Multi-scale data on intertidal macrobenthic biodiversity and environmental features in three New Zealand harbours

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Abstract. Understanding how the plants and animals that live in the seafloor vary in their spatial patterns of diversity and abundance is fundamental to gaining insight in the role of biodiversity in maintaining ecosystem functioning in coastal ecosystems, as well as advancing the modelling of species distributions under realistic assumptions. Yet, it is virtually unknown how the relationships between abundance patterns and different biotic and environmental processes change depending on spatial scales, which is mainly due to a lack of data. Within the project Spatial Organization of Species Distributions: Hierarchical and Scale-Dependent Patterns and Processes in Coastal Seascapes at the National Institute for Water and Atmospheric Research (NIWA) in New Zealand we collected multi-scale and high-resolution data on macrobenthic biodiversity. We found 146 species, dominated by~~i.e.~~ bivalves, polychaetes and crustaceans (> 500µm) that live hidden in marine sandflats, and collected point measurements of important environmental variables (sediment grain-size distributions, chlorophyll *a* concentration, organic content, and visible sandflat parameters) in three large intertidal Harbours (Kaipara, Tauranga and Manukau). In each Harbour we sampled 400 points for macrobenthic community composition and abundances, as well as the full set of environmental variables. Using an elaborate sampling design, we were able to cover scales from 30 centimetres to a maximal extent of 1 km. All data and extensive metadata are available from the data publisher PANGAEA via the persistent identifier https://doi.org/10.1594/PANGAEA.903448 (Kraan et al., 2019).

1 Introduction

Understanding how the plants and animals that live in the seafloor vary in their spatial patterns of diversity, biomass, and abundance is fundamental to gaining insight in the role of biodiversity in maintaining ecosystem functioning in coastal ecosystems, as well as advancing the modelling of species distributions under realistic assumptions. Yet, it is virtually unknown how the relationships between abundance patterns and different biotic and environmental processes change depending on spatial scales (e.g. Lohrer et al., 2015; Kraan et al., 2015).

Most broad-scale research on mapping species distributions ignores spatial patterns (Kraan et al., 2010), scale-dependent variability (Kraan et al., 2015), and biotic interactions (Dormann et al., 2018), rendering these topics a main frontier in ecology (Araújo and Luoto, 2007). Moreover, twisting these often-separate lines of research together requires the availability of data to support such research. At present, data that allow bridging the gap between small-scale and landscape-scale ecological research, enabling full inference of pattern and process from the individual to the landscape scale across environmental gradients are scarce.

The research project Spatial Organization of Species Distributions: Hierarchical and Scale-Dependent Patterns and Processes in Coastal Seascapes at the National Institute for Water and Atmospheric Research (NIWA) in New Zealand aimed to asses scale-dependent variation in species distributions across environmental gradients in estuarine communities, dominated by ~~i.e.~~ bivalves, polychaetes and crustaceans that live hidden in marine sandflats. By employing an elaborate sampling scheme, we covered a large number of different spatial scales with enough replicate samples within each scale to allow explicit spatial analysis and warrant statistical power during analysis (see Kraan et al., 2015; Greenfield et al., 2016). This efficient ~~time effective~~ sampling design allowed us to map intertidal macrobenthic fauna from the scale of a few centimetres to a maximal extent of 1 km. We focussed on macrobenthos (organisms > 500µm), due to their role in ecosystem functioning (e.g. Thrush et al., 2017), their ability to serve as sentinels for change (e.g. Hewitt and Thrush, 2009; Kraan et al. 2009), and the relative ease of collecting samples (Fig. 1). To increase the generality of our field study, we performed this sampling along an environmental gradient from the mangroves to ~~the~~ the lower end

of the intertidal zone ~~mid-tidal level~~ in three large intertidal harbours (Manukau, Kaipara and Tauranga Harbours in the North Island, New Zealand).

Given the scarcity of large-scale high-resolution biodiversity data, identified to the lowest taxonomic level possible, and associated point-measurements of environmental features, such as sediment grain-size parameters, chlorophyll *a* concentration, organic content, and visible sandflats parameters, such as the coverage of seagrass or shellhash (broken shell fragments), we here publish these one-of-a-kind data (see Kraan et al., 2019) so that they can serve as key-data to advance and support future multi-scale biodiversity studies.

2 Material and methods

2.1 Fieldwork

Sampling macrobenthic fauna and environmental variables was conducted during the austral summer 2012 in Kaipara, Manukau, and Tauranga harbours, North Island, New Zealand (Table 1). Physical descriptions of each of these areas can be sourced from a large number of publications by Simon F. Thush and co-workers (e.g. Thrush et al., 2003). In each Harbour we took 400 cores (13 cm diam., 20 cm deep) on a pre-determined grid (four 1000m transects, spaced at 100m) on foot during low tide (n = 3*400 [1200 in total]), thereby covering the area from the high- to low-water mark (Fig. 1 for an illustration). Sampling points along transects were spaced at distances of 30 cm, 1 m, 5 m, 10 m, 30 m, 50 m, 100 m, 500 m and 1000 m (see Fig. 1 in Kraan et al., 2015), located by using measuring tape and handheld GPS. Given the close proximity of sampling locations we provide sampling coordinates in NZTM (New Zealand Transverse Mercator; Geodetic CRS: NZGD2000; Unit = m) at the data publisher PANGAEA (Kraan et al., 2019). Cores were sieved in the field (500µm mesh) and the residue preserved with 70% isopropyl alcohol.

Prior to destructive sampling, we took a photograph of 50cm x 50cm at each sampling point (n = 960) to assess coverage of seagrass (*Zostera mulleri*), bare sand, and shell-hash. In addition, at each point (n = 960), we pooled three surface sediment cores (2 cm diam., 2 cm deep) to do sediment grain-

size analyses (median grain-size and sediment fractions), chlorophyll *a* measurements, and determine the organic content of the sediment (Table 1). These samples were stored in the dark on ice immediately after collecting. Note that at the smallest spatial scale, i.e. 30 cm, we took 3 adjoining benthic cores, but we limited ourselves to taking one photograph and one sediment sample to represent the environmental features for these three locations. This was done to economically manage our time in the field and our financial budget for processing samples, leading to 320 photographs and 320 sediment samples per Harbour. See Kraan et al. (2015, 2019) or Greenfield et al. (2016) for details.

2.2 Macrobenthic data

In the laboratory, Rose Bengal (2%) stained taxa were identified to the lowest practical taxonomic resolution and their abundance assessed. In total we identified 146 species, mostly bivalves, polychaetes and crustaceans, encompassing 73813 individuals (Table 1; Kraan et al., 2019). For bivalves, the longest shell axis was also measured, allowing adults and juveniles to be distinguished, because habitat preferences can differ between adults and juveniles (Kraan et al., 2010, 2013). Size-classes were categorized as: < 1mm, 1-5mm, 5-10mm, 10-15mm, 15-20mm, 20-25mm, 25-30mm, 30-35mm, 35-40mm and > 40mm. Each sample was sorted and its taxa identified by Casper Kraan, after which Barry L. Greenfield verified species identifications on each sample~~. Samples t4.35.5, k3.24.3 and k4.35.5 were lost during processing~~ (Kraan et al., 2019).

2.3. Chlorophyll a measurements

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Sediment samples were freeze-dried upon arrival in the laboratory. Prior to freeze-drying, seagrass and bivalves were removed. For measuring, 0.1g~~r~~. sediment was weighed and topped-up with 90% acetone buffer and centrifuged for 10 min. at 3300rpm. Chlorophyll a and pheophytin concentrations (n = 960) were determined using a fluorometer, using standard methods (see Kraan et al., 2015). First sample was measured May 10th 2012 and the last sample was measures June 28th 2012, avoiding degradation of samples over time (see Kraan et al., 2019).

2.4 Sediment grain-size distributions

To determine sediment median grain-size and sediment fractions (silt < 63µm, very fine 63–125µm, fine 125–250µm, medium 250–500µm, and coarse > 500µm), sediment grain-sizes were measured (n = 960), following standard methods for using a Malvern Mastersizer 2000 with a particle range of 0.02-2000 µm (see Kraan et al., 2015). This involved digesting about a teaspoon of sediment by adding 10% hydrogen-peroxide to remove organic content from the sediment, leave to digest for 7 days, stirring every couple of days.

2.5 Organic content of the sediment

Organic content (n = 960) was determined after burning a tea-spoon of freeze-dried sediment for 5.5 hrs in a furnace at 560 ^{0}C, i.e. the loss-on-ignition approach.

2.5 Visible sandflat parameters

Coverage of seagrass, shellhash and bare sand within each photograph (n = 960) was estimated based on 75 random points within a photograph using the software CPCe (Kohler and Gill, 2006). ~~For the following photographs estimating coverage failed due to too much water on the sampling plot: m.1.10.9, m.4.39.7, k1.4.2, k2.19.4, k2.19.5, k2.19.6, k2.19.7, k2.19.8, k2.19.9, k2.19.10, k2.20.1, k2.20.2, k2.20.3, k2.20.4, k2.20.5, k2.20.6, k2.20.7, k2.20.8, k2.20.9, k2.20.10, k4.31.1, k4.31.2, k4.31.3, k4.37.3, k4.38.10, and t1.8.5~~ (see Kraan et al., 2019).

3 Data availability

All data collected during this project, including extensive meta-data, are available from the data publisher PANGAEA (Kraan et al., 2019). For convenience, all data are grouped into a parent dataset (https://doi.org/10.1594/PANGAEA.903448, Kraan et al., 2019).

A number of scientific studies have used these data. For example, Kraan et al. (2015) described the cross-scale variation in biodiversity-environment links using Moran's Eigenvector mapping (MEM). Greenfield et al. (2016) focussed on the spatial distribution of functional groups to gain insight in the scale-dependency of resilience. Thrush et al. (2017) and Douglas et al. (2017) based their experimental set-up on the spatial distribution of functional hot- and cold-spots to experimentally study the impact of nutrient-loading on ecosystem functioning and resilience.

Competing interests. The authors declare no conflict of interest.

Author contribution. CK and SFT designed the study, and CK and BLG carried them out. CK prepared this manuscript with contributions and final approval of all authors.

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Table 1. Regional summary of collected data and their mean values to give an impression of their physical appearance and the macrobenthic benthic biodiversity they harbour.

	Region		
Fieldwork 2012	**Manukau**	**Tauranga**	**Kaipara**
Sampling	4-5 May	23-25 April	18-19 April
Sediment samples (*n*)	320	320	320
Organic content samples (*n*)	320	320	320
Chlorophyll a samples (*n*)	320	320	320
Visible sandflat parameters (*n* photos)	318	319	297
Lost photos due to water coverage	m.1.10.9, m.4.39.7	k1.4.2, k2.19.4, k2.19.5, k2.19.6, k2.19.7, k2.19.8, k2.19.9, k2.19.10, k2.20.1, k2.20.2, k2.20.3, k2.20.4, k2.20.5, k2.20.6, k2.20.7, k2.20.8, k2.20.9, k2.20.10, k4.31.1, k4.31.2, k4.31.3, k4.37.3, k4.38.10	t1.8.5
Macrobenthos samples (*n*)	400	399	398
Lost m~~M~~acrobenthos samples ~~(*n*)~~	~~400~~	T4.35.5~~399~~	K3.24.3, k4.35.5~~398~~
Results of laboratory work 2012-2014			
Species identified (*n*)	109	81	114
Individuals (*n*)	26573	25394	21846
Median grain-size (µm)	166	197	213
Silt (% <63µm)	14	5	1
Very fine sediments (% 63–125µm)	17	17	6
Fine sediments (% 125–250µm)	48	44	6
Medium sediments (% 250–500µm)	18	28	32
Coarse sediments (% > 500µm)	3	6	0.4

Organic content (%)	2	2	0.8
Chlorophyll a (mg/g)	23	11	5
Bare sand cover (%)	79	73	84
Shellhash cover (%)	16	3	2
Seagrass cover (%)	5	23	13

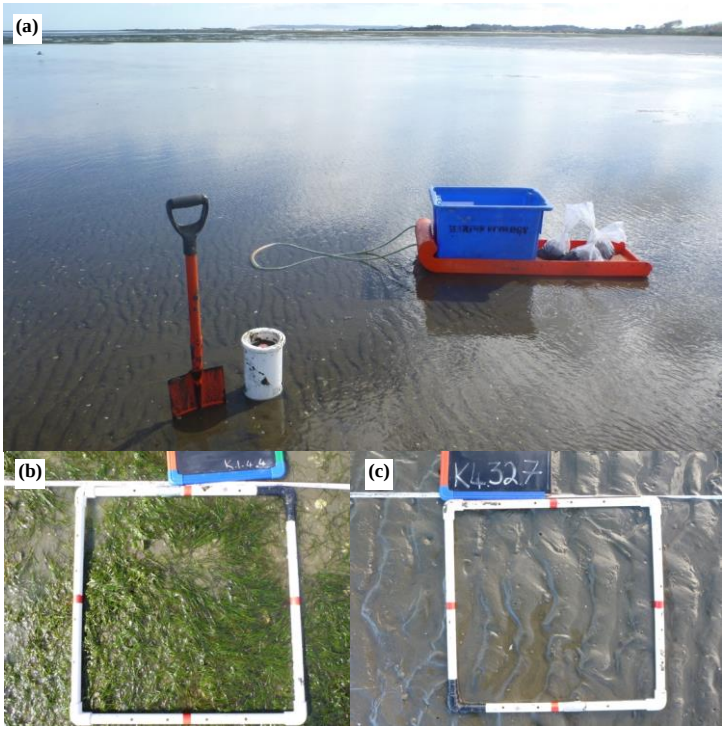

Figure 1. (a) Example of a sampling area during low-tide and the low-tech gear used for sampling. Examples of **(b)** a high-density seagrass sampling point and **(c)** of a sandy sampling point (photos: Casper Kraan).