# Developing and trialling a citizen science approach to mudflat condition monitoring in Gulf St Vincent, South Australia

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# Executive summary

The Samphire Coast in Upper Gulf St. Vincent are important foraging grounds for migratory shorebirds and fish. Mudflats are a distinct habitat in the region and previous surveys in 2008, 2012 and 2018 by Flinders University have investigated the importance of macroinvertebrate epifauna and infauna in sediments across the expansive intertidal zones. However, the field sampling of food availability in sediments and condition of sediments is often very time consuming for regular (e.g. seasonal or yearly surveys) assessments by scientists. Thus, for this project, a citizen science protocol was established, trialled and tested to examine the feasibility, scientific accuracy and precision for a continuing mudflat monitoring program that can align with the migratory shorebird surveys already being conducted with citizen science groups along the Samphire Coast.

Quadrat counts and sediment core sampling are easy to use methods and were selected as useful scientific equipment for citizen science mudflat monitoring trials at Port Gawler during April 2019. The citizen science group received training from experienced researchers from Flinders University on the scientific approach to mudflat monitoring, use of sampling equipment and identification of macroinvertebrate taxa. Citizen scientists sampled the mid and high tide zones of the mudflat and did some counting of macroinvertebrate fauna in the field, which was then conducted by experienced researchers so that two separate datasets could be analysed further for accuracy. However, assessment of the datasets collected by citizen scientists and experienced researchers from quadrat counts and sediment cores were not correlated. Further investigation revealed that the difficulty in determining whether very small bivalves and gastropods were alive or dead was an underlying issue that resulted in over-or-under representation by citizen scientists, compared to experienced researchers. Therefore, we suggest further training between experienced researchers and citizen scientists so that identification of macroinvertebrates can be improved over time. A smaller shell size threshold could also be introduced for some of those molluscs that are difficult to identify, to make it easier for citizen scientists to differentiate between live and dead specimens. Overall, the citizen science protocol was positively received by those individuals that were involved in the mudflat monitoring trial and useful feedback was provided by them so that the citizen science guide for monitoring mudflats could be adapted into a useable manual in future.

# 1. Background

Along the Samphire Coast in Gulf St Vincent, a large expanse of mudflats provides important foraging grounds for migratory shorebirds, juvenile fish and prawns. Their main prey items are benthic macroinvertebrates, such as molluscs, polychaete worms and crustaceans, which are abundant in these mudflats (Ditttmann et al. 2012). The relevance of the Samphire Coast for overwintering shorebirds led to the proclamation of the Adelaide International Bird Sanctuary National Park – Winaityinaityi Pangkara National Park, which covers most of the tidal wetlands of the Samphire coast. Data for performance assessments and conservation management can come from condition monitoring, however, scientific monitoring of benthic communities can be costly due to the time needed to sort through samples, identify and count macroinvertebrates. Instead, involving volunteers as citizen scientists can provide cost and time effective solutions for monitoring over a larger spatial and temporal scales (Thiel et al. 2014; Vermeiren et al. 2016).

For intertidal ecosystems, citizen science programs have focused on migratory birds rather than their food sources such as molluscs and crustaceans (Chandler et al. 2017; Studds et al. 2017). Citizen science programs have been implemented to detect climate change induced range shifts in organisms, river health through monitoring freshwater invertebrates, marine debris surveys, or to collate observational records of iconic or non-indigenous species (Thiel et al. 2014; Jackson et al. 2016; Bean et al. 2017; Pecl et al. 2017). Additional benefits of citizen science include education, understanding or awareness of ecosystem ecology which, in turn, grows public literacy for the benefit of conservation and restoration efforts (Silvertown 2009; Boero et al. 2015; Huddart et al. 2016). Globally, citizen science is increasingly included as a component of monitoring programs, due to the value-add provided to conservation (Jackson et al. 2016).

Citizen science programs can be extremely valuable if planned and managed well, but they can also be marked with controversy (Vann-Sander et al. 2016). Some of the issues with citizen science approaches which should be managed during the planning of pilot programs include; data quality assurance, data management, continuity and reliability of data collection, and clear objectives with simple hypotheses (Silvertown 2009; Dickinson et al. 2010; Conrad & Hichley 2011; Tulloch et al. 2013; Bird et al. 2014; Hyder et al. 2015; Huddart et al. 2016; Kosmala et al. 2016; Swanson et al. 2016; Vann-Sander et al. 2016; Vermeiren et al. 2016, Bean et al. 2017). Also, citizen science monitoring often applies semi-quantitative methods and coarser taxonomic resolution, so the sensitivity to detect changes can be lower (Huddart et al. 2016). A review by Thiel et al. (2014) identified that volunteers found identification of species and estimating abundances most challenging. Thus, expertise and identification skills of volunteers for citizen science projects needs to be increased through workshops and training by qualified personnel (Huddart et al. 2016, Vermeiren et al. 2016). Communication is key between qualified experts and volunteers so that citizen scientists can receive ongoing training to build confidence in what they are doing, and gain a sense of ownership for the project (Conrad & Hilchey 2011; Tulloch et al. 2013; Cigliano et al. 2015; Hyder et al. 2015; Huddart et al. 2016; Levesque et al. 2016; Vann-Sander et al. 2016). For citizen science projects to be successful there need to be clear program and community outcomes built upon mutually beneficial and stable partnerships (Jordan et al. 2012; Cigliano et al. 2015; Levesque et al. 2016). Carefully planned synergies with other already established programs can also be beneficial for advancing individual learning and motivation of citizen scientists (Jordan et al. 2012; Cigliano et al. 2015; Chandler et al. 2017).

Monitoring of benthic communities in intertidal mudflats can inform on the conservation status and improvements over time (Warwick & Somerfield 2015), and is usually carried out by trained experts. Citizen science approaches for mudflat monitoring has not been attempted, with identification skills being one of the obstacles. Previous monitoring in mudflats of Gulf St Vincent has revealed a high diversity of benthic macroinvertebrates, with site-specific patterns for abundance and community composition (Dittmann et al. 2008, 2012). Already established community-based citizen science groups that monitor shorebirds in the Adelaide International Shorebird Sanctuary provided an opportunity to incorporate a citizen science component into monitoring of mudflats in the region. The aim of this project was to design a citizen science protocol for long-term mudflat condition monitoring, trial it, and refine the protocol based upon community feedback. The refinement also considered an analyses of community versus expert data for some methods, with recommendations of progression towards a citizen science program over time.

# 2. Approach & methods

The project included three stages (i) the development of a protocol, (ii) a trial conduct of the protocol with community volunteers, and (iii) a refinement and finalisation of the protocol.

## 2.1 Development of a citizen science protocol

From previous mudflat monitoring in Gulf St Vincent (Dittmann et al. 2008, 2012) and recent mudflat monitoring in 2018/19 at four sites (Section Bank, Port Gawler, Middle Beach, Thompson Beach/Port Prime, Figure 1), we evaluated the various methods that could be used for monitoring macroinvertebrates and sediment condition. Methods used in the condition monitoring included timed searches for 10 minutes, taking sediment core samples, quadrat counts, sediment vertical profiles and burrow counts. A further method (emergence traps) as a non-invasive technique was trialled, but due to loss of several traps from dislodgement or other causes, was discontinued, despite attempts to improve the trap design.

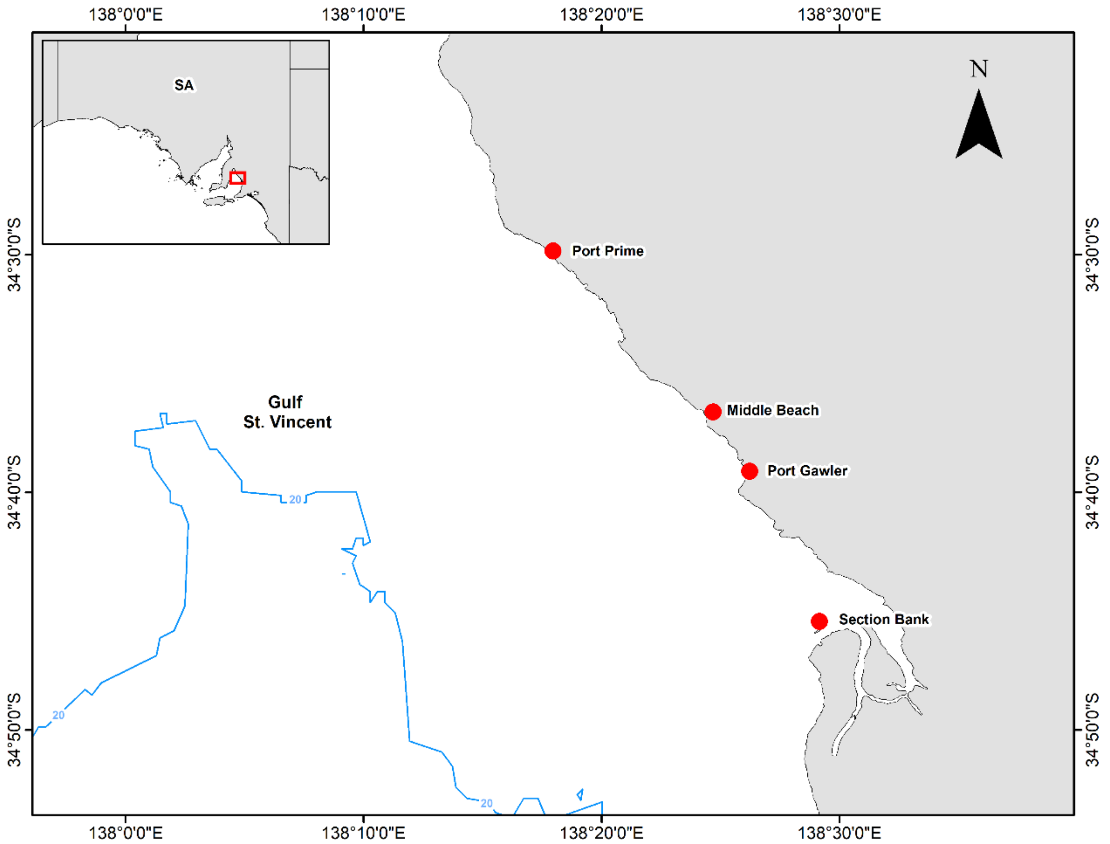



**Figure 1**: Location of the mudflat monitoring sites in Gulf St Vincent, South Australia. PP = Port Prime/ Thompson's Beach, MB = Middle Beach, PG = Port Gawler, SB = Section Bank. The site for the citizen scientist field trial was Port Gawler.

Criteria to evaluate the potential of a particular method for citizen science monitoring included; ease of use, rapid assessment, potential as surrogate, requirement to identify fauna at least to a coarse taxonomic level in the field. A preliminary protocol was a drafted, and used for the community-based trial in the field, to determine what information was redundant or if more information was further required.

## 2.2 Trial of community based mudflat monitoring

The preliminary citizen science protocol for mudflat monitoring was trialled in early April 2019 at the Port Gawler monitoring site. This trial occurred later than originally planned, and only at one site, for several logistic reasons (incl. low tide times), the very hot summer, and availability of community group members.

A group of twelve community-based volunteers and AMLR NRM Board staff were involved in the trial. At the beginning of the trial session, participants received the preliminary protocol field manual and each method was explained to the group by an experienced researcher. Two experienced researchers were on hand throughout the day to help guide participants with methods and taxonomic identifications.

Several methods for macroinvertebrate sampling and sediment condition assessment were used in the high- and mid-tide zones:

- Quadrats (dimensions 0.5 m x 0.5 m) were used to assess epifauna and burrow density. Macroinvertebrate fauna from quadrats were identified *in-situ* to coarse taxonomic levels (e.g. bivalves, gastropods, amphipods) and counted.
- PVC corer (84 $cm^2$) were used to obtain sediment samples, which were sieved in the field through 500 µm mesh to assess macroinvertebrate infauna. The content of each core sample was placed into a sorting tray, and macroinvertebrate fauna identified *in-situ* to coarse taxonomic levels (e.g. bivalves, gastropods, amphipods) and counted.
- Sediment was excavated using shovels to obtain vertical sediment profiles, record depth of oxic depth using sediment colour, number of burrow present, and maximum burrow depth.

Ten replicate samples of each method were taken in each of the two tidal zones and all sampling was undertaken haphazardly.

Every quadrat sample was also assessed separately for macroinvertebrate identification and counts at the finest possible taxonomic level (e.g. family or species) by experienced researchers. All core samples were kept and frozen for future identification to finer taxonomic levels and individual counting by experienced researchers back at the Flinders University laboratory.

## 2.3 Refinement of the protocol for mudflat monitoring through citizen science

After the field trial, accuracy of abundance estimates and community structure were assessed with correlations between data obtained from citizen scientists and professional scientists. Total abundance data for macroinvertebrates, gastropods and bivalves were analysed using PERMANOVA tests based on Euclidean Distance matrices for data obtained by the community group and experienced researchers from the two tidal zones at Port Gawler. For community structure, we tested whether differences in communities between zones were detected regardless of the origin of the data set. This test was done through a second-stage (2stage) analysis, a rank correlation between multivariate similarity matrices (Clarke & Gorley 2015). The two similarity matrices compared were the one from the community group and one from experienced researcher data. The closer the Spearman correlation is to 1, the more similar the resemblance matrices. Non-Metric Multidimensional Scaling (nMDS) plots of community data from community groups and researchers were also assessed separately and PERMANOVA tests were conducted to determine differences across zones. It could then be assessed whether similar statistical test results were detected from the two separate datasets, e.g. whether differences between zones emerged from monitoring by the community group and/or researchers. All data were fourth-root transformed and analyses were conducted in PRIMER/PERMANOVA+ V7.

Throughout the field trial, feedback from participants was noted so that refinements could be made to the field protocol manual. The finalised field manual with protocols for each method and the process of mudflat monitoring was thus established based on field participant feedback, assessment of method use and analyses of data from the community group and experienced researchers.

# 3. Results

## 3.1 Protocol development

The development of a protocol for mudflat monitoring that could be used by community groups was drafted based on the 2018/19 mudflat condition monitoring surveys. Based on the methods used in the scientific monitoring, three of the four methods applied were considered to be suitable for citizen science monitoring (Table ...). Timed searches appeared challenging as they require taxonomic knowledge to be able to identify, count and record macroinvertebrates in a time efficient manner (e.g. across a 10 minute period per replicate). Quadrats and cores cover a smaller spatial area and macroinvertebrates can be identified at coarse taxonomic levels (e.g. Class versus Family or Species levels) without the constraint of time as in timed searches. Sediment profiles were easily interpreted for depth of oxic layer, burrow counts and burrow depth, and sediment colour, which could all be quickly recorded in the mudflat monitoring surveys. Based on the mudflat monitoring field surveys, a citizen science protocol was drafted to trial and determine what would and would not work.

**Table 1**: Overview of methods for mudflat monitoring and evaluation of their suitability for use in a citizen science protocol.

| Method | Advantage | Disadvantage | Suitability for citizen science |
|---|---|---|---|
| Timed search | Rapid assessment method capturing rarer or more mobile species which could be otherwise missed. | Requires solid taxonomic knowledge of species to quickly ID on site | Unsuitable |
| Sediment cores | Potentially quantitative method capturing macroinvertebrates in a defined area to a set depth; common practice in benthic ecology. Samples could be retained for further scientific study. | Requires several steps (extraction of sediment, sieving, sample analysis). Analysis of sample content in the field less accurate as expert analysis in lab. Requires some knowledge for identification | Suitable |
| Quadrat count | Rapid method to assess presence or absence of epifaunal organisms and burrowing infauna. Easy to use. Burrow counts possible surrogate for density. | Requires guidance for interpretation of surface signs and some taxonomic knowledge for identification | Suitable |
| Sediment profiles | Rapid assessment of sediment condition and infaunal activities. Easy to use method. Requires no taxonomic skills. | Guidance required for interpreting sediment patterns | Suitable |

The citizen science mudflat monitoring manual was drafted with an introduction section that described a background to the monitoring program, personal requirements and safety information for working in mudflat environments, followed by a description of data collection methods (e.g. quadrats, cores and sediment profiles). Data sheets were also prepared for community groups to use, based on standard field data sheets used in other mudflat monitoring programs as a starting point. These were refined based on feedback from citizen scientists. The data sheets include field site information, vertical sediment profiles, quadrat counts for activity signs and macrofauna and sediment core macrofauna count sheets. At the end of the manual, a list of common species with photographs were included to facilitate identification of the most common species.

## 3.2 Protocol trial with community volunteers

The field trial at Pt. Gawler with community volunteers was successful. Participants were comfortable with the instructions given at the beginning of the day. All community members picked up the techniques quickly and were soon conducting the various methods smoothly. Two experienced researchers were on hand to instruct the group of volunteers, clarify methods and answer any questions. The community volunteers were very interested in the importance of mudflat monitoring and how it could be introduced as a value-add exercise to the current citizen science shorebird-monitoring program.

Sediment profiles were the easiest method for community members to use, with simple measurements of oxic depth, burrow depth and burrow counts easily interpreted and understood. Based on quadrat counts, findings form citizen scientists and researchers were compared to evaluate whether monitoring outcomes (difference in mudflat fauna between zones) would be subject to who conducted the survey. The total abundance, as well as the abundance of gastropods which were most commonly recorded from quadrat samples, were significantly higher between zones based on the citizen science counts, but not from the researcher counts (Figure 2a, b; Table 1a). For bivalve abundances and the number of burrows counted in quadrats, no significant difference was detected between zones for counts by citizen scientists and researchers (Figure 2a, b; Table 1a).

For macroinvertebrate community structure from quadrats, the citizen scientist's data detected a significant difference between zones, which was not detected by the researchers (Figure 3a, b; Table 1a). Using 2Stage analysis, we identified that the similarity matrices based on citizen scientist and researcher data were very different (Spearman Rank correlation -0.03). Differences in community structure detected thus depended on the source of the underlying data set.

For core samples, a great difficulty was taxonomic identification and counts of macroinvertebrates. This was particularly noticeable for some of the smaller gastropods that are difficult to differentiate as live or dead with the naked eye; resulting in under-or over-estimates in counts by community members. Using 2Stage analysis, we identified that the similarity matrices based on citizen scientist and researcher sediment core data were different (Spearman Rank correlation 0.19).

In sediment core samples, abundances of all macroinvertebrates, as well as gastropods and bivalves, were significantly higher in the high tide zone from samples counted by citizen scientists (Figure 2c; Table 1b). Analysis of sediment core samples by researchers at Flinders University identified significantly higher abundances of total macroinvertebrates in the mid-tide zone (Figure 2d, Table 1b). Researcher data of gastropods and bivalves showed similar abundances between zones with no significant different differences identified between zones for those groups. Sediment core data from both the citizen science and researcher datasets showed significantly different communities between zones (Figure 4; Table 1b).

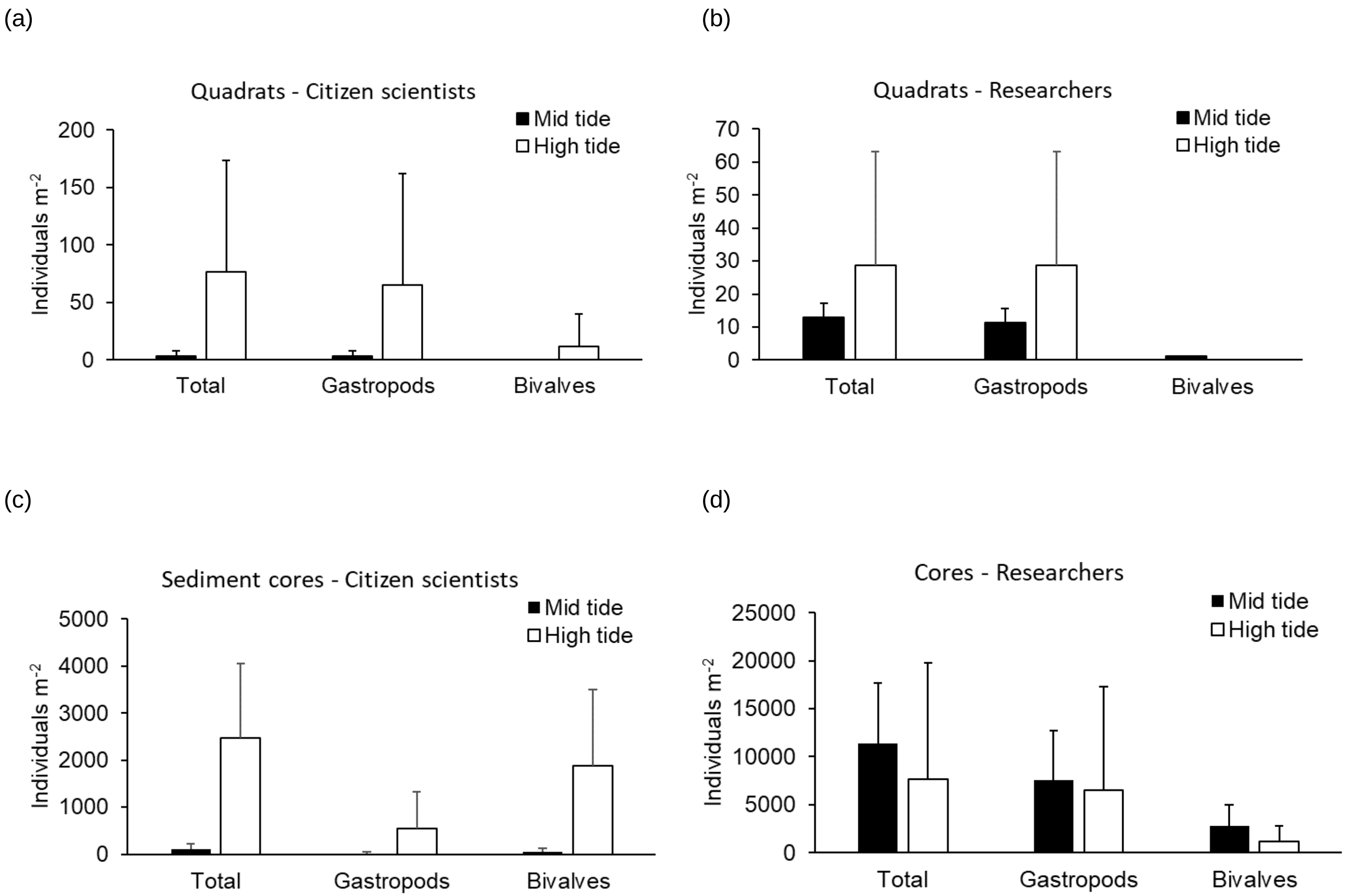



**Figure 2**: Abundances for total macroinvertebrates, gastropods and bivalves in the mid-and high-tide zones at Pt. Gawler counted by (a) citizen scientists and (b) experienced researchers in quadrats and, in sediment cores by (c) citizen scientists and (d) experienced researchers.

**Table 1**: PERMANOVA results for analyses between zones of (a) quadrat and (b) core count data for; total macroinvertebrates, gastropods, bivalves, burrow counts and community structure. CS, citizen scientists; R, Researchers; R (fine), Researchers fine taxonomic level. ns = non-significant result *p* >0.05. TBA = to be announced

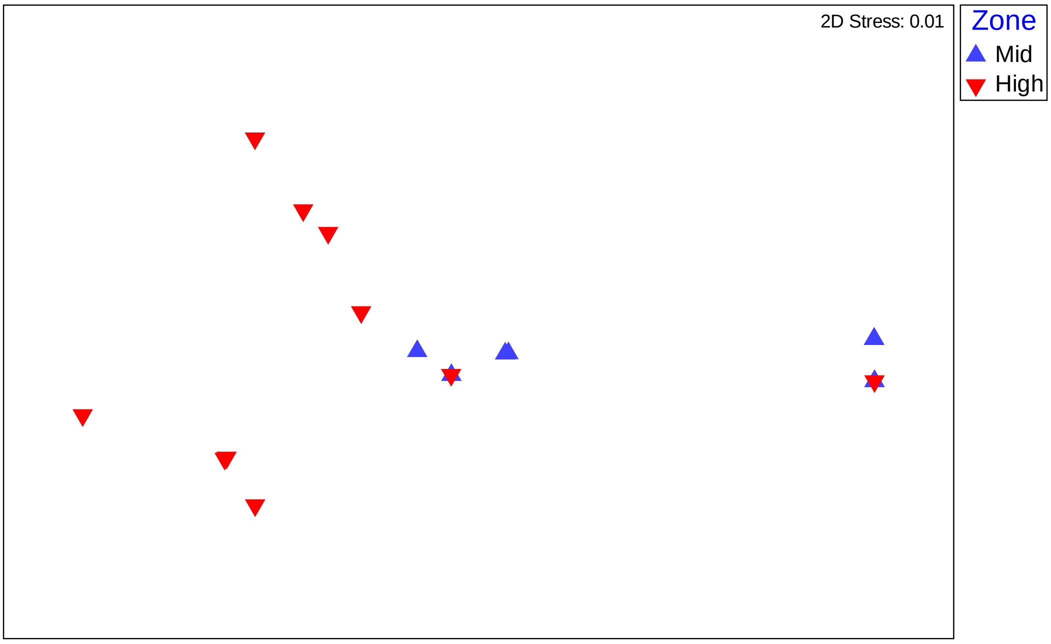
(a)

| **Quadrats** | | Total | | Gastropods | | Bivalves | | *Burrows* | | *Community* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CS | R | CS | R | CS | R | CS | R | CS | R |
| | *df* | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ |
| Zone | 1 | 0.002 | ns | 0.004 | ns | ns | ns | ns | ns | 0.005 | ns |
| Residual | 17 | | | | | | | | | | |

(b)

| **Cores** | | Total | | Gastropods | | Bivalves | | *Community* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CS | R | CS | R | CS | R | CS | R | R (fine) |
| | *df* | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ | $P_{(perm)}$ |
| Zone | 1 | 0.002 | 0.047 | 0.02 | ns | 0.004 | ns | 0.006 | 0.018 | 0.0005 |
| Residual | 17 | | | | | | | | | |

(a)

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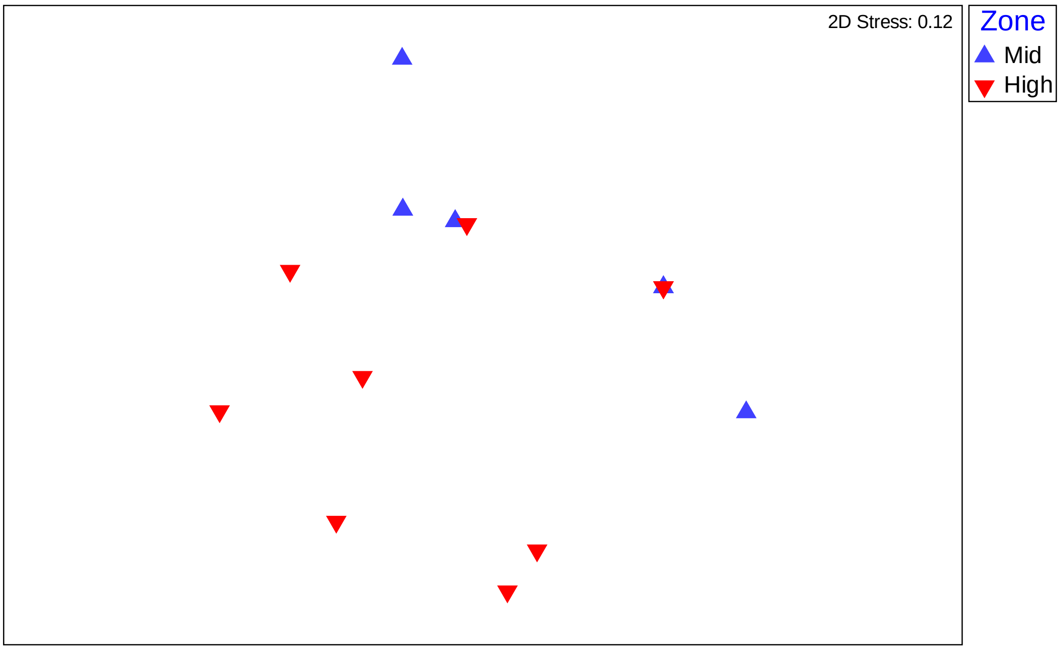
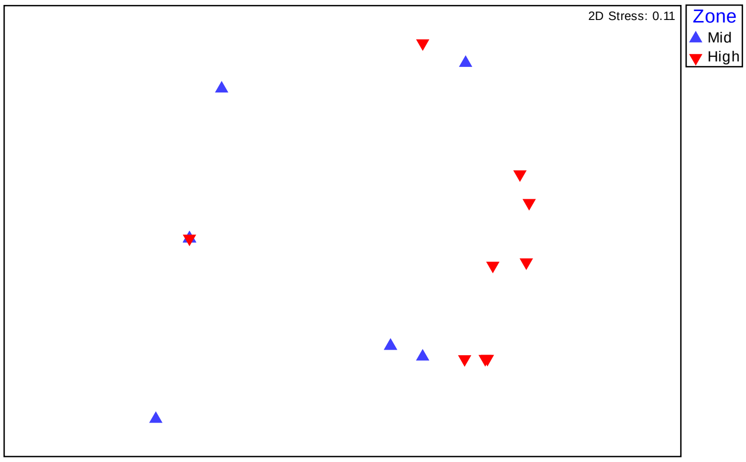
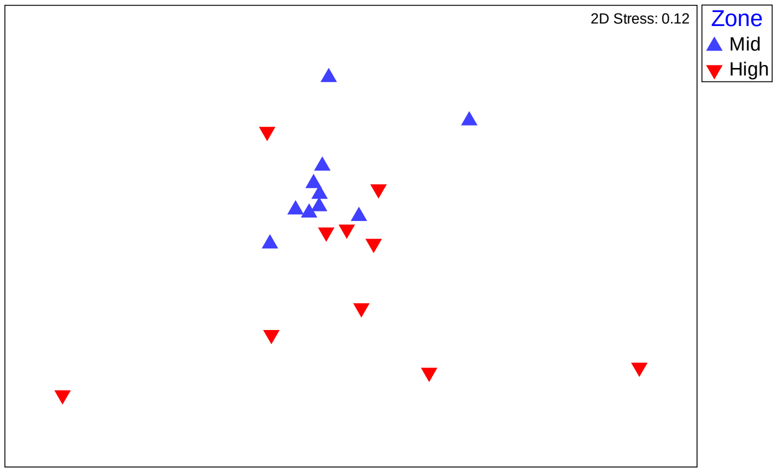



**Figure 3**: Macroinvertebrate community structure of mudflats in the mid- and high-tide zones at Pt. Gawler from quadrat counts based on (a) citizen science data, and (b) experienced researcher data.

(a)




(b)




(c)

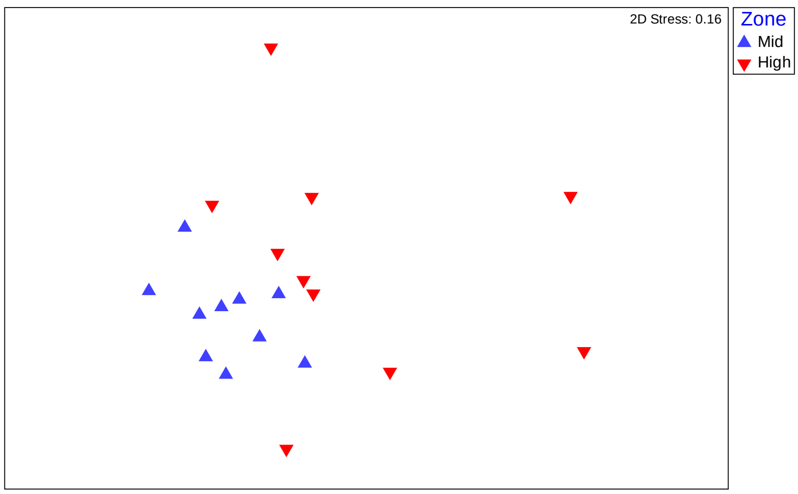



**Figure 4**: Macroinvertebrate community structure of mudflats in the mid- and high-tide zones at Pt. Gawler from sediment core samples based on (a) citizen science data, (b) experienced researcher data and (c) at finer taxonomic level for the experienced researcher data.

.3.3 Refinement of protocol from reflection of community volunteers

During the field survey, community volunteers were asked to provide feedback about the field protocol for the various methods and any suggestions for further refinement of the field manual. Particular aspects that individuals suggested for improvement in the field document and the field survey process were;

- The citizen science manual needs to be supplied with detailed maps of where sampling should be conducted with reference to vegetation, tidal height and any other identifying features.
- Flipbooks with taxonomic photographs and descriptions as identification guides that can easily be kept in the pockets of volunteers during surveys.
- Small identifying illustrations for each taxa could be inserted on data recording sheets for easy, quick reference of major groups (e.g. gastropods, bivalves etc.).
- GPS marks should be recorded as northings and eastings to match the records for shorebird surveys.
- There are too many sheets per site (e.g. tide level), so that should be reduced as much as possible so that there is less chance for sheets to be lost in the field and easy for volunteers to manage.
- Some taxa that are very small can be very difficult to identify and to determine if they are live animals or not (e.g. small gastropods, such as Batillariidae).

Based on the recommendations from the community volunteers, we managed to address some of those suggestions. The number of sheets required for each site has now been reduced from 22 to four pages, which should simplify the management of data recording for volunteers in future surveys (Appendix 1). The GPS records should be identified as Northings and Eastings, which is now displayed on all data sheets as the standard (Appendix 1). We agree that further improvements should focus on some detailed annotated drawings of each of the main taxa against the labels on data sheets for quick reference. A quick reference flipbook could be produced that volunteers can keep handy as a pocket guide to mudflat fauna and where they are found. In the future, maps of each site should be provided at the start of each survey by researchers at Flinders University, with reference points to sampling positions for each method.

# 4. Discussion & conclusion

Through the process of drafting a citizen science protocol and manual, we have identified some things that worked really well or could be refined during this project, and other areas that would require refinement in the future. The protocol we have produced worked well with the community group and with positive feedback, we were able to refine the manual as a quick reference document for citizen scientists to begin monitoring mudflats in the near future. Some aspects of the guide can be further improved with graphical representation of taxa on data sheets and a pocket guide to mudflat fauna for quick access during field surveys.

One of the noticeable discrepancies between citizen scientist and experienced researcher datasets was the lack of correlation between macroinvertebrate community structure due to the over-and-under representation of gastropod and bivalve counts by the citizen scientists. Some of the very small gastropods and bivalves, which can be in dense patches, are difficult to determine as live or dead individuals. In that case, we recommend further training sessions by experienced researchers with the community group. Alternatively, there could be a scaled minimum size limit placed on gastropods and bivalves, in particular to reduce erroneous abundance counts, but that would need to be assessed further to determine if it provides a satisfactory assessment of mudflat condition.

Based on the assessment of the trial, we identified suitable methods which can be applied by citizen scientists, while also detecting the need for further training to avoid inaccurate detection of benthic community patterns in mudflats. As a summary, further steps are suggested to establish a citizen science mudflat monitoring program accompanying the current shorebird monitoring program along the Samphire Coast;

(1) Further training on specific taxa (e.g. gastropods and bivalves)
(2) Pocket taxonomic guide for macrofauna identification
(3) Detailed maps of survey sites
(4) Provide feedback to community groups to improve monitoring capability
(5) Provide community groups with results and reports from ongoing monitoring

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# Appendix 2: Mudflat Monitoring Manual

This version of the manual is refined following feedback from community volunteers during the trial.

# Citizen science protocol:

# Mudflat Monitoring Manual

2019

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## Background

The Samphire Coast, in Gulf St Vincent, is composed of a large expanse of mudflats that are important foraging grounds for migratory shorebirds, juvenile fish and prawns. These mudflats provide rich foraging grounds that consist of benthic macroinvertebrates such as molluscs, polychaete worms and crustaceans (Dittmann et al. 2012). The Samphire Coast is also important as a recently proclaimed National Park (Adelaide International Bird Sanctuary National Park – Winaityinaityi Pangkara), which covers most of the tidal wetlands of the Samphire coast.

To assess the performance and provide advice for environmental management and future improvements to conservation, data are needed and traditionally obtained from scientific monitoring and further targeted investigations. However, scientific monitoring can take time and be costly. . As an alternative, Community volunteers can become citizen scientists (Thiel et al. 2014; Vermeiren et al. 2016).

To monitor the condition of mudflats, and the food available for shorebirds, rapid assessments could be a time and cost effective solution. Such rapid assessment could be carried out by trained citizen scientists, and provide information throughout the year and from multiple shorebird foraging sites  This citizen science protocol includes general considerations for field work conduct and equipment needs, and a manual for data recording in the field. It is intended to be used by community groups, so that you as a citizen scientists can be involved in further understanding mudflat communities and the foraging of shorebirds in the Gulf St Vincent region.

## Personal requirements

Mudflats are an exciting place to explore, but like all natural habitats there are risks involved and conditions can change quickly. To ensure your safety and wellbeing are top priority, please familiarise yourself with the safety guidelines below.

### Safety considerations

#### *Mudflat environments*

Mudflats can be difficult to walk through and the middle to lower tide zones may be very soft resulting in people falling or slipping over. Take your time walking and tread lightly to avoid sinking or slipping across sediments.

#### *Dangerous marine fauna*

There are some marine fauna that are dangerous to humans but are often not encountered until we step into their habitat. One of the most dangerous marine animals in Gulf St Vincent is the Blue-ringed Octopus, which has a neurotoxin in its saliva glands. If you encounter one of those, observe but do not touch; also be wary of any empty shells that you pick up as they like to live in those microhabitats.

*Tides*

Always keep a watch on what the tides are doing. Be aware of low and high tide times for the mudflat site that you are surveying. In Gulf St Vincent, tides along mudflats can change quickly with water depths rising over a matter of minutes, often resulting in quick escape to avoid getting too wet.

*Sun exposure*

One of the biggest problems in field work along coastal areas such as mudflats is sun exposure. Make sure you where appropriate clothing to protect you from the sun and use sunscreen on exposed skin. With the direct sun and reflecting UV off the seawater and mudflat surface it doesn't take long to get severely sunburnt.

*Clothing and footwear*

Make sure that you wear a hat and sunglasses for sun protection, shorts or quick-dry long pants (e.g. you will get wet), ideal footwear (e.g. wetsuit boots, gumboots or old runners) and a rain jacket for inclement weather.

*First aid*

For any coastal field work including mudflats make sure that you only do the surveys with other people and never alone. When you do go and do a mudflat survey, make sure that you let someone at home know where you are going and when you are likely to get back. Lastly, make sure that you have a first aid kit with you. We never want to use one but they are crucial if an accident does happen.

# Protocols for Monitoring Mudflats

## Monitoring Sites

Previous monitoring of mudflats occurred at four sites (Section Bank, Pt Gawler, Middle Beach and Thompson Beach) within the AMLR NRM region using trials of the methods proposed herein. From those surveys, we have established a protocol of rapid methods that citizen scientists can use with only some basic instruction from experienced scientists or managers.

## Field equipment requirements

- Clip board
- Data sheets (attached as appendices)
- Pencils
- Ruler for sediment profiles
- Quadrat (50 cm square)
- PVC corer (100 cm diameter)
- Sieve (500 µm mesh size)
- Digital camera for photographs of fauna and sediment
- GPS unit

## General Observations

Remember to write down any general observations on the field sampling sheet so that there is a record of field conditions at the time of surveys. Be sure to include the site name, personnel involved in the survey and GPS positions if you are able. Unusual observations have often become the beginning of more intriguing questions in science, so it is good to be aware of the things we don’t know. These observations might be how habitats change through tides or the behaviour of fauna that you are identifying or counting. It could also be the sighting of unusual critters, and that is where good observational descriptions, drawings and photographs are all helpful.

# Data Collection

## Vertical Sediment profiles

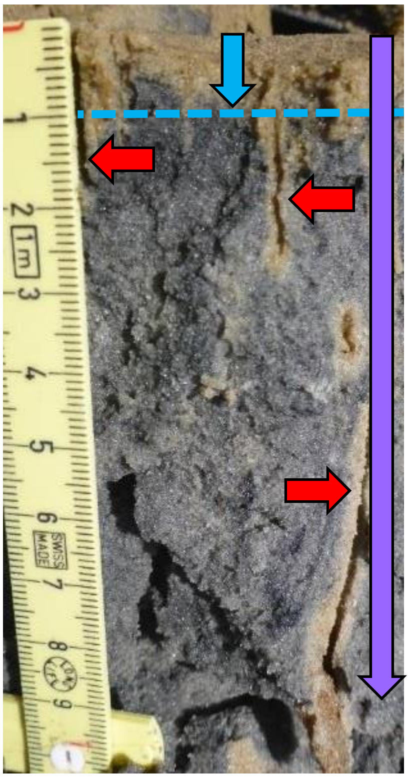
Sediment vertical profiles are an important aspect of mudflat monitoring as they give us some insight into the fauna that burrow and act as environmental engineers by moving the sediment around, allowing those sediments to receive oxygen (e.g. a healthy, active benthos). To get a sediment profile, use a shovel to dig into the sediment and remove the sediment in a block and lay it on the sediment surface ready for observation and measurement (see figure 1). There are four things that need to be recorded;

1) Sediment colour, based on the colour chart provided (Table 1) you will be able to determine if the sediment is oxic (e.g. oxygenated) or anoxic (e.g. lacking oxygen) with colours or shades of grey, respectively.
2) Measure where the oxic layer begins by laying the zero mark of a ruler at the sediment top surface and record the interface point where the oxic layer ends and the anoxic sediment first appears along the ruler length (Figure 1 & 2).
3) Count the number of burrows in one vertical sediment profile from top to bottom layer of the sediment (Figure 2).
4) Measure the maximum length of the burrow that reaches furthest into the sediment profile from top layer sediment surface through to bottom layer (see Figure 2).


**Figure 1**: Photograph of benthic sediment top layer removed for assessment of anoxic layer and, presence and depth of burrows.

**Table 1**: Colour chart for assessing sediment colour from sediment profile removed from benthos.

| | | |
|---|---|---|
| **1** | | Oxic sand |
| **2** | | Oxic mud |
| **3** | | Iron oxide |
| **4** | | Light anoxic |
| **5** | | Anoxic |
| **6** | | Dark anoxic |

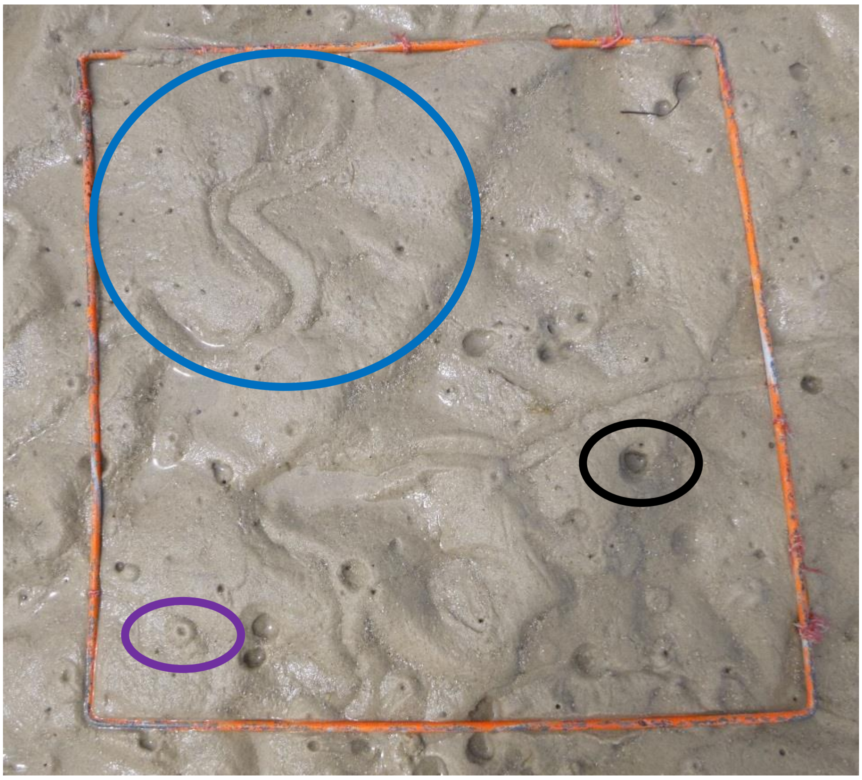


- Oxic layer = 1 cm
- Number of burrows = 3
- Maximum burrow depth = 8.8 cm

**Figure 2**: Example of measurements taken for anoxic layer, number of burrows and maximum burrow depth.

## Quadrats

Quadrats are a square perimeter that allows for a defined area to be assessed for macroinvertebrate epifauna (e.g. fauna that move along the sediment surface). A standard size quadrat like the one shown in Figure 3 is 50 cm x 50 cm square. We generally sample with quadrats in a haphazard way by throwing it over our shoulder, to avoid any bias in sampling area selection (i.e. make sure that no one is behind you when throwing quadrats). Wherever the quadrat lands is the defined area to count and record the fauna within. Have a go at identifying the animals you see to broad taxonomic groups (see section at the end for identification guide), count the number of each group and record those values on your datasheet. We also record the number of burrows (e.g. holes or mounds) and, presence and number of tracks (Figure 3). If there is any algae, seagrass, detached and decaying seaweed (e.g. wrack), then record that to as an approximate percentage of cover out of the entire quadrat area.



- **Burrow**
- **Mound burrow**
- **Track**

**Figure 3**: Quadrat haphazardly placed on benthos with burrows, mound burrows and animal track shown.

## Cores

To gain insight of the fauna that live within sediments (e.g. infauna), the easiest and most appropriate method to use in mudflats is sediment coring. You can obtain a sediment core with a small PVC pipe, which can be inserted into the sediment to about 10 to 15 cm depth. When removing the core and sediment within a rubber bung is inserted into the top so that suction will keep the sediment retained within the PVC corer. Dig the corer out of the sediment with a shovel if it is difficult to get out by hand and place the PVC corer with sediment into a 500 µm mesh sieve. Remove the PVC corer from the sediment and you will be left with a cored sediment profile section (see Figure 4). Find a small pool of water and use the sieve to rinse the fine sediment through (e.g. a lot like panning for gold), this may take some time depending on how much fine sediment grains there are, but be patient. The remaining sediment and fauna can then be poured onto a white sorting tray. You can also use a wash bottle from the underside of the sieve to help wash fauna into the sorting tray. With the sample in the sorting tray, you can use fine forceps or tweezers to sort through, identify and count the animals you have captured. Fauna only need to be identified to a coarse taxonomic level, which can be done with the identification guide provided.

**Figure 4**: Remaining cored sediment section on sieve after it has been removed from PVC corer.

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**Data Sheets**

| | | |
|---|---|---|
| **Mudflat Site Survey Sheet**<br>**Site Name:** | **Date:**<br><br>**Time:**<br><br>Tide | **GPS Position**<br>Northing:<br>________________________<br>Easting:<br>________________________ |
| **Personnel:** | | |
| **Were any photographs taken:** | | |
| **How and where are photographs stored:** | | |
| **Weather conditions**:<br>Sunny ☐ Overcast ☐ Showers ☐ Heavy Rain ☐ Breeze ☐ Windy ☐ | | |
| **Tide level sampled**:<br><br>Low ☐ Middle ☐ High ☐ | | |
| **Observations Flora and Fauna (e**.g. **tracks, burrow openings, algae, any other sightings)** | | |
| **Site drawing**<br><br><br><br>**Any other observations:** | | |
| **Samples:**<br>*Benthic macroinvertebrate samples*<br>Cores 83 $cm^2$ _________ Quadrats ________<br><br>*Sediment characteristic description*<br>Sediment condition ____________ | | |

| | | |
|---|---|---|
| **Mudflat Vertical Sediment Profiles Sampling Sheet**<br>**Site Name:**<br>**Site Code:** | **Date:**<br>**Time:** | **GPS Position**<br>Northing:<br>____________________________<br>Easting:<br>____________________________ |
| **Personnel:** | | |

| **Replicate 1:** | **Replicate 2:** |
|---|---|
| Were photographs taken:<br>Depth of anoxic layer (cm) __________<br>Number of Burrows ____________<br>Maximum depth of burrows (cm) __________<br><br>Observations: | Were photographs taken:<br>Depth of anoxic layer (cm) __________<br>Number of Burrows ____________<br>Maximum depth of burrows (cm)<br>__________<br>Observations: |
| **Replicate 3:** | **Replicate 4:** |
| Were photographs taken:<br>Depth of anoxic layer (cm) __________<br>Number of Burrows ____________<br>Maximum depth of burrows (cm) __________<br><br>Observations: | Were photographs taken:<br>Depth of anoxic layer (cm) __________<br>Number of Burrows ____________<br>Maximum depth of burrows (cm)<br>__________<br>Observations: |
| **Replicate 5:** | **Replicate 6:** |
| Were photographs taken:<br>Depth of anoxic layer (cm) __________<br>Number of Burrows ____________<br>Maximum depth of burrows (cm) __________<br><br>Observations: | Were photographs taken:<br>Depth of anoxic layer (cm) __________<br>Number of Burrows ____________<br>Maximum depth of burrows (cm)<br>__________<br>Observations: |
| **Replicate 7:** | **Replicate 8:** |
| Were photographs taken:<br>Depth of anoxic layer (cm) __________<br>Number of Burrows ____________<br>Maximum depth of burrows (cm) __________<br><br>Observations: | Were photographs taken:<br>Depth of anoxic layer (cm) __________<br>Number of Burrows ____________<br>Maximum depth of burrows (cm)<br>__________<br>Observations: |

| Replicate 9: | Replicate 10: |
|---|---|
| Were photographs taken:<br>Depth of anoxic layer (cm) _________<br>Number of Burrows ___________<br>Maximum depth of burrows (cm) _________<br><br>Observations: | Were photographs taken:<br>Depth of anoxic layer (cm) _________<br>Number of Burrows ___________<br>Maximum depth of burrows (cm)<br>_________<br>Observations: |

| **Mudflat quadrat sampling sheet**<br>**Site Name:**<br>**Site Code:** | **Date:**<br>**Time:**<br>**Low Tide:**<br>**Method:**<br>**Quadrat size:** | **GPS Position**<br>Northing:<br>____________________<br>Easting:<br>____________________ |
|---|---|---|

Personnel:

Were photographs taken:

| **Replicate** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| Burrow openings | | | | | | | | | | |
| Mounds | | | | | | | | | | |
| Tracks | | | | | | | | | | |
| Other surface activity signs | | | | | | | | | | |
| Polychaete worms | | | | | | | | | | |
| Small crustaceans (amphipods & isopods) | | | | | | | | | | |
| Large crustaceans (shrimps & crabs) | | | | | | | | | | |
| Gastropods (snails) | | | | | | | | | | |
| Bivalves (cockles, mussels) | | | | | | | | | | |
| Seastars | | | | | | | | | | |
| Other | | | | | | | | | | |
| | | | | | | | | | | |
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| **Mudflat core sampling sheet**<br>**Site Name:**<br>**Site Code:** | **Date:**<br>**Time:**<br>**Method:**<br>**Corer size:**<br>**Sediment depth:**<br><br>**Sieve mesh size:** | **GPS Position**<br>Northing:<br>____________________<br>Easting:<br>____________________ |
|---|---|---|

| Personnel: |
|---|
| Were photographs taken: |

| **Replicate** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| Burrows | | | | | | | | | | |
| Polychaete worms | | | | | | | | | | |
| Small crustaceans (amphipods & isopods) | | | | | | | | | | |
| Large crustaceans (shrimps & crabs) | | | | | | | | | | |
| Gastropods (snails) | | | | | | | | | | |
| Bivalves (cockles, mussels) | | | | | | | | | | |
| Insect larvae | | | | | | | | | | |
| Seastars | | | | | | | | | | |
| Other | | | | | | | | | | |
| | | | | | | | | | | |
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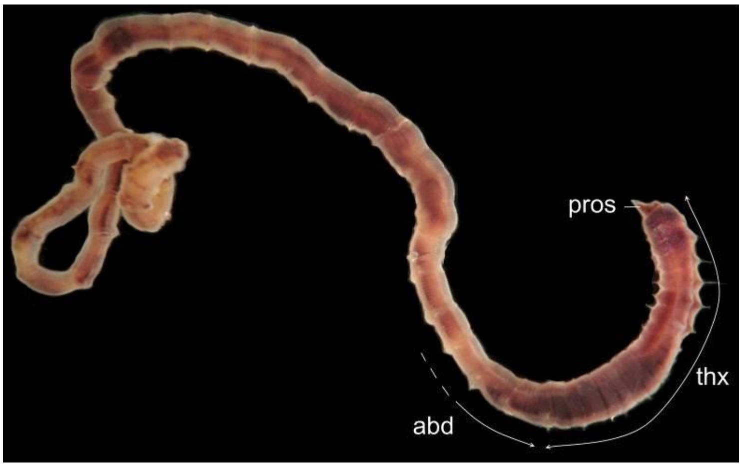
## Species Identification List

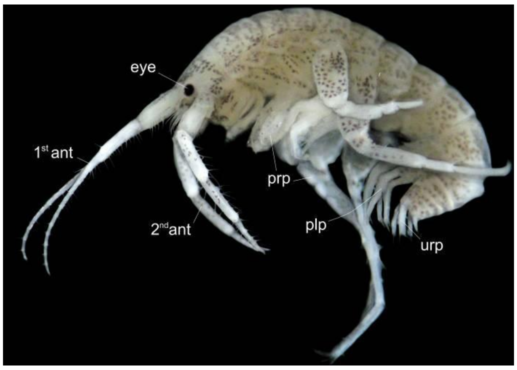
*Polychaete worms*



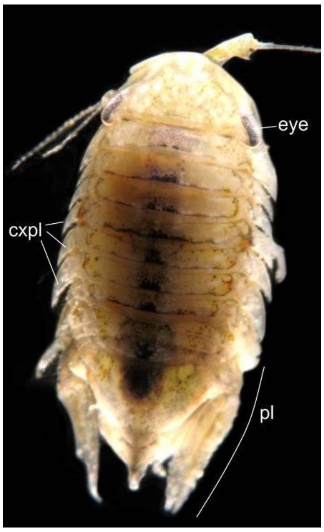

**Capitellidae**


**Nereididae**

*Small crustaceans*

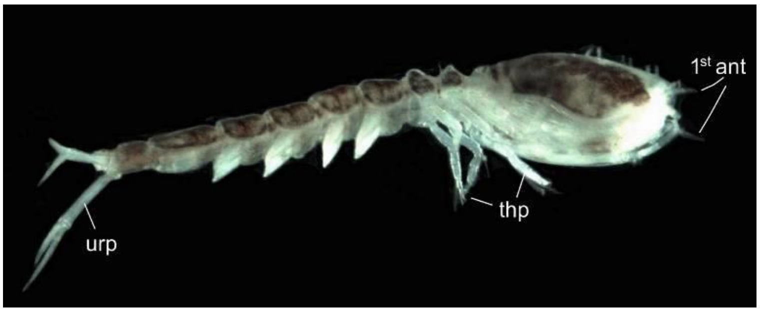



**Gammaridea Amphipod**



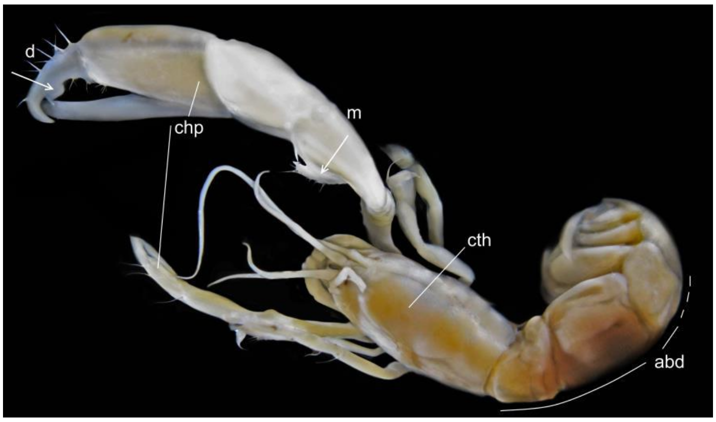

**Flabellifera Isopod (slater type)**

**Paridotea Isopod (sea centipede type)**

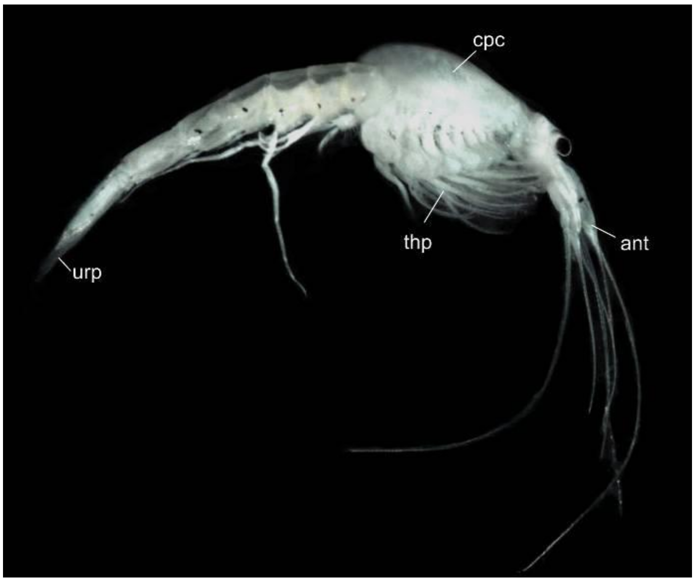



**Cumacea (shrimp-like)**

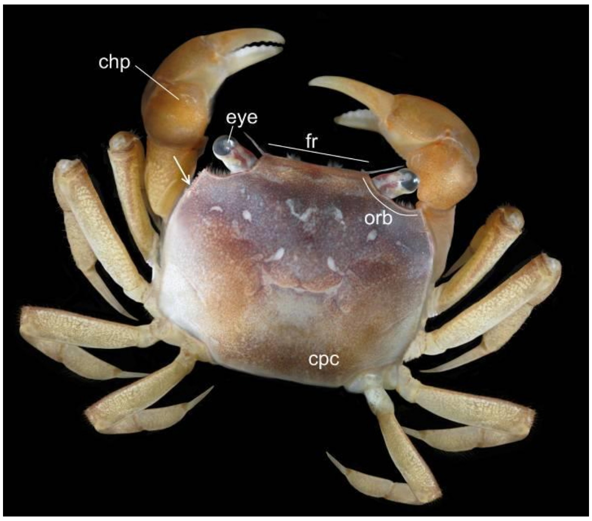
*<u>Large crustaceans</u>*



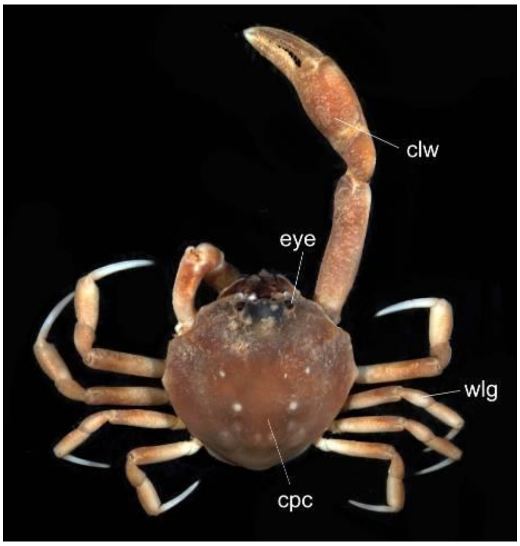

**Callianassidae (Ghost shrimp)**




**Mysidacea (Opossum shrimp)**



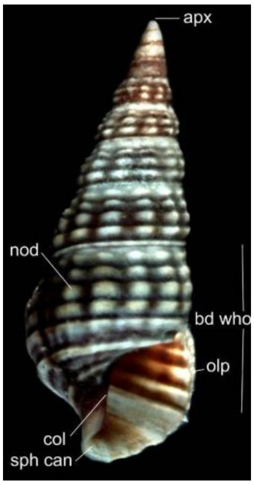

**Grapsidae (*Helograpsus haswellianus*)**



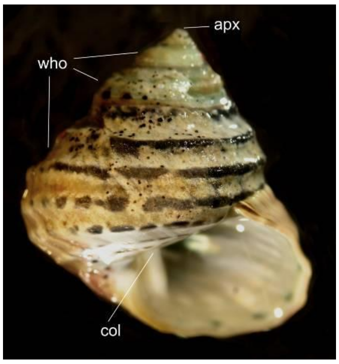

**Leucosiidae (Pebble crabs)**

*Molluscs – Gastropod snails*

***Salinator fragilis***




**Batillariidae (mud creeper)**




**Trochidae (*Austrocochlea constricta*)**

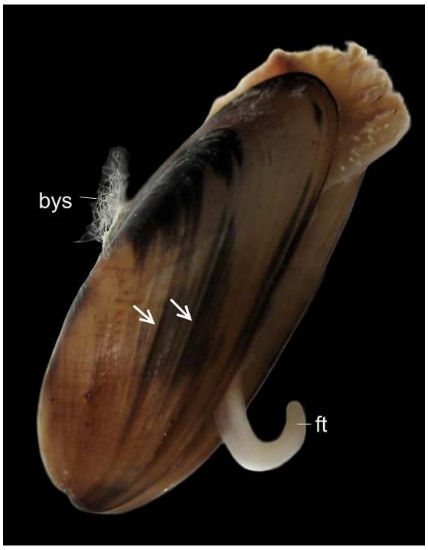
**Nassaridae (Dog whelks)**

*Molluscs – Bivalves (e.g. cockles, mussels)*

**Veneridae Katelysia spp.**

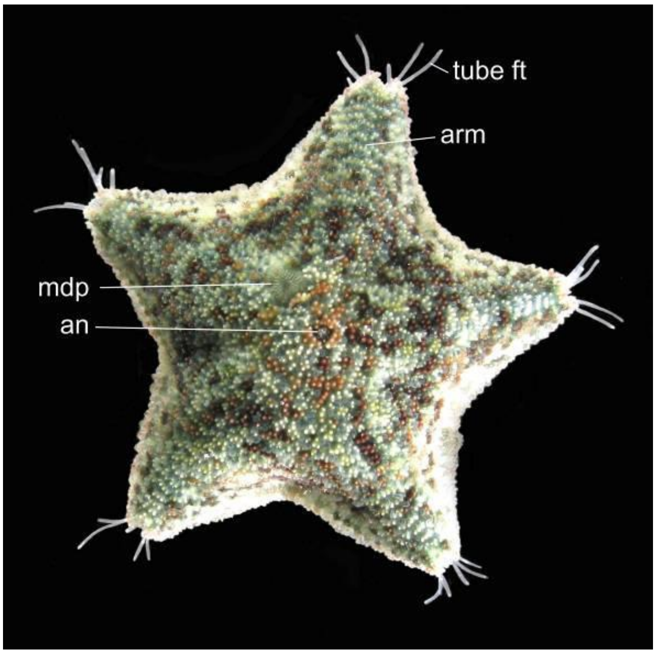

**Tellinidae (*Tellina deltoidalis*)**


**Psammobiidae (*Soletellina alba*)**




**Mytilidae (Xen*ostrobus inconstans*)**

*Seastars*




**Asterinidae (*Parvulastra exigura*)**

*Insect larvae*

**Chironomidae (non-biting midges)**