depending on site). **Measured variables** = This programme monitors long-term changes in the landward position of the beach, changes in volume of sand stored within the beach, changes in beach width, and determination of the envelope of beach change for the entire dataset for each beach. The programme provides information on beach dynamics, coastal hazards and changes that can potentially be linked to changes in climatic patterns. **Sampling protocol and QA** = Internal protocol - the beach profile is surveyed to the nearest cm. from dunes to water's edge (historically, some have gone deeper with sounder/sonar)

Programme	Description and sampling details
Saline Water Quality	Water quality monitoring of harbours and coastal waters within the Auckland region. **Sampling frequency** = monthly. **Sampling began** in 1986 (not at all sites) and is ongoing. **Number of sites** = 36 total: East Coast (x9), Kaipara Harbour (x7), Manukau Harbour (x7), Waitemata Harbour (x11), Tamaki Estuary (x2). **Number of replicates** = 1. **Measured variables** = Salinity, conductivity, DO%, DOmg/l, temp, PH (YSI meter), Enterococci, TP, DRP, TKN, NNN, TN, NO_3, NO_2, chlorophyll a, chloride, turbidity, suspended solids, ammoniacal nitrogen and total oxidisable inorganic nitrogen (external lab). Water samples taken from top 0.5m of water column on the falling tide, just after high water. **Sampling protocol and QA** = Internal sampling protocol, samples are collected by helicopter or boat.

11.0 Appendix 2: Rotational monitoring of marine ecology sites

Harbour

Table 6: Rotational monitoring of harbour sites through time. As Kaipara is still in its first five years of sampling, it is not known if site numbers can be reduced or what they would be reduced to. All sites in Upper Waitemata are currently monitored as changes in catchment land use and subsequent effects in the receiving environment are expected.

	Manukau	Waitemata	Mahurangi	Kaipara
2011	2	4	Full (6)	Full (6)
2012	2	4	5	Full (6)
2013	Full (6)	4	5	Full (6)
2014	Full (6)	4	5	Reduced
2015	Reduced	Full (6)	5	Reduced
2017	Reduced	Full (6)	5	Reduced
2018	Reduced	Reduced	Full (6)	Reduced
2019	Reduced	Reduced	Full (6)	Reduced
2020	Reduced	Reduced	Reduced	Full (6)
2021	Full	Reduced	Reduced	Full (6)
2022	Full	Reduced	Reduced	Reduced
2023	Reduced	Full	Reduced	Reduced
2024	Reduced	Full	Reduced	Reduced
2025	Reduced	Reduced	Full	Reduced
2026	Reduced	Reduced	Full	Reduced

In the Manukau Harbour, the sites, Auckland Airport (AA) and Clarks Beach (CB) have been sampled bimonthly between October 1987 and February 2011. Two sampling occasions were missed (October and December 1988) due to a gap in funding. Sites Cape Horn (CH), Elletts Beach (EB), Karaka Point (KP) and Puhinui Stream (PS) have been sampled for the ARC from October 1987 to February 1993, and again from August 1999 to April 2001. Sampling continued at site CH from April 2001 to monitor the effects of improvements in water quality discharging from Mangere. Additional sampling was carried out at Cape Horn by NIWA, without funding from ARC, between February 1993 and December 1995. This data was collected as part of studies conducted on Te Tau Bank, and funded by the Foundation for Research Science and Technology. Sampling at sites EB, KP and PS commenced again in August 2006 on the recommendation of Funnell and Hewitt (2005) for 2 years until June 2008. Monitoring of Cape Horn ceased in June 2010, whilst Auckland Airport and Clarks Beach have remained ongoing.

For Mahurangi Harbour, six intertidal sites are monitored Cowans Bay (CB), Dyers Creek (DC), Hamilton Landing (HL), Jamieson Bay (JB), Mid Harbour (MH) and Te Kapa Inlet (TK) during the full rotation. A review in 2011 determined that resting Cowans Bay for five will not compromise our ability to detect changes in the estuary's macrofauna.

The Waitemata Harbour has six intertidal soft-sediment sites, three of which have been monitored since 2000 near the Whau estuary (Whau), Hobsonville (HBV) and Shoal Bay (ShB). Two of the sites (located near Henderson Creek (HC) and Te Tokoroa Reef (Reef)) are not presently monitored, and a new site was added at Lower Shoal Bay (LoS) in October 2010.

Monitoring in the Kaipara Harbour was established in 2009 and includes six intertidal sites distributed through the main body of the southern section of the harbour; Tapora Bank (TPB), Kakarai Flats (KKF), Omokoiti Flats near the mouth of Haratahi Creek (HCK), Kaipara Flats (KaiF), near the mouth of Ngapuke Creek (NPC) and Kaipara Bank near the mouth of the Kaipara River (KaiB). All sites are currently monitored.

Estuaries

After 5 years of consistent monitoring across all estuarine sites, a spatially and temporally nested design was introduced in 2009. The number of sites continuously monitored in each estuary was reduced to 7 core sites, from 10, with the extra 3 sites being sampled on a rotational basis over 5 years. The rotation of sites is shown in table 7 below, and the rotational programme through time is shown in table 8.

Table 7: Sites retained as core sites in each estuary and sites for 5 yearly rotation. All 7 sites in Whangateau are core sites.

Estuary	Sites for rotation	Core sites
Puhoi	5, 8, 10	1–4, 6,7, 9
Waiwera	4, 7, 10	1-3, 5, 6, 8, 9
Orewa	7, 9, 10	1–6, 8
Okura	5, 6, 10	1–4, 7–9
Mangemangeroa	1, 4, 8	2, 3, 5–7, 9, 10
Turanga	2, 5, 9	1, 3, 4, 6–8, 10
Whangateau		1-7
Waikopua	2, 5, 10	1, 3, 4, 6–9

Table 8: Programme of estuarine site rotation through time

Estuary	**2013/14**	**20014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**
Puhoi	7+2	7	7	7	7+1	7+2
Waiwera	7	7	7+2	7+1	7	7
Orewa	7	7	7	7	7+3	7
Okura	7	7+1	7+2	7	7	7
Mangemangeroa	7	7	7	7+3	7	7
Turanga	7	7+3	7	7	7	7
Waikopua	7+2	7	7	7	7	7+2
Whangateau	7	7	7	7	7	7

12.0 Appendix 3: Databases

The following provides a brief explanation of the key components of each database.

EcoBase

EcoBase is a database system that assists with the storage of ecological data, and provides tools to assist with the importing, validation, and reporting and analysis of such data. The EcoBase system comprises a front-end client application and a back-end SQL database.

The information collected includes the nature of the sites (habitat), the method used to take the samples, and the analytical results. Results can be counts of the various species found in each sample, individual weight and size of species found, through to the pH of the water, temperature, substrate parameters such as grain size, chlorophyll a levels, riparian vegetation, channel shade, bank stability, etc.

HydroTel 2000™

HydroTel 2000™ is iQuest's leading edge, high performance hydrological / environmental telemetry and database system. It is used by the majority of New Zealand's regional councils as their front-line environmental telemetry and flood warning system. HydroTel™ 2000 has been designed not only for data acquisition, data processing and comprehensive alarm management, but also barrage gate and/or flood pump station control.

HydroTel™ 2000 is central to Auckland Council's environmental data flow operations, in particular:

- Data acquisition system, telemetry retrieval from remote field data loggers and other data sources such as FTP.
- Management of data to the Environmental Data Online website.
- Providing automatically created and despatched reports to customers.
- Providing alarm alerts (SMS text, email, paging) representing exceedances of environmental conditions to customers.

HYDSTRA - Time-Series and Water Quality modules

The Hydstra Data Management Suite incorporates components to manage time-series data, groundwater bore information and water quality data as well as providing modelling tools. The Hydstra Product Suite is designed for organisations that manage large amounts of data. The Hydstra data management system not only stores data but also comprises powerful tools for viewing, editing, data analysis and reporting.

Hydstra provides the ability to consolidate data from different sources. Consequently, Hydstra serves as the primary archive for the majority of the Auckland Council's environmental monitoring programmes.

HydroTel Web Application and ArcGIS Adobe Flex - Spatial Web Viewer

These two components comprise the Environmental Data Online website.

The GIS web viewer uses the latest ESRI Flex technology and is the standard web data portal for the Auckland Council. The various environmental data layers spatially present discreet monitoring locations that are managed through a custom-built widget.

The Hydrotel web application comprises a CGI file that dynamically serves up the web pages at the request of the web user. Dynamic data queries are passed back to the Hydrotel database using a VPN connection.

Remote Monitoring Instrumentation

The M and R group has standardised to the IQuest Iris data logger range. These data loggers are fully compatible with HydroTel™ 2000 telemetry system using data transfer communication protocols GPRS and 3G. Monitoring sensors are standardised based upon preference of using SDI12 communications to data logger.

RMAP (Beach Morphology Analysis Package)

Is a standalone data storage and analysis package for beach profile morphology.