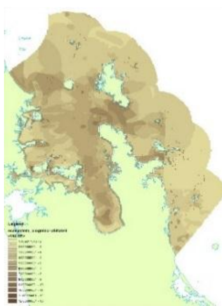
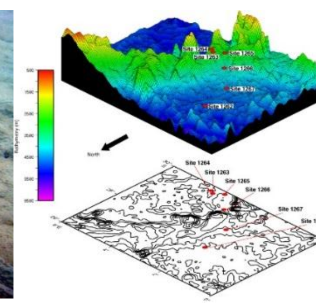
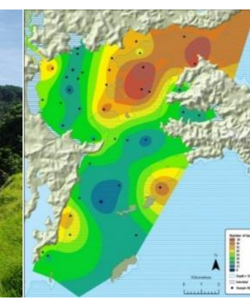
Ecosystem Services for the Hauraki Gulf Marine Spatial Plan

Michael Townsend, Simon Thrush , Drew Lohrer , Judi Hewitt,
Carolyn Lundquist, Megan Carbines & Malene Felsing







In the Talk today:

- What we mean by *Ecosystem Services* and why they are important.
- The challenges we face in working in marine systems and at the gulf scale.
- Ways we have made progress and moved forward to create maps of ecosystem services.
- Validation of these maps.
- The challenges that remain and ways of making progress.

The wide variety of services derived from coastal systems:

Provisioning Services

Production of food (wild stock, captured by commercial, traditional or recreational fishing; aquaculture)
Production of medicines

Regulating and Supporting Services

Storing and cycling of nutrients
Gaseous composition of the atmosphere
Climate regulation
Cleansing water and air
Absorbing and detoxifying pollutants
Sediment formation and stability
Shoreline protection and maintaining hydraulic cycles
Habitat formation
Maintaining biodiversity

Cultural Services

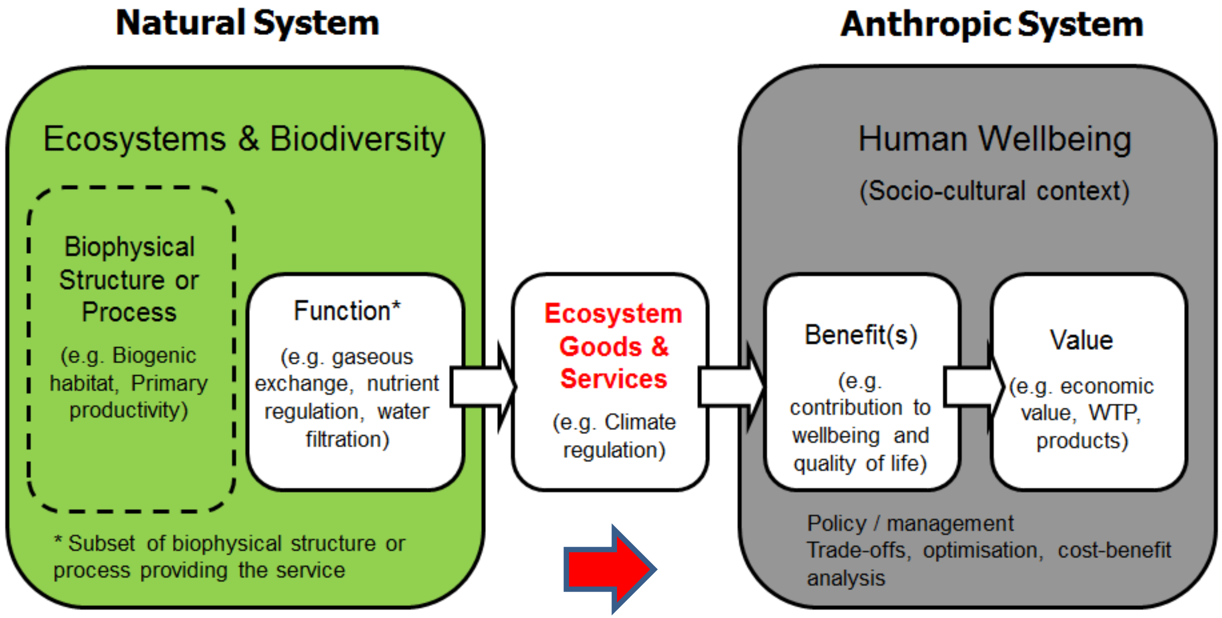
(recreation and tourism; provision of beauty, inspiration and value)

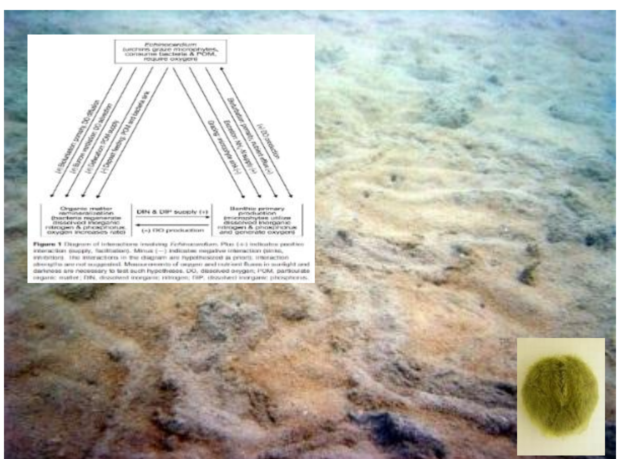
What are *Ecosystem Services?*

- " The direct and indirect benefits that mankind receives or values from natural or semi-natural habitats."

- A concept and a 'language'

- A pragmatic way to help foster good environmental stewardship and achieve sustainability


Natural System
Anthropic System
Ecosystems & Biodiversity
Biophysical Structure or Process
(e.g. Biogenic habitat, Primary productivity)
Function*
(e.g. gaseous exchange, nutrient regulation, water filtration)
* Subset of biophysical structure or process providing the service
Ecosystem Goods & Services
(e.g. Climate regulation)
Human Wellbeing
(Socio-cultural context)
Benefit(s)
(e.g. contribution to wellbeing and quality of life)
Value
(e.g. economic value, WTP, products)
Policy / management
Trade-offs, optimisation, cost-benefit analysis



Why is there a need for the ES approach?

- Many ES go unrecognised, are highly valuable but are obtained 'free of charge'
- We don't currently factor them into decision making processes (often because they lack $).
- This can lead to decisions being made where the true costs out way the benefits.

"Imagine if tree gave off wifi signals, we would be planting so many trees and we'd probably save the planet too.

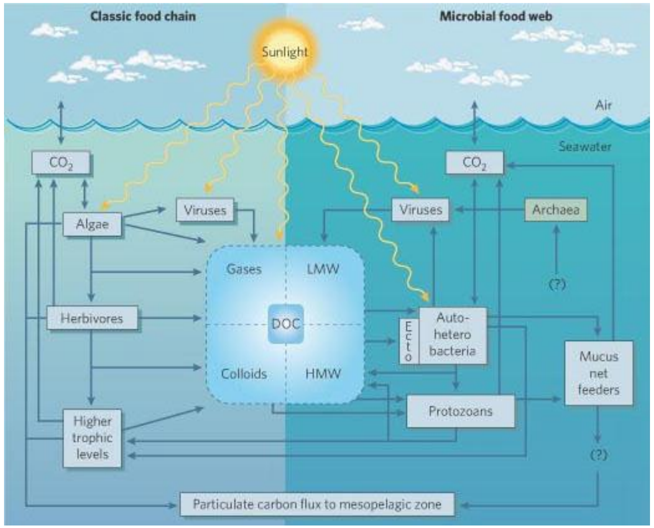
Too bad they only produce the oxygen we breathe."

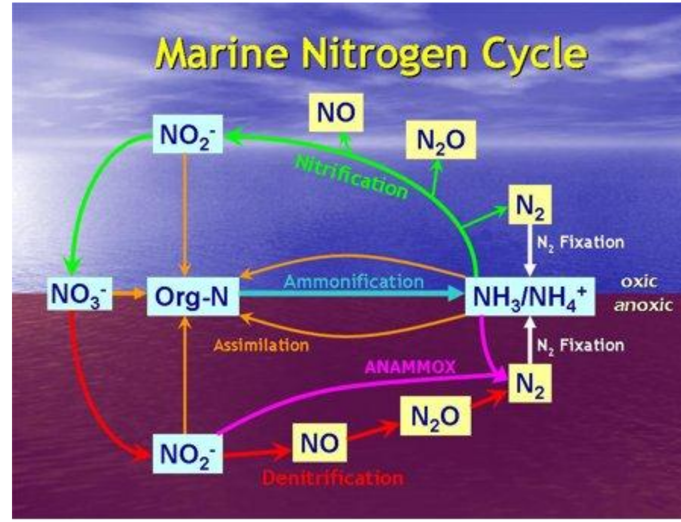
Challenges (particularly for marine systems)

- Balance simplicity and complexity
- Large areas to manage
- Substantial data gaps (spatially)
- Incomplete understanding
- Complicated and complex
- large scale processes

Effective management is needed today. Approaches must be able to use the **best available** information in conjunction with techniques that facilitate **the filling of knowledge gaps.**

Nutrient cycling -What do we measures and what does that mean?!





Multi-functional & multi-dimensional

No single proxy, No simple units

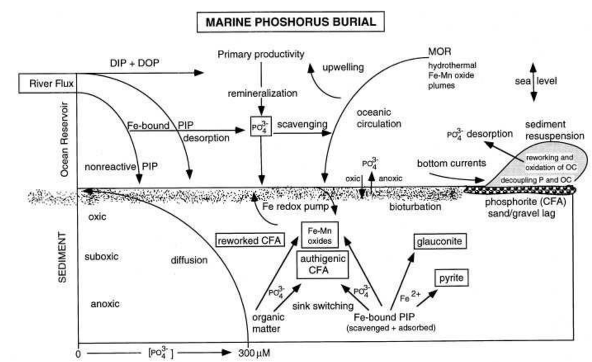
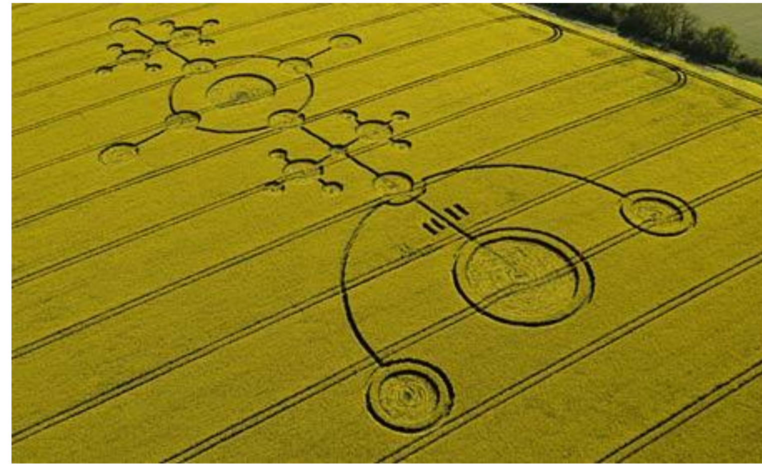
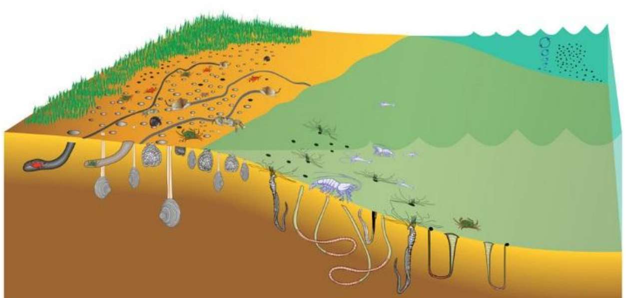


Fig. 2.— Overall schematic of the processes involved in the burial of phosphorus in marine sediments. After burial, most of the organic matter and iron-manganese oxyhydroxide primary phosphorus is released and taken up by authigenic CFA and iron-manganese oxide surfaces in the sediment during diagenesis. This redistribution (sink switching) makes it difficult to determine the net reactive phosphorus burial flux in marine sediments, particularly on continental margins having abundant iron-bound PIP, and possibly reworked CFA.

Spatial data for marine systems can be lacking

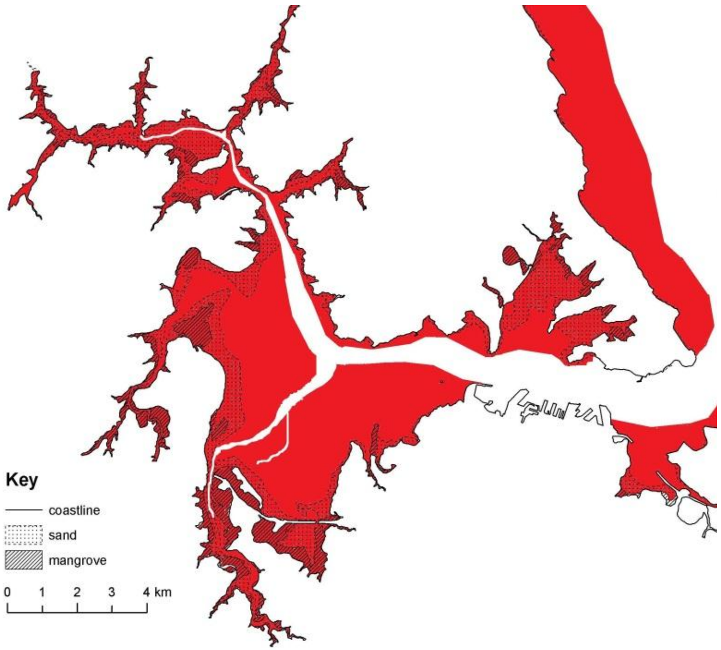




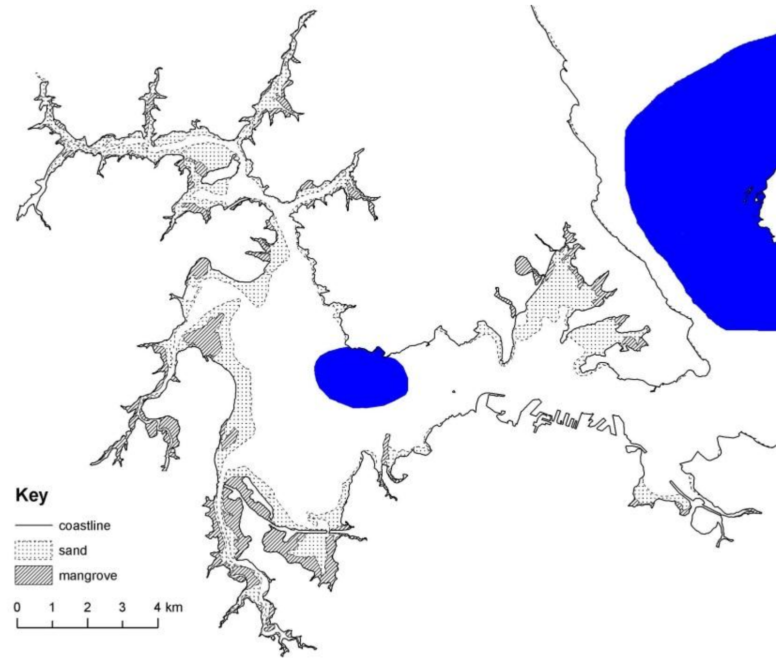
Particularly for biotic and habitat data
These are important for ES

The relevance of spatial separation, connectivity and flow

Shallow productive water

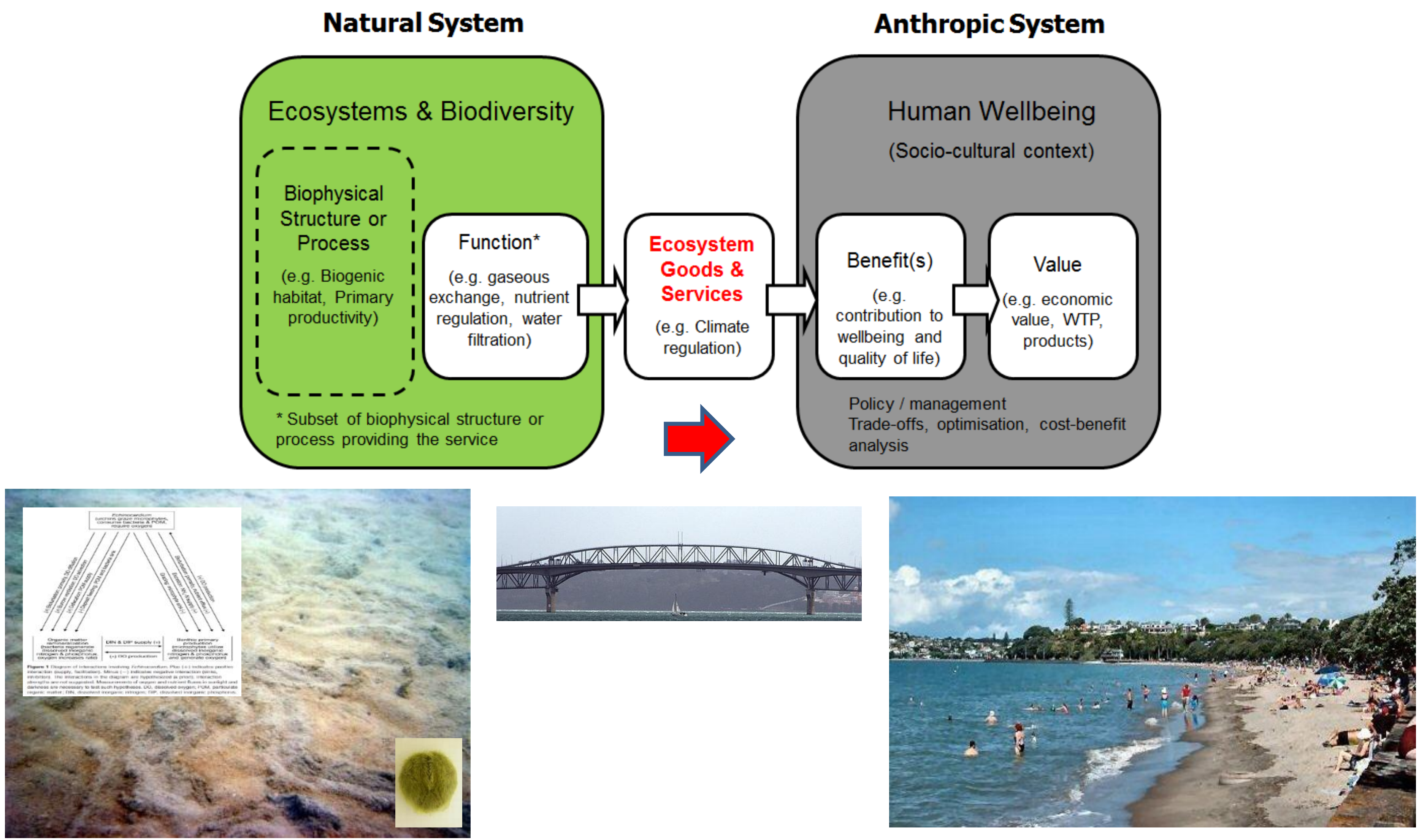


Where people like to go fishing



Where are important locations for food production?

Townsend and Thrush (2010): Ecosystem functioning, goods and services in the coastal environment. Auckland Council report



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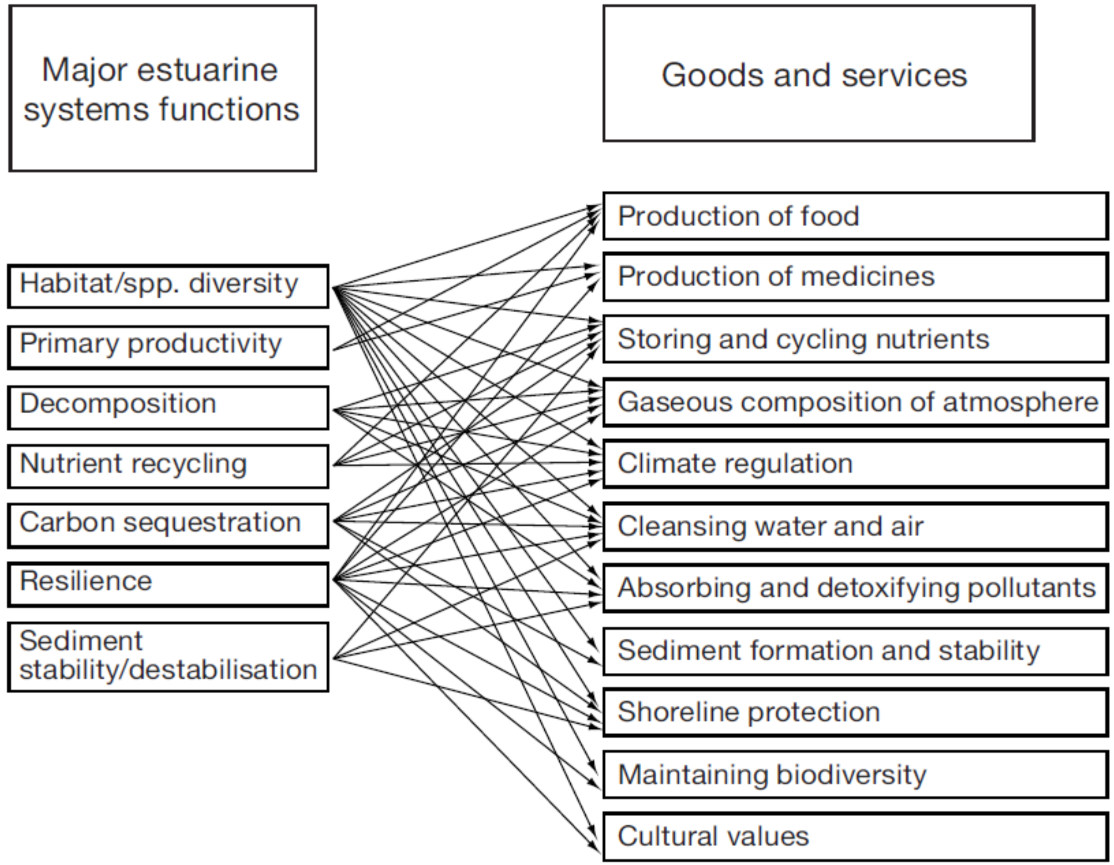

Major estuarine systems functions
Goods and services
Habitat/spp. diversity
Primary productivity
Decomposition
Nutrient recycling
Carbon sequestration
Resilience
Sediment stability/destabilisation
Production of food
Production of medicines
Storing and cycling nutrients
Gaseous composition of atmosphere
Climate regulation
Cleansing water and air
Absorbing and detoxifying pollutants
Sediment formation and stability
Shoreline protection
Maintaining biodiversity
Cultural values

Ecosystem Principles

An 'ecosystem principle' explicitly defines a key element of how we expect the ecological system to operate (when the system is not already badly degraded)

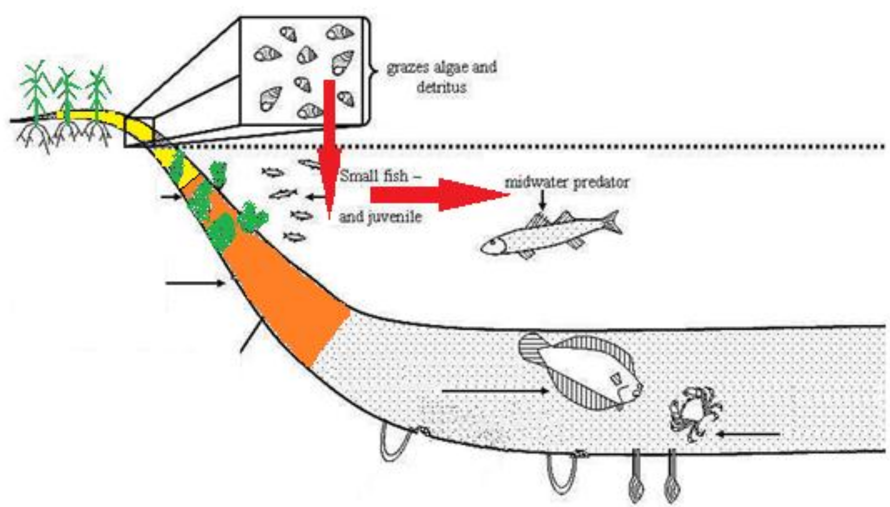
While there may be exceptions, in essence the principles should highlight information that is widely accepted as 'general system rules' and so are defendable.

A key requirement therefore is that principles are clear and easily interpreted to ensure uptake by all stakeholders.

Current Principles

P1 Benthic productivity is an important contributor to system productivity and is greater in shallow than deeper waters.

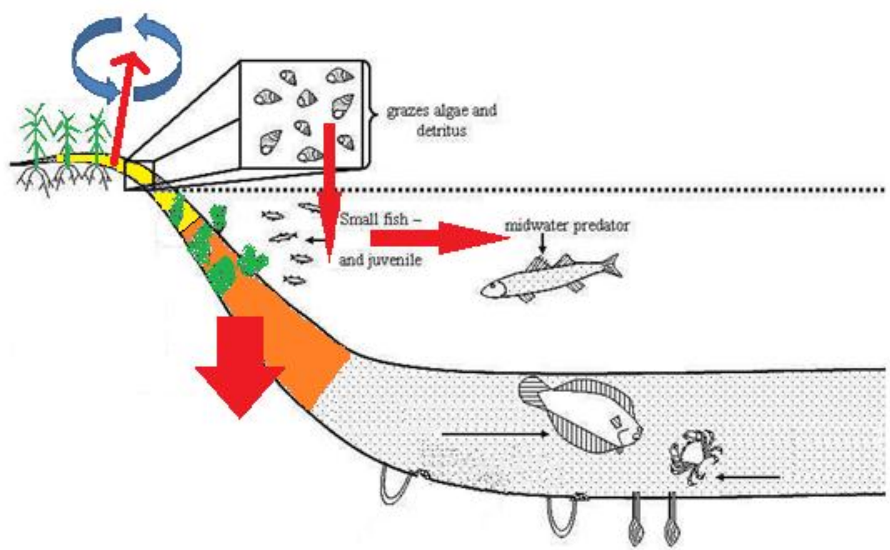
P3 Healthy areas that maintain high productivity at low trophic levels should fuel high productivity at high trophic levels.



Current Principles

P2 Benthic productivity is greater in sandy substrates (i.e. sediment dominated by particles in 2 – 0.063 mm size range) than muddy substrates (<0.063 mm).

P4 Mudflats are predominantly involved with the storage and sequestration of organic and inorganic material. Sandflats are predominantly involved with the processing, modification and recycling of organic and inorganic material.

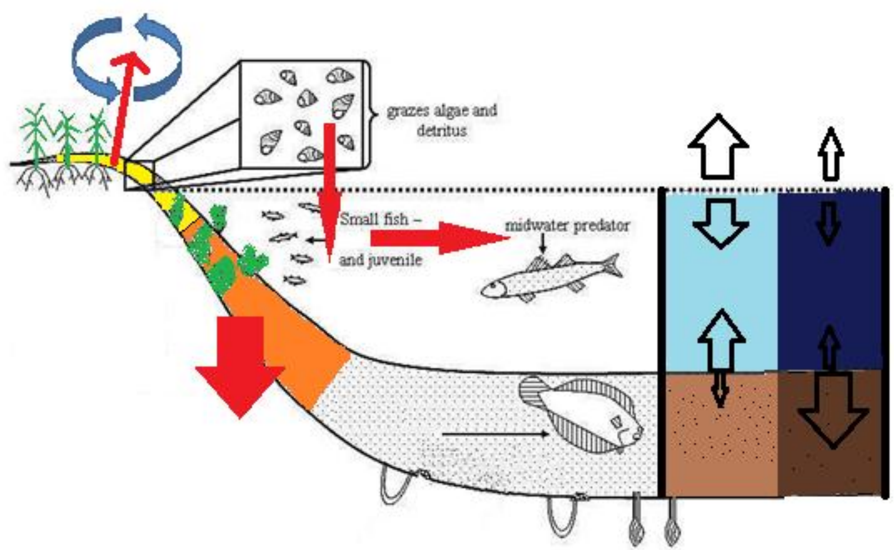


Current Principles

P5 Shallow waters where the water column is well-mixed, have higher rates of processing relative to deeper less well-mixed areas, which can be storage 'sinks' for material.

P9 Shallow, well-mixed waters have a higher ratio of gaseous exchange than deeper, less well-mixed waters.

P10 Shallow, well-mixed waters have higher concentrations of bacteria relative to deeper, less well-mixed waters.



Current Principles

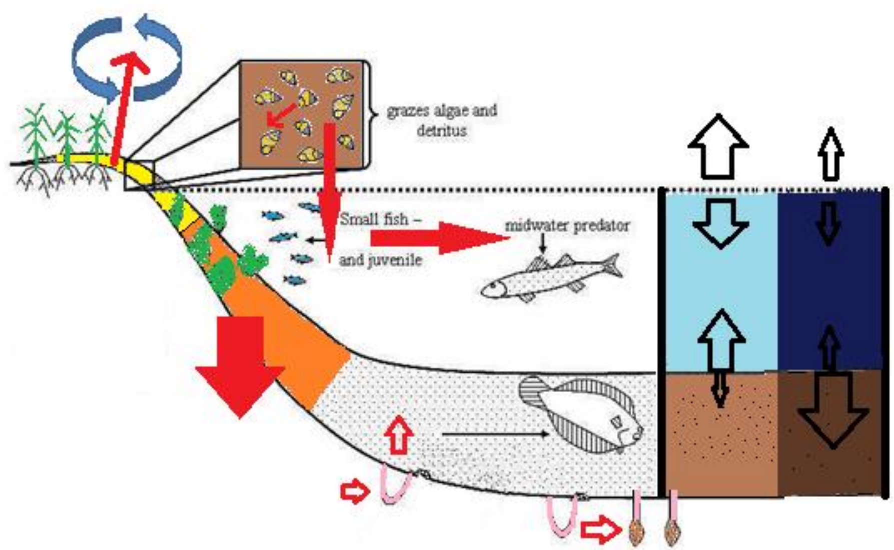
P6 Species can play a dominant role in the determination of nutrient exchange with respect to the magnitude and direction.

P7 Flora and fauna that filter food or nutrients from the water column and maintain a sedimentary lifestyle have a stabilising effect on the sediment.

P8 Organisms that have a mobile lifestyle, moving through and on the sediment surface, or those that deposit feed on the sedimentary material have a destabilising effect on the sediment.

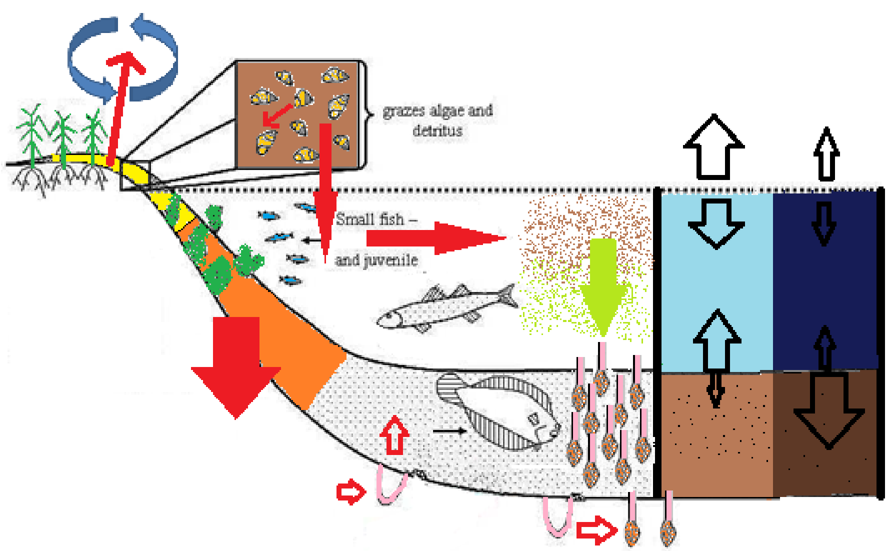
P11 Organisms produce and mediate habitat structures that are utilised for predation refugia and nurseries for juvenile life stages and surface area for attachment of other species.

P12 Molluscs and other organisms sequester carbon by producing shells and skeletons that create sediment over long time scales.



Current Principles

P13 Suspension-feeders can influence the turbidity of overlying water through their filtration activity.
P14 Increased suspended sediment concentrations reduce primary production through increased light attenuation.



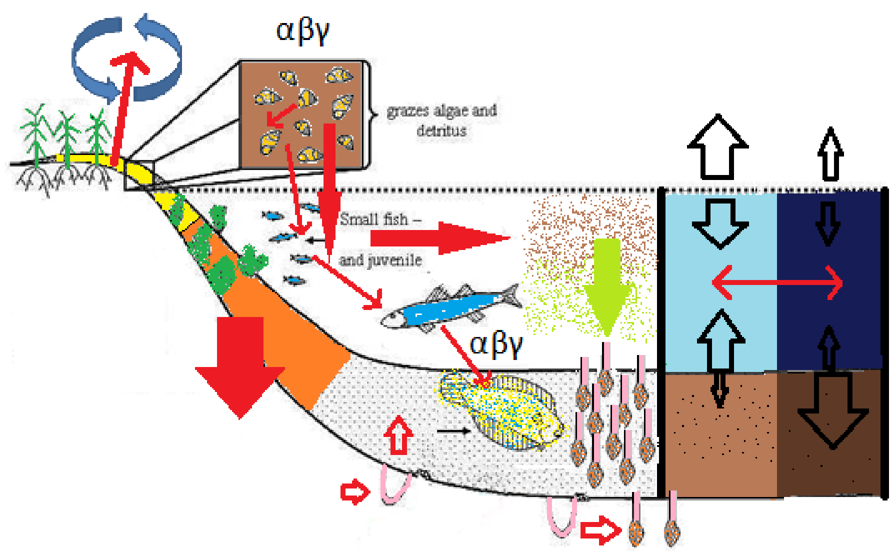
Current Principles

P15 Connectivity is required to translocate material between different locations within a coastal area and from shallow to deeper waters.

P16 The level of connectivity influences the supply and removal rates of biotic and abiotic material.

P17 Space and resource occupancy by native species can decrease invasion risk.

P18 Higher biodiversity increases the number of functional groups and/or the range of species within a functional group.



Ecosystem Principles

Simplifying the complex: an ‘Ecosystem Principles Approach’ to goods and services management in marine coastal ecosystems. Townsend, Thrush & Carbines (2011). Marine Ecology Progress Series **434:291-301.**

Table 1. Examples of ecosystem goods and services in marine coastal ecosystems and their relationship to ecological processes and the associated principles

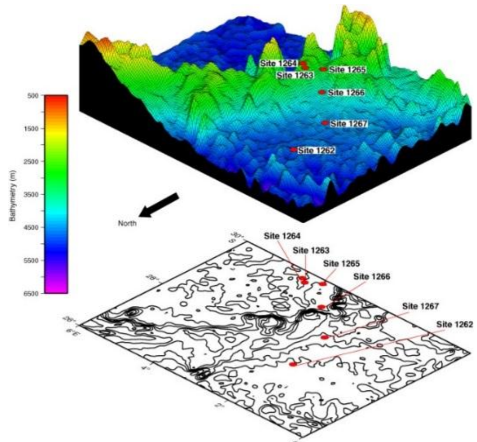
Services category	Functional roles contributing to services	Associated ecosystem principles
Provisioning services		
Production of food (wild stock, captured by commercial, traditional or recreational fishing; aquaculture)	Primary production Secondary production Trophic relationships Reproductive habitats Refugia for juvenile life stages Ontogenetic habitat shifts Biogeochemical cycles associated with enrichment and nutrient recycling Biogenic habitat generators	P1, P2, P3, P6, P11, P14, P15, P16
Production of medicines	Maintenance of biodiversity	P1, P11, P17, P18
Regulating and supporting services		
Storing and cycling nutrients	Role of ecosystem in biogeochemical cycles Role of organisms in storage and processing	P1, P3, P4, P5, P6, P12, P15, P16
Gaseous composition of the atmosphere	Role of ecosystem in biogeochemical cycles Role of organisms in storage and processing	P1, P4, P5, P6, P9, P10, P12, P15, P16
Climate regulation	Benthic-pelagic coupling Bioturbation/irrigation Nutrient and carbon flux Role of organisms – specific species/microbes/enzymes	P1, P4, P5, P6, P9, P10, P12, P15, P16
Cleansing water and air	Benthic-pelagic coupling Bioturbation/irrigation Nutrient and carbon flux Role of organisms –	P1, P4, P5, P6, P7, P15, P16

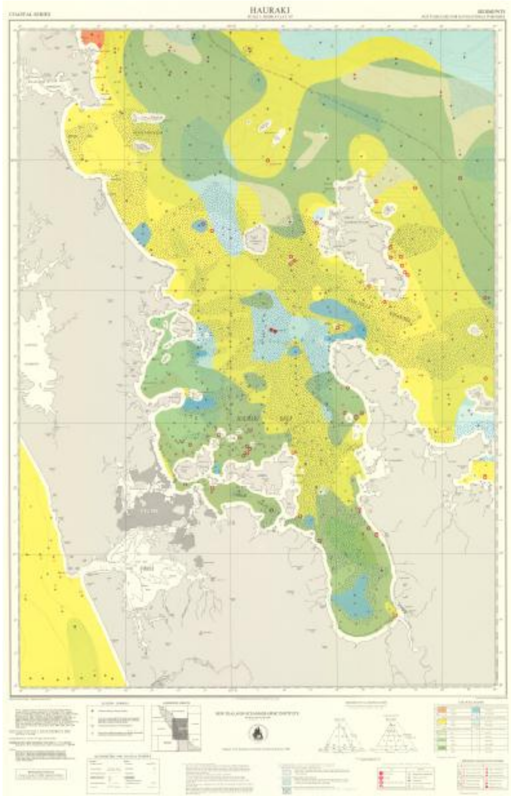
Number, range, frequency, groupings and connections of principles to different services proved insightful.

But in the management of any system we don just need to know the processes involved, we also want to know where services occur.

Ecosystem Principles

- Maximise the inherent spatial nature of many if the principles
- Identify data which exemplifies each principle
- Use a ‘working group’ to identify the <u>best available data</u>





Spatial adaptation of the EPA

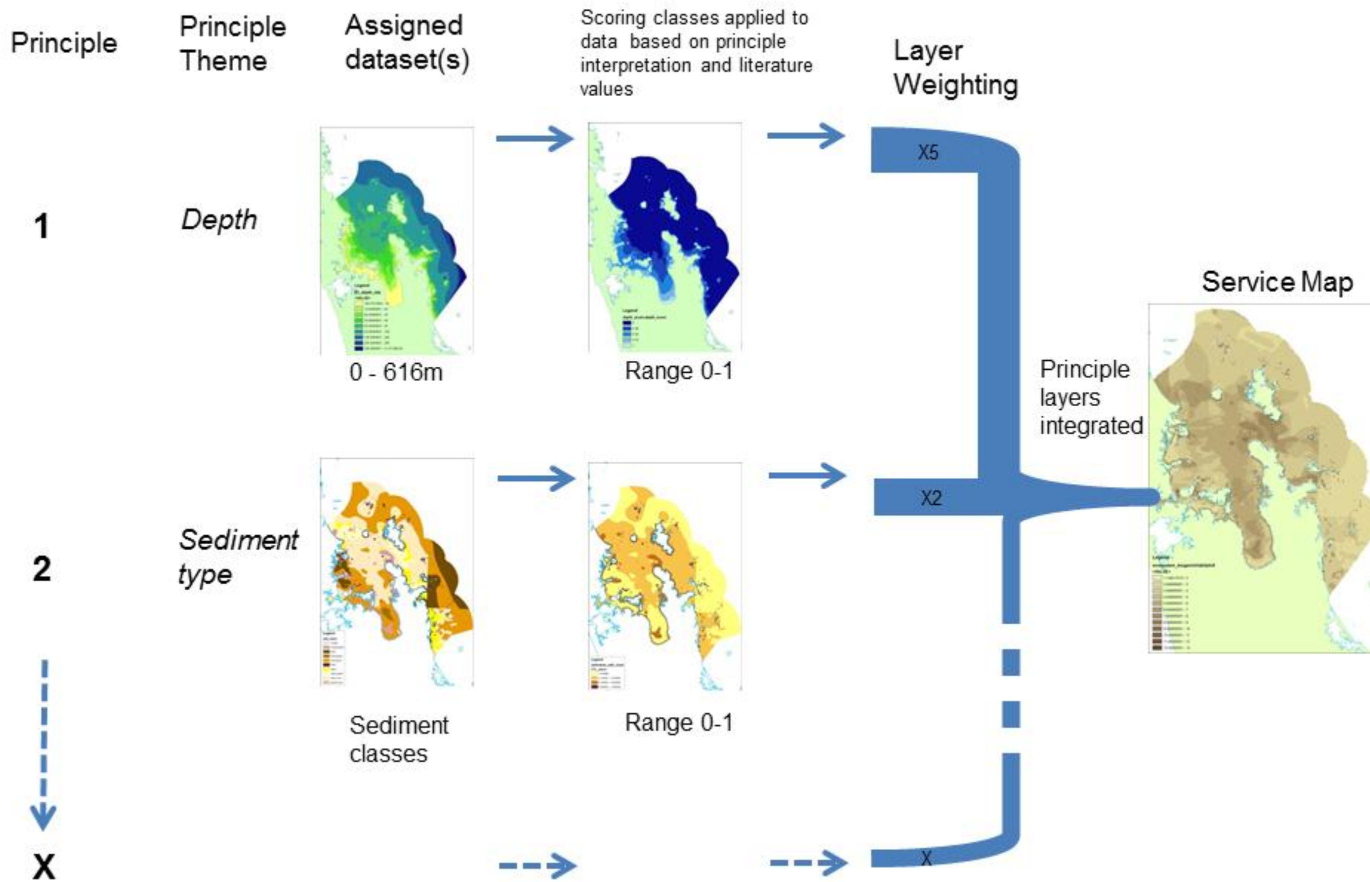
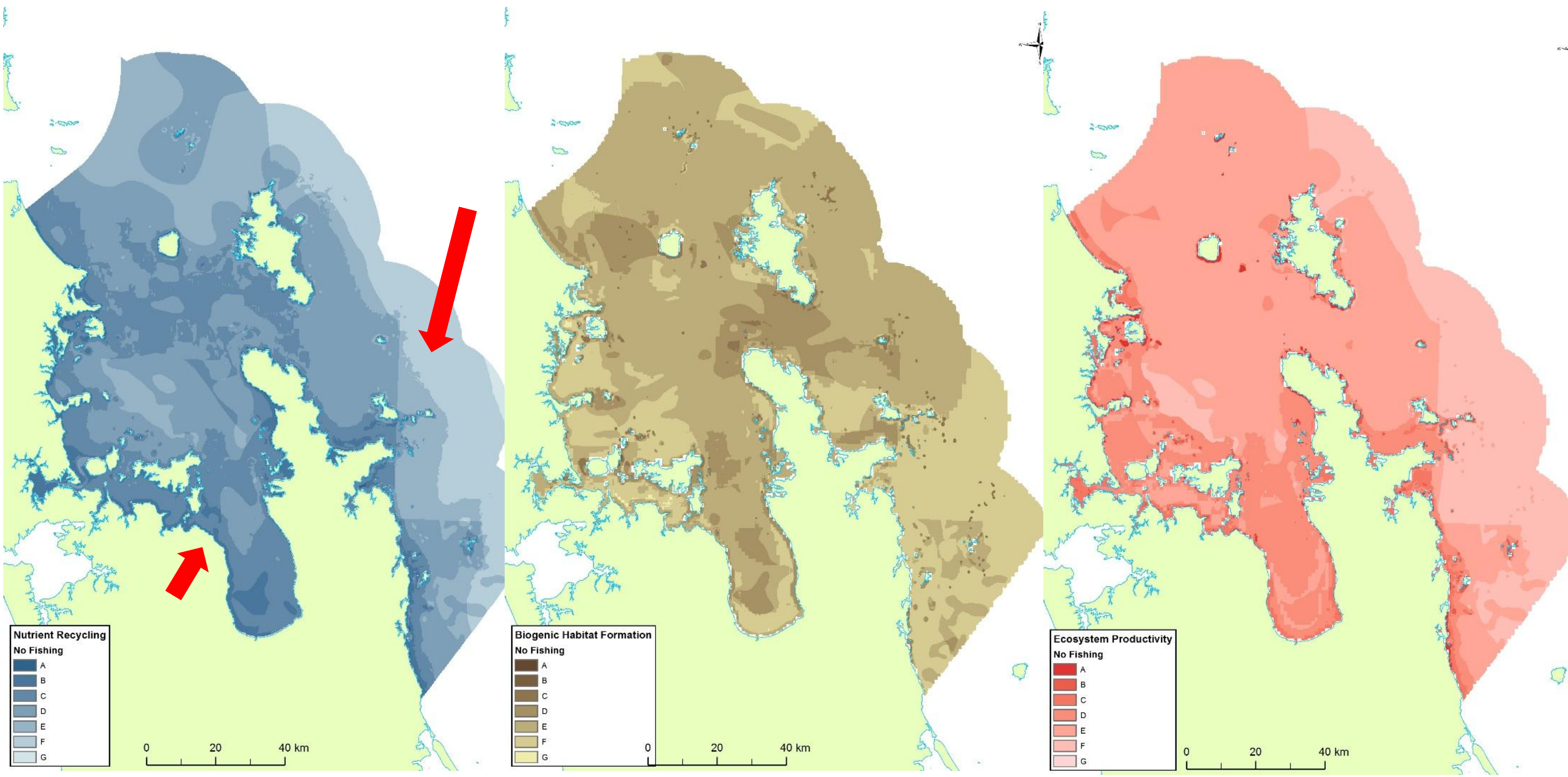
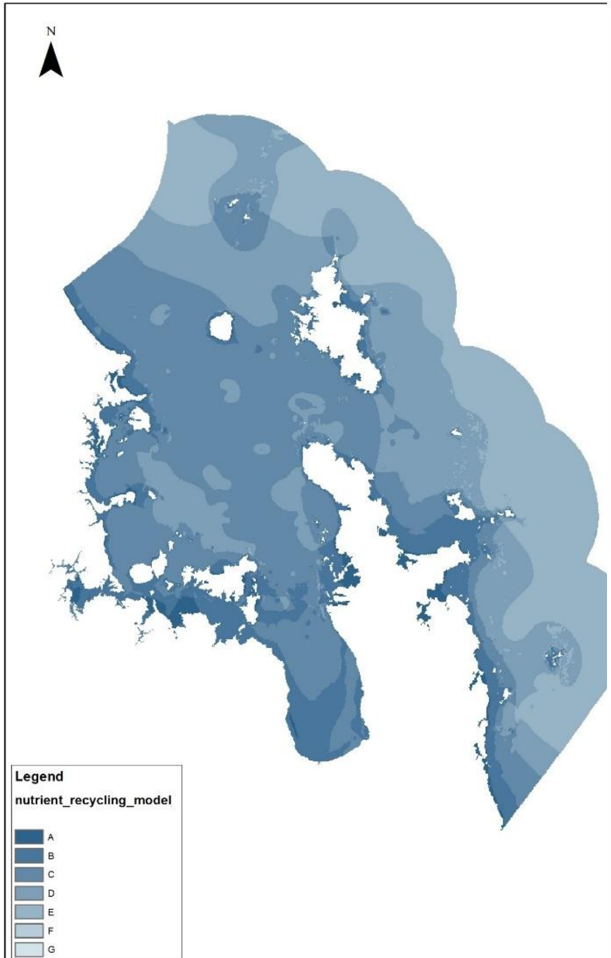


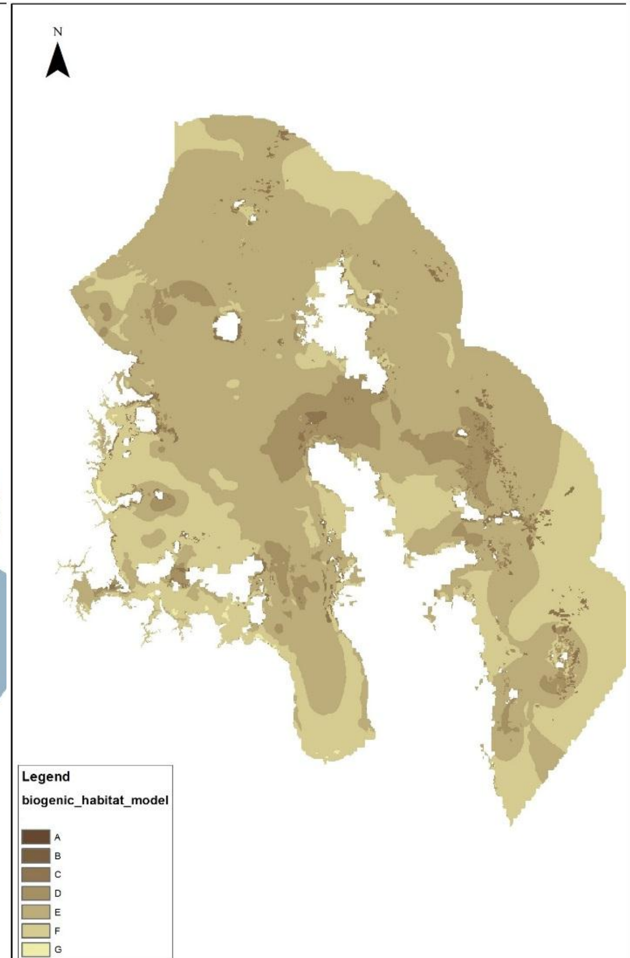
Table 3.
Scoring allocation for Principle 1 associated with changes in depth.

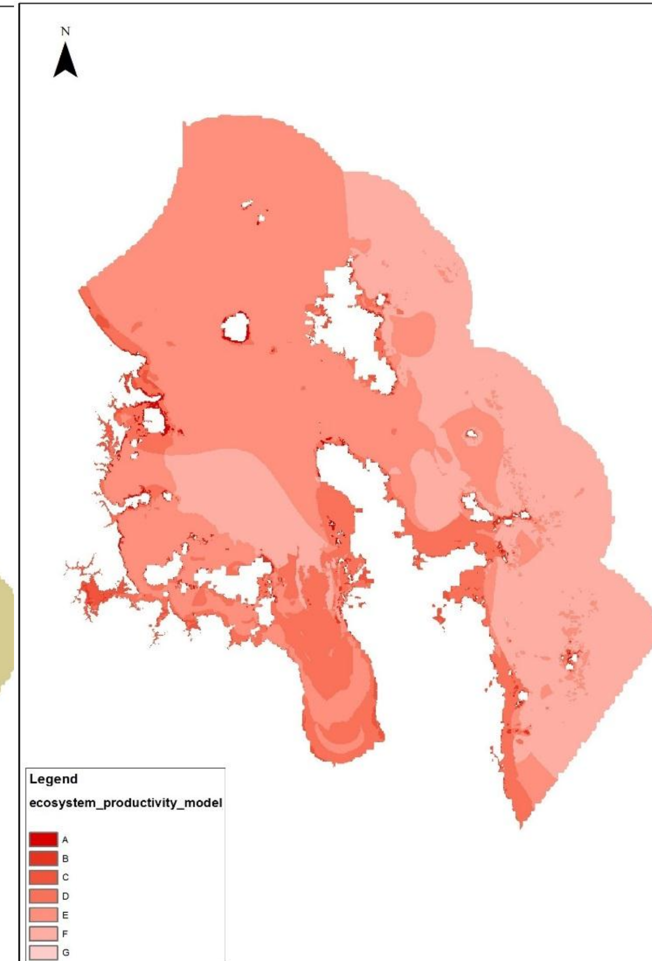
Depth range	Benthic Production from Cahoon (1999)	Normalised Score
(m)	(gC m^{-2} yr^{-1}) (+/-)	(Ratio to max score, X:111 gC m^{-2} yr^{-1})
Intertidal	111 +/- 99	1.00
0-5	87 +/- 90	0.78
5-20	62 +/- 116	0.56
20-35	54 +/- 29	0.48
>35	0	0.00



Townsend et al. (2014) Overcoming the challenges of data scarcity in mapping marine ecosystem service potential, *Ecosystem Services*







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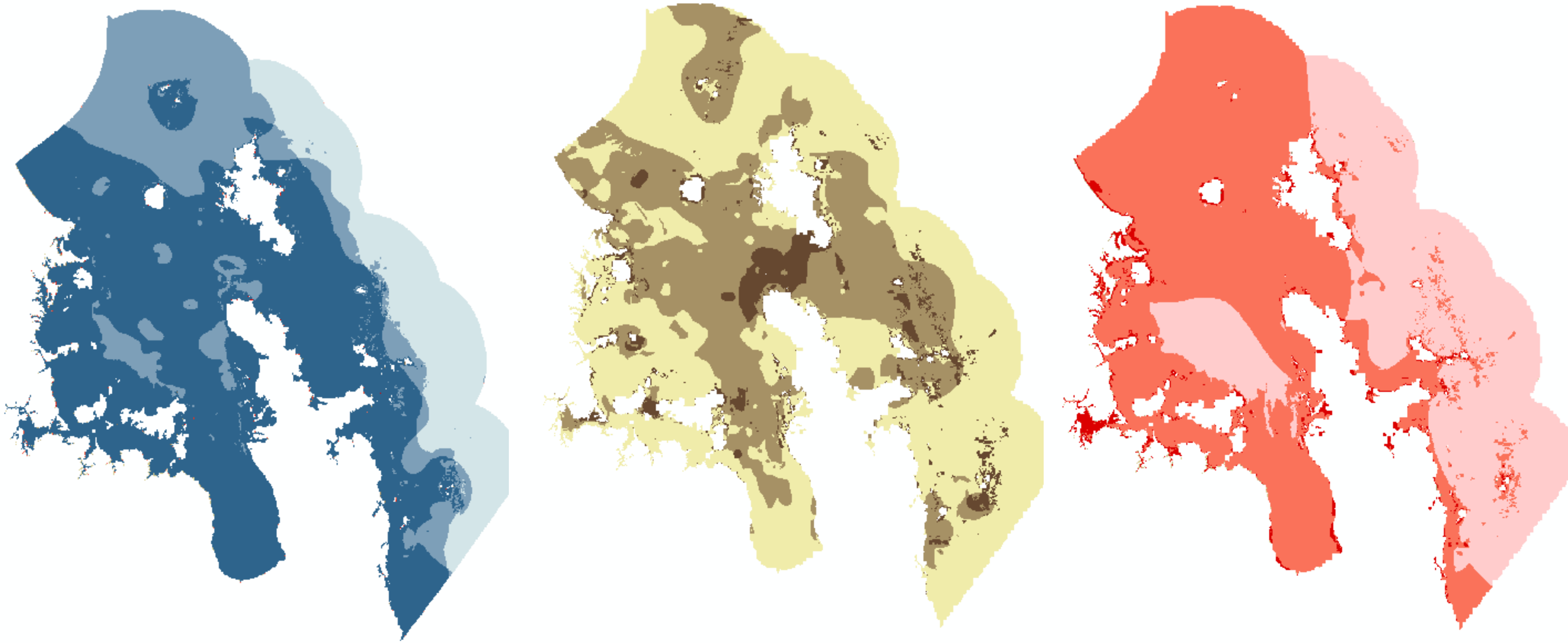


Townsend et al. (2014) Overcoming the challenges of data scarcity in mapping marine ecosystem service potential, *Ecosystem Services*

"*essentially, **all models are wrong**, but some are useful*"

George E. P. Box

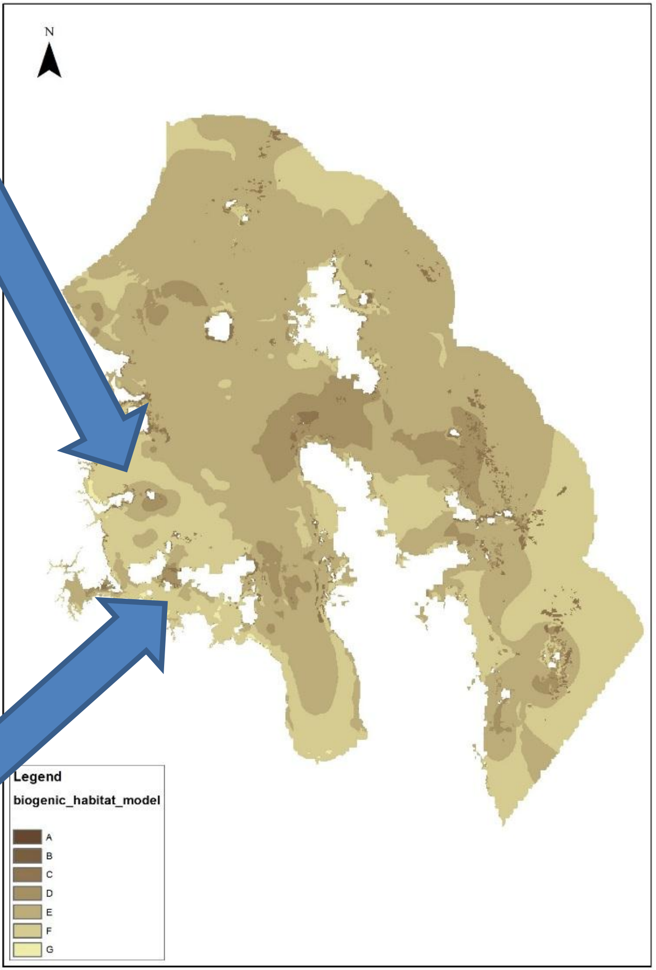
Validation procedures are essential

- Phase 1, expert review

- Phase 2 statistical analysis
- Using data independent of the map construction to test the maps
- However, as ES are 'multi-dimensional' concepts actually finding data suitable for testing them is also a challenge and most areas are data scarce
- BUT! We can use Auckland Council Tier II/III Monitoring data to test two of the maps (habitat and nutrient recycling).

Chiaroni, L.; Hewitt, J.E.; Hancock, N. (2008). Benthic Marine Habitats and Communities of Kawau Bay. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report 2008/006.

- Use data from 117 sites across Kawau Bay and the Tamaki Strait
- At each site (>25 m^2) video footage used to characterise habitats into broad categories of dominant epifauna/flora or the indication of infauna.
- This empirical habitat data was paired with its corresponding ES map score for the site-cell location and used in discriminant analysis



Chiaroni, L.; Hewitt, J.E.; Hailes, S.F. (2010). Tamaki Strait: Marine benthic habitats, ecological values and threats. Prepared by NIWA for Auckland Regional Council. *Auckland Regional Council Technical Report 2010/038*

Table 3
Results from the biogenic habitat map, showing the Discriminant Analysis (Exact and One-off) separation based on habitat types, Overall ANOSIM significance for the differences between map groups and SIMPER indicating the influential habitat categories.

Map group	DA classification success (Exact)	DA classification success (One-off)	ANOSIM Pairwise	SIMPER (influential habitat types for map grouping)
Biogenic habitat provision			$R=0.058$ $P=0.001$	
1	83	90	A	Bioturbators
2	54	90	B	Bioturbators Infaunal dominated
3	12	73	B	Bioturbators Infaunal dominated Low density *Atrina*
4	67	83	C	High current community Sponge and scallops
5	100	100	C	*Ecklonia* (kelp)

Discriminant Analysis

- The range of maps scores divided into 5 equal categories
- Discriminant analysis used to determine the degree to which the empirical habitat data could successfully classify the 5 categories
- SIMPER to determine which habitat elements were most indicative of the map groups
- Analysis of Similarities (ANOSIM) to determine whether the map score groups contained significantly different habitat elements overall

Table 4
Results from the nutrient recycling map, showing the Discriminant Analysis (Exact and One-off) separation based on habitat types, Overall ANOSIM significance for the differences between map groups and SIMPER indicating the influential habitat categories.

Map Groups	DA classification success (Exact)	DA classification success (One-off)	ANOSIM Pairwise	SIMPER (influential habitat types for map grouping)
Nutrient recycling			$R=0.069$ $P=0.001$	
1	50	50	A	*
2	36	84	B	Sponge and scallops
3	66	86	B and C	Bioturbators
4	60	90	C and D	Infaunal dominated
5	50	62	C and E	Low density *Atrina*

* Each habitat associated with Group 1 map scores did not occur more than once, invalidating SIMPER comparison.

Discriminant Analysis

- The range of maps scores divided into 5 equal categories
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- SIMPER to determine which habitat elements were most indicative of the map groups
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Uses of the Maps

- Broad scale patterns
- Educational (places, processes, diversity of benefits)
- Powerful communication tools
- Starting guide

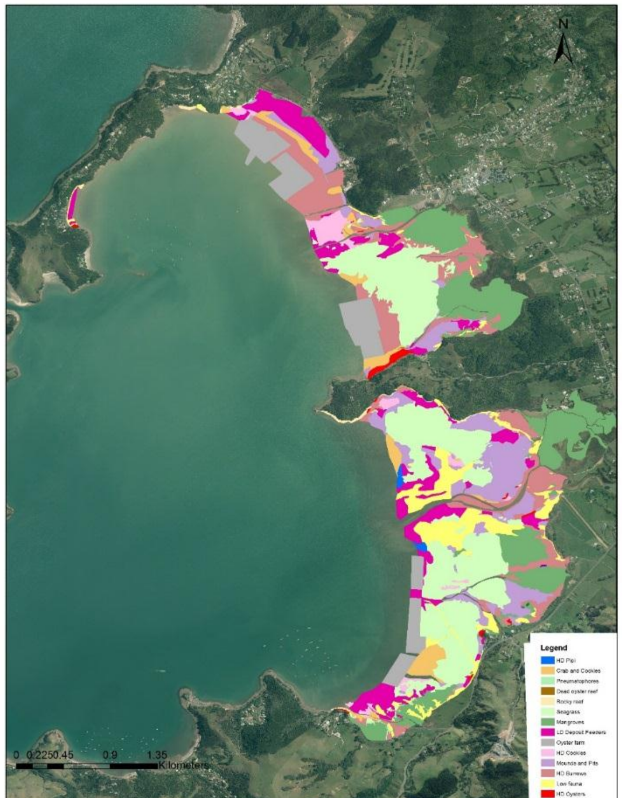
- Cannot replace detailed, empirical driven assessments i.e. a specific question in a specific place (RMA)

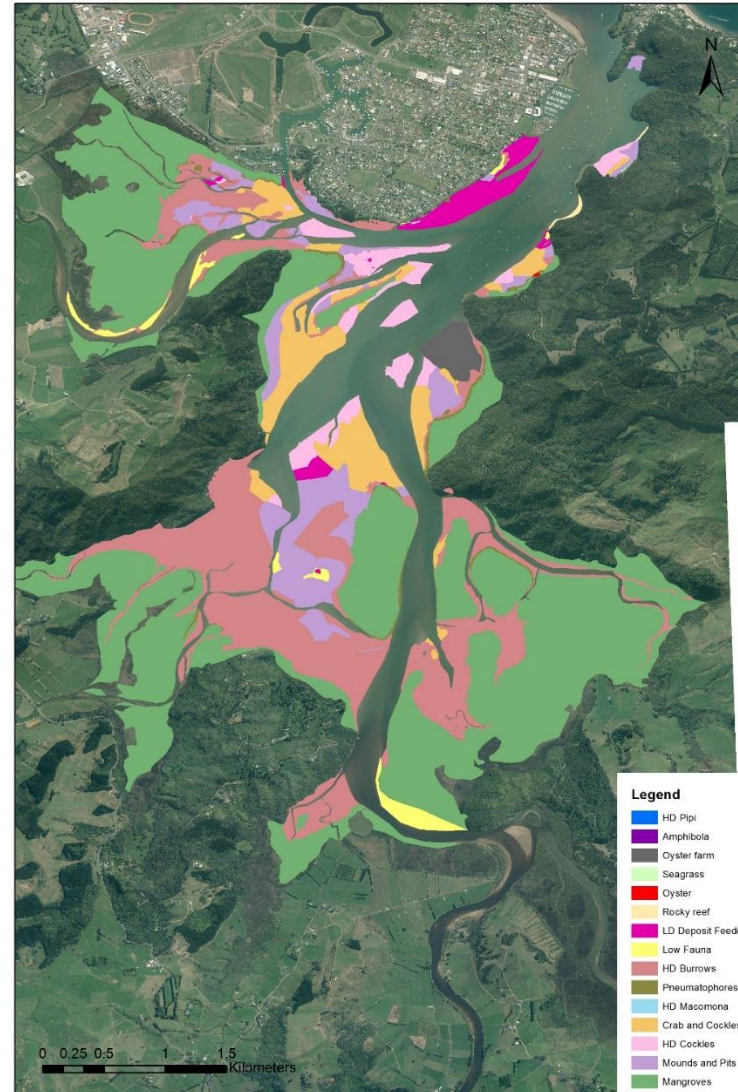
Future Challenges

- We’ve looked at 3 services, but there are many other that we should be considering, that we should be communicating to the public and factoring into decision making.
- Climate regulation, carbon sequestration, detoxification of pollutant, shoreline protection etc. We cant stop now!
- We can apply the techniques we have been developing to new areas, to further test, validate and refine them.
- Everything we’ve achieved is underpinned by ecological understanding (from research) and empirical data (Auckland Council monitoring) has been vital in the assessment. The continuation of both of these is vital for plugging knowledge and data gaps.

Filling Knowledge gaps

Rapid Habitat Assessments





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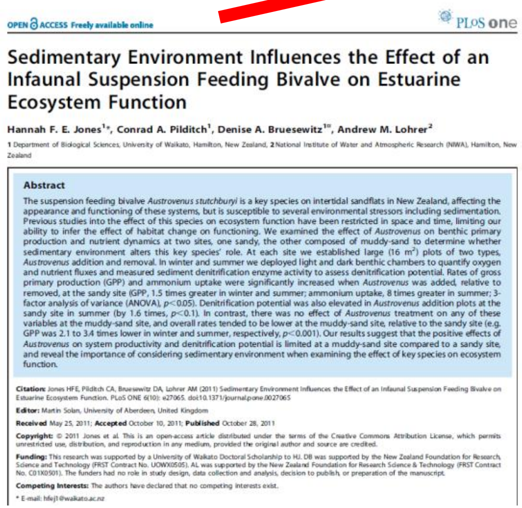
A Matrix approach

- Following Potts et al. (2014) *Marine Policy*
- Developed in the UK for assessing MPAs for ES
- ~80 habitats, varying levels (broad categories to more specific classes of habitat)
- Inventory of useful ES information

	Habitat & supporting services				Regulating services				Regulating services		Provisioning services			Cultural services	
Components	Primary production	Nutrient regeneration	Biogenic habitat provision	Formation of sediments	Regulation by key habitat components	Carbon sequestration & storage	Sediment retention	Gas balance	Bioremediation of contaminants	Storm protection	Food	Raw materials	Biochemical/medicinal resources	Leisure & eco-tourism	Spiritual & cultural wellbeing
Black coral garden	1	1	3	[illegible]	2-2	1	1	1		1	1	1	2-2	3	1
Brachiopod bed	[illegible]	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bryozoan bed	1	1	3	1		3	1	1		1	1	1	2-2	1	1
Bull kelp (*Durvillaea*) forest	3	1	3	3		1	2-2	1	2-2	1	1	3	2-2	1	3
Cerianthid bed	1	1	2-2	1	1	1	1	1	2-2	1	1	1	2-2	1	1
Cockle bed	3	3	3	1	3	1	1	1	2-1	1	2-1	1	[illegible]	[illegible]	[illegible]
Coralline paint	2-2	1	3	3	2-1	[illegible]	[illegible]	1	1	1	1	1	2-2	1	1
Coralline turfing algae	2-2	1	3	3		3	1	1	1	1	1	1	2-1	1	1
Deep/cold coral garden	2-2	1	3	3		1	1	1	1	1	1	1	2-2	3	1
Ecklonia forest	2-1	1	2-2		2-2	2-2	1	2-2	3	1	2-1	1	3	[illegible]	
Erect soft sediment inverts	[illegible]	[illegible]	2-1	1		1	1	1		1	1	1	1		
Mangrove forest	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1		1	1

	Habitat & supporting services				Regulating services						Provisioning services			Cultural services	
	Primary production	Nutrient regeneration	Biogenic habitat provision	Formation of sediments	Regulation by key habitat components	Carbon sequestration & storage	Sediment retention	Gas balance	Bioremediation of contaminants	Storm protection	Food	Raw materials	Biochemical/medicinal resources	Leisure & eco-tourism	Spiritual & cultural wellbeing
Cockle bed	3	3	3	1	[illegible]	1	1	1	2-1	1	2-1	1		3	2-1



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Sedimentary Environment Influences the Effect of an Infaunal Suspension Feeding Bivalve on Estuarine Ecosystem Function

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Abstract

The suspension feeding bivalve *Austrovenus stutchburyi* is a key species on intertidal sandflats in New Zealand, affecting the appearance and functioning of these systems, but is susceptible to several environmental stressors including sedimentation. Previous studies into the effect of this species on ecosystem function have been restricted in space and time, limiting our ability to infer the effect of habitat change on functioning. We examined the effect of *Austrovenus* on benthic primary production and nutrient dynamics at two sites, one sandy, the other composed of muddy-sand to determine whether sedimentary environment alters this key species' role. At each site we established large (16 m^2) plots of two types, *Austrovenus* addition and removal. In winter and summer we deployed light and dark benthic chambers to quantify oxygen and nutrient fluxes and measured sediment denitrification enzyme activity to assess denitrification potential. Rates of gross primary production (GPP) and ammonium uptake were significantly increased when *Austrovenus* was added, relative to removed, at the sandy site (GPP, 1.5 times greater in winter and summer; ammonium uptake, 8 times greater in summer; 3-factor analysis of variance (ANOVA), $p<0.05$). Denitrification potential was also elevated in *Austrovenus* addition plots at the sandy site in summer (by 1.6 times, $p<0.1$). In contrast, there was no effect of *Austrovenus* treatment on any of these variables at the muddy-sand site, and overall rates tended to be lower at the muddy-sand site, relative to the sandy site (e.g. GPP was 2.1 to 3.4 times lower in winter and summer, respectively, $p<0.001$). Our results suggest that the positive effects of *Austrovenus* on system productivity and denitrification potential is limited at a muddy-sand site compared to a sandy site, and reveal the importance of considering sedimentary environment when examining the effect of key species on ecosystem function.

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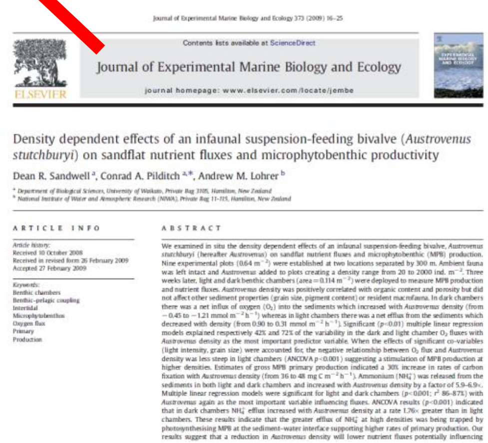

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Density dependent effects of an infaunal suspension-feeding bivalve (*Austrovenus stutchburyi*) on sandflat nutrient fluxes and microphytobenthic productivity

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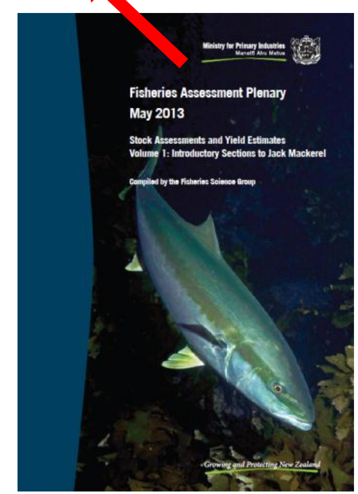
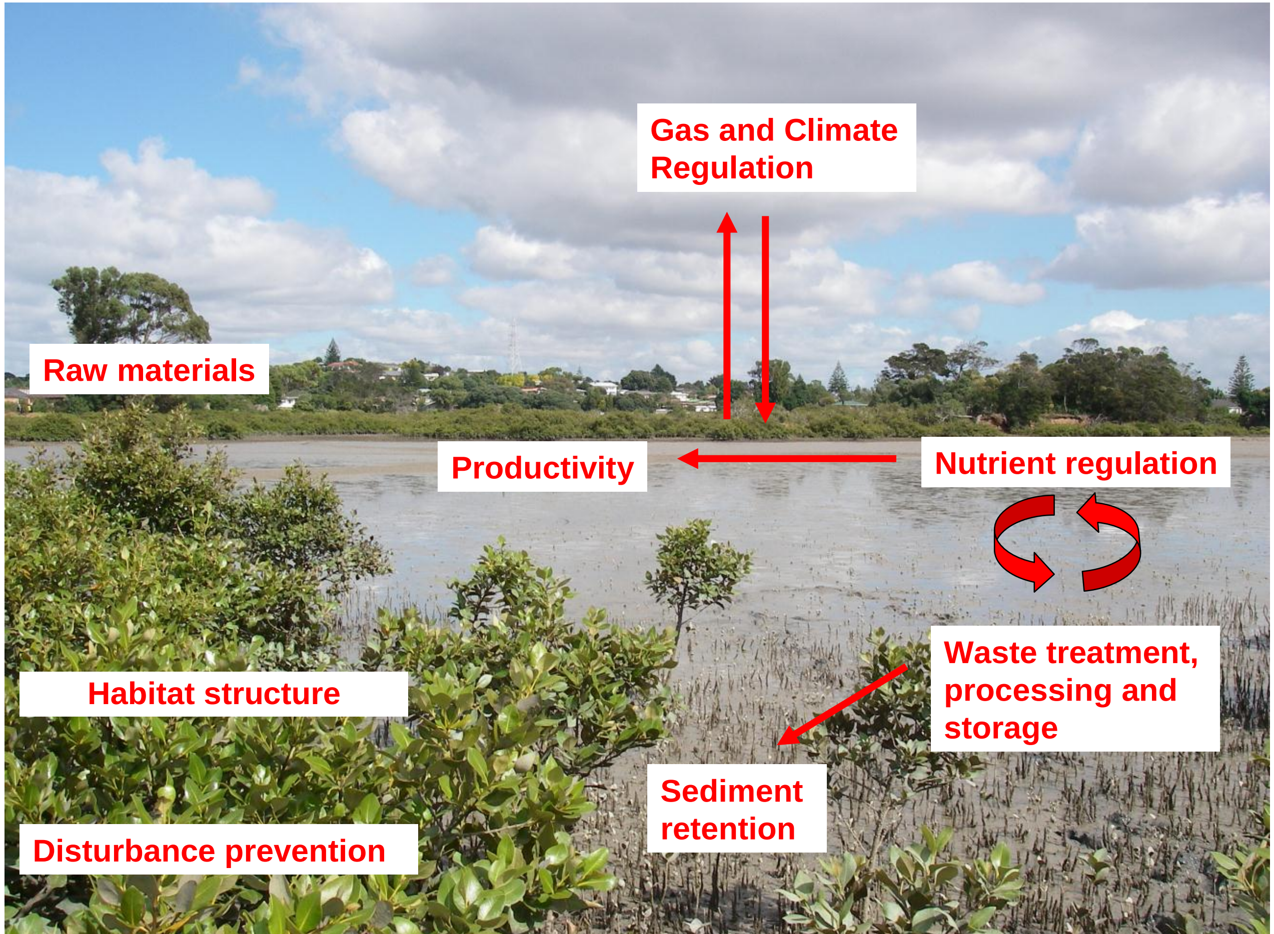
ABSTRACT

We examined in situ the density dependent effects of an infaunal suspension-feeding bivalve, *Austrovenus stutchburyi* (hereafter *Austrovenus*) on sandflat nutrient fluxes and microphytobenthic (MPB) production. Nine experimental plots (0.64 m^{-2}) were established at two locations separated by 300 m. Ambient fauna was left intact and *Austrovenus* added to plots creating a density range from 20 to 2000 ind. m^{-2}. Three weeks later, light and dark benthic chambers (area = 0.114 m^{-2}) were deployed to measure MPB production and nutrient fluxes. *Austrovenus* density was positively correlated with organic content and porosity but did not affect other sediment properties (grain size, pigment content) or resident macrofauna. In dark chambers there was a net influx of oxygen (O_2) into the sediments which increased with *Austrovenus* density (from −0.45 to −1.21 mmol m^{-2} h^{-1}) whereas in light chambers there was a net efflux from the sediments which decreased with density (from 0.90 to 0.31 mmol m^{-2} h^{-1}). Significant ($p<0.01$) multiple linear regression models explained respectively 42% and 72% of the variability in the dark and light chamber O_2 fluxes with *Austrovenus* density as the most important predictor variable. When the effects of significant co-variables (light intensity, grain size) were accounted for, the negative relationship between O_2 flux and *Austrovenus* density was less steep in light chambers (ANCOVA $p<0.001$) suggesting a stimulation of MPB production at higher densities. Estimates of gross MPB primary production indicated a 30% increase in rates of carbon fixation with *Austrovenus* density (from 36 to 48 mg C m^{-2} h^{-1}). Ammonium (NH_4^+) was released from the sediments in both light and dark chambers and increased with *Austrovenus* density by a factor of 5.9–6.9×. Multiple linear regression models were significant for light and dark chambers ($p<0.001$; r^2 86–87%) with *Austrovenus* again as the most important variable influencing fluxes. ANCOVA results ($p<0.001$) indicated that in dark chambers NH_4^+ efflux increased with *Austrovenus* density at a rate 1.76× greater than in light chambers. These results indicate that the greater efflux of NH_4^+ at high densities was being trapped by photosynthesising MPB at the sediment–water interface supporting higher rates of primary production. Our results suggest that a reduction in *Austrovenus* density will lower nutrient fluxes potentially influencing




Gas and Climate Regulation
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