THE INFLUENCE OF TEMPORAL CHANGES IN BIOMASS OF BROWN MUSSEL *PERNA PERNA* ON ABUNDANCE OF AMBIENT MACROFAUNA ON THE CENTRAL COAST OF NAMIBIA

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ABSTRACT

Like terrestrial systems, marine ecosystems are constantly impacted upon by conditions arising from anthropogenically modified abiotic environments, climate change, as well as biotic agents. Marine mussels are widely regarded as ecosystem engineers. The Brown mussel species *Perna perna* is one such species. Mussels offer a wide range of advantages to intertidal communities through their structure and biomass, as they help increase the spatial heterogeneity in benthic processes, by serving as habitat or substrate for associated organisms and also as food for predators. However, very little research on Mussels has been done specifically on Namibian marine ecosystems. Moreover, the invasive species such as *Mytillus galloprovincialis* threaten the very existence of the indigenous brown mussel *P. perna*, due to the lower fecundity, recruitment and growth rate of latter. It is against this background that this study focused on the ecological implication of temporal changes in biomass of the *P. perna* on ambient macrofauna at Long Beach, on the Namibian central coast. The objectives of the study were: (a) To assess the temporal changes in biomass of *P. perna*; (b) To determine the temporal changes in condition of *P. perna*; and (c) To investigate the influence of changes in biomass of *P. perna* on the abundance of its ambient macrofauna. Samples were collected from 10cm x 10cm quadrats along a line transect on a 2m interval, over 50m across the intertidal zones. Data analysis was performed in Microsoft excel as well as Past and MaxStat. A t-Test for equal means was used to test all data, except for data on the influence of change in biomass of *P. perna* on the abundance of ambient macrofauna, where a Multiple linear regression analysis used at 0.05 significance level. The statistical test results on biomass of *P. perna* at 0.05 significance level yielded (t =2.3567; df = 2; p = 0.056542), hence there was no significant change in biomass of *P. perna* between autumn and winter. Similarly, statistical test results on condition index of *P. perna* at 0.05 significance level yielded (t = 0.23896; df = 2; p = 0.81909), hence there was no significant change in condition of *P. perna* between autumn and winter. The change in biomass of *P. perna* significantly influenced the abundance of ambient macrofauna, as the statistical test at 0.05 significance level yielded (r = 0.807; 0.574; 0.479 and p = 0.0002; 0.0138; 0.0354).

Keywords: *Perna perna*, macrofauna, biomass

LIST OF PUBLICATIONS

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LIST OF ABBREVIATIONS AND/OR ACRONYMS

ANOVA	Analysis of variance
BCLME	Benguela Current Large Marine Ecosystem
FAO	Food and Agriculture Organisation of the United Nations
GPS	Global Positioning System
HWM	High water mark
ICZM	Integrated Coastal Zone Management
IGP	Intraguild Predation
LWM	Low water mark
MFMR	Ministry of Fisheries and Marine Resources
P/B	Overall Productivity over Biomass ratio
TMII	Trait-mediated Indirect Interactions
UNAM	University of Namibia
USA	United States of America
VPA	virtual population analysis

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DEDICATION

I dedicate this mini-thesis to my family, especially my parents and my siblings (Ignatius Haingura, Anastasia Haingura, Willem Haingura and Emilie Haingura), for they have been a source of support and motivation to me. I would also like to dedicate this work to my late colleague and mentor, Mr. Greenwell Matongo Jnr, from whom I learned so much as a professional and as conservation scientist. His passion and work ethics has inspired to pursue my dreams without doubt, and this has helped me excel in my career so far. May his soul rest in eternal peace. To the all the war stricken countries and those devastated by extreme natural disasters, that they may never lose hope that they will one day realise the peace and tranquility that they have been longing for. Finally, I dedicate this entire project to the Almighty God, who made it possible for it to be successfully completed.

DECLARATIONS

I, Innocent Haingura Haingura, hereby declare that this study is my own work and is a true reflection of my research, and that this work, or any part thereof has not been submitted for a degree at any other institution.

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Name of Student	Signature	Date

1. Introduction

1.1 Background of the study

Like terrestrial systems, marine ecosystems are constantly impacted upon by conditions arising from anthropogenically modified abiotic environments, climate change, as well as biotic agents (Lauringson and Kotta, 2016). Consequently, the ripple effect caused by these factors is also apparent in populations of species that are ecosystem engineers. Ecosystem engineers are species that directly or indirectly influence the availability of resources to other species, by altering the physical or biotic environment (Jones et.al, 1994). Camacho, Aguiar, Labarta et.al (2014); and Degger et.al (2011) have also defined contributed to defining ecosystem engineers, referring to them as organisms that create, significantly modify, maintain or destroy native and non-native habitats. According to Jones et.al (1994: 374), two main types of ecosystem engineers exist. They are: 'autogenic engineers – species that change the environment through their own physical structures i.e. their living and dead tissues; and allogenic engineers - species that change the environment by transforming living or non-living materials from one physical state to another, through mechanical other means'. Numerous papers such as Camacho *et al*. (2014) have declared most bivalves and marine mussels in particular as ecosystem engineers. The brown mussel *Perna perna* (Linnaeus, 1758), which occurs along the Atlantic Ocean, is one is one of the ecosystem engineers in the intertidal zones.

The distribution of mussel species is widely known to be impacted by various environmental factors such as salinity and temperature (Rusk, 2012). Camacho *et al.* (2014: 539) underlined that, 'organisms can generally survive at suboptimal environmental conditions until the stress level reaches some physiological threshold'. However, population properties of affected taxa, in terms of demography, density, individual size, or biomass, are likely to be altered by deteriorating habitat conditions above the survival threshold (Lauringson and Kotta, 2016). In inter-tidal macrofaunal communities, altered abundance patterns of engineering organisms may modify the biotic environment for other taxa. Therefore, changes in biomass and abundance of brown mussels may alter population properties of other macrofaunal species and taxa.

Despite the considerable amount of studies done on Brown mussels, only a small percentage of studies have been carried out on Namibian marine ecosystems. The majority of literature such as Louda, Dowd, Bilir et.al (2008); Helm (2004); Delegrange, Vincent, Duret et.al, (2015); just to mention a few, dwell much on the physiology and molecular aspect of mussels, and less on their population dynamics and biological interactions with ambient macrofaunal communities. Moreover, relatively little ecological research has been conducted on *P. perna* compared to other mussel species.

Although modern conservation methods are more ecosystem-based, information and research on individual species especially keystone species and ecosystem engineers remains crucial. Ecosystem engineers such as *P. perna* can serve as a reference point for conservation of intertidal ecosystems. Like freshwater mussels, marine mussels provide perform various key functions in the ecosystems they occur in. These functions can be referred to as ecosystem services, although some of these services may not directly benefit humans. Ecosystem services are the benefits that humans derive from ecosystems (Vaughn, 2017:1). According to Vaughn (2017:1), ecosystem services provided my mussels include supporting services such as nutrient recycling and storage, structural habitat, substrate and food web modification, and the use as environmental monitors; regulating services include water purification (biofiltration); while provisioning and cultural services include the use of mussels as a food source, as tools and jewelry, and for spiritual enhancement.

A substantial amount of literature indicates that mussel-provided ecosystem services are on the decline due to a reduction in mussel populations in certain localities. Hence there is a need to establish conservation approaches that based on sound scientific research, in order to promote the sustainable use of mussels in order to ensure the ecosystem services that they provide. It is against this background that this study focused on the ecological implication of temporal changes in biomass of the *P. perna* on ambient macrofauna at Long Beach, on the Namibian central coast.

1.2 Statement of the problem

According to Lauringson & Kotta (2016), mussels offer a wide range of advantages to intertidal communities through their structure and biomass, as they help increase the spatial heterogeneity in benthic processes, by serving as habitat or substrate for associated organisms and also as food for predators. However, very little research on Mussels has been done specifically on Namibian marine ecosystems. Moreover, Erlandsson et.al (2006) revealed that invasive species such as *M. galloprovincialis* threaten the very existence of the indigenous brown mussel *P. perna*, due to the lower fecundity, recruitment and growth rate of latter. A desktop review of existing literature on marine mussel ecology e.g. Rola et.al (2017) and Wang et.al (2015) seemed to be relatively focused on the physiology and molecular aspects rather than on mussel population dynamics and how they ecologically interact with ambient macrofaunal communities in the intertidal zones. At species level, very little ecological research has been on *P. perna* compared to other mussel species. This implies that there is less scientific understanding on the coexistence of *P. perna* with ambient species in the intertidal zones in Namibia and its implications on ambient macrofauna, hence comprehensive conservation and value addition measures on fisheries species in intertidal zones cannot be formulated and implemented effectively.

1.3 Research Objectives

a) To assess the temporal changes in biomass of *P. perna* at Long Beach, on the Namibian central coast
b) To determine the temporal changes in condition index of *P. perna* at Long Beach, on the Namibian central coast
c) To investigate the influence of changes in biomass of *P. perna* on the abundance of its ambient macrofauna at Long Beach, on the Namibian central coast

1.4 Research Hypotheses

a) There are significant temporal changes in biomass of *P. perna* at Long Beach, Swakompund due to changes in physical conditions over time.

b) There are significant temporal changes in condition index of *P. perna* at Long Beach, Swakompund due to changes in physical conditions over time.
c) The change in biomass of *P. perna* significantly influences the abundance of its ambient macrofauna at Long Beach, over time.

1.5 Significance of the study

1.5.1 P. perna an ecosystem engineer and needs to be conserved

Based on the literature review for this project, Brown mussels possess two very important characteristics. One is that they are ecosystem engineers, and contribute towards the natural moderation and sustenance of marine ecosystems. The second key characteristic is that they have an economic value attached to them just like many fisheries species. According to the Gulf Region's Policy and Economics Branch (2006), mussels are usually sold fresh in the shell, but some attention has been directed towards value-added products such as mussels in a prepared sauce, smoked mussels, and blast frozen cooked mussels in recent years. Considering the fact that the fisheries sector is of such great importance to Namibia's economy, understanding the biophysical factors that impact on *P. perna*'s biomass and how this in turn affect its ambient species in the intertidal communities will help guide conservation strategies for these species, since they are all susceptible to biophysical conditions and anthropogenic threats. For instance, large-scale sediment disturbance around breeding localities of marine predators was singled out by Benguela State of the Marine Environment Report (2014) for the Benguela Current Large Marine Ecosystem (BCLME) region, as one of the factors that influence local prey availability and may also seriously affect nearshore fish populations and other marine communities such as mussel beds. Furthermore, inshore reef areas and kelp beds provide a crucial role as food source and shelter for various organisms, such as juvenile rock lobster, and repeated kelp cutting to facilitate diver access has been reported to result in a loss of kelp forest habitat.

1.5.2 Sustainable harvesting of mussels

There has been increased interest in small and medium aquaculture schemes for mussels and other marine species in recent years. Such initiatives can be beneficial to Namibia's economy and will, amongst other benefits, create more jobs. However, if not carefully implemented these kind of projects may negatively affect the species. For instance, harvesting mussels during or close to spawning time may harm the mussel populations, let alone the commercial stock of mussels (Food and Agriculture Organization of the United Nations, 2017). Therefore, the knowledge and understanding generated from this study will aid the sustainable implementation and management of possible aquaculture schemes for mussels and other marine species. Understanding the impact of biomass changes of *P. perna* on ambient macrofaunal communities will also allow marine scientists and decision makers to develop comprehensive strategies to valorize and conserve mussels on the Namibian coast.

2. Literature Review

2.1 Characteristics of intertidal zones on rocky shores

The coastline of Namibia consists mainly of long stretches of sandy beaches. 'These long sandy stretches are sparsely interspersed by rocky shores, of which most occur south of Easter Point or Oyster Cliffs in the in Karas, Namibia, at 25°19'60" S and 14°48'0" E' (Currie, Grobler & Kemper, 2008). The heterogeneous rocky shore community structure offers a wide variety of niches, occupied abundantly by both seaweeds and representatives of most invertebrate phyla. Rocky shores in Namibia support the highest biomass of mussels per unit area in the southern African region. Rocky shores also provide feeding and breeding grounds for the attached fauna (Currie et.al, 2008).

A key physical characteristic of the intertidal zones underpinned by Stickle, Carrington, Hayford (2017: 83) is that 'the upper end of a species vertical range in the rocky intertidal zones is frequently determined by the species tolerance of emersion temperature and desiccation and by biotic interactions at the lower end of the species range'. Stickle et.al (2017: 83) stated that the horizontal and vertical patterns of species distributions in the intertidal zones are usually a representation of gradients or discontinuities in emersion temperatures, further underlining that biota in the upper regions of the intertidal zones are exposed to a longer duration of emersion during neap tides in the mixed semidiurnal tidal pattern.

In a study by Murray, Weisberg, Raimondi, Ambrose, Bell, Blanchette et.al (2016: 803), rocky intertidal communities can be quite complex to study or evaluate. One of the challenges is that rocky intertidal communities occupy heterogeneous habitats with considerable spatial and temporal variations in key abiotic environmental aspects. This could lead to multiple changes in community structure over time, thereby complicating attempts to evaluate eco-logical state. Secondly, rocky shore communities are constantly exposed to significant physical (e.g. wave action, sand scour, substratum instability, aerial emersion) and biological (e.g. predation), whose impacts are often very hard to differentiate from anthropogenic impacts. Third, the rocky intertidal zones are greatly affected by tides, where submersion and emersion regimes limit the fundamental niches of species on the shore.

Bellgrove, Mckenzie, Cameron et.al (2017: 17 - 18) describe intertidal rocky shores as ‘physically stressful environments, with gradients in wave action, heat and desiccation stress’. One would then expect that in such environments, ecosystem engineers that can absorb these physical stresses facilitate the survival of other species might be particularly important. Moreover, ‘changes in the intertidal abiotic conditions by ecosystem engineers may have both positive and negative effects on associated species’ (Bellgrove, Mckenzie, Cameron et.al, 2017:18).

According to a coastal profiling study conducted for the entire Erongo region by the Integrated Coastal Zone Management (ICZM) Project (1999), shallow and benthic intertidal fauna tends to exhibit low diversity but high density. Moreover, Shore invertebrates are mainly filter feeders, benefiting from the vast amounts of organic particulate matter – which mainly exists in the form of diatoms from phytoplankton and microalgae, which occur in abundant amounts in the intertidal zones. The coastal profile referred to above also revealed that mussels dominated the macrofaunal biomass on the rocky shore, with biomass per unit area of mussels in the rocky intertidal zones much higher on southern African shores than anywhere else. In addition, the highest density of mussels occurred at the lower water mark, where layering more often than not create hummock formation. Three mussel species were found not to be present namely the endemic species *P. perna* and *Semimytilus algosus*, as well as the alien black mussel *M. galloprovincialis*.

2.2 Physical and climatic characteristics of the Namibian central coast

One key characteristic of Namibia's marine environment is coastal upwelling, which is driven by wind. 'Upwelling mainly refers to an upward movement of water parcels in the water column that is maintained over a reasonably long period, long enough to lift water parcels over a vertical distance of 100 m or more' (Solaris, 1961). The concentrations of nutrients that result from upwelling may vary significantly off the coast depending on the season, the intensity of upwelling, the rate of utilisation by phytoplankton and the depth (ICZM Project, 1999). Based on the magnitude of wind impulse for an upwelling event, the wind stress causes the density interface to rise towards the coast and this may or may not eventually reach the sea surface, resulting in either partial upwelling or full upwelling (Solaris, 1961). The prevalence of upwelling on the Namibian coast has the potential to making the country's coastal ecosystems and fisheries to be amongst the highly productive and lucrative in the world. Coastal upwelling regions, of which Namibia is part, only covers 1% of the total area of the world's oceans, but they provide about 50 percent of the fish harvest brought back to shore by the world's fisheries (The National Geographic Society, 2017). This indicates that coastal upwelling contributes immensely to productivity in marine ecosystems, as it supports the growth of seaweed and plankton, which subsequently provide food for marine invertebrates, fish, marine mammals, and birds.

According to the ICZM (1999), tides along the Namibian central coast are mostly semi diurnal with a maximal tidal range of 2m, where the main tidal movement is usually offshore-onshore. As such, the resultant tidal currents are quite negligible and compared to the dominant northerly movement of the Benguela. Moreover, Colder coastal water temperatures than normal at these latitudes do occur, ranging from 11-16°C in the winter months of June to October with seasonal lows recorded when upwelling more vigorous, to 15-19°C during summer when calmer upwelling allows inflow of oceanic and tropical Angolan.

2.3 Biomass of *P. perna* and the assessment thereof

Literature shows that mussel species vary in terms of individual and population growth. For instance, growth in *P. perna* may be much more rapid than in *M. galloprovinvialis*, with individuals reaching 5 cm in less than 18 months (Bayne & Worral, 1980). Furthermore, Narvaez, Freites, Guevara, Mendonza, Guderley, Lodeiros et.al, (2008) states that can *P. perna* can mature at 35mm while Vakily (1989) adds that adults may grow up to 110-120mm. In terms of gonadal tissue color, *P. perna* like most mussels comprises of bright orange gonadal tissue in females and off white in males (Petes, Menge, Chan, Webb, 2008).

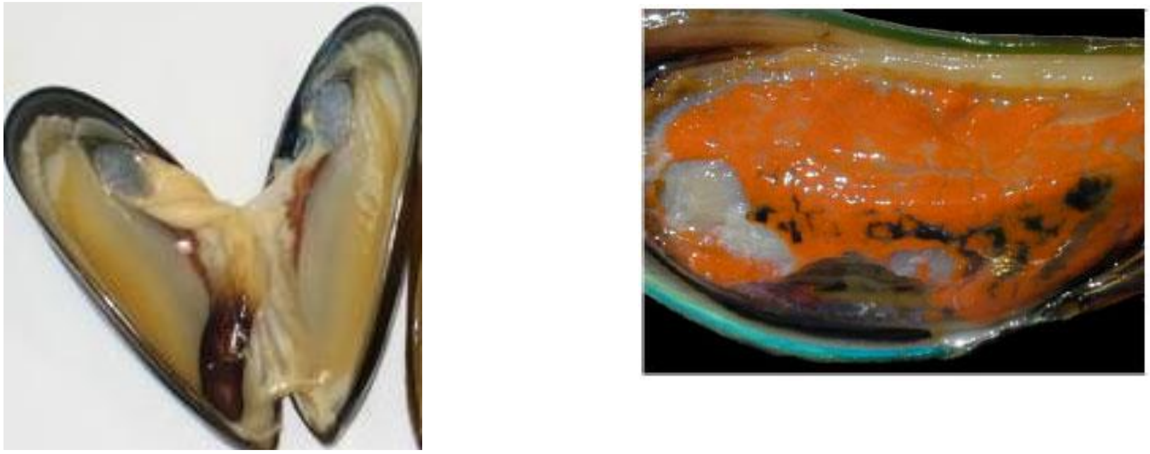
(a) (b)

Figure 1: Barf-fuer-hunde. 2016. *P. perna* (a) female and (b) male gonads

Schwinghamer as cited in Burd, Barnes, Wright et.al (2008) estimated that, in soft sediments in temperate coastal regions, macroinvertebrates constitute approximately 95% of the total invertebrate biomass. Rowe et al. as cited in Burd et.al (2008) also found that in coastal areas in global temperate and sub-tropical regions, benthic macroinvertebrates tend to dominate the benthic biomass in mid-depth subtidal areas, followed by the other two major benthic consumer groups, the meiofauna (interstitial invertebrates sized 42 lm to 0.5 mm at maturity) and the single-celled organisms (primarily bacteria, benthic algae and foraminifera). One would therefore assume that a significant change in biomass of an ecosystem engineering macroinvertebrate species like *P. perna* may result in huge shifts in the abundance of other species, through the availing or reduction of niches for other species in the process. This is further emphasised by Lauringson & Kotta (2016), that 'mussels can increase the spatial heterogeneity in benthic processes by their structure and available biomass stock, by providing food for their predators and as hiding places and a secondary substrate for all associated organisms'.

The literature review has shown that the general method used by most marine mussel scholars to collect data on biomass and condition index of mussels. Amongst the researchers who have used this method are Golightly & Kosinski (1981), during a study on freshwater mussels. In that particular study, mussels were collected from three sampling sites, and once in the lab, the mussels were cleaned to remove foreign matter before being sorted according to species. The whole wet weight, tissue wet weight, and shell dry weight of the mussels was then measured with a beam balance. The inner tissues were dried at 105 °C for 72 hours and measured thereafter. This allowed for actual biomass data to be obtained.

Babarro & Carrington (2013) used the Gonadal index of mussels to make tenacity measurements for the proportion of mussel biomass composed of mantle tissue (site of gametogenesis in *Mytilus* Wet mantle was dissected from the wet body and together with the rest of the organs was freeze-dried for 48 hours. Samples were weighed to the nearest 0.001 g and gonadal index was calculated as the dry weight of the mantle divided by the whole soft body (sum of the dry weight of the mantle and remaining tissues).

From these two examples, the current study therefore used the following formulas to measure biomass and condition index of *P. perna*:

Biomass = (Dry shell mass + Dry tissue mass)/size of sampling quadrat, while Condition index = (Dry mass of tissues/Total wet mass) x 100.

2.4 Factors influencing species abundance of *P. perna's* ambient macrofaunal communities of Brown mussels in the intertidal zones

2.4.1 Biotic factors

Murray et.al (2016) revealed that coastal managers often rely on species composition and abundance data to evaluate the ecological states of biological communities and to interpret the extent of biotic anthropogenic impacts. However, this involves thorough investigation of the factors that influence the very population parameters such as composition and abundance, which are used to determine the state of biological communities. When assessing density, biomass and abundance of organisms in ecological communities, studies such as (Quinn, Boudreau, Hamilton, 2012) have considered predation and competition as key determinants of the structure of biological communities. These are negative interactions in that they result in negative effects on one or both organisms. However, positive interactions, in which the presence of one species in some way benefits another, also play important roles in community dynamics. A classic example was presented by Quinn et.al (2012) whereby the foraging activity of one consumer facilitates the feeding of another. Furthermore, trophic dynamics in natural communities may be further influenced by intraguild predation (IGP), in which predators that should be potential competitors for the same prey species also engage in predator–prey interactions with each other (Quinn et.al, 2012). 'The intermediate consumer in IGP often undergoes some change in its traits or behavior to avoid predation, resulting in trait-mediated indirect interactions (TMIIs) between consumers and prey' (Quinn et.al, 2012).

While many biotic and abiotic factors are known to influence byssal attachment strength of mussels, body size represents an endogenous parameter that is not often considered explicitly. The influence of byssal attachment strength is often viewed to be synergistic with other factors such as byssal thread thickness and recruitment (Babarro & Carrington, 2013).

2.4.2 Physical factors

According to Lauringston & Kotta (2016), mussels generally need sufficient water exchange to provide enough suspended food and satisfactory oxygen conditions, as they are benthic suspension feeders. Oxygen concentration was identified by some studies e.g. Beyers, Wilke & Goosen, 1994) as one of the major factors impacting on benthic intertidal communities. According to an experiment by Beyers et.al (1994), the general responses of intertidal macrofaunal organisms to various levels of oxygen saturation were decreased growth, diminished food ingestion. Although Beyers et.al (1994)'s experiement was focused on lobsters, other invertebrates such as mussels may exhibit similar responses to changes in dissolved oxygen levels in the intertidal zones.

In a study to assess the influence of oxygen concentration on the biomass of macroinvertebrates in the intertidal zones along the Northern Sea, Greenstreet, Robinson, Reiss, Craeymeersch, Callaway, Goffin et.al (2006) found that the total epibenthic biomass varied significantly, but was seemingly lower where sediment particle size was less than 200µm. As a result of this low biomass, the overall productivity over biomass ration (P/B) was observed to be lower in the muddier habitats. Greenstreet et.al (2006) further stated that due to the decline in the overall P/B was largely related to bottom water temperature, which was not strange in any way, given that temperature is one of the terms in the models used to estimate productivity. Furthermore, it was established by Greestreet et.al (2006) that epibenthic productivity and P/B ratios were also associated with depth, due to the fact that there was a link between water depth and water temperature. Moreover, it was found in that same study that the three species richness and diversity indices that they generated seemed to be inversely proportional to epibenthic P/B ratio. When different weight classes of epibenthic invertebrates were examined, considerable variation in the spatial and temporal patterns of biomass, production and P/B ratio were evident between different sized epibenthic invertebrates (Greenstreet, 2006).

In the case of estuarine tidal zones, environmental factors like temperature, salinity, aerial exposure and hydrodynamics represent key elements that influence population dynamics. According to Babarro & Carrington (2013), specific disturbances created by wave-generated hydrodynamic forces have a controlling influence in structuring mussel bed communities as mussels become dislodged and new space is created for colonization. Mussels are sessile and gregarious organisms capable of withstanding strong flows as consequence of their ability to secrete an extracellular structure called byssus, a bunch of collagenous threads secreted in the ventral groove of the foot (Babarro & Carrington, 2013). However, different changes in environmental conditions may induce morphological changes in mussels, such as shell dimensions and may also alter energy allocation to other vital physiological processes such as soft tissue growth or byssus secretion. Energy allocation can also shift with body size as larger animals mature reproductively.

The distribution of species along and within the intertidal zones has been widely explained based on the physiological characteristics of species in the intertidal zones, which enable them to cope with the environmental factors that they are exposed to. Stickle et.al (2017) revealed the physiological traits that are associated with intertidal vertical zonation. These are mainly: thermal tolerance, heart function, mitochondrial respiration, membrane fluidity, action potential generation, protein synthesis, heat-shock protein expression and protein thermal stability.

A key discovery from the literature review for this study is that most scholars of intertidal zones management and the ecology thereof have generally argued that it is important to link patterns and mechanisms of physiological adaptation species to global climate change (Stickle et.al, 2017; Somero, 2010).

According to Denny (2011), a variety of intertidal organisms do from time to time, experience temperatures that are at or close to their thermal limits. Consequently, species that manage to adapt to such warm and testing conditions tend to have very little physiological capacity to withstand further warming in their habitat. A good example of this is the recent mass mortalities of mussels and limpets on wave-swept shores in Carlifornia, United States of America (USA) (Denny, 2011). The general interpretation of the above mentioned findings by Denny (2011) was that minimal changes in imposed body temperatures, due to direct or indirect effects of global change, could result in considerable population and ecological alterations, making intertidal communities a near-perfect site for studying the consequences of climate change. Murray et.al (2016) suggested that spatial and temporal changes in rocky inter-tidal communities sometimes can be quite significant, due to environmental factors such as substratum characteristics, tidal position, and exposure to wave energy, sand influence, and freshwater input.

According to Arribas et.al (2015), the recruitment of mussels on rocky shores often changes both temporally and spatially. This can be associated with spatial and temporal variations in the reproductive output of species, as well as larval mortality and redistribution in the open oceanic waters (Arribas et.al, 2015). As a result, changes in the recruitment of mussel larva can have major implications on adult distribution and abundance. Arribas et.al (2015) further stated that at smaller spatial scales, recruitment and/or post-settlement survival can change depending on the amount of wave exposure, tidal height, heat and desiccation stress, stress amelioration by conspecifics, settlement cues, predation on the recruited larvae either by adult conspecifics or by other organisms, food concentrations, or hydrodynamic perturbations that are a result of substrate roughness elements.

2.5 Influence of Brown mussels on ambient macrofaunal communities

Various examples on the role of bivalves as ecosystem engineers have been articulated in literature. One is that bivalve-dominated reefs are not only of high biodiversity value but help to maintain water quality, stabilize shorelines e.g. mangroves and marsh), enhance fisheries productivity, and cycle nutrients (Degger et al., 2011). ‘Burrowing bivalves can, by bioturbating sediments, modify oxygen concentration, sediment porosity, stability, metal concentration and pH, thereby making sediments more or less habitable to other organisms’ (Degger et al., 2011).

According to Degger et.al (2011), brown mussels and other bivalve molluscs have been widely utilised as bioindicators of choice due to their ability to accumulate a wide variety of lipophilic contaminants, as they accumulate trace levels of pollutants. Mussels can also provide information on their bioavailability in intertidal zones, which allows for the identification of temporal and spatial variation in various aspects of mussel populations, such as density and biomass. However, intrinsic limitations have become evident, as several authors have highlighted the influence of natural fluctuations in body burdens due to season (Degger et.al, 2011). By being able to monitor and justify the changes in density and biomass of mussels for instance, scholars have the opportunity to infer how the change in mussel density and biomass impacts on other organisms that mussels interact with in the intertidal zones.

'Bivalves are regarded as an essential part of the benthic community in marine and brackish water systems, especially in brackish water systems where several important phyla of marine invertebrates do not occur due to reduced salinity' (Darr et.al, 2014). Darr et.al, (2014) further stated that bivalves are an important food source for benthivore fish, sea-birds and species of other higher trophic levels of the food-web. Mussels play an even more predominant role in soft-bothic environments, through benthic–pelagic coupling by filtering the water column for nourishment and deposing pseudofaeces onto or into the sediment. Additionally, bivalve species combine several autecological features with potential value for assessment and management purposes. For instance, 'most adult bivalves are, once settled, more or less sessile and therefore reflect the environmental conditions in the area where they were found' (Darr et.al, 2014). Moreover, 'benthic invertebrates, of which *P. perna* is part, process the particulate, organic materials (detritus and small organisms) that are deposited on the seafloor or that are suspended within reach of the organisms, using a wide range of feeding strategies such as deposit feeding, suspension feeding, filter feeding, or scavenging' Burd et.al (2008). Benthic invertebrates may also be predators, herbivores (grazing on living plant material) or they may rely, at least partially, on chemoautotrophy via symbioses with bacteria for their nutrition.

2.6 Review of sampling and data analysis techniques used in previous studies on *P. perna*

Darr et.al (2014) sampled three replicates of mussels at different station on the shore using a van-Veen grab. Samples were washed through 1 mm mesh-size following Helcom guidelines and preserved in 4% buffered formaldehyde-seawater solution. All macro-benthic organisms were sorted, identified to the lowest possible taxonomic level, counted and weighted (fresh mass). The brown mussels were not identified on species level as

Mytilus edulis, *Mytilus trossulus* and, to a large extent, hybrids between these species occur sympatric in the study area.

‘Although multivariate approaches, such as non-metric multidimensional scaling are powerful tools for differentiating community structures, analyses based on biological data can be difficult to interpret, particularly when the effects of multiple potential stressors need to be considered in a setting of large natural biological variation’ (Murray et.al., 2016). Further, coastal managers hardly have access to temporal data sets with sufficient history to evaluate ecological community state. According to Murray, Weisberg, Raimondi, Ambrose, Bell, Blanchette et.al (2016), biotic indices that translate complex ecological data into simpler statistics can sometimes serve as tools for representing community states. Such indices are widely used for benthic macrofaunal communities, which are the exact subject of this research project.

2.7 Recruitment and settlement of mussels

According to Reaugh, Harris, Branch (2007), the recruitment process *i.e. the addition of surviving juvenile to a population, by birth or immigration, such that they are able to be detected by an observer* (Helm, 2004), begins with the attachment of planktonic pediveliger larvae onto the substratum. The pediveliger larvae is the stage in the D-stage. This is followed by a metamorphosis into a benthic plantigrade stage, is called settlement.

Figure 2: Helm .2004. Photomicrograph of mussel D-larvae

The sampling method used by Flower (2010) could suggest that samples that are collected from sites that are away from each other by a considerable distance may yield good quality data. Flower (2010) sampled mussels at sites that were spaced 0.5–25.0 km apart. In that study, recruitment into natural mussel beds was measured every three months at all localities, except for one site that was sampled monthly, perhaps serving as a control site. Samples were collected from dense mussel clumps. Similarly, Reaugh et.al (2007) sampled algal turf and mussel bed at various sites for their study, by removing three replicates from randomly selected patches of 100% algal cover and 100% mussel cover, situated 1–20m apart in the center of mussel beds. Moreover, Reaugh et.al (2007) explored time-lagged correlations between densities of 0.5–5mm settlers and recruits in algae and densities of small adults (10–35mm) in the mussel beds, to assess whether the attachment of mussels to algae was followed by secondary settlement into the mussel beds.

2.8 The importance of intertidal communities in monitoring climate change impacts on marine ecosystems

Under increasing concerns of climate change, scientific information is required to predict the ecological impacts of climate change. Denny et.al (2011) revealed that: ‘Wave-washed rocky shores provide a potentially important system in which to develop and test these predictive abilities, in large part because the rich history of experimentation on intertidal communities provides a wealth of baseline information on distribution and the roles of competition, predation, facilitation, dispersal, recruitment, disturbance, environmental stress, and patch dynamics'. The findings from this study will contribute to the existing baseline information on the dynamics of macrofaunal communities on the Namibian rocky shore and beyond, and can be used to predict climate change impacts on such ecological ecosystems.

2.9 The importance of intertidal ecosystem engineers such as *P. perna*, in restoration efforts

According to Bellgrove, Mckenzie, Cameron et.al (2017), coastlines around the world are facing increasing pressure from anthropogenic developments associated with population growth. Namibia's central coast or perhaps the country's entire coastline is faced with the same kind of pressure from present and prospective anthropogenic developments. A textbook example of the adverse effects of anthropogenic developments on the Namibian coastline is the growing levels of pollution in the form of plastic and other solid waste material, which could be harmful to the local marine environment. Another issue is that of human trampling, to which most intertidal species are sensitive. These are fast becoming contentious issues, with the public's increased awareness on protection of biodiversity. Authorities should therefore seek vigorous ways to reduce disposal of plastic and other solid waste material on the shore environment in order to prevent impact that such an ecological disturbance could have its marine life. Plastic pollution for instance is unlikely to be solved by ecosystem engineers. Mussels, however, can be very useful as "cleaning agents" for pollutants like heavy metals in harbours.

By virtue of it being an ecosystem engineer in the intertidal zones, the brown mussel *P. perna* is one species that could be used as a vehicle to restore disturbed intertidal ecosystems. As stated earlier on in this paper, ecosystem engineers are species that influence the availability of resources to other species, by changing the physical or biotic environment. According to Greenberg (2013), the possibility of using bivalves such as mussels, oysters, and clams to purify waterways has been explored by conservationists and scientists for years. Mussels feed on plankton, and when they grow they incorporate into their shells and meat nutrients the abundant nutrients from the surrounding waters. In New York City for instance, mussels are harvested, and along with this harvest comes the excess nutrients from the environment that have been incorporated into their shells and tissue, thereby improving water quality for other marine life (Greenberg, 2013). Using ecosystem engineers as tools for restoring disturbed intertidal ecosystems may require adequate knowledge about such species, with respect to their local environment, including ambient macrofaua. This study could therefore serve as a source of that knowledge, and could go a long way in being a resource base approaches that are being devised to protect marine biodiversity in the intertidal zones and beyond.

3. Research Methods

3.1 Research design and location

The research project was conducted through a quantitative approach, whereby numerical data of biomass of *P. perna*, as well as the number of individuals of each ambient macrofauna individual were used to test the research hypotheses. The biomass of *P. perna* was calculated as the sum of the dry shell mass and the dry mantle tissue mass, based on the formula used by Branch & Steffani (2003), while the abundance of the ambient macrofauna was obtained by counting individuals of that particular species sampled at each distance along the 50m line transect through the intertidal zones.

Samples were collected at Long Beach, which is situated at 22° 49' 24.024" S, 14° 32' 33.4932" E on the rocky shore. Sampling was conducted during spring tide when the maximum tidal range is obtained and the spring low water mark is exposed in order to cover the entire area of the intertidal zones.

Figure 3: Google Maps. 2018. Sampling area for the study

3.2 Research sampling procedure

The data were collected during two seasons, namely autumn (March) and winter (August) in order to fulfill the objectives of the study by equally upholding the temporal (time-based) aspect. A line transect was laid from the LWM to the HWM using a measuring tape. The samples were collected along this line transect, on a 2m interval over 50m. Quadrat frames of size 0.5m x 0.5m were used to demarcate the sampling quadrats. Samples were collected from 10cm x 10cm quadrats in the corner of the 0.5m x 0.5m frames, which were demarcated using a ruler and a marker pen. The starting point of sampling at the HWM was marked with the GPS in order to return to the same point every sampling and monitor the same population. The next sampling was done 50 cm to the right of the previous line transect. This is necessary, since removal sampling was employed and if exactly the same quadrats were sampled, it may reduce the quality of data. In each of the 10cm x 10cm quadrats, all macrofauna were collected in plastic Ziplock bags which were then sealed. Samples were stored at -20°C until analysis in the laboratory.

3.3 Processing of samples and statistical analyses

In the laboratory, the mussels of *P. perna* were identified from the samples collected. The sorting was done by emptying the plastic bag containing the sample into a sieve (mesh size =150µm) under a running tape water. Water was let to run through the sieve to rinse the sample and make the mussels to be easily spotted for sorting. A light microscope and an identification guide by Branch, Griffiths, Branch, Beckley (2007) was used to distinguish the *P. perna* from other species by comparing the observations on the microscope with type graphics in literature. According to Rusk (2012), the genus *Perna* is comprised of three species of mussels, and it differs distinctively from the genus *Mytillus* in terms of their geographic distributions and certain morphological characteristics such as the shape and color of the shell as well as tissue morphology. Figure 4 below displays the external morphological characteristics of *P. perna*, which distinguishes it from other mussel species.

Figure 4: Mantelatto, Christofoletti, Camargo et.al. 2002. *P. perna* (Brown mussel; South American rock mussel)

Figure 5: Lamark. 1819. Polichromatic series of *Mytilus galloprovincialis*

A key feature that was used to distinguishe adults of *Perna* from other mussel species such as *Mytilus* in the laboratory was ‘the pattern of the scars left at the area of muscle attachment on the shell (Vakily, 1989). In *Mytilus*, the anterior and posterior components of the retractor muscle are united forming a continuous band of myostracum along the dorsal margin of the pallid line. In contrast, these two components attach separately on the shell in *Perna*, resulting in a discontinuous muscle scar’. Another distinct morphological characteristic used was the anterior adductor muscle which occurs, though less obvious, in *Mytilus* but not in *Perna* (Vakily, 1989).

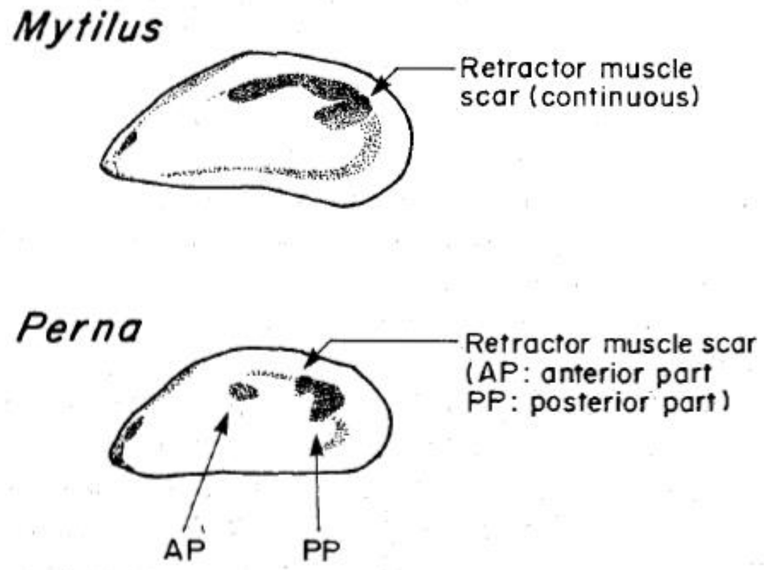

Figure 6: Vakily. 1989. Mussel scar difference between *Perna* and *Mytilus*.

The three species that belong to the *Perna* genus as stated by Rusk (2012) are: *Perna canaliculus* (Gmelin, 1791) which is endemic to New Zealand, *P. perna* which is mostly found throughout South America and Africa, as well as *Perna viridis* (Linaeus, 1758) which occurs within the Indo-Pacific region.

The shells of the adult and juvenile *P. perna* were opened to remove the mantle tissues and collect them on pre-weighed empty petri dishes. The wet empty shells of the adult and juvenile mussels were weighed separately by placing them on a balance to obtain the wet shell mass. The wet mass of soft mantle tissues was also obtained separately. The shells and mantle tissue were then put into the drying oven at 72˚C for 24 hours.

After 24 hours the dry mass of the shells and mantle tissue of adults and juveniles was obtained separately. The Condition index (CI) was calculated as: CI = (Dry mass of tissues/Total wet mass) x 100. This is supported by the fact marine research on population dynamics, energy flow, food web interactions, and fishery yields is dependent on estimates of biomass and secondary production, which are normally based on dry weights (Ricciardi & Bourget, 1998).

The biomass of *P. perna* was calculated as: (Dry shell mass + Dry tissue mass)/$10cm^2$. This is due to the fact that dry ash-free weight of organisms serves as a good representation of their total biomass, as emphasised by Ricciardi & Bourget (1998). Individuals of the ambient macrofauna were identified using an identification guide by Branch et al. (2007). Data on abundance of the ambient macrofauna were then obtained as the sum of individuals of each species in that particular quadrat.

Additional data, mainly the average minimum and maximum sea temperature at Long Beach, Swakopmund for autumn and winter was obtained from the World sea temperature website, to serve as an indication of the physical conditions that affect *P. perna* and its ambient macrofauna and the study site. These data were collected on a later date, but were accurate enough as per the source.

Data analysis was performed in Microsoft excel as well as other statistical software such as Past and MaxStat. All data were tested for normality using the Shapiro-Wilk test. The *P. perna* biomass and condition index data were normally distributed, hence a parametric test, namely the t-Test for equal means was used to test whether there were significant changes in biomass and condition index of *P. perna* from autumn to winter. Additionally, a one sample t-Test was conducted for the biomass and condition index data, to determine how these two parameters changed in the different intertidal zones. In order to determine the influence that the change in biomass of *P. perna* has on ambient macrofauna, a Multiple linear regression analysis was used. This is because data on the influence that the change in biomass of *P. perna* has on ambient macrofauna were not normally distributed, hence a non-parametric test had to be used in this case. Data were tested statistically at 0.05 significance level.

4. Results

4.1 Changes in biomass of *P. perna* from autumn to winter

There was a decline in biomass of *P. pema* from autumn to winter at Long Beach (figure 7). Moreover, the mean biomass of *P. perna* generally decreased towards the higher water mark of the intertidal zones, both in autumn and winter. The significance of this change is represented by the corresponding statistical test results.

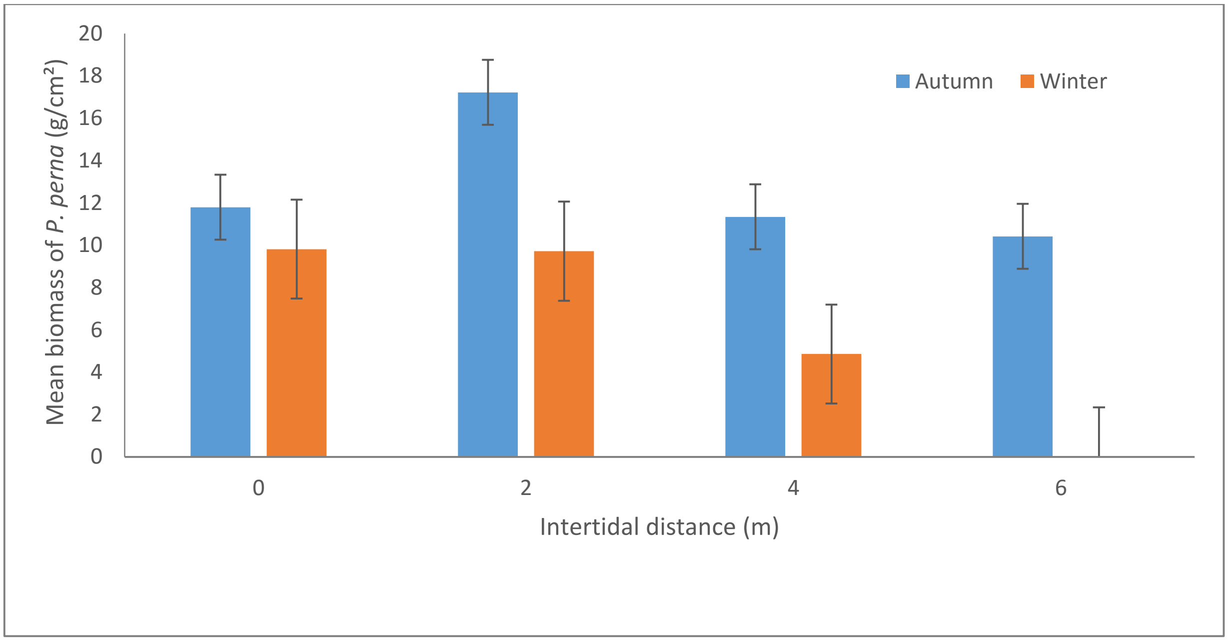

Figure 7: Changes in mean biomass (g/cm²) of *P. perna* in the intertidal zones from autumn to winter. There was a decrease in mean biomass of *P. perna* from the lower water mark to the higher water mark of the intertidal zones during both seasons.

A t-Test for equal means was carried out to determine whether there was a significant change in biomass of *P. perna* from autumn to winter. The test yielded that (t =2.3567; df = 2; P = 0.056542). There was no significant change in biomass of *P. perna* between autumn and winter.

However, in terms of changes in biomass of *P. perna* between the different intertidal zones, a One sample t-Test yielded that (t = 5.2946; df = 3; p = 0.013147), showing that there was a significant difference in biomass of *P. perna* between the different intertidal zones.

4.2 Change in Condition index of *P. perna* from autumn to winter

The condition index of *P. perna* seemingly fluctuated along the intertidal zones, both in autumn and winter (figure 10). The significance of this variation is represented by the statistical results.

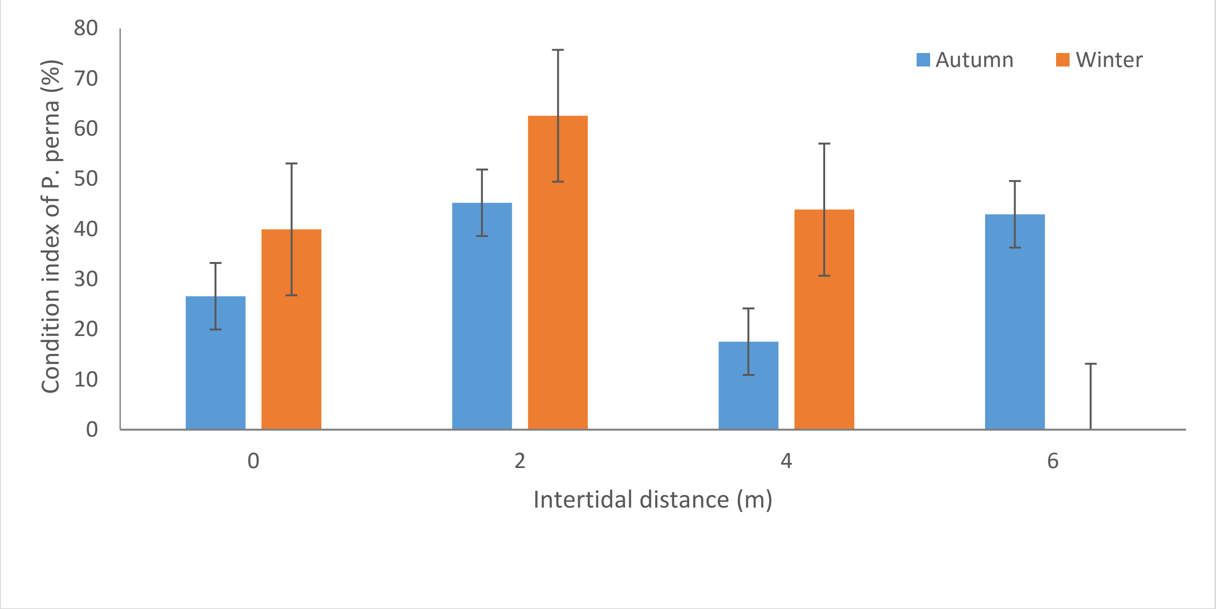

Figure 8: Changes in condition index (%) of *P. perna* from autumn to winter. The condition index of *P. perna* varied along the intertidal zones during the two seasons.

Similar to the biomass statistical analysis, a t-Test for equal means was used determine whether there was a significant change in biomass of *P. perna* from autumn to winter. The statistical test yielded that (t = 0.23896; df = 2; P = 0.81909), indicating that there was no significant change in condition of *P. perna* between autumn and winter.

However, in terms of changes in condition index of *P. perna* between the different intertidal zones, a One sample t-Test yielded that (t = 5.0929; df = 3; p = 0.014634), showing that there was a significant difference in condition index of *P. perna* between the different intertidal zones.

4.3 Influence of change in biomass of *P. perna* on abundance of ambient macrofauna from autumn to winter

The abundance of ambient macrofauna was generally inversely proportional to biomass of *P. perna*, both in autumn (figure 9) and winter (figure 10). The abundance of ambient macrofauna declined as the biomass of *P. perna* increased.

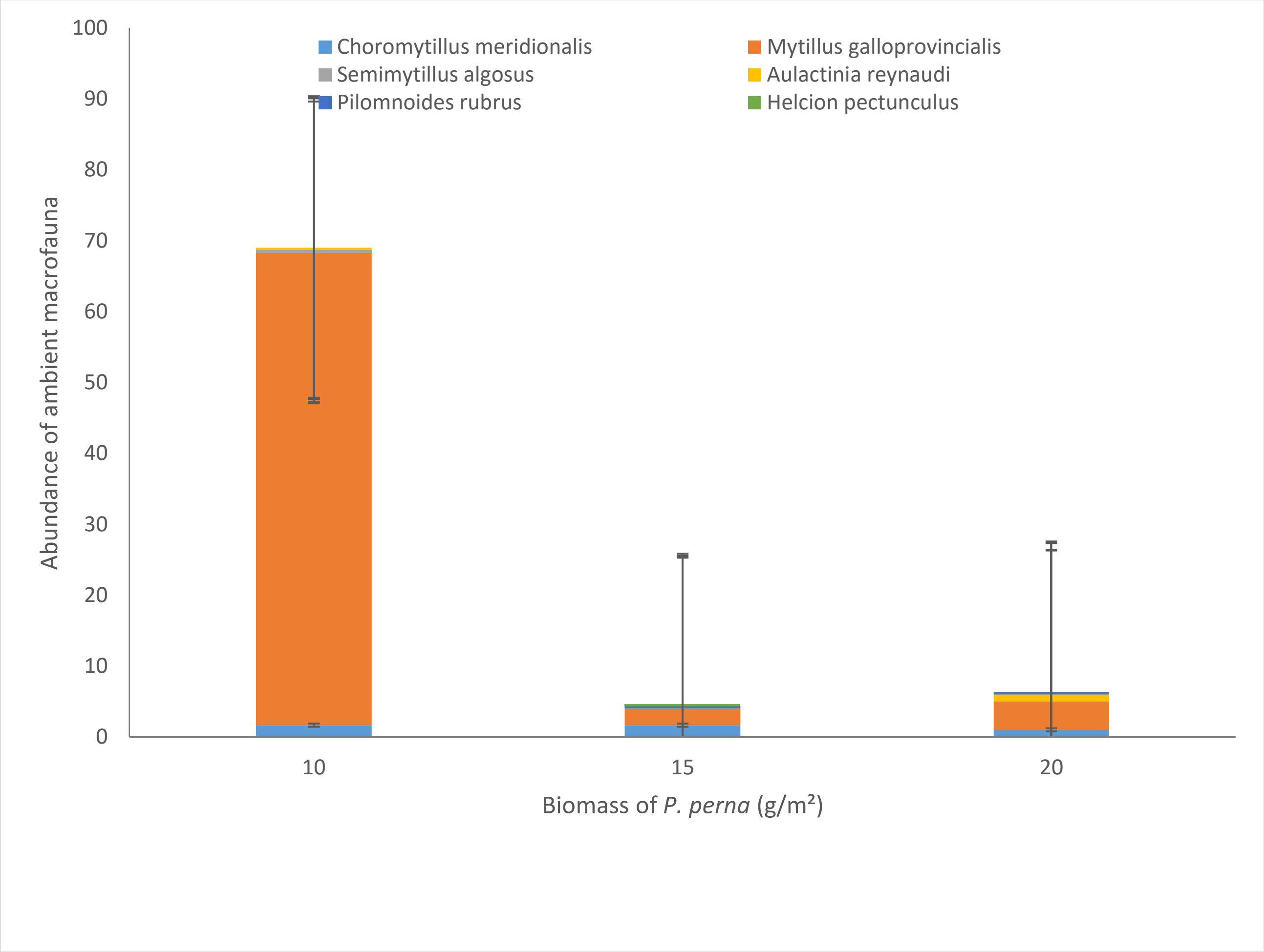

Figure 9: Change in abundance of ambient macrofauna in autumn as a result of change in biomass of *P. perna*. There was a decrease in abundance of ambient macrofauna as the biomass of *P. perna* increased.

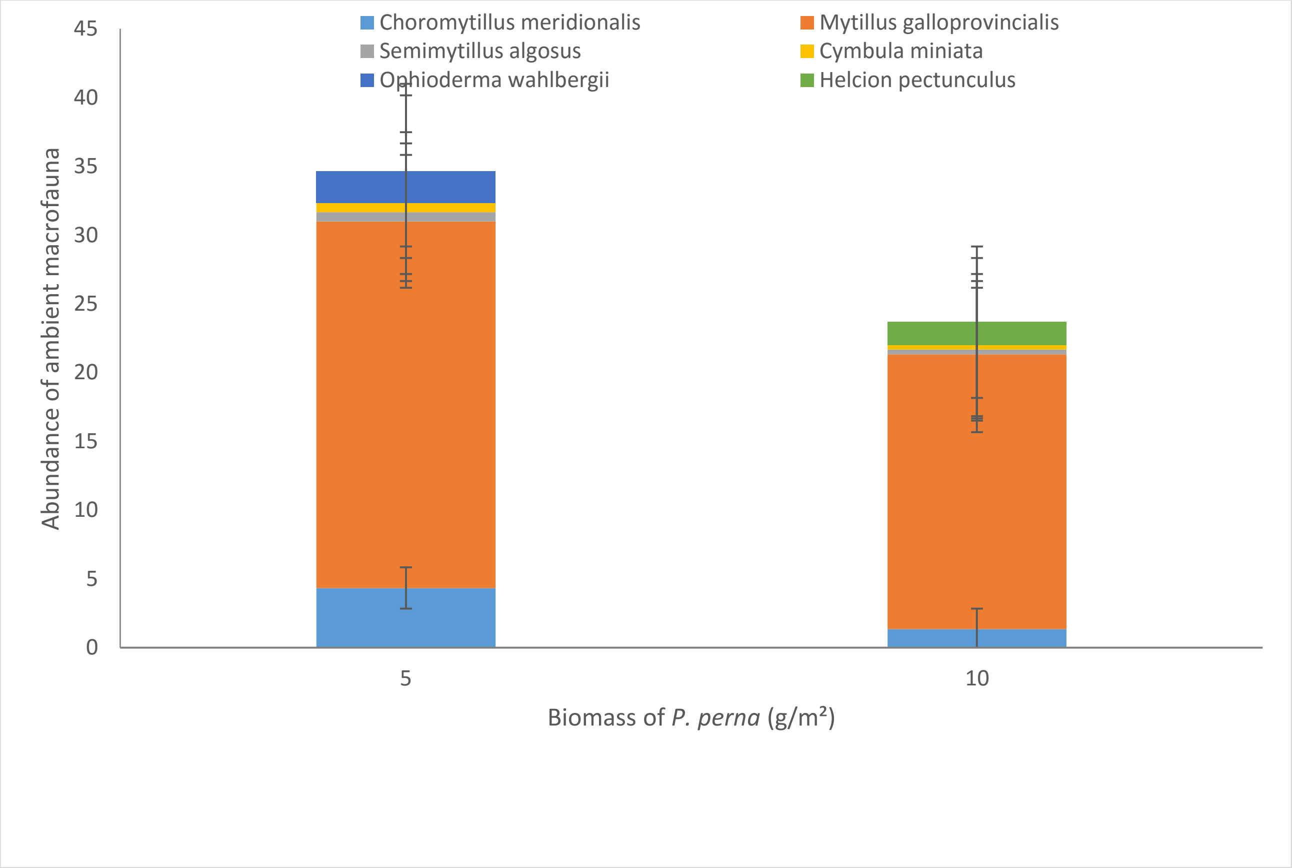

Figure 10: Change in abundance of ambient macrofauna in winter as a result of change in biomass of *P. perna*. There was a decrease in abundance of macrofauna as the biomass of *P. perna* increased.

A Multiple linear regression analysis on the influence of change in biomass of *P. perna* on ambient macrofauna for both autumn and winter was conducted (table 1). The statistical test results yielded that (r = 0.807; 0.574; 0.479 and P = 0.0002; 0.0138; 0.0354), showing that the change in biomass of *P. perna* did have a significant influence on the abundance of ambient macrofauna.

Table 1: A Multiple linear regression analysis on the influence of change is biomass of *P. perna* on ambient macrofauna from autumn to winter. The change in biomass of *P. perna* significantly influenced the abundance of ambient macrofauna.

Regression coefficients and statistics				
	Coeff.	Std.err	r	p
C. meridionalis	6.2143	1.241	0.807	0.0002
M. galloprovincialis	47.643	16.745	0.574	0.0138
S. algosus	0.7143	0.304	0.479	0.0354

4.4 Influence of temperature on biomass of *P. perna* and abundance ambient macrofauna on the central coast of Namibia

From figure 11 below, the highest sea temperature reading (20°C) was recorded in autumn, while the lowest (12°C) was recorded in winter.

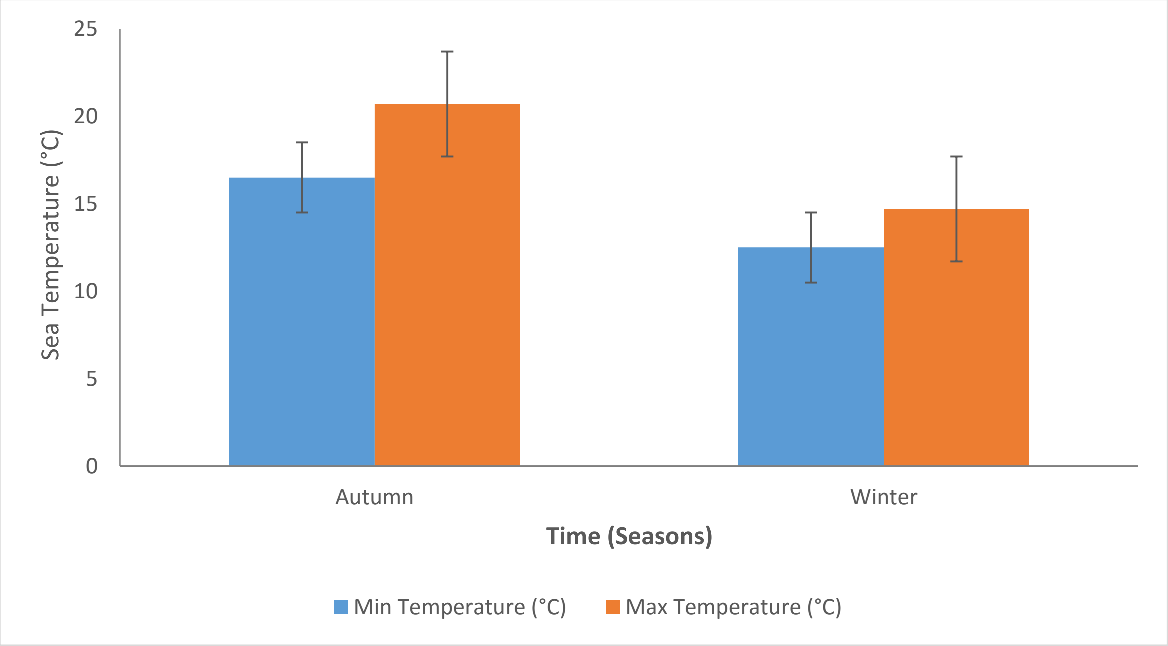

Figure 11: Sea temperature (°C) from autumn to winter, 2017. The sea water temperature was higher in autumn than in winter.

5. Discussion

The was no significant change in biomass and condition index of *P. perna* at Long Beach, Swakopmund from autumn to winter. However, significant changes in biomass and condition index of *P. perna* were observed at intertidal zones level in both autumn and winter, which could be a result of significant changes in physical conditions such as sea temperature. Overall, the abundance of ambient macrofauna significantly varied as a result of changes in biomass of *P. perna*.

5.1 Causes of change in biomass of *P. perna*

The statistical test results revealed that there no significant change in biomass of *P. perna* at Long Beach from autumn to winter. This could be due to minimal or lack of influence from physical factors such temperature (figure 11). A study by Ortiz & Piug (2007) in estuarine environments suggested that benthic macroinvertebrates do respond to changes in temperature that result from changes in seasons. The most common trend observed by Ortiz & Piug (2007) is that the biomass of *P. perna* tends to be higher in warmer seasons than in colder ones, with the notion that warmer seasons are characterised by a relatively higher abundance of nutrients, which is expected to cause an increase in recruitment and growth of mussels. In the case of this study, temperature did not change significantly from autumn to winter, which could be the main reason why there was no significant change in biomass of *P. perna* over the same time period. The results on changes in biomass of *P. perna* for this study are consistent with the results obtained by Ortiz & Piug's (2007), where temperature as an environmental factor was used to justify why the biomass of mussels did not change significantly over time. Reugh-Flower et.al (2011) suggested that significant changes in mussel biomass are usually evident in the later months of the year i.e. November and December, when the sea water temperature is much cooler. Reugh-Flower et.al (2011) further stated that cooler temperatures in sea water are a result of upwelling, hence it can be deduced that lower temperature is associated with high availability of nutrients.

Reugh-Flower et.al (2011) emphasised that there is a significantly positive relationship between the amount of mussel recruitment and adult abundance, the intensity or magnitude of upwelling, which can be inferred from sea water temperature readings. Erlandsson et.al (2006) found that enhanced food supplies increase larval survival and hence settlement and recruitment; they will also improve conditions for adults, thus elevating reproductive output and, ultimately, larval abundance. In the case of the current study, the sea water temperature did not reduce significantly from autumn to winter, which means that other effects that are associated with low sea water temperature such as the high availability of nutrients due to upwelling did not prevail, hence the insignificant change in biomass of *P. perna*.

In terms of the different intertidal zones however, the biomass on *P. perna* varied significantly, as indicated by the statistical results. This is consistence with what is displayed in figure 7, where the mean biomass of *P. perna* decreased with intertidal distance. This could be due to the differences in temperature between the intertidal zones, as temperature is generally high in the higher water mark than in the lower water mark (Hunt et.al, 1996). The high temperature that occurs in the high water mark could result in reduced mussel populations, as it is perhaps on the extreme end of the temperature range that they tolerate. However, changes in temperature may not necessarily be the cause for change in biomass of *P. perna* between the intertidal zones, as wind is known to be the main driver of upwelling and the impact thereof on marine organisms (Solaris, 1961).

5.2 Condition index as a good reflection of biomass of *P. perna*

Murray et.al (2016) suggested that biotic indices can serve as simpler representation of results from rather complex ecological datasets. One of the ecological indices which can equally represent the change in biomass of marine mussels over time is the condition index, which is basically the percentage tissue mass of mussles. Similarly, Perez-Camacho, Aguiar, Labarta et.al (2014) used condition index data to assess the change in biomass and productivity of mussels. From figure 8 above, the condition index of *P. perna* did not vary significantly from autumn to winter, as revealed by the statistical results. Bayne & Worral (1980) have argued that changes in condition index and productivity of mussels are largely caused by physical factors, such as sea water temperature. Perez-Camacho (2014) manipulated the physical factors i.e. temperature and available nutrients in a mussel culture, and found that they significantly impacted on the biomass and productivity of the mussels that were sampled for that particular study.

The experiment by Perez-Camacho (2014) could be considered when explaining the condition index results (figure 8), as temperature has the potential to influence the condition index and productivity of mussels in the intertidal zones. From a deductive point of view, the lack of major changes in temperature (figure 11) could also be the main reason why the condition index and biomass of *P. perna* did not change significantly, as mentioned in the subsection 5.2 above.

Although condition index is usually based on the individuals, it goes a long way in indicating the state of the of the mussel population in terms of biomass and density. The percentage tissue mass of mussels can be influenced by temperature and associated factors such as nutrient availability, as argued by Perez-Camacho (2014). Now, if the dry tissue mass of individual mussels is does not change significantly as it was the case in this study, then overall dry tissue mass of mussels in the population will consequently not change significantly either. This could be the reason why the biomass and condition index statistical results are in concurrence with each other, in showing that there was no ultimately significant difference in biomass of *P. perna* at Long Beach, Swakopmund from autumn to winter of 2017. However, the interpretations made in this study regarding nutritional availability are only inferential, as there was no actual data was collected on this.

Like in the case of biomass, there was a significant difference in the condition index of *P. perna* between the different intertidal zones. This is also consistence with what is displayed in the corresponding graph (figure 8), where the condition index of *P. perna* decreased with intertidal distance. Again this could be attributed to differences in temperature between the different intertidal zones, as emphasised by Hunt et.al (1996).

5.3 Possible drivers of the influence of change in biomass of *P. perna* on abundance of ambient macrofauna

Among the ambient macrofauna presented in figure 9 and figure 10, the invasive Mediterranean mussel *M. galloprovincialis* was seemingly the most impacted by the change in biomass of *P. perna* over time, as it experienced the steepest decline in species abundance due to the increase in biomass of *P. perna*. On the other hand, the black mussel abundance of *Choromytillus meridionalis* and *S. algosus* was low compared to that of *M. galloproviancialis* throughout the seasons, but did experience a decline too due to increase in biomass of *P. perna*.

The statistical results in table 1 showed that there was a significant change in species abundance of ambient macrofauna as a result of change in biomass of *P. perna*. While considering physical factors such as temperature, which might have caused the change in abundance of ambient macrofauna in relation to temporal changes in biomass of *P. perna* (figure 9 and figure 10), it is important to interpret such findings in the terms of how change in temperature can form synergistic effects with biotic factors such as interspecific competition, to influence abundance of macrofauna in the intertidal zones.

Nevertheless, it can be suggested that the ability of a species to compete with other species for resources and habitat depends on the species ability to cope with the physical environment in which it occurs. This called ecological tolerance, and was defined by Bravo et.al (1998) as the measure of how the change of an external factor may impact on the organisms and their ability to adapt to such changes. This is in concurrence with what was emphasised by Flower et.al (2011), that the retentive or extractive nature of local environments in the intertidal zones has been shown to significantly influence settlement and recruitment success.

According to Gosling (2003), mussels and other marine bivalves live within the temperature range of -3˚C to 44˚C. However, the different species have different degrees of tolerance with respect to changes in temperature in the intertidal zones. A good indication of this comes from the statistical results, which yielded that there was a significant difference biomass and condition index of *P. perna* between the different intertidal zones, possibly as a result of desiccation. Even within species, different age groups have different degrees of tolerance with respect to temperature, as recruits for instance have narrower temperature tolerance than adults. Moreover, the average amount of temperature required for spawning is generally higher than what is required for growth of mussels (Gosling, 2003). Although the changes in sea water temperature were not statistically significant, the little variation in temperature observed in figure 11 might have still affected the ambient macrofauna.

Another factor that could be used to justify this observation is interspecific competition between *P. perna* and the mussel ambient species, especially for food. Erlandsson et.al (2006) disclosed that non-native species such as *M. gallloprovincialis* have the potential for shrinking *P. perna*'s niche in the intertidal zones. This suggests that during the primary settlement of mussel species, there is a distinct separation in the spatial ranges occupied by mussel species in the intertidal zones, with *P. perna* being more abundant in the lower water mark while *M. galloproviancialis* among others would usually be more dominant in the middle water mark of the intertidal zones.

According to Erlandsson et.al (2006), mussel species normally dominate different levels in the intertidal zones, and can co-exist in the mid mussel zone. However, the same study found that *M. galloprovincialis* showed faster re-colonisation and three times more cover than *P. perna* when populations had recovered. Interspecific competition as a limiting factor on *P. perna* biomass does not occur in isolation, but it is rather intensified by physical disturbance events such as storms in the sea which have the tendency of washings away mussels from their mussel beds.

A factor key factor suggested by Reaugh et.al (2007) to be of great influence to density and biomass of mussel species especially *P. perna,* is the availability of algae as a substrate for primary settlement by mussels, stating that algae is in-part a facilitator of primary settlement for mussels. In their study, Reaugh et.al (2007) found that recruitment of *P. perna* onto algae substrate exceeded that onto mussel beds. Now it is an undisputed fact that the availability of nutrients does affect primary production, of which algal growth is part. It can therefore be implied that during seasons that are characterised by colder sea water temperature, the availability of algae will be relatively higher than in warmer seasons when the upwelling of nutrients was low. Incidentally, this might have been the case during this year.

The abundance of adult mussels is largely determined by the recruitment level (Flower et.al, 2011). In their study, Flower et.al (2011) discovered that there seemed to be a strong a relationship between adult abundance and recruitment. According to Halla et.al (2017), *P. perna* is known to mature faster than other mussel species such as *M. galloprovincialis*, while *C. meridionali* and *S. algosus* generally mature at an even slower pace and compared to *P. perna*. This could imply that *P. perna* has the potential outcompete *M. galloprovincialis* and other ambient species in the early stages after settlement, although this is the case only in the lower water mark, thereby affecting their abundance.

While taking into account the justifications of the results of this study, it should be noted that there were a number of limitations that might have influenced these findings. One is that studies of this nature normally require that data are collected over a long period of time e.g. for two years in order to clearly observe the changes in trends of parameters being assessed. However, data used in this study were collected over a period of just half a year (less than 6 months), and the data collection trips were delayed because the sampling material were not availed on time. Therefore, the quality of results yielded by the study may not be strong as desired.

6. Conclusions

The biomass of *P. perna* did not change significantly over time from autumn to winter, due to insignificant changes in temperature. Similarly, the condition index of *P. perna* did not change significantly from autumn to winter, also largely due to lack of significant changes in temperature and other associated environmental factors such as nutrient availability as influenced by upwelling. On the other hand, the biomass and condition index of *P. perna* differed significantly among the different intertidal zones, possibly due to difference in sea temperature in the different intertidal zones. Moreover, the change in biomass of *P. perna* did influence on abundance of ambient macrofauna significantly, mainly due to *P. perna*’s fast population growth rate compared to its ambient macrofauna, including *M. galloprovinacialis*, which is a tough competitor during secondary settlement. The impact was negative, in that the abundance of ambient macrofauna decrease as a result of increase in biomass of *P. perna*.

7. Recommendations

In order to obtain reliable data on biomass of mussels and their ambient macrofauna, there has to be sufficient time for data collection, as the life cycle of mussels occurs over at least a year. As a matter of fact, there were strong suggestions by scholars such as Flower et.al (2011) who assessed recruitment processes of several intertidal mussels in southern Africa over 5 years, that studying biomass and productivity of mussels over a year period only may not be sufficient. Nevertheless, it was evident throughout the duration of this study there is lack of research on the ecology of *P. perna* in the local context i.e. on the Namibia coast. There is a need to therefore undertake studies of this nature in order to gather reliable information that is crucial for the conservation of this species in Namibia.

Furthermore, there was an interesting gap discovered during the study, mainly on how ambient species such as the invasive *M. galloprovincialis* impact on biomass of *P. perna*. This could be worth researching in future, as it is of much relevance to the conservation of the native *P. perna* species on the Namibian central coast. Although *P. perna* has a relatively faster growth rate compared to *M. galloproviancialis*.

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9. Appendices

Appendix 1: Raw data on biomass of *P. perna* and abundance of ambient macrofauna at Long Beach-Central during the autumn season

Date and site: 25.03.17 **Locality: Long Beach Central** **Temp: 20.8˚C**
Collector's name: Innocent Haingura **GPS: 22˚49'27"S 14˚32'29"E**

Distance on the line transect (m)	**Biomass of *P. perna***					**Ambient species found (number per species)**				
	Wet shell + Tissue mass (g)	Wet shell mass (g)	Wet tissue mass (g)	Dry shell mass (g)	Dry tissue mass (g)					
						Helcion pectunculus	*Choromytillus meridionalis*	*Mytillus galloprovincialis*	*Jassa spp.*	*Aulactinia reynaudi*
0	458.712	257.705	235.935	247.439	121.916	3	1	3	1	0
2	108.78	80.54	72.23	77.63	49.17	0	3	6		1

Appendix 2: Raw data on biomass of *P. perna* and abundance of ambient macrofauna at Long Beach-West during the winter season

Date and site: 26.03.17 **Locality: Long Beach West** **Temp: 23.7˚C**
Collector's name: Innocent Haingura **GPS: 22˚49'33"S 14˚32'28"E**

Distance on the line transect (m)	**Biomass of *P. perna***					**Ambient species found (number per species)**			
	Wet shell + Tissue mass (g)	Wet shell mass (g)	Wet tissue mass (g)	Dry shell mass (g)	Dry tissue mass (g)				
						H. pectunculus	*C. meridionalis*	*M. galloprovincialis*	*A. reynaudi*
0	90.605	75.184	63.329	72.75	45.207	0	1	2	0
2	187.694	145.833	133.847	141.983	100.591	0	0	5	2
4	74.62	65.62	56.27	64.95	48.46	2	6	10	0
6	124.431	88.775	80.799	84.818	53.428	0	5	117	1
16	83.745	59.107	64.443	57.816	45.67	0	2	4	9

Appendix 3: Raw data on condition index of *P. perna* in the autumn season

	Condition index (%) of *perna perna* at each site			
Intertidal Distance (m)	**LBC**	**LBE**	**LBW**	**Median**
0	26.57789637	23.7248	49.89459743	26.5779
2	45.20132377	31.61289	53.59308236	45.20132
4	0	17.56051	64.9423747	17.56051
6	0	89.10548	42.93785311	42.93785
10	0	43.46502	0	0
16	0	0	54.53459908	0
18	0	55.72428	0	0
30	0	59.24656	0	0

Appendix 4: Raw data on condition index of *P. perna* in the winter season

	Condition index (%) of perna perna at each site			
Intertidal Distance (m)	**LBC**	**LBE**	**LBW**	**Median**
0	32.39104211	39.93181488	62.71688532	39.93181
2	62.57660878	43.09532999	91.38233574	62.57661
4	43.8530288	28.9232824	78.78589007	43.85303
6	62.9203025	0	0	0

Appendix 5: Normality test for data on biomass of *P. perna*

	Autumn	Winter
N	4	4
Shapiro-Wilk W	0.7972	0.8694
p(normal)	0.09723	0.2952
(p>0.05)?	Yes	Yes

Appendix 6: Normality test for data on condition index of *P. perna*

	Autumn	Winter
N	4	4
Shapiro-Wilk W	0.8946	0.9173
p(normal)	0.4047	0.5217

(p>0.05)?	Yes	Yes

Appendix 7: Normality test for data on influence of changes in biomass of *P. perna* on species abundance of ambient macrofauna from autumn to winter, at Long Beach, Swakopmund.

	C. meridionalis	*M. galloprovincialis*	*S. algosus*	*C. miniata*	*H. pectunculus*	*O. wahlbergii*	*S. granularis*
N	14	14	14	14	14	14	14
Shapiro-Wilk W	0.8816	0.7582	0.6805	0.2968	0.2968	0.3535	0.2968
p(normal)	0.06129	0.001589	0.000234	2.19E-07	2.19E-07	5.135E-07	2.19E-07

Appendix 8: Mean sea temperature from January to August at Long Beach, Swakopmund

Temperature	Time (Seasons)	
	Autumn	Winter
Min Temperature (°C)	16.5	12.5
Max Temperature (°C)	20.7	14.7

Appendix 9: Normality test for sea temperature data from Autumn to Winter at Long Beach, Swakopmund

	Autumn	Winter
N	2	2
Shapiro-Wilk W	1	1
p(normal)	1	1

Appendix 10: A t-Test for equal means, for change in biomass of *P. perna* from autumn to spring at Long Beach, Sawkopmund.

Autumn		**Winter**	
N:	4	**N:**	4
Mean:	12.695	**Mean:**	6.0991
95% conf.:	(7.8057 17.583)	**95% conf.:**	(-1.3457 13.544)
Variance:	9.4394	**Variance:**	21.89
Difference between means:	6.5954		
95% conf. interval (parametric):	(-0.25259 13.443)		
95% conf. interval (bootstrap):	(1.5694 10.84)		
t : 2.3567		p (same mean):	0.056542
Uneq. var. t : 2.3567		p (same mean):	0.063225
Monte Carlo permutation:		p (same mean):	0.0085
Exact permutation:		p (same mean):	0.014286

Appendix 11: A one sample t-Test for changes in biomass of *P. perna* between the different intertidal zones at Long Beach, Swakopmund.

Given mean:	0
Sample mean:	9.3968
95% conf. interval:	(3.7486 15.045)
Difference:	9.3968
95% conf. interval:	(3.7486 15.045)
t :	5.2946
p (same mean):	0.013147

Appendix 12: A t-Test for equal means, for change in condition index of *P. perna* from autumn to winter at Long Beach, Swkopmund.

Autumn	**Winter**

N: 4	**N:** 4
Mean: 33.069	**Mean:** 36.59
95% conf.: (11.975 54.164)	**95% conf.:** (-5.2889 78.47)
Variance: 175.75	**Variance:** 692.68
Difference between means: 3.521	
95% conf. interval (parametric): (-32.533 39.575)	
95% conf. interval (bootstrap): (-19.717 29.563)	
t : 0.23896	p (same mean): 0.81909
Uneq. var. t : 0.23896	p (same mean): 0.82179
Monte Carlo permutation:	p (same mean): 0.9112
Exact permutation:	p (same mean): 0.91429

Appendix 13: A one sample t-Test for changes in condition index of *P. perna* between the different intertidal zones.

Given mean: 0

Sample mean: 34.83

95% conf. interval: (13.065 56.594)

Difference: 34.83

95% conf. interval: (13.065 56.594)

t : 5.0929

p (same mean): 0.014634

Appendix 14: Tidal table for Walvis Bay, 2017

TIME ZONE - 2 TIME ZONE - 2

JANUARY						FEBRUARY						MARCH					
DAY	TIME	M	DAY	TIME	M	DAY	TIME	M	DAY	TIME	M	DAY	TIME	M	DAY	TIME	M
	05 14	1.62		06 05	1.68		06 15	1.69		00 14	0.56		05 12	1.83		05 28	1.62
1	11 12	0.43	16	12 07	0.42	1	12 15	0.40	16	06 38	1.53	1	11 13	0.25	16	11 30	0.43
$	17 29	1.53	M	18 38	1.54	W	18 44	1.57	T	12 40	0.56	W	17 38	1.74	T	17 57	1.56
	23 24	0.46								19 19	1.42		23 28	0.38		23 43	0.52

2 M	05 54	1.60	17 T	00 13	0.51	2 T	00 27	0.51	17 F	00 51	0.66	2 T	05 54	1.76	17 F	05 58	1.52
	11 52	0.46		06 47	1.59		07 03	1.62		07 16	1.42		11 53	0.31		12 00	0.52
	18 14	1.49		12 49	0.52		13 01	0.47		13 19	0.66		18 24	1.66		18 32	1.47
				19 27	1.44		19 41	1.50		20 12	1.34						
3 T	00 03	0.51	18 W	00 54	0.61	3 F	01 15	0.61	18 S	01 36	0.76	3 F	00 08	0.46	18 S	00 17	0.60
	06 39	1.56		07 32	1.49		08 02	1.54		08 11	1.32		06 41	1.66		06 33	1.42
	12 37	0.51		13 36	0.61		13 59	0.54		14 16	0.75		12 36	0.41		12 33	0.61
	19 07	1.45		20 22	1.36		20 52	1.44		21 25	1.29		19 19	1.56		19 15	1.38
4 W	00 49	0.58	19 T	01 41	0.71	4 S	02 21	0.70	19 $	02 58	0.84	4 S	00 54	0.57	19 $	00 55	0.70
	07 33	1.52		08 26	1.40		09 17	1.47		09 40	1.25		07 41	1.54		07 17	1.32
	13 32	0.55		14 39	0.69		15 24	0.60		16 17	0.79		13 29	0.53		13 13	0.71
	20 11	1.41		21 25	1.31		22 08	1.42		22 41	1.28		20 29	1.47		20 17	1.30
5 T	01 47	0.65	20 F	02 50	0.79	5 $	04 09	0.74	20 M	04 59	0.83	5 $	01 58	0.69	20 M	01 49	0.79
	08 37	1.48		09 34	1.33		10 35	1.45		11 05	1.25		09 02	1.44		08 35	1.23
	14 43	0.58		16 03	0.72		16 54	0.60		17 35	0.75		14 59	0.64		14 33	0.81
	21 24	1.39		22 31	1.30		23 19	1.45		23 47	1.32		21 48	1.42		21 43	1.26
6 F	03 07	0.70	21 S	04 26	0.82	6 M	05 35	0.68	21 T	06 05	0.76	6 M	04 05	0.74	21 T	04 09	0.83
	09 47	1.47		10 45	1.30		11 46	1.48		12 10	1.30		10 24	1.41		10 18	1.22
	16 04	0.57		17 14	0.71		18 02	0.54		18 30	0.68		16 43	0.66		16 53	0.80
	22 34	1.42		23 33	1.32								23 03	1.42		23 00	1.28
7 S	04 34	0.69	22 $	05 40	0.78	7 T	00 24	1.52	22 W	00 43	1.39	7 T	05 30	0.68	22 W	05 28	0.77
	10 55	1.49		11 48	1.31		06 39	0.59		06 54	0.67		11 38	1.44		11 33	1.27
	17 14	0.51		18 11	0.66		12 49	1.55		13 02	1.39		17 54	0.61		17 55	0.73
	23 39	1.48					18 59	0.46		19 14	0.60						
8 $	05 45	0.63	23 M	00 29	1.37	8 W	01 22	1.61	23 T	01 28	1.48	8 W	00 10	1.49	23 T	00 02	1.36
	11 58	1.55		06 35	0.71		07 32	0.48		07 34	0.58		06 32	0.58		06 21	0.67
	18 14	0.43		12 43	1.36		13 46	1.64		13 45	1.48		12 42	1.52		12 29	1.37
				18 57	0.60		19 49	0.39		19 52	0.52		18 50	0.54		18 42	0.64
9 M	00 38	1.56	24 T	01 16	1.44	9 T	02 13	1.70	24 F	02 08	1.58	9 T	01 09	1.58	24 F	00 53	1.46
	06 44	0.54		07 20	0.64		08 20	0.38		08 11	0.48		07 23	0.47		07 03	0.56
	12 57	1.62		13 29	1.42		14 36	1.72		14 24	1.58		13 37	1.61		13 15	1.48
	19 07	0.35		19 38	0.54		20 34	0.34		20 28	0.45		19 37	0.46		19 22	0.54
10 T	01 33	1.65	25 W	01 57	1.50	10 F	02 59	1.77	25 S	02 44	1.67	10 F	01 58	1.67	25 S	01 35	1.58
	07 38	0.44		07 59	0.56		09 03	0.31		08 46	0.39		08 06	0.38		07 41	0.44
	13 52	1.69		14 09	1.48		15 22	1.76		15 00	1.67		14 24	1.69		13 56	1.60
	19 57	0.29		20 15	0.48		21 16	0.31		21 03	0.38		20 19	0.40		19 59	0.44
11 W	02 24	1.73	26 T	02 34	1.57	11 S ○	03 41	1.81	26 $ ●	03 19	1.76	11 S	02 41	1.75	26 $	02 14	1.69
	08 27	0.35		08 35	0.49		09 44	0.28		09 22	0.31		08 46	0.32		08 18	0.33
	14 44	1.74		14 45	1.55		16 05	1.77		15 37	1.74		15 06	1.74		14 35	1.71
	20 45	0.25		20 50	0.43		21 55	0.31		21 38	0.33		20 57	0.36		20 36	0.36
12 T ○	03 12	1.78	27 F	03 09	1.63	12 $	04 20	1.82	27 M	03 55	1.82	12 $ ○	03 19	1.79	27 M	02 51	1.79
	09 15	0.29		09 09	0.43		10 22	0.28		09 58	0.26		09 22	0.29		08 56	0.23
	15 34	1.77		15 21	1.60		16 45	1.74		16 15	1.78		15 44	1.76		15 14	1.79
	21 30	0.24		21 24	0.39		22 32	0.34		22 13	0.31		21 33	0.35		21 14	0.30
13 F	03 58	1.81	28 S ●	03 43	1.69	13 M	04 56	1.79	28 T	04 33	1.85	13 M	03 55	1.79	28 T ●	03 30	1.86
	09 59	0.27		09 44	0.38		10 58	0.32		10 35	0.23		09 57	0.29		09 34	0.17
	16 21	1.76		15 57	1.65		17 23	1.68		16 55	1.78		16 19	1.74		15 54	1.84
	22 14	0.27		21 58	0.37		23 06	0.40		22 50	0.33		22 07	0.36		21 52	0.26
14 S	04 42	1.80	29 $	04 19	1.73	14 T	05 31	1.72				14 T	04 27	1.76	29 W	04 09	1.88
	10 44	0.29		10 19	0.35		11 32	0.39					10 29	0.31		10 12	0.14
	17 07	1.71		16 34	1.67		17 59	1.60					16 53	1.70		16 36	1.84
	22 55	0.33		22 33	0.37		23 40	0.48					22 39	0.39		22 31	0.27
15 $	05 24	1.76	30 M	04 55	1.75	15 W	06 04	1.63				15 W	04 58	1.70	30 T	04 51	1.85
	11 26	0.34		10 56	0.34		12 06	0.47					10 59	0.36		10 52	0.17
	17 53	1.63		17 14	1.66		18 37	1.51					17 25	1.63		17 20	1.79
	23 34	0.41		23 09	0.39								23 11	0.45		23 11	0.32

			31 T	05 34 11 34 17 56 23 46	1.73 0.36 1.63 0.44										31 F	05 36 11 33 18 08 23 54	1.77 0.25 1.70 0.41

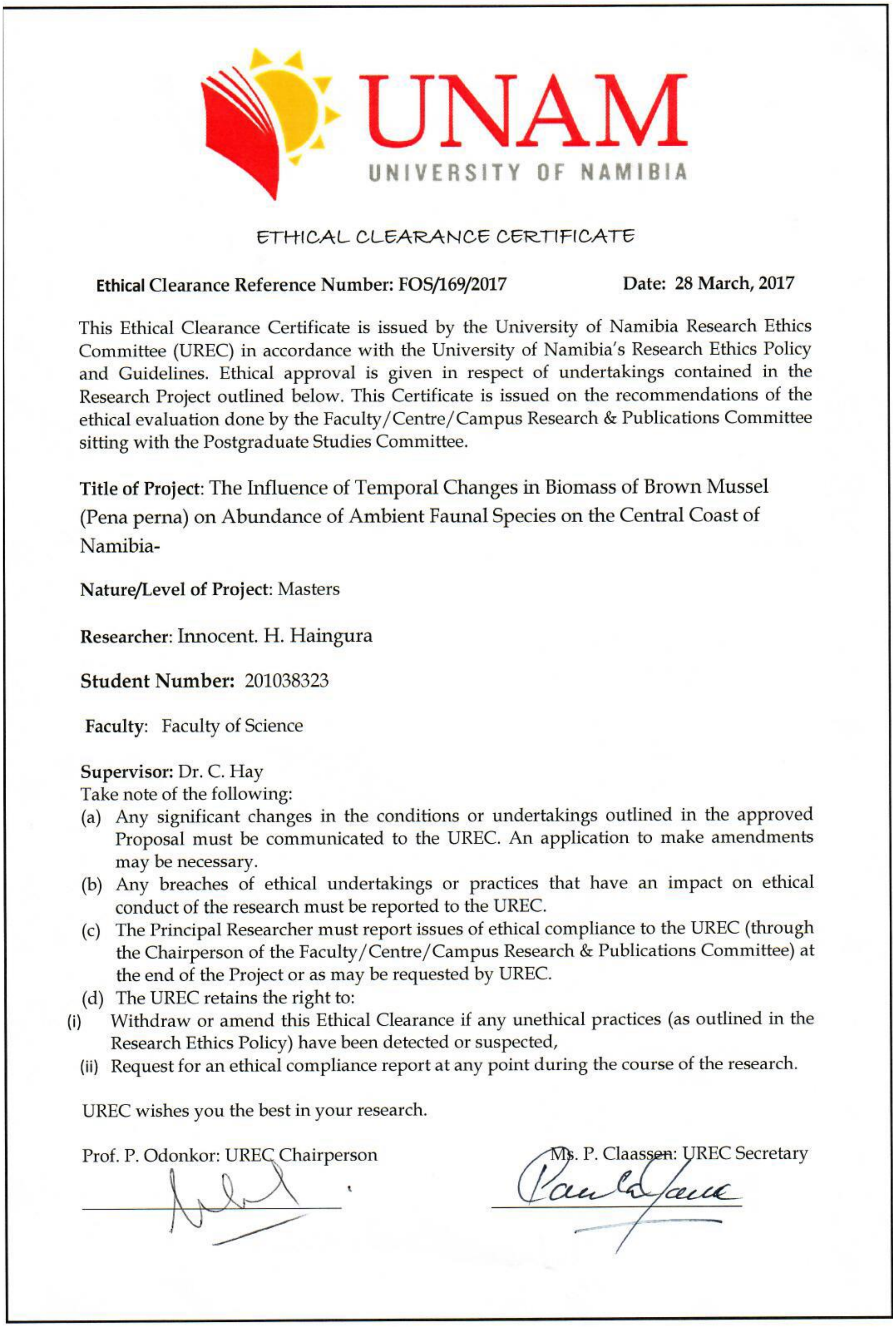
TIME ZONE - 2

TIME ZONE - 2

JULY						AUGUST						SEPTEMBER					
DAY	TIME	M	DAY	TIME	M	DAY	TIME	M	DAY	TIME	M	DAY	TIME	M	DAY	TIME	M
1 S	03 32 09 56 15 42 22 08	0.52 1.28 0.66 1.32	16 $	02 01 08 44 14 16 21 05	0.47 1.30 0.60 1.37	1 T	04 53 11 13 17 20 23 29	0.61 1.24 0.69 1.21	16 W	04 11 10 43 16 57 23 09	0.51 1.33 0.62 1.36	1 F	06 15 12 29 18 40	0.59 1.30 0.59	16 S	00 09 06 20 12 37 18 54	1.43 0.46 1.50 0.41
2 $	04 37 10 56 16 52 23 09	0.54 1.28 0.66 1.29	17 M	03 16 09 55 15 44 22 15	0.48 1.31 0.62 1.37	2 W	05 52 12 10 18 19	0.57 1.27 0.63	17 T	05 28 11 50 18 06	0.46 1.39 0.53	2 S	00 49 06 59 13 14 19 20	1.29 0.52 1.38 0.50	17 $	01 06 07 09 13 29 19 39	1.53 0.37 1.60 0.30
3 M	05 33 11 52 17 52	0.53 1.30 0.63	18 T	04 34 11 02 17 07 23 22	0.45 1.35 0.58 1.41	3 T	00 26 06 41 13 00 19 05	1.24 0.52 1.33 0.56	18 F	00 15 06 28 12 50 19 02	1.43 0.38 1.49 0.41	3 $	01 31 07 37 13 53 19 56	1.37 0.45 1.47 0.41	18 M	01 56 07 52 14 14 20 21	1.62 0.31 1.69 0.23
4 T	00 04 06 22 12 43 18 43	1.30 0.49 1.35 0.58	19 W	05 39 12 04 18 12	0.38 1.43 0.50	4 F	01 14 07 23 13 43 19 45	1.30 0.46 1.39 0.48	19 S	01 15 07 20 13 43 19 52	1.52 0.30 1.59 0.30	4 M	02 08 08 11 14 28 20 30	1.46 0.38 1.56 0.33	19 T	02 40 08 32 14 55 20 59	1.68 0.26 1.75 0.19
5 W	00 54 07 05 13 28 19 27	1.32 0.45 1.39 0.52	20 T	00 24 06 37 13 02 19 09	1.47 0.30 1.51 0.40	5 S	01 56 08 01 14 21 20 22	1.36 0.40 1.45 0.42	20 $	02 07 08 07 14 32 20 38	1.61 0.24 1.68 0.21	5 T	02 43 08 45 15 01 21 04	1.54 0.32 1.64 0.26	20 W ●	03 20 09 10 15 33 21 36	1.71 0.25 1.76 0.18
6 T	01 38 07 44 14 08 20 06	1.35 0.40 1.44 0.46	21 F	01 22 07 29 13 55 20 01	1.55 0.23 1.60 0.29	6 $	02 33 08 36 14 56 20 56	1.42 0.36 1.51 0.36	21 M ●	02 56 08 51 15 16 21 21	1.67 0.20 1.75 0.16	6 W ○	03 18 09 18 15 35 21 38	1.60 0.28 1.70 0.21	21 T	03 59 09 46 16 08 22 11	1.69 0.26 1.73 0.21
7 F	02 17 08 20 14 45 20 42	1.38 0.37 1.47 0.41	22 S	02 16 08 19 14 46 20 50	1.62 0.17 1.68 0.21	7 M ○	03 07 09 09 15 29 21 30	1.47 0.33 1.56 0.31	22 T	03 41 09 32 15 57 22 02	1.70 0.19 1.77 0.15	7 T	03 53 09 52 16 10 22 13	1.64 0.26 1.73 0.18	22 F	04 35 10 21 16 42 22 43	1.65 0.30 1.67 0.26
8 S	02 53 08 55 15 19 21 17	1.41 0.34 1.50 0.38	23 $ ●	03 08 09 06 15 34 21 37	1.67 0.14 1.73 0.16	8 T	03 42 09 42 16 02 22 04	1.51 0.30 1.61 0.28	23 W	04 23 10 11 16 37 22 40	1.68 0.22 1.74 0.18	8 F	04 31 10 27 16 47 22 50	1.65 0.27 1.72 0.19	23 S	05 10 10 54 17 14 23 15	1.58 0.36 1.57 0.34
9 $ ○	03 28 09 29 15 52 21 51	1.43 0.33 1.52 0.35	24 M	03 58 09 52 16 19 22 23	1.68 0.15 1.75 0.16	9 W	04 17 10 15 16 36 22 38	1.53 0.30 1.63 0.27	24 T	05 04 10 48 17 14 23 17	1.63 0.27 1.68 0.25	9 S	05 11 11 03 17 26 23 27	1.63 0.30 1.67 0.23	24 $	05 45 11 28 17 47 23 47	1.49 0.44 1.47 0.44
10 M	04 02 10 02 16 26	1.45 0.33 1.53	25 T	04 46 10 35 17 04	1.66 0.19 1.72	10 T	04 53 10 49 17 12	1.53 0.31 1.62	25 F	05 45 11 24 17 50	1.54 0.35 1.58	10 $	05 55 11 41 18 10	1.57 0.37 1.59	25 M	06 22 12 02 18 22	1.40 0.53 1.35

	22 25	0.34		23 08	0.19		23 14	0.27		23 52	0.34						
	04 37	1.45		05 33	1.60		05 33	1.51		06 25	1.45		00 08	0.31		00 21	0.54
11	10 36	0.35	26	11 17	0.27	11	11 24	0.35	26	11 59	0.45	11	06 45	1.48	26	07 08	1.31
T	17 00	1.53	W	17 47	1.66	F	17 50	1.59	S	18 27	1.47	M	12 24	0.46	T	12 42	0.63
	22 59	0.35		23 51	0.26		23 52	0.30					19 05	1.48		19 09	1.25
	05 14	1.43		06 21	1.51		06 16	1.47		00 28	0.44		00 56	0.42		01 03	0.65
12	11 10	0.38	27	11 58	0.36	12	12 02	0.41	27	07 10	1.35	12	07 51	1.40	27	08 14	1.24
W	17 37	1.52	T	18 31	1.57	S	18 34	1.53	$	12 37	0.55	T	13 17	0.58	W	13 39	0.73
	23 37	0.37								19 08	1.35		20 21	1.38		20 34	1.16
	05 55	1.41		00 34	0.35		00 34	0.35		01 07	0.55		02 07	0.53		02 39	0.74
13	11 46	0.42	28	07 11	1.41	13	07 08	1.41	28	08 06	1.27	13	09 12	1.34	28	09 37	1.20
T	18 17	1.49	F	12 38	0.47	$	12 45	0.49	M	13 22	0.65	W	15 11	0.66	T	16 01	0.76
				19 17	1.46		19 26	1.45		20 05	1.24		21 47	1.33		22 10	1.15
	00 18	0.40		01 21	0.45		01 23	0.42		02 04	0.64		04 04	0.58		04 41	0.73
14	06 41	1.37	29	08 06	1.32	14	08 13	1.35	29	09 17	1.21	14	10 29	1.34	29	10 50	1.23
F	12 26	0.47	S	13 24	0.58	M	13 38	0.58	T	14 44	0.74	T	16 55	0.62	F	17 17	0.70
	19 03	1.45		20 10	1.35		20 34	1.38		21 32	1.17		23 03	1.36		23 21	1.20
	01 04	0.44		02 19	0.54		02 33	0.49		04 04	0.69		05 21	0.53		05 42	0.66
15	07 37	1.33	30	09 07	1.26	15	09 29	1.32	30	10 29	1.20	15	11 38	1.40	30	11 50	1.29
S	13 14	0.54	$	14 26	0.67	T	15 10	0.64	W	16 46	0.74	F	18 01	0.52	S	18 08	0.61
	19 58	1.41		21 14	1.26		21 55	1.34		22 52	1.16						
				03 38	0.60					05 21	0.66						
			31	10 11	1.23				31	11 33	1.24						
			M	16 01	0.71				T	17 52	0.67						
				22 24	1.21					23 57	1.21						

Appendix 15: Ethical clearance certificate for the study



UNAM
UNIVERSITY OF NAMIBIA

ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: FOS/169/2017 **Date: 28 March, 2017**

This Ethical Clearance Certificate is issued by the University of Namibia Research Ethics Committee (UREC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the Faculty/Centre/Campus Research & Publications Committee sitting with the Postgraduate Studies Committee.

Title of Project: The Influence of Temporal Changes in Biomass of Brown Mussel (Pena perna) on Abundance of Ambient Faunal Species on the Central Coast of Namibia-

Nature/Level of Project: Masters

Researcher: Innocent. H. Haingura

Student Number: 201038323

Faculty: Faculty of Science

Supervisor: Dr. C. Hay
Take note of the following:

(a) Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the UREC. An application to make amendments may be necessary.
(b) Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the UREC.
(c) The Principal Researcher must report issues of ethical compliance to the UREC (through the Chairperson of the Faculty/Centre/Campus Research & Publications Committee) at the end of the Project or as may be requested by UREC.
(d) The UREC retains the right to:
(i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,
(ii) Request for an ethical compliance report at any point during the course of the research.

UREC wishes you the best in your research.

Prof. P. Odonkor: UREC Chairperson

Ms. P. Claassen: UREC Secretary