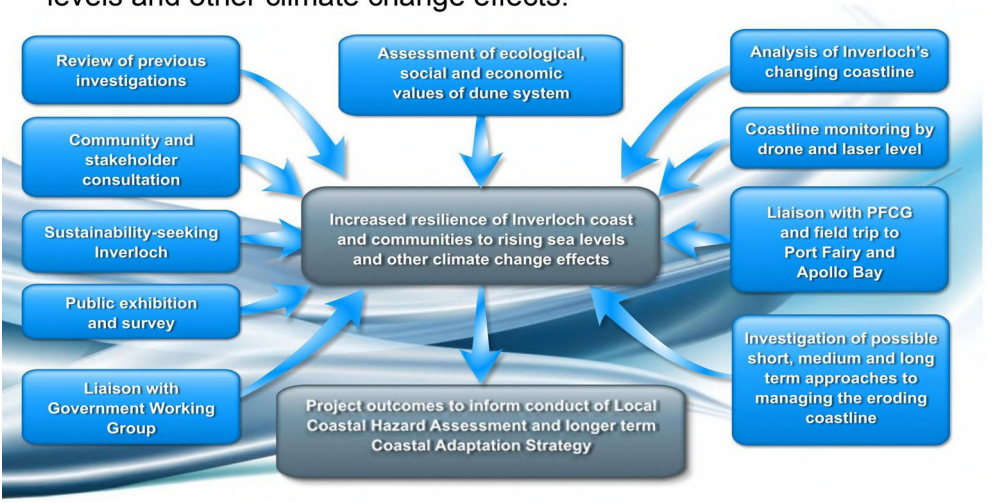
This document captures the content of the public exhibition of the Inverloch Coastal Resilience Project. The exhibition, together with an accompanying survey, was mounted at the Inverloch Community Centre, the Inverloch Surf Lifesaving Club and Wonthaggi Public Library between March and June 2019.

Contents

Project Aim and this Exhibition

Project Aim

South Gippsland Conservation Society is seeking to increase the resilience of the Inverloch coast and its communities to rising sea levels and other climate change effects.



This Exhibition

- Our changing coastline and recent beach erosion
- Environmental, social and economic values at risk
- Wet-sand fencing trial and further recommended actions
- Coastline monitoring and other research projects underway
- Feedback and survey

Feedback from this exhibition and our survey will be presented to the Inverloch Coastal Erosion Working Group, including Bass Coast Shire Council and the Department of Environment, Land, Water and Planning. Your opinion is vitally important to ensure that community values are considered in the forthcoming Local Coastal Hazard Assessment for Inverloch and Anderson Inlet.

South Gippsland CONSERVATION SOCIETY
Celebrating over 40 years of Conservation.

The Inverloch Coastal Resilience Project is funded, with thanks, by the Lord Mayor's Charitable Foundation.

LORD MAYOR'S CHARITABLE FOUNDATION

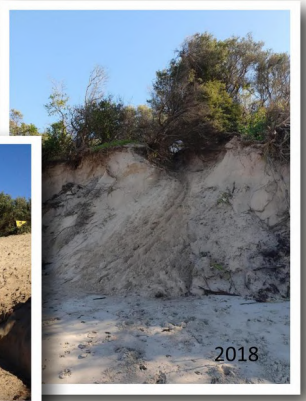
Our Changing Coastline

The Inverloch coast is particularly vulnerable to rising sea levels and increases in storm intensity and frequency. Historical photography shows changes at Inverloch surf beach, the Anderson Inlet channels and Pt Smythe.

Our Changing Coastline

Current Erosion Threat

Since 2013, Inverloch's surf beach has lost around 40 metres of its dunes and vegetation. Beach erosion is threatening Inverloch Surf Life Saving Clubhouse, lookout tower and Bunurong Road.



Erosion of lookout tower, Inverloch Surf Beach. 2013 to 2018.

Current Erosion Threat

Previous coastal erosion, including in the late 1970s, resulted in eroded sand being deposited offshore. Under favourable conditions, this sand was then available to replenish the beach.

Rebuilt tower - December 2014

May 2015

11 May 2015

October 2016

3rd tower position - July 2018

Current Erosion Threat

Recent erosion has behaved differently and, for the first time in living memory, sand from surf beach erosion has built up in Anderson Inlet, possibly permanently. If the surf beach is not replenished, the beach dune system will be susceptible to further losses from future winter storm surges.

March 2015

January 2017

Extents of Beach Erosion

Historic coastal erosion 1985 and 2017. Research indicates significant erosion in 1985 (yellow line) occurred as early as 1979.

The 2017 coastal erosion (red line) commenced in 2013 and continued through 2018, with the section between Flat Rocks and Wave Street most affected.

Shoreline Monitoring

Inverloch selected as one of 17 priority sites to be regularly monitored under the Victorian Coastal Monitoring Program - drone monitoring commenced in September 2018 and is undertaken every 6 weeks.

Research scientists from Deakin and Melbourne Universities are training Citizen Scientists in the use of drones – we're aiming to have 6 volunteers fully trained by mid-2019.

Survey results are uploaded to Propeller Aero portal and cross-section and volume comparisons made from one survey to the next – results are publicly available to enable the extent of coastal erosion and accretion to be monitored.

Laser level monitoring at 13 sites commenced in March 2019.

Inverloch's Dune System

Bass Coast is renowned for its natural, unspoilt coastline. Inverloch's surf beach is highly valued by residents and visitors and is a major attraction for swimmers, surfers, nippers, kite surfers, fishermen and beach walkers.

The beach features an extensive, vegetated dune system, stretching from Flat Rocks to Point Smythe and Venus Bay, that provides a buffer for homes and coastal infrastructure. The dunes also have a range of ecological, geomorphological, cultural heritage and economic values.

Ecological Values

The ecology of the vegetated dunes between Flat Rocks and Point Smythe is diverse, with many rare and threatened plant and animal species. Shorebirds, such as the vulnerable Hooded Plover, are dependent on the dune habitat. The vegetation also acts as a biolink for local fauna.

Almost half of the dune system vegetation has been lost to coastal erosion since 2013, including mature Coast Banksia Woodland at Flat Rocks. There has also been an almost complete loss of foredune habitat that is critical to beach nesting shorebirds.

The newly-formed dune system at Point Hughes is being colonized by Marram Grass and Sea Wheat Grass. These grasses form steep-sided dunes that are unsuitable for beach nesting shorebirds.

Cultural Heritage Values

At European settlement, the Inverloch region was occupied by the Bunwurrung and Gunaikurnai people.

Fourteen Aboriginal places (shell middens) are listed in the Aboriginal Heritage Register in and adjacent to the study area, between Flat Rocks and Pt Smythe. Four of these sites within the coastal reserve are at high to very high risk from climate change and rising sea levels.

In addition, the following sections of coast are likely to contain further sites and are also at most risk:

- Flat Rocks to Goroke Street
- Veronica Street to Bowling Club
- Angling Club to Screw Creek

Consultation is underway with Bunurong Land Council Aboriginal Corporation and Gunaikurnai Land and Waters Aboriginal Corporation.

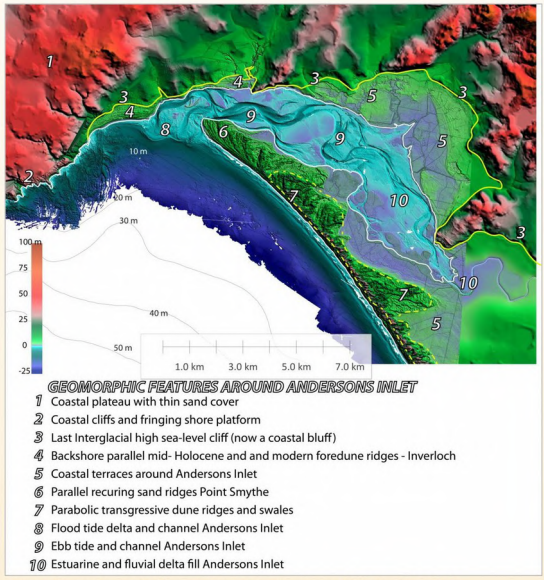
Statements from both groups about the values that they ascribe to the Inverloch dune system are in preparation.

Geomorphological Features

The Inverloch coastline is a complex dynamic system of State Geoscience significance comprising:

- stranded marine cliffs (now coastal bluff), fringing shore platforms and preserved backshore sand ridges linking the bluff and Holocene sand dunes at the surf beach
- Anderson Inlet, a former marine embayment, now an estuarine system, characterised by substantial and rapid shifts in the location, width and depth of tidal channels
- Pt Smythe, a coastal barrier composed of multiple curving ridges shaped by north-trending long shore drift.

COASTAL GEOMORPHOLOGY: VENUS BAY



Coastal geomorphology at head of Venus Bay.(Derived from 0.5 m bathymetric and coastal LiDAR and 10 m DEM)

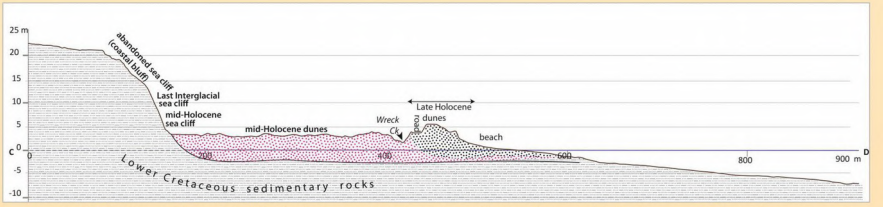
Geomorphological Features

The changes to this system since 2010 represent the most rapid recession and accretion events recorded on the Victorian coast in recent times, with both the exchange of sediment between shore sectors on the coast and within Anderson Inlet, and the changes occurring in the position of the ebb and flood channels at the entrance to Anderson Inlet.

The range of factors, including metocean conditions and sand sources, that have contributed to these changes requires detailed analysis.

Coastal Dune System

The current-day, surf beach dunes were formed by wind action over the last 3,000 -4,000 years, once the previously higher sea levels (about one metre higher than present) fell and stabilised. Almost 50% of the volume of these dunes has been removed, leading to the recession of the shoreline that has occurred since 2013.



Last Interglacial / Mid-Holocene High Sea-Level Cliff and mid-Holocene and modern dunes. Profile drawn from coastal and bathymetric LiDAR. (Vertical Exaggeration x 5).

Bluff is a steep slope 20 metres high at edge of coastal plateau north of Cape Paterson - Inverloch Road

- Was in active cliff at Last Interglacial Stage high sea-level and again during mid-Holocene high sea-level

Geomorphological Values

Active cliffs, Last interglacial bluff, older and modern Holocene dunes west of Inverloch. Location of profiles across cliffs and bluff. (Image from Google Earth Dec 2018).

Ayr Creek Lagoon

Following the accumulation of sand at a spit on the ocean-side of Pt Norman in 2010, a continuous coastal barrier has formed linking Pt Norman to Pt Hughes. A now-enclosed lagoon exists behind the barrier. The barrier is progressively extending east into Anderson Inlet.

Based on very preliminary estimates, it appears that the volume of sand accumulation between Pt Norman and Pt Hughes significantly exceeds the volume of sand eroded from the shoreline between Flat Rocks and Pt Norman, over the same period.

Further investigations are needed to identify the additional source of sand, and possible scenarios for the future configuration of Anderson Inlet.

The forthcoming Local Coastal Hazard Assessment for the Inverloch coast needs to examine the complex inter-relationships between coastal processes and the surf beach, Anderson Inlet and Pt Smythe, as well as sources of sediment for the entire coastal area.

Economic Values

The coastline is arguably Australia's most important recreation resource with natural, undeveloped settings being highly valued by residents and visitors. These values are increasingly at risk from the effects of rising sea levels and other climate change effects.

Over the summer, recreation activities at Inverloch surf beach were adversely affected by:

- Very little dry sand at high tide
- Unstable dunes that posed a risk to beachgoers
- The need to move the Inverloch SLSC lookout tower to another new location
- Very steep access tracks that were difficult to negotiate
- Erosion very close to Bunurong Coastal Drive

A preliminary economic valuation has found that resident and tourism values at risk from further sustained coastline erosion translate to a financial cost of more than $3M per year.

Wet-Sand Fencing Trial

As a short term measure, two 50m sections of double row wet-sand fencing have recently been installed to protect threatened infrastructure at Inverloch Surf Life Saving Club and Bunurong Road. In addition, a 5 metre stretch of foredune will be filled to 1.5m above the current beach level, on the dune side of the fence.

Constructed using thin, vertical slats of timber connected by wire, the fence is designed to decrease the energy of incoming waves, allowing sand to accumulate behind the fence.
It is likely that other medium and long term measures will be required in the future.


Sandy Point 2019

Recommended Actions

Actions recommended following installation of the wet-sand fence

- Revegetate the re-formed foredune with native grasses such as Hairy Spinifex and plant appropriate native shrubs, and monitor
- Cordon-off area between the re-formed foredunes and either end of the sand fences

Other recommended actions for 2019 are:

- Supplementary planting of rear dune, including Coast Banksia Woodland at Flat Rocks
- Control weeds and replant vegetation to increase dune resilience
- Control pests, especially foxes and rabbits

In the event that the trial proves to be successful over the 2019 winter, consider extending the wet-sand fence to protect the ecological, cultural heritage, geomorphological and economic values of the broader dune system, from Flat Rocks to Pt Norman.

Plan for and initiate (during 2019) a Local Coastal Hazard Assessment to analyze coastal processes at play at Inverloch and to determine the most appropriate medium term control measures, including such options as augmentation of existing reefs, rock groynes and offshore reefs, as well as long term adaptation strategies.

Sustainably-seeking Inverloch

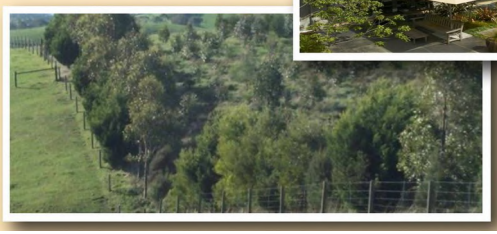
Inverloch needs to play its part in containing climate change-related impacts, such as sea level rise.

South Gippsland Conservation Society is developing a framework for local actions that are consistent with limiting global temperature increase to less than two degrees, in accordance with the 2015 Paris Climate Agreement.

Possible actions by 2030 could include:

- 50% renewable energy and battery storage
- Electric vehicle charging stations
- Hydrogen-powered buses and trucks
- Network of bike lanes and shared paths
- Maintaining town boundary limits
- Establishment of wildlife corridors
- Community gardens for food production
- Low impact recreation activities

Will you join us in developing this initiative?



Research Projects Underway

Research projects underway at Melbourne and Deakin Universities (for the Victorian Coastal Monitoring Program) are of direct relevance to Inverloch.

Modern Dune Dynamics on the Inverloch Spit

This project is monitoring the development cycle of the sand spit and foredunes that have formed at the former channel entrance to Anderson Inlet since 2013. The role of different plant species in foredune development, including Sea Wheat Grass, Marram Grass and Coastal Spurge (initial exotic colonisers) and native Hairy Spinifex (also now colonising the site),will be examined.

Spinifex sericeus: Spinifex Grass

Thinopyrum junceiforme: Sea Wheat Grass

Vegetation of the incipient dune at Inverloch.

Predicting Future Geomorphological Change along Victoria's Coastline

Innovative numerical modelling techniques are being used to predict the possible extent and nature of shoreline erosion at threatened sections of the Victorian coastline, including Inverloch. The predictions will take account of climate change effects including sea level rise, changing patterns of storm activity and variance of the wave climate.

Further details of these projects are provided elsewhere in this exhibition.

Predicting future geomorphological change along Victoria's Coastline, using innovative numerical modelling techniques

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Introduction

Coastal environments are increasingly being influenced by processes of climate change that can induce geomorphological change. Sea level rise, changing patterns of storm activity and variance in the wave climate can alter sediment dynamics, including pathways and supply. This can lead to an increased risk of coastal erosion and flooding in vulnerable localities.

Understanding the response of coastal systems to changes in environmental conditions is key to predicting their future evolution and the potential impact this could have on enviro socioeconomic factors. Our ability to predict long-term climate driven morphodynamics could lead to more informative decisions concerning management practices and adaption measures.

Forming part of the Victorian Coastal Monitoring Program (VCMP), this research uses innovative modelling techniques to predict the future morphodynamics of the Victorian coastline, south east Australia. Numerical models provide powerful tools for understanding and predicting behaviours in coastal systems, although a compromise is often found between model complexity and scale.

Research Questions

- What primary processes are influencing coastal morphodynamics along the Victorian Coast?
- How might sediment transport pathways change over time?
- How might each of the study sites (Figure 1) behave under changing environmental conditions (including wave climates, storm activity and sea level change)?
- Will the shoreline recede with sea level rise and what is the nature of that recession?

Sites of Interest

Figure 1 *Outline Map of the coast of Victoria, with the location of sites of interested (images given above)*

Models of Interest

Numerical models are designed to address specific types of coastal systems and the dominating processes over varying spatiotemporal scales. Each site of interest (Figure 1) presents a different modelling challenge and as such, a range of models have been selected to suit each study site. Four principle models have been selected at this preliminary stage:

COVE	CEM2D	XBeach	Delft3D
One-line vector model	2D 'smudge line' model	2D wave and sediment transport	3D flow and sediment transport
10—100 km, 10—1000 years	10—100 km, 10—1000 years	Kms, storm scale	1—10 km, 0-1 years

PhD Research - CEM2D

University of Hull (UK)

CEM2D was developed as part of my PhD research into the morphodynamic behaviour of sandy, wave-dominated coastal systems. In Figure 2 the role of different wave and water level scenarios on two-dimensional coastal morphodynamics is presented. These processes influence the sediment budget, the direction of sediment transport and the balance between supply and submergence. This influences the coasts evolution including the shape of the planform shoreline and it's morphology.

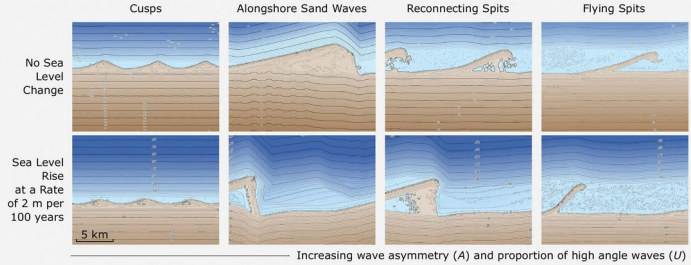

Figure 2 *Outputs from CEM2D showing the influence of different wave conditions and sea level change on coastal morphodynamics*

CEM2D and the results of my PhD research will be used to explore the morphodynamics behaviour of the Victorian Coastline, forming the first site-specific application of this model.

Conclusion

This study will explore the short to long-term geomorphological evolution of the Victorian Coastline under changing environmental conditions. The project will focus on a number of key sites of interest (Figure 1) to decipher more specific evolutionary behaviours.

The use of numerical models to investigate the behaviour of the systems to date is limited in this region and so the results will provide an advanced insight into how this stretch of coastline may evolve in the future.

Acknowledgements: This project is supported through funding from Department of Environment, Land, Water & Planning, as part of the Victorian Coastal Monitoring Program (VCMP) in partnership with Deakin University and the University of Melbourne.

Modern Dune Dynamics on the Inverloch Spit

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Introduction

Incipient dunes, are found closest to the ocean, forming small sand mounds, just above the elevation of spring high tide as sand accumulates in and around pioneer species of vegetation or swash deposited debris.

The formation of incipient dunes does not necessarily occur uniformly on the backshore. Hummock shaped dunes, often termed shadow dunes, form on the downwind side of debris and vegetation. It is the fact that the size and shape of plants changes over time (they grow), that results in the formation of dunes. As vegetation growth occurs the sand trapping process also changes, and more sand is deposited in and around the vegetation, and over time the dune shape increases both laterally and vertically, these larger dunes are termed foredunes.

There is currently a deficient in quantitative knowledge of the role which species of coastal plants such as *Spinifex sericeus*, *Thinopyrum junceiforme, Ammophila arenaria* and *Cakile edentula* play in the in the formation and morphology of incipient dunes.

Management Question

In 2014 a large spit was developed at the mouth of Andersons Inlet sourced from sand eroded from the west.

This bare sand spit was rapidly colonised by exotic species.

These species are known globally to fix sand to a greater ability than natives .

This may limit the natural recycling of sediment from the spit back onto the beaches to the west.

This project is focussed on understanding how these plants are affecting sand movement.

The formation of a sand spit and growth of incipient dunes at Inverloch Victoria

Figure 1: Google earth images of the growth of the sand spit at Inverloch from 2010 to 2017.

Studies of foredune dynamics occur on systems that are already established and have often existed for millennia. There is little understanding on the evolution of these systems from the first accumulation of debris to a mature dune form.

This project will quantify a complete foredune development cycle at Inverloch. A bare spit formed after 2010, in the former channel entrance to Anderson Inlet, on which a foredune of meter-scale relief has now developed. This project will document dune develop from time -zero and will reveal the role of specific plant species in foredune development.

Methods

Vegetation surveys and foredune mapping form the core of this project. The 2010 Future Coasts LiDAR provides a baseline dataset which will be combined with terrestrial UAV LiDAR collected in 2016 and supplemented by field quadrat-based vegetation surveys collected in November 2016 .

Citizen-science surveys as part of the Victorian Coastal Monitoring Program, will continue to monitor the sites using UAV-based photogrammetry supplemented by field quadrat-based vegetation surveys. Vegetation surveys will be conducted every 6 months.

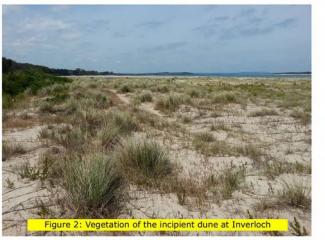


Figure 2: Vegetation of the incipient dune at Inverloch

Vegetation of the incipient dune at Inverloch spit

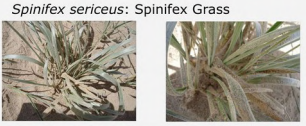
The incipient dune at the Inverloch spit was initially dominated by the exotic species of plants:

- *T.junceiforme* (Sea Wheat Grass)*,*
- *A.arenaria* (Marram Grass*)*
- *E.paralias* (Coastal spurge).

Australian native grass *S.sericeus* (Spinifex grass) is also now colonising the site.

Plant growth attributes that influence sand capture

Spinifex sericeus: Spinifex Grass



Thinopyrum junceiforme: Sea Wheat Grass

The more hirsute leaves of the Spinifex plant in combination with greater length and width, enable it to trap sand at a greater rate than the Sea Wheat Grass

Figure 3: Comparison between different leaf structure of Spinifex Grass and Sea Wheat Grass.

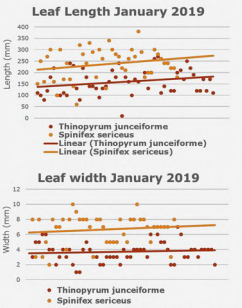


Figure 4: Comparison between leaf width and leaf length of Spinifex Grass and Sea Wheat Grass

Conclusion

The initial formation of the incipient dune at the Inverloch Spit has been dominated by exotic species, which have resulted in the formation of a hummocky dune morphology.

The more recent growth of Spinifex grass amongst the exotic species has the potential to change the morphology of the dune form.

Acknowledgements: This project is supported through funding from Department of Environment, Land, Water & Planning, as part of the Victorian Coastal Monitoring Program (VCMP) in partnership with Deakin University and the University of Melbourne. This project is also supported through funding from the Earth Systems and Climate Change Hub of the Australian Government's National Environmental Science Program

Citizen Science UAVs for Monitoring Shoreline Change

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Introduction

Climate change is projected to increase risks to coastal environments through drivers such as sea-level rise, changes in wave-direction and increases in swell energy and storm tide events. These drivers affect coastal erosion, sediment supply and inundation and are expected to vary geographically across Victoria's coastal zone.

We have developed an integrated system of modelling shoreline change, and the rate of coastal erosion or accretion and sediment budgets over different temporal scales using Unmanned Aerial Vehicles, or UAVs. UAV coastal mapping provides an effective, non-destructive way to monitor shorelines that have been difficult to achieve with traditional approaches. The resultant data can be used for assessing and monitoring shoreline change, sand erosion and accretion, land slips, sand height, and cliff change.

The Victorian coastline is too vast to us to monitor alone. For that reason, the Victorian Coastal Monitoring Program (VCMP) is training Citizen Science groups in the use of UAVs for Monitoring Shoreline Change in priority areas. The Citizen Science groups operate under the < 2 kg Excluded category for UAV operation in the We are providing the communities with the skills and understanding to capture meaningful data on coastal change, and subsequently inform management processes along the entire Victorian coastline.

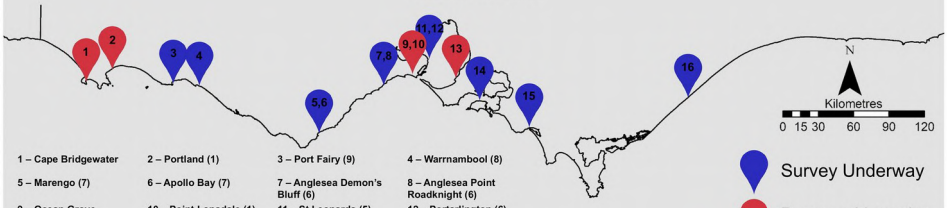
Equipment and Training

Each Citizen Science group is provided with professional survey-grade equipment, including:

- DJI Phantom 4 Pro
- 3 Batteries
- Spare Propellers and SD Cards
- Launch Pad
- iPad Mini
- Propeller AeroPoint high-precision PPK Ground Control Points
- Standard Survey & Operational Procedures for UAV Mapping Coastal Erosion

The survey methods were designed for citizen science groups to maximise the collection of geophysical information related to shoreline change within a timeframe of half a day using a single airframe, 3 batteries and smart targets for positioning.

Sites of Interest

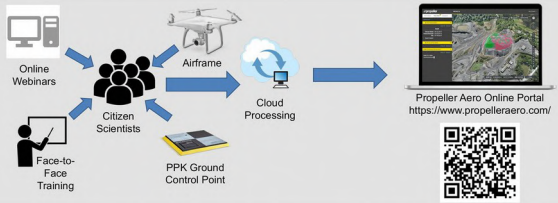


1 – Cape Bridgewater
2 – Portland (1)
3 – Port Fairy (9)
4 – Warrnambool (8)
5 – Marengo (7)
6 – Apollo Bay (7)
7 – Anglesea Demon's Bluff (6)
8 – Anglesea Point Roadknight (6)
9 – Ocean Grove
10 – Point Lonsdale (1)
11 – St Leonards (5)
12 – Portarlington (6)
13 – Mount Martha
14 – Cowes (5)
15 – Inverloch (4)
16 – Seaspray (4)

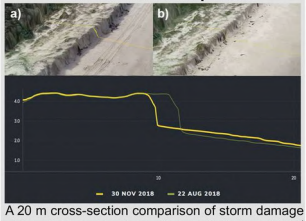
Data Processing

We have teamed up with PropellerAero, a cloud-based data processing and analysis portal. The portal was developed for the mining and surveying industry, but is extremely intuitive and user-friendly.

The PropellerAero Online Portal ensures the data is freely accessible to land managers and the wider community not only to visualise, but to take measurements and perform analysis. From this, we are able to visualise and calculate the extent of coastal erosion and accretion at priority locations along the Victorian coastline.



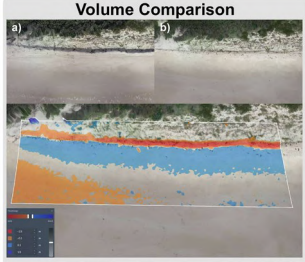
Cross-Section Comparison



A 20 m cross-section comparison of storm damage at Inverloch over a 4-month period a) August 22nd 2018, b) November 30th 2018. Over this time, over 1.5 m has been lost from the dune face, but the height of the beach in front of the dune has increased by approximately 20 cm.

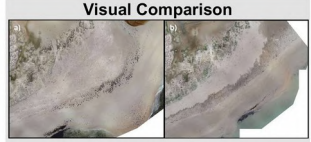
Acknowledgements: This project is supported through funding from Department of Environment, Land, Water & Planning, as part of the Victorian Coastal Monitoring Program (VCMP) in partnership with Deakin University and the University of Melbourne.

Volume Comparison



A volume comparison of sand movement along a 100 m section of beach at Inverloch over a 4-month period a) August 22nd 2018, b) November 30th 2018. Red indicates erosion, and blue indicates accretion. Over 470 m^3 of sand has changed position in just 4 months, resulting in a net loss of approximately 70 m^3 of sand.

Visual Comparison



A visual comparison of the change at Inverloch between. a) August 22nd 2018, b) November 30th 2018. There has been significant change in the volume of sand at the inlet mouth and the opening of the lagoon.

Conclusion

The VCMP Citizen Science Coastal Monitoring Program has currently trained 24 community members in the safe operation of UAVs, independent data collection by the Citizen Scientists at 5 sites, and 70 datasets collected across the 11 sites currently being monitored. By June 2019, we intend to have baseline data collected at all the identified priority locations, and independent data collection by the Citizen Scientists at 9 sites. By the end of 2019 we intend for data collection at all sites to be undertaken independently by the Citizen Scientists.

Acknowledgements

South Gippsland Conservation Society would like to thank all those who have contributed to this exhibition, including:

- Lord Mayor's Charitable Foundation
- Department of Environment,Land,Water and Planning
- Bass Coast Shire Council
- Parks Victoria
- Inverloch Historical Society
- Aileen Venning (Sustainably-Seeking Inverloch)
- Oates Environmental Consultants (Flora & Fauna)
- Joanna Freslov (Cultural Heritage)
- Econsult (Economics)
- Neville Rosengren (Geomorphology)
- Deakin University (Coastline Monitoring)
- Melbourne University (Research Projects)

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Panoramic heading banner created by Dr. David Smith
Exhibition display - Colin Suggett

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