TASMAN ENVIRONMENTAL TRUST

Core & Restore Project Pilot:

Overview, Results & Next steps

20 November 2023

Prepared by Lauren Walker Ltd

for Tasman Environmental Trust and key project partners & supporters:

Cawthron Institute, Beca, Ngāti Apa ki te Rā Tō, Nelson City Council, Manawhenua ki Mohua, the Department of Conservation and HealthPost Nature Trust

Purpose

This document has been prepared by Lauren Walker Ltd[1] for the benefit of Tasman Environmental Trust and its key project partners and supporters in the Core & Restore Blue Carbon Project Pilot. The purpose of this report is to share the blue carbon mahi we have undertaken collaboratively from 2021-2023.

Recommended citation

Walker, L. 2023. Core & Restore Project Pilot: Overview, Results and Next Steps. Nelson: Lauren Walker Ltd. Prepared for Tasman Environmental Trust.

Limitation

While every effort has been made to ensure that the document is accurate, Lauren Walker Ltd accepts no responsibility or liability whatsoever for any action taken as a result of reading this document, or reliance placed on it, or for any error, inadequacy, deficiency, flaw or omission in the document.

Copyright ©

[1] www.laurenwalker.co.nz

Preface

The Core and Restore Project has been a challenging and rewarding project for Tasman Environmental Trust (TET) and is one that would have ground to a halt many times had it not been for the perseverance and vision of Lauren Walker. Lauren has brought a unique blend of intellectual drive and collaborative energy to this project which has resulted in two valuable reports: Core & Restore Blue Carbon Project Pilot and Core & Restore Field Protocol.

TET would also like to thank the wider team that has contributed to the project. The momentum created by the project is now being carried forward by a wider group of participants in a national Community of Practice facilitated by Helen Kettles of the Department of Conservation in Wellington.

A National Coastal Wetland Blue Carbon Strategy is being developed and key advisers from a variety of government, council, iwi, community and science organisations are working together to achieve Blue Carbon and associated biodiversity gains. TET is pleased to contribute to the growth of knowledge and collaborative effort with the Core and Restore Project and looks forward to working together to protect and restore Blue Carbon habitats in Te Tauihu.

Gillian Bishop
Chair

Acknowledgements

Tasman Environmental Trust (TET) gratefully acknowledges the significant contributions and commitment of its key partners and supporters in the Core & Restore Blue Carbon Project Pilot: Cawthron Institute (Cawthron), Beca, Ngāti Apa ki te Rā Tō, Nelson City Council (NCC), Manawhenua ki Mohua (MKM) and the Department of Conservation (DOC).

We especially thank the following individuals:

Gillian Bishop (QSM)	Project advocacy & governance (TET)
Lauren Walker	Project lead and key contributor (Lauren Walker Ltd)
Dr Anna Berthelsen	Technical lead and key contributor (Cawthron)
Dr Sean Waters	Technical advisor and key contributor (Cawthron)
Elaine Asquith	Technical advisor and key contributor (Cawthron)
Dan Chamberose	Technical advisor and key contributor (Beca)
Sam Flewitt	Technical advisor and key contributor (Independent, previously Beca)
Dr Jen Skilton	Technical advisor and key contributor (Ngāti Apa ki te Rā Tō)
Aaron Hemi	Cultural advisor (Ngāti Apa ki te Rā Tō)
Helen Kettles	Key advisor, project supporter and contributor (DOC)
Dr James Butler	Technical advisor and key contributor (Cawthron)
Vikki Ambrose	Tea Bag Experiment (NCC)
Dr Harry Allard	Tea Bag Experiment (NCC)
Shane Paratene	Cultural Monitor, NCC Tea Bag Experiment (Ngāti Kuia)
Ursula Passl	Manawhenua ki Mohua Liaison & Support
Makere Chapman	Project Kuia (MKM)
Syd Eru	Cultural Monitor and Field Assistant (MKM)
Raelene Mason	Cultural Monitor and Field Assistant (MKM)
Andrew Lamason	DOC Liaison & Support (Takaka)
Amanda Harvey	DOC Liaison and Practical Advisor (Onetahua)
Dr Chris Wheatley	HealthPost Nature Trust Liaison & Support
Graham & Belinda Postles	Landowners (Manuka Island)
Frank & Shelley Creighton	Landowner (Neimann Creek)
Shane Paratene	Cultural Monitor, NCC Teabag Experiment (Ngāti Kuia)

We thank the following individuals for their technical advice and input:

Trevor James	Habitat health, extent & restoration options (TDC)
George Daly	Saltmarsh restoration options (TDC)
Leigh Stevens	Habitat health, extent & restoration options (Salt Ecology)
Mike Crump	Laboratory analysis protocols (NIWA)
Dr Richard Bulmer	Coring techniques, lab analysis, data comparison (Tidal Research)

Dr Stracey Trevathan-Tackett	Various technical aspects (Deakin University)
Olya Albot	Sampling & lab analysis methods; sharing preliminary results (PhD Researcher)

We acknowledge the cultural significance of Waimeha Inlet and Onetahua Farewell Spit and are grateful for the support and kind wishes of Te Tauihu iwi for our pilot study.

We especially thank the following iwi:

- **Ngāti Apa ki te Rā Tō** : For being a key project partner from the outset, helping us navigate tikanga and cultural safety, blessing our mahi at our launch celebration, being part of our team in both Waimeha Inlet and Onetahua Farewell Spit, and blessing our mahi at our Core & Restore Hui in March 2023.
- **Manawhenua ki Mohua**: For supporting our Onetahua Farewell Spit fieldwork, welcoming our project team to Mohua with a pōwhiri, blessing our mahi with a beautiful karakia at dawn, providing cultural monitoring and field assistance, allowing us to share the Onetahua Farewell Spit blue carbon data, and being part of our Core & Restore Hui in March 2023.
- **Te Ātiawa**: For providing guidance and information to help us engage with Te Tauihu iwi early on and help us ensure the cultural safety of our Waimeha Inlet fieldwork, and for being part of our Core & Restore Hui in March 2023.
- **Ngāti Kuia:** For providing cultural monitoring for the NCC Tea Bag Experiment and being part of our launch celebration and our Core & Restore Hui in March 2023.

We thank the following individuals for their advice and support with media and communications:

Niki Morrell	Lead media and communications advisor (Bold Communications)
Kirsten Fitzsimmons	Key partner communications (Cawthron)
Sandrine Marrasse	Key partner communications (NCC)
Andrew Hobbs	Key partner communications (Beca)
Sam Thorn	Key partner communications (Ngāti Apa ki te Rā Tō)

Thanks also to the TET team for their project support:

Sky Davies	Project governance and funding
Marios Gavalas	Administrative support & help with events
Abby Boffa	Funding and accountability reporting
Kathryn Brownlee	Project accounting & financial reporting; help with events; blue carbon restoration (Battle for the Banded Rail).

The input into project development provided by Dr Fiona Ede, Dr Ed Challies (University of Canterbury), Jo Martin (NCC) and the Kidson family (Sally Kidson, Liz Gavin, Matthew Kidson and Katrina Kidson) is very much appreciated.

The funding support provided by TET, NCC, Pic's Peanut Butter, HealthPost Nature Trust, Kidson Investments Ltd, Live Ocean, and Nelson Tasman Climate Forum is greatly appreciated, as are the in-kind contributions provided by the key partners and project team members, Lauren Walker Ltd, Andy McDonald (photographer and videographer @NZAndy) and Nikki Morrell (Bold Communications).

Contents

This report 7
The backdrop to our mahi 10
Our blue carbon journey 12
Pilot study 14
Waimeha Inlet – saltmarsh coring 17
Onetahua Farewell Spit – seagrass core sampling 22
Tea bag experiment (NCC) 26
Results summary 28
Saltmarsh 28
Seagrass 28
Unvegetated areas 29
Depth of carbon storage 29
Influences of carbon stocks 29
Interpretation 30
NZ and overseas comparison 30
Insights from the pilot 33
Co-benefits of the pilot 36
Wider contribution 40
Next steps 40
References 42
APPENDIX A: Core & Restore Hui Programme (March 2023) 43
APPENDIX B: Next Steps 44

This report

This report is the culmination of a unique, rich, and diverse collaboration between a wide range of organisations and individuals from across Te Tauihu. Over a two-year period from mid-2021 we built new connections and came together with our unique skills and perspectives to design and carry out the Core & Restore Blue Carbon Project Pilot.

This document provides an overview of our mahi: a summary of the results and wider co-benefits, insights we gained, and possible next steps. It is part of a substantial package of information about the pilot (see table below).

Special thanks to Dr Anna Berthelsen (Cawthron), Leigh Stevens (Salt Ecology), Vikki Ambrose (Ministry of Primary Industries) and Dr Harry Allard (Nelson City Council) for helping refine various parts of this document.

General description	**Title / Links**
Core & Restore Case study in the National Emissions Reduction Plan	Aotearoa-New-Zealands-first-emissions-reduction-plan.pdf (environment.govt.nz)
A series of videos about the pilot produced by Andy MacDonald (nzandy.com)	Blue Carbon 'Core & Restore' videos | Tasman Environmental Trust (tet.org.nz)
A video about Core & Restore by HealthPost Nature Trust	Blue Carbon Project (Core & Restore) NZ – YouTube
A video about the NCC tea bag experiment by ArtAlchemy.Studio	Citizen science tea bag experiment Part 1 – YouTube
A series of media articles about the pilot project	Blue carbon project pivotal in efforts to help protect and restore estuaries, hui hears | Stuff.co.nz 'Blue carbon' stores measured in ground-breaking Nelson inlet study | Stuff.co.nz https://www.stuff.co.nz/environment/climate-news/128593257/blue-carbon-study-grows-along-with-national-recognition 'Blue carbon' sites could limit retreat from coast, groups say | Stuff.co.nz PressReader.com - Digital Newspaper & Magazine Subscriptions
A set of videos about the Core & Restore collaboration produced by Mission Zero for the Mission Insights Initiative	"core and restore" - Mission Zero

The Core & Restore Blue Carbon Project Field Protocol	Walker L, Berthlesen A, Chamberose D, Ambrose V, Skilton J, Waters S, Asquith E, Flewitt S, 2023. Core and Restore Project Field Protocol. November 2023. Prepared for Tasman Environmental Trust.
A detailed technical report outlining the findings of the pilot core sampling	Berthelsen A, Walker L, Skilton J, Chamberose D, Flewitt S, Waters S, Asquith E, Butler J, Kettles H. 2023. Sediment organic carbon stocks in coastal blue carbon habitats: pilot study for Te Tauihu. Nelson: Cawthron Institute. Cawthron Report 3867. Prepared for Tasman Environmental Trust.
A detailed technical report outlining the results of the NCC tea bag experiment	Zaiko A, Pearman J 2022. Bacterial assemblages associated with carbon sequestration potential in marine wetland sediments. Prepared for Nelson City Council. Cawthron Report No. 3845. 13 p. plus appendices.
A published academic article about blue carbon in New Zealand that draws on Core & Restore pilot data	Ross, F. W., Clark, D. E., Albot, O., Berthelsen, A., Bulmer, R., Crawshaw, J., & Macreadie, P. I. (2023). A preliminary estimate of the contribution of coastal blue carbon to climate change mitigation in New Zealand. New Zealand Journal of Marine and Freshwater Research, 1-11.

Other key outputs from the Core & Restore Project Pilot include:

- A project launch celebration with key stakeholders at Neimann Creek on the 29th November 2021.
- A presentation of the Onetahua seagrass results and return of the sediments to Manawhenua ki Mohua in Takaka in March 2023.
- The Core & Restore Hui held in Richmond on the 28th March 2023 to report the results of the pilot, measure the co-benefits, and brainstorm next steps with key stakeholders.[3]
- Input into the concept planning for the National Blue Carbon Hui hosted by DOC and The Nature Conservancy (TNC) in 2023; as well as participation in the hui and subsequent collaboration by a number of the Core & Restore Project team members.

[3] See Appendix A for the hui programme.

Nelson Mayor, Rachel Reese launching the Core & Restore Project, November 2021

Photo credit: Andrew McDonald

Core & Restore Hui, Richmond, March 2023

Photo credit: Nikki Morrell

The backdrop to our mahi

Climate action is urgent

The climate crisis is now confronting us on a daily basis. We can see extreme weather events and climate related disasters occurring around the world with alarming frequency affecting millions of people, impacting communities, businesses, markets, and economies. As a global community, we not only need to drastically and urgently reduce global emissions, we also need to find ways to suck carbon dioxide out of the atmosphere and lock it up so that we can begin to slow down the warming and stabilise the climate. Protecting and restoring natural carbon sinks is 'low hanging fruit' when it comes to climate action.

Coastal blue carbon habitats such as saltmarsh, seagrass and mangroves are among the world's most effective natural carbon stores. They store carbon in their roots, leaves, branches and stems, and in the soil[4] beneath them. The 'blue carbon' stored in the soils can stay locked up for very long time periods (centuries to millennia), as long as it isn't disturbed[5].

> *"Storage of carbon in these coastal blue carbon habitats is a compelling global natural climate solution that with restoration and protection could sequester an additional 841 Tg/CO2 per year by 2023, or up to 3% of annual global emissions" (Macreadie et al. 2021, from Ross et al. 2023, p. 2).*

In addition to storing carbon, coastal blue carbon habits are important for climate resilience, as they provide a natural buffer to sea level rise and storms and help prevent coastal erosion. They are also critical for biodiversity, providing habitat for birds and marine species (including endangered species, and commercially important species), and acting as a filter to maintain water quality and help keep the oceans healthy.

Coastal blue carbon habitats such as saltmarsh, seagrass and mangroves play a valuable natural climate solution, providing long-term secure carbon storage.

Photos courtesy of Leigh Stevens, Salt Ecology.

[4] In this report we use the terms 'sediment' and 'soil' interchangeably. 'Sediment' is more commonly used in the marine context, so we have largely used this term.
[5] Howard, et al., 2014.

Coastal blue carbon habitats are threatened

Globally it is estimated that up to 35% of tidal salt marshes and 29% of seagrasses have been lost, and an estimated 340,000 to 980,000 hectares are destroyed each year[6]. In Te Tauihu (the Top of the South Island) there have been huge losses in blue carbon habitat. It is now estimated that only around 12% (1195ha) of the original saltmarsh habitat remains in Te Tauihu estuaries[7]. Significant losses have occurred in the two estuaries adjacent to the Nelson and Richmond urban areas; and in the Whanganui Inlet (Golden Bay):

- **Nelson Haven**: only 6.7ha of saltmarsh remains of the estimated 300 ha that existed in 1840; and 135.9 ha of the estimated seagrass remains of the 284 ha that existed in 1840[8];
- **Waimeha Inlet**: Reliable estimates of the natural extent are not available, but it is estimated that 80-90% of the natural saltmarsh has been lost in the eastern part of the inlet and around 2782 ha now remains across the inlet. Large losses in the seagrass habitat are also estimated as only 34ha (2% of the intertidal area) remains, and the natural extent would likely have been similar to or greater than that in Nelson Haven (~15% of the intertidal area).
- **Whanganui Inlet**: 718 ha (80%) of seagrass has been lost from 1948-2021, with a dramatic decline occurring in between 2013 and 2021 – the causes of which are not yet understood.[9]

Historical losses were mainly due to land reclamation, dredging and horticultural development. Current threats and pressures include:

- Sediment / mud running off the land, into rivers, and out into the estuary. This can be from a variety of land uses (e.g., roading, subdivisions, farming, forestry, and regenerating native bush that hasn't yet reached canopy closure). Increasingly frequent storms and heavy rainfall events are exacerbating the issue.
- Structures being built in the middle of blue carbon habitats and / or restricting the natural extent of the habitat. For example, bunds, flood banks, cycle ways, roads etc.
- Tidal flood gates / flaps restricting natural tidal flows to protect land-based assets.

There have been significant losses of coastal blue carbon habitat in the two estuaries adjacent to the Nelson and Richmond urban areas. This is further exacerbated by threats and pressures such as sedimentation, and hard structures. Photos courtesy of Leigh Stevens, Salt Ecology.

[6] Howard, et al., 2014.
[7] Stevens, 2023.
[8] Pers. comm Stevens, 2023.
[9] Stevens, 2023.

Our blue carbon journey

Tasman Environmental Trust (TET) has been carrying out restoration work around the margins of the Waimea Inlet since 2015 and has so far restored 16.5km. But it wasn't until 2020 that TET realised that the saltmarsh habitats on the edges of our estuaries; and the seagrass growing further out in the estuaries are 'blue carbon' habitats and that protecting and restoring them is not only essential for biodiversity enhancement, but also for storing carbon and providing a natural buffer to storms and sea level rise.

Gillian Bishop (TET Chair) quickly set about hosting a blue carbon hui in September 2020 (the first in Aotearoa New Zealand) to bring together key regional stakeholders to learn about blue carbon from the Department of Conservation's national blue carbon expert, Helen Kettles, and Deakin University's Dr Stacey Trevathan-Tackett, among others. What we learned changed the way we looked at estuaries, and we saw the potential for others to look at estuaries differently too – to see them as vital carbon stores and natural buffers to storms and sea level rise, as well as critical habitats for birds, nurseries for fish, and filters that are vital to the health of the ocean.

After the hui Dr Fiona Ede pulled together a group of passionate stakeholders to develop a proposal for the Core and Restore Blue Carbon Project, and within a few short months the team had designed a $3.5m project to carry out core sampling and restoration work in six estuaries across Te Tauihu, using rangatahi-based crews. The idea was to measure how much blue carbon is stored in local estuaries and to restore blue carbon habitats in key areas.

Although an application to the Ministry for the Environment's (MfE) Freshwater Improvement Fund was unsuccessful, we knew the project had legs because it had support from Te Tauihu iwi, as well as a range of agencies, councils and businesses. So, with seed funding from Nelson City Council, project lead Lauren Walker set out to see if we could run a pilot study to take a 'first look' at how much carbon is stored in local blue carbon habitats and understand what would be involved in setting up community or rangatahi-based crews to sample at scale.

A diverse, whole-community collaboration

First we approached the local branch of Beca, one of Asia Pacific's largest engineering consultancies, to see if they'd be willing to do some core sampling for us, which they enthusiastically agreed to do, putting forward geologist Dan Chamberose and GIS specialist Sam Flewitt[10] to help us. Before we could do any sampling, we needed to establish scientifically robust sampling protocols to ensure that the data was credible and comparable with published blue carbon studies. We were very fortunate that the Cawthron Institute ('Cawthron'), a charitable trust based locally and New Zealand's largest independent science organisation, put forward Dr Anna Berthelsen to provide technical leadership for the project, as well technical advisors Dr Sean Waters and Elaine Asquith.

Pic's Peanut Butter offered to fund the laboratory analysis costs; and HealthPost Nature Trust offered to support sampling at Onetahua Farewell Spit with funding and the use of Te Whare Whakatā – HealthPost Nature Trusts field station at Onetahua.

[10] Sam Flewitt later left Beca and stayed with our team as an independent.

During the process of engaging with Beca and Cawthron and securing the funding for laboratory analysis, we found out that Nelson City Council (NCC) was planning to run the 'tea bag experiment', which is something we'd heard about from the Deakin University Blue Carbon Lab at TET's blue carbon hui in 2020 and were keen to try. NCC readily agreed to join our growing pilot team and include their 'tea bag experiment' in our pilot, so that we could include both 'hard science' and 'citizen science' methods for measuring blue carbon in our pilot.

We were aware that estuaries and coastal areas have great cultural significance for Māori, and once we got to a stage where we knew a pilot was feasible, we approached the eight iwi of Te Tauihu to gauge interest in co-designing the pilot with us. Many of the iwi faced capacity constraints that meant they couldn't actively participate in the mahi, but wished us well. We were delighted to find that Dr Jen Skilton, Ngāti Apa ki te Rā Tō's Te Taiao Advisor, holds a PhD in estuary restoration and was keen to join our pilot team.

With Beca, Cawthron, NCC and Ngāti Apa ki te Rā Tō on board as key partners, and with well wishes from iwi and funding committed by Pic's Peanut Butter and HealthPost NatureTrust we were able to go ahead and plan our pilot study.

Pilot study

There were two parts to the pilot, which was carried out from November 2021 to May 2022:

1. **Core Sampling at Waimeha Inlet and Onetahua:** this was carried out by TET, Cawthron, Beca, Ngāti Apa ki te Rā Tō, with technical leadership from Cawthron, and assistance from DOC. Manawhenua ki Mohua also assisted at Onetahua.
2. **Tea bag experiment at Waimea Inlet and Nelson Haven:** this citizen science experiment was carried out by NCC and volunteers, including Jen Skilton Ngāti Apa ki te Rā Tō and Lauren Walker.

Our main goal was to be able to report reliable data for blue carbon habitats at Waimeha Inlet and Onetahua to help demonstrate the value of local estuaries for storing carbon and the importance of protecting and restoring them. Besides gathering this carbon storage data, we also wanted to understand:

- Whether different soil sampling methods deliver the same results
- The practicality, safety, and cost effectiveness of the soil sampling methods
- How many people are needed in a field crew and what their roles would be
- What might be involved in training community / rangatahi-based field crews
- What the costs might be for a full-scale project across Te Tauihu
- How the data from both 'hard science' and 'citizen science' methods can be used to (a) help communities understand the carbon storage value of coastal wetlands; and (b) inform the development of protection and restoration plans.

Field protocol

With leadership from Cawthron and input from our whole team, we developed the Core & Restore Project Field Protocol (Walker et al. 2023) to guide our fieldwork and ensure that the resulting data was scientifically robust and reliable. The Field Protocol is divided into two parts, with part one covering the core sampling work; and part two covering the tea bag experiment. It sets out the aims of the pilot; considerations around site selection, timing, and layout; risk management requirements (permits, service location checks, cultural safety, health and safety, environment); sampling methods; field equipment list; laboratory analysis and results calculations.

Much of the information in the Field Protocol is taken from or based on the Blue Carbon Initiative Manual (Howard et al. 2014) but is very much tailored to our needs. Cultural safety was a significant focus in the development of the Field Protocol and planning of the field work and we were very fortunate to have significant iwi input into this aspect of the mahi. Key cultural safety aspects included:

- Te Atiawa offering us a karakia to use before and after our fieldwork, and cultural monitoring protocols to include in our Field Protocol;
- Ngāti Apa ki te Rā Tō offering cultural advice to our team; a karakia to launch the mahi at Waimeha Inlet; cutlrual monitoring protocols to include in our Field Protocol, a mihi whakatau for our hui[11];
- Ngāti Kuia providing cultural monitoring for the NCC tea bag experiment;

[11] We held a hui in Stoke in May 2023 to report the results to our stakeholders.

- Manawhenua ki Mohua inviting our project team to Onetahua Marae for a powhiri prior to our mahi at Onetahua Farewell Spit, and supporting our mahi with a project kuia, two cultural monitors / field assistants, and cultural monitoring procedures to include in our Field Protocol.
- Returning the sediment samples to Manawhenua Ki Mohua.

Core sampling, subsampling, and laboratory analysis[12]

In simple terms, core sampling is the process of extracting sediment so that it can be analysed. For our pilot, we extracted sediment samples from the estuaries and analysed how much blue carbon was stored in it.

We had two coring teams in our field crew[13] and tested two slightly different coring methods in each location so that we could compare the practicality, cost effectiveness and results to help determine the best method for community-based blue carbon sampling.

We aimed to sample to a depth of 1m below the surface, but the gravelly substrate at Waimeha Inlet, and the thick shell hash layer at Onetahua, at a depth of around 50cm, respectively, meant that we could only target a depth of 50cm.

We trialled two similar manual coring methods at all sites in both locations: (1) a thick-walled core tube; (2) a thin-walled core tube. Both methods involved hammering the metal tube corer into the ground; carefully pulling the tube out of the ground; extruding the core onto a 'split[14]'; cutting the core into subsamples with a knife; placing the subsamples into sample containers, labelling them, and storing them in a chilly bin with ice packs. Various information and calculations, including compaction measurements (where applicable) were recorded.

Subsampling involved cutting the core into 10 cm sections and taking a 2 cm sample from the middle of each 10 cm section. We also took the top 2 cm from the first subsample. Subsamples were sent (in a chilly bin) to the National Institute of Water and Atmospheric Research (NIWA) laboratory in Hamilton where they were dried, weighed and then ground up. Any big chunks of shell / vegetation that couldn't be ground up was sieved and weighed separately. An elemental analyser was then used to measure the total carbon in the subsamples. The carbon content of any vegetative material that was sieved out was also measured.

The resulting data was then sent to Cawthron, where further calculations were performed and the results analysed, interpreted, and reported in a technical report (Berthelsen et al. 2023).

Tea bag experiment[15]

The 'tea bag experiment' is a global citizen science project launched by the Blue Carbon Lab and formally known as "TeaComposition H2O[16]". It involves burying two types of tea bags

[12] Detailed methods for sampling, subsampling and lab analysis are set out in the Field Protocol.
[13] A 'Beca team', and a 'Cawthron team'.
[14] A 'split' is a half tube.

[15] The detailed methods for conducting the tea bag experiment are outlined in the Field Protocol.

[16] Tea Composition H2O - Blue Carbon Lab

(green tea and rooibos/red tea) in blue carbon habitats and then digging them up months later and measuring how much they have decayed. The tea in the tea bags simulates a mix of fine and coarser plant matter naturally deposited in coastal wetlands[17] and the extent to which the leaf litter in the tea bags decays during the time they are buried provides insights into the extent of the carbon retained by the sediments at each site. 19,000 household teabags have so far been planted by volunteers across 300 sites in 30 countries and the data from Nelson will be added to this[18].

In December 2021, NCC ran their 'tea bag experiment' with community volunteers in Nelson Haven (Paruparurao) and Waimeha Inlet as a cheap, effective, simple method for estimating the carbon storage and sequestration potential of sediments in habitats in these estuaries. 960 tea bags were planted by NCC and volunteers across various locations in these two local estuaries. Two types of tea bags (green and rooibos/red) were planted in four estuarine habitats; seagrass, patchy seagrass, saltmarsh, and mud.

After three months 720[19] teabags were retrieved, dried, and cleaned and then sent for weighing and analysis. Each teabag's weight was compared with its original weight to determine how much it had decomposed. NCC subsequently asked Cawthron to carry out DNA barcoding analysis to understand the bacterial composition of the sediments at each site, as this information helps scientists make sense of how plant matter is broken down and why.

Volunteers sought to dig up teabags

Vanessa Phillips · 06:00, May 05 2022

BRADEN FASTIER / STUFF

Nelson City Council coastal and marine scientist Vikki Ambrose and Nelson City Council water quality scientist Paul Fisher at Nelson Haven, before teabags were buried for an experiment late last year. Now they need volunteers to help dig them back up.

[17] Green tea bags simulating finer litter, and red (rooibos) simulating coarser litter.
[18] Ambrose & Allard pers comm. (2023).
[19] Some of the quadrats could not be located, or the tea bags could not found within the quadrats.

Waimeha Inlet – saltmarsh coring

Waimeha Inlet is the largest enclosed inlet in the South Island, the largest saltmarsh habitat in Te Tauihu, and an area of great cultural significance to Te Tauihu iwi Māori. The main focus of our work at Waimeha Inlet was to collect samples in two saltmarsh habitats (herbfield, rushland), and to sample farmland adjacent to the herbfield site to estimate the potential for blue carbon storage if the farmland[20] was restored to saltmarsh.

Herbfield

Location: Neimann Creek
Habitat type: Intact
Number of cores: 4
Number of core collection areas: 2 (6m apart)

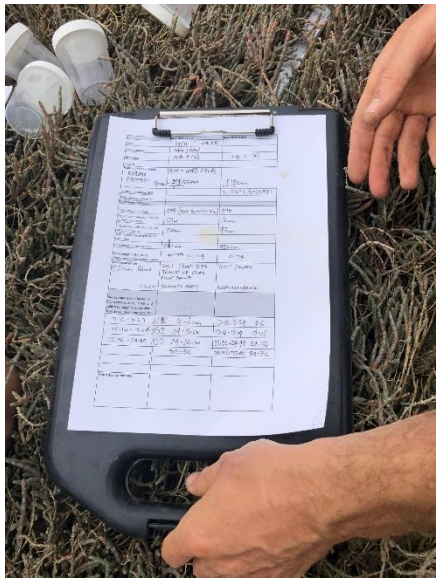
Ureure, Glasswort
Salicornia quinquefolia

Herbfield saltmarsh habitat site at Neimann Creek.

Sample collection at herbfield (saltmarsh) habitat at Neimann Creek.

[20] The farmland is currently being grazed, but is naturally establishing saltmarsh due to frequent wetting from seawater.

Extracting a core sample at herbfield (saltmarsh) habitat at Neimann Creek.



Subsampling in the herbfield (saltmarsh) habitat at Neimann Creek.

Photos courtesy of Lauren Walker.

The results for the 4 core samples taken in the intact herbfield habitat at Neimann Creek showed that this habitat has a soil carbon stock of around 38.9 tonnes per hectare (to a depth of 40cm).

Adjacent farmland

Sample collection at adjacent farmland at Neimann Creek, with saltmarsh naturally re-establishing in the background.

Photo courtesy of Lauren Walker

We hoped to be able to quantify the blue carbon potential for this farmland. In other words, we wanted to estimate how much blue carbon could be stored if this land was restored to herbfield (by rewetting). Unfortunately, we were only able to push the coring tubes into a depth of around 3cm because the soil was so compacted, and we were unable to get the soil out of the tubes afterwards and therefore unable to analyse the farmland samples.

We are aware that others are measuring soil carbon on farmland and that NIWA has developed a tool called AotearoaBLUECAM[21] for estimating the carbon potential of sites like this. An exciting next step for the project would be to pilot this NIWA tool with a local landowner who is currently grazing marginal land.

Rushland

Location: Manuka Island
Habitat type: Intact
Number of cores: 4
Number of core collection areas: 2 (6m apart)

Oioi, Jointed Wire Rush
Apodismia similis

Intact rushland habitat at Manuka Island.

Sample collection at intact rushland habitat at Manuka Island. Photos courtesy of Lauren Walker

[21] Dr Phoebe Stewart-Sinclair (NIWA) is leading this work.

The results for the 4 core samples taken in the intact rushland habitat at Manuka Island showed that this habitat has a sediment carbon stock of 37.9 tonnes per hectare (to a depth of 40cm).

Recovering herbfield

Location: Manuka Island
Habitat type: Recovering Herbfield
Number of cores: 1

Glasswort
Stopped grazing around 20 years ago

Recovering herbfield site at Manuka Island. Grazing ceased around 20 years ago.

Photo courtesy of Lauren Walker

We took one core sample in a recovering herbfield site close to the rushland site at Manuka Island and found that the sediment carbon stock for this habitat was 29.1 tonnes of carbon per hectare (to a depth of 50 cm).

Onetahua Farewell Spit – seagrass core sampling

Onetahua Farewell Spit is home to 25% of Aotearoa New Zealand's remaining seagrass (6955ha[22]). It is a RAMSAR[23] site and a DOC Nature Reserve and holds great cultural significance for manawhenua.

Seagrass meadow

Location: Onetahua
Habitat type: Intact, 3 percent covers[24]
Number of sample locations: 3
Number of cores: 12

Seagrass meadow
Zostera muelleri

Seagrass meadow habitat site at Onetahua.

[22] Calculated using the NZ mangrove and seagrass database and extrapolating from spatially limited data (Berthelsen et al. 2023).
[23] Home page | The Convention on Wetlands, The Convention on Wetlands (ramsar.org)
[24] Seagrass is known to be inherently temporally variable in its spatial distribution (Turner and Schwarz 2006). However, we decided to focus our seagrass sampling on different percent cover categories to align with our saltmarsh sampling which related to different vegetation types (Berthelsen et al. 2023).




Sample collection in the seagrass meadow habitat at Onetahua.

Photo credit: Andrew McDonald

Extracting a core in the seagrass meadow habitat at Onetahua.

Core sample collected in the seagrass meadow habitat at Onetahua; and subsampling the core.

Photos courtesy of Lauren Walker

There was relatively little difference in the amount of carbon stored in three sampling locations. The average carbon storage for the seagrass habitat across the three sampling locations was 16.7 tonnes of carbon per hectare (to a depth of 40cm).

Tea bag experiment (NCC)

Locations: Waimeha Inlet, Nelson Haven (Paruparuroa)

Habitat types:

- Seagrass meadow
- Sparse seagrass
- Mud/no growth
- Saltmarsh

Quadrats per habitat: 2
Teabags per quadrat: 30
Tea bags planted: 960
Teabags buried: 90 days
Tea bags retrieved: 720[25]

Sample collection by NCC and volunteers at tea bag experiment sites, with cultural monitoring by Ngāti Kuia.

Photos courtesy of Vikki Ambrose and Lauren Walker.

The Tea Bag Index (TBI) stabilisation factor (S) is the metric used to estimate how much carbon is retained in the sediment and is estimated from the combined change in the weight of the teabags during the time they're buried. The higher the S-value, the more carbon is being retained in the sediment.

The TBI stabilisation factors estimated from the NCC tea bag experiment ranged from 0.14 to 0.65 in the Haven samples and from 0.14 to 0.56 in the Waimea Inlet samples (see Figure

[25] Note that some of the quadrats could not be located, or the tea bags could not be located within the quadrats.

1)[26]. While the results didn't clearly reveal any difference in the carbon sequestration potential between the estuaries or habitats, the S-values were generally higher in both estuaries compared to other terrestrial / wetland ecosystems elsewhere[27] and indicated "the significant value of Nelson estuaries as blue carbon ecosystems to help mitigate climate change".[28]

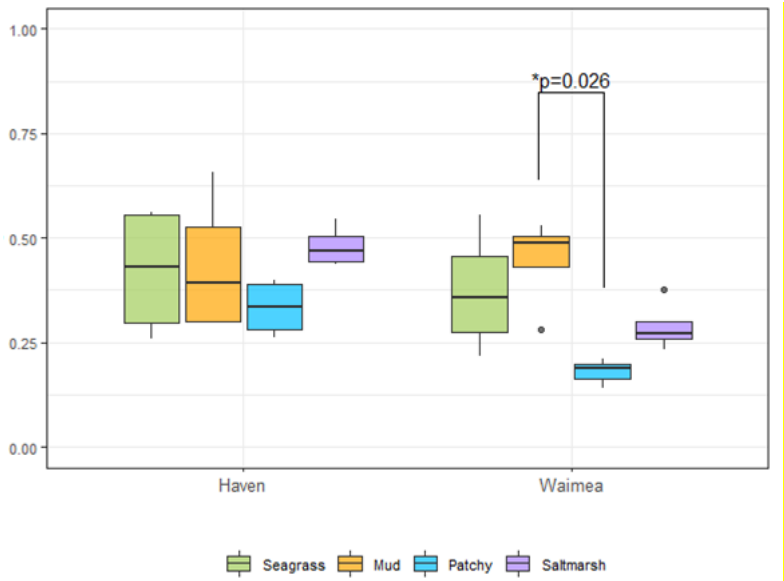


Figure 1: The TBI stabilisation factor calculated for seagrass, mud, patchy seagrass and saltmarsh habitats in Nelson Haven and Waimea Inlet. Data range (whiskers), upper and lower quartiles (edges) and the median (horizontal line) are represented for each habitat type. Statistically significant pairwise within-estuary difference is indicated with horizontal brackets and corresponding p-value. Figure and figure title reproduced from Zaiko & Pearman 2022.

The results also showed that wetland plants (rushes, glassworts, seagrass etc) were the main contributor to sediment carbon in all habitats except the 'mud' habitat in the Waimeha Inlet, which was dominated by terrestrial plant matter[30].

The patchy seagrass sites in both estuaries had lower S-values, indicating that they had lower carbon retention than the other habitat types[32]. The Cawthron bacterial analyses showed that the seagrass and patchy seagrass habitats in the Waimeha Inlet had lots of sulphate-reducing bacteria, a feature often reported from less healthy, nutrient enriched sediments[33].

The NCC tea bag experiment confirmed that Waimeha Inlet and Nelson Haven are effective sites for carbon sequestration and that blue carbon habitats play a critical role in storing carbon in these estuaries. It also highlighted the potential threat that nutrient enrichment can pose to blue carbon habitats and their ability to store carbon.[34]

[26] Zaiko & Pearman (2022)
[27] See note 25.
[28] Pers comm Allard (2023)
[30] Ambrose & Allard (2023)
[32] See note 25.
[33] See note 27.
[34] See note 27.

Results summary

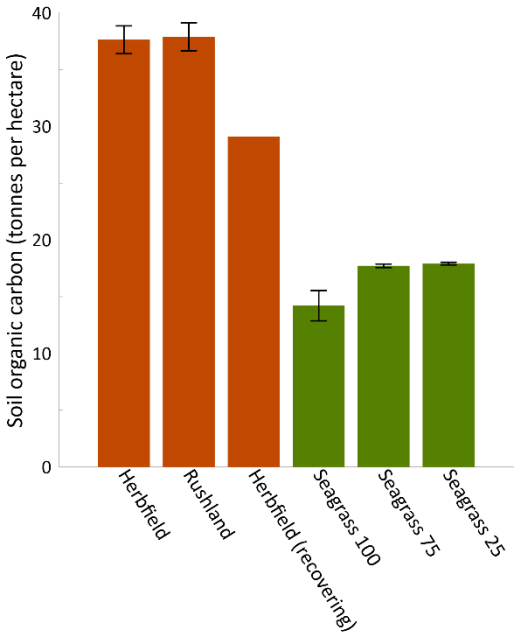


Figure 2: Soil organic carbon stocks (tC/ha to 40 cm depth, average ± standard error) by site. Waimea Inlet Saltmarsh sites in red. Onetahua Farewell Spit seagrass in green (3 percentage cover categories; 25%, 75%, 100%).

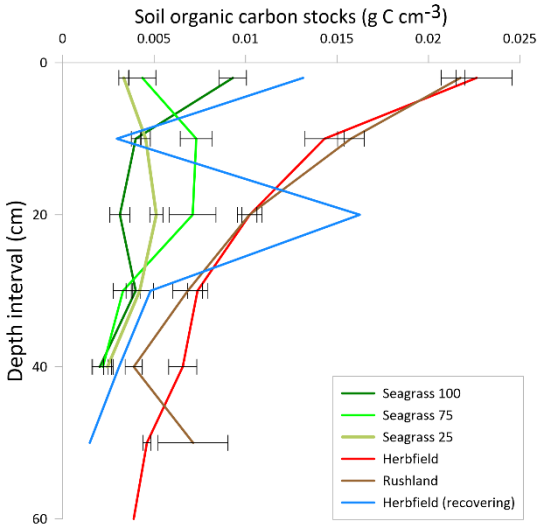


Figure 3: Soil organic carbon density down the core profile (g/cm3, average ± standard error). Waimea Inlet Saltmarsh sites in red, brown and blue. Onetahua Farewell Spit seagrass in green (3 percentage cover categories; 25%, 75%, 100%).

Figures reproduced from Berthelsen et al. 2023, pages 9 and 10.

Saltmarsh

The results illustrated in Figures 1 and 2 showed that the average sediment carbon stock to a depth of 40cm below the surface was very similar for the two saltmarsh habitats (herbfield and rushland) in the Waimeha Inlet at around 38 tC/ha[35]. The naturally recovering herbfield at Manuka Island had slightly lower carbon storage at around 29.1tC/ha.

Seagrass

The seagrass results also illustrated in Figures 1 and 2 showed that the seagrass at Onetahua Farewell Spit was storing around half as much carbon as the saltmarsh and Waimeha Inlet at around 17t/ha. This is consistent with a study conducted in the Tairua Estuary (Bulmer et al. 2020). Of the three areas with different seagrass percent cover we sampled[36], the '100% cover' site stored slightly less carbon than the two lower covers sites. Seagrass cover can vary seasonally and between years, however, so current cover may not be a good indicator of the amount of carbon stored in the soil. However, our results help to give a general estimate of the carbon stored in the seagrass habitat in the sampling area.

[35] Tonnes of carbon per hectare.

[36] We sampled three different seagrass percent covers: (1) 75-100% cover; (2) 50-75% cover; and (3) 25-50% cover.

Unvegetated areas

Based on Bulmer et al. (2020) we also know that unvegetated areas may store large amounts of carbon overall, however we didn't core sample any unvegetated areas in either location for our pilot study[37]. Core sampling unvegetated areas would be an important next step for understanding total blue carbon storage across whole estuaries.

The tea bag experiment collected data from unvegetated areas as one of the soil types. Results showed that unvegetated areas stored less carbon than vegetated areas, but unvegetated areas were much larger and so could potentially still be important blue carbon stores.

Depth of carbon storage

Our results were consistent with a study conducted Bulmer et al. (2020) and indicated that the soil carbon storage decreases substantially with depth, especially at the shallower depths. This means that there is more carbon stored higher up towards the 'top' of the core near the surface and that the amount stored gets less the deeper you go below the surface.

Influences of carbon stocks

Unfortunately, we were not able to determine the factors influencing the results from our pilot[38], but preliminary results from research being conducted in the North Island[39] indicates that geomorphic setting appears to have a strong influence on carbon stocks and that carbon stocks could be independent of the dominant vegetation type (Albot et al. forthcoming; Berthelsen et al. 2023):

- Our saltmarsh carbon stocks could have been influenced by the close proximity of the Neimann Creek river mouth to the herbfield site, and the local of the sites in the inner estuary, away from the inlet entrance.
- Our seagrass carbon stocks could have been influenced by the relatively high-water movement and flushing that occurs at Onetahua and the fact that there is relatively limited nutrient and sediment inputs from the land at the sites we sampled.

[37] Due to funding and time constraints.
[38] Because this was outside the scope of our pilot.
[39] Albot et al. (forthcoming)

Interpretation

Waimeha Inlet & Paruparuroa Nelson Haven

The results of the 'tea bag experiment' confirmed the importance of Waimeha Inlet and Nelson Haven (Paruparuroa) as blue carbon ecosystems and the critical role of saltmarsh and seagrass in storing carbon in estuaries. The results confirmed that wetland plants (saltmarsh, seagrass) were the main contributors to the sediment carbon in each of the habitats except for the Waimeha Inlet mud. The 'patchy seagrass' and 'mud' sites in the Waimeha Inlet are storing less carbon than other habitats and this could because of nutrient enrichment in the Inlet.

Waimeha Inlet Saltmarsh

Based on the total current extent of saltmarsh in the Waimeha Inlet (249.2ha) and an average carbon storage of 37.7tC/ha, we estimate that there is around 9,400 tonnes of blue carbon (tC) stored in the sediments beneath the saltmarsh habitat in the Waimeha Inlet. Based on the current extent of herbfield and rushland habitats, we estimate that of this 9,400 tC, 6,095tC is stored in the sediments beneath the herbfields and 3305tC is stored in sediments beneath the rushlands. Further sampling would be needed to validate this estimate.

Onetahua Farewell Spit Seagrass

Based on an estimated area of 6955 ha of seagrass at Onetahua Farewell Spit and based on the average of the carbon stocks from the three sampling locations (16.7tC/ha), we estimate that the total blue carbon stored in the sediments below the Onetahua seagrass is around 115,453 tonnes. Further sampling would be needed to validate this estimate.

Blue carbon sediment from Onetahua Seagrass Meadow

Photo credit: Andrew McDonald

NZ and overseas comparison

There is little blue carbon data available for Aotearoa New Zealand and direct comparisons both nationally and internationally are difficult because data can be reported at different depths[42]. For illustrative purposes, we have set out our saltmarsh sediment carbon stock results in Table 1 alongside saltmarsh carbon stock data collected by Bulmer et al. (2020) in the Tairua Estuary; saltmarsh carbon stock data collected by Albot et al., (forthcoming) at four sites across the North Island; and carbon stock data from rushland and herbfield habitats collected by Elison and Beasey (2018) in Tasmania. Likewise, in Table 2 we have set out our seagrass carbon stock data alongside seagrass carbon stock data collected by Bulmer et al. 2020 in the Tairua Estuary; and that collected in two Australian Studies (Queensland, New South Wales).

The purpose of our comparison is simply to show what stocks are present in the sampled locations, to demonstrate the importance of these coastal wetland habitats for storing carbon, and to outline the variation in stocks observed between different sites. The pilot study results do not provide enough information to be able to assess or compare how much carbon is being stored over time. For example, our 40cm core sample results could represent slow deposition and sequestration over thousands of years, or very rapid deposition over a few years or 10s of years, but we can't confirm this without measuring the sequestration rate[43]. Measuring carbon sequestration rates would be a useful addition to any further coastal blue carbon studies in Te Tauihu.

Table 1: Saltmarsh sediment carbon stock data

Location	**Habitat**	**Average carbon stock (tC/ha)**	**Sediment sampling depth**
Waimeha Inlet	Herbfield	38.9	40cm
	Rushland	37.9	40cm
Tairua Estuary[45]	Rushland	85	100cm
Four North Island Sites[46]	Various saltmarsh types	57	Various
Tasmania[47]	Rushland and/or herbfield	49.5	30cm

[42] Samples are usually taken to a 1m depth, but sometimes there are hard gravel or shell layers that make it impractical to sample to that depth. It is usually a case of sampling to the depth that is most practical.
[43] Pers. comm. Stevens, 2023.
[45] Bulmer et al. 2020
[46] Albot et al. (forthcoming)
[47] Ellison and Beasy (2018)

Table 2: Seagrass sediment carbon stock data

Location	**Average carbon stock (tC/ha)**	**Sediment depth**
Onetahua	14.2-17.9	40cm
Tairua Estuary[48]	27	100cm
Queensland[49]	≤ 6	10cm
New South Wales[50]	365	50cm

[48] See note 28.
[49] Ricart et al. 2015, from Berthelesen et al. 2023
[50] Brown et al. 2016, from Berthelesen et al. 2023

Insights from the pilot

The Core & Restore team gained a significant amount of knowledge during the course of planning and carrying out the pilot. Much of the technical knowledge is reflected in our Field Protocol and a number of insights are shared below for the benefit of others wishing to carry out community-based blue carbon sampling projects.

Tikanga and cultural safety

- Iwi permission and whanau involvement is really important in coastal blue carbon sampling and restoration work because estuaries have special cultural significance to Māori and whanau and hapu are kaitiaki for these ecosystems. Some sites may be wahi tapu and it is important not to disturb them without express permission.
- In any location there could be multiple iwi who consider the area to be culturally significant. Each iwi needs to be engaged separately.
- Soil samples are part of the whenua for Māori and so it is important to ask if you can take the samples and then return the remaining material to whanau after the sampling is completed.
- It is important for the cultural safety of iwi and the project team to observe tikanga in planning and carrying out the work. It is important to have cultural guidance on tikanga from iwi.
- The key cultural safety steps we took for the core sampling part of our pilot included:
  - Asking Te Tauihu iwi if they wanted to be involved in the pilot, maintaining an open invitation for iwi to join the project at any time, and keeping them informed of what we were doing;
  - Asking Te Tauihu iwi for permission to carry out the sampling and providing an opportunity for iwi to raise any questions or concerns about our proposed activities;
  - Inviting project partner Ngāti Apa ki te Rā Tō to offer a karakia at our launch ceremony prior to the Waimeha Inlet work and later gratefully accepting their offer of cultural guidance for the project.
  - Including karakia and cultural monitoring (accidental discovery) procedures in our field protocol to use in the field;
  - Gratefully accepting support from Manawhenua ki Mohua, including: a welcoming powhiri at Onetahua marae for our project team; a karakia from our Project Kuia before our mahi at Onetahua; and two cultural monitors joining our Onetahua field team.
- Key cultural safety steps for the NCC Tea Bag Experiment included:
  - Asking Te Tauihu iwi if they wanted to be involved in the pilot, maintaining an open invitation for iwi to join the project at any time, and keeping them informed of what we were doing;
  - Asking Te Tauihu iwi for permission to carry out the sampling and providing an opportunity for iwi to raise any questions or concerns about our proposed activities;
  - Ngati Kuia providing cultural monitoring.

Planning, permits and compliance

- There was a lot of planning and coordination involved in planning and organising the pilot field work.
- It is important to allow plenty of time to get the appropriate permissions and permits. For our pilot, this included:
  - Iwi permission and tikanga (see above)
  - Landowner permission (we met with the landowners and Neimann Creek and Manuka Island to discuss the work and ask permission to do it)
  - Services check (we carried out checks to make sure there weren't any buried services where we were planning to sample, for example power or phone cables etc)[51]
  - MPI permit (we carried out our sampling under Cawthron Institute's MPI special permit and would not have been allowed to collect the samples without this. We also needed MPI permission to return the samples to Manawhenua ki Mohua)[52]
  - DOC concession / permit (this may be required if the sampling location is on DOC land)
- There was also a considerable amount of work involved in coordinating and making plans with our multi-agency team, although once we had the Field Protocol set up and had carried out the pilot in one location there was a lot less coordination involved for the next location.
- Safety management and compliance also required planning and coordination because we operated under the TET Health and Safety System, but each agency had their own internal health and safety management system requirements.

Coring methods

- We trialled two similar manual coring methods (thin-walled coring tube and thick-walled coring tube).
- Both methods worked well, were practical and safe and produced consistent results using the methods and safety procedures set out in the Field Protocol.
- The thin-walled coring tube seemed to be lighter and simpler to use and is likely better suited for community-based crews than the thick-walled tube.
- Both methods took roughly the same time, so there weren't any obvious efficiency gains from either method.
- Compaction was an issue in the saltmarsh and on the farmland with both methods. It would have been good to trial other methods to see if we could reduce compaction (e.g., an open-faced auger / gouge corer / hand auger / piston corer).
- The seagrass habitat was 'sloppier', and we needed to hold the sediment in the corer by placing a hand over the bottom of the tube when extracting. We were able to do this because we had a team member in each team who had very long arms and they could reach down to the bottom of the corer. This would be difficult further out in the estuary where the soils are sloppier, or if coring to a deeper depth.

[51] The Field Protocol includes procedures for carrying our Service Checks.

[52] We understand that biosecurity and contamination risk are the key MPI concerns regarding the return of sediments to the estuary after sampling and laboratory analysis.

Rangatahi / Community-based crews

- The original concept for the Core & Restore Project was to have rangatahi-based crews carrying out the sampling and doing restoration work across Te Tauihu.
- One of the goals of the pilot was to see whether we could set up methods that such crews would be able to use.
- Based on our pilot, we think it would be possible to set up rangatahi / community-based crews. It would just require a simple training and supervision process, based on the Field Protocol.
- During the Onetahua field work, one of our teams trained up Syd Eru, one of our cultural monitors, to record data and information. Within 20 minutes he was doing this easily.
- Now that our coring procedures and field protocol are well tested, we could do a small pilot to train a rangatahi / community-based crew. There would likely need to be 3 people in a crew and the crew would need to be supervised by a senior scientist.
  - Two people to carry out the sampling (at least one person needs to be tall and strong; they both need to be practically minded)
  - One person to do documentation, subsample packaging and labelling.
- From a regional perspective, it probably makes sense to have one set of equipment, and then train up a crew in Mohua and one in Te Tai Aorere, with the science supervisor being the only person that works in both locations.

Costs for a larger scale project across Te Tauihu

- To accurately cost a larger scale project we would need to determine how much further sampling is needed, where the sampling needs to be done and why we're doing it. We could then work out the most practical and cost-effective way of doing it.
- The pilot has delivered scientifically robust blue carbon data and the Field Protocol is now in place to be able to collect more samples, either with the existing team or with rangatahi / community-based crews.
- The main costs that would need to be included in a budget are:
  - Planning and coordination
  - Permissions, iwi engagement, permits (Coordinator)
  - Field crew fees
  - Courier costs (to send samples to laboratory)
  - Laboratory analysis costs
  - Data analysis, interpretation, and reporting.

Funding sustainability

- Securing ongoing funding has been the biggest challenge for the project to date.
- Much can be achieved with this kind of wide, cross sector collaboration, but funding is needed to support the person leading / coordinating the collaboration.

Co-benefits of the pilot

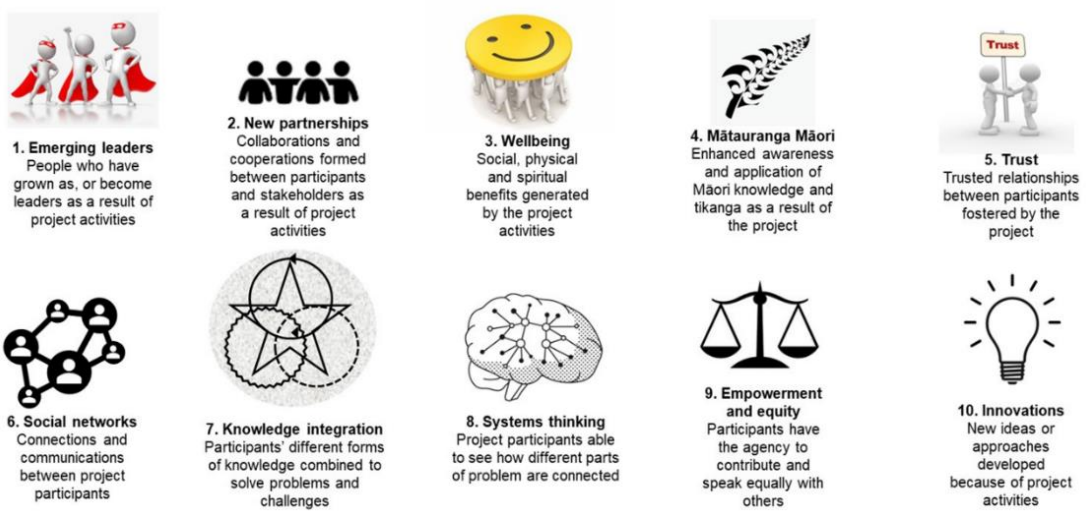
The Core & Restore Project Pilot was only possible due to the passion, commitment, expertise and unique and generous contributions of our key partners, supporters and advisors. This project had 'legs' because everyone liked the idea of 'doing what we can together' in terms of taking action on climate change.

The unique way that we worked generated benefits we never intended or anticipated. Cawthron worked with the Core & Restore team to develop a set of ten indicators to measure the co-benefits of the project, developed an approach to measuring these co-benefits and tested it at the Core & Restore Project Hui held in Richmond in the Tasman Region on the 28th March 2023.

Hui participants worked in small groups to reflect on the outcomes of the project in relation to each indicator and then scored the project on each indicator. The results are re-produced in Table 3 below and show that:

> *"overall, the indicators and narratives suggested that the social outcomes, and hence adaptive capacity generated by Core & Restore Pilot study had been significant, providing a useful foundation for future collaborative efforts and climate action" (Berthelsen et al, 2023).*

Hui participants worked in groups to score the co-benefits of the pilot
Photo credit: Nikki Morrell



Indicators developed by Cawthron to measure the co-benefits of Core & Restore. Image copied from Berthelsen et al. (2023).

Co-benefits of the Tea Bag Experiment were not measured at the Hui, but included community involvement, education (learning about estuary and blue carbon) and connecting to place/estuaries leading to a desire to protect them for future generations[53].

A clerical error resulted in the 'wellbeing' indicator not being measured during the hui, however in the discussion at the hui "it was agreed that the overall sense of positivity was high due to everyone working together successfully.[54]" The volunteers / community members that participated in the NCC tea bag experiment were "very happy to be asked to be involved, really enjoyed taking part, and learned a lot. They would love to do it again and were keen to see the outcomes[55]".

[53] Pers comm. Ambrose, 2023.
[54] Berthelsen et al., 2023, p. 27.
[55] Pers comm. Ambrose, 2023.

Table 3: The adaptive capacity indicators, the question posed to the workshop (local hui) participants, and their scores & explanations for each (title and table copied from Berthelsen et al 2023).

Indicator	Core and Restore context/question	Score (0 = strongly negative; 5 = strongly positive)	Explanatory comments
1. Emerging leaders	Did the project encourage the emergence of leadership amongst the partners?	4	"Citizen science – people keen to be involved in something new" "Repeated community samples wanting to know the results" "Professionally more opportunities" "Community conservation leaders result in healthier biodiversity from land to sea, which increases mauri" "Provides a platform for new leadership to sprout from rangitahi"
2. New partnerships	Did the project create any new partnerships?	4.5	"It was important to have Lauren there to help pull together partners and make connections meaningful" "From an iwi perspective, this project may have been pushed to one side, had it not been for Lauren's perseverance"
3. Wellbeing	How much happiness and positivity did the project generate for the participants?	N/A	
4. Mātauranga Māori	Did the project encourage and promote mātauranga Māori and tikanga?	3	"Knowledge of what estimates used need to be clearer" "Observations of change over time were not incorporated" "Ownership of who controls the financial benefits need to be considered" "Need to discuss black mud"
5. Trust	How much trust has the project generated between participants and stakeholder groups?	4	"Much effort put into relationship building between partner organisations - especially iwi, DoC, Nelson Port – led to high level of trust" "Room to move organisations' research competition in this space e.g. NIWA and Cawthron"
6. Social networks	Have social networks been grown by the project, especially across levels (e.g. community-government)?	4.5	"Great cross-representation across the community brought together many sectors – local government, DoC, citizen science, iwi, business, social knowledge" "Potential to grow more or be replicated in other areas" "Potential flagship for climate-positive action"

7. Knowledge integration	Has the project successfully integrated different kinds of knowledge (e.g. about blue carbon, estuaries, restoration and climate change)?	5	"Engineering/science/whanau/council/citizen science/social science working together to enrich each other's experiences" "Understanding tikanga (e.g. returning knowledge to whenua) and long term nature of environmental change" "Knowledge exchange through working together"
8. Systems thinking	Has the project encouraged people to think more about how different issues are connected?	4	"Participants have explored and seen lots of different/varied parts of the problem, and there is a diversity of people – lots to build on" "It 'makes sense'" "Comparing nationally, internationally and globally" "Thinking across spatial scales"
9. Empowerment and equity	Did the project empower its participants, and give everyone an equal voice?	5	"As a landowner, I felt part of the team from the beginning, able to speak equally" "Lauren's facilitation skills are off the scale/good – that made all the difference" "Participants are friends and really interested in understanding what blue carbon is, and they are able to share their knowledge" "Today (at the workshop), having all organisations, people, agencies contributing presentations" "Teabag report back was complementary, and added breadth to the project"
10. Innovations	Did any new ideas or innovations emerge from the project?	4.5	"Developing scientific protocol and turning it into a guide for community-based blue carbon sampling" "Hard/soft science (scientists versus citizens)" "Innovative way of connecting iwi and community in coastal habitat teabag experiment" "Developing blue carbon expertise" "Leaders in NZ blue carbon" "Blue carbon is a new field internationally – NZ might be seen as one of the first projects"

Wider contribution

At the time we carried out our blue carbon sampling (late 2021 and mid 2022) there was only one set of published blue carbon data for salt marsh and seagrass habitats for Aotearoa New Zealand that was known to us.

- Bulmer et. al collected carbon stock measurements in the Tairua estuary in 2016 and published their results in 2020.
- The Core & Restore team undertook the first blue carbon sampling in the South Island, and the largest of only two seagrass studies carried out in Aotearoa New Zealand to date.
- Albot et al (forthcoming) collected carbon stock and carbon sequestration measurements across three locations in the North Island (Northland, Thames-Coromandel and Lower North Island) around the same time as our pilot; and we understand Bulmer et al have further carbon stock measurement work underway in Whangarei Harbour.
- There are now many blue carbon studies for estuaries underway around Aotearoa New Zealand[56]. A summary of these studies is currently being collated as an output from the National Blue Carbon Hui hosted by DOC and TNC in 2023.

The Core & Restore Blue Carbon pilot has made a significant contribution to the understanding of blue carbon in Aotearoa New Zealand.This was demonstrated recently when our pilot data was used in an article published in the New Zealand Journal of Marine and Freshwater Research titled “A preliminary estimate of the contribution of coastal blue carbon to climate change mitigation in New Zealand” (Ross et al, 2023). We are very proud that our project Technical Lead, Dr Anna Berthelsen was a co-author on this paper.

Next steps

Participants at the Core & Restore Hui on the 28th of March 2023 brainstormed potential next steps for the project and these are included in Appendix A. The key next steps that came out of this discussion included:

1. Put together a team to develop a funding strategy. A key part of this would be developing a one-page pitch document to make it easy for funders to understand the data and co-benefits and convey the ‘energy in the room’.
2. Form a technical workgroup to address the uncertainties around the science and determine further core sampling requirements for Te Tauihu at a high level[57].
3. Carry out a collaborative pilot to demonstrate the blue carbon potential of restoring marginal farmland, potentially using the AotearoaBLUECAM tool.

As a number of months have passed since the hui, the immediate priority is for the key project partners to get together to check in and discuss how they would like to progress things in light of the wider efforts underway in the blue carbon space nationally and within Te Tauihu.

[56] Refer to the Appendix of Ross et al. 2023 for more details.

[57] Note that subsequently a number of working groups covering multiple aspects of blue carbon have been formed following the National Blue Carbon Hui hosted by DOC and TNC in 2023, so this will need to be taken into consideration in planning next steps for Core & Restore.

Special thanks to our amazing team

Core & Restore Onetahua Pilot Field Team (from bottom left to back left): Lauren Walker (Project Lead, Lauren Walker Ltd), Elaine Asquith (Cawthron), Dr Anna Berthelsen (Project Technical Lead, Cawthron), Raelene Mason (Manawhenua ki Mohua), Helen Kettles (DOC), Dan Chamberose (Beca), Dr Sean Waters (Cawthron), Sam Flewitt (Independent – previously Beca), Dr Jen Skilton (Ngāti Apa ki te Rā Tō), Syd Eru (Manawhenua ki Mohua)

Photo credit: Andrew McDonald

Job done. Photo courtesy of Lauren Walker

References

Albot O, Levy, R, Ratcliffe J, Kind D, Naeher S, Ginnane C, Cooper J, Streatfield J, Phillips A, Wood C, et al. Forthcoming. Carbon stocks, sources and preservation in New Zealand's saltmarsh soils.

Allard, A. 2023. Personal communication.

Ambrose, V. 2023. Personal communication.

Ambrose V, Allard A. 2023. Presentation to the Core & Restore Blue Carbon Hui, Richmond, 28th March 2023.

Berthelsen A, Walker L, Skilton J, Chamberose D, Flewitt S, Waters S, Asquith E, Butler J, Kettles H. 2023. Sediment organic carbon stocks in coastal blue carbon habitats: pilot study for Te Tauihu. Nelson: Cawthron Institute. Cawthron Report 3867. Prepared for Tasman Environmental Trust.

Bulmer RH, Stephenson F, Jones HF, Townsend M, Hellman JR, Schwendenmann L, Lundquist CJ. 2020. Blue carbon stocks and cross-habitat subsidies. Frontiers in Marine Science. 7:380.

Howard J, Hoyt S, Isensee K, Pidgeon E, Telszewki M, editors. 2014. Coastal blue carbon: methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes and seagrass meadows. Arlington, Virginia: Conservation International.

Ross, F. W., Clark, D. E., Albot, O., Berthelsen, A., Bulmer, R., Crawshaw, J., & Macreadie, P. I. (2023). A preliminary estimate of the contribution of coastal blue carbon to climate change mitigation in New Zealand. New Zealand Journal of Marine and Freshwater Research, 1-11.

Stevens, L., 2023. Presentation to the Core & Restore Blue Carbon Hui, Richmond, 28th March 2023.

Stevens, L., 2023. Personal Communication.

Walker L, Berthlesen A, Chamberose D, Ambrose V, Skilton J, Waters S, Asquith E, Flewitt S, 2023. Core and Restore Project Field Protocol. November 2023. Prepared for Tasman Environmental Trust.

Zaiko A, Pearman J 2022. Bacterial assemblages associated with carbon sequestration potential in marine wetland sediments. Prepared for Nelson City Council. Cawthron Report No. 3845. 13 p. plus appendices.

APPENDIX A

Core & Restore Blue Carbon Project Hui

PROGRAMME

Date: Tuesday 28th March 2023 | 10:00 am - 4:15 pm
Venue: Pūtangitangi Greenmeadows Centre | Tui Room, Main Road Stoke
RSVP: Last minute RSVPs to lauren@laurenwalker.co.nz

Timing	Topic	Speaker / Leader
10:00 – 10.20	Mihi whakatau	Ngāti Apa ki te Rā To
	KAI	
10.35 12.30	Welcome & opening remarks	Gillian Bishop (TET)
	Introductions & overview of the day	Lauren Walker
	The Core & Restore Journey	Lauren Walker
	The current health of coastal blue carbon habitats in Te Tauihu	Leigh Stevens (Salt Ecology)
	Results, lessons learned and outcomes of the Core & Restore Pilot	Core & Restore Project Team
	LUNCH	
1.00-3.00	Co-benefits of our mahi – measuring the difference we made	James Butler (Cawthron)
	The contribution of Core & Restore to the development of the blue carbon space in Aotearoa/NZ	Helen Kettles (DOC)
	What's happening in the blue carbon space regionally & nationally? Project overviews on: · Local saltmarsh restoration projects · Restoring Aotearoa's seagrass meadows · Voluntary carbon markets for blue carbon credits · Implications of coastal blue carbon sequestration for (national) greenhouse gas budgets · Aotearoa BlueCAM – a tool for assessing blue carbon storage for restoration sites.	Speakers will include: Sky Davies (TET), George Daly (TDC) Dr Anna Berthelsen (Cawthron) Olya Albot (The Nature Conservancy) Dr Richard Bulmer (Tidal Research) Dr Phoebe Stewart-Sinclair (NIWA)
	TEA BREAK	
3.15-4.15	Next steps for Core & Restore - facilitated discussion	Lauren Walker & James Butler
	Wrap up & next steps	Lauren Walker
	Karakia	Ngāti Apa ki te Rā To

APPENDIX B: Next Steps[58]

POST-IT NOTES

Uncertainty around spatial distribution of carbon:

- How do we compare what we currently seeing on the ground with what was there in the past?
- Do we need to know this?
- Cannot do enough samples to cover TTI, so need to innovate

Further consideration of associated qualities that turn up with sequestration*:

i.e., from a 'its not all about carbon' perspective, how can we infer active sequestration while viewing/measuring systems through a qualitative mauri / vibrance / abundance / diversity lens?

Automating / Augmenting the core process*.

- How much more could be mapped it if wasn't such a manual process?

Understanding carbon mobility across environments*:

- i.e., seagrass vs herbfields.
- But is the seagrass biomass simply more mobile due to immersion etc? Is it being sequestered elsewhere at depth?

Sharing more stories on different platforms so that you reach many members of the community, and they can understand the concept**

Ensure protection of native species so that other species that may sequester more carbon (e.g., Posidonia seagrass) are not introduced**

How does blue carbon fit alongside other estuarine ecosystem services? Things that might add to the value proposition for land owners to refine / restore coastal lands?

How can their value be reflected?

Do baseline core sampling of unvegetated areas. Also to understand what type of carbon is stored in mud (i.e., local plants or washed into estuary)

What is the (ballpark) carbon storage potential of our local coastal environments if restored?

Tea bags / planting / coring = options for more iwi / community involvement

Comms / storytelling around restoration projects so that landowners / community understand that BC restoration looks like

Baseline core sampling for TDC and NCC saltmarsh restoration projects

Strengthening relationships with iwi and whanau so we can weave mātauranga into the project

Trial other coring methods (e.g., open face auger)

FACILITATED GROUP SESSION

1. Send out presentations to those that are interested
2. Australian case study from Phoebe (Annette)
3. **Local pilot with AotearoaBLUECAM**
4. **Funding strategy**, including below ideas:
    a. LTPs – presentation to both councils covering the five well-beings (Jo)
    b. NRDA + COC presentation
    c. Fishing & forestry sector companies
    d. Fonterra, Airport, AirNZ (Dana / James)
    e. Iwi channels for funding (Jen)? E.g.,
        i. MKM (or Ngati Apa) drive the project to funders?
        ii. Look for linkages with Te Mana o Te Wai (because quite a bit of funding there)
    f. Foundations (James)
        i. International options?
    g. 1 page report-back / pitch to funders making data and co-benefits easily understood & showing energy in the room.
    h. Clarity on what we want funding for (Abby)
    i. Funding restoration through environmental offsets (e.g., Waimea Dam offsets) from infrastructure / hard structure projects. This would be a way to create a financial benefit to the landowner (i.e., through compensations where offsets are required) (David)
    j. Science funding – could partner, with a focus on the collaborative relationships
    k. Should there be a national contestable fund for BC? (Helen)
5. Applying the science:
    a. Take science and apply with landowners (brokering) – making the science easily digestible for farmers
    b. Strengthen collaboration
6. Focus on the supply side – goodwill from farmers that care about co-benefits (Ed)
    c. Simple summary for landowners so they can understand co-benefits
    d. Bundling co-benefits to help landowners understand what's involved (e.g., biodiversity credits etc)
7. Think about aims for national hui (Helen)
    e. Gifts we can offer
    f. Gains we hope for
15. Coring the unvegetated habitat – fill this gap
16. Coring – getting a better understanding of spatial variability and how representative our BC data is

6. Landcare Trust doing work on SLR (taking subsidence into consideration)
    a. BC as part of SLR adaptation planning (natural buffering), as well as mitigation tool (through sequestration)
    b. Future Coasts Project (NIWA) will be an input to help us understand habitat response to SLR
    c. Mississippi river example – can we take sediment from Motueka Catchment and make a natural barrier?
7. **Form a working group to bring everyone together (Sky) / a multistakeholder coalition (Gillian)**
    a. TNC / TET / NCC / Cawthron
    b. Iwi (!)
    c. To develop a joint strategy and get clear on who is leading which niches
    d. To progress next steps
    e. **Maybe limit by location (e.g., Waimeha Inlet – lots going on; could look at sources of funding and gaps) (Gillian**)
8. IMPACT:
    a. Science funding (Ed, Dana) – we can demonstrate community engagement; need to also demonstrate excellence
    b. Restore: buy in from community and iwi – citizen science
    c. MKM: bringing whanau together and sharing whakapapa through experiences in the field
    d. Ngati Apa: Mana rangatahi – day in the estuary with tea bags / cores; this would flow up to whanau
9. Evolve the social indicators with iwi to reflect Te Ao Maori perspective
10. Split restore off?
11. Employ 1 role – e.g., a BC version of Elliot (Yachal)
12. **Technical working group** – to address uncertainties around the science at a quick and dirty level (Leigh). The restoration space is straightforward, but the coring is trickier. Where does it sit in a national context?
13. Is there enough baseline data for restoration sites?
    a. If you would restore without the BC data, then don't need more
    b. Some landowners may be willing on the basis of the co-benefits.
14. Biodiversity outcomes for restoration projects:
    a. Need monitoring so we can report the outcomes
    b. And measure other social metrics (e.g., mahinga Kai, fishing etc, recreation, mātauranga, volunteer numbers

[58] Ideas put forward by stakeholders at the Core & Restore Hui, Richmond, 28th March 2023.