Faculty of Science and Technology

A comparison of the benthic fauna and habitat health of three Poole Harbour lagoons and their potential as refugia

A dissertation submitted as part of the requirement for the BSc Marine Ecology and Conservation (top-up)

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Abstract

Lagoons are highly productive and nationally scarce coastal ecosystems that are vulnerable to loss from sea-level rise and coastal squeeze. Their extreme and stochastic environmental parameters lead to relatively poor biodiversity but support several rare species that have specialised to inhabit this environment. However, severe eutrophic conditions can further limit biodiversity, and lead to dominance of anoxic-sulfidic species such as Chironomid larvae and oligochaetes. The benthic biota of previously unstudied Seymers lagoon on Brownsea Island, Poole Harbour, was surveyed and compared with similar studies conducted in Poole Park lagoon and the main Brownsea lagoon. The relative ecosystem health of each lagoon was analysed and compared and environmental variables dictating lower species richness were identified. This study shows that a poor water exchange regime can exacerbate eutrophic events and severely impact species richness and abundance, as seen in Poole Park lagoon and Seymers lagoon. Though Brownsea lagoon is a healthy example of a lagoon habitat, the sea wall that separates it from the harbour will soon be breached and the lagoon will be lost. It is anticipated that, with improved hydrology, Seymers lagoon and Poole Park lagoon will be pivotal in providing refugia for those species reliant on the Brownsea lagoon habitat, with the adjacent uplands of Seymers lagoon possessing the capacity for expansion.

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1. **Introduction**

1.1 Lagoons: Described

Coastal lagoons are shallow, open bodies of saline water usually oriented parallel to the sea and partially separated by a sediment barrier with limited water exchange, either via an inlet channel, percolation or overspill (Kjerfve 1994; Davidson et al. 1991; Barnes 1989). They are transitional coastal ecosystems and geologically ephemeral (Tagliapietra et al. 2009). Spatial heterogeneity of physico-chemical variables and fluctuations that exceed the minima and maxima parameters of the adjacent sea are characteristic of lagoons, which leads to spatial gradients and patchiness of these variables (Ghezzo et al. 2011; Rosselli et al. 2009; Attrill 2002). Water exchange between a lagoon and the sea is a complex product of bathymetry, tidal processes, fluvial discharge, and wind and is challenging to both predict and assess (Mahanty et al. 2016; Geyer 1997). Their size can vary substantially but depth is typically between 1-3m and seldom exceeds 5m (Kjerfve 1994). Temperatures within lagoons are more dynamic and extreme than the open sea, as the relatively shallow depth and reduced turbulent mixing will be greater influenced by air temperature; lagoons have been known to freeze over in very cold weather, a situation unheard of in most marine environments (Bamber et al. 1992).

Lagoons have a stochastic salinity regime that is moderated by the volume of water exchanged and flushing. Lagoons that have good water exchange with each tide via a channel will have a salinity closely resembling that of the adjacent sea, whereas a lagoon that receives seawater via percolation may be relatively hyposaline. Salinity is also influenced by freshwater input via streams and groundwater which will vary spatially, as per the water catchment area and between latitudes, and temporally, throughout seasons. However, salinity is not spatially homogenous throughout a lagoon. Lagoon shape can influence the degree of mixing it will undergo; wide, circular lagoons will achieve greater wind fetch than narrow lagoons, and thus may be better mixed. Poorer mixing often leads to stratification, that is the creation of layers within the water column with denser saline water sinking below a layer of freshwater (Fiandrino et al. 2017; Carvalho et al. 2011; Bamber et al. 1992; Guelorget and Perthuisot 1983). Furthermore, the salinity may be higher closer to a channel entrance where water exchange is greatest, and decrease with distance from the channel entrance, creating a gradient. Temporal interannual variation also occurs; lagoons within temperate regions experience increased rainfall during autumn and winter months and greater evaporation in summer due to increased air temperature and sunlight exposure (Newton and Mudge 2003).

Another characteristic of lagoons is that they are often hypertrophic and receive large amounts of organic nutrients from anthropogenic activity, such as agricultural and industrial effluents, into a relatively small area that is poorly flushed, and so they are particularly sensitive to eutrophic events (Gaertner-Mazouni and De Wit 2012; Bachelet et al. 2000; Barnes 1991). Moderate nutrient input in marine environments causes an increase in growth for phytoplankton and algae which initially increases food availability for primary consumers (Gray 1992). Beukema and Cadee (1986) found increased enrichment in the Dutch Wadden Sea over a 15-year period doubled macrozoobenthic biomass. However, excessive nutrient input can cause harmful algal blooms which in turn leads to dystrophic events that involve the depletion of oxygen, production of hydrogen sulphide, and mortality (Rybarcyzk et al. 1996; Peterson et al. 1994).

1.2 Ecology

The stochastic and extreme variability of environmental factors within lagoons means they are highly stressed systems which strongly influences the associated biota, and consequently ‘ideal’ lagoon parameters have not been described (Stringell et al. 2013; Gamito et al. 2005). Nevertheless because of high nutrient loading and high primary and secondary production, lagoons are ranked as productive as nutrient-rich upwelling areas (Viaroli et al. 1996; Knoppers 1994). They are utilized as nurseries by several fish species, such as European seabass *Dicentrarchus labrax*, and are often colonized by seagrass beds (Barnes 1991; Ardizzone et al. 1988; Nixon 1982). The brackish water characteristic of lagoons has long been associated with limiting species diversity, and Remane (1934) considered brackish water to have the lowest species diversity of the salinity gradient, limiting because of the high energetic costs of osmoregulation (see Figure 1) (Arndt 1989). However, it is challenging to isolate any one environment variable as directly influencing biodiversity as they are all interdependent and compounding (Como and Magni 2009). For example, Paturej et al. (2017) found

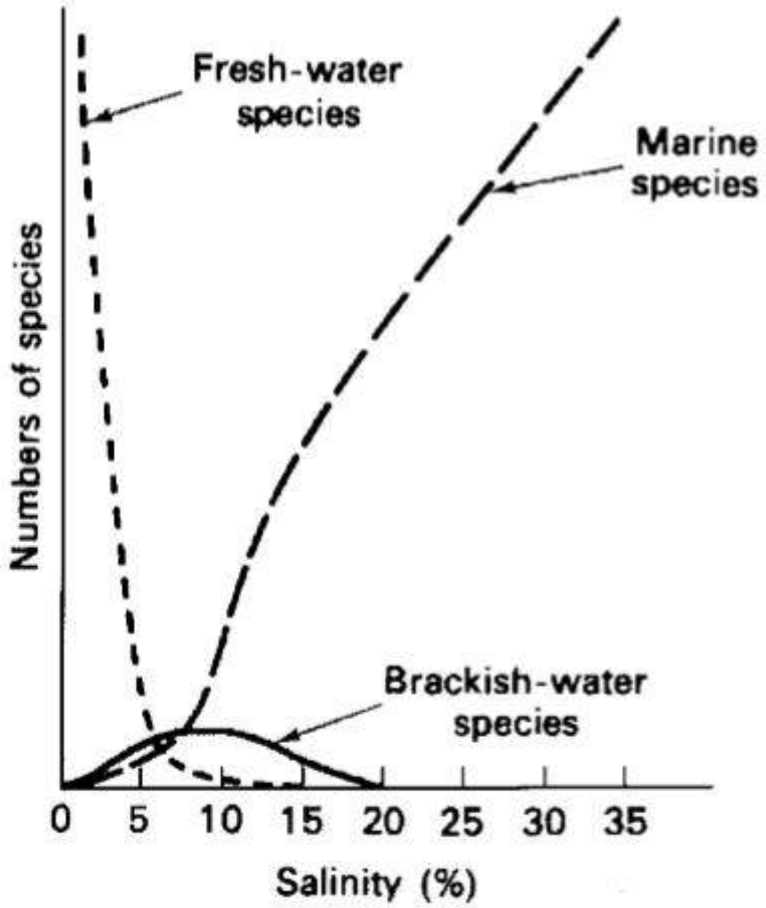

Figure 1 A line graph showing the relative species diversity along a salinity gradient (Remane 1934).

that several zooplankton species within Vistula lagoon in the Baltic Sea, Russia, declined in abundance as water pH increased, despite having high tolerance to pH variation. Reise (1985) noted that molluscs were smaller in a lagoon than those in the local sea. His assumption that their size was because of metabolic stress from maintaining homeostasis was incorrect; the bird population that utilized the lagoon for foraging fed on molluscs so frequently that they seldom exceeded 2 years in age and therefore failed to attain a larger size. Barnes (1989) opined that several hypotheses could apply to the low species diversity of lagoons; the environmental hostility hypothesis; the low habitat diversity hypothesis, due to the characteristic homogenous soft sediment; the short timescale/ isolation hypothesis, because of poor water exchange and subsequent lack of opportunity for colonization and intermittent closure of inlet channels due to sedimentation. The niche environment produced by extreme and unpredictable salinity, temperature and other abiotic factors has led to the evolution of brackish water specialists which can outcompete estuarine generalists, such as the lagoon sandworm *Armandia cirrhosa* (Bamber et al. 2001).

However, salinity, dissolved oxygen, and temperature can vary spatially and so faunal community composition can change within and between sites within a lagoon depending on these factors. Patchy distribution of species within lagoons along environmental gradients is well documented, particularly with macrozoobenthic communities (Kanaya et al. 2011; Perez-Ruzafa et al. 2007; Carvalho et al. 2005; Benedetti-Cecchi et al. 2001). Following the temporal variations in environmental variables, macrozoobenthic assemblages also undergo seasonal fluctuations that follow a regression/ recovery pattern, with biodiversity peaking in winter/ spring in temperate latitudes (Como and Magni 2009).

1.3 Ecosystem Services

Ecosystem services are the products and services contributed by an ecosystems structure and function to human well-being and lagoons provide numerous socio-economic benefits (Burkhard et al. 2012; Chapman 2012; Elliott and Whitfield 2012). Lagoons mitigate against coastal erosion by reducing wind fetch and thus wave action and supporting the growth of seagrasses that are also known to attenuate wave action (Christianen et al. 2013; Fagherazzi et al. 2006). They provide nurseries for commercially important juvenile fish and shellfish, such as the European flat oyster *Ostrea edulis* and Pacific oyster *Crassostrea gigas* fisheries of the Fleet lagoon in Dorset (Rova et al. 2015; Langston et al. 2003). However, it should be noted that not all lagoons provide all these ecosystem services to the same degree, particularly where habitats are degraded, and these should be assessed on a site-specific basis. Additionally, degraded lagoon habitats may lead to scenarios which require expensive and labour intensive treatment, such as the proliferation of midge swarms in Poole Park (Harrison et al. 2016).

1.4 Threats

Climate change induced sea-level rise is threatening coastal ecosystems with flooding and where adjacent uplands are steeply elevated or have been claimed by urban development, leads to the loss of transitional ecosystems such as coastal lagoons (Carrasco et al. 2016; Pontee 2013). In the case of tidal marshes in Chesapeake Bay, USA, even where there is adequate space in which to retreat landwards, succession is not occurring fast enough to keep up with the rising sea levels and there is a net loss of marshland area (Beckett et al. 2016). Stralberg et al. (2011) emphasized the need for proactive ecosystem engineering, such as conserving suitable upland areas for landward migration and redistributing sediment to raise the elevation. Such development would create refugia, which is the perseverance of favourable environmental conditions in a changing climate and its associated effects (Berry et al. 2014; Keppel et al. 2012). Species within refugia are pivotal in the supply of propagules into new and former areas of habitat (Ashcroft 2010; Carvalho et al. 2010). The impact of sea-level rise is site specific, particularly depending on the type of lagoon and availability of adjacent uplands, but solutions, such as ecosystem engineering, are available (Stralberg et al. 2011; Bamber et al. 2001).

1.5 Lagoons in the UK

Lagoons are priority habitats under Annex 1 of the Habitat Directive (92/43/EEC) and comprise just 5% of European coastlines (Lillebo et al. 2015; Kjerfve 1994). North Atlantic lagoons are particularly scarce due to the macrotidal range, with most European lagoons clustered on the coasts of the Mediterranean, Baltic, and Black seas. Therefore, their occurrence on UK coastlines is considered rarer still (Bamber et al. 1992).

1.5.1 Poole Harbour

Poole Harbour is in Dorset on the south coast of England. It formed due to flooding from sea level rise in the late Holocene and has an area of 3600ha at high water spring tide. It has an unusual microtidal regime with a tidal range of 0.6m-1.8m and a double high tide for 16 hours of 24 hours (May 2005; McClusky and Elliot 2004). Its sea level has risen by 0.26m since the late 19th Century because of local land reclamation (Edwards 2001; Pethick 1993). It has been previously described as a lagoon itself, predominantly because the narrow entrance channel occluded by sand spits presented as a lagoon inlet channel and was thought to limit water exchange with the adjacent sea. However, several geomorphological and environmental factors define Poole Harbour as an estuary. The channel depth of 18m and tidal ebb flow of 2.6m/s^{-1} negates any water exchange limitation impacted by the narrow channel width. Subsequently the salinity regime within the harbour fluctuates with the tidal cycle and is vertically homogenous within the main harbour area, with a salinity of 20-35‰ which is indicative of estuarine characteristics. Despite this, flushing of the harbour is poor and can take up to 4 days (Humphreys 2005). Estuaries and lagoons are closely placed on a continuum of coastal environments and many physical, chemical and ecological factors should be considered when determining lagoon habitats. Poole Harbour is designated as a Nitrate Vulnerable Zone, a Sensitive Area (Eutrophic) and Polluted Water (Eutrophic) because of high levels of nitrogen from agriculture run-off via the rivers Piddle and Frome (Environment Agency 2016).

Poole Harbour is a Special Protected Area (SPA), a RAMSAR site and has several Sites of Specific Site Interest (SSSI) (Herbert et al. 2010). Sixty-one macro-invertebrate species have been recorded in the intertidal zone, which comprises up to 80% of the estuary bed. The oligochaete *Tubificoides benedini* was the second most abundant invertebrate species found in the survey and was one of two species that occurred at all sample sites throughout the harbour at an average density of >1000 individuals/ m^{-2}. Polychaete and oligochaete abundance has increased since the 1970s but sieve sizes and survey methodology has changed over time, so this rise should be treated cautiously (Caldow et al. 2005). It is a highly productive estuary with many species of fish, bivalve and decapod found in larger quantities than outside the harbour, including a high value Manila clam *Venerupis phillipinarum* fishery (Drake and Bennett 2011).

Three artificial lagoons can be found within the harbour, including (recently described) Poole Park lake and Brownsea lagoon which have their water input controlled via sluices, and Arne lagoon, a clay quarry flooded by seawater via a purpose-built channel (RSPB 2012; Bournemouth University Global Environmental Solutions 2015; Dorset Wildlife Trust 2016). A fourth lagoon, known as Blue Lagoon, ceased to exist and became intertidal in the late 1980s (Sheader and Sheader 1992; Sheader and Sheader 1985). Brownsea lagoon is threatened by sea-level rise and collapse of the sea wall that separates it from Poole Harbour, putting it at risk of also becoming intertidal (National Trust 2015; Guthrie and Eggiman 2014; Herbert et al. 2010). A lake on Brownsea Island 1km north west of the main Brownsea lagoon was found to have potentially connected to the sea and was investigated for its potential as climate change refugia.

1.5.2 The New Lagoon

Seymers (Seymour's) lake based on the north-west coast of Brownsea Island was surveyed on 16th November 2016 and 10th April 2017 (see Figure 2). A map dated 1857 shows the lake was preceded by marshland which was mined for pipe clay from the Parkstone Clay stratum for use in producing china in the late 19th Century (Battrick and Lawson 1978). It is noted that the mines, some as deep as 55ft, frequently flooded; it is likely that the lakes were formed by flooding of seawater from the mines and via percolation through the promontory (West and West 2007; White 1917). It can be assumed that the water of the lake has been brackish since its formation, particularly as the watershed supplementing the lakes will be relatively small and freshwater input minor. Subsequently, the lake can be described as a lagoon. An inlet channel was positively identified as a source of seawater into the lagoon during the survey, though historical aerial photographs indicate a channel may have existed for several decades. A photograph taken in 1945 shows a sediment discharge originating from a land-based water source in a different location as the channel seen in 2016 (see Figure 3).

A channel will have facilitated the recruitment of marine fauna but there is no photographic evidence of its existing between 1945 and 2002; as lagoons are considered transitional environments and are ephemeral, the channel location

Figure 2 Location of Seymers Lagoon (Google Maps 2017).

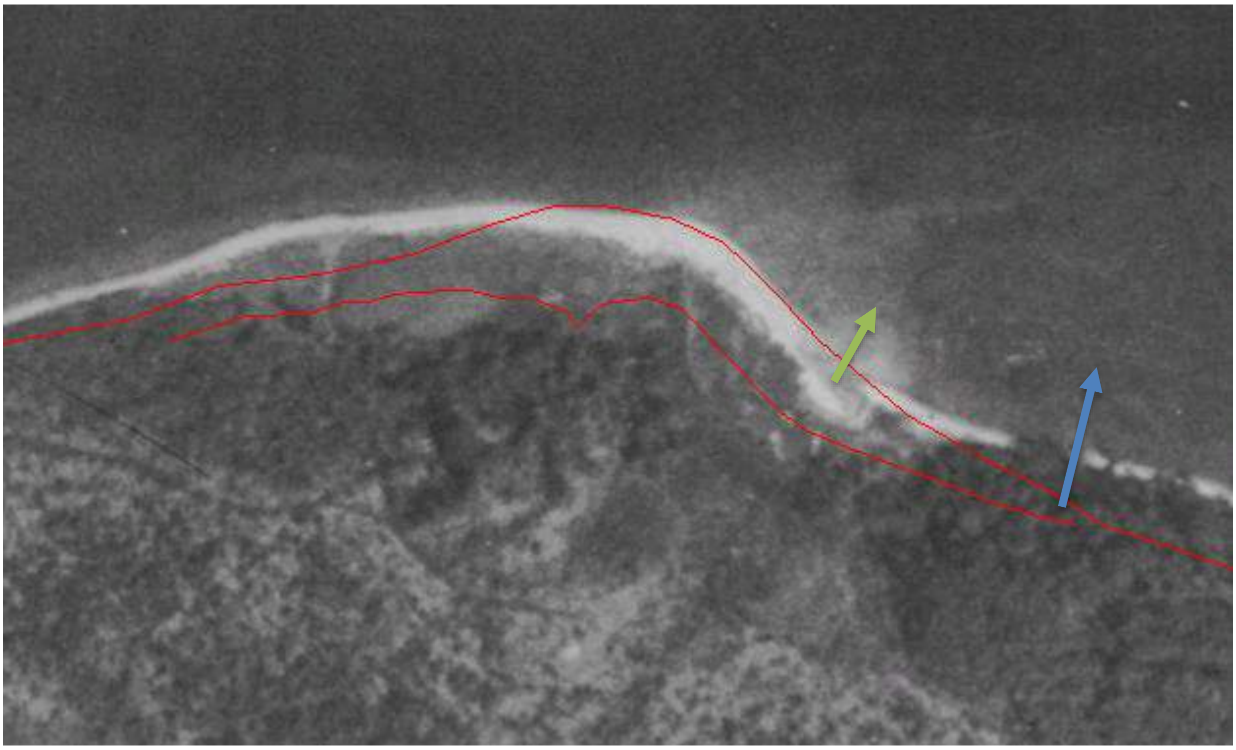
Figure 3 An aerial photograph taken in the 1940s with the present-day sediment barrier perimeter overlaid in red. The inlet channel location of 1945 is denoted by the green arrow and the present-day channel location denoted by the blue arrow (The Geoinformation Group 2017).

function may have changed over time. The lagoon can be divided into two sections connected by a narrow channel of water. The west section is less likely to benefit from tidal flushing because of its limited exchange with the east section, which receives the seawater source via the inlet channel. The seaward perimeter is separated from Poole Harbour by a sand dune populated by marram grass *Ammophila* spp. and the landward perimeter is populated with trees and *Rhododendron* spp.. The landward side receives a high organic input from terrestrial sources, such as leaf fall.

1.6 Aims and Objectives

The aims and objectives for this study are:

- Obtain data from environmental parameters and macrozoobenthic biota to serve as a baseline for monitoring thereafter by:
    1. using standardized field survey and laboratory methodology for benthic biota previously used in the Poole Park and Brownsea

    lagoon surveys (Harrison et al. 2016; Herbert et al. 2010; Dalkin and Barnett 2001),
    2. taking salinity, temperature, and dissolved oxygen measurements at each site,
    3. taking sediment cores for particle size analysis and organic matter content analysis.

- Identify relationships between the spatial distribution of macrobenthic taxa, feeding traits and communities, and environmental parameters, and assess overall health by
    1. Conducting appropriate statistical analyses,
    2. Reviewing the results within context of existing literature.
- Understand the overall health of the Poole Harbour lagoons and how their respective level and types of management have influenced their ecological status by
    1. Comparing pre-existing faunal assemblage data for Poole Park lagoon and Brownsea Island lagoon and new data from Seymers lagoon.
- Identify the potential ecological capacity of Poole Park lagoon and Seymers lagoon as refugia for lagoon communities and specialists in the event of the main Brownsea lagoon becoming intertidal by
    1. Reviewing existing literature on the impacts of climate change on coastal ecosystems, particularly lagoons,
    2. Producing potential management measures to improve the health and thus biodiversity of Seymers lagoon,
    3. Investigate the capacity for the expansion of Seymers lagoon to accommodate a greater abundance and diversity of lagoon dependent species.

However, it is acknowledged that coastal lagoon systems are highly variable and there has been limited success in correlating faunal community composition with environmental parameters within lagoons, in addition to a paucity of data (Stringell et al. 2013; Talley et al. 2003; Healy 1997).

The hypotheses for this research are:

H_1 The biodiversity of the benthic macrofaunal community of Seymers lagoon will be significantly less rich than Brownsea lagoon and Poole Park lagoon.

Seymers lagoon has not previously been surveyed or described and so it is challenging to ascertain how long the main channel source has been functional, how long the lagoon has been accessible to recruit fauna, and if there has been a pattern of local extinction – recolonisation over time. Based on the lack of data, its small size and relatively high nutrient input, it is assumed that it is significantly less species rich than Poole Park lake lagoon and Brownsea Island lagoon. Arne lagoon has been omitted from this study as it is relatively young having been less than a decade ago.

H_2 The western basin of Seymers lagoon will have a greater biodiversity than the eastern basin.

Poor flushing and mixing in the west basin may lead to a more variable and stochastic salinity and temperature regime, which is likely to support more lagoon specialists, and so the two basins may have distinct faunal communities. This will be exacerbated by the high organic input which may lead to excessive nutrient loading and eutrophication in the west basin if water exchange is not adequate.

H_0 There will be no significant difference between the richness of Seymers lagoon and the other two lagoons.

2. Materials and Methods

2.1 Field Survey

Two surveys were conducted at Seymers lagoon on 16th November 2016 and 10th April 2017 with permission from the Dorset Wildlife Trust. In November, two sample methods were employed. Six sample stations per lagoon basin were identified, totaling 12, accessed on foot (see Figure 4). Benthic sampling was conducted according to the JNCC Marine Monitoring Handbook (Dalkin and Barnett 2001). A mud core was obtained using a 10cm diameter suction corer from each sample station at a depth of 15cm and sealed in plastic zip-lock bags labelled with waterproof permanent marker. Using a 1mm mesh standard pond net, eight sweeps were taken to quantify the abundance of biota in the water column. The mud core samples were sieved *in-situ* through a 0.5mm mesh to remove fine sediments and break up nodules of clay. Leaves and stones were washed and removed. Samples were drained, fixed in 10% buffered formalin and stored in labelled pots. Salinity readings were taken using a Hach HQ40D multimeter, in addition to temperature and dissolved oxygen readings. Observations of additional *in-situ* fauna were noted and photographs were taken of each site. These methods were also used in data collection for macrozoobenthos at Poole Park and Brownsea lagoon, details of which may be found in Herbert et al. (2010) and Harrison et al. (2016).

In April, another 12 sediment cores were taken from the same sample stations with the same suction corer and the method was replicated for sediment analysis only. Sediment samples were stored in plastic zip-lock bags labelled externally with waterproof marker and frozen to prevent organic content decomposition. Salinity and temperature readings were also taken.

2.2 Laboratory Analysis

Fixed samples were decanted through a 0.5mm sieve in a fume cupboard and rinsed with water to remove the formalin. Samples were then rinsed again through a sieve to remove any remaining fine sediment and large stones and leaves, before fauna were picked under a low power stereo binocular microscope and

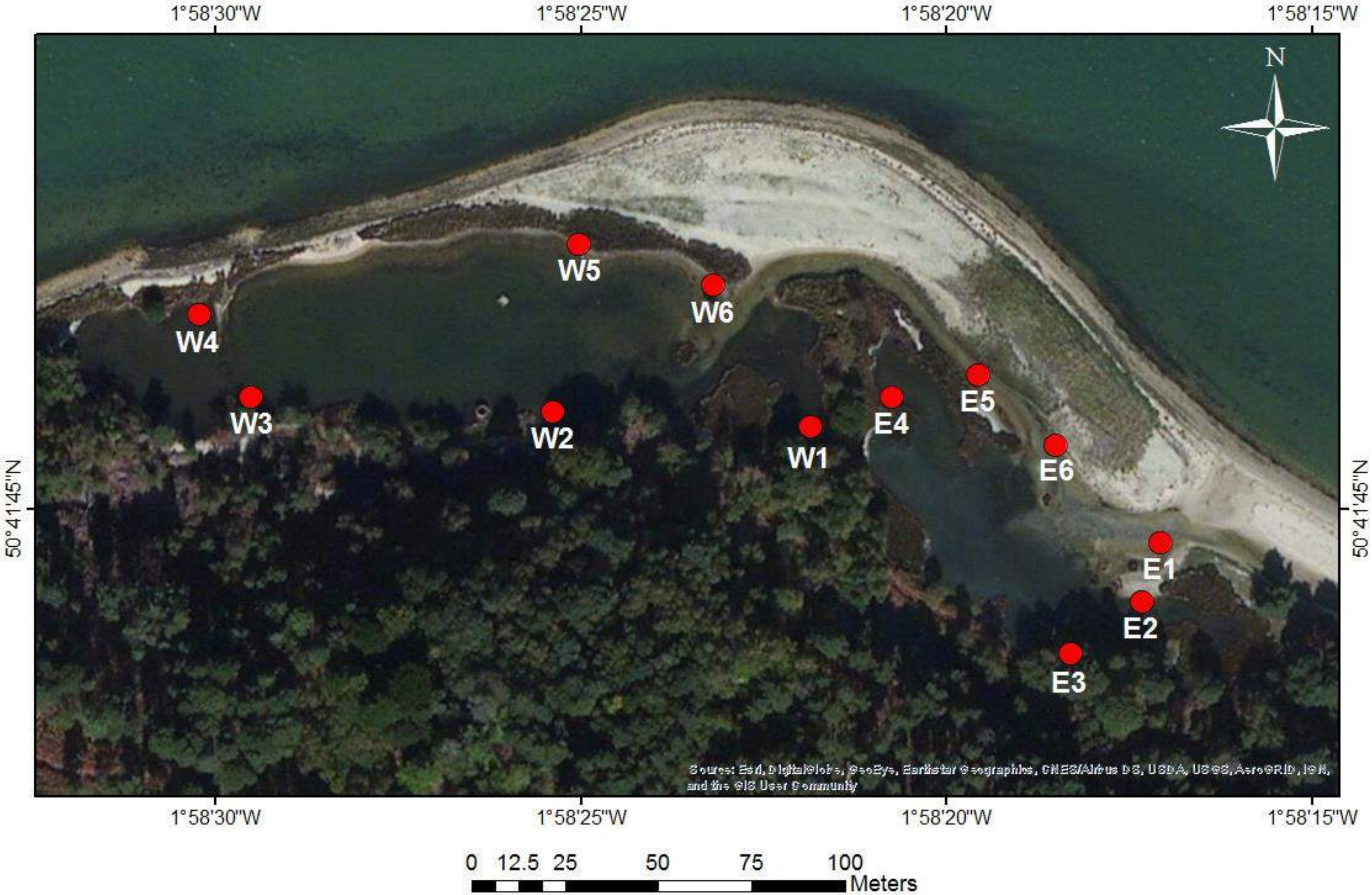

Figure 4 Sample site locations in the east (E) and west (W) basins at Seymers lagoon.

preserved in 70% Industrial Methylated Spirit (IMS). Once all mud core samples had been sorted, numerical abundance of fauna were counted with biota identified to species-level taxonomic resolution wherever possible. Specimens without a head were discounted. Identified biota were returned to preservation in IMS in their original sample pots for quality assurance purposes. Unidentifiable biota was sent to a taxonomic expert for analysis.

Organic content of the sediment samples was measured by first drying a 10g homogenised subsample in an oven at 105˚C for 48h and then placing in a muffle furnace at 450˚C for 12h and measuring the loss of mass on ignition.

Particle size analysis was obtained using a Malvern Mastersizer 3000 laser diffractometer with subsamples of the processed sediment. Samples were sieved through a 2mm sieve and particles greater than 2mm were weighed separately. Sieved samples were added to distilled water until the obscuration threshold was reached and readings commenced. The water was changed between samples as per the Mastersizer instructions. Silt content was determined by grain sizes ≤63μm and sand content was determined by grain sizes >63μm.

2.3 Data Analysis

Data from pre-existing macrozoobenthic surveys for Poole Park and Brownsea lagoon and data from the Seymers lagoon survey were collated on Microsoft Office Excel spreadsheets (Harrison et al. 2016; Herbert et al. 2010). A Levene test of homogeneity of variances was conducted for species richness, abundance, Shannon and Simpson Diversity Indices to establish if the data were parametric or non-parametric. If data were parametric, a one-way ANOVA was conducted to determine if there were statistically significant differences in dependent variables between Poole Park lagoon, Brownsea lagoon, and Seymers lagoon samples, and between the east and west basin of Seymers lagoon samples using IBM SPSS. If data were non-parametric, a Kruskal Wallis was conducted instead. Regression analyses was performed for the biotic and abiotic data for Seymers lagoon to see if there were any correlations between environmental variables and number of species, abundance, and Simpsons Diversity Index. A Pearsons correlation test was run between independent environmental variables to assess relationships. A multivariate analysis was conducted using Primer v6 software to assess the similarity of the Poole Harbour lagoon macrozoobenthic communities (Clarke and Gorely 2006). This was achieved with non-metric multidimensional scaling (MDS) and cluster analysis and using the Bray-Curtis similarity index.

Dominant feeding strategies of species were determined using pre-existing literature (Har et al. 2015; Attrill et al. 2009; Henriques-Oliviera et al. 2003; Bousfield and Hoover 1997; Moens and Vincx 1997; Philippart 1995; Ulrich et al. 1995; Barnes 1994; Gerdol and Hughes 1994; Hand and Uhlinger 1994; Brinkhurst 1982; Fauchald and Jumars 1979; Frank and Bleakney 1978; Fenchel et al. 1975). Feeding strategy categories were then collated on a map of Seymers lagoon using ArcGIS mapping software and their respective abundance data were transformed via square root so rarer strategies were better represented. Lagoon biotopes were assigned as per the classification in Bamber (1997).

2.4 Poole Park and Brownsea Lagoon Data

The data for benthic biota at Brownsea lagoon were collected by Herbert et al. (2010) on 6th November 2009. Eighteen samples were obtained over 6 sample sites with 3 replicates samples taken at each site, totaling 18 samples. The data for benthic biota at Poole Park lagoon were collected by Harrison et al. (2016) on 1st April, 15th April, 29th April, 13th May, 27th May, 10th June, 24th June, 8th July, 22nd July, 5th August in 2015. One sample was obtained from each of the two sample sites on each date, totaling 20 samples. The materials and methods for these surveys can be referred to in their reports.

3. Results

3.1 General Observations – November 2016

Sweep netting revealed several *Palaeomonetes varians* prawns in the water column. A patch of *N. vectensis* was positively identified in the field, in addition to the isopod *Idotea chelipes*, slipper limpets *Crepidula fornicata* attached to hard substrata, a juvenile goby *Pomatoschistus* spp., a snakelocks anemone *Anemonia viridis*, and lugworm *Arenicola marina* casts were noted near the inlet channel. The lagoon was visited during an outgoing tide and *P. varians* could be seen swimming in the water flowing from the lagoon into the sea. The sediment on the landward side appeared to be very fine and became coarser towards the seaward sediment barrier. The lagoon is directly beside a deciduous forest and leaves, pinecones and other plant matter were seen both floating on the surface and settled on the bottom of the lagoon. Most if not all sediment cores taken from the landward side of the lagoon caused the eruption of hydrogen sulfide bubbles from the sediment characterized by the smell of rotten eggs. Precise depth measurements were not taken but water depth at sample sites did not exceed 50cm. Temperature, dissolved oxygen and conductivity readings were taken but the salinity conversions suggest the Hach multimeter was improperly calibrated before use and subsequently all conductivity readings from this date have been deemed unreliable.

3.2 General Observations – April 2017

The lagoon was not visibly connected to the adjacent sea and the channel appeared dry and the lagoon area was reduced, particularly in the east section. The channel connecting the east and west side had dried up as it approached the east section, so both sections were isolated from one another. In some areas, the smell of hydrogen sulfide was apparent and all sediment samples were dark in colour, with some of the sandier samples topped with a thin layer of approximately 1cm light coloured sand. Several patches of *N. vectensis* were located and lugworm casts were found in abundance on the seaward side. *P. varians,* mud shrimp *Corophium volutator,* and amphipod shrimp were observed in the water column and a live shore crab *Carcinus maenas* approximately 2.5cm in diameter was found, in addition to several small carapace molts. A patch of spaghetti algae *Chaetomorpha linum* was found in the far west of the lagoon within which the lagoon amphipod *Microdeutopus gryllotalpa* and lagoon specialist *I. chelipes* were frequently abundant. *Ulva* spp. and invasive species Japanese wireweed *Sargassum muticum* were found attached to the substrate in the eastern section. Shelduck *Tadorna tadorna*, teal *Anas crecca*, and Canada geese *Branta canadensis* were observed predominantly in the western section.

3.3 Biota of Seymers Lagoon

The overall abundance of Seymer's lagoon numbered 952 individuals with a total of 10 species. Numeric abundance between sample sites ranged from 1 (W1) to 344 (W5). Species richness ranged between 1 (W1) and 8 species (W2, W4 and W5). The sample site with greatest diversity as ranked by Simpsons Diversity Index and Shannon Diversity Index was W6 with 0.137 and 1.74 respectively and the least diverse sites were E2, E3, E6 and W1, all with the same Simpsons Diversity Index and Shannon Diversity Index score of 1 and 0 respectively. Overall mean Simpsons and Shannon diversity indices were 0.68 and 0.84 respectively. The most abundant phylum was Insecta with Chironomid larvae with $\bar{x}$ 28 individuals per sample site which were found in a variety of sizes in all sample sites but W5. The least abundant phylum was Mollusca with 5 mudsnail *Peringia ulvae* individuals (previously known as *Hydrobia ulvae*), found exclusively in seaward sample sites in the west section. The least abundant species was the annelid *Baltidrilus costatus* numbering 2 individuals (W5). The most abundant fauna identified to species taxonomic level was the lagoon isopod *Monocorophium insidiosum* with 295 individuals and was found exclusively in samples from the west section (previously known as *Corophium insidiosum*). The most species diverse phylum represented within the lagoon was Annelida with at 4, including the rag worm *Hediste diversicolor*, polychaete *Capitella capitata*, and oligochaetes *B. costatus* and *Tubificid* spp., with a total of 250 individuals. Chironomid larvae abundance is negatively correlated with silt content (ANOVA, F = 5.134, d.f. = 1 and 10, p = 0.047) as is *M. corophium* abundance (ANOVA, F = 25.730, d.f = 1 and 4, p = 0.007). The relationships are summarised in scatter plots in Figure 5. No other species were significantly correlated with environmental variables.

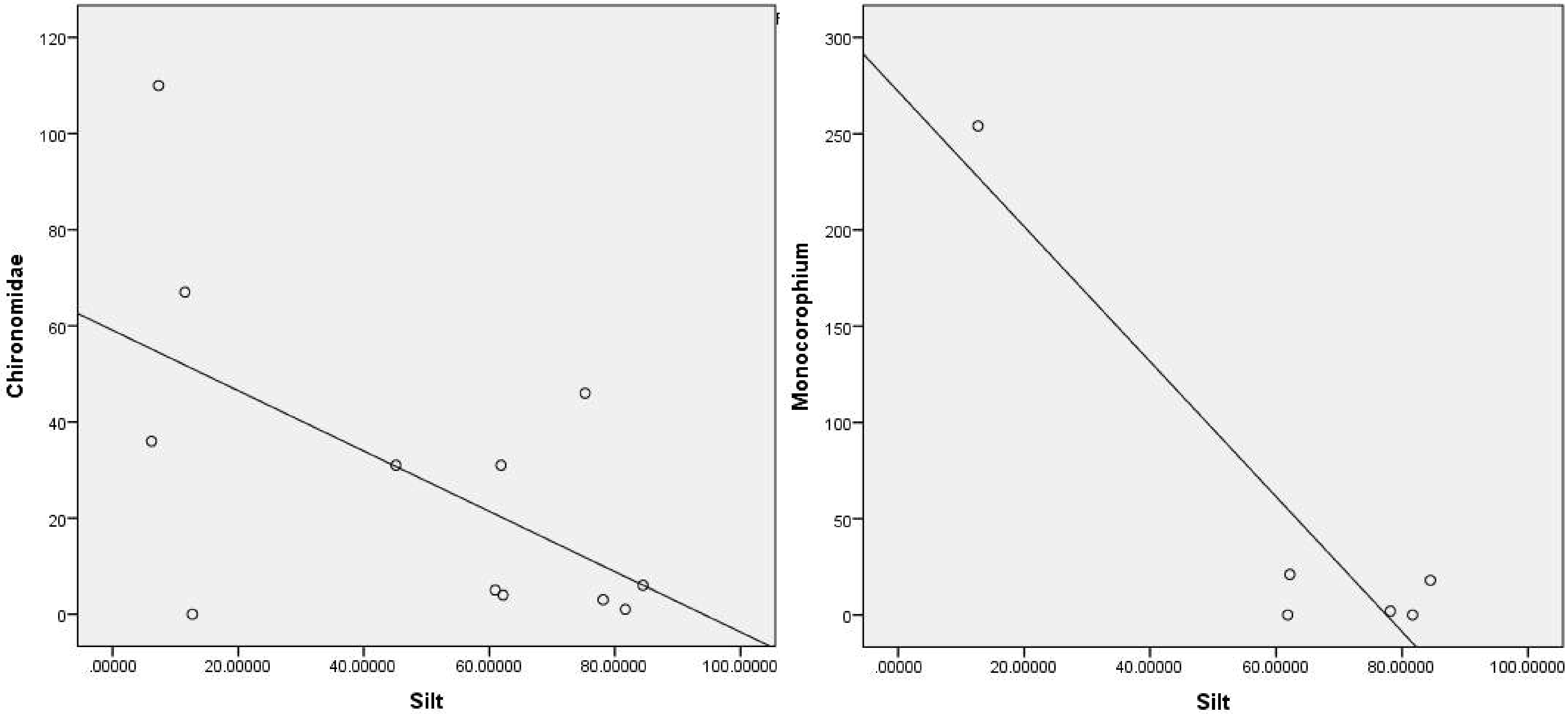

Figure 5 The negative correlation between the numeric abundance of Chironomid larvae ($r2 = 0.339$) with silt content, left, and the negative correlation between the numeric abundance of *M. insidiosum* ($r2 = 0.865$) with silt content, right.

Omnivorous deposit feeders are the dominant trophic level and comprise 57% of the total abundance, including *H. diversicolor, C. capitata, M. insidiosum, C. volutator* and *P. ulvae*. Detritivores were the second largest diet group, comprising 42% and consisting of high numeric abundances of Chironomid larvae and *Tubificid* spp.. Carnivores were the least abundant diet group, comprising just 1% with *N. vectensis*. The spatial distribution of feeding strategies is summarised in Figure 6. Biotopes identified were ENLag.Veg and ENLag.IMS.Ann characterized by the presence of algae such as *C. linum* and *Ulva* spp. and associated fauna (see table 1). Lagoon specialist abundance comprised 32% of the biota sampled.

Table 1 Biotopes identified in Seymers lagoon, adapted from Herbert et al. (2010) and Bamber (1997). Qualifying features are coloured green.

Biotope Designation	Description
ENLag.Veg	Submerged vegetation and associated fauna: *Ruppia/ Enteromorpha/ Chaetomorpha/ Ulva* and *Idotea chelipes, Monocorophium insidiosum, Sphaeroma, Gammarus, Hydrobia* spp., *Gasterosteus aculeatus*
ENLag.IMS.Ann	Infralittoral muddy sand with Tubificids, Chironomids, Hydrobiids, *Capitella capitata, Hediste diversicolor, Cerastoderma glaucum, Monocorophium volutator, Abra tenuis.*

3.4 Abiotic Factors of Seymers Lagoon

Environmental results are summarised in Table 2. Water temperature ranged by 1.7ºC ($\bar{x}$ 12.1ºC) in November and by 4.1ºC ($\bar{x}$ 16.6ºC) in April and was on average highest in the east section on both occasions. Salinity ranged by 7.19‰ ($\bar{x}$ 33.82‰) in November and was on average highest in the east section. In April salinity ranged by 12.3‰ ($\bar{x}$ 30.53‰) in April and was on average highest in the west section. Dissolved oxygen ranged by 3.46mg/L ($\bar{x}$ 7.2075mg/L) in November and was on average highest in the east section. No measurements for dissolved oxygen were taken in April. Organic matter (OM) content of sediments ranged by

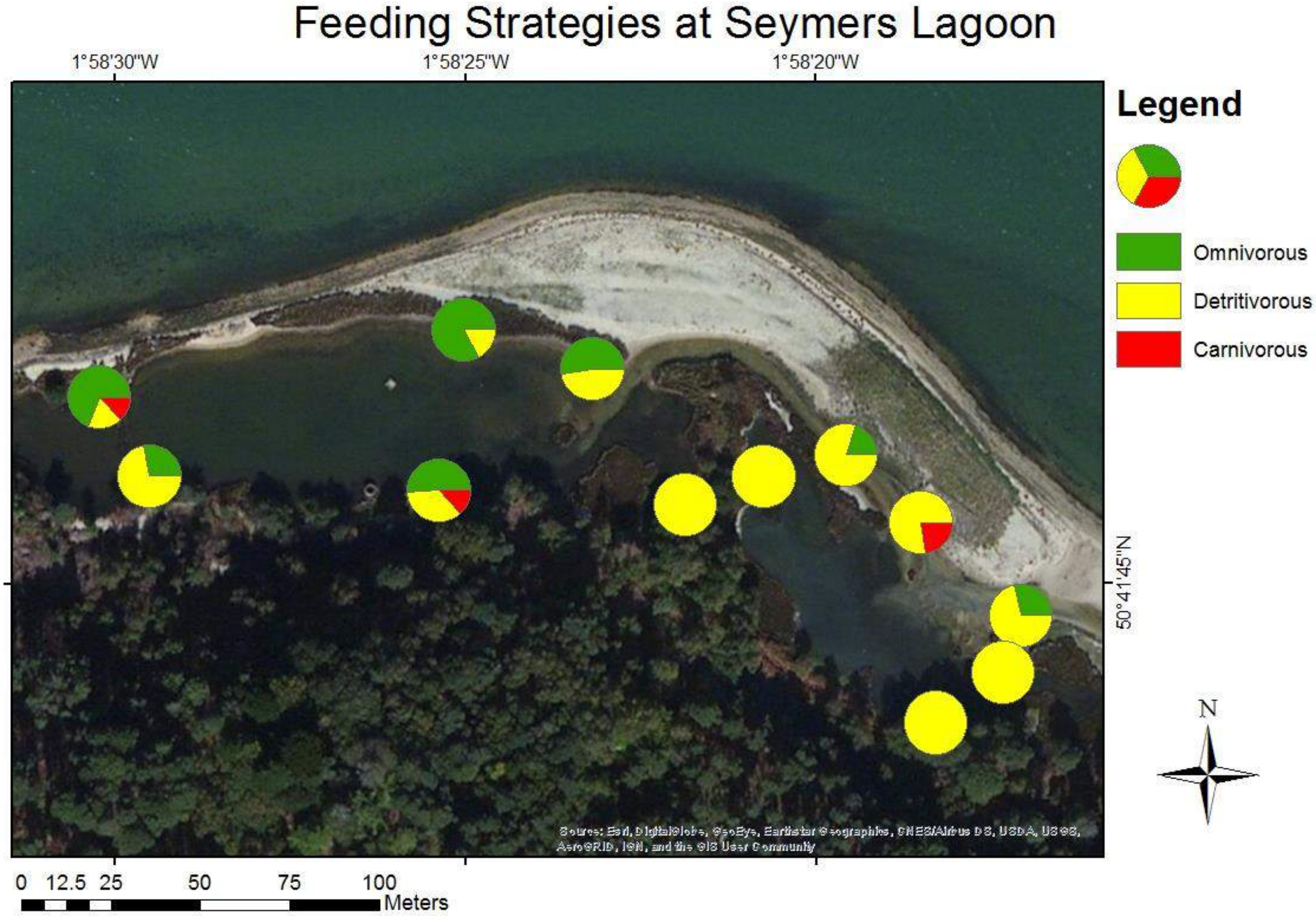

Figure 6 The spatial distribution of macrozoobenthic diets using transformed abundance data.

39.86% (x̄ 10.12%) and was on average highest in the west section. No measurements for OM were taken in November.

Table 2 A summary of the environmental data taken for Seymers lagoon.

Site	Temperature (°c)		Salinity (‰)		OM (%LOI)	Granulometry (%)		O2 (mg/l)
	November	April	November	April	April	April		November
						Silt (≤63µm)	Sand (>63µm)	
East 1	12.1	16.3	35.37	26.7	7.33	45.11763	54.88237	6.25
East 2	11.9	17.3	35.06	26.8	8.91	60.93398	39.06602	7.4
East 3	12.5	17.8	36	23.1	15.81	75.24997	24.75003	7.55
East 4	13.1	18.6	35.18	23.3	0.35	7.31011	92.68989	8.14
East 5	12.7	DRY	34.44	DRY	0.46	6.19038	93.80962	7.01
East 6	12.3	DRY	28.81	DRY	0.04	11.51500	88.48500	9.04
West 1	11.6	14	31.59	32.6	39.9	81.65324	18.34676	5.58
West 2	11.6	14.1	34.65	33	18.02	84.48067	15.51933	6.93
West 3	11.4	15	33.37	35	6.41	61.85376	38.14624	6.97
West 4	12.1	17.4	33.71	34.4	7.47	62.17437	37.82563	7.02
West 5	11.9	16.9	34.65	35	0.5	12.69537	87.30463	7.03
West 6	12	18.1	32.95	35.4	16.18	78.13464	21.86536	7.57

Particle size fractions for each sample site are summarised in Table 3. Most sample sites were predominantly silt based sediments (E2, E3, W1, W2, W3, W4, W6) and 5 sites were predominantly sand based sediments (E1, E4, E5, E6, W5). Silt content ranged by 69% (x̄ 34.4%) and by 71.8% (x̄ 63.5) in the east and west basin respectively. Sand content ranged by 68.7% (x̄ 65.6%) and 71.8% (x̄ 36.5%) in the east and west basin respectively.

Table 3 A summary of average particle size fractions for each sample site. Particles >2mm were sieved and weighed separately.

	% Particle Size Fraction							
Site	<63µm	63µm	125µ	250µm	500µm	1mm	2mm	>2mm (g)
E1	37.04	7.72	14.37	37.04	3.47	0	0	0
E2	49.80	11.13	5.74	22.90	10.43	0	0	0
E3	62.68	12.57	4.71	11.78	8.25	0.01	0	0
E4	7.31	0.00	2.44	53.36	36.89	0	0	0.35
E5	6.17	0.02	1.97	51.77	40.07	0	0	0.04
E6	11.30	0.18	8.33	67.41	12.74	0	0	0.18
W1	66.63	15.02	7.81	7.60	2.94	0	0	0
W2	73.15	11.34	5.75	5.84	3.90	0.03	0	3.70
W3	48.81	13.04	13.64	20.59	3.92	0	0	6.03
W4	51.74	10.44	7.79	24.05	5.98	0	0	1.11
W5	12.59	0.11	2.09	53.13	32.09	0	0	0
W6	62.95	15.19	8.08	10.24	3.55	0	0	0

There was a positive correlation between OM and silt content (Pearson's coefficient, $r = 0.779$, $n = 12$, $p = 0.003$). A scatterplot summarises these results, with an r^2 value of 0.6 (see Figure 7). There were no further correlations between environmental variables. There was a significant difference between the temperature of the east and west basin (ANOVA, $F = 10.204$, d.f = 1 and 10, $p = 0.10$). There were no further significant differences between environmental variables in the east and west basin.

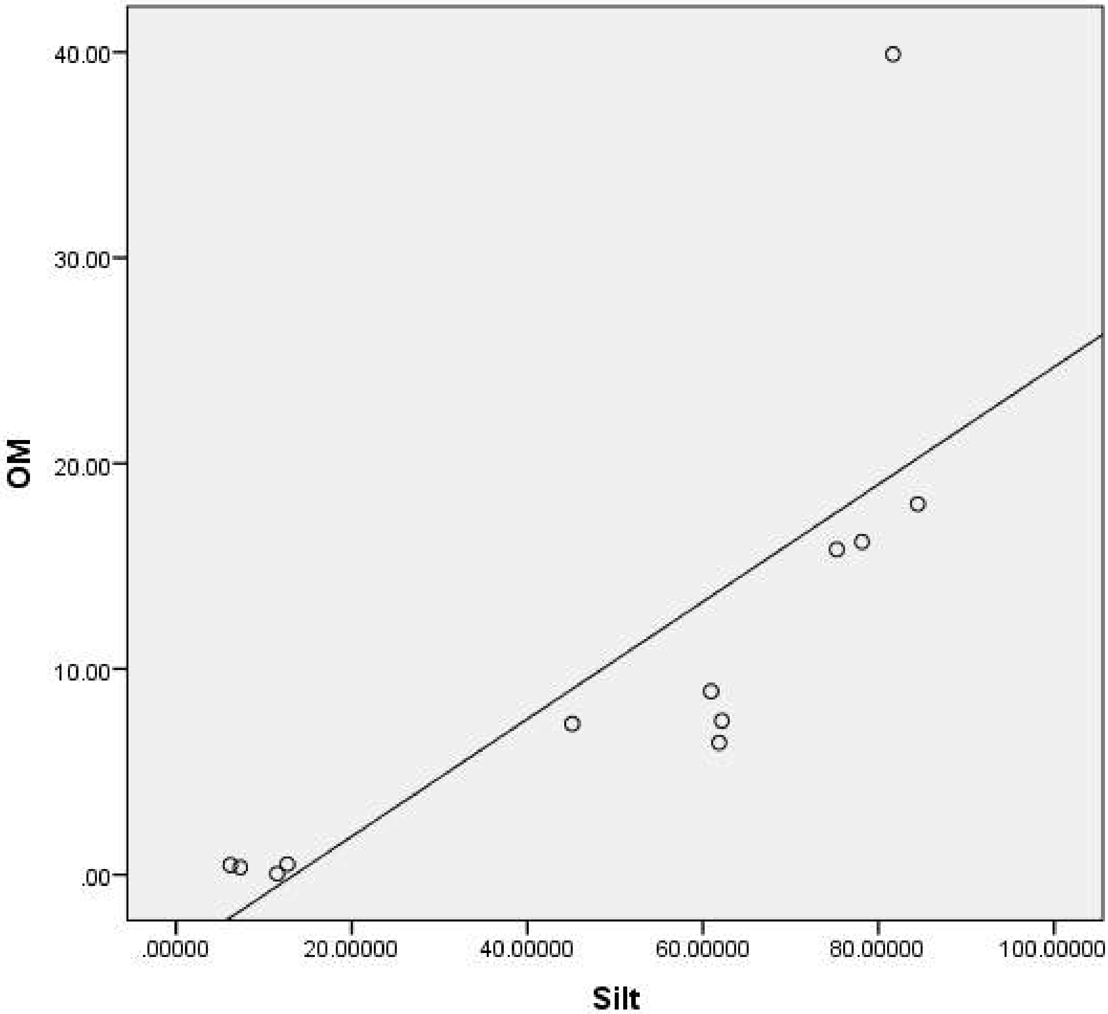

Figure 7 A scatterplot summarising the relationship between silt content and OM for Seymers lagoon.

There are no correlations between species richness, abundance, and Simpsons and Shannon diversity indices with temperature, salinity, OM, and silt/ sand particle size (ANOVA, $p = >0.05$).

3.5 Comparison of the East and West Side of Seymers Lagoon

The west basin had a greater abundance of individuals and number of species with 644 individuals and 10 species compared with 310 individuals and 3 species in the eastern basin and was significantly more biodiverse in species richness (Kruskal Wallis, d.f. = 1, p = 0.026), Shannon Diversity Index (Kruskal Wallis, d.f. = 1, p = 0.028), and Simpsons Diversity Index (ANOVA, F = 12.028, d.f. = 1 and 10, p = 0.006). Simpsons and Shannon Diversity indices for the east had a mean score of 0.916 and 0.15 respectively and the west had a mean score of 0.451 and 1.013 respectively. Abundance is not significantly different between east and west basins (ANOVA, F = 1.056, d.f. = 1 and 10, p = 0.328). The multidimensional scaling plot shows the east and west basin plots do not overlap (see Figure 8).

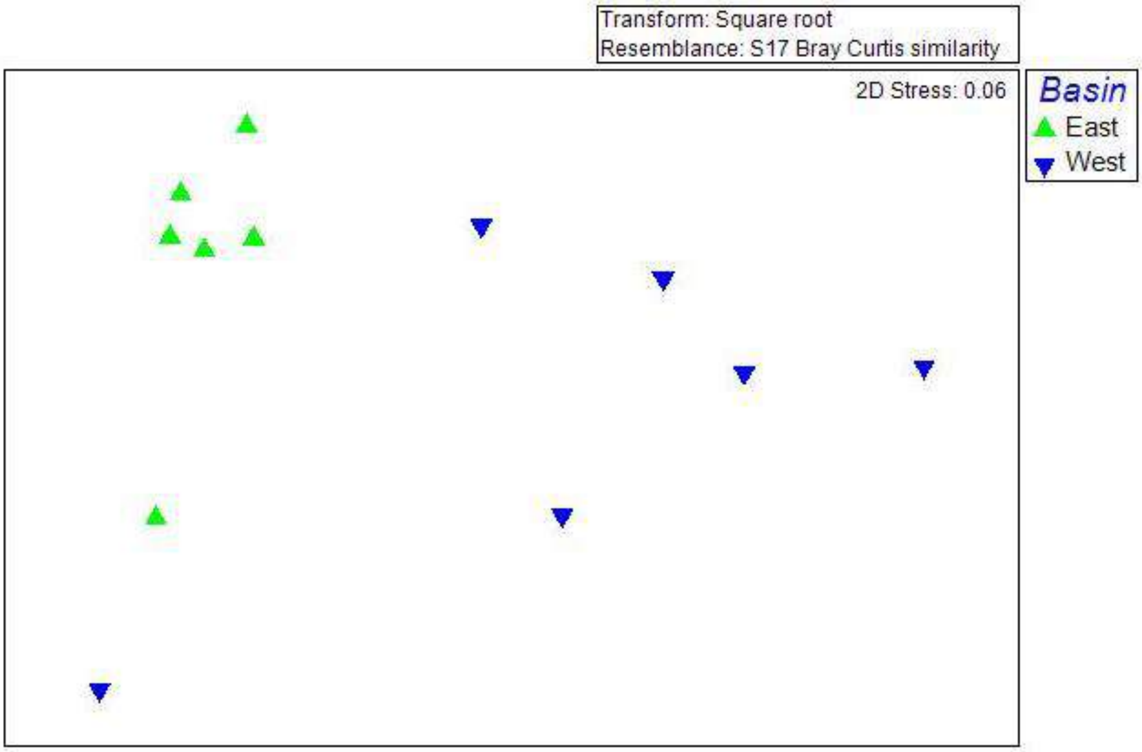

Figure 8 A MDS plot showing the dissimilarity between the communities of the east and west basins of Seymers lagoon.

The east basin plots are more closely clustered which reflects the homogenous communities comprised nearly exclusively of Chironomid larvae. The west basin plots show greater distances between them, reflecting more heterogenous communities. The most abundant phylum in the east basin was Insecta with 295

Chironomid larvae present in all east site samples. The least abundant phylum in the east section was Cnidaria with 3 *N. vectensis* individuals which were only present in E5. The most abundant phylum in the west section was Crustacea with an abundance of x̄ 49 *M. insidiosum* individuals per sample site. The least abundant phylum in the west basin was Mollusca with 5 individuals in W4, W5, and W6. The communities between the east and west basin are significantly different (ANOSIM, Global R = 0.594, $p = <0.05$).

3.6 Biodiversity of Poole Park Lagoon

The overall abundance of Poole Park lagoon numbered 1055 individuals with a total of 13 species over 2 sample sites, BL5 and BL6. The most abundant sample site was BL6 with 613 individuals over 5 months (x̄ 61.3 per survey). The most abundant date was 24th June 2015 with 594 individuals, dominated by *M. insidiosum* in BL6 (N = 268) and by Tubificid spp. in BL5 (N = 88). Overall mean Simpsons and Shannon diversity indices were x̄ 0.61 and x̄ 1.02 respectively. The most abundant phylum was Crustacea with 468 individuals dominated by *M. insidiosum* (N = 296) with the amphipod *M. gryllotalpa* frequently abundant (N = 168) and *Mysida* spp. scarcely abundant. The least abundant phylum was Mollusca (N = 66) but this phylum represented the greatest species richness with 5 species; *P. ulvae*, the lagoon spire snail *Ecrobia ventrosa*, the sand gaper *Mya arenaria*, the lagoon cockle *C. glaucum*, and bivalve spat (Harrison et al. 2016). Four lagoon specialists were present in sediment core samples including *N. vectensis*, *M. insidiosum*, *E. ventrosa,* and *C. glaucum*, comprising 42.5% of the total abundance.

3.7 Biodiversity of Brownsea Lagoon

The overall abundance of Brownsea lagoon numbered 4856 individuals with a total of 23 species over 6 sample sites and 18 total samples. The most abundant sample site was 1 with 1304 individuals and the least abundant site was 5 with 516 individuals. Overall mean Simpsons and Shannon diversity indices were x̄ 0.29 and x̄ 1.99 respectively. The most abundant and species rich phylum was Annelida with 2366 individuals and 9 species, dominated by the oligochaete

Tubificoides benedii (N = 1069), *H. diversicolor* (N = 274), the bristleworm *Aphelochaeta marioni* (N = 645), and the polychaete *Polydora cornuta* (N = 341). The oligochaete *Tubificoides pseudogaster* and 4 polychaetes were scarcely abundant. The least abundant phylum was Nematoda which was scarcely abundant (N = 4), followed closely by Insecta also scarcely abundant (N = 9) (Herbert et al. 2010). Four lagoon specialists were present in sediment core samples including *N. vectensis, Idotea chelipes*, *M. insidiosum* and *E. ventrosa*, comprising 45.9% of the total abundance.

3.8 Comparison of Poole Harbour Lagoons

Five species were present in each of the three lagoons; *N. vectensis, H. diversicolor, M. insidiosum, Tubificoides* spp. and Chironomid larvae (see Figure 9). These were most abundant in Brownsea lagoon except for Chironomid in which it was the least abundant (N = 2). Cnidaria, Annelida, Crustacea, Insecta, and Mollusca were represented in all three lagoons but Nematoda was absent from Poole Park lagoon. Brownsea lagoon had the greatest abundance (N = 4856), the greatest species richness (23 species), and the most diverse Simpsons Diversity and Shannon indices, $\bar{x}$ 0.29 and $\bar{x}$ 1.99 respectively. Seymers lagoon had the least abundance (N = 952) and the poorest species richness with 10 species. The Simpsons Diversity Index scores between Seymers and Poole Park lagoon were similar with a score of $\bar{x}$ 0.68 and $\bar{x}$ 0.61 respectively, showing similar evenness. The biodiversity indicators are summarised in table 4.

Table 4 A summary of the biodiversity indicators for the three Poole Harbour lagoons.

Lagoon	Species Richness	Abundance	Simpsons Diversity Index ($\bar{x}$)	Shannon Diversity Index ($\bar{x}$)
Brownsea	23	4856	0.29	1.99
Poole Park	13	1055	0.61	1.02
Seymers	10	952	0.68	0.84

The least abundant phylum in both Poole Park lagoon and Seymer’s lagoon was Mollusca though in Brownsea lagoon it was the second most abundant phylum with 1198 individuals with two species; the bivalve (*Abra tenuis*) and the lagoon

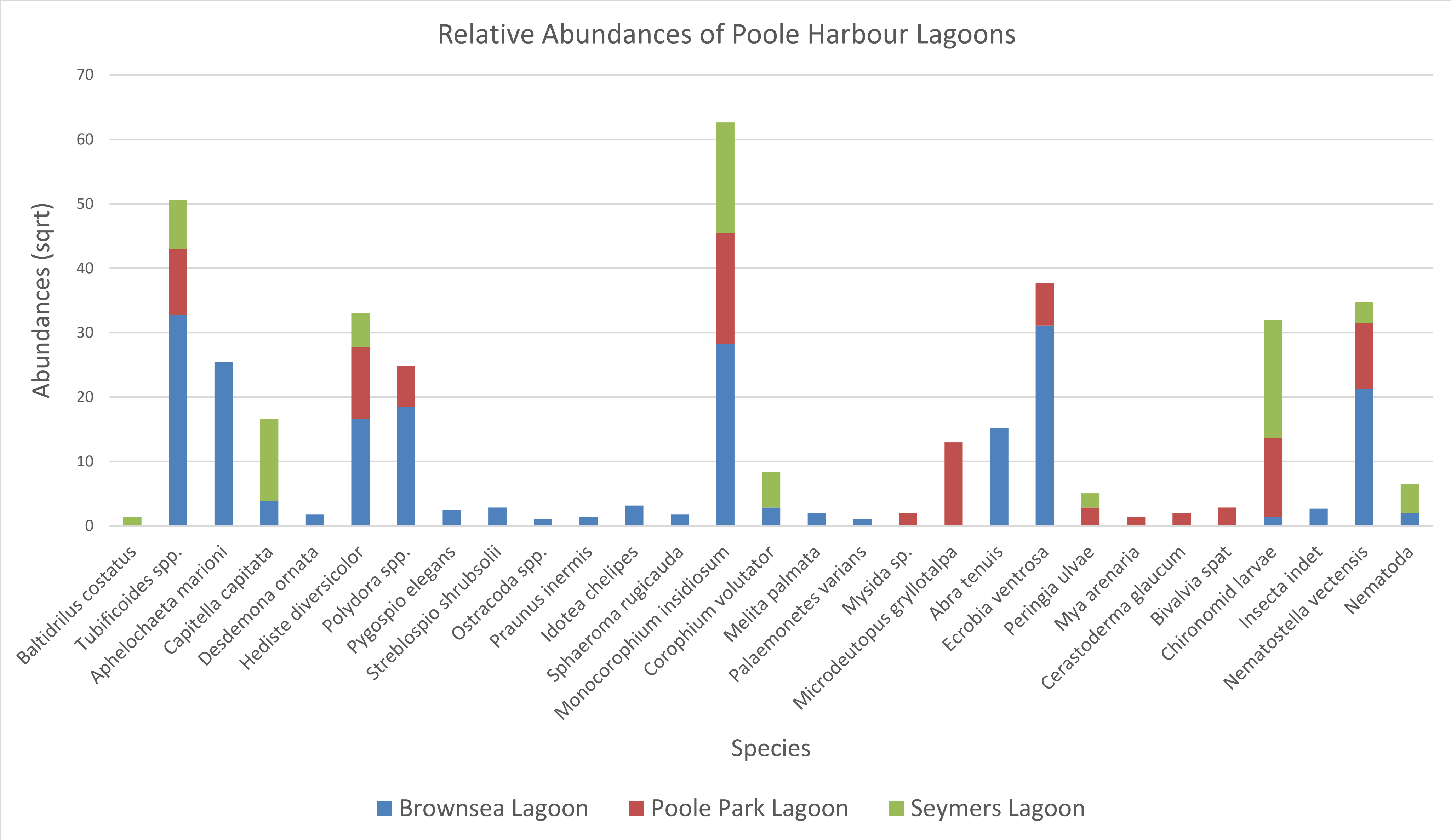

Figure 9 A summary of the relative abundances of the Poole Harbour lagoons. The abundance data have been transformed (square root) so rarer species are better represented.

spire snail (*E. ventrosa*). However, Poole Park had a greater species richness within Mollusca with 5 species, including the sand gaper (*M. arenaria*) and bivalve spat that were not found in the other two lagoons. Both ENLag.Veg and ENLag.IMS.Ann biotopes were found in both Seymers lagoon and Brownsea lagoon (see Table 1).

The multivariate analysis revealed the macrozoobenthic communities of Poole Park lagoon, Brownsea lagoon and Seymers lagoon are significantly different to each other (ANOSIM, Global R = 0.682 p = <0.05) (see Table 5). The MDS plot shows Brownsea lagoon samples in a discrete, tightly clustered group, indicating more homogenous communities (see Figure 10). Poole Park and Seymers lagoon sample plots are more widely spaced apart but show some overlap, indicating some similarity between sample assemblages. The stress level of the MDS output (0.12) exceeded the acceptable threshold of 0.1 and so should be interpreted cautiously. Simpsons Diversity Index (Kruskal Wallis, d.f. = 2, p = 0.00), Shannon Diversity Index (Kruskal Wallis, d.f = 2, p = 0.00), species richness (ANOVA, d.f. = 47 and 49, p = 0.00), and abundance (ANOVA, d.f. = 47 and 49, p = 0.00) of the three lagoons were also all significantly different from each other.

Table 5 The pairwise tests output from the Poole Harbour lagoon ANOSIM analysis.

Pairwise Tests					
Groups	R Significance		Possible Permutations	Actual Permutations	Number >= Observed
	Statistic	Level %			
Brownsea Island, Poole Park	0.786	0.1	Very large	999	0
Brownsea Island, Seymers Lagoon	0.846	0.1	86493225	999	0
Poole Park, Seymers Lagoon	0.333	0.1	225792840	999	0

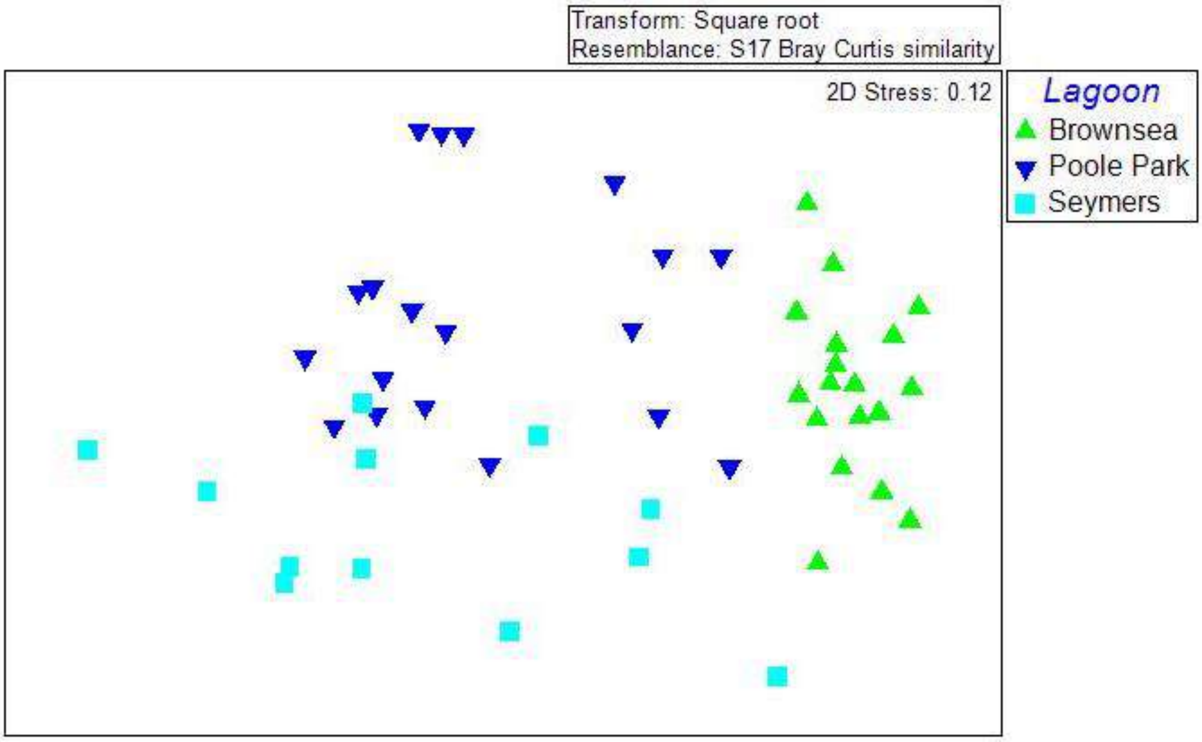

Figure 10 A MDS plot showing the dissimilarities of communities between the lagoons of Poole Harbour.

4. Discussion

Lagoons are characterized by highly variable environmental parameters which thus leads to relatively low biodiversity when compared to other coastal ecosystems (Bamber et al. 1992). This study has described some of the environmental parameters within a previously unknown lagoon on Brownsea Island and explains how this affects the distribution of macrozoobenthos therein. Seymers lagoon was characterized by two basins with discrete faunal communities and was ranked as the second most biodiverse Poole Harbour lagoon, with Poole Park lagoon with the least biodiverse biota and Brownsea lagoon with the greatest diversity. The implications of these findings will be discussed with specific reference to developing management measures to mitigate the imminent threat of sea level rise and the potential loss of Brownsea lagoon.

4.1 A Snapshot into Seymers Lagoon

The western basin of Seymers lagoon had significantly greater species richness ($n = 10$), and Simpsons and Shannon diversity indices values (0.451 and 1.013 respectively) than the east basin so this study will therefore accept the alternative hypothesis (H_2). The MDS plot (see Figure 8) reflects the homogeneity of the communities in the east basin sample sites with closely clustered plots, whereas the west basin sample sites are more loosely scattered. All but two sample sites in the east basin were comprised exclusively of Chironomid larvae, suggestive of unfavourable environmental conditions. In November 2016, the channel was discharging water seaward as the tide retreated in the harbour and when the lagoon was visited in April 2017, the channel was dry. In April, the area of the eastern section of the lagoon was reduced and sample sites E5 and E6 were dry. The narrow channel connecting the east and west basin was also dry, ceasing the water exchange between them. The western lagoon area was not as noticeably reduced and was deeper, up to approximately 1m at one site, whereas the eastern basin was no deeper than approximately 30cm. Despite the east basin's closer proximity to the inlet channel, its shallower depth makes it vulnerable to dehydration by evaporation, as observed in April, increasing the likelihood of mortality for macrozoobenthos, with recovery made challenging by hypoxic, sulfide-rich sediment. Evaporation appears not to have promoted hypersalinity with the east basin and it had a mean salinity of 25.25‰. The east basin was also significantly warmer than the west (ANOVA, $F = 10.204$, d.f = 1 and 10, $p = 0.10$). Temperature of shallow water responds rapidly to air temperature; the shallower depth of the east basin explains this significant difference in temperature (Abbasi et al. 2016). Temperature is positively correlated with rate of development in Chironomid larvae, therefore the warmer water may selectively favour Chironomid larvae proliferation (Huryn and Wallace 1986). Furthermore, their possession of haemoglobin allows them to survive in hypoxic environments and the abundance of organic matter provides a sufficient food source for this deposit feeding detritivore (Panis et al. 1995; Weber 1980; Ewer 1942). Chironomid larvae are not significantly affected by sedimental sulfide, and have been found to be more abundant in sulfidic habitats (Kanaya 2014; Kanaya 2005). Lack of connection with the sea and the west basin will also impair recruitment of marine organisms within the lagoon by preventing transport of larvae and migration. However, this would not affect recruitment of Chironomid larvae, as their adult life stage is terrestrial, with eggs laid on the surface of still bodies of water (Tokeshi and Reinhardt 1996). In the east basin, hydrology seems to be the predominant environmental parameter influencing species diversity via desiccation of sediments and isolation from the western section and the sea.

The species composition of fauna provides an indication of the ecological health of the west basin. It was significantly more biodiverse than the east basin with a greater presence of omnivores (see Figure 6). Chironomid larvae and *M. insidiosum* were negatively correlated with silt content (see Figure 5) which is known to limit species richness and abundance (Day et al. 2017). *M. insidiosum* was the most abundant species and comprised 46% of the west basin fauna. *N. vectensis* was the only carnivorous species present, comprising 1%, and the low presence of carnivores suggests a simplified trophic chain. Omnivorous species comprised 82% and play similar ecological roles. *Tubificoides* spp. and *C. capitata*, which comprised 34% of the west basin abundance collectively and are typical ‘sulfide annelids’, are well known colonizing pioneer species with *C. capitata* an indicator species of organically enriched sediments (Kodama et al. 2012; Kinoshita et al. 2008; Nicolas et al. 2007; Cuomo 1985; Warren 1977). The annelid *A. marina*, which was observed in frequent abundance, also occupies this ecotrophic guild (Giere et al. 1999). The community structure of Seymers benthic habitat is typical of hypoxic-sulfidic sediments, which are likely to have formed because of the anaerobic microbial decomposition of organic material from the adjacent perennial forest (Godbold and Solan 2009; Hargrave et al. 2008; Capone and Kiene 1988). Bishop et al. (2010) found that excessive nutrient enrichment along the coast of Sydney, Australia, increases abundance of opportunistic macroinvertebrate species, much like those found in Seymers lagoon. Sulfide and hypoxia may be limiting factors in abundance and succession as it is toxic to most benthic invertebrates (Vaquer-Sunyer and Duarte 2010). *C. volutator,* an amphipod sensitive to hypoxic sulfidic conditions, was found only in seaward sample sites where organic content was lowest though was not significantly correlated. The annelid worms present are all highly tolerant of hypoxic and sulfidic conditions, particularly *H. costata* and *Tubificoides* spp. which are found in deeper sediment layers (Gamenik et al. 1996; Theirmann et al. 1996; Dubilier et al. 1995; Vismann 1990). Such vertical distribution of oligochaetes may prevent interspecific competition. Oligochaete and Chironomid dominance in fine sediments and presence of *P. ulvae* in coarse sediments in Seymers lagoon is similar to the spatial distribution of macrozoobenthos in the Obidos lagoon, Portugal (Carvalho et al. 2005).

Though deposit feeders are crucial to nutrient recycling, their small size is less effective at retaining nutrients within the sediments, making the lagoon less resistant to eutrophic events (Lloret and Martin 2011). Additionally *A. marina* release nutrient-rich porewater through bioturbation, exacerbating nutrient loading in the water column (O'Brien et al. 2009). Guano and porewater release from sediment resuspension from wildfowl activity may also exacerbate nutrient loading of this eutrophic lagoon. Though *C. linum*, *Ulva* spp., and *S. muticum* were present, much of the observed lagoon was bare sandy substrata, unsuitable for attachment. The paucity of nutrient-sequestering macrophytes may also increase vulnerability to eutrophic events (Jeppesen et al. 1997). *P. ulvae*, which comprised <1%, are more intolerant of excessive nutrients which may explain their low abundance, in addition to the notable absence of bivalves, particularly *C. edule* which was present in the other Poole Harbour lagoons. Long term nutrient enrichment is known to result in reduced species diversity and abundance (Macleod et al. 2004; Savage et al. 2002; Sarda et al. 1996).

4.2 Hydrodynamics: The Importance of Flushing

The lagoon basin was initially formed from mining activity and flooded with seawater via the mine shafts with the inlet channel likely developing later (West and West 2007). The inlet channels location has changed over time, as seen in Figure 3, and changes in location and function will determine the hydrological regime subsequently influencing salinity, depth and area, and trophic status. It is unknown how frequently the west basin is flushed by tidal seawater and it appears that the east basin must first be “topped up” before the channel between the two basins is reconnected. Therefore, it is unlikely the west section is sufficiently flushed of excess nutrients when this does occur. Previous studies have correlated faunal community structures with proximity to the inlet channel, with more confined communities furthest away (McArthur et al. 2000; Guelorget and Perthuisot 1992). Seymers lagoon has two basins with distinct faunal assemblages that do not fit this model, with no relationships between distance to inlet channel and species richness or abundance. Bazairi et al. (2003) found that the spatial distribution of species within Merja Zerga lagoon in Morocco were not discrete communities within single habitats, but occurred along a coenocline reflecting a gradient of environmental variables. Spatial heterogeneity of macrozoobenthic communities can occur on small scales, with different taxa distributed differently depending on various environmental parameters as found in Idoura lagoon, Japan, by Kanaya and Kikuchi (2008). Hence, it may be prudent in future to survey Seymers lagoon on a finer spatial scale, particularly as it is relatively small, and take more than one sample from each site to improve validity.

Salinity is commonly thought to be the primary factor responsible for determining spatial distribution within lagoons but it is the complex outcome of mixing, diffusion, evaporation and freshwater input, and was not correlated with biodiversity in Seymers lagoon (Fiandrino et al. 2017; Carvalho et al. 2011; Bamber et al. 1992; Guelorget and Perthuisot 1983). Recently there has been greater emphasis on hydrology and edaphic factors determining spatial distribution (Joyce et al. 2005; Bazairi et al. 2003; Pfannkuche 1980). Faunal assemblages and observations suggest that water exchange is infrequent enough to limit the biodiversity Seymers lagoon can support. When the inlet channel was functional in November, Poole Harbour tide height was 2.5m, thus water exchange may only occur on spring tides which are high enough to breach the inlet channel. However, this speculation should be treated cautiously until further research can be done to ascertain frequency and volume of tidal exchange. Furthermore, the north coast of Brownsea Island is an area of sedimentation which risks permanent closure of the inlet channel (Carter et al. 2012).

Lagoon hydrodynamics is a complex interaction in the sea level difference between the lagoon and neighbouring sea, inlet geometry, and bathymetry (Tenorio-Fernandez et al. 2016; Schoen et al. 2014; DiLorenzo 1988). A recent study by Fiandrino et al. (2017) has shown that hydrology within a lagoon is pivotal in determining its physico-chemical parameters and consequently the spatial distribution of biota. Mitchell et al. (2017) assessed the importance of flushing with water quality at several coastal lagoons in Ghana and found their ecological health was diminished where flushing was low, which supports the notion that Seymers lagoon is not sufficiently flushed and therefore degraded. Moreno et al. (2010) studied the effects of littoral drift on the water exchange of the Zahara de los Atunes lagoons in southern Spain. Water exchange is artificially facilitated and naturally ceases following sedimentation but the date of inlet channel closure is dependent on when sedimentation occurs in conjunction with freshwater inputs that flush sediments out of the inlet channel. This emphasizes the need to obtain seasonal temporal data to understand the hydrodynamics of Seymers lagoon and how this may be connected to the littoral drift that occurs along the northern coast of Brownsea Island (Carter et al. 2012). It should be noted that this study does not consider the effect of biotic factors, such as predation of macrozoobenthos by wildfowl or competition and how this may impact biodiversity.

4.3 Poole Harbour Lagoons

Poole Park lagoon, Brownsea lagoon and Seymers lagoon all had significantly different faunal communities. Poole Park lagoon is a recreational boating lake within an urban park and is managed by Poole Borough Council. Brownsea lagoon is a wildlife reserve managed by Dorset Wildlife Trust with little public access. Seymers lagoon is unmanaged as a lagoon habitat but is incorporated within the Dorset Wildlife Trust wildlife reserve with no public access. All three were formed in the mid to late 19th century (Harrison et al. 2016; Herbert et al. 2010; West and West 2007). Hydrology appears to be the predominant environmental variable determining the macrozoobenthic communities and ecological health within the Poole Harbour lagoons compared in this study, which is supported by several studies (Fiandrino et al. 2017; Netto and Fonseca 2017). Lagoon specialists *N. vectensis* and *C. insidiosum* were present in all three lagoons which highlights their importance as habitats for these scarce lagoon specialists (Sheader et al. 1997).

Seymers lagoon had the poorest abundance (N = 952) and species richness with 10 species, 3 species less than Poole Park, and had the smallest proportion of lagoon specialists with 32%. Therefore, this study will accept the alternative hypothesis (H_1); it is significantly less species rich than the other two Poole Harbour lagoons (ANOVA, d.f. = 47 and 49, p = 0.00). Though significantly different to Brownsea and Poole Park lagoons (ANOSIM, Global R = 0.594, p = <0.05), the MDS plot showed some overlap and thus similarity between the faunal assemblages of Poole Park and Seymers lagoon (see Figure 10). This is supported by their similar species richness and abundance, and can be explained by their similarly insufficient water exchange regime. It should be noted however that samples were taken over a 5-month period in Poole Park lagoon and 3 replicate samples were taken from each sample site in Brownsea lagoon; only 1 sample per sample site was obtained from Seymers lagoon on 1 day. Therefore, their comparison should be treated cautiously. Furthermore, the samples for Seymers and Brownsea lagoon were obtained in November whereas Poole Park lagoon was surveyed during spring and summer, when biodiversity in lagoons is known to be depressed by higher temperatures and eutrophic events (Carvalho et al. 2011). Despite this, abundance and species richness in Poole Park lagoon peaked in late June before declining in subsequent samples.

4.3.1 Brownsea Lagoon: An Example of Good Habitat Health

Brownsea lagoon is the largest lagoon of the three. It is managed by the Dorset Wildlife Trust where public access is limited due to the sensitive avifauna associated with the site. Freshwater is discharged via small streams draining Brownsea Island and tidal water exchange is more frequent than Poole Park lagoon, with the sluice gates left open over the autumn to expand the foraging area available to wildfowl. The relatively stable salinity regime ranges from 26-29‰ and supports 23 species of benthic invertebrates, the biomass of which exceeds the energy requirements of all bird species that rely on the lagoon for winter foraging, excluding oystercatchers (*Haematopus ostralegus*) (Herbert et al. 2010; Thomas et al. 2004). Its management under the Dorset Wildlife Trust as a wildlife reserve on a relatively isolated island has facilitated its good ecological health, with pumps and a sluice gate actively managing its water exchange regime.

4.3.2 Poole Park: An Example of Good Potential

Poole Park lagoon had moderate species richness with 13 species and low abundance (N = 1055) which is explained by the management of its water exchange regime. As it is predominantly an ornamental lake, originally formed in 1890, the priority of its management has historically been skewed towards recreational use with little consideration towards its ecology. Consequently, the sluice gate is not opened enough to sufficiently flush the excessive nutrients from sewage and surface water overflow input from over 50 freshwater pipes discharging into the lake and the habitat is degraded (Harrison et al. 2016). The historic practice of draining the lake to allow winter frosts to eradicate algal growth still occurs on occasion to curb the proliferation of nuisance Chironomid swarms and tasselweed *Ruppia* spp., and was last fully drained in 2007. Such desiccation of sediments will render the macrozoobenthic community moribund. Recolonization and succession will take time with little opportunity for recruitment via the sluice gate. If freshwater inputs are also greater than marine, it will reduce the number of species able to survive in the hyposaline conditions and increase abundance of Chironomid larvae. Poole Park lagoon has only recently been recognized for its ecological potential and planning applications have been made for several management measures to improve water quality and thus biodiversity (Harrison et al. 2016). These include opening the sluice gate on the monthly spring tide and diverting surface water inputs to Poole Harbour. Improving the water exchange regime is known to improve water quality and it is anticipated to curb the proliferation of nuisance species and reduce hypertrophic conditions (Mitchell et al. 2017). Though Poole Park lagoon is degraded, it is unlikely this will persist in the future if restoration plans are enacted successfully (Harrison et al. 2016). Spatio-temporal surveying of abiotic factors and biodiversity should continue post restoration to assess ecosystem health and monitor changes to learn what is within “normal” ranges throughout the year.

4.3.3 Shifting Shorelines

The starlet sea anemone occurred in all three lagoons, which represents a hotspot for its distribution as it is only thought to occur in approximately 20 lagoons in Europe, all found in England. It is protected under Schedule 5 of the Wildlife and Countryside Act 1981 and is listed as Vulnerable on the IUCN Red List of Threatened Species (ICUN 2017; JNCC 2010). Its designation has arisen from the transitional nature of its coastal lagoon habitat which faces a multitude of anthropogenic threats, exacerbated by climate change related pressures, and are particularly pronounced in small lagoons such as Seymers (Mateus et al. 2016; Newton et al. 2014; Chapman 2012; Lloret et al. 2008). Additionally, lagoons are scarce habitats and a priority feature for designations of Special Areas of Conservation. Poole Harbour has already lost Blue lagoon that was inhabited by the starlet sea anemone (Sheader and Sheader 1992; Sheader and Sheader 1985). Currently, Brownsea lagoon is threatened with the loss of the sea wall the separates the lagoon from the sea, a scenario which will not be prevented in line with its Shoreline Management Plan which is supported by the National Trust under their Shifting Shorelines policy (National Trust 2015; Guthrie and Eggiman 2011). The timescale for its failure is not known but is thought to be inevitable in the advent of climate change induced sea-level rise and storm activity (Anthony et al. 2009; Oouchi et al. 2006). Loss of the lagoon would include loss of a highly productive ecosystem, including key foraging sites for wildfowl and nationally scarce lagoon specialists (Herbert et al. 2010). Therefore, the ecological potential of Seymers lagoon and Poole Park lagoon is that much more pertinent as it can provide refugia for biota that are dependent on coastal lagoons and act as buffers against an uncertain future.

4.4 Applications

From Poole Park and Brownsea lagoon examples, it is evident that getting the balance right with tidal exchange is key in preventing hypoxic-sulfidic sediment conditions while still promoting the physico-chemical parameters that will support the resident lagoon specialists. Subsequently, to reverse the degradation in Seymers and Poole Park lagoon it is necessary to facilitate better water exchange to improve flushing, an example of a proactive management measure (Chapman 2012). Management of water exchange at Poole Park is set to improve but further surveys must be undertaken at Seymers lagoon to fully inform the design and implementation of appropriate management measures. Identifying nutrient sources is recommended by Bamber et al. (2001) and remedial action is advised to improve water quality, which supports Elliot and Whitfield's (2012) conclusion that management of lagoons should include consideration of the adjoining marine and terrestrial areas. Surrounding trees and shrubbery can be coppiced to reduce the organic matter entering the lagoon and contributing to the nutrient loading. As water exchange occurs via an inlet channel, improving water exchange may be less labour intensive as that of the sluice operation at Brownsea and Poole Park lagoon; the inlet channel can be deepened so water exchange can occur more frequently, though this may require maintenance depending on sedimentation rates (Carter et al. 2010). As climate change increases air temperature, and anthropogenic activity increases availability of nitrogen, eutrophic events and harmful algal blooms are predicted to increase in frequency (Rodriguez-Gallego et al. 2017; Moss et al. 2011; Conley et al. 2007). Therefore, establishing effective management measures now will help mitigate these threats to ecosystem functioning and biodiversity in the future (Chapman 2012). Research into seasonal temporal changes should first occur to understand the natural fluctuations in biota, in addition to obtaining a greater understanding of the hydrology and pelagic fauna. The standardized methodology utilized in this study makes it easily repeatable and comparable to future datasets. Interspecific competition should also be investigated as attempts to conserve lagoonal specialists can be thwarted by increased abundance of generalist species (Barnes and Gandolfi 1998).

Adaptive and proactive management of Seymers lagoon must be considered to mitigate against habitat loss from climate change and anthropogenic pressures. It should be noted however, that lagoons are transitional ecosystems and are therefore dependent on human intervention to prevent their succession and maintain the characteristics on which they are reliant (Cognetti and Maltagliati 2008). Unlike Poole Park lagoon, which has little scope for expansion, Seymers lagoon has potential to extend landwards. Such development is necessary to consider in the advent of losing Brownsea lagoon and its associated biodiversity, not including the loss of ecosystem services and socioeconomic implications such as reduced tourism revenue. It is also an example of adaptive coastline management, known as managed realignment, which is the designation of land that allows shorelines to respond dynamically to sea-level rise and erosion (Kuklicke and Demeritt 2016; Esteves 2014). Its implementation is becoming more popular within coastal management policy worldwide as it encourages longer term spatial planning and reduces the high cost of hard coastal defenses that are ultimately degraded (Reisinger et al. 2014; Abbott 2013). This creation of space is essential for the preservation of vulnerable coastal habitats, such as lagoons.

Small bodies of surface water already exist immediately behind Seymers lagoon where the ground level appears to drop below the water table and it would be relatively straightforward to expand into these by removing the sediment between them and the lagoon. Due care must be given to avoid negatively impacting the existing faunal communities and protected species *N. vectensis* during such works. It would be prudent to plan and enact such works sooner rather than later to allow the extension to be sufficiently colonized and functional before the failure of the Brownsea wall, rather than as a reaction (Beer and Joyce 2013; Brooks and Spencer 2012). Landward migration of shorelines is anticipated in the years to come due to sea-level rise, so facilitating this now will offer Seymers lagoon resilience against the inevitable (Esteves 2014; Anthony et al. 2009; Church and White 2006).

5. Conclusion

Following an initial survey, a snapshot into the biodiversity and environmental parameters of Seymers lagoon has given a first glimpse at its ecological status, which is degraded. There were no significant relationships between spatial distribution of benthic communities and measured environmental variables so, using pre-existing literature, alternative environmental factors were investigated and discussed. It is postulated that a poor water exchange regime is promoting hypertrophic events which are restricting the species diversity to hypoxic-sulfidic annelids and a small number of lagoon specialists. Both Seymers lagoon and Poole Park lagoon are degraded habitats with ecological potential based on improved trophic status via the facilitation of greater water exchange. Improvement in their habitat quality and biodiversity is pertinent in the inevitable loss of Brownsea lagoon and threat of sea-level rise, to provide refugia for the lagoon specialists, wildfowl, and protected species that are dependent on these ephemeral and scarce habitats. Seymers lagoon has scope for landward expansion which would compensate loss of area when Brownsea lagoon is defunct, in addition to buffering against the uncertainty of climate change induced sea level rise.

This study will be made available to the organisations responsible for the management of the nature reserve which Seymers lagoon is a part of, for their information. Though this study has provided a snapshot into the lagoon’s ecosystem, surveys should continue over a year to investigate seasonal fluctuations in environmental variables and consequently the biota. A greater understanding of the lagoons hydrodynamics should be obtained by using data loggers to record the frequency and magnitude of water exchange before modifications to the channel are considered. Following this, the feasibility of expanding the lagoon should be explored.

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Appendix

Appendix 1 - Table of species abundance at Seymers Lagoon

Species	Sample Site											
	East Basin						West Basin					
	1	2	3	4	5	6	1	2	3	4	5	6
Chiromonid larvae	31	5	46	110	36	67	1	6	31	4	0	3
Capitella capitata	0	0	0	0	0	0	0	8	6	95	50	2
Hediste diversicolor	5	0	0	7	0	0	0	1	0	11	1	3
Tubificid spp.	0	0	0	0	0	0	0	16	21	5	12	5
Baltidrilus costatus	0	0	0	0	0	0	0	0	0	0	2	0
Monocorophium insidiosum	0	0	0	0	0	0	0	18	0	21	254	2
Corophium volutator	0	0	0	0	0	0	0	2	0	10	21	0
Peringia ulvae	0	0	0	0	0	0	0	0	0	1	1	3
Nematode spp.	0	0	0	0	0	0	0	15	2	0	3	0
Nematostella vectensis	0	0	0	0	3	0	0	3	0	5	0	0

Appendix 2 - Reflective Evaluation

The skills I have obtained have underpinned theory and complemented much of what I have learnt throughout my degree. It has helped me understand and appreciate the complex interdependency between environmental factors and biota within lagoons, and the sheer complexity of ecology in general, and has reinforced my interest in temperate coastal ecology. I have been supported by several staff, PhD students and undergraduate students throughout the study, for which I am grateful, and without my supervisor presenting me the opportunity to partake in the survey, this would not have been possible.

This study considers the faunal communities from one point in time and uses only one sample from each site. Replicates at each site would have improved the validity of this study, though the snapshot survey has provided sufficient information to glean some idea of what lives in the lagoon. The efficiency of statistical and data analysis would have been improved by collating raw data onto spreadsheets more sensibly and keeping better track of copied files. An error in the data processing that was noticed relatively late could have been prevented by taking more time to understand the raw data when it was first obtained. However, it was fortunate I had the foresight to double check data before submission and thus rectify the error. A positive outcome of these data issues is that I am now well-rehearsed in ANOVA, Kruskal Wallis, regression, ANOSIM, and MDS statistical analyses on Primer 6 and IBM SPSS statistical software. Formatting headaches of the final document could have been avoided if each chapter was written in separate documents before collation onto one document. My knowledge of taxonomy and key identifying features with lagoonal benthic invertebrates has improved throughout the study though it is clear there is still much room for improvement, given the relative morphological similarity of many species under a low magnification. Though there have been a number of weaknesses within this study, they have always been lessons to learn and will allow me to produce better work in the future.

This study provides an initial glimpse into Seymers lagoon, an unsurveyed ecosystem that has not previously been on the radar of the National Trust or Dorset Wildlife Trust who manage the island. The discovery of a protected species and a nationally scarce habitat will likely influence their ongoing management of the site, and recommendations for its future based on existing literature have been made in this paper as guidance. Seymers lagoon has capacity to compensate somewhat for the inevitable loss of Brownsea lagoon if its water exchange regime is improved; further study should first be conducted to garner a greater understanding of seasonal patterns in biodiversity, and the environmental factors that influence them. A data logger should be installed in the inlet channel if possible, to ascertain the hydrodynamics before any works on the channel are enacted.

I hope to further my study of the lagoon as my Masters project when I study MSc Biodiversity Conservation at Bournemouth University in September 2017, working with the National Trust and Dorset Wildlife Trust to facilitate this. I will continue to sample the macrozoobenthos to obtain baseline temporal data, in addition to the environmental readings taken in the present study. This will be augmented with the use of fish traps to investigate pelagic fauna, the installation of a data logger to assess lagoon hydrodynamics, and the analysis of eutrophic indicators such as chlorophyll a concentration and sediment nutrient content. The adjacent uplands will be assessed for the capacity to expand the lagoon and management measures will be established based on the results and evidence from existing case studies. The methodology of these field and lab skills will augment my ability to survey coastal ecosystems and complement the field of research I wish to continue with post Masters degree.

Appendix 3 - Ethics Checklist

Bournemouth University

Initial Research Ethics

Note: ***All researchers*** must complete this brief checklist to identify any ethical issues associated with their research. Before completing, please refer to the BU *Research Ethics Code of Practice* which can be found www.bournemouth.ac.uk/researchethics. School Research Ethics Representatives (or Supervisors in the case of students) can advise on appropriate professional judgement in this review. A list of Representatives can be found at the aforementioned webpage. **Sections 1-5 must be completed by the researcher and Section 6 by School Ethics Representative/ Supervisor prior to the commencement of any research.**

1 RESEARCHER DETAILS						
Name	**Jessica Bone**					
Email	**S4390700@bournemouth.ac.uk**					
Status	☒ **Undergraduate**		☐ **Postgraduate**		☐ **Staff**	
School	☐ **BS**	☐ **AS**	☐ **DEC**	☐ **HSC**	☐ **MS**	☒ **ST**
Degree Framework & Programme	**BSc Marine Ecology and Conservation (top-up)**					
2 PROJECT DETAILS						
Project Title	**A comparison of the benthic fauna and habitat health of three Poole Harbour lagoons and their potential as refugia**					
Project Summary ***Sufficient detail is needed; include methodology, sample, outcomes etc***	**The benthic ecology of a new lagoon on Brownsea island was surveyed for fauna and sediment analysis using suction core sampling in November 2016 and April 2017. The results of the new lagoon were compared with the fauna of Poole Park lagoon and Brownsea lagoon using statistical analyses and the results were discussed. Reasons for their respective habitat health were explored in addition to evaluating the threats facing lagoons, particularly the inevitable sea wall breach at Brownsea lagoon, and how the new lagoon will be able to mitigate against habitat loss due to sea-level rise.**					
Proposed Start & End Dates	**November 2016 – May 2017**					
Project Supervisor	**Roger Herbert**					
Framework Project Co-ordinator						

3 ETHICS REVIEW CHECKLIST – PART A			
I	Is approval from an external Research Ethics Committee (e.g. Local Research Ethics Committee (REC), NHS REC) required/sought?	☐ **Yes**	☒ **No**
II	Is the research solely literature-based?	☐ **Yes**	☒ **No**
III	Does the research involve the use of any dangerous substances, including radioactive materials?	☐ **Yes**	☒ **No**
IV	Does the research involve the use of any potentially dangerous equipment?	☐ **Yes**	☒ **No**
V	Could conflicts of interest arise between the source of funding and the potential outcomes of the research? (see section 8 of BU Research Ethics Code of Practice).	☐ **Yes**	☒ **No**
VI	Is it likely that the research will put any of the following at risk: Living creatures?	☐ **Yes** ☐ **Yes**	☒ **No** ☒ **No**

	Stakeholders?	☐ Yes	☒ No
	Researchers?	☐ Yes	☒ No
	Participants?	☐ Yes	☒ No
	The environment?	☐ Yes	☒ No
	The economy?		
VII	Does the research involve experimentation on any of the following: Animals? Animal tissues? Human tissues (including blood, fluid, skin, cell lines)? Genetically modified organisms?	☐ Yes ☐ Yes ☐ Yes ☐ Yes	☒ No ☒ No ☒ No ☒ No
V11 1	Will the research involve prolonged or repetitive testing, or the collection of audio, photographic or video materials?	☐ Yes	☒ No
IX	Could the research induce psychological stress or anxiety, cause harm or have negative consequences for the participants or researcher (beyond the risks encountered in normal life)?	☐ Yes	☒ No
X	Will the study involve discussion of sensitive topics (e.g. sexual activity, drug use, criminal activity)?	☐ Yes	☒ No
XI	Will financial inducements be offered (other than reasonable expenses/ compensation for time)?	☐ Yes	☒ No
XII	Will it be necessary for the participants to take part in the study without their knowledge / consent at the time?	☐ Yes	☒ No
XII	Are there problems with the participant's right to remain anonymous?	☐ Yes	☒ No
XIV	Does the research *specifically* involve participants who may be vulnerable?	☐ Yes	☒ No
XV	Might the research involve participants who may lack the capacity to decide or to give informed consent to their involvement?	☐ Yes	☒ No

4 ETHICS REVIEW CHECKLIST – PART B

Please give a summary of the ethical issues and any action that will be taken to address these.

Ethical Issue: None	**Action:**

5 RESEARCHER STATEMENT

I believe the information I have given is correct. I have read and understood the BU Research Ethics Code of Practice, discussed relevant insurance issues, performed a health & safety evaluation/ risk assessment and discussed any issues/ concerns with a School Ethics Representative/ Supervisor. I understand that if any substantial changes are made to the research (including methodology, sample etc), then I must notify my School Research Ethics Representative/ Supervisor and may need to submit a revised Initial Research Ethics Checklist. By submitting this form electronically I am confirming the information is accurate to my best knowledge.

Signed	**Jessica Bone**	**Date**	**29-05-17**

6 AFFIRMATION BY SCHOOL RESEARCH ETHICS REPRESENTATIVE/ SUPERVISOR

Satisfied with the accuracy of the research project ethical statement, I believe that the appropriate action is:

The research project proceeds in its present form	☐ **Yes**	☐ **No**
The research project proposal needs further assessment under the School Ethics procedure*	☐ **Yes**	☐ **No**
The research project needs to be returned to the applicant for modification prior to further action*	☐ **Yes**	☐ **No**

** The School is reminded that it is their responsibility to ensure that no project proceeds without appropriate assessment of ethical issues. In extreme cases, this can require processing by the School or University's Research Ethics Committee or by relevant external bodies.*

Reviewer Signature		**Date**	
Additional Comments			

Appendix 4 - Learning Contract

LEARNING CONTRACT:
INDEPENDENT RESEARCH PROJECT

Student Name:	**Jessica Bone**
Degree Programme:	BSc Marine Ecology and Conservation (top-up)
Proposed Project Title:	A comparison of the benthic fauna and habitat health of three Poole Harbour lagoons and their potential as refugia
Supervisor:	Roger Herbert

Research Proposal Attached ☐ **YES** ☒ **NO** **and includes:**

☒ YES	☐ NO	**Risk Assessment for fieldwork and evidence of COSSH assessment for all laboratory procedures (online risk assessment completed)**
☐ YES	☒ NO	**Completed booking forms for all field equipment**
☐ YES	☒ NO	**Letters of permission where appropriate providing evidence of access to such things as field sites and/or museum archives**
☒ YES	☐ NO	**Completed Ethics Checklist**

Copies of all relevant forms may be found on myBU - SciTech tab - Projects - Project Forms

INTERIM INTERVIEW – Progress evaluation

The nature of this review should be clearly defined and agreed. Please complete the box below with the agreed details including the agreed submission date which is normally the first week of November in Level 6/H. Submission is via a formal tutorial with the supervisor.

Progress evaluation was ongoing throughout the year with meetings and via emails, no formal interim interview was agreed.

Assessment Due: 15th June 2017

FINAL ASSESSMENT – RESEARCH PAPER/REPORT

This assessment is normally governed by the guidance provided in the Independent Research Project Guide. Any variance in terms of format and word limit should be agreed and specified in the box below. Submission date cannot however be changed unless evidence of mitigating circumstances are provided in accordance with the standard BU Guidelines.

PTO

As the student undertaking the above project I agree to:
• E-mail my supervisor on a fortnightly basis with a progress report • Meet with my supervisor at least once a month to discuss progress and I understand that it is my responsibility to organise these meetings • Comply with the terms of this learning contract and the guidance set out in the Guide to Independent Research Projects • I understand that this is an *independent* project and that I am solely responsible for its completion • I agree to comply with all laboratory and fieldwork protocols established by the Faculty.
As the supervisor of this project I agree to:
• Meet with the student undertaking this project on at least a monthly basis and to respond to the progress e-mails as appropriate • To meet formally with the student during the first week in November to undertake the interim interview • To provide guidance and support to the student undertaking this project bearing in mind that it is an *independent* research project. This is inclusive of commenting on drafts of the final report in a timely fashion.

Both of the undersigned parties agree to be bound by this learning contract:	
Student Signature:	J Bone
PRINT NAME:	JESSICA BONE
Date:	29-05-17

Supervisor Signature:	
PRINT NAME:	
Date:	

When completed, this form should be handed in to SciTech Admin (C114) and a copy retained by the student to be included in an appendix to the final IRP document.

Appendix 5 - Interim Interview

Independent Research Project Interim Interview : Agreed Comments Form

Student Name: Jessica Bone	Programme: BSc Marine Ecology and Conservation (top-up)
Date: 29-05-17	IRP Title: A comparison of the benthic fauna and habitat health of three Poole Harbour lagoons and their potential as refugia
Supervisor Name: Roger Herbert	

No formal interim interview was agreed but communication was maintained by frequent emails and occasional meetings.

Two copies of this form are needed – student to retain one copy the other is to be handed in to the student admin office C114.

Student Signature: Jess Bone	Supervisor Signature:

Appendix 6 - Risk Assessment

REF SciTech- /

Faculty of Science & Technology
RECORD OF RISK ASSESSMENT

BU

NAME: Jess Bone

PROGRAMME(S) OR PROJECT: BSc Marine Ecology and Conservation (top-up)

Independent Research Project

MOBILE TEL NOS: 07817637928

Please note that mobile must be kept on at all times

PROJECT AUTHORISATION: ***F&R/IPO Signature:***

TITLE OF ACTIVITY: Collecting benthic samples in a lagoon using a suction corer/ lab analysis

DATE(S) OF ACTIVITY: 16th November 2016, 10th April 2017

LOCATION: Brownsea Island, Poole, Dorset/ Dorset House labs, Bournemouth Uni

DATE OF ASSESSMENT: 15th June 2017

EQUIPMENT: Suction corer, formal saline, muffle furnace

VEHICLE HIRE: None

HAZARD/RISK	PERSONS AT RISK	RISK			ACTION		
		A PROBABILITY (5)	B SEVERITY (5)	(A * B)	WHAT	WHO	WHEN
Drowning	Students and staff	1	5	5	Ensure no lone workers and no working at depth, obtain samples without going into lagoon where possible.	Students and staff	
Slips, trips, falls	Students and staff	2	2	4	Ensure appropriate footwear is worn, do not traverse areas that appear unstable or thickly vegetated	Students and staff	
Rinsing formal saline from sediment sample with tap water	Students	1	3	3	Wear appropriate PPE and rinse in fume cupboard	Students	
Burns from drying oven/ muffle furnace	Students	1	3	3	Receive training prior to use, wear appropriate PPE and ensure ovens are at room temperature before removing samples	Students	

ACTIVITY LEADER SIGNATURE: __________ **DATE:** __________

This form must be completed 5 working days prior to date of activity

Please use continuation sheet if required