Measuring coastal natural character in eastern Northland

Report for Northland Regional Council

Envirolink medium-sized project 675NLRC95

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June 2009

Abstract

A methodology to measure a variety of attributes that affect natural character is described. This methodology will be useful for assessing natural character changes in the context of the relevant provisions of the Resource Management Act 1991 and the Reserves Act 1977.

The methodology uses a consistent framework across terrestrial, intertidal and marine coastal environments. Parameters and the associated methods for measurement are tailored for the particular coastal environment. The methodology is designed to operate at different scales although some additional work is to be done to fine tune that process.

The overall assessment of natural character for a mapped terrestrial or aquatic unit combines three scores:

- Ecological naturalness score (ENS);
- Hydrological and geomorphological naturalness score (HGNS);
- Building and structure impact score (BSIS); and

An optional Sound and light impacts (SLI)) score can also be included. More work is needed to work out the relative weightings of these scores

The methodology has been developed after extensive trials and more detailed case studies for the Ruakaka coastline, the Waipu coastline, and the inner and outer Bay of Islands. The case studies include a range of coastal environments and levels of development.

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3 Comparing actual and potential vegetation/benthic cover as part of an assessment of coastal natural character

1 Introduction

The purposes of this project were to:

- refine and trial provisional methodology for measuring natural character and its change in the coastal environment of Northland
- prepare a report that describes the methodology and how it can be used

The provisional methodology referred to in the first purpose had previously been developed by the author following earlier investigations into alternative approaches and trials of possible methods for measuring coastal natural character.

2 Background

2.1 Why measure natural character?

New Zealand has a long-standing statutory policy goal to preserve the natural character of the coastal environment. This policy goal is an important part of the planning/development control and the protected areas legislation. It was first included in the planning/development control legislation via a 1973 amendment to the 1953 Town and Country Planning Act. This amendment added a new "matters of national importance" section which included the preservation of the natural character of the coastal environment and the margins of lakes and rivers.

This provision was transferred into the 1977 Town and Country Planning Act and expanded in the 1991 Resource Management Act to include wetlands, rivers and lakes. The Resource Management Act specified that the coastal marine area component of the coastal environment included all the territorial sea from mean high water springs out to 12 nautical miles. No guidance was given as to the inland terrestrial boundary.

The policy goal to preserve natural character of the coastal environment and the margins of lakes and rivers was incorporated within the protected areas legislation as part of one of the three purposes of the 1977 Reserves Act. This provision remains unaltered.

While preservation of natural character has been one of New Zealand's earlier environmental policy goals, it has not been possible to measure performance in an objective way because there has not been a comprehensive methodology for doing this. A first step in developing a method was to develop a "first principles" definition of natural character that is relevant and useful in the New Zealand environmental and legal/policy context.

2.2 What is natural character?

Natural character is a complex concept. It is used by a variety of disciplines including conservation biology/ecology, landscape planning and design, environmental management and restoration, resource planning, geography, ethics/philosophy and psychology.

A comprehensive analysis of literature and the New Zealand context provided the basis for developing the following definition (Froude et al. 2009 in press)

> "Natural character occurs along a continuum. The natural character of a "site" at any scale is the degree to which it:
> - is part of nature, particularly indigenous nature;
> - is free from the effects of human constructions and non-indigenous biological "artefacts"
> - exhibits fidelity to the geomorphology and biological structure, composition and pattern of the reference conditions chosen;
> - exhibits ecological and physical processes comparable to reference conditions"
>
> Human perceptions and experiences of a "site's" natural character are a product of the "site's" biophysical attributes, individual sensory acuity and a wide variety of personal and cultural filters."

2.3 What is the coastal environment?

Policy 1 from the proposed New Zealand Coastal Policy Statement (Department of Conservation 2008a, 2008b) requires Resource Management Act policy statements and plans to recognise that the coastal environment includes at least:

- The coastal marine area;
- Land and waters where coastal qualities or influences are a significant part or element;
- Land and waters affected by active coastal processes;
- Areas at risk from coastal hazards;
- Coastal vegetation and habitat; and
- Landscapes and features that contribute to the natural character, visual qualities or amenity values of that environment

The outcome of the Board of Inquiry hearings and the final shape of the revised New Zealand Coastal Policy Statement are unknown.

> For the purposes of the current project it was necessary to develop a workable definition of the coastal environment to include the coastal marine area (as defined in s2 of the Resource Management Act) plus the coastally influenced terrestrial and freshwater environments. The terrestrial component of the coastal environment includes:
> - Areas where existing or former ecosystems are/were part of natural coastal processes (e.g. active and consolidated dunelands including dune swales and lakes, freshwater wetlands hydrologically linked to estuarine wetlands, tidal reaches of rivers)
> - Areas in the coastal catchments, especially where these catchments can be readily seen from the near shore coastal marine area (e.g. most of the Bay of Islands)

This later definition includes the first five items in the proposed New Zealand Coastal Policy Statement definition. Although it is unclear exactly what is meant by the sixth item, it is likely that aspects of it are covered by my working definition of natural character.

3. Management applications

Developing a comprehensive yet practical methodology for measuring natural character is very complex. This is why multiple re-iterations and refinements were required. Refinements were made throughout the trial and case study process to improve the utility, practical application, and robustness of the methodology being developed.

The methodology presented in this report:

- is scalable,
- can be expanded or contracted as required to address the purpose(s) for measurement,
- is practical to implement
- uses basic GIS technology and
- is quantitative

As a number of adaptations are needed to address different types of coastal environment a considerable amount of this report explains the rationale and implementation of the different parameters required to do this.

The methodology for measuring coastal natural character has been designed to address a range of management applications including:

- Measuring the level of natural character, in a transparent way, at a "site", for a group of sites, for a coastal catchment and at a wider district scale
- Measuring change in the level of natural character in an area over time
- Measuring change in the components of natural character including ecological naturalness, hydrological and geomorphological naturalness, built environment impact, and sound and light regime
- Providing a framework for "testing" or "predicting" the potential natural character impacts of particular activities before the activities occur
- Providing a framework for comparing potential natural character changes at a site or group of sites over time based on different assumptions or different actions
- Providing a transparent way to consider the temporal differences between the often immediate impacts of a development and the benefits of long-term mitigation, especially where the later includes large scale restoration planting

As long as it is appropriately implemented, the proposed methodology should be able to be used for:

- evaluating current natural character at a site, for a section of coast, an island, for a geomorphological or hydrological system such as the coastal environment associated with the Waipu River mouth and its estuary; or a human activity unit such as the Opua marine servicing industry area
- determining the relative magnitude or influence of different parameters on natural character at a location
- evaluating change in natural character at a location or at a range of locations
- comparing levels of natural character at different sites or locations
- identifying potential natural character outcomes resulting from particular activities or management actions at a site or location. This could assist both decision-making and any subsequent monitoring.

It should be emphasised that the refinement of the methodology for measuring coastal natural character is continuing. The next stage is to develop robust weightings between the different core components of natural character. This is needed for those applications where a single natural character assessment is required and for the comparative assessment of the impacts on natural character of different types of actions.

4 Approach to developing methodology for measuring natural character

Previous investigation and initial trials led to the development of a provisional methodology. Within the ambit of the Envirolink project there were:

- Stage I trials covering a large number of locations and a broad range of coastal environments and situations, and
- Detailed Stage II case studies fully applying the revised methodology

The purpose of the Stage I trials was to identify the issues that the methodology for measuring coastal natural character needed to address. The Stage I trials initially used the provisional methodology referred to in the introduction. After each trial, aspects of the methodology were refined and the methodology was amended for the subsequent Stage II case studies.

This iteration process resulted in significant changes to the original provisional methodology to address issues raised in trials. Changes included: the development of a new "viewpoints" method to address aspects of human perception; revised basis for defining mapping units and a revised approach for addressing "shoreline" detail. Table 1 in Appendix 1 lists the locations of the Stage 1 trials and the major issues raised during the methodology trials by each location.

By the end of the Stage I trials there was a new approach for mapping units; and considerable refinement of what was to be measured and how. The revised methodology was used in the Stage II case studies.

Table 2 in Appendix 1 provides information about the locations of the Stage II case studies. The Stage II case studies cover a lesser number of locations. Although a wide range of environment types were included it was not possible to include the full range. The main omissions were the deeper marine environments.

The Stage II case studies implemented the field methodology developed in the Stage I trials with relatively minor revisions. The mapped units were initially defined by hand on laminated or paper aerial mosaic prints. These unit boundaries were digitised along with their unique identifier unit code. Experience with this process was used to provide further methodology refinement. In practice this ongoing process of methodology refinement did require the revision of the boundaries or inclusion of additional mapped units. Some of the Stage II trial data was collected several times to be consistent with ongoing methodology refinements.

Data about each mapped unit was collected using aerial image interpretation and field inspection. It was entered initially onto paper forms and then into Excel spreadsheets.

The collected data were used to refine the analysis methodology. There were a considerable number of iterations of the analysis methodology.

Once the analysis methodology, and the boundaries and the data for each mapped unit were finalised, the spreadsheet data was connected to the GIS images. This was done by linking the mapped unit unique identifier code on the GIS images with the unique identifier in the Excel spreadsheets. The size or area of each mapped unit was calculated. This facilitated the aggregation of natural character data by giving each mapped unit a weighting dependent on its size.

5 The proposed methodology for measuring coastal natural character

5.1 Overview

The proposed methodology for measuring coastal natural character is designed to operate using:

- imagery at a variety of scales of resolution
- a core set of parameters that can be expanded as the situation requires and/or resources permit to include additional parameters

The core methodology has developed using standard aerial imagery previously commissioned by Northland councils. The spatial resolution of the standard imagery varied, although the default scale of the field prints was 1:10,000. High resolution imagery was available for limited sections of coast. The scale of the field prints for this scale of imagery was 1:4500. Marine charts are generally used for the subtidal environment.

The core methodology uses a suite of parameters designed to measure the major factors affecting natural character. The parameters have been carefully selected to be relevant, meaningful and measurable. A smaller suite of parameters is used for subtidal environments.

At lower resolutions a more limited suite of parameters could be used. In contrast, site specific work with high resolution imagery, could use additional or expanded parameters. Where the environment is very complex (from a natural character perspective) some data aggregation is required except where the assessment is being made as part of a highly detailed site evaluation.

5.2 Concepts and principles

The methodology for measuring natural character of the coastal environment was developed considering the following principles:

- That it addresses a comprehensive set of criteria relevant for the New Zealand environmental and legal context (Froude et al. 2009 in press)
- That it recognises the role of natural disturbance and ecological succession processes in environmental change and is able to distinguish between natural change and change resulting from human actions (Froude et al. 2009 in press)

- That a consistency of approach is maintained across different types of coastal environment (Froude et al. 2009 in press)
- That state indicators (as in the pressure-state-response model of indicator development) are used where possible (Froude 2003). Where there are no practical state indicators surrogate pressure indicators can be used as long as care as taken to avoid double counting

Distinguishing between natural change and that resulting from human actions can be difficult in some situations. For example some landslides that occur during heavy rain may be triggered by diverted stormwater flowing onto a vulnerable slope. Volcanic and tectonic disturbance events can cause dramatic change, especially in locations close to the volcanic vent(s), tsunami path or earthquake epicentre. Disturbance from climatic events can regularly affect floodplains, rivers, estuaries and shallow reefs on exposed headlands/shore.

Two terms of particular importance for the methodology are types of cover description:

“Natural areas”: are areas where natural processes predominate, although the species are not necessarily native and may include ecological pest plants. There is a separate assessment of % native cover.

“Biological artefact areas” are areas where human management of the biota prevails. This is evident in the biological processes and patterns. Typically it includes areas in agriculture, horticulture, forestry, orchards, vineyards, gardens and lawns. There is a separate assessment of % native cover. “Biological artefact areas also include sites in the early stages of active restoration to a canopy of native species. Once this canopy becomes a continuous native canopy the area’s cover becomes indistinguishable from natural regeneration and the area’s cover description changes to “natural area”.

5.3 Criteria for methodology to measure changes in coastal natural character

The first stage in methodology development was to identify what the attributes of the methodology should be. A set of criteria were developed after consideration of the following:

- a detailed examination of New Zealand's case law on natural character in the context of the Resource Management Act (and its predecessor the Town and Country Planning Act 1977) (Froude 2009 in prep)
- an assessment of the early documentation relating to the implementation of the natural character purpose in section 3 of the Reserves Act 1977 (Froude 2009 in prep)
- an assessment of the published literature on natural character and related concepts (Froude et al. 2009 in press)
- evaluations of New Zealand monitoring programmes that may be related to the monitoring of natural character (Froude 1999a, 1999b, 1999c, 2000)
- development and implementation of LakeSPI-a methodology to measure lake ecological condition (Clayton et al. 2002)

- the development of the proposed national framework for monitoring terrestrial biodiversity (Froude 2003)

Table 1 lists the criteria that have been developed, with a summary of how the proposed methodology addresses each criterion.

Table 1: Criteria for the methodology to measure changes in coastal natural character

Methodology criterion	**Assessment of how the methodology addresses each criterion**
Show consistency of approach across different types of coastal environment	The approach is standardised as much as possible across different types of terrestrial, freshwater and marine coastal environments
Be highly relevant to measuring the outcomes of the long-standing national policy goal to preserve natural character	The methodology facilitates the measurement of outcomes by addressing parameters that are sensitive to change. Ongoing testing is intended to improve the sensitivity of the methodology
Be robust	The methodology has been developed and tested in a wide range of environments and situations.
Avoid subjectivity where ever possible	The parameters are assessed using objective measures. Parameters based on subjective assessments are not used
Use quantitative or semi-quantitative methods to facilitate measurement repeatability over time	The methodology uses a mixture of quantitative (e.g. % cover), semi-quantitative data (e.g. categories) to facilitate repeatability over time. Some descriptive base data is converted to quantitative data (e.g. comparing current cover with the potential)
Be sensitive to changes in natural character resulting from different causes	The parameters cover a relatively wide range of parameters, especially at finer scales. This should detect changes to natural character resulting from a range of causes
Be capable of being implemented at different scales	The methodology can be implemented at different scales by adjusting the: number and therefore size of the mapping units; number of parameters assessed; and the level of detail used for some parameters
Measure relevant aspects of ecological/biophysical natural character	Parameters include: • the relationship of current cover to the potential; • % native cover; • % alien pest cover; • geomorphological & hydrological naturalness
Measure relevant aspects of the human perception of natural character	Parameters address a variety of aspects relating to the characteristics of buildings and other human constructions, non-natural sounds and artificial light
Be able to be applied in a way that makes use of additional or more detailed information if this is available	The number and therefore size of mapping units can be altered; additional parameters can be added; additional data can be collected for some parameters
Allows results to be depicted	Mapping unit positions can be depicted on

Methodology criterion	Assessment of how the methodology addresses each criterion
spatially	remotely sensed images. As the digitised units are linked to the data about the mapped units there are a number of options for the spatial presentation of data
Provides for a relatively comprehensive evaluation of natural character – thereby reflecting the complex nature of the concept	The methodology addresses a range of ecological, natural physical, human construction physical, sound & light parameters relevant to an assessment of natural character
Be practicable to implement in a range of coastal environment types	The methodology has been developed and refined in a diverse range of coastal environment types. The methodology has been designed to be practical to implement. In some environments (e.g. subtidal and deeper dune lakes) it is necessary to use more complex methods to collect the necessary data.
Allow results to be reported in a way that can be understood by decision-makers and the public	The reporting framework is relatively simple

5.4 Choosing indicators and parameters

During the Stage I trials and Stage II case studies a suite of potential indicators were developed and refined. The correlation between the proposed indicators and the component parts of the definition of natural character is in Table 2.

Parameters are the specific measures that address high level indicators. Some parameters are directly measured (e.g. % cover that is natural area/natural surface) while others are derived or calculated (e.g. Current vegetation cover relative to potential vegetation cover).

Tables 3 and 4 show the measured and derived parameters for each indicator. Table 3 addresses terrestrial coastal environment and coastal lakes while Table 4 addresses the marine coastal environment. Some of the parameters in these two tables are additional to the core set (enclosed in brackets) because they require the collection of quantitative biological data.

Table 5 explains why some parameters require more complex measurement methodology. A number of parameters were considered but not selected. Table 6 explains why some potentially useful parameters were not included in the core set.

Table 2: Correlation of proposed indicators with the definition of natural character*

Definition component for coastal natural character	Proposed indicators
occurs along a continuum	• Method provides for a continuum in natural character
part of nature	• Natural cover • Biological artefact cover
part of nature, particularly indigenous	• Natural area native cover

Definition component for coastal natural character	Proposed indicators
nature	• Alien plant pest cover • Absence of alien vertebrate pests • Native biological artefact cover
free from the effects of human constructions	• Building, structure, paved or surfaced cover • Building & structure height • Building colour & reflectivity • Non-natural sounds • Artificial light
exhibits fidelity to the geomorphology of reference conditions	• Hydrological and geomorphic naturalness
exhibits fidelity to the biological structure, composition and pattern of the reference conditions chosen	• Cover relative to potential • Natural area native cover • Status of indicator species that represent the state of naturalness • Alien plant pest cover • Absence of alien vertebrate pest species
exhibits ecological and physical processes comparable to reference conditions	• Hydrological and geomorphic naturalness • Water clarity

*Indicators in teal blue are negative indicators for natural character

Table 3: Terrestrial coastal environment and coastal lake parameters*

Indicator	Terrestrial coastal environment parameters	Coastal lake parameters
Natural cover	• % natural surface or natural cover	
Native cover	• % of natural canopy that is composed of native species • [% of each tier that is composed of native species in forest and older scrub communities]	% benthic vegetative cover that is native
Cover relative to potential	• Current vegetation cover relative to potential vegetation cover	LakeSPI native score
Status of indicator species that represent the state of naturalness [mobile biota requiring different measurement regime to address seasonal variability]	• % rocky coastline with mature healthy pohutukawa • [Presence & relative abundance of ground dwelling birds (e.g. robin), dotterels (dunelands) and fernbird (coastal wetlands and adjacent scrub), reef heron]	Extent of characean meadow cover?
Alien pest plant cover	• % of natural cover that is alien pest plant species	LakeSPI invasive score

Indicator	Terrestrial coastal environment parameters	Coastal lake parameters
Absence of alien vertebrate pest species	• Absence of alien vertebrate pest species as indicated by the pest management strategy	Absence of alien fish species
Biological artefact cover	• % cover of biological artefact	n/a
Native biological artefact cover	• % biological artefact cover that is native	n/a
Hydrological and geomorphic naturalness	• Magnitude of human mediated hydrological and geomorphological change • Extent of unit affected by human mediated hydrological and geomorphic change	• Magnitude of human mediated hydrological and geomorphological change • Extent of unit affected by human mediated hydrological and geomorphic change
Building, structure, paved or surfaced cover	• % area that is buildings • % area that is structures (excluding buildings) • % area that is paved or surfaced	• % area that is structures
Building & structure height	• Maximum and median building height • Maximum and median structure height	• Spatial occupancy of structures
Building and structure colour & reflectivity	• Building colour naturalness category • Building reflectivity category • Structure colour naturalness category • Structure reflectivity category	
Non-natural sounds	• Risk of non-natural sounds • Resilience to non-natural sounds category	• Risk of non-natural sounds • Resilience to non-natural sounds category
Anthropogenic light	• Anthropogenic light category	• Anthropogenic light category

Indicators and parameters in teal blue are negative for natural character;
[Brackets] identify those parameters that are additional to the core parameter set

Table 4: Intertidal and sub-tidal parameters*

Indicator	Intertidal soft sediment, sheltered waters parameters	Other intertidal parameters	Sub-tidal soft sediment near shore parameters	Sub-tidal hard substrate near shore parameters	Sub-tidal offshore to outer limit of 12NM parameters
Cover relative to potential	Current vegetation /benthic cover relative to potential vegetation cover	Current benthic cover relative to potential benthic cover			
Natural cover	% natural surface or natural cover	% natural surface or natural cover	% natural surface or natural cover	% natural surface or natural cover	% natural surface or natural cover
Native cover	[% of natural surface that is composed of native species?]	% of natural surface that is composed of native species	[% of natural surface that is composed of native species]	% of natural surface that is composed of native species	[% of natural surface that is composed of native species]
Alien pest cover	% of emergent cover that is alien pest species OR Abundance class for alien flora and fauna	Abundance class for alien flora and fauna	Abundance class for alien flora and fauna	Abundance class for alien flora and fauna	[Abundance class for alien flora and fauna]
Status of indicator species that represent the state of naturalness [mobile biota requiring different measurement regime that addresses seasonal variability]	[Presence & relative abundance of sea grass] [Presence & relative abundance of reef heron]	[Presence & relative abundance of reef heron for rocky shore; New Zealand/banded dotterel for sandy beaches]	Presence & relative abundance of sea grass, horse mussels [Presence & relative abundance of snapper]	[Presence & relative abundance of snapper, butterfish, trevally, rock lobster, terakihi, kina]	[[Insufficient information to identify indicator species at this time]]
Biological artefact cover	% biological artefacts	% biological artefacts	% biological artefacts	% biological artefacts	% biological artefacts
Native biological artefact	% of area of biological artefact that is native	% of area of biological artefact that is native	% of area of biological artefact that is native	% of area of biological artefact that is native	% of area of biological artefact that is native
Hydrological and geomrphological naturalness	Magnitude of human mediated hydrological and geomorphological change	Magnitude of human mediated hydrological and geomorphological change	Magnitude of human mediated hydrological/hydraulic and geomorphological	Magnitude of human mediated hydrological/hydraulic and geomorphological	Magnitude of human mediated hydrological/hydraulic and geomorphological

Indicator	Intertidal soft sediment, sheltered waters parameters	Other intertidal parameters	Sub-tidal soft sediment near shore parameters	Sub-tidal hard substrate near shore parameters	Sub-tidal offshore to outer limit of 12NM parameters
	Extent of unit affected by human mediated hydrological and geomorphic change	Extent of unit affected by human mediated hydrological and geomorphic change	change Extent of unit affected by human mediated hydrological/hydraulic and geomorphic change	change Extent of unit affected by human mediated hydrological/hydraulic and geomorphic change	change Extent of unit affected by human mediated hydrological/hydraulic and geomorphic change
Water clarity	Relative extent of intertidal sea grass		Relative extent of subtidal sea grass	Maximum depth of tall brown algae forests (>80% cover)	
Building, structure, paved or surfaced cover	% area that is occupied by buildings or structures	% area that is occupied by buildings or structures	% area that is occupied by structures	% area that is occupied by structures	% area that is occupied by structures
Building & structure height	Maximum and median building & structure height	Maximum and median building & structure height	Maximum and median structure relative occupancy in the water column & above the water	Maximum and median structure relative occupancy in the water column & above the water	Maximum and median structure relative occupancy in the water column & above the water
Building & structure colour & reflectivity	Building colour naturalness category Building reflectivity category Structure colour naturalness category Structure reflectivity category	Building colour naturalness category Building reflectivity category Structure colour naturalness category Structure reflectivity category			
Vulnerability to non-natural sounds	Risk of non-natural sounds category Resilience to non-natural sounds	Risk of non-natural sounds category Resilience to non-natural sounds	Risk of non-natural sounds category Resilience to non-natural sounds	Risk of non-natural sounds category Resilience to non-natural sounds	Risk of non-natural sounds category Resilience to non-natural sounds

Indicator	Intertidal soft sediment, sheltered waters parameters	Other intertidal parameters	Sub-tidal soft sediment near shore parameters	Sub-tidal hard substrate near shore parameters	Sub-tidal offshore to outer limit of 12NM parameters
	category	category	category	category	category
Anthropogenic light	Anthropogenic light category	Anthropogenic light category	Anthropogenic light category	Anthropogenic light category	

* Indicators and parameters in teal blue are negative for natural character;
[Brackets] identify those parameters that are additional to the core parameter set

Table 5: Parameters requiring higher resolution methodology

Environment and parameter	Why this parameter requires a more complex measurement methodology
Soft coast intertidal without emergent vegetation: • % of natural surface that is composed of native species • % of natural surface that is composed of alien species	It can be very difficult to assess these parameters accurately using rapid visual assessment methodologies. Reasons for this include: variability within a mapped unit; and difficulties with accurately identifying epifaunal organisms in a quick survey. It is practical to use categories of abundance for highly visible alien intertidal species (e.g. Pacific oyster). The % intertidal benthic cover that is native can be measured in a detailed survey where quantitative data collection methods can be used.
All coastal environments: • Status of indicator species that represent the state of naturalness- This is particularly applicable to mobile biota as a different measurement regime is required to address seasonal variability	Mobile biota presence and abundance can not be measured using the quick survey approach used for other indicators. This is because their presence and abundance can vary over time (e.g. seasonally, diurnally). Replicates sets of quantitative data are needed for abundance estimates unless populations are so low that it is possible to undertake a census. In general very rare species are not used as indicator species as there would be too few measurements. The measurement of change requires repeat measurements using appropriate protocols to address seasonal migrations (e.g. snapper, rock lobster) and variability in conspicuousness (e.g. dotterel)
% of each tier that is composed of native species	Visual assessments of % cover (top tier of vegetation or benthic cover) can be made using a combination of remotely sensed images and visual inspections. To accurately estimate % native species for each tier under a canopy it is necessary to use quantitative sampling methods

Table 6: Reasons for not selecting particular potential parameters

Potential parameter	Reason for not selecting
% area in mangroves or small mangroves (representing the amount of sedimentation)	While some members of the public consider that increases in the area of mangroves, particularly small mangroves represent an increase in sedimentation for an estuary or inlet, increases in mangroves can reflect mangrove recovery after: previous clearance or cutting of mangroves or mangrove grazing. It may also reflect local changes in sedimentation patterns resulting from structures such as a causeway. In this latter case additional sediment may not be being produced from the catchment but its pattern of deposition may change.
Rate of sedimentation	This requires a special monitoring programme using in-situ plates. Only a few rivers in Northland are currently measured this way and so this parameter

Potential parameter	Reason for not selecting
	could not be widely applied at this time. The may change in future
The presence and/or relative abundance of mobile terrestrial biota that represent naturalness - kereru	Kereru can be highly mobile as they search for suitable food. While they require mature native forest, they can be found in residential gardens where there is suitable food, particularly in winter. The presence of kereru, does not mean that a specific site is highly natural. It does mean that a general area contains native forest of sufficient quality to produce food for kereru over much of the year (i.e. forests contain a variety of fruit bearing plants). Kereru also eat some leaves, including early season kowhai leaves.
Level of contrast of biological artefacts compared to the natural matrix	It can be difficult to determine the natural matrix that the biological artefact is to be compared with. This is because often the contrast is between different forms of biological artefact (e.g. pine shelter belts on ridge tops surrounded by pasture)
Level of fragmentation of natural ecological associations in terrestrial coastal environments	It is not practical to measure this parameter at this time. Challenges that would need to be addressed before using this parameter include: • What constitutes the “natural area” in which fragmentation is to be measured? • What scale should fragmentation be measured at? If fragmentation is measured at a scale that is larger than a mapped unit, how would the fragmentation results be integrated with other mapped unit results?

6. Application of parameters for the terrestrial coastal environment and mapped intertidal emergent vegetation

6.1 Overview of methodology

Remotely sensed imagery (typically aerial) forms the base for natural character evaluation and reporting. The methodology consists of the following:

- Determining mapped unit boundaries on the imagery
- Giving each unit a unique identifier (on occasions the same identifier may be given to small units that are in close proximity and have the same attributes)
- Completing data collection forms for the mapped units (six units per form)
- Completing “viewpoint” assessments and the associated data form
- Entering the data into a spreadsheet
- Undertaking the analysis of the data
- Digitising the unit boundaries, entering the unique identifier for each unit, linking the unit data to the digitised unit and calculating the area (size) of each unit

Where the analysis is at the site level and/or extra information is required there are additional parameters that can be assessed. The “shoreline” straddles mean high water springs, and typically is too narrow to map as a separate unit. As it is often of great interest from a natural character perspective there is the option of collecting data for a small suite of "shoreline" parameters.

The remainder of this section discusses the process of unit mapping, how to measure the relevant parameters, and "viewpoint" and "shoreline" assessment. Appendix 2 contains the data collection forms for:

- Terrestrial and intertidal parameters
- Viewpoint assessment
- Shoreline assessment

6.2 Mapping the units in which the parameters are measured

The first step is to define the boundaries of the total area being assessed. This includes the inland boundary which is typically the inland boundaries of the coastal environment although the boundaries may be chosen for other reasons (e.g. edge of a proposed development site, inland limit of quality aerial images).

The next step is to provisionally identify relatively homogenous units with respect to their "natural character". These units are marked on aerial images and are provisional until the boundaries have been confirmed in the field. The field inspection stage should only be completely removed in circumstances where a very low level of detail is required and few parameters are to be measured. This is because:

- there can be significant changes since the date of the image (e.g. logging of a pine plantation, new residential and other development, clearance of vegetation); and
- it can be difficult to assess some parameters that affect the location of unit boundaries without collecting some field-based information.

The mapped units are to be as homogeneous as possible within the constraints of the scale of resolution of the imagery and purpose of the assessment. Homogeneity is sought because this makes the methodology more sensitive to detecting differences between units and over time for the same unit.

6.3 Parameter addressing current vegetation cover relative to potential vegetation cover

Potential vegetation is that which would be in an area today had humans and their agents (including introduced species) not arrived in New Zealand. To avoid confusion with other possible interpretations of potential vegetation (see Appendix 3) and to facilitate the extension of the concept to include benthic cover in aquatic environments, the term "present-potential cover" is used.

The difference between present-potential [vegetation/benthic] cover and pre-human vegetation cover in that the former takes account of the natural environmental changes that have occurred since human arrival while the later does not. These natural changes may be episodic and major (e.g. volcanic eruptions) or more regular and of lesser magnitude (e.g. alternating phases of coastal dune erosion and accretion in response to climatic cycles). More information about the concept of "present-potential cover" and how it is applied is in Appendix 3.

The relevant information entered into the data collection form is a brief description of current vegetation cover in the "natural areas" and "biological artefact areas", and the likely present-potential vegetation cover for those areas. This description includes the main vegetation structural classes, the predominant species or species group in the canopy, and the approximate age or succession stage of the vegetation cover. Tools that can be used to prepare the description include: analysis of aerial/satellite images, visual inspections, and/or examination of other information sources. An example of a description is tall kanuka forest with scattered broadleaved species and totara.

It is helpful to give an indication of succession stage (and possibly height) unless this is obvious from the structure class and species. Where there is a variety of succession stages in a large unit it would be useful to indicate the relative proportion of the succession stages to assist with later analysis.

Guidance on estimating present-potential (vegetation) cover for an individual unit is in Appendix 3. This Appendix also describes how to score the relationship between the actual observed and present-potential cover.

6.4 Parameters addressing % cover for "natural" areas, biological artefacts, buildings and structures, paved and surfaced areas, cuttings and quarries, and un-surfaced tracks

The following parameters addressing % cover for a unit are to collectively total 100%:

- % cover of "natural areas"
- % cover of biological artefact areas
- % cover of buildings
- % cover of structures
- % cover paved and surfaced
- % cover un-surfaced tracks

Where possible, % cover estimates for buildings, structures, paved and surfaced areas, are adjusted to remove the effects of overhanging vegetation on these estimates. This is because the overhanging vegetation is usually a thin screen over a substantially altered ecosystem underneath.

% cover estimates for un-surfaced tracks typically only include those tracks that are clearly visible and not covered by overhanging vegetation. This is because un-surfaced tracks under a dense forest canopy tend to have a lower ecological impact. Such tracks can also be difficult to detect using remotely sensed images for forest environments. In contrast, vehicle and foot tracks in dunelands are highly visible and damage vulnerable vegetation and dune stability.

These parameters are estimated visually for each unit using a combination of resources and methods including:

- Assessment of electronic and/or hard copy ortho-rectified aerial images
- Assessment of Google Earth electronic images
- Visual inspections from the water, on-site or from a viewing position usually on public land

6.5 Parameters addressing % native cover for "natural areas" and "biological artefact areas"

As for the previous parameter set, visual estimates of % native cover use a combination of resources and methods. In forest and scrub this assessment is made using a combination of visual inspection (most often from the water and/or public land that provides a good vantage point) and aerial/satellite image interpretation. This estimate is made at the same time that current vegetation and pest plant cover is assessed.

In low stature vegetation it is typically more difficult to assess the degree to which the canopy is occupied by native species. An on-site inspection is usually required to assess this accurately. This also applies to the assessments of current vegetation and % pest plant cover.

The estimates of "% cover of biological artefact areas that are native" use a combination of visual assessment and aerial/satellite imagery. Typically, traditional plantation forestry, horticulture and pastoral agriculture use non -native species. The same applies to lawns and other areas of mown grass.

It can be difficult to estimate the "% native cover" where there have been recent native plantings into areas of pasture. Such plantings may be part of the mitigation associated with a coastal development. Over time properly managed native plantings can be expected to coalesce into a continuous canopy and began to function as a "natural area". At this time these areas would be "reclassified" as "natural area" for the purposes of measuring percent cover.

Public and domestic gardens may have any combination of native and introduced species. It is often difficult to obtain a good view of most gardens or groups of gardens for the purposes of estimating percent native cover. In practice most estimates are indicative, but because the area involved is typically small and of low stature relative to the potential cover for the site, it should not matter too much.

Areas of native regeneration within gardens should be treated as "natural area" unless the area is very small. Where a coastal property has clearly used a large percentage of native plants for landscaping, the % native cover will be higher than for the "typical" coastal garden. Where native species (e.g. totara) are used for plantation forestry this will lead to a higher % native cover for the "biological artefact areas".

6.6 Parameters addressing % alien plant pest cover in "natural" areas

The procedure for assessing % alien pest plant cover in "natural areas" is the basically the same as that used for assessing the % native cover. This parameter is not the flip side of % native cover as it is unnecessary to measure that. Instead it assesses the % cover of those species formally identified by the Department of Conservation as environmental weeds. These are species that are major pests in natural areas and potentially have an impact beyond the current occupation of space. Often these are species that are difficult to remove and they can change or halt succession processes.

In low stature vegetation these species can prevent the establishment of, and in some cases replace, native vegetation.

The most authoritative list is the 2008 consolidated list of environmental weeds in New Zealand (Howell 2008). This list includes 328 vascular species, of which a much smaller number may be present in the coastal environment of a particular district or region. While this is a list for areas administered by the Department of Conservation it is equally applicable for lands in other tenures. A smaller list with illustrations and descriptions can be found in the Department of Conservation Weed Manager (Craw 2000). In practice, there is usually a relatively small suite of pest plant species in the canopy of the forest and scrub in a particular location. In low stature communities (e.g. wetlands and non-woody dune vegetation) where there may be a wider suite of pest species. These pest plants may be more difficult to distinguish from native species without close inspection.

The option of using regional council pest plant lists was not pursued because these lists:

- vary from region to region
- include pests of production systems (e. g pasture) that are not necessarily pest plants of natural areas
- may exclude widespread pest plant species that are very difficult to control or where there is no effective control for certain situations

The other alternative is the National Pest Plant Accord list (http://www.biosecurity.govt.nz/pests/surv-mgmt/mgmt/prog/nppa/list accessed on 22 June 2009). This list is part of an agreement between regional councils and government departments with biosecurity functions, whereby regional councils undertake surveillance of nurseries to prevent the sale and propagation of the plants on the list. This list (Biosecurity New Zealand 2008) is incomplete for the purposes of this indicator in that it excludes a number of widespread environmental pest plants (e.g. gorse, variety of troublesome wattles, wilding pine species).

In the basic methodology only the canopy is addressed. Where a detailed site assessment is required it is recommended that each vegetation tier is assessed using quantitative vegetation assessment methods such as those developed for assessing terrestrial riparian vegetation in Hawke's Bay (Froude 2008).

Alien plant pest cover is not assessed in biological artefacts. This is because it is very difficult to do this in a quick visual assessment of gardens and because a number of garden plants are pest plants in natural areas (e.g. agapanthus, arum lily, canna lilies, shrub balsum, monkey apple). Some species used in plantation forestry, horticulture and agriculture are pest plants in natural areas (e.g. variety of pine species, various pasture species, olives, kiwifruit). Also some pest plant species can be managed biological artefacts- such as mown kikuyu grass.

6.7 Parameters addressing building and structure heights

The maximum and median heights of buildings and structures are estimated visually. The purpose of these estimates is to identify the approximate overall median height as well as any much taller structures (using maximum height). Building and structure height is multiplied by the % area occupied to provide the bulk parameters of buildings and structures

6.8 Parameters addressing building and structure colour "naturalness" and reflectivity

These parameters are included because a more “natural” colour and low reflectivity can help mitigate some of the adverse effects of buildings and structures. Because of this potential for mitigation councils may restrict building colours in environmentally sensitive locations, particularly where resource consents are required. Some district plans restrict the level of building reflectivity permitted in environmentally sensitive zones (e.g. alpine villages in Selwyn District, Queenstown Lakes District, Great Barrier Island).

The naturalness of the colours used on buildings and structures depends on the environmental context of those buildings and structures. Where buildings and structures are close to native forest olive greens, certain grey and brown tones most closely approximate nature's colours. In and adjoining dunes light greys and browns and yellow greens more closely approximate nature's colours.

The overall colour naturalness of buildings and structures within a unit is assessed visually as being high, medium or low. Where there are many buildings or structures it is the overall “average” colour that is assessed.

The approximate light reflectance value (RV or LRV) of a colour indicates the amount of visible light that a colour reflects. At one end of the range is black, with a light reflectance of 0% and at the other end is white which has a light reflectance of 100%. Colours with high reflectivity typically contrast with vegetation, especially native forests. Where district plans restrict the level of building reflectivity permitted in a zone, reflectivity values greater than about 37% are typically considered inappropriate.

Resenes paint charts were used to identify the light reflectance values of particular colours. This is because professional painters most commonly use Resenes paint and their colours match pre-painted products such as Coloursteel roofing. Reflectivity is assessed visually considering all buildings and structures in a unit and all visible parts of those buildings and structures. This visibility is assessed from the water, shoreline or other public area (e.g. crest of foredunes in public ownership, viewpoint on a hill).

Although paint charts provide a reflectivity “score” for a particular tone, a typical building or group of buildings may incorporate many tones. Accordingly building and structure reflectivity is assessed visually in three categories-high, medium and low. Where there are many buildings or structures it is the average reflectivity that is assessed. It was the difficulty of determining reflectance for many structures and buildings or even the variation within a single large structure that led to the use of a three category scale.

6.9 Hydrological and geomorphological naturalness

This indicator addresses geomorphological and hydrological changes that are caused by humans and their activities. Such changes may often occur together (e.g. dune flattening removes dune swales with the associated wetlands and lakes; bulldozing a river mouth to a different location affects both hydrological and geomorphological processes).

The initial approach taken to measure the naturalness of the hydrology and geomorphology was to measure each type of change or agent of change, and then search for a common denominator to aggregate these measures. It was not possible to find a suitable common denominator and so an alternative approach was pursued.

In the alternative approach two parameters are measured:

- The magnitude of the changes from the "natural state"
- The amount of unit affected by these changes

The first parameter measures only the magnitude of change to hydrological and geomorphological processes. The associated ecological changes or adaptations are addressed in other parameters.

The first parameter is assessed in categories: nil, low, low-moderate, moderate, moderate-high, high and very high. The second parameter provides an approximate assessment of the amount of the unit affected. Table 7 provides examples of how different types of changes could be scored. These scores are highly indicative as the actual impact may vary significantly depending on the characteristics of the area pre-impact and the type and magnitude of a particular action.

Table 7: Indicative scoring for different types of hydrological and geomorphological change

Impact category	Indicative type of hydrological +/or geomorphological change
Nil	None
Very low	Small cutting (e.g. <2m); small amount of fill (e.g. <1m)
Low	Cutting 2.1m -5m high, accelerated estuarine sedimentation from catchment land uses
Low-moderate	Cuttings 5.1m- 8m high, drainage of a "wet area", sea wall on a low-energy coast
Moderate	Training walls at river mouths, large scale cut and fill for infrastructure; area behind a causeway with opportunities for water movement past the causeway; sea wall on a high energy coast
Moderate-high	Dune re-contouring, channelizing streams; area behind a causeway with limited opportunities for water movement past the causeway, sand mining
High	Drainage of a wetland system; Large scale dune re-contouring including infilling of dune swale wetlands, channelizing river lower reaches
Very high	Damming a waterbody to form an impoundment, drainage of a lake, landfill, quarry, reclamation (of seabed)

6.10 The naturalness of sounds

Two parameters address the naturalness of sounds:

- The risk of non-natural sounds being heard in a unit
- The resilience of a unit to non-natural sounds

Non-natural sounds are those from human sources including people, machinery and other human constructions. While sounds from non-indigenous biota could be considered to be “unnatural”, it is not practical to address these. These two parameters address human perception of sound. Other biota can hear sounds at frequencies outside the range that is detectable by humans.

The two parameters were selected because they can provide a consistent assessment without the multiple on-site visits that would be required to measure mean sound levels in particular places. Sound levels are traditionally measured using a logarithmic scale where an increase in 10 decibels (dB) means a sound is ten times as loud. All contributions to sound, whatever their source, are included. Because actual sound levels can vary considerably depending on environmental features that block and amplify sound. Accordingly an accurate assessment of sound levels for a mapped unit would be a complex exercise. It would be further complicated by temporal variability in sounds.

In addition, because the standard decibel assessment measures all sounds it does not distinguish between sounds from “natural” and “unnatural” sources. This is of particular concern because sounds from “natural” sources (e.g. waves breaking on a shore) can act like white noise (http://science.howstuffworks.com.question47.htm accessed 20 July 2009), masking some unnatural sounds. To the average observer the overall pattern of sounds would seem more natural even though the actual level of sound (recorded in decibels) may be greater.

Where natural sounds mask unnatural sounds to some degree, this gives a site or a unit some level of “resilience” to unnatural sounds. The day to day resilience of a site can vary. Accordingly an assessment is made of the likely resilience based on exposure to wind and waves, the shore type and local topography. For example an enclosed arm of a harbour surrounded by steep topography would show low resilience, while an exposed escarpment subject to frequent heavy seas would show high resilience.

Both risk and resilience are measured in categories: very low, low, low-moderate, moderate, moderate-high, high and very high. Table 8 provides examples for each category of risk and resilience. The table shows for example that the Upper Waikino Inlet has a low risk to non-natural sounds and a low resilience to such sounds. Examples of areas where there is a higher risk of unnatural sounds come from outside the Northland region.

The boundaries of units are determined by factors other than the naturalness of sounds. Local topographic variation may result in considerable variation, especially to the risk of unnatural sound being detected at different places within a mapped unit. Resilience to unnatural sounds may be similarly affected. Accordingly it is suggested that the two parameters only be applied in more detailed assessments where the size of the mapped units is smaller.

The assessment of parameters should include a thorough assessment of the risks of non-natural sounds and factors affecting the resilience of a mapped unit. Factors affecting the risk of non-natural sounds being heard in a unit include: the proximity of road, rail, sea and air transport routes; the level of use of those routes; proximity and type of settlement; proximity and type of recreational activities (e.g. water skiing), and the level and type of economic activity. Wind and wave height data should be studied to assist in the determination of resilience to non-natural sounds, especially for areas where the assessor has a low level of familiarity.

Table 8: Sound naturalness examples* by category

Category of risk or resilience	Examples of areas where the risk of non-natural sounds matches the row heading*	Examples of areas where the resilience to non-natural sounds generally matches the row heading*
Very low	Upper Waikino Inlet	Upper Waikino Inlet
Low	Mid-upper reaches of Waikare Inlet, excluding areas around operational oyster farms	Whangaroa Harbour: cove with Department of Conservation hut
Low-moderate	Tapu Point mooring area, Waikare Inlet	Tapeka Point
Moderate	Paihia waterfront	Cape Brett
Moderate-High	Dockland 5 area, Whangarei	Ruakaka-Uretiti Beach
High	Port of Napier	Cape Reinga coastal marine area
Very high	Wellington Airport and adjoining coast	

* These are general examples, although particular units within these general areas may vary. Also the categories assigned represent typical daytime risk and resilience. On any one day the risk and/or resilience at a site may differ from the typical. For example, there may be no wind or surf action at an exposed site with typically moderate to high resilience.

6.11 Anthropogenic light

Anthropogenic light affects plants and animals as well as human perceptions of naturalness. This parameter (level of risk of anthropogenic light) is assessed during daylight hours. It identifies the risk of anthropogenic light in categories for each unit. It is based on an assessment of likely anthropogenic light sources and their relative strength. Many small coastal settlements in the Far North have no street lighting which considerably reduces night light sources in many areas.

Ideally the risk of anthropogenic light would be assessed at night. If this is not practical, this parameter can be assessed in daylight hours provided that there is a thorough assessment of likely anthropogenic light sources within and beyond a unit's boundary.

Anthropogenic light is assessed in the following categories: nil, low, low-medium, medium, medium-high, high, very high. As with sound naturalness the unit boundaries were not defined on the basis of artificial light effects, and so there may be variation in anthropogenic light levels across a unit. Accordingly it is suggested that this parameters only be applied in more detailed assessments where the size of the mapped units is smaller. Table 9 provides examples of anthropogenic light risk by category.

Table 9: Examples of possibility of occurrence of anthropogenic light by category

Anthropogenic light category	Example
Nil	Upper Waikino Inlet, Bay of Islands; Spirits Bay
Very low	Cavali Islands
Low	Waikare Inlet, Bay of Islands
Low-medium	Russell, Bay of Islands; Waipu Cove
Medium	Paihia, Bay of Islands
Medium-high	Opua Marina
High	Whangarei CBD
Very high	Oriental Parade, Wellington waterfront

6.12 Indicator species

Indicator species are those where changes in their distribution, abundance and condition represents wider scale changes in the environment.

For terrestrial environments the primary parameter addressing indicator species is the *abundance and condition of pohutukawa, especially on rocky coasts*. Pohutukawa is selected as an indicator species because it:

- is an iconic species for northern New Zealand,
- approximately 90% of the original area of pohutukawa has been lost (Hosking et al. 1989)
- in 1989 an assessment showed the pohutukawa in Northland were in poorest condition (relative to other areas) and that many old trees had recently died(Hosking et al. 1989)
- is at risk from a wide variety of factors including clearance, humans causing root and stem damage, fire and possum defoliation(Hosking et al. 1989)
- is a beneficiary of possum control programmes as part of TB vector control, Department of Conservation and community control programmes
- subject to a national restoration programme, Project Crimson

A 2000 assessment (Hosking 2000) of pohutukawa found that there had been a significant decline in possum damage and a large increase in regeneration. Much of this was attributed to comprehensive actions to trap and poison possums, fencing and restoration planting.

Mature healthy pohutukawa along particularly the rocky coastal margins is an indicator of the naturalness of that coastline. The pohutukawa parameters are assessed in the field by estimating:

- % length rocky coast (and other coastal type) with pohutukawa
- % length rocky coast with mature pohutukawa
- Condition class for mature pohutukawa as measured using the foliar browse scale (<5%. 5-25%, 25-50%, 51-75%, >75%) with an added category of dead

Mature pohutukawa are defined as those >8m tall, although trees 4-8m high in highly exposed sites where the branch spread is greater than the tree height are also classified as mature for the purposes of this parameter.

To date it has not been possible to develop a way to integrate the iconic species data with the other unit data. Until this matter is resolved it is proposed that this data be reported separately, and only for more detailed assessments.

7 Applying natural character parameters in the intertidal environment

7.1 Overview

This part of the report discusses the methodology for measuring the intertidal parameters. It does not specifically address the methodology for measuring intertidal habitats with emergent vegetation as these have been addressed as part of the section on terrestrial coastal environment parameters.

7.2 Depicting mapped unit boundaries

In general intertidal habitats can be divided into those which cover a sufficiently large width because of a low gradient that they can be mapped; and those that are much narrower in width and can not be mapped except at a very detailed scale of assessment. In practice this means that the estuarine soft sediment intertidal habitats are mapped while those on steeper rocky shores are not.

The boundaries of the shallow gradient intertidal units can usually be depicted on the same aerial images used for terrestrial units. These intertidal units should then be given a unique identifier (including the specific intertidal identifier IT) to allow the collected data to be associated with the mapped unit. In some cases these intertidal habitats may have a subtidal thread, such as a channel that would not be practical to separate out for mapping purposes. The unique identifier for these units would include the specific intertidal and subtidal identifier SIT.

Where the intertidal environment is too narrow to map, data can still be collected although it is unlikely that this would be done except for detailed assessments. While the data would be associated with a unique identifier it would not be possible to calculate the area involved. It would be useful to link such intertidal data to the adjoining terrestrial unit.

7.3 Parameters addressing % natural surface cover, % buildings & structures cover, % biological artefacts

The procedures for the terrestrial environment % cover indicators generally apply although there are fewer specific parameters. It is likely that these parameters will primarily be assessed for those intertidal areas that are mapped.

7.4 Parameters addressing % native cover and % alien species cover

The % native cover addresses macro-flora and macro-fauna as this is all that is practical with a visual survey. It is indicative only and applies only to the cover on natural surfaces.

The % alien species cover addresses natural surfaces and surfaces created by humans (e.g. wharves). It is too difficult to accurately assess % cover alien species on all surfaces and so it is proposed to use abundance classes. In Northland the major alien intertidal species is Pacific oyster. Because Pacific oyster and several other alien species found in intertidal areas are encrusting species or at least attach themselves to hard surfaces it is proposed that alien species abundance classes be recorded for all intertidal areas regardless of whether they are mapped.

7.5 Parameters addressing hydrological and geomorphic change

As with terrestrial environments, marine geomorphological and hydrological change is to be addressed by the following two assessments:

- The magnitude of the changes from the "natural state"
- The amount of unit affected by these changes

Those areas that were previously intertidal but have been altered extensively to become dry land should be assessed using the terrestrial parameters and methodology. This includes the hydrological and geomorphological naturalness parameters.

7.6. Parameters addressing building and structures, non-natural sounds and anthropogenic light

These parameters use the same protocols as for the terrestrial environment.

8 Applying natural character parameters in the marine subtidal environment

8.1 Overview

Table 4 lists the parameters for each indicator by the following marine environment types:

- Subtidal soft sediment near shore
- subtidal hard substrate near shore
- subtidal offshore to outer limit of 12NM

To avoid repetition the following sections address each parameter once.

8.2 Depicting mapped unit boundaries

It is difficult to define appropriate boundaries for subtidal units, compared to terrestrial and intertidal units because:

- Less spatially based information is available for subtidal environments

- It is not possible to "view" marine environments (other than those in shallow clear water) using aerial or satellite imagery.
- It is more difficult to identify appropriate drivers of subtidal boundaries
- It is more difficult to inspect subtidal environments to obtain information on physical characteristics and associated biotic communities, especially as depths increase beyond 30 metres
- It is not possible to view all or most of a subtidal unit to obtain a quick "overview" of its attributes
- Water readily transports sediment, nutrients, larvae etc. creating a greater level of mixing compared to land based ecosystems

Accordingly the marine subtidal units are typically larger with more generalised boundaries compared to those used for the terrestrial environment. The most appropriate base for depicting the boundaries of marine subtidal units is a bathymetric chart with sediment detail if that is available. This base could be a standard LINZ hydrographic chart provided that a chart of sufficiently fine detail is used. In some areas more detailed bathymetry may be available. Subtidal units should be given a unique identifier that includes a specific subtidal identifier of S.

8.3 Parameters addressing % cover

Several parameters address percent cover for the subtidal marine environment. These parameters are:

- % natural surface or natural cover
- % natural surface that is composed of native species
- % area that is occupied by biological artefacts
- % area occupied by biological artefacts that is native
- % area occupied by structures

A range of sources of information will be needed to estimate % cover. The % cover for the following parameters should total to 100%:

- % natural surface or natural cover
- % area that is occupied by biological artefacts
- % area occupied by structures

Natural surfaces and areas of natural cover are those that have developed without direct human interventions. They exclude structures of all types. Biological artefact areas" are those where human management of the biota prevails. This is evident in the biological processes and patterns. In the marine environment it typically involves areas used for aquaculture. The primary exception to this is where there are substantial structures in which case that part or type of aquaculture area is treated as a structure for the purposes of estimating percent cover. An example of this would be the extensive rack system associated with the cultivation of Pacific oyster.

Before the % native cover can be estimated it is necessary to distinguish between native and introduced species. This can be difficult without a good knowledge of different benthic species. (Cranfield et al. 1998) identified 148 species that had been introduced into New Zealand marine waters accidentally as well four deliberately introduced species. They found that repeated introductions, enclosed receiving waters and certain characteristics of the species were important factors in the establishment of introduced marine species. A recent survey found 13 introduced species in the Opua area (National Institute of Water and Atmospheric Research 2009).

As the major areas with alien species invasion tend to be in the vicinity of ports, harbours and other sheltered waters more effort should be made to estimate likely cover by non-native species in these areas. This is likely to be difficult where low water clarity makes it difficult to estimate percent cover. In such situations estimates are likely to be indicative only

8.4 Parameters addressing alien species

Recognition of the potential risks of alien species in the marine environment probably happened later than for terrestrial and freshwater environments. The first compilation of adventive species across the taxa for the New Zealand marine environment was by Cranfield et al (1998). This report did not provide a list of pest species. Various alien species have been identified by Biosecurity as pest species for the purposes of surveillance and containment.

Given the difficulty in identifying which subtidal species are alien it is suggested that this indicator initially focus on a suite of known introduced species that have an adverse effect on naturalness. One such species is Pacific oyster (primarily intertidal). Further work is required to assemble a list of appropriate species for Northland. Abundance of alien species would be assessed for both natural and artificial surfaces. It is suggested that alien flora and fauna abundance be estimated using Braun-Blanquet cover classes (Braun-Blanquet 1932).

8.5 Parameters addressing hydrological and geomorphic change

As with terrestrial and intertidal marine environments, marine geomorphological and hydrological change is addressed by the following two assessments:

- The magnitude of the changes from the "natural state"
- The amount of unit affected by these changes

Subtidal changes to hydrology and geomorphology include dredging (particularly to create navigation channels), sediment dumping (usually from dredging), sediment-supply and water velocity changes resulting from structures and other human environmental changes.

8.6 Parameters that address long term water clarity changes

Plants can be useful indicators of long term trends in water clarity. This is because they integrate a range of environmental conditions supporting plant growth over an extended period of time prior to sampling (Clayton et al. 2002). This contrasts with physical and chemical assessments (e.g. Secchi disc transparency) which measure factors that can change frequently and so need frequent measurements to identify long term trends.

In Europe the lower depth limits of members of the tall brown algae order Laminariales were found to vary by more than an order of magnitude because of water clarity (Luning 1991?). The limits were similar if they were expressed as light percentage depth. The New Zealand members of the Laminariales include species of the genera *Lessonia, Ecklonia* and *Macrocystis*. Of these, *Ecklonia* is the primary tall brown algal species that forms the lower depth limit for brown algae species on the open coast.

As individual algal plants can be found at depths of at least 60m in the clearer waters of offshore islands (Choat & Schiel 1982), it is proposed to use the maximum depth of continuous tall brown algal forest for this parameter. It is proposed that the maximum depth of continuous tall brown algal forest be defined as the depth where algal cover is greater or equal to 75%. This minimises the depths to be dived and so improves safety. Maximum depths would need to be measured in several locations within a unit to ensure that an average maximum depth limit is identified.

As *Ecklonia* requires suitable substrate for the holdfast to attach to, care will be needed to ensure the observed maximum depths are limited by water clarity and not substrate. This would be particularly important if the focus was on the maximum depth of any Ecklonia plants. Novaczek (1984) found the depth distribution of *Ecklonia* sporophytes at Goat Island Bay was substrate-limited at 22 metres.

Where there is solid or broken rock substrate in sheltered waters with lower water clarity the New Zealand tall brown algae species reaching the deepest depths are often members of the genus *Carpophyllum* from the order Fucales. These depths are less than what occurs on the open coast, and in turbid waters may be only a couple of metres.

The absence of submerged seagrass beds from most New Zealand harbours is probably because of poor water clarity reducing light levels (Inglis 2003). It is likely that existence of permanently submerged seagrass beds in sheltered sediments adjoining some offshore islands is because of the relatively high water clarity in those locations (Schwarz et al. 2006). The extent of subtidal or permanently submerged seagrass beds could be an indicator of water clarity for subtidal environments. While it may be difficult to identify a potential state it should at least be possible to measure changes and to compare current extent with past extent in some locations.

8.7 Parameters that use indicator species

Table 4 proposes several indicator species for near shore subtidal environments. It is proposed that the main indicator species for near shore soft sediment environments be:

- Subtidal sea grass extent and abundance
- Horse mussel extent and abundance
- Snapper relative abundance

Subtidal seagrass is adversely affected by poor water clarity (Inglis 2003), sedimentation and disturbance such as anchoring. It is thought that it was once much more widespread in harbours (Inglis 2003). Recently, some northern offshore subtidal seagrass beds have been shown to have higher macroinvertebrate abundance and diversity than intertidal mainland sites and high fish populations, especially juvenile snapper (Schwarz et al. 2006). Subtidal sea grass extent can be measured by mapping the extent of patches. Seagrass abundance can be measured using an international standard, the Braun-Blanquet cover classes (Schwarz et al. 2006). These cover classes are: 1=1-%%; 2=6-25%; 3+26-50%; 4=51-75%; 5=>75% (Braun-Blanquet 1932).

Horse mussels are readily damaged by dredging (the predominant commercial method for harvesting scallops that is also used by recreational fishers), anchoring and trawling. Intact beds of horse mussels in shallow soft sediment subtidal environments indicate a relatively undisturbed benthic environment. Such beds are likely to be much less common today because of the widespread disturbances of shallow soft sediment seabed. While changes in extent can be measured, more work is required to construct a suitable baseline.

Table 4 proposed several indicator species for near shore hard substrate environments as follows:

- Presence and relative abundance of snapper, butterfish, rock lobster
- Presence and relative abundance of kina

The distribution and relative abundance of the species in the first parameter reflects the level of direct harvest pressure on those species. The use of direct controls on the harvesting of marine fisheries is outside the reach of the natural character provision in the Resource Management Act and the Reserves Act. However changes in species that predate kina can have a major impact on the entire ecosystem.

Shears & Babcock (2003) describe benthic communities changes at Leigh Marine Reserve since the reserve's establishment in 1978. The benthic community changed from being one dominated by kina to being dominated by macro-algae. This change was considered to be the result of a trophic cascade that was an indirect effect of increased numbers of predators of kina. The dramatically increased numbers of predators, especially rock lobster and snapper, are an outcome of the no-fishing rule in the Leigh Marine Reserve (Willis et al. 2003; Shears et al. 2006).

The relative abundance of various reef fish species is typically measured using diver surveys with belt transects as described by Taylor et al (2005) although they preferred the use of baited underwater video to assess the abundance of snapper. Assessments of the relative abundance of species listed in the first parameter could be made using the standard method and compared with the baseline established at the Leigh Marine Reserve. A further step will be needed to convert the relative abundance data into a form that could be used in the natural character formulae.

Alternatively (or as well as) the relative abundance of kina could be assessed. This is potentially more a complex indicator as kina abundance is affected by both direct harvest and the removal of its predators. As previously described, predation on kina that occurs in long-term no-take marine reserves can led to a dramatic recovery in shallow benthic communities from one dominated by kina to one dominated by macro-algae.

In northern areas without reserves, kina is a key species determining the ecology of shallow subtidal reefs (Andrew 1988). It directly affects the distribution and abundance of tall brown algae species in shallow waters as well as a range of herbivores.

Relative abundance of kina can be estimated (by size class) using either belt transects or quadrats. It may also be useful to estimate the upper depth of *Ecklonia* forest (as well as the bottom depth as a measure of water clarity). The inside and outside marine reserve comparisons found the greatest differences in algal communities were at depths where kina were most abundant (4-6m) (Shears & Babcock 2003). Leigh Marine Reserve provides baseline abundance data for kina. The data collected from units can be analysed against the baseline and converted into an assessment of shallow subtidal reef naturalness.

8.8 Parameters that address sound and light

The marine environment has the same sound and light parameters as are used for the terrestrial environment. That is the parameters address risk and resilience. Underwater sound affects marine biota as well as humans who venture underwater. Sound affects a variety of fish behaviours including migration and habitat selection and probably assists pre-settlement reef fish to find "their" reef. Sound is also a component of marine mammal behaviour including migration/navigation, feeding and communication. Human generated sounds in the marine environment can affect these processes.

The risk of unnatural sounds is estimated in categories (as for the terrestrial environment) using information from a variety of sources. The resilience to unnatural sounds is estimated in fewer categories because the main influence on resilience is the sea generated sound caused by swells interacting with the seabed. It may be necessary to partition a unit with respect to its resilience which is likely to be highest in shallow waters that are exposed to swells.

The light impact on subtidal environments is likely to be that associated with facilities such as wharves. It is likely to localised and probably only a few categories will be required. Given its likely associated with facilities it is likely that high light levels will be associated with those units with certain types of facility.

9 Measuring the natural character of the "shoreline"

The "shoreline" is a narrow width of coast straddling mean high water springs. As it is the land-water interface it can be subject to a variety of pressures that are not typical of the terrestrial and aquatic units that it is part of. In addition this area is often one of great interest and focus in human assessments of natural character.

Typically the "shoreline" is too narrow to map as a separate unit and so a stretch of shoreline is annotated using the two terrestrial and aquatic units it is part of (e.g. PK28nc1/PK1sit.

The parameters measured are:

- % foredune face or first 5m of vegetated terrestrial shore that is native

- Pacific oyster density class
- % shoreline with building and structures below mean high water springs, within 5m and within 20m mean high water springs
- Litter category
- % length used by vehicles
- % length shore with sea wall

10 Viewpoint assessment

The "viewpoint assessment method addresses human perception of natural character in a relatively objective way. An aluminium frame of set dimensions and a 5x4 string grid held at a set distance from the body to provide a quantitative way to assess the relative composition of the "view". The size and position of the grid are designed to "match" the angle of view of an observer.

The viewpoint position is always on public land or the sea and the direction of view is typically at right angles to the shore. Common viewpoints are the near shore looking onshore (usually from a boat), at low or mid-tide looking onshore, on the crest of the foredune, or at a public view point looking either onshore or offshore. Figure 1 provides examples of viewpoint positions.

The purpose of the grid is to assist estimates of % cover which are made in categories as in the viewpoint field sheet. Where there is undulating or hilly topography the top line of the grid should be lined up with the crest of the highest point. Where the topography is flat the top of the second line of the grid should be lined up with the highest point.

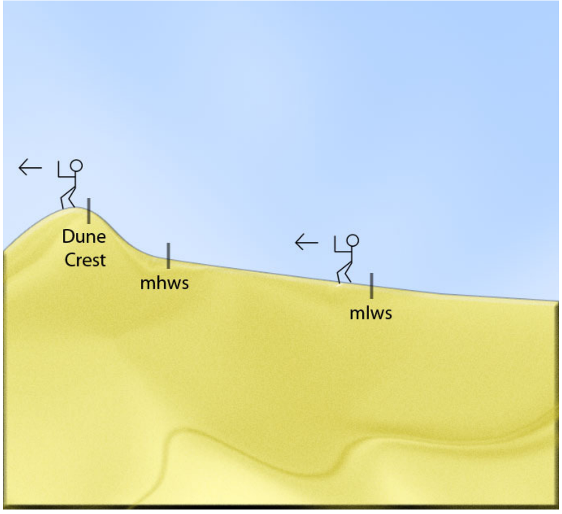
The first set of estimates total 100%. They address the following categories: sky, water without structures, water with structures, natural surface without vegetation, natural surface with vegetation, biological artefact, paved/surfaced, buildings and land structures. Additional estimates are made of the % native vegetation, % shoreline structures. Building colour and reflectivity are addressed as is the contrast of the biological artefacts.

Viewpoints can be set up at particular places of interest or they can be established on a systematic or random basis. Establishing viewpoints on a systematic basis will facilitate a greater degree of extrapolation from a limited number of sample points.

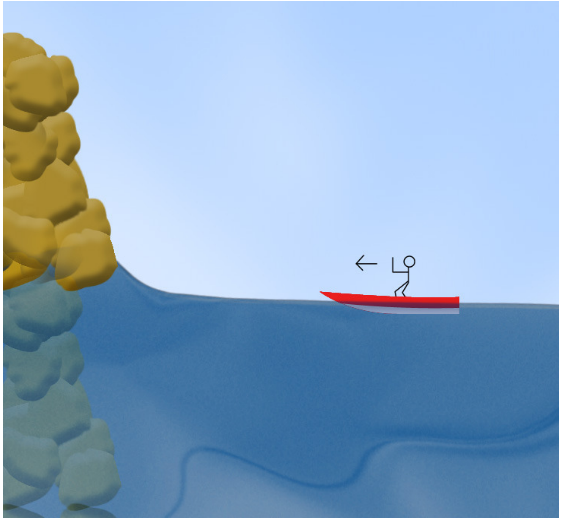
It is important that the viewpoint date and time is recorded along with the nearest high tide. The stage in the tidal cycle can significantly alter the % cover assessments for some categories in some locations. In the data analysis step adjustments are needed to take account of the tidal stage at the time of the assessment(s).

Figure 1: Viewpoint assessment positions in different types of coastal environment

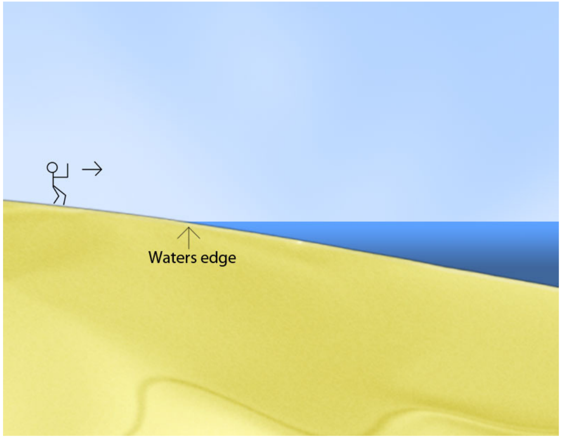
1. Inland from the foredune crest and mean low water springs



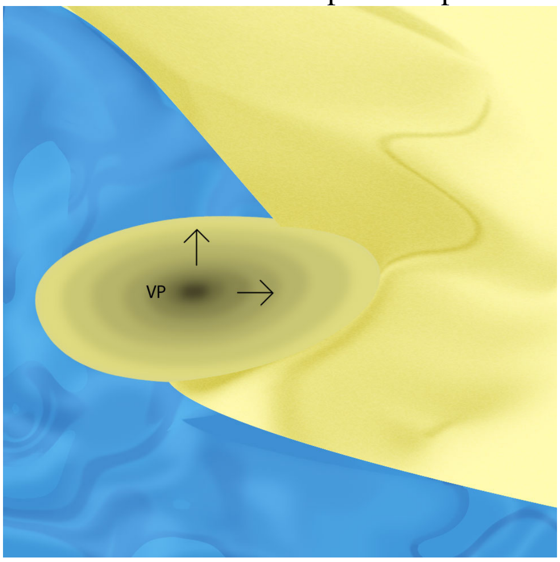
2. Rocky coast from a boat



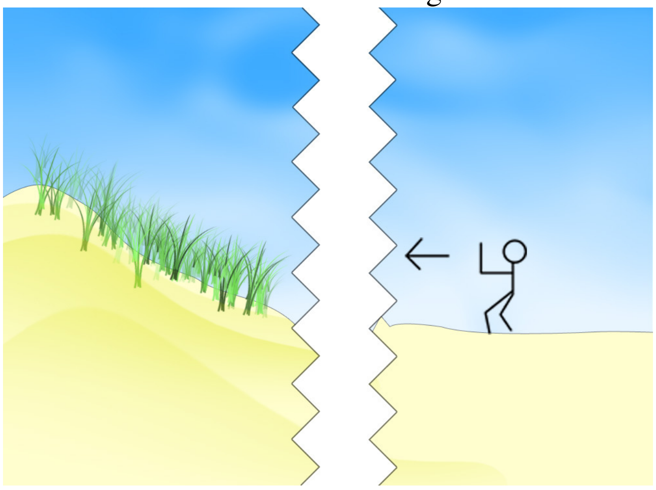
3. Out to sea



4. From a terrestrial viewpoint on public land



5. On land from the coast looking inland



11 Analysis framework: Terrestrial coastal environments

11.1 Overview

The data for each unit in the area being assessed is entered into an Excel spreadsheet. The suggested protocol is a worksheet tab for each of the:

- Unit descriptive material
- Unit data
- Shoreline data

The analyses should use additional tabs to avoid any risk of interfering with the raw data.

The following indices are proposed for each unit:

- Ecological Naturalness Score
- Hydrological and Geomorphological Naturalness Score
- Building and structure impact score
- Sound and Light Naturalness Score (optional)

The precise weighting between the first two indices versus the third index has still to be determined.

As the units are of different sizes, digitising the unit boundaries allows the actual size of each unit to be calculated. Once the size of each of the units in an area of interest is known, the calculated indices for those units for can be aggregated according to the relative size of each unit.

The formulae used to calculate the score give a raw score ranging from 0 to 1. % cover data can easily be converted to this format by dividing by 100. Categorical data has to be converted to this format as does the actual vegetation/benthic cover v potential cover relationship. Once the calculations are complete it is suggested that the raw scores be multiplied by 100 to give a more user friendly score which ranges from 0 to 100% (rather than 0 to 1).

11. 2 Ecological Naturalness Score:

The Ecological Naturalness Score (ENS) addresses the naturalness of the current biotic cover. It uses the following measured and calculated parameters for each unit:

- The score for current vegetation/benthic cover in natural areas compared to the potential vegetation/benthic cover (This is discussed in detail in Appendix 3)
- The score for current vegetation/benthic cover in biological artefacts compared to the potential vegetation/benthic cover (This is discussed in detail in Appendix 3)
- % cover of natural area
- % cover biological artefact
- % of natural area cover that is native
- % of biological artefact cover that is native
- % “natural area” vegetation/cover that is alien pest plants

In the formula below, the ENS is the sum of the contents of three brackets. The elements within each bracket are multiplied because they are not independent. The bracket sets are independent and so they are not multiplied. The first two bracket sets are added as both are positive contributions to ecological naturalness. The last bracket set is subtracted because alien pest plants are negative. As K (% “natural area” vegetation that is alien pest plants) is of less importance in determining overall ecological naturalness it is multiplied by 0.1 to reduce its impact on the total score.

ENS = (G*I*L)+(F*H*J*)-(0.1*K)
Where for the first bracket:

G=Score that represents the current BA vegetation v the potential vegetation
I=%area in the unit that is BA/100
L=%BA that is native

For the second bracket:

F=Score that represents the current vegetation cover in “natural areas” v potential vegetation
H=%area in the unit that is “natural area”/100
J=%natural area vegetation that is native/100

For the third bracket

K=% “natural area” vegetation that is alien pests/100

11.3 Hydrological and geomorphological naturalness score

There are two relevant parameters in hydrological and geomorphological naturalness score (HGNS):

- The magnitude of the changes to hydrological and geomorphological processes compared to the “potential natural state”
- % area affected by these hydrological and geomorphological process changes

“Potential natural state” for hydrological and geomorphological process is an equivalent concept to potential vegetation cover as described in Appendix 3). It is that which would be expected today had humans and their agents not arrived in New Zealand. This means that, for example, seabed and wetland uplift due to earthquakes (such as that which occurred in the 1855 Wellington earthquake) or rock slide damming of rivers (such as that which occurred in the 1929 Murchison Earthquake) are accounted for in the “potential natural state”.

The magnitude of change is assessed in categories. For the purpose of analysis these categories are converted into a numerical score as shown in Table 10.

Table 10: hydrological and geomorphological naturalness conversion for HGI formula

Impact category	Conversion for CEIS formula
Nil	0
Very low	.1
Low	.2
Low-moderate	.3
Moderate	.5
Moderate-high	.7
High	.9
Very high	1

The formula is:
HGNS=Hi*Ha
Where: Hi= Impact score for hydrological and geomorphological processes
Ha=% area affected by these hydrological and geomorphological process changes/100

11.4 Building and structure impact score

Much of the data relevant to this score is in collected in categories. This data needs to be transformed to a numerical format before it can be used in calculations. Also the open-ended nature of the building and structure height information needs to be converted into a 0 to 1 scale to be consistent with the other data.

Table 11 converts the open-ended building and structure height information to a suitable format for using in the Building and structure impact score (BSIS). Table 12 contains that BSIS adjustment for building colour and reflectivity.

Table 11: Building and structure heights: conversion for BSIS formula

Height estimated in metres	Conversion for CEIS formula
<0.5	0.05
0.5-2	.1
2.1 -5	.2
5.1-8	.3
8.1-11	.4
11.1-14	.5
14.1-17	.6
17.1-21	.7
21.1-25	.8
25.1-29	.9
>29.1	1.0

Table 12: Building colour "naturalness" and reflectivity categories: conversion for BSIS formula

Building colour "naturalness" category	Conversion for CEIS formula	Building reflectivity category	Conversion for CEIS formula
High	0.6	Low	0.8
Medium	0.8	Medium	0.9
Low	1.0	High	1.0

The Building and structure impact score formula is:

BSIS= (B* HB*CB*RB) + (S*HS*CS*RS) + (P*HP*CP*RP)

Where: B= % cover of buildings in a unit/100
HB=building height class
CB=colour "naturalness" impact of building code
RB=reflectivity of building score
S=% cover of structures/100
HS=structure height class
CS=colour "naturalness" impact of building
RS=reflectivity of structures score
P=% cover paved or surfaced/100
HP=default 0.05 height score for paving or surfaced
CP= default medium colour "naturalness" score
RP=default medium reflectivity score

The default scores for "paving and surfaced" heights, colour and reflectivity can be varied using the system set up for buildings and structures. Default scores are given because these default scores are typical and it can be difficult to see the characteristics of paved areas during a quick assessment.

11.5 Sound and Light Naturalness Score

This is an optional formula because it is not possible to obtain meaningful measures for all units, especially those that are large.

Table 13 contains the conversions for the unnatural sounds risk and resilience as well as artificial light for use in the sound and light impact formula.

Table 13: Unnatural sounds risk, resilience and artificial light categories: conversion for CEIS formula

Unnatural sound risk or resilience category	Unnatural sound risk conversion for CEIS formula	Unnatural sound resilience for CEIS formula	Artificial light risk category	Artificial light conversion for CEIS formula
Very low	.1	.5	Nil	0
Low	.3	.4	Low	.1
Low-medium	.4	.3	Low-medium	.2
Medium	.5	.2	Medium	.3
Medium-high	.6	.1	Medium-high	.4
High	.7	.01	High	.5
Very high	.9	n/a		

The formula for sound and light impacts (SLI) is:

SLI=(Srk*Sre) + (L)

Where: Srk= unnatural sound risk score
Sre= unnatural sound resilience score
L= artificial light score

11.6. Overall natural character score for the terrestrial environment

The overall natural character score combines four scores:

- Ecological naturalness score (ENS)
- Hydrological and geomorphological naturalness score (HGNS)
- Building and structure impact score (BSIS)
- Sound and light impacts (SLI)

The first score (Ecological Naturalness Score) is positive while the other three scores detract from this. The exact weightings between the four sub-scores are not matters for direct scientific measurement or calculation. Instead alternative scientific tools will be used to determine relative weightings.

NC=ENS*W1(1-BSIS)*W2(1-GHI)*W3(1-SLI)

Where: W1=weighting for first bracket
W2= weighting for second bracket
W3= weighting for third bracket

12 Conclusions

The overall assessment of natural character for a mapped terrestrial or aquatic unit combines three scores:

- Ecological naturalness score (ENS);
- Hydrological and geomorphological naturalness score (HGNS);
- Building and structure impact score (BSIS); and

An optional Sound and light impacts (SLI)) score can also be included. More work is needed to work out the relative weightings of these scores.

The next stage of this research is to determine the relative weightings of these scores. Informed participants will be used to assist with determining the relative weightings of the ENS (and possibly the HGNS) relative to the BSIS. Another step will be to further develop some case studies to assess the impact on natural character scores of using larger aggregated mapped units for data collection.

13 Acknowledgements

This report incorporates material from my unpublished PhD thesis (Measuring the outcomes of long standing national policy to preserve coastal natural character). Funding for this project was provided by the Foundation for Research Science and Technology as an Envirolink project. Other assistance, including aerial images, was provided by Northland Regional Council. Chris Richmond assisted with field work. Tim Baigent of GeographX supervised the largely automatic digitising process, labelled the mapped units and went through several iterations of images as we sorted out the gremlins in the mapping and digitising processes. Mathew Dooley prepared the diagrams. Professor Janet Bornman of the University of Waikato and Dr Hamish Rennie of Lincoln University provided comments on an earlier draft

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Appendix 1: Locations of Stage 1 methodology trials and Stage II case studies

Table 1: Locations of the Stage I methodology trials

Location	Type of coastal environment assessed in the first round of methodology trials	Major issues for natural character measur
Mangawhai Estuary	Estuary mouth, developed estuary margins, open coast to the north including developed public access area	• the naturalness of an estuary mouth wher human effort to maintain; • potential impacts of sand mining south of • highly developed public access areas tha ecological impact
Waipu Cove, Waipu River Estuary	Entire estuary, entire Waipu dune system including highly modified and undeveloped areas, coastal escarpment, coastal catchments including residential settlement, native forest, plantation pine forest, agriculture	• the effects of a training wall on natural ch • the natural character effects of periodic se • the naturalness of particular dune blowou • determining the natural vegetation endpo • the naturalness of wildlife, especially for e
Uretiti Beach	Dunelands	• the effects of vehicles on dune naturalnes • the naturalness of dunes where there is n foredune face but extensive alien plant in
Ruakaka Coast & Ruakaka Estuary	Dune system including sand mining, whale burial site, high public use and areas set aside for bird breeding and roosting, estuary mouth, residential development	• the effects of sand mining of stored sand ponds that potentially benefit wildlife; • the effects of whale burials on dune natur • dune planting & stabilisation with non-nat effects of vehicle use on the beach; "fenc dotterel breeding areas • the natural vegetation of consolidated du
Marsden Point to One Tree Point	Dunelands and harbour entrance, residential development, race course, Marsden B power station, Marsden Point including the oil refinery and port operations, wharves, Marsden Cove Marina (still being constructed)	• the effects of very large buildings and stru the dune naturalness ; • the extent to which planting mitigates the • determining the context of natural charac Refinery and wharves given its location o headlands with native vegetation • addressing natural character impacts of M being created by excavation from land
Bream Head to Onerahi: Whangarei Harbour	Open bays with rocky headlands, native forest and scrub, small settlements, mangroves, marine reserve	• assessing the natural character impacts o • comparing naturalness of marine reserve reserve
Whangamumu Harbour and nearby open coast	Small harbour, extensive pohutukawa dieback around harbour margins	• addressing the natural character impacts pohutukawa along parts of rocky coast N
Waikare Inlet, Inner Bay of Islands	Large inlet with estuarine habitats in the many arms. Some of these estuarine areas include extensive areas of tall mangroves. Catchment is mainly low intensity agriculture and native forest and scrub. Extensive areas of Pacific oyster marine farms.	• addressing the effects (including sedimen oyster farms on natural character • the extensive colonisation of intertidal by • addressing estuarine natural character wh causes that are not upstream e.g. Lower quality and increased sediment and nutri River • assessing the naturalness of intensive m

Location	Type of coastal environment assessed in the first round of methodology trials	Major issues for natural character measure
Opua, Veronica Channel, Te Waihapu, Matauwhi Bay: Bay of Islands	Terrestrial rocky coast, bays with mangroves at head, marina and reclamation, houses amongst vegetation	• identifying intertidal and subtidal alien spe clarity (e.g. 13 alien marine species have water visibility is almost always low) • assessing the naturalness of intensive mo • addressing the naturalness of structures t column • exhibiting "character" (e.g. old style buildi natural character • assessing the effects of dredging on natur
Paihia- Waitangi	Sand and rock shore with wharves and commercial buildings over water, commercial development on waterfront	• assessing the natural character effects of development (including a planned water fr and more walls)
Whangae River (tidal reaches) & catchment	Tidal reaches with primarily mangrove margins, terrestrial margins	• Addressing the natural character effects o and bridge across the bay entrance and id • Addressing the natural character impacts
Waikino River (tidal reaches) & catchment	Relatively unmodified estuarine habitat including tall mangroves, extensive area of saltmarsh, catchment largely in native scrub and forest	• mapping and labelling units that cross into
Haumi River (tidal reaches) & catchment	Estuarine habitat including mangroves and saltmarsh, catchment residential development, upper catchment agriculture	• Addressing natural character impacts of ro • Addressing natural character effects of cu
Russell- Tapeka Point, Bay of Islands	Rocky shore, small sand beaches, rocky peninsula with patches native regeneration and some remnant pohutukawa	• Mapping and labelling units on very narro shoreline • Measuring colour and reflectivity of reside considerable variation in building colour a • defining unit boundaries where there are c small to map (e.g. collection of small but c • addressing new developments that are no where it is not possible to get close enoug location • addressing the effects of pest plants on na
Outer eastern Bay of Islands group and subtidal	Predominantly rocky shore with some cliffs/ escarpments, much of terrestrial area in native regeneration, some houses on private land, grazing and open grass areas on Urupukapuka, subtidal sea grass, subtidal sand flats and rocky coast	• addressing the upcoming total vertebrate • evaluating the effects of anchoring damag • evaluating the effects of extensive marine subtidal and intertidal ecological communi • addressing the effects of commercial and
Purerua Peninsula	Outer coast with pasture, few buildings and some small remnants of native vegetation	• Determining the extent to which extensive intensive pest control, planting of native p and how this may vary in different context
Cavalli Islands	Rocky islands mostly with native regeneration. Subtidal sand and rocky reefs	• Assessing the impacts of extensive netwo temporary) • Addressing water clarity variation due to c

Location	Type of coastal environment assessed in the first round of methodology trials	Major issues for natural character measur
		• Identifying what constitutes a "natural" sub
Mahinapua Peninsula and coast to the south east, Flat Island and subtidal	Narrow peninsula, small coastal settlement, subtidal sand and reefs	• Addressing the natural character impacts settlement • Identifying vegetation endpoints for locally
Whangaroa Harbour & adjoining sections of open coast	Outer Harbour terrestrial environment includes hill slopes (often steep) with primarily native vegetation; inner harbour with pasture, pine plantations, native vegetation and several small settlements; variety of aquatic environments including a marina & estuarine flats in the inner harbour. Outer coast is rocky with subtidal reefs and largely native vegetation on steep hills. Two settlements in sandy bays to east and west of Harbour	• addressing the effects of derelict and ope character • distinguishing between naturalness and th
Stephenson Island and subtidal	Grassed island with little native vegetation, subtidal reefs	• Addressing the natural character impacts away from past or present oyster farms • Distinguishing between "naturalness" and
Mangonui Harbour	Outer harbour including the settlements of Mangonui and Hihi	• assessing natural character in locations w moorings • Distinguishing between having character (natural character
Berghan Point and mainland coast to east and west, including subtidal	Open coast rocky shore. Land uses primarily extensive pastoral faming and regeneration of primarily native species	• Assessing the natural character impacts o landscape • Addressing the extensive dieback of coas
Karikari Peninsula, including subtidal	Northern peninsula including extensive scrub area, motor camp, extensive forestry areas (some being cleared); subtidal rocky coast north eastern shore and NW islands	• Addressing the natural character impacts plantation to residential sections • Identifying what constitutes a "natural" sub

Table 2: Locations of the more detailed Stage II case studies

Location	Type of coastal environment	Case study commentary
Omarino-Waipiro Bay-Parekura Bay, Outer Bay of Islands	Rocky coast, estuarine arms, several small settlements, forestry, low intensity agriculture, native forest & scrub including relatively mature areas of mixed broadleaved forest	• There has been a lot of change in the NW se since the date of the aerial images. Former p planted in native species, roads of a high sta has subdivided into large exclusive lots. To d facilities in Waipiro Bay and on one north-fac (Waipiro Bay) has been recently logged. • The existing settlement areas in Waipiro Bay of residential building styles and contexts. • The mature mixed broadleaved forest in the S Bay) is some of the most mature water's edg area contains some low density housing.

Location	Type of coastal environment	Case study commentary
		• There is one abandoned Pacific oyster farm o Pacific oysters are spreading through the enti
Uruti-Orongo Bay-Waikare Inlet, Inner Bay of Islands	Estuarine habitats. Extensive areas of marine farms The terrestrial coastal environment is mixed native vegetation and low intensity agriculture.	• There has been a lot of change in landward C images. Relatively extensive areas of previou converted to low intensity “coastal living” subd converted. Few houses have been built. To t subdivision are the Russell landfill and wastew outskirts of Russell (not included in the case s Russell. • Orongo Bay is one of the densest areas of ma New Zealand (Rennie 2002). On the other sid of Waikare Inlet. There is a relatively large ar Waikare Inlet, especially Ngangeroa Creek ar marine farms in the study area have remained • The southern shore of Waikare Inlet contains regenerating native scrub and forest. The coa one of which has remained operational during • The case study includes a small section of the area.
Waipu Cove and Waipu River Estuary, Uretiti Beach; Bream Bay	Open coast dunelands, small estuary, intensive agriculture, forestry, residential settlement and native scrub and forest in adjoining terrestrial coastal environment	• This case study uses higher resolution image open coast below about mean high water and • There are a diverse range of natural areas as • There are areas of natural vegetation, includin The small estuary is important for its wildlife v • There are cliffs with tall remnant pohutukawa mature coastal indigenous forest. • Land uses include residential settlement, lifes forestry
Ruakaka Beach settlement and Ruakaka River Estuary	Open coast dunelands with a variety of vegetation types, estuary and escarpment. This includes residential settlement as well as unsettled areas	• This case study uses higher resolution image coast below about mean high water. • It includes a diverse range of uses and states environments. The uses include residential d access facilities, large motorcamp, planted for • There are areas of natural vegetation (dune a important for its wildlife values
Motorua and Motukiekie Islands, Eastern Bay of Islands outer islands and surrounding subtidal	Rocky shores with a few sandy bays. Predominantly native vegetation with some weed species. Some private development. Subtidal sand and rocky reefs	• These islands are largely regenerating natura many areas. Motorua Island is largely Crown with some private holdings in the south-east. the water margin. In the eastern part of Haha buildings designed to blend into the environm while the older buildings in the east of the Bay plants. • Motukiekie Island is privately owned. The hou northwest. The owners are removing some o • These two islands are part of the area where vertebrate pests • There is intensive recreational fishing and boa
Opua marina and settlement, Inner Bay of Islands	Estuarine environment, marina, reclamation with marine servicing environments, buildings over water, causeway	• This case study includes a moderate sized ma activities, buildings over water, causeways as boat mooring areas and residential settlement hillsides. • Pest plants are common on the hills, especial

Appendix 2:

NATURAL CHARACTER TERRESTRIAL AND INTERTIDAL ASSESSMENT FORM
NATURAL CHARACTER VIEWPOINT ASSESSMENT FORM

NATURAL CHARACTER GENERAL TERRESTRIAL & INTERTIDAL ASSESSMENT FORM V19

Locality & code Date:

Observer:

Description for Intertidal (it) Near-Coast (nc) and Inner-Coast (ic) Units

Unit code			
Topography	FGMS VS U marine	FGMS VS U marine	FGMS VS U marin
Landform/substrate			
Site summary			
Natural area vegetation/cover			
Likely potential cover			
Natural area cover pest species			
Biological artefacts			
Hydrological/geomorphic changes			
Non-natural sounds			

Unit code			
Topography	FGMS VS U marine	FGMS VS U marine	FGMS VS U marin
Landform/substrate			
Site summary			
Natural area vegetation/cover			
Likely potential cover			
Natural area cover pest species			
Biological artefacts			
Hydrological/geomorphic changes			
Non-natural sounds			

% Cover

Unit code						
% primarily natural vege/natural surface						
% biological artefacts						
% buildings/ structures						
% marine farm structures						
% paved/surfaced						
% cuttings/quarries						
% un-surfaced tracks						
%total	100			100	100	100
% natural vegetation/ cover that is native						
% natural vege/ cover that are alien pests						
Hydro/geomorph change magnitude class						

Hydro/geomorph change % cover						
% biological artefact native						
Colour HML natural buildings						
Reflectivity LMH buildings						
Colour HML natural structures						
Reflectivity LMH structures						
Height buildings max/median in metres						
Heights of structures max/median						
Artificial sounds risk LMH VH						
Artificial sounds resilience LMH VH						
Artificial light levels N LMH VH						
Dunes: Level of tracks NLMH						

NATURAL CHARACTER TERRESTRIAL & SHORE ASSESSMENT FORM VIEWPOINTS V14

Locality Aerial no: Date:

Observer:

VP no	GPS E	GPS N	In/ out	Deg M	From	To

% cover

Viewpoint no					
Height of viewer					
View time					
Photo time					
Nearest high tide					
%sky					
% water without structures					
% water with structures (excl shoreline)					
% natural surface without emergent vegetation					
%natural surface with vegetation					
% biological artefacts					
% buildings					
% structures					
% mining/quarries					
% paved/ surfaced					
% cuttings, tracks					
Total	100	100	100	100	100
% natural vegetation that is native					
% biological artefact that is native					
Biological artefact contrast to natural area matrix					
Building colour HML reflectivity LMH (N/F)					
Structure colour HML reflectivity LMH (N/F)					
v% shoreline structures					

NATURAL CHARACTER TERRESTRIAL & SHORE ASSESSMENT FORM VIEWPOINTS V14

Locality Aerial no: Date:

Observer:

Site no	VP no	GPS E	GPS N	In/ out	From	To	To deg M

% cover

Site/viewpoint no					
Height of viewer					
View time					
Photo time					
Nearest high tide					

%sky					
% water without structures					
% water with structures (excl shoreline)					
% natural surface without emergent vegetation					
%natural surface with vegetation					
% biological artefacts					
% buildings					
% structures					
% mining/quarries					
% paved/ surfaced					
% cuttings, tracks					
Total	100	100	100	100	100
% natural vegetation that is native					
% biological artefact that is native					
Biological artefact contrast to natural area matrix					
Building colour HML reflectivity LMH (N/F)					
Structure colour HML reflectivity LMH (N/F)					
% shoreline structures					

Appendix 3

Comparing actual and potential vegetation/ benthic cover as part of an assessment of coastal natural character

Potential vegetation and benthic cover

Potential vegetation is one of the concepts addressed during the Land Environments of New Zealand (LENZ) development process. LENZ is a classification of New Zealand's terrestrial landscapes using a set of 15 climate, landform and soil drivers selected because of their role as key environmental drivers affecting vegetation (especially forest) pattern (Leathwick et al. 2003). In this context potential terrestrial vegetation is that which would be in an area today had humans and their agents (including introduced species) not arrived in New Zealand. This could be described as the present-potential vegetation cover.

Present potential vegetation cover differs from the pre-human vegetation cover in that it takes account of the natural environmental changes that have occurred since human arrival. These changes may be episodic and major (e.g. volcanic eruptions) or more regular and of lesser magnitude (e.g. alternating phases of coastal dune erosion and accretion in response to climatic cycles). Advantages of using present-potential vegetation as a baseline for part of the natural character assessment are:

- The identification of pre-human vegetation at the site level (especially for non-forested areas) is very difficult. The "construction" present-potential vegetation is more practical given a good knowledge of a site's geomorphological, hydrological history and the site overall attributes.
- It is more suitable for addressing areas subject to regular natural change (e.g. foredunes, migrating river mouths)
- This concept can be extended beyond the terrestrial environment into aquatic environments with the focus on present-potential cover. This would not be possible with pre-human vegetation

An alternative interpretation of potential vegetation is that it is the vegetation that could eventually occur on a site if the adverse effects of historic, current and future anthropogenic disturbance are minimised. This includes the effects of prior introductions of non-indigenous species. This interpretation for "future-potential" vegetation focuses on the succession endpoint. The disadvantages of this interpretation are:

- Early succession stages which are entirely natural on a recent surface would be considered less natural
- It does not adequately recognise the role of natural disturbance at varying scales in New Zealand terrestrial and aquatic environments

For the purposes of this methodology the interpretation of present-potential vegetation will be used. The concept will be extended to address aquatic environments and so the term used will be present-potential cover.

National studies to identify potential vegetation

Prior to the arrival of humans 730 years ago (Wilmshurst et al. 2008) about 90% of the New Zealand land area was covered by indigenous forest (Froude et al. 1985) and by 2002 that had reduced to 24.17% (Ministry for the Environment 2007).

Pollen studies (e.g. Dodson et al (1988)) are often used to identify pre-human vegetation for an area. Leathwick (2001) describes an approach to predict potential forest cover based on matching environmental variables to national plot data on native canopy tree distribution. Regressions were used to predict New Zealand's potential forest composition (using the "present-potential" interpretation). The environmental variables were measured at the sites of the plots as well as a 1km grid across New Zealand. The parameters measured were very similar to those used in the final LENZ classification (Leathwick et al. 2003).

The national database of vegetation plots (NIVS) does not equally sample all areas of New Zealand. Areas without extensive tracts of indigenous forest such as Northland are not well represented in this database. Additionally many types of lower stature vegetation are not well represented, especially in the coastal environment. The potential forest cover map in Leathwick (2001) was very general with the eastern Northland study area included within one large potential forest unit extending well beyond the boundaries of the study area.

A more detailed map of New Zealand's potential vegetation pattern was produced by Leathwick et al (2004). This map was also not sufficiently detailed for the purposes of assessing natural character of the coastal environment.

Another approach to estimating potential vegetation cover discussed in Leathwick et al (2003) is to use one of the LENZ classification levels to identify appropriate intact forest remnants in the land environment of interest. The most detailed LENZ level IV classification has 500 environments and is mapped at a scale of 1:50,000.

The Level IV classification was assessed for eastern coastal Northland. In much of Eastern Northland many of the units are large and relatively uniform. This is at least partly due to the poor quality of some of the underlying data sets, especially for soils. The soils data was largely that in the New Zealand Land Resource Inventory which had a primary focus of describing the productive potential of agricultural land (Leathwick et al. 2003). In this context, areas such as the Far North coastal environment (excluding the volcanic soils in the vicinity of Kerikeri) and some of the steeply forested hinterland were unlikely to have been priorities for soil assessment.

Matters to address when predicting present-potential vegetation for the Northland coastal environment

Using remnant areas within Level IV land environments to identify potential vegetation is practical and should theoretically be relatively robust. In practice most relevant land environments straddle far more than the coastal environment, and there are not necessarily any suitable coastal remnants within a particular land environment. Many areas in the coastal environment are small scale and their potential vegetation may be more similar to equivalent small areas in other nearby land environments than to the other areas in the same land environment.

LENZ was developed for terrestrial environments, particularly forests. Because the methodology framework for measuring natural character in the coastal environment applies across terrestrial and aquatic environments this paper extends the concept of potential vegetation cover to include the benthic cover in aquatic environments. Complications include gaps in:

- understanding the full range of ecological changes in marine (especially subtidal) environments since the first humans arrived, and
- spatial data for some environmental drivers in the marine environment,

For some coastal systems it is very difficult to estimate potential cover. Examples of such systems and areas include:

- systems that may regularly change positions naturally (e.g. river mouths in some soft-sediment coasts),
- systems subject to periodic major natural disturbance (e.g. major storms breaching a foredune)
- areas that were once wetlands but have been drained by humans (e.g. extensive areas of low-lying alluvial coastal flats)
- intertidal areas that have been subject to accelerated sedimentation, especially of fine material. Such acceleration is typically the result of catchment and riparian land uses
- areas where humans have changed the natural regimes for water depth, flow or salinity.
- coastal areas affected by human activities that have changed the coastal long-shore sediment transport processes and/or the sediment amounts being transported. For example near-shore and intertidal mining can affect sand supply along the coast as can the construction of breakwaters, extensive seawalls and upriver dams
- areas where causeways have reduced tidal flushing and increased sedimentation upstream (e.g. SH11 causeway across the Haumi “Inlet”; the rail causeway across the Whangae River mouth)
- coastal wetlands where the previously adjoining freshwater wetlands have been drained. This reduces the supply of fresh groundwater to saltmarsh communities

Estimating potential cover in Northland coastal environments

Change in cover (in the form of vegetation canopy and benthic cover for submerged environments) is used to represent the overall change in attached components of an ecological community. In multi-tiered systems, especially forests, this omits a considerable amount of the attached biota. The assessment of cover has the benefit of being relatively quick to assess and can be meaningfully used for most coastal environments. In detailed single site assessments of areas with multi-tiered vegetation it would be appropriate to identify the composition of each vegetation tier.

A range of resources were used to predict potential cover including LENZ Level IV, present day good examples, historical records, scientific papers addressing pollen records, succession pathways and species ecology, and ecological reports.

At the scale of a mapped unit local exposure, geomorphological and hydrological variations can be critical in a determination of potential cover. The prediction of the potential cover is particularly difficult where there have been hydrological and geomorphological changes arising from natural causes or more typically anthropogenic activities. To move forward it is necessary to make assumptions. Some assumptions are general and others may be specific to a certain situation. In all cases the assumptions should be clearly specified.

Three general assumptions were made to assist the identification of present-potential cover for the Northland case studies as follows:

- Where an area has been subject to accelerated sediment deposition resulting from catchment sources or structures causing reduced water velocity, the present-potential vegetation/benthic cover should be reset to the new geomorphology. Where sediment deposition is the result of a specific potentially removable structure (e.g. marine farm rather than a road or rail causeway) this would not require a resetting of the potential cover.
- Where there has been such significant change in the environmental parameters that the potential cover prior to those modifications is no longer attainable then the present-potential cover should be reset. Examples include:
    - A reclamation that converts permanently submerged land to dry land (the present potential cover would become forest in most cases)
    - Excavation of dry land to create permanently submerged canals or marina waterways (the present potential vegetation would become an indigenous subtidal benthic community)
- Where an area has been subject to extensive drainage the present-potential vegetation should not be reset to the new hydrological regime. This is because the wetland vegetation may remain (especially if it is forest or scrub vegetation) and gradually change over time. Typically drainage is accompanied by actions to remove the natural vegetation as an area is typically drained so that it can be used for agricultural or other human purposes. In other cases drainage of an area is a form of collateral damage and the natural vegetation is left. Examples of such surviving (non-coastal) vegetation include the kahikatea forest remnants adjoining the Waipapa commercial area and Riccarton Bush in Christchurch. The latter is the subject of an ecological restoration programme which includes re-flooding and predator proof-fencing.

In all situations covered by these assumptions the extent and magnitude of the hydrological and geomorphological changes would be addressed in the hydrological and geomorphological naturalness score. This approach ensures that effects of major changes to the hydrological and geomorphological attributes of an area would not be counted twice.

Potential forest vegetation in the coastal environment of eastern Northland

Leathwick (2001) identifies the potential forest of eastern Northland as primarily *Agathis- Beilschmedia* forests (a subset of conifer-broadleaved forests of warm climates). Rimu (*Dacrydium cupressinum*) is often associated with these kauri

(*Agathis australis*) and taraire (*Beilschmedia taraire*) forests, commonly as a subdominant (Norton et al. 1988).

LENZ Level II classifies much of eastern coastal Northland south of Karikari Peninsula (and excluding the volcanic soils around Kerikeri) as Environment A6 Leathwick et al (2003). The original vegetation for this Environment was kauri and its associated species on infertile hill crests and upper slopes. On mid-slopes there were rimu, miro (*Prumnopitys ferruginea*), totara (*Podocarpus totara*), northern rata (*Meterosideros robusta*), tawa (*Beilschmedia tawa*), taraire, kohekohe (*Dysoxylum spectabile*) and nikau (*Rhopalostylis sapida*). These graded into kahikatea (*Dacrycarpus dacrydioides*), matai (*Prumnopitys taxifolia*), puriri (*Vitex lucens*)and pukatea (*Laurelia novae-zelandiae*) on lower slopes and valley floors. Pohutukawa (*Meterosideros excelsa*) established on steep coastal slopes with smaller trees such as taraire and mageao (*Litsea calicaris*) underneath. Mangroves were common on the coastal margins (Leathwick et al. 2003).

Some of steeper coastal headlands (including Cape Brett, parts of the open coast between Whangaroa Harbour and Berghan Point north of Mangonui Harbour) are within LENZ Level II category D1. D1 includes most of the remaining kauri stands on leached upland soils. On lower slopes kauri was present and species such as kohokohe, puriri, pukatea and kahikatea occurred in sites of higher fertility (Leathwick et al. 2003). Environment D1 is widely distributed in the upper north Island and includes upland sites.

Less than 0.5% of the original mature kauri forest remains (Froude et al. 1985), and virtually none is in the coastal environment.

Potential vegetation for the terrestrial non-forested coastal environment

Within the study area of the coastal environment of eastern Northland, (south of Karikari Peninsula), there are limited areas where the potential terrestrial vegetation is not forest. These areas are primarily where:

- there is a new surface (e.g. recent dune surface, a recent natural landslide, unweathered surface rock); or
- the geomorphology and hydrological regime has created conditions suitable for non-forested wetlands; or
- high levels of saltwater inundation or spray prevent the establishment of forest; or
- steep rocky coastal cliffs mitigate against the establishment of forest

The present potential vegetation of young “active” dunes (especially the face) is typically native sand binders on the most exposed parts of the foredune and dunes that have recently become mobile (providing that the mobility is due to natural causes such as the sea breaching the foredune).

Behind the most active foredune face the present-potential vegetation is a mosaic of native sand binders, native shrubs and other low stature native vegetation (with the precise mixture depending on seed availability and local conditions). Moving further inland the potential vegetation transitions to kanuka forest and then podocarp/ mixed hardwood forests on the older dunes.

The width of the present-potential vegetation transition zone that extends from native sand binders to mature forest varies depending of the probability of natural periodic disturbance. This zone can be extremely narrow (e.g. the abrupt transition from mature podocarp/mixed broadleaved forest to exposed sandy beach found in some parts of southern Westland and the southern Catlin coast). This zone is much wider where a coast is subject to regular cycles of erosion and deposition due to cyclical weather patterns and/or periodic tsunamis (e.g. Bay of Plenty).

Lower lying ephemeral wetlands, using the description in Johnson & Gerbeaux (2004), or swales, can occur between dunes. Depending on their location the potential vegetation is typically turf and sward and sometimes rushland and scrub (Johnson & Gerbeaux 2004).

Potential vegetation for freshwater wetlands in the coastal environment

The potential vegetation of wetlands depends on the type of wetland and its history. Prior to the major hydrological and geomorphological changes implemented by humans, the wetlands on most lowland alluvial plains draining into estuaries and harbours were typically swamps, as described by Johnson & Gerbeaux (2004), adjoining the water course. The vegetation cover would have been tall podocarp dominated forest with areas of sedge, flax and scrub.

Extensive drain construction and river channelization has drained much of these once large wetlands. Today the potential vegetation for the drained areas of former wetland is podocarp/ mixed broadleaved forest.

There are limited areas of coastal environment that still have a hydrological regime that supports freshwater wetlands. Within the study area (eastern coastal Northland south of Karikari Peninsula) the most prevalent wetland class remaining is swamp. This is a wetland class that receives a relatively rich supply of nutrients and sometimes sediment (via runoff) and groundwater from nearby land. Swamps occur on valley floors, deltas and plains and today are typically small in the coastal environment. While a range of vegetation structural classes can be found in swamps (Johnson & Gerbeaux 2004), swamp forest is the predominant present-potential vegetation cover. In low gradient areas, especially adjoining the transition from saltmarsh to freshwater wetland, the likely present-potential vegetation is likely to include combinations of flax, scrub, rush and sedge vegetation.

Potential cover for the marine coastal environment

The following are the major present-potential cover patterns that have been addressed in the marine environment:

- Mangrove forest and scrub
- Saltmarsh and scrub
- Seagrass meadows (intertidal and subtidal)

- Shallow rocky reef kelp forest

Further work is required to describe additional present-potential cover patterns for marine environments.

Mangrove forest and scrub

The New Zealand mangrove is a small evergreen tree or shrub that can grow to about 10 metres. Its size and growth form can vary considerably (Beard 2006). De Lange and de Lange (1994) found no systematic trends in maximum mangrove size and distinguished three growth forms including a form that was significantly taller than average at about 10m tall and often forming an incomplete cover. Larger trees are also more common on the outer margins of mangrove systems and the borders of streams where there is favourable drainage (Dingwall 1984).

Eastern Northland harbours and estuaries typically contain extensive areas of mangroves, often of varying sizes. This is most pronounced where there are rivers and streams draining large catchments. Several factors have affected the extent of mangroves in eastern Northland:

- There has been an increase in the area of suitable habitat due to increased levels of fine sediment being transported into the lower reaches of rivers and streams and their downstream estuaries
- In the past areas of mangrove had been cleared or cut for various reasons; some of these areas are now covered by regenerating mangroves (e.g. Haumi River)
- In the past areas of mangroves have been grazed. This practice has been steadily phased out, allowing areas of former mangrove forest to regenerate (e.g. Orongo Bay)
- The past construction of road and rail causeways in harbours and estuaries has changed water circulation and velocity patterns. The amount of suitable mangrove habitat has increased in locations where water movement has slowed because of these structures (e.g. SH11 causeway across the Haumi River, causeways associated with the old Opua railway including the extensive Whangae causeway)

In very general terms mangrove forest is the present-potential cover in locations where it currently exists and areas where it has been cleared, cut and/or grazed. Mangrove trees of short stature and shrubs may be recently established possibly because of an increase in the extent of suitable habitat. In other cases specific conditions of the site favour shrub or shorter tree growth forms (e.g. inland margins adjoining saltmarsh). Where such situations are obvious and of sufficiently large scale the present-potential vegetation can be adjusted accordingly.

Saltmarsh

As saltmarshes form in physical environments that are similar to those where mangrove forests are found their relative extent in Northland is more limited than for more southern estuaries where mangroves have less vigour or are absent due to temperature limitations. Typically saltmarshes in Northland occur upstream and/or inland of mangrove forests in areas of very gradual topography. They are usually absent where the topography landward of the estuarine coast is anything other than gentle. In these cases if there is emergent vegetation it is dominated by mangroves.

There are very limited areas of saltmarsh on open Northland coasts. These areas are usually where there is a barrier providing protection that allows sufficient sedimentation for saltmarsh to establish. Mangrove propagules are usually extremely limited. Such areas of saltmarsh are typically small.

Chapman (1976) discusses North Atlantic seral pathways that begin with saltmarsh. New Zealand's uplift and sea level rise both mitigate against the ongoing sedimentation that eventually converts saltmarsh to dry land in parts of the North Atlantic. Some of the most effective saltmarsh plants for trapping sediment – species from the genus *Spartina* – are generally absent in New Zealand. *Spartina* species are pest plants that colonise intertidal environments trapping sediment to raise ground level above high tide so allowing a range of terrestrial (usually weed) species to establish (Craw 2000). This results in considerable loss of biodiversity and naturalness as the area of intertidal habitat is reduced.

Saltmarsh in eastern Northland is typically dominated by rushes such as oioi (*Apodasmia similis*) and *Juncus krausii* as well as low shrubs such as marsh ribbonwood (*Plagianthus divaricatus*). It can transition to freshwater wetlands, typically swamps with species such as flax (*Phormium tenax*), raupo (*Typha orientalis*) and manuka (*Leptospermum scoparium*). In many areas these freshwater wetlands have been drained. In some areas the transition to dry land is through salt – tolerant manuka-dominant scrub.

In general terms, the extent of areas where the present-potential vegetation is saltmarsh is the current extent, plus areas that have been actively drained and converted to other vegetation. Where the latter has occurred it may be difficult to identify the former inland boundary of saltmarsh, especially where there was a transition to freshwater wetland.

Sea grass meadows
New Zealand's sea grass species (*Zostera capricorni*) has a much higher light requirement than most seagrass species found overseas(Reed et al. 2005). It appears that the New Zealand species of *Zostera* may require up to 30-40% of incident irradiance on average over a year (Schwarz unpublished data reported in Reed et al (2005). This makes the New Zealand *Zostera* relatively sensitive to the effects of factors that lower water clarity. Subtidal beds are particularly susceptible.

Park (1999) found that the extent of subtidal seagrass beds in Tauranga Harbour diminished by 90% from 1959 to 1996. In contrast Whanganui Inlet in the north-western South Island has extensive intertidal and subtidal seagrass beds. The catchment of this large inlet is mostly in original native forest, the incoming waters are not stained with humic acids (in contrast to estuaries further south on that coast) and the Inlet water clarity is high.

Hayward et al (2001) found extensive beds of seagrass covering over half the area of Parengarenga Harbour in the Far North of Northland. Most was found growing on sandy substrate in the low intertidal, between mid and high tide. The only areas where seagrass was not well developed were the harbour entrance and the upper muddier arms of the Waiheuheu Arm.

Whanganui Inlet and Parengarega Harbour could provide initial indicative baselines on what could be the present-potential cover throughout much of the eastern Northland harbours and estuaries. Clearance of the original native vegetation cover and past and present catchment land uses have increased the levels of sediment and nutrients being delivered to most Northland estuaries. This decreases water clarity and changes the nature of the sediment, thereby reducing the extent of suitable present day habitat for seagrass.

While it is possible (although potentially complex) to improve water clarity there are several other constraints. Seagrass does not naturally occur in areas that are highly exposed to heavy surf and swell. It generally avoids very fine silt and mud substrates that are re-suspendible, especially for subtidal beds. Some residual upper intertidal seagrass beds may remain as sediment particle size diminishes and water clarity decreases, provided they are able to get enough light while they are uncovered without suffering from summer desiccation.

In general terms, the extent of areas where the present-potential cover is *subtidal* seagrass include:

- Harbour and estuary outer bays and inlets protected from large swells, with a substrate that has a low percentage of fines, but excluding high current scour channels (e.g. extensive areas of the outer Bay of Islands)
- Harbour and estuary middle and inner bays excluding: those subtidal areas where the substrate contains high levels of fine silts and muds and high velocity channels. Also excluded are those areas where the hydrology and geomorphology has been changed (e.g. by causeways) to make the substrate unsuitable for seagrass beds

The extent of areas where the present-potential cover is *intertidal* seagrass include

- Harbour and estuary outer bays and inlets protected from large waves and the substrate is sand (e.g. extensive areas of the outer Bay of Islands)
- Harbour and estuary middle and inner bays where the substrate is sand and/or a mixture including finer particle sizes. This excludes the innermost bays where the substrate is dominated by high levels of the finest particle sizes. The mean substrate particle sizes for the intertidal seagrass beds can be higher compared to subtidal beds.

The relationship between actual and potential cover patterns

The units chosen for the measurement of natural character are each designed to be relatively homogeneous in terms of their ecological naturalness and the type and degree of impact from structures. This is to improve the sensitivity of the methodology for measuring change. Various parameters are measured and combined into several scores or indices:

- Ecological Naturalness Score (ENS);
- Hydrological and Geomorphological Naturalness Score (HGNS)
- Building and Structure Impact Score (BSIS).
- Sound and Light Naturalness Score (SLN) (optional)

For each unit each of these scores is between 0 and 1 (and can be scaled to a percentage between 0 and 100).

An important component of a unit's Ecological Naturalness Score is a comparison between the actual observed and present-potential cover. This involves the following steps:

- An assessment of the actual observed cover using aerial and satellite images and inspection (either on-site for low stature cover; or from a location(s) where the site can be viewed)
- A prediction of the present-potential cover using a variety of tools as described above
- A comparison between the actual observed cover and the present-potential cover

To be consistent with the methodology for other parameters it is necessary to convert the comparison between the actual observed cover and the present-potential cover into a number between 0 and 1. This is needed so that the measures from different types of parameters can be aggregated.

It was not possible to develop a simple "one size fits all" table to translate the comparison in the third bullet point into a numerical measure. This is because there are:

- many types of potential cover;
- a variety of succession start points and processes (at least for some potential covers); and
- local site conditions affect progress.

The initial approach was to plot time against % progress towards reaching present-potential cover. This approach was rejected because a literature review and trial showed that there was:

- too much variation in the actual time taken to reach/remain at a particular "successional stage";
- it was difficult to obtain good estimates of the time taken for the different components of succession pathways; and
- field assessments and aerial interpretations addressed the structure and composition rather than age of the cover.

The alternative approach was to identify thresholds of structure and composition change along generalised succession pathways to potential cover. For some types of potential cover the length of the pathway and number of thresholds is relatively small. The longest and most complex pathways are those leading to a mature native conifer/ mixed broadleaved forest.

The role of natural disturbance is addressed in the present-potential cover concept by the selection of the appropriate present-potential cover for each unit. While the present-potential cover for a unit incorporates the effects of past geological, geomorphological and climatic events, it can not address possible future events. This means that the present-potential cover for a unit is not necessarily fixed. Future significant natural disturbance events may change a unit's present- potential cover if the unit is affected by such an event. Climate change may also affect the potential vegetation or benthic cover for some units.

The next sections describe: the identification of thresholds of structure and composition change for the main succession pathways where the present-potential vegetation is native forest. The next stage is to use this information to develop an appropriate numerical scoring system. .

Processes leading to the development of mature native forest in mainland northern New Zealand

It takes many years for newly established pioneer vegetation on a secondary surface (one where soil has already formed) to develop into mature native forest, particularly a native conifer/mixed broadleaved forest. In Northland the native conifer component can be kauri and/or one or more of the podocarp species. Typically the coastal mixed broadleaved canopy component is dominated by large specimens of species such as taraire and puriri.

Site conditions and factors affecting seed supply can have a major influence on which species are involved at different stages in the succession process. These matters also affect the timing of the “stages” which are really just steps along a continuum.

Throughout much of eastern Northland south of the Karikari Peninsula the primary early succession species is kanuka (*Kunzea ericoides*), sometimes with manuka. Initially kanuka forms dense scrub which develops into kanuka forest which may be 20+ metres tall with trees over 120 years of age. Native canopy species establish under the kanuka forest and progressively overtop the kanuka as the vegetation evolves to become conifer/ mixed broadleaved forest.

There have been several studies of kanuka and manuka growth and the associated succession patterns. Of particular interest is the time span of different stages in the succession process in different situations.

In Dunedin Allen et al (1992) found that kanuka established readily on bare ground and more slowly on grazed pasture. For 27-50 years dense kanauka stands of 1/sq m suppressed the growth of other tree species, but after 50 years kanuka stem density began to decrease, and after 70 years there were scattered podocarps with succession to mature broadleaved forest just beginning. It would take several centuries to develop mature podocarp/mixed broadleaved forest.

Esler & Astridge (1974) evaluated manuka and kanuka succession in the Waitakere Ranges. Kanuka and manuka reached 7m in 20 years with kanuka aged more than 100 years in age exceeding 18 metres in height. They considered there were two main succession routes. In the first kauri established early and formed kauri rickers overtopping the kanuka; and growing to form a kauri/mixed broadleaved forest. In the second podocarp seedlings established later (than the kauri seedlings) and developed into podocarp (especially rimu)/mixed broadleaved forest. On exposed steep coastal slopes stunted manuka dominated over a prolonged period and the future vegetation type was uncertain.

Lloyd (1960) evaluated the regeneration of kauri, rimu and tanekaha (*Phyllocladus trichomanoides*) under a kanuka canopy in Russell Forest, Bay of Islands. He found few other species under young kanuka because of the intense competition and dense litter. A few saplings of kauri, rimu and tanekaha established in the early years and then only tanekaha established until the kanuka reached 60 years of age. From 60 years of age kauri, rimu and tanekaha all regenerated continuously. The kauri that established in the early years grew rapidly (reaching 9 inches in diameter after 110 years). This contrasted with the kauri that established later which had a slower growth rate because of suppression. Lloyd found a few kauri trees of 109 years of age that were 55 feet tall - slightly taller than the tallest of the slightly older kanuka trees. Rimu and tanekaha were also present at heights at or close to the canopy.

Ahmed & Ogden (1987) found a weak relationship between age and diameter of kauri with individuals in the same 10cm diameter class varying by in age by 300 years. They found that growth rates were slower than those commonly reported, and concluded that the normal attainable age for kauri was more than 600 years. Individuals with a diameter greater than 2 metres probably exceed 1000 years.

Ogden et al (1987) disputed a common view that kauri is a successional species that does not regenerate in mature forest. They supported a "cohort regeneration model" where dense regeneration occurs in successional communities following large-scale disturbance. This leads to self-thinning ricker stands where seedling establishment is rare, creating a local "regeneration gap". Once the forest is mature then canopy gaps from windthrow create opportunities for other recruitment, although hardwood species would often be more effective in establishing in the gaps. Ogden et al (1987) considered that the longevity of kauri implies that would survive in the area long enough for a large scale disturbance to reinitiate the process.

Burns & Smale (1990) observed changes in the composition and structure of a secondary kauri –tanekaha forest in Coromandel. This stand was considered to be intermediate between previously described young and mature kauri stands, with the kauri mostly being from 100-200 years in age. The larger trees were beginning to develop mature crowns. They concluded that several successional pathways were evident as follows:

- Tanekaha was replacing second generation kanuka
- Kauri was replacing towai (*Weinmannia silvicola*), and probably tanekaha in future

They expected that kauri would become dominant over much of the stand, (suppressing many younger kauri, the temporarily prominent tanekaha, towai and the ephemeral rewarewa (*Knightia excelsa*)) and that canopy diversity would be enhanced by a few podocarps and hardwoods such as hinau (*Elaeocarpus dentatuts*) and kohekohe (*Dysoxylum spectabile*).

Bergin (1979)discussed forest succession in the low altitude Wairongomai Valley, in the Kaimai ranges. The youngest sites were dominated by thick gorse and bracken. At about 20 years shining karamu, fivefinger moved into the canopy. From 20-80 years manuka, kamahi and rewarewa became important. Tawa, kohkohe and too a lesser extent mahoe became the main canopy species, with kamahi gradually dying out. Sites greater than 300 years were dominated by tawa with frequent podocarps. Concern was expressed about the spread of radiata pine into recently cleared areas, and it was thought that its effects may extend well beyond 100 years.

Bergin (2001) evaluated natural totara stands in Northland. Totara was able to colonise open steep grazed slopes, often with manuka, kanuka and gorse (*Ulex europeaus*). The shorter stature species such as manuka and gorse were eventually suppressed as totara increases in height. The longer lived kanuka could remain a significant component in the canopy for several decades, and large unthifty kanauka could still be present in stands that are 100 years of age. Totara-dominant stands of 50-70 years of age averaged heights of 9-14 metres, while stands of 80-120 years averaged heights of 16-20 metres. Bergin reported that totara were able to live to at least 600 years of age.

The process to mature native forest for northern New Zealand islands and the mainland open coast

Atkinson (2004) reviewed major trends in forest succession following fires on northern offshore islands larger than 15 hectares. These observations are probably also relevant to succession trends on mainland coastal sites (outside of sheltered estuaries and harbours) where human disturbance has been periodic rather than ongoing. The supply of seed and the very local site conditions have a major influence on which of a variety of possible succession pathways are followed.

Atkinson (2004) found that after a fire one or more of five pioneer species with wind-blown seeds establish on northern offshore islands. These species were kanuka, manuka, pohutukawa, flax and bracken. The most widespread succession was that initiated by the establishment of pohutukawa and kanuka mosaics. Once the more salt tolerant pohutukawa and/or kanuka have established succession is dominated by a suite of five bird-dispersed species, particularly mapou (*Myrsine australis*), mahoe (*Melicytus ramniflorus*), kohekohe, karaka (*Corynocarpus laevigatus*) and puriri (*Vitex lucens*).

Atkinson found that on favourable sites kohekohe could establish in pohutukawa or kanuka within 50-100 years of the initiating fire. Karaka (*Corynocarpus laevigatus*) was found to establish more readily near the coast than kohekohe but both species could establish under their own canopy. Puriri needed more light, but established readily in kanuka forest. It is rare on extensively burnt islands. The next stage is the entry of taraire and/or tawa. Although wind-dispersed kauri frequently replace kanuka on the mainland this was rarely found on the islands.

The development of pohutukawa successions is influenced by the effects of wind-driven salt and the increased soil fertility generated by burrow nesting petrels. Burrow nesting seabirds were once common on the mainland (Hamil et al. 2003) and influenced succession process there as well. . Pohutukawa/mahoe forests often become dominant on more exposed slopes with higher salt levels and higher fertility generated by burrow-nesting petrels from seabirds, while pohutukawa/mapou dominated in more sheltered sites.

Atkinson (2004) observed that pohutukawa could maintain a continuous canopy for at least 100 years and individual trees could live for 300 years or more. On favourable sites on Hen Island, taraire or tawa could become dominant within 200 years of the initiating fire provided that they established within a pohutukawa forest soon after it formed a closed canopy.

Where kanuka formed the initial canopy the succession process was faster than under pohutukawa. On Little Barrier Island much of the extensive kanuka forest on lower slopes that originated in the late 19th century was between 100 and 125 years of age. It was found to be thinning rapidly with many deaths. A major replacement species was haekaro (*Pittosporum umbellatum*) with juvenile kohekohe and puriri. Where taraire and/or tawa established, especially in valley sites, Atkinson (2004) expected that either or both would dominate within 150 years of the initiating fire. On low fertility sites kauri was thought to be the likely replacement, although this would take some time.

Another common starting point for island succession was manauka scrub and bracken fernland. Manuka can overtop the bracken and then be overtopped by mapou. Mapou is short-lived and so the resulting forest is usually kohekohe or karaka forest with scattered pohutukawa (where the pohutukawa established at the same time as the manuka.). Atkinson (2004) found areas of manuka on poor soils with a low tight canopy showing little evidence of any succession. Flax (*Phormium tenax*), like pohutukawa, is very resistant to salt and is common as a long term coastal cliff and shoreline fringe species.

Effects of naturalised species on forest succession

Near settlements naturalised pest species (e.g. gorse (*Ulex europaeus*), wattles, privet, pampas, pines, tobacco weed (*Solanum mauritianum*) and hakea) may establish with the young kanuka and in some cases these species may dominate the vegetation. These naturalised species affect succession processes especially where they are present in large numbers. (Sullivan et al. 2007) compared succession through kanuka and gorse and found there were more differences in species composition in comparable mature stands than would be expected if succession processes under kanuka and gorse were leading to convergent trajectories. It was thought that these differences would proceed to the next generation canopy. Williams & Karl (2002) found the different morphology and structure of gorse encouraged greater use by introduced species of bird and animal (compared to kanuka) and a greater chance of succession leading to vegetation dominated by naturalised woody species.

Pampas can quickly colonise disturbed sites, quickly forming very dense stands that prevent the establishment of other species. Eventual succession is typically to naturalised vines (Craw 2000). Examples of such vines include: Japanese honeysuckle (*Lonicera japonica*), mothplant (*Araujia sericifera*) and blue morning glory (*Ipomoea indica*).

Wattles (e.g. *Acacia dealbata*) are common components of pioneer forest and scrub canopies in parts of the Bay of Islands. Eventually native forest species should grow above the wattles (Craw 2000). Tobacco weed is common invader of disturbed forest, scrub and coastal margins where it can form pure stands that inhibit recruitment by native species and slow regeneration (Craw 2000). Tree privet (*Ligustrum lucidum*) and monkey apple (*Acmena smithii*) can both form dense carpets of seedlings under the existing vegetation canopy. Where there is any damage to the canopy the seedlings can grow to become the new permanent canopy. Both species can form pure associations (Craw 2000). Chinese privet (*Ligustrum sinense*) forms dense stands that can prevent the recruitment of native tree species.

Dense kikuyu grass (*Pennisetum clandestinum*) can delay the initial establishment of woody tree species for many years – thereby delaying the start of the succession process. Pest plants that form a dense ground cover under early succession species can distort or delay succession processes. For example dense Tradescantia (*Tradescantia fluminensis*) can prevent the establishment of native canopy species.

Scoring progress towards present-potential vegetation for mainland northern New Zealand

Tables 1, 2 and 3 set out the provisional scoring system to measure the progress toward potential vegetation for mainland northern New Zealand. Succession beginning with kanuka is addressed in Table 1; succession where kauri predominates in addressed in Table 2, succession via gorse and/or mixed broadleaved scrub is addressed in Table 3, and variations to succession caused by a wattle dominated canopy with or without emergent pines.

Table 1: Succession beginning with kanuka

Score	Threshold or stage	Notes
0	Bare surface, pasture	
0.1-0.15	Kanuka dominant scrub with alien pest species	
0.2-0.3	Kanuka dominant scrub with manuka and possibly other native scrub species	Kanuka establishes on bare surface within 1-2 years, but takes up to 12 years where there is pasture in Dunedin (Allen et al. 1992) [kikuyu absent]
0.35-0.45	Young kanuka forest	Kanuka was 7m tall at 20 years in the Waitakere Ranges (Esler & Astridge 1974) Between 27 & 50 years kanuka formed a dense stand in Dunedin (Allen et al. 1992)
0.5-0.6	Kanuka canopy thinning with initial entry of other species into the canopy	Kanuka stand was 70 years of age in Dunedin (Allen et al. 1992) Kanuka at 100 years of age were 18 metres tall (Esler & Astridge 1974)
0.7-0.8	Second stage of other species entering and overtopping the kanuka canopy	Kauri (130 year) that established in the initial kanuka scrub were emergent above the kanuka canopy, with rimu following (Lloyd 1960; Esler & Astridge 1974) The kauri are 100-200 years of age before they start to develop these crowns in the Coromandel (Burns & Smale 1990)
0.85-0.95	No kanuka remains in the canopy, relatively mature broadleaved canopy with podocarps and/or kauri	
1.0	Mature mixed classical	Taraire is the dominant component of the

Score	Threshold or stage	Notes
	mixed broadleaved canopy with emergent kauri and/or podocarps	broadleaved canopy in Northland This takes several hundred years (Esler & Astridge 1974; Allen et al. 1992) The average kauri lifespan is 600 years, with trees with a dbh >2m being >1000 years (Ahmed & Ogden 1987)

Table 2: Kauri succession (probably not likely to occur on coast today)

Score	Threshold or stage	Notes
0.7?	Dense kauri ricker stand	Reported as developing where there has been large scale disturbance (Ogden et al. 1987) and presumably a seed supply A stage in (Ogden et al. 1987) cohort-regeneration model. Probably more likely on drier ridges away from coast
0.75-0.85	Dense kauri ricker stands thin and increasing amounts of broadleaved species enter the canopy. Kauri beginning to develop mature crowns	The next major phase in the (Ogden et al. 1987) cohort-regeneration model. The kauri are 100-200 years of age before they start to develop mature crowns in the Coromandel (Burns & Smale 1990)
0.9-0.95	Kauri and broadleaved forest, kauri generally with crowns still maturing	
1.0	Mature kauri with some podocarps (e.g. rimu) and broadleaved species (e.g. hinau)	"climax" stage for succession in studied area of Coromandel (Burns & Smale 1990)

Table 3: Variations to scoring resulting from succession via gorse and/or mixed broadleaved scrub

Score	Threshold or stage or state	Notes
0.1	Dense gorse scrub	
0.25-0.45	Mixed broadleaved scrub typically including combinations of karamu, mahoe, mapou, five finger	
0.2-0.4	Older gorse scrub with native species beginning to enter the canopy	This may include introduced species (Sullivan et al. 2007), especially nearer settlement
0.5-0.65	Low mixed broadleaved including towai and rewarewa	Especially where succession has been via gorse Bergin (1979) reported kamahi, but towai is the northern equivalent
0.7-0.8	Medium age mixed broadleaved forest including kohekohe, taraire, mahoe	Bergin (1979) reported tawa, but taraire is the northern equivalent
0.85-1.0	Mature mixed	This takes about 300 years (Bergin 1979)

Score	Threshold or stage or state	Notes
	broadleaved forest (especially taraire)with podocarps	

Table 4: Variations to scoring resulting from succession via wattles and other naturalised tree species

Score	Threshold or stage or state	Notes
0.1-0.15	Wattle dominant scrub with or without emergent pines, eucalypts. Some native scrub species	
0.2-o.25	Wattle (& flame tree) dominant forest with or without emergent pines, eucalypts. Some native forest species (especially in understorey)	Wattles are relatively short lived and native species can grow up through wattle canopies. Once the natives have largely overtopped the wattle then the scoring should follow Table 1 in most cases

More work is being done to develop the scoring protocols for those situations where “natural areas” are dominated by introduced tree species that are shade tolerant and can reproduce under themselves (e.g. privet, monkey apple, tobacco weed). The scoring protocols are being refined to address the effect of introduced species in areas where the present-potential cover is low stature vegetation. An example of the later is the effect of the introduced marram grass (*Ammophilia arenaria*) in dunelands.

Scoring progress towards present-potential vegetation for northern New Zealand islands and the mainland open coast

Table 5 addresses the scoring for succession towards present-potential vegetation on islands (larger than 15 hectares) and the exposed mainland coast.

Table 5: Island (>15 ha) and exposed mainland coast succession

Score	Threshold or stage	Notes
0	Bare surface, pasture	
0.1	Manuka scrub and bracken fernland mosaic	
0.2-0.3	Manuka scrub and young forest	
?0.7	Persistent manuka dominant scrub on infertile coastal soils	This is only to be used where it is clear that this is persistent manuka because of poor site conditions. This stage is observed in coastal sites by (Atkinson 2004) and (Esler & Astridge 1974)- the former for offshore islands; the later for western Waitakere Range coast
0.25-0.3	Kanuka scrub or as mosaic with pohutukawa scrub	As described in Atkinson (2004)
0.35-0.45	Kanuka forest	

Score	Threshold or stage	Notes
0.35-0.45	Pohutukawa low forest – often as a mosaic with kanuka forest	
0.5-0.6	Kanuka forest with kohekohe, karaka and/or other broadleaved species in the canopy	
0.5-0.65?	Tall pohutukawa forest with or without broadleaved species in the canopy	Pohutukawa stand can maintain a continuous canopy for at least 100 years and individual trees can live for 300 years or more (Atkinson 2004) Pohutukawa can retain dominance for many years (e.g. a valley on Cuvier Island had pohutukawa dominant and with trees at least 250 years old (Atkinson 2004)
0.65-0.75	Mixed broadleaved, typically kohekohe or karaka dominant forest still maturing	In favourable sites kohekohe can establish within 50-100 years (Atkinson 2004)
0.8-0.95	Mature broadleaved forest typically kohekohe or karaka dominant forest with or without puriri and/or scattered large pohutukawa	
1.0	Mature taraire [and/or tawa] dominant forest often with puriri	Where established in kanuka valley sites taraire and/or tawa can dominate within 150 years of the initiating fire on larger islands (Atkinson 2004) Where established just after the pohutukawa canopy closed, taraire and/or tawa can dominate in about 200 years
0.8-1.0	Kauri dominant	In poorer infertile sites where kanuka established initially, kauri may eventually dominate (Atkinson 2004) although kauri is not common on offshore islands. Score range is to reflect kauri size

Comparing actual-observed vegetation with present-potential vegetation for duneland cover

The assessment of the spatial pattern of present-potential vegetation cover for dunes is more complex, and therefore more difficult, than for many other terrestrial environments. In general terms the spatial pattern of the present-potential vegetation cover on the dune system on the Marsden Point-Ruakaka-Ureti-Waipu Cove follows a pattern. Heading inland from mean high water springs this pattern is:

- Native sand binders on the foredune and sites of recent natural dune blow-outs
- Native scrub including *Coprosma acerosa* and pohuehue (*Muehenbeckia complexa)* and manuka

- Native forest dominated by local variety of kanuka (*Kunzea ericoides var linaris*)
- On the older consolidated dune ridges the present-potential vegetation cover pattern is probably mature native forest including totara (based on current regeneration trends). In the south where the dunes were closer to the steeper coastal cliffs pohutukawa is likely to be a prominent component (Lux et al. 2006)

In the past there would also have been a series of dune swales for which the present-potential vegetation cover includes flax, rushes and reeds. There were also dune lakes. Today only one natural (although highly modified) dune lake remains (Lux et al. 2006)). There has been considerable modification to the hydrology and geomorphology of the duneland areas. The hydrological and geomorphological naturalness is addressed in a separate index. The identification of present-potential vegetation cover is based on present hydrology and geomorphology.

Comparing actual-observed vegetation with present-potential vegetation for coastal cliffs and rocky coastal margins

Coastal cliffs and rocky coastal margins are examples of the small scale terrestrial environments that have not traditionally been addressed by potential vegetation assessments or succession studies. In general the vegetation on coastal cliffs is of lower stature because of climate, topography and skeletal soils. The vegetation on rocky coastal margins in exposed coastal sites is also subject to some extreme conditions including salt spray, strong winds and skeletal soils. Few species are able to tolerate these conditions.

The start point for succession is typically bare surface or poor quality "pasture". Native species that are able to grow here, especially initially, include pohutukawa, flax, taupata (*Coprosma repens*). The progression in the height, and especially the spread of pohutukawa, provides an indication of vegetation development in this type of environment. Table 6 provides a provisional scoring system for vegetation development on exposed hard substrate on coastal margins. The scoring may need to be adapted in situations where conditions are particularly tough for terrestrial plants.

Table 6 Provisional scoring for vegetation development on exposed hard substrate coastal margins in northern New Zealand shores

Score	Threshold or stage	Notes
0	Bare surface after disturbance, pasture	
0.2-0.55	Flax, pohutukawa shrubs with other native shrubs	Cover and height affect score
0.6-0.75	Pohutukawa trees with other broadleaved species (e.g. taupata)	
0.8-1.0	Very large pohutukawa with other native species	

A substantial intrusion of sweet pea shrub, tobacco weed or pampas would decrease the score. An area with kikuyu grass scores 0.

Specific assumptions used in predicting the present-potential cover for the case studies

In each eastern Northland case study the coastal environment was divided into a number of units. Where these units were relatively small (because of the present day attributes) this does not imply that the potential vegetation estimate is more accurate. The present day unit boundaries may lead to generalisation of present-potential vegetation patterns in some locations.

In addition to the already discussed general assumptions for estimating present-potential cover, specific assumptions were made for the individual case studies as follows:

Waipu Cove and Estuary:

This case study covers the following coastal environments: active and partly consolidated dunes; estuary and river mouth; coastal flats, cliffs & hills.

The assessment of potential vegetation and benthic cover for each mapped unit assumes:

- no changes to longshore sediment transport regimes
- no breaching of dunes in an alternative location (i.e. any new river mouth position remains in a similar position as today)

Ruakaka

This case study covers the following coastal environments: active to older consolidated dunes; estuary and river mouth.

The assessment of potential vegetation and benthic cover for each mapped unit assumes:

- no changes to longshore sediment transport regimes
- no breaching of dunes in an alternative location (i.e. any new river mouth position remains in a similar position as today)
- no removal of estuarine reclamations

Parekura Bay

This case study covers the following coastal environments: estuarine environments (including extensive saltmarsh and mangroves), tidal rivers, alluvial flats, hillslopes and coastal rocky shore

The assessment of potential vegetation and benthic cover for each mapped unit assumes:

- The road causeway at the head of the bay will remain

Orongo Bay

This case study covers the following coastal environments: estuarine environments (including extensive saltmarsh and mangroves), tidal rivers, freshwater wetlands, alluvial flats, hillslopes

The assessment of potential vegetation and benthic cover for each mapped unit assumes:

- The reclamation remains

Waikare Inlet middle reaches
This case study covers the following coastal environments: estuarine environments (including mangroves), tidal rivers, alluvial flats, hillslopes and coastal rocky shore

The assessment of potential vegetation and benthic cover for each mapped unit assumes:

- The inlet water margin road will remain

Opua
This case study covers the following coastal environments: estuarine environments (including mangroves), hillslopes and coastal rocky shore
The assessment of potential vegetation and benthic cover for each mapped unit assumes:

- The reclamations will remain
- The rail causeways will remain

Motorua and Motukiekie Islands and associated marine environment
No additional assumptions were made

Conclusion

Present-potential (vegetation and benthic) cover is that which would be in an area today had humans and their agents (including introduced species) not arrived in New Zealand. It takes account of the natural environmental changes that have occurred since human arrival.

To date the application of the potential vegetation concept (as opposed to benthic cover in aquatic environments) has largely focused on broad national scale assessments (e.g. (Leathwick et al. 2004; Capelo et al. 2007). The methodology for measuring natural character (in the primary report) is designed to operate at a more detailed scale. This paper has discussed the identification of present-potential vegetation at a more detailed level for different types of coastal environment.

The methodology for assessing natural character includes a comparison between the actual observed and present-potential cover. As the present-potential cover and the actual observed cover show considerable variation, a series of tables based on analyses of succession literature identified the scoring for different combinations. This needed to be standardised to improve the accuracy of the methodology. When applying this scoring system care is needed in some cases to ensure that the appropriate present-potential cover and the appropriate succession pathway are selected. For example *dense manuka scrub at an early stage in succession to mature native fores*t should score differently to *low dense manuka scrub that remains on a site because of naturally infertile soils*.

The identification of present-potential cover is most difficult at or close to particular land-water margins that are subject to frequent natural disturbance. Examples include foredunes, estuary mouths and smaller coastal wetlands. These areas occupy a small amount of the coastal environment. Work is ongoing to improve the accuracy of potential vegetation assessments in these difficult areas.

More work is needed to improve the methodology for assessing potential vegetation/cover in subtidal environments. This is ongoing.

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Proceedings of the National Academy of Sciences of the United States of America 105(22): 7676-7680.