Student investigations into the effect of salinity of macroinvertebrate diversity in wetlands surrounding Jurien Bay

MURDOCH
UNIVERSITY
PERTH, WESTERN AUSTRALIA

Contents

Summary

The Murdoch University Ecology camp was undertaken from the 23rd August until 27th of August 2015 at Jurien Bay. 44 students were involved with sampling macroinvertebrates over this period and eight reports were written using the collected data (which can be viewed in the following document). The aim of the project was to assess whether salinity had an effect on macroinvertebrate diversity in wetlands surrounding Jurien Bay.

Four wetlands surrounding Jurien Bay were selected for sampling and measurements for pH, salinity, turbidity and color. The results showed that while there were differences between pH, turbidity and color they were likely to have a limited effect on macroinvertebrate diversity. However, there was considerable variability in salinity in the wetlands, with salinities ranging from brackish (Cow Swamp ~2112 ppm) to a brine (Sandy Cape Lake ~34624 ppm).

Macroinvertebrates were collected from each of the four wetlands. Over this period of sampling 28 families of aquatic macroinvertebrates were collected from the four wetlands. The results indicated macroinvertebrate richness was greatest in the fresher wetland (Cow Swamp) and diversity decreased with increasing salinity (lowest in Sandy Cape Lake). Crustaceans were abundant in each of the wetlands with ostracods (Family: Cyprididae), cladocerans (Family: Ilyocryptidae) and copepods (Calanoida and cyclopoida) being the most common macroinvertebrate encountered, which is unsurprising given the salinities measured in the wetlands. The greatest diversity and a higher proportion of insects were found in the fresher wetlands, a trend that is consistent with the literature. A more detailed explanation of these findings can be found in the following student reports.

This field work provides a valuable opportunity for students to get out in the field and gather real world experience in regards to environmental science and aquatic ecology. It allows them to consolidate the theories behind their studies and provide valuable insight into how fieldwork is completed.

Report 1

The effect of increased salinity on wetland invertebrates

Abstract

This experiment was designed to test the effects of various levels of salinity on the species richness of wetland macroinvertbrates. Netted samples were taken from a sweep of a 10m transect, large invertebrates were removed for identification and smaller species in water samples were fractioned. A variety of water quality tests were taken to gauge the status of the wetlands. These included pH, dissolved oxygen and conductivity. The results showed that of the four wetlands sampled, the lowest salinity wetlands had the highest taxon richness on average. This shows conclusively that with increasing salinity in freshwater wetlands there will be a steady decrease in the average taxon abundance.

Introduction

One of the greatest environmental challenges to be faced by the world today are the effects of climate change. The effects are seen all over the world and can be attributed to an increase in greenhouse effects in the atmosphere, this is no longer a hypothesis but now in the realm of theory. Globally the average surface temperature of the planet has increased by 0.6±0.2°C since the early 1900s and it is likely that the speed and length of the warming trend will be greater than at any time in the last 1000 years (Peters 2004)

The current scientific consensus is that the shifting weather patterns could lead to decrease in seasonal rainfall in already traditionally arid zones. Among the most affected areas are those contained in a Mediterranean climate system such as Spain, Chile, south west Western Australia (WA), California and the cape of South Africa (Kottek et al. 2006). A mean temperature increase, since 1951, of 0.1–

0.2°C per decade has been seen over most of Australia, with the greatest warming inland, particularly in Queensland and the southern half of Western Australia (Hughes 2003). The Southwest of WA has become on average 25% drier in winter, with most of the decline between 1960 and 1972 (IPCC 2007).

The effects of urbanisation, clearing and lowered rainfall in some cases can lead to an increase in salinity levels in seasonally recharged freshwater wetlands, especially those found in and around coastal dune systems, due to lower levels of fresh water feeding into the systems. Salt is found in much of the Australian landscape and many species have adapted some degree of tolerance to the natural levels, however with the increasing prevalence of secondary salination the effects are yet to be fully realised (Jolly et al. 2008).

Freshwater ecosystems are an often concentrated centres of biodiversity with many organisms having one or more parts of their life-cycle within the water column or benthic zone (Covich, Palmer and Crowl 1999). Macroinvertebrates are often used as indicators of health due to the relatively well known taxonomy of the species collected, the ease of sampling, sensitivity to a range of conditions, the fact that in most cases they cannot escape pollution and may show effects of bio-accumulation (EPA 2015). This study was designed to test how salinity affects the macroinvertebrate communities of coastal wetlands. We hypothesise that an increase in salinity levels will correlate with a decrease in mean taxonomic abundance.

Methods

Site description-

Site A) Town Swamp; Latitude -30.290504, Longitude 115.052202

Depth of water along the edge of the wetland where sampling occurred was between 10-15cm. The sediments appeared quite silty. There were a number of birds present with obvious nesting sites close by at Town Swamp including seagulls and stilts. The wetland had adistinct sulphurous odour. The water appeared quite still. There were obvious signs of pollution in the form of a wrecked car body that was rusting, evidence of the past use of the wetland which was a dump. There was a main road running due south.

Site B) Dune Swamp; Latitude -30.20945, Longitude 115.00778

Dune Swamp appeared to be kidney shaped with a large dune running along the east side. It is a seasonably wet system, the depth was approximately 10-40 cm deep. Salt marsh vegetation fringing. Variety of bird life present including terns, stilts and ducks.

Site C) Sandy Cape Lake; Latitude -30.207632, Longitude 115.010183Sandy Cape Lake was seasonably wet though is hypo-saline at times. Salt marsh vegetation fringing. Water depth was approximately 10-30cm deep. Presence of a gypsum mine site close by. Water surface colour appeared to be a dull clear brown.

Site D) Cow Swamp; Latitude -30.254988, Longitude 115.150157

This permanent water body had a depth in excess of approximately 60cm, presence of flying insects such as dragonfly and mosquitos. Melaleuca fringing water body contributing to the dark appearance of water due to tannins.

Sampling method-

Physio-chemical variable analysis-

The wetland water samples were tested for pH using previously calibrated pH meters. This was done for each of the four wetlands. Temperature for each wetland was measured in the field by taking an average of 3 samples taken in degrees Celsius. A dissolved oxygen (D.O) reading was taken using a dissolved oxygen meter and sensor. The units of measure were in mg/L. Turbidity was tested for water clarity and cloudiness using a turbidimeter. The units of measure were NTU (Nephrelometric Turbidity Units). Colour was measured by determining the absorbance of water at 440nm using a spectrophotometer. This figure is multiplied by 2.303 x100 to give the absorption coefficient (for a cuvette 1cm in width). The units of absorbance are g440m-1. Salinity was measured using an electrical conductivity metre, the units of measure were in millisiemens

Field sampling method-

The field sampling firstly involved collecting samples using a sweep net over a 10m transect, while trying to minimise the amount of sediment collected. The sample collected was then deposited into a white tray (to maximise visibility) and topped up with a litre of water from the wetland. All the large invertebrates (anything exceeding 2mm) were removed and placed into a vial containing 70% ethanol. Anything remaining that was smaller than 2mm was then also collected and placed into a separate vial, this was then topped up with 70% ethanol. The remainder of the sample was then deposited into a sample splitter which was fractioned 5 times to reduce the sample to 1/32th , this sample was then deposited into another separate vial and topped up with 70% ethanol. Each vial was labelled with the site name, date, “large” or “small” as well as the name of the individual who collected the sample. This process was followed for each group member taking their sweep and for also each wetland that was sampled.

Macroinvertebrate identification method-

Using stereomicroscopes the collected invertebrate samples were identified to the family level using a variety of keys and resources, refer to appendix 1. Once identified the individuals were counted and recorded. The number for each individual was then multiplied by 32, which was how many times the sweep was fractioned into.

Results

Figure 1 shows that the dominant taxa found in Town Swamp was by far Ilyocriptidae at 84% with the second most dominant taxa being Ostracoda with 14%, five times less common. Figure 2 shows again the Ilyocriptidae to be the dominant taxa found in Dune Swamp with Ostracoda again being the second most common species found, although by a much closer margin of 43% to 48%. Figure 3 shows Ostracoda to have dominance in Sandy Cape with the second most dominant species being Calenoida at 15% close to Ilyocriptidae at 11%. Figure 4 shows the most diverse wetland to be Cow Swamp, with Calenoida (60%) being the dominant taxa and Ostracoda(22%) being the second most abundant taxa and Ilyocriptidae (8%) being third most abundant. The appearance of Hirudinae at 4% is worth noting as leeches were not found in any other wetland systems sampled.

Table 1 shows the increasing levels of salinity found in all four wetlands sampled with Sandy Cape being the most saline environment, saltier than the red sea (?). The second most saline environment was dune swamp at just below the average oceanic salt levels. Town Swamp had a salinity amount around the mid-range salinity level for brackish water while Cow Swamp was the least saline environment but still could be classed as in the lower range of a brackish system.

Figure 5 displays a fairly linear approximate negative trend towards increasing salinity and decreasing taxon richness. The equation for the regression line is ($y=16.53 \times -0.25$). There appears to be a strong correlation between the two factors as shown by the large R-square value of 0.708. This model shows a higher proportion of variability of the response.

Table 1 salinity of the four wetlands calculated in parts per thousand (ppt) and the average for the total taxa present in each wetland.

	Town Swamp (A)	Dune Swamp (B)	Sandy cape lake (C)	Cow Swamp (D)
Salinity (ppt)	14.8	33.2	45.6	2.3
Total taxon		7	7	19

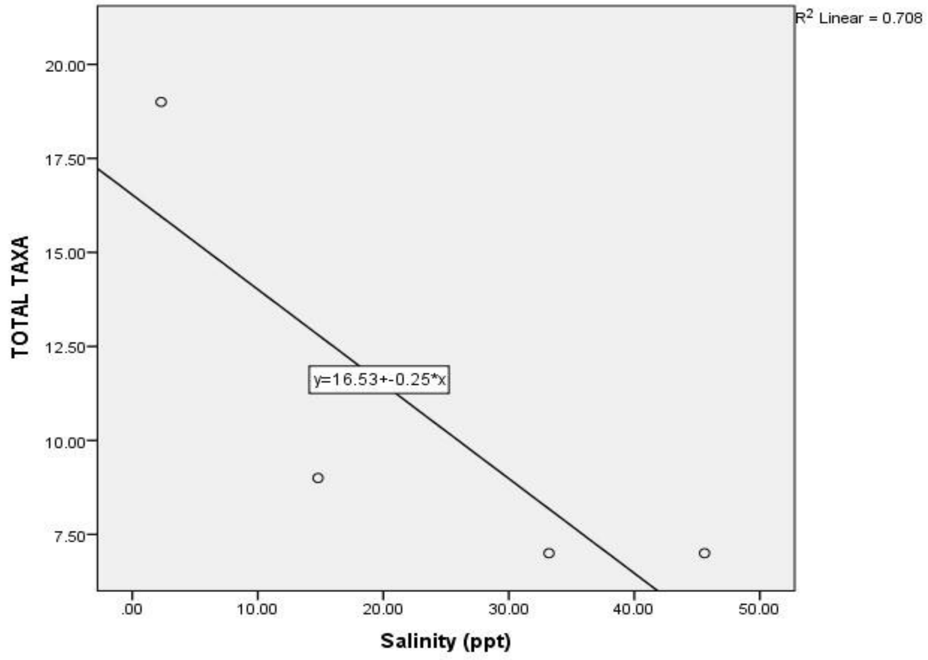


Figure 5 correlations between the average salinity of the four wetlands Town Swamp, Dune Swamp, Sandy Cape Lake and Cow Swamp in PPT, and the total taxa of all four wetlands. The equation for the regression line is y=16.53+-0.25^x

Discussion

The results seen in this study support the hypothesis that increasing salinity in freshwater wetlands will correlate with a decrease in mean taxon abundance. These finding are in keeping with the work of Brock, Nielsen and Crossle who found that concentrations of salinity in excess of 1000mg/L caused a decrease in species richness and hatching rates in freshwater wetlands. A study by Horrigan et al. in 2004 found changes in freshwater communities at salt concentrations as low as 400mg/l.

The high levels of salinity seen in Dune Swamp and Sandy Cape could be attributed to their proximity to the ocean, which carries sea spray on the wind and deposits it in the landscapes. The effects of this natural salt deposition process are compounded by a lack of vegetation in the surrounding area to lower the water table and utilise some of the seasonal rainfall. Instead the water flows through the sandy landscape collecting salts in solution and finally ending up in the swamps that form in the low points of the area.

The three most abundant species found in all of the wetlands are all members of the sub-phylum Crustacea. Micro-crustaceans are among the most well equipped to deal with unfavourable conditions, due to their multiple resistant stages throughout their lifecycle (Kefford et al. 2004)(Strachan et al. 2015).

Australian wetlands ecosystems are in a delicate balance and are particularly susceptible to changes in amount and timing of water supply from rainfall (Erwin 2008). It appears that climate change will have the most pronounced effect on wetlands through alterations in weather patterns in the future.

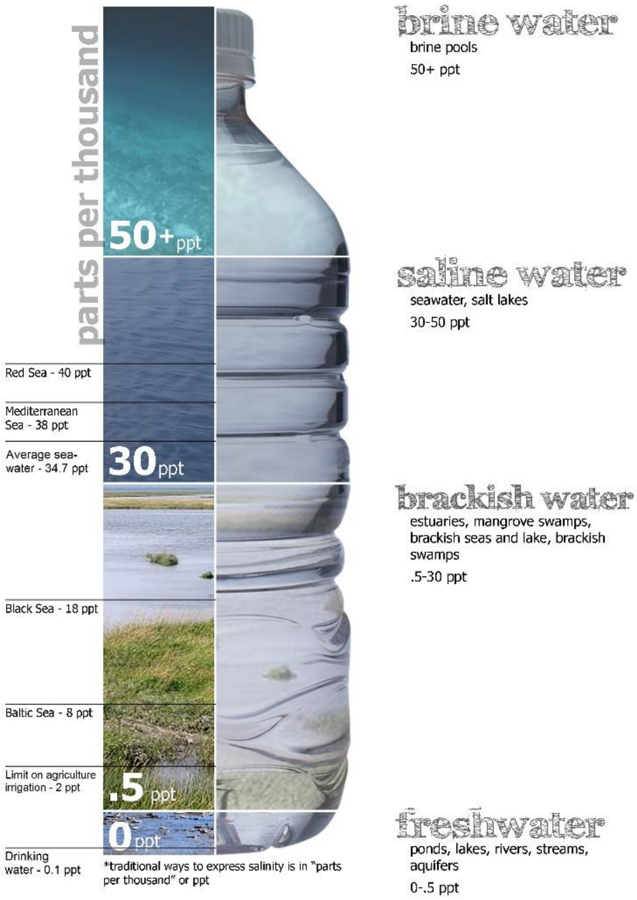
If we are to protect these fragile environments from further degradation we must act now to preserve them. Remedial planting programs in and around the effected areas with salt tolerant species is one such proposed action. Another proposed action is the reduction of CO2 emissions and better education of residents, farmers and businesses that live or operate in the areas surrounding affected wetlands to reduce the use of heavy irrigation, high water use activities and land over clearing.

Appendix 1

Literature used in the identification of macroinvertebrates;

1. "A guide to wetland invertebrates of south western Australia" by Jenny A. Davis and Faye Christdis
2. "Australian fresh water life" by William David

Relevant figures used- From Wiki media; water salinity diagram



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"Water salinity diagram" by Peter Summerlin - Own work. Licensed under CC BY-SA 3.0 via Commons
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Report 2

Salinity and its impact on Macroinvertebrate Biodiversity in the Kalbarri region of Western Australia

Abstract

Salinity is one of WA's most pressing ecological issues, with macroinvertebrates useful as a bioindicator to assess the wetland health. To study the relationship between water quality and macroinvertebrate biodiversity, four wetlands in the Jurien Bay region of WA were sampled, with three being seasonal saline wetlands and one a permanent freshwater wetland. Water quality parameters (DO, pH, Salinity, Turbidity and Colour) were recorded for each wetland, and macroinvertebrate communities were sampled with taxa and abundance recorded. Species richness, biodiversity indexes and functional feeding group structure data was analysed. Macroinvertebrate species richness were shown to have a fairly linear inverse relationship with salinity levels. Biodiversity indexes, Shannon's and Simpson's DI, showed the highest diversity for the freshwater wetland, and varied results for the three saline sites. Functional feeding group structure showed that the three saline had a simple structure dominated by filter feeders and grazers, while the freshwater wetland had higher number of predators. Overall salinity was shown to have a negative impact on the biodiversity of the macroinvertebrate communities for the sampled wetlands.

Introduction

One of most pressing environmental issues Western Australia currently faces is the increasing salinification of WA's wetlands and river systems (State Salinity Council, 2000). Many regions within the state face wide scale degradation of water resources, in both rivers and wetlands, resulting in serious potential ecological issues. Given that a large area of the state is a globally recognised biodiversity hotspot, with a large number of endemic flora and fauna, the threat this issue poses to the ecology of the region is of particular importance. A large proportion of the endemic species are salt intolerant, resulting in habitat loss which could potentially cause already endangered species to go extinct (Halse et.al, 2003).

The primary drivers of the increasing salinity of the region is the rising of local water tables due to changing land use patterns, and decreasing long-term rainfall patterns. Large areas of the state, particularly in the South west, were cleared during the 1900s, with formerly native forest land being converted into large areas of agricultural land (Schofield & Ruprecht, 1989). This change in land use led to the modification of the water balance of the ground water system, with the water table rising and leaching stored salt within the soil, bringing the salt to the surface. The other main factor leading to increased salinity levels within the region is the long term trend of decreasing rainfall amounts throughout much of the state. The decrease in rainfall leads to the concentration of existing salt stored within the system, which can lead to dramatically higher salinity levels of waterbodies such as wetlands (Mayer, Ruprecht & Barry, 2005).

To assess the ecological impact of increasing salinity levels in the region, one method is the use of a bioindicator. One of the most commonly used bioindicators are the macroinvertebrates, as they are relatively the most effective and efficient taxonomic group in regards to cost and ease of study (Chang et. al., 2014). By using a bioindicator, it is possible to assess the health and ecological state of the wetland, in an easily comparable manner. Overall, increasing salinity levels have been shown to impact the taxological distribution and structure of macroinvertebrates communities and correlate with a reduction in the species richness of the wetland (Blinn, et.al, 2004)

The aim of this study is to determine what impact differing water quality parameters, with a particular focus on salinity, has on the macroinvertebrate communities of wetlands within the Jurien Bay region of Western Australia. To do this we have sampled a small number of wetlands which exhibit a natural salinity gradient, assessing water quality and the biodiversity of the macroinvertebrate communities. Overall we expect biodiversity to form an inverse trend with salinity levels.

Methods

Site description

Four small wetlands were chosen to be sampled in the Jurien Bay region of Western Australia (Fig 1.). Three of the wetlands (Sites 1, 2, 3) were all seasonal wetlands, which dry up during summer, with only site 4 being a permanent wetland.

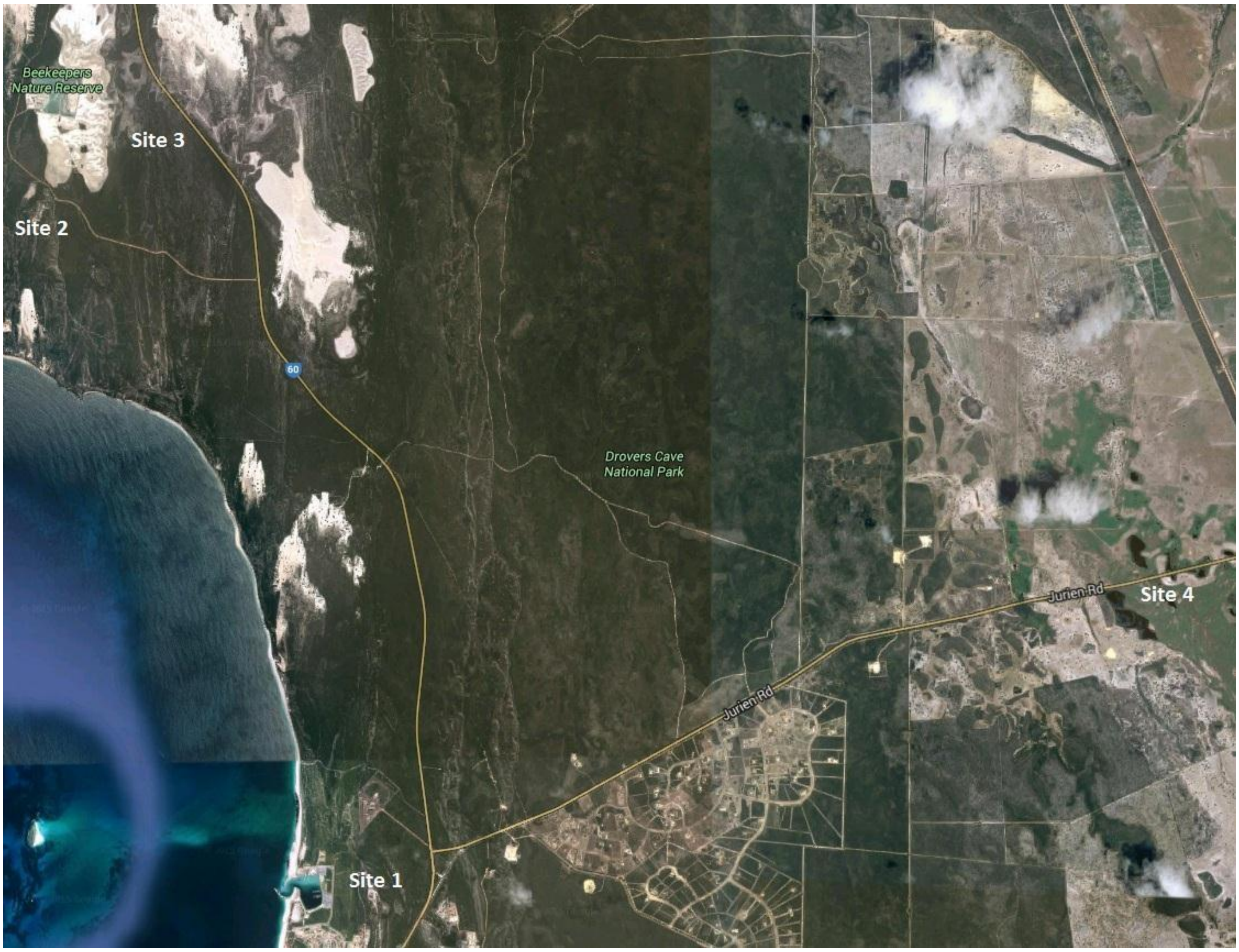

Figure 1. Map of Jurien Bay region with sites 1 through 4. Sourced from Google earth.

Site 1 (Fig 2.a) was situated close to the Jurien Bay township, within a high disturbance zone (the dried wetland bed was driven over during summer, varying amounts of a waste material such as a wrecked car). The wetland was shallow (average approximate depth 30-50cm), with a clay bed with limestone outcrops. Site 2 (Fig 2.b) was located in the Beekeepers nature reserve north of Jurien Bay , surrounded by a dune system and low lying costal heathland. The wetland also had a clay bed within a limestone area, and was shallow (20-30cm deep) and had some reed vegetation in the top part of the wetland. Site 3 (Fig. 2.c), also located in beekeepers nature reserve, was a larger salt lake, surrounded by a dune system and bordered to the north by a lime quarry. Depth was very shallow, approximately 10-20cm in most parts. Site 4 (Fig 2.d) was situated to the east of Jurien Bay , surrounded by pasture. The wetland was much deeper than the other sites, possibly over a metre deep with high tannin levels and a muddy base. The wetland was fringed by shrubs, including some dead plants in the water.

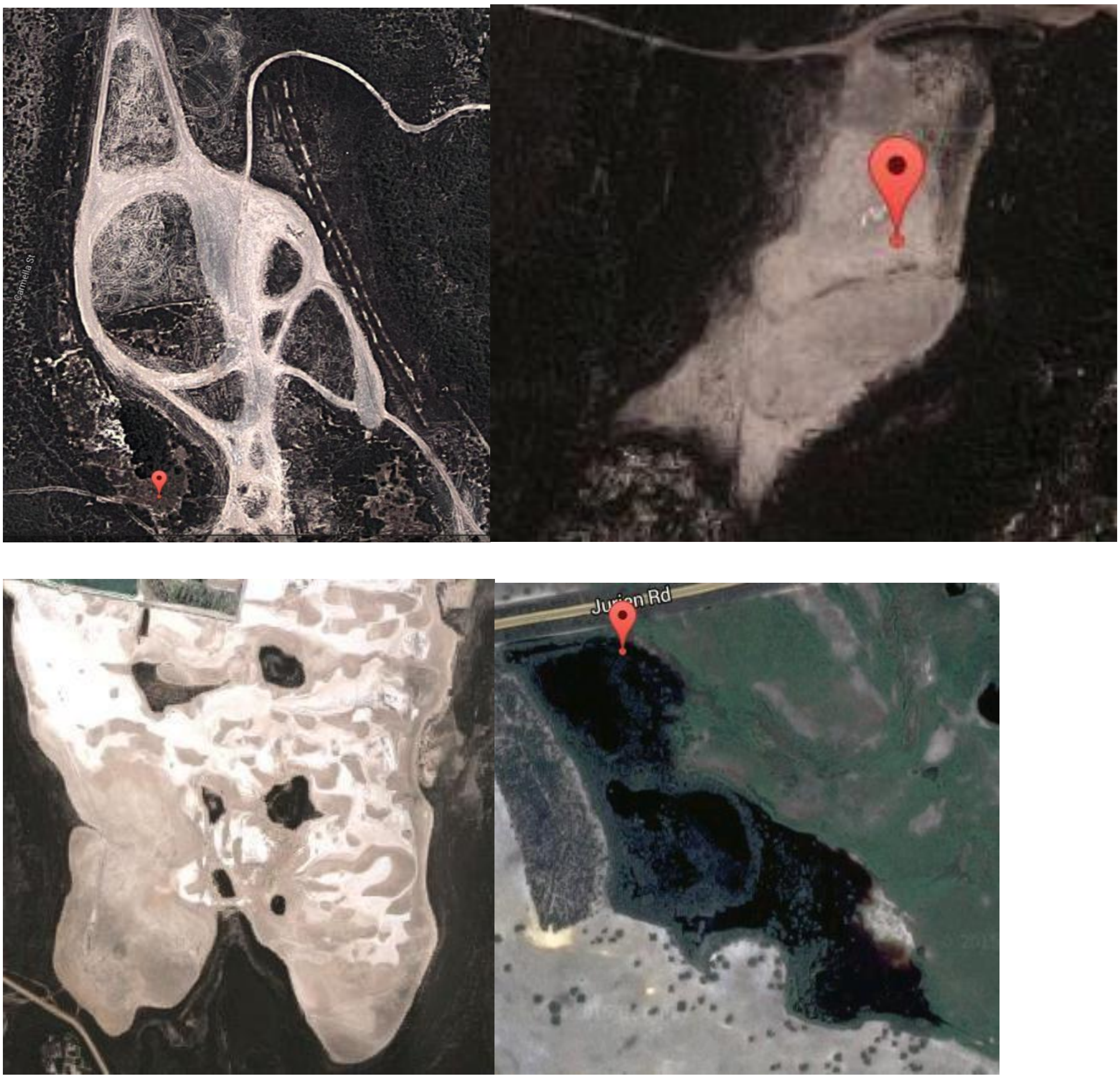

Figure 2. Map of each wetland sampled. Top left (a) – Site 1. Top right (b) Site 2. Bottom left (c) – Site 3. Bottom right (d) – Site 4. Sourced from Google earth.

Procedure

Water quality – Data for five primary water quality parameters (DO, pH, Salinity, Turbidity and Colour) were recorded either on site or water samples were taken back to the laboratory for analysis, with 6 water samples were taken from each site. A total of 15 individual analyses of each variable were recorded.

Macroinvertebrate sampling – Sampling was conducted using a dip net, using a sweep method. A total of 10 meters distance was covered for each sample, with each wetland being sampled 45 times over a range of areas of each wetland. Samples were empting into a tray, and individuals of larger species were then removed and placed into vial containing 70%

ethanol. Remaining sample was then placed into a splitter, and split down to either 1/16th or 1/4th, and the split sample placed into another vial containing 70% ethanol. The samples were then taken back to the laboratory for analysis under a microscope, where the families of macroinvertebrates present were record, and the number of individuals for each family present in the split sample was counted.

Data Analysis

<u>Water quality</u> – Average and standard error for each water quality variable was calculated and compared for each site. One way ANOVA analysis was used determine if each water quality parameter varied significantly between each site, with the Levene's test for homogeneity of variance used to determine if variances within each data set were homogeneous across the 4 sites.

<u>Macroinvertebrates species richness and abundance</u> – To measure the species richness of each site, the total number of Taxa (in number of families) present in each sample was recorded. Total abundance of each sample was calculated by multiplying the number of individuals recorded in the split sample, by the ratio to which the sample was divided. Average and standard error of total Taxa and total abundance was calculated for each site. One way ANOVA was used to compare differences in the species richness of each site, using the total taxa data of each sample with the Levene's test for homogeneity.

To further examine how the biodiversity changes between the sites, two diversity indexes, Shannon’s Diversity Index (SHDI) and Simpson’s Diversity Index (SPDI) (Beals, Gross & Harrell, 2000) was calculated for each site, by taking the total abundance of each Taxa (As), dividing it by the total abundance data for each site (At), then using the formula SHDI = -(As/At*ln(As/At)) and the formula SPDI = 1/ Σ (As/At)^2. Index factoring in equitability was also calculated. The diversity indexes for each site was then directly compared.

Lastly, structural changes in functional feeding groups were assessed by calculating the percentage of total individuals that belonged to each functional feeding group. Classification and system of functional feeding groups used was sourced from MDRFC database (Hawking, et al, 2013).

Results

Water quality

Analysis of water quality parameters shows that average levels of DO and pH were fairly constant over the four sites (Fig 3), with turbidity and colour having some variation (particularly for site 4 in colour). Of main interest was the variation in salinity levels, with site 1 to 3 showing a fairly consistent increasing gradient of between an average of 25.52 mS/cm for site 1 to the average of 65.2 mS/cm for site 3, and site 4 having a much lower reading of an average of 3.56 mS/cm.

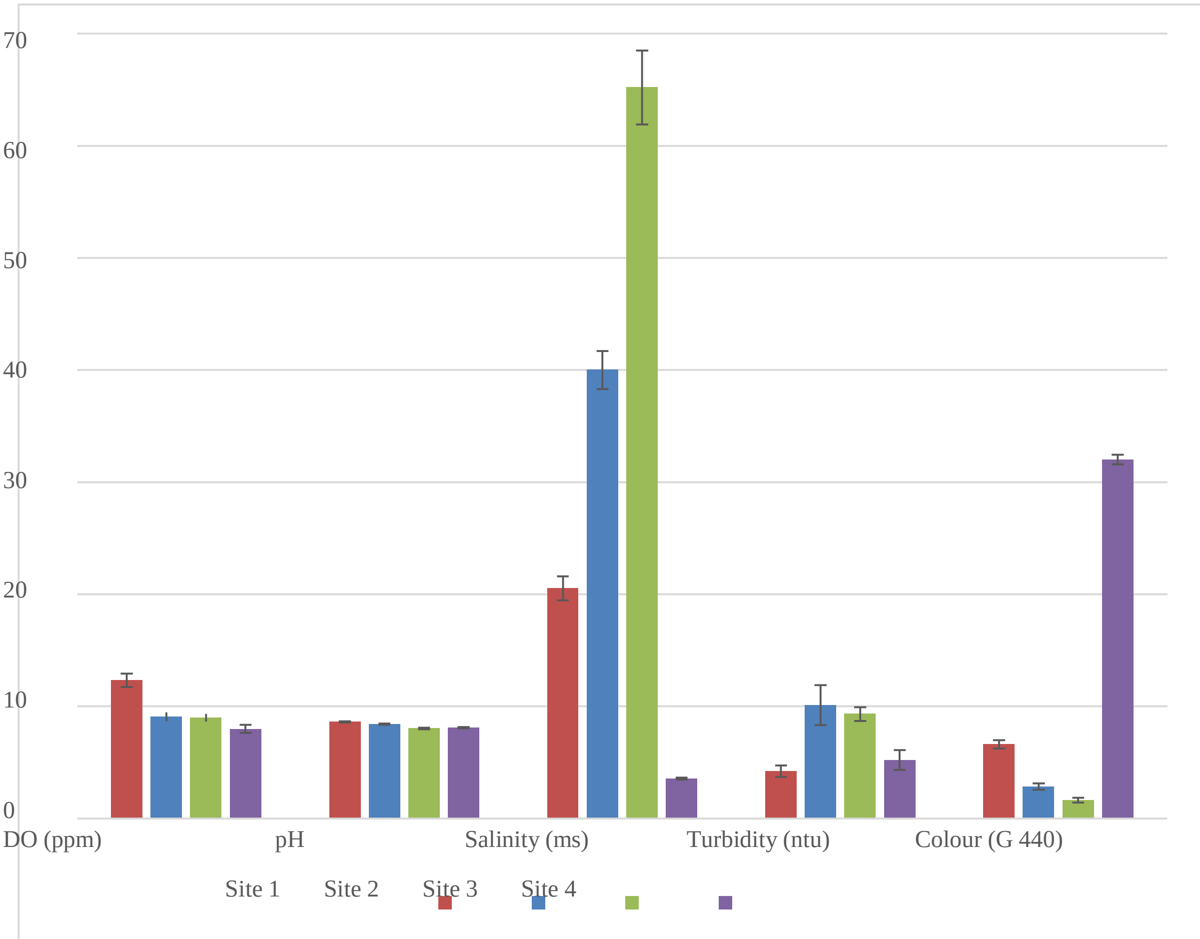

Figure 3. Water quality parameters for site 1 through 4, for dissolved oxygen (in ppm), pH, Salinity (in ms/cm), Turbidity (in ntu) and colour (in g440/m). n=16 with +/- SE error bars.

ANOVA analysis showed there was a significant difference between the sites for each of the parameters: DO (F=16.3, df=61, P <0.001), Salinity (F=166.5, df=63, P <0.001), pH (F=16.89, df=63, P < 0.001), Colour (F=1519.7, df=57, P <0.001), Turbidity (F=6.58, df=63, P=0.001). Looking at the Levene's test for homogeneity, both Salinity and turbidity failed to provide reasonable assumption of homogeneity, with both having a $P < 0.001$. This is likely to have been due to errors within the data set, and overall should not affect the validity of the analysis.

Macroinvertebrate data

A total of 28 taxa were found across the four sites sampled. Species richness data shows that species richness was greatest for site 4 (Table 1.), with an average of over 7 families present in every sample. Site 3 had the lowest amount of diversity, with diversity decreasing from site 1 through to site 3 (Fig. 4). Total abundance had a large amount of variation between samples, evident from the high values of the standard error for each site. Overall there was a negative trend from site 1 through 3, with site 4 displaying a relatively low figure (compared to site 1 and 2). ANOVA analysis of the species richness data showed there was a significant difference in total taxa found between each site ($F=130.4$, $df=179$, $P < 0.001$). Levene's test for homogeneity failed to show homogeneity in variance ($P < 0.001$), but large equal sized sample should mean ANOVA is still valid.

Table 1. Average total taxa found and average total abundance of individual macroinvertebrates sampled for each site with the standard error. n=45.

	site 1	**site 2**	**site 3**	**site 4**
Total Taxa	5.22	4.04	2.38	7.76
SE	0.21	0.13	0.13	0.28
Total Abundance	10223.26	4134.20	863.33	1870.98
SE	1859.83	568.23	225.44	319.55

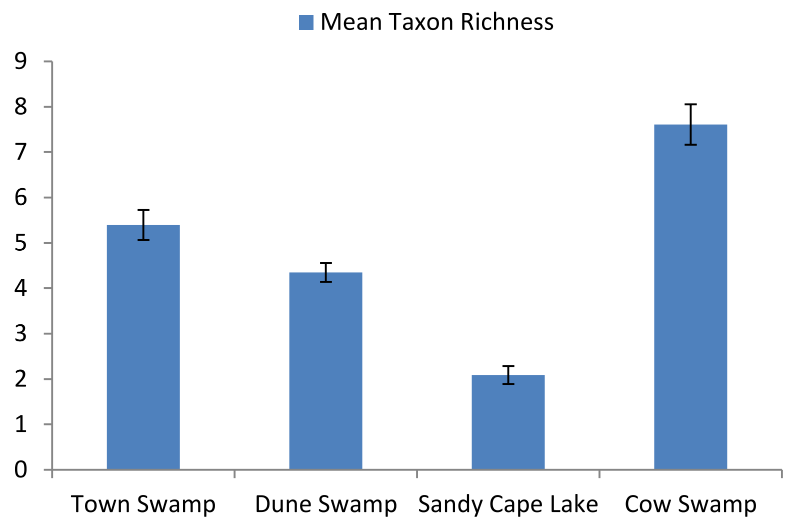

Figure 4. Average number of total taxa in families found for each site. n=45 with +/= SE bars.

Biodiversity was greatest for site 4 for both of the indexes used (table 2.), but variable between sites 1 and 3 with site 2 having the highest score out of the 3 saline sites. Both Shannon's (SHDI) and Simpson's diversity index (SPDI) for equitability showed sites 1-3 had a fairly low rate of biodiversity, with the equal value being between 0.18 and 0.27 for SHDI and between only 0.05 and 0.07 for SPDI, which indicates an overall low amount of biodiversity. For site 4, only SHDI showed a significant increase in biodiversity taking into account of equitability.

Table 2. Biodiversity indexes Shannon's diversity index (SHDI) and Simpson's diversity index (SPDI) for both equal and unequal versions, for each site.

Shannon's diversity index		Simpsons diversity index		
	unequal	equal	unequal	equal
Site 1	0.65	0.20	1.50	0.05
Site 2	0.90	0.27	2.22	0.08
Site 3	0.61	0.18	1.46	0.05
Site 4	1.40	0.42	4.10	0.15

Discussion

A linear inverse trend between species richness and wetland salinity levels was shown. While this trend for species richness was fairly clear, the lower than expected overall species richness in the freshwater wetland (site 4) was surprising. The species richness for the three saline sites showed a very distinct inverse relationship, with the species richness being very low at site 3. The two biodiversity indexes showed a large difference between the 3 saline sites and the freshwater site, but indistinct differences within the saline sites. Overall the relationship between salinity levels and biodiversity was largely as expected.

The difference in biodiversity indexes between the saline sites and site 4 may also be largely attributed to the fact that the only site which a permanent wetland was site 4. Wetlands that exhibit a cycle of drying and wetting over a long period tend to limit the number species able to survive in the habitat (Sommer & Horwitz, 2009). This may explain the difference between the biodiversity indexes and the species richness data, as the biodiversity indexes take into account the relative abundance numbers for each taxa with the saline sites having a larger abundance of the same few taxa.

The other water quality parameters of interest did not produce any meaningful result in the context of this study. Dissolved oxygen levels were fairly consistent over the sampled sites, and the inherent error within the DO sampling is likely to be greater than the difference between sites. pH was varied slightly between sites, with site 1 having the most alkaline conditions, followed by site 2. Overall it is not expected that the relatively small pH differences would have measureable impact on the macroinvertebrate communities in relation to this study (Zalizniak, 2009). Turbidity varied somewhat between sites, but was not assessed to have any clear relationship to biodiversity, and Colour only varied for site 4, which was created due to other environmental issues (presence of fringing flora) and is unlikely to affect macroinvertebrate biodiversity.

Studying how the structural composition of function feeding groups changed in relation to differing salinity levels prodcued somewhat contradictory results, with site 1 and 2 having a higher than expected percentage of grazers, and site 4 having higher percentage of filter- collectors than expected. The high level of grazers in site 1 was is presumed to be a result of increased nutrient load within the system, possibly due to run off from the surrounding town area. Only site 4 had any significant level of predators, suggesting that the saline conditions only favoured the relatively simpler filter feeding and grazing organisms such as Ostracods, Copepods and water mites. Other studies have shown a reduction in predators and grazers and an increase in filter feeders associated with an increase in salinity levels (Piscart, Moreteau, & Beisel, 2005).

The overall validity and rigour of study is somewhat problematic, due to the possible errors within the data set. Given the data was collected by inexperienced students, some error within the data set is to be expected, evidenced by some of the large standard error values for many of the water quality variables. Of particular significance was the error likely within the abundance data, due to differences in methodology, analysis and identification from each sample. It is unknown to what degree abundance calculations were standardised, which could lead to widely varying numbers between samples, which in turn may put the biodiversity index and the functional feeding group figures in question. To further quantify the impact of salinity of macroinvertebrate biodiversity, a larger number of wetlands would be needed to be sampled, including non-seasonal wetlands with elevated salinity levels to remove the possibility of the results being influenced by the normal difference in biodiversity for seasonal/permanent wetlands.

Salinity remains an ever constant threat to the biodiversity of Western Australia wetlands, with salinity levels likely only to increase over the next 50 years due to climate change. Higher salinity levels in small wetlands of the Jurien Bay region have shown to decrease the overall macroinvertebrate species richness and biodiversity present in sampled wetlands. Macroinvertebrate biodiversity can be used as an indicator for the general health of the wetland system, suggesting that as the salinity levels of the wetlands increase, the general ecological condition of the wetland deteriorates.

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Report 3

Survey and analysis of four aquatic sites within the Jurien Bay region of south-western Western Australia with regards to salinity and other water quality factors, and their effect on invertebrate abundance and taxon richness

Abstract

Western Australia is one of the most ecologically diverse regions of the world with a wide variety of species unique to the region (Davies, 2010). This includes many invertebrate species found in the variety of ecological wetland and river habitats. To categorise and develop an understanding of invertebrate communities, and determine how changing water quality factors effect these invertebrate populations, surveys were taken of invertebrate life in four wetland and riverine systems within the Jurien Bay area of South-Western West Australia. Analysis of the data gathered suggested that there was a significant relationship between salinity and colour factors, and taxon richness. However, no significant relationships were found between invertebrate abundance and water quality for salinity, pH, dissolved oxygen, turbidity, colour or temperature.

Taxon richness was significantly reduced for aquatic systems with increased salinity. There was a large numerical dominance by salinity-tolerant Crustacea species, such as Ostracods and Ilyocryptidae. Crustacea were also dominant in the freshwater Cow Swamp system. This finding conflicts with findings from past surveys of Australian wetlands, which have found Insecta order species to be the most numerically dominant (Bunn, 1992). However several freshwater systems have been surveyed within the Southern Australian wetland ecosystem and similar dominance in Crustacea species has been observed (Hart, 1990), (Pinder, 2005).

The abundance data gathered show a relatively weak relationship with differing site location and water quality, and have a high variance and number of outlier variables. It is recommended that, in future surveys and collection of invertebrate species within Australian wetland systems, a more robust and accurate method to determine abundance counts is used. Water quality measures to determine nutrient levels are

also recommended, as this factor plays a large role in the degradation and changes in invertebrate species within wetland systems throughout Western Australia, and is likely to be a significant factor in invertebrate abundance and/or taxon richness.

Introduction

Western Australia is one of the most biodiverse regions of the world, with a rich array of freshwater fauna found in both wetland and river environments (Davies, 2010). Many of the invertebrate species are endemic to Australia and are found nowhere else in the world. However, many of these species are under threat due to increasing loss of habitat from agricultural and urban development (Davis, 1999), increasing salinity levels and desiccation of water sources due to changing climatic conditions (Williams, 1987), (Halse, 2003).Due to these concerns, it is increasingly important to develop an understanding of the water conditions and local biota that live within these systems. This will enable a greater understanding of the ecological health and diversity and to identify and prevent further loss of habitat and biodiversity through conservation efforts and risk management procedures.

Invertebrates are a key biological indicator in many aquatic systems, and analysis of the taxonomic richness and abundance of the various species within each unique water source can be powerful measures in monitoring water quality and ecological changes (Davis, 1999). Salinity has been shown to have a significant negative relationship with taxon richness, with increased salinity reducing invertebrate diversity to only the moderately tolerant halophilic organisms. Studies have shown marked differences in invertebrate abundance and diversity within different water bodies, with the Insecta class most abundant in freshwater systems , while Crustacea species are more tolerant of saline conditions and tend to numerically dominate more conductive water bodies (Hart, 1990), (Pinder, 2005)

In order to further the understanding of invertebrate communities and the effects of changing water conditions upon them, surveys of four sites in the Jurien Bay region of Western Australia were undertaken. These survey sites covered a range of water conditions, with particular variance in the salinity levels of the water sources.

The main focus of this study was to determine how salinity influences the macroinvertebrate communities of coastal wetlands in the Jurien Bay region.

Methods

Visual observations of the different sites were recorded, invertebrate samples were collected from each site using sweep nets, and water was collected for analysis of several factors, including pH, dissolved oxygen concentration, turbidity, colour, temperature and salinity. These water quality factors were then analysed for their effects on the abundance and diversity of the collected invertebrates in order to further collective knowledge regarding the changes in invertebrate populations caused by changing water conditions, particularly in regards to degradation caused by urbanisation, climate change effects and increasing salinity levels.

Pictures and a general description of each site were recorded to provide an accurate description of each site, the vegetation levels both surrounding and inhabiting the aquatic environment, any possible pollution or human effects, sediment type and other observable features.

Dissolved oxygen (mL/L) and water temperature measurements were taken at each site utilising a dissolved oxygen meter and sensor, and water samples were also taken for later analysis to determine pH, salinity, turbidity and colour properties at each site.

Three 10m transects were performed by groups of 3 at varying locations at each site using a $1m^2$ sweep net, with the collected specimens emptied into a white tray for collection. Large macroinvertebrates (>2mm in length) were then collected into a vial containing 70% ethanol. After collection of the macroinvertebrates, a splitter was utilised to reduce the remaining sample down to ¼ or 1/16, with the split recorded for later analysis. The ¼ or 1/16 micro-invertebrate sample was then added to a separate vial and filled with 70% ethanol.

Following collection of samples at each site, these samples were analysed under a microscope to identify individual species by family and determine abundance of each. Micro-invertebrate samples with samples exhibiting a large abundance were further separated into 1/8 divisions. The invertebrates in this 1/8 sample were then identified and counted, and these counts were then multiplied by their divisions, to determine the number of each identified micro-invertebrate species that was in the original $10m^2$ transect. Identification of invertebrate species was undertaken using several published books on Australian invertebrate life (Davis, 1999), (Williams W. , 1980). Abundance and taxon richness data were analysed against the collected water factors using

ANOVA one way analyses, with significant factors linearly regressed to determine accuracy of the relationships. Abundance and taxon richness were also analysed against each other to determine any significant relationships.

Results

The survey sites were photographed and notable conditions and environmental variables were recorded.

Cow swamp (Figure 1), a perennial waterbody, had a large amount of plant life both surrounding and living within the water. Of these plants, Melaleuca trees were the prominent species, with several relatively large stands colonising the shallow shore water. The lake bed was dark brown in colour, with the water exhibiting dark brown colouration. A grass species colonising the shore also extended a short distance into the aquatic area. Water depth increased relatively quickly away from the shore, increasing to an estimated depth of 1-2m.

Figure 1: Cow Swamp site photograph

Town Swamp (Figure 2) showed signs of human disturbance, with a rusted car body left within the site. The swamp dries out during the summer, with cars driven along the lakebed. This may explain the sandy areas devoid of vegetation that wound along the lake bed. There was a relatively fast flow within the water body, which was relatively shallow, between 5 and 10 cm in depth. Plant life was situated in clusters on the raised soil around the river flow, with a small red shrub also extending into the water body. Eucalypt bushes were a prominent shrub, 30cm to 1m in height, sited along the shoreline. The riverbed showed some level of organic material deposits within the lower water flow areas colonised by the red grass/shrub, but was absent from the areas of faster flow, where the sand bed was prominent.

Figure 2: Town Swamp site photograph

Dune swamp (Figure 3) had saline tolerant salt scrub colonising the shore, including several bushels living within the shallow lake edge, however plant life was limited and no aquatic grasses or plant organisms were found further from the shore. Cover provided by the plant life increased as distance from the water increased. There were also Melaleuca plants situated further from the lake edge. Sediment was comprised of a clay soil, with a small layer of sediment deposited upon the white sand/clay bottom of the lake. Water depth increased slowly, though at a greater rate than the Sandy Cape Lake location, and increased in depth up to an estimated 40cm. Dune hills were also observed along the opposite shore, with a much denser level of plant life.

Figure 3: Dune Swamp site photograph

Sandy Cape Lake (Figure 4) exhibited deposits of salt along the shore, with prominent sandy clay sediment. Salt bush was again the most prominent plant species along the lake edge, though aside from two small areas, was constrained to the shore away from the hydrated zone. The plant species close to the water edge were greater in density and height than those observed in the Dune Swamp. The water level remained shallow, with 3-5cm depths observed up to 20m from the lake edge, with depth increasing to 15cm much further from the shore.

Figure 4: Sandy Cape Lake site photograph

Utilising ANOVA two-way analysis of taxon richness against colour and salinity, a significant relationship between richness and these values was demonstrated (Figures 5 and 6, Appendix 1).

For these factors, colour was observed to have a positive relationship with taxon richness (Figure 5), while increased salinity was significant in affecting an decrease in taxon richness in the aquatic environment (Figure 6).

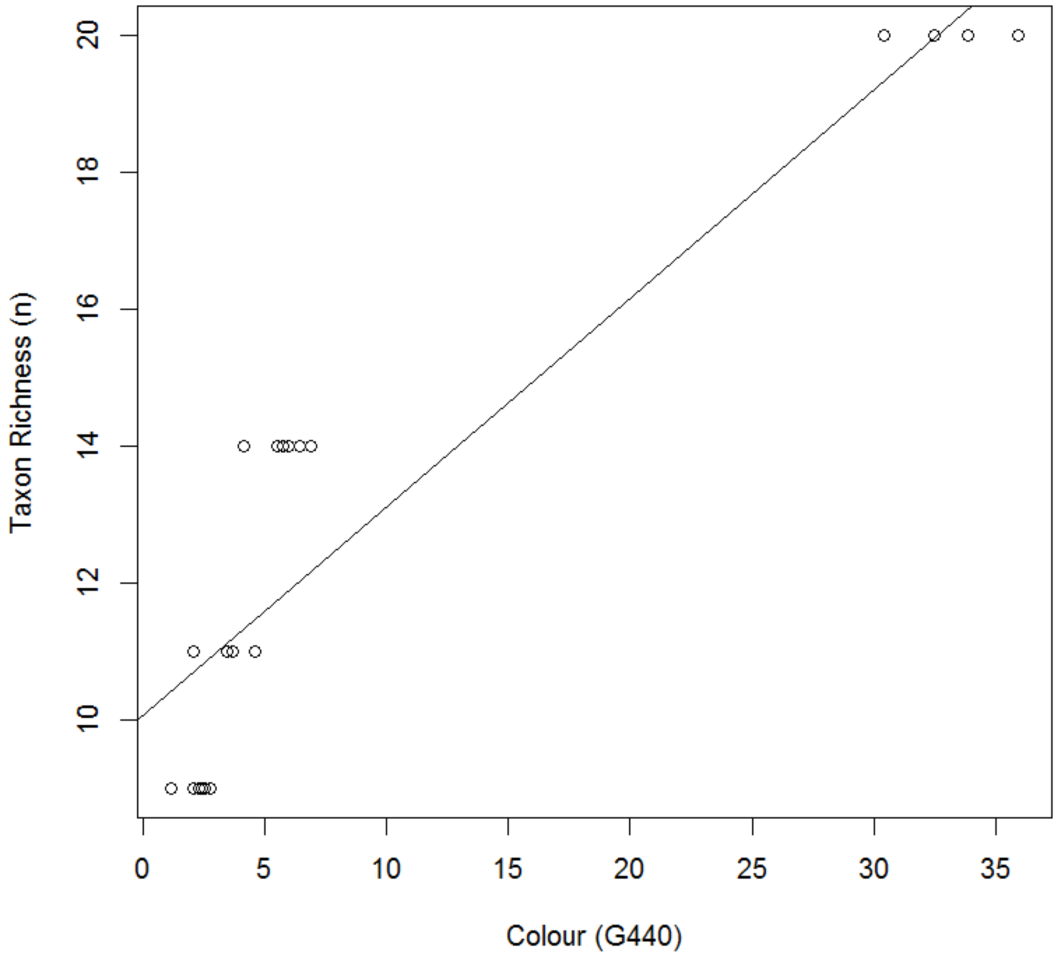

Figure 5: Scatter plot of the significant positive relationship (p=1.72e-15) between measured water colour and taxon richness for the four sampled sites with linear regression model, R^2= 0.8825.

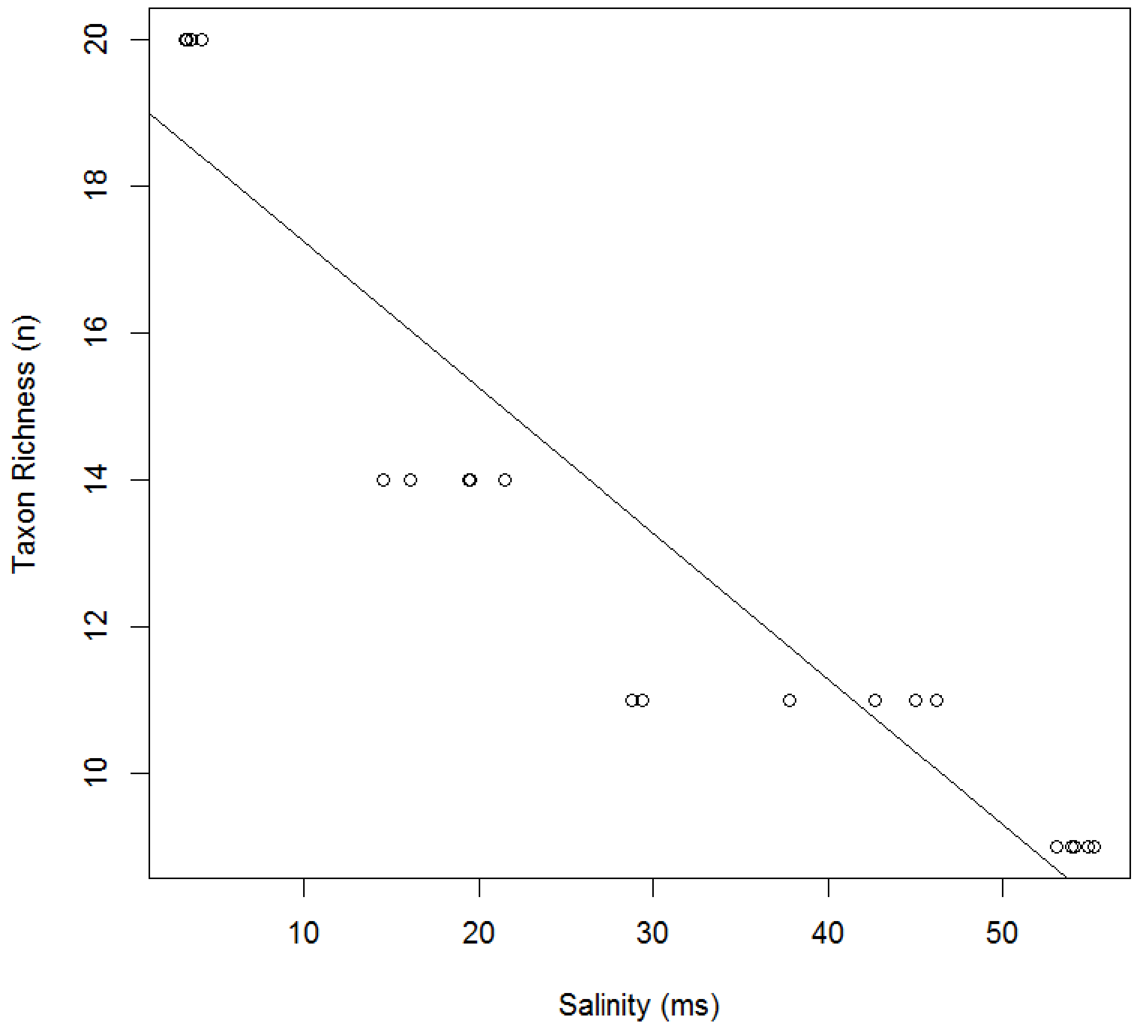

Figure 6: Scatter plot of the significant negative relationship (p= 2.76e-16) between measured water salinity and taxon richness for the four sampled sites with linear regression model, R^2= 0.8959.

Linear regression analysis demonstrates strong relationships between salinity and colour variables, and taxon richness, at .88 and .89 respectively. When combined and run through a two-way ANOVA and linear regression model, the combined salinity and colour factors give an R^2 value of .9879, showing a very strong linear relationship, with salinity and colour changes responsible for 98.79 percent of changes in taxon richness (Appendix 2).

Cow Swamp had the greatest taxon richness and abundance means. It also had the highest alpha and beta diversity values. Town Swamp had relatively low diversity values, especially in comparison to abundance and taxon richness values. Sandy Cape Lake had the lowest diversity values, while Dune Swamp had moderate values for diversity (Table 1).

Table 1: Alpha, Beta and Gamma calculated diversities for the four sample sites of Town Swamp, Dune Swamp, Sandy Cape Lake and Cow Swamp.

	α-Diversity (Shannon ln)	B-Diversity (Shannon ln)	Γ-Diversity (Shannon ln)
Town Swamp	0.479	0.42	0.898
Dune Swamp	0.638	0.975	0.975
Sandy Cape Lake	0.335	0.45	0.786
Cow Swamp	0.943	1.102	2.046

Taxon richness and abundance did not have a significant relationship within the samples gathered at the four sample sites (p=0.869) (Appendix 3).

Crustacea were the dominant class in all four samples, making up 55% of all collected samples at Cow Lake and over 88% at each of the other 3 sites (Figure 7).

Chydoridae, Ilyocriptidae and Ostracoda were the dominant species, with Ilyocriptiddae and Ostracoda present at all 4 sites. Chydoridae was present in relative abundance in the Cow Swamp, but had only a minor appearance in Dune Swamp. Calanoida were also found in relative abundance in Town Swamp (Figure 7).

Ostracods made up 72% of all invertebrate samples collected in Sandy Cape Lake, a hyper saline site. Ilyocriptidae made up a further 20% (Figure 7).

The Insecta order were relatively rare, and appeared to be particularly affected by high salinity levels, with very few organisms collected at the more saline sites (Figure 7).

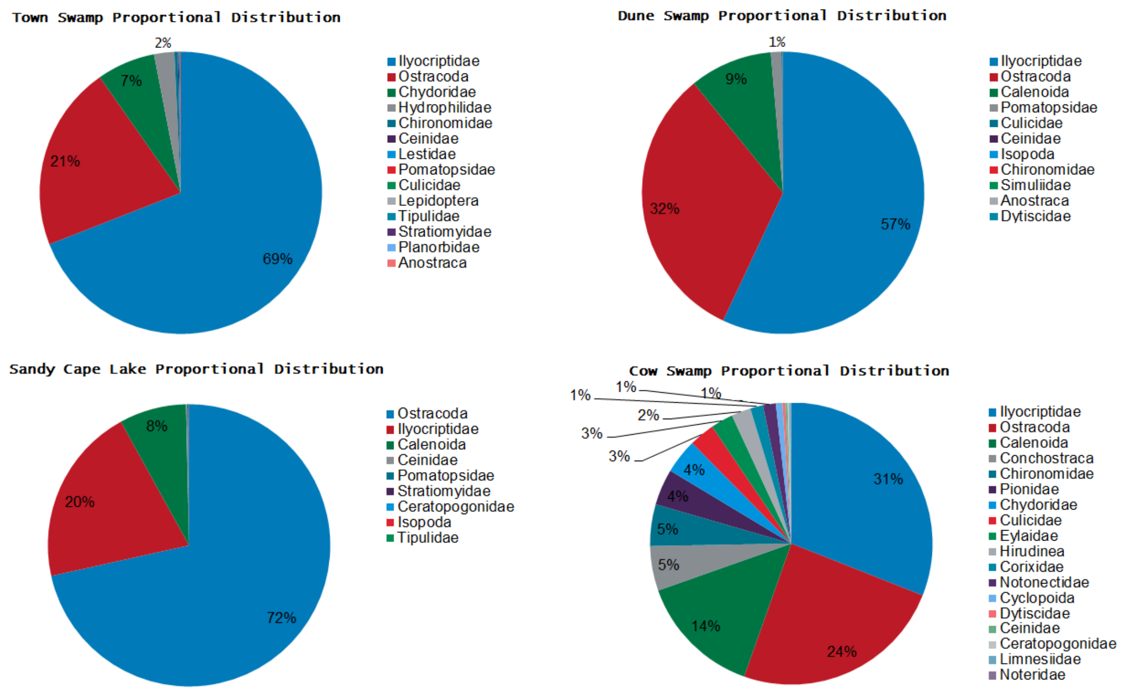

Figure 7: Distribution of invertebrate families at Town Swamp, Dune Swamp, Sandy Cape Lake and Cow Swamp sites.

Cow Swamp had a much higher colour reading compared to the other swamps. The water was brown in colour, and the lake bed was also significantly darker in colour compared to the other sites.

One way ANOVA tests for the four sites show that they were significantly different in abundance and taxon richness (see Appendix 4).

Abundance had a statistically significant relationship with site location but a very low R^2 value. There were several significant outliers, particularly at the Town Site. Due to the high variability and relatively large number of outliers, while there was a significant relationship between abundance and sample site, this relationship when regressed, accounts for only 26.45% of variance, and so shows a weak relationship (Figure 8, Appendix 5).

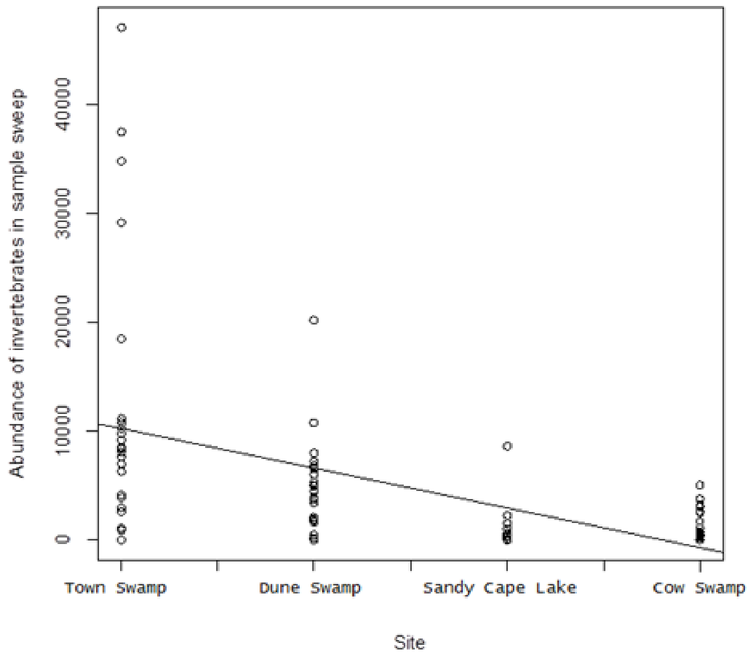

Figure 8: Scatter plot showing abundance values recorded for the four sample sites, with fitted linear regression model, R^2=0.2645.

All water factors aside from turbidity were also significantly different between sample sites ($p<0.05$) (Appendix 6), and so were viable factors for use in determining variance in abundance and taxon richness data.

Discussion

Effects of Salinity on Taxon Richness

Salinity has been increasing in many wetland systems through the effects of climate change and human activity (Williams W. , 1987), (Williams W. , 1999), (Davies, 2010). Salinity has been shown to have a significant effect on biological life in aquatic systems (Williams W. , 1987), (Piscart, 2005), (Kefford et al., 2012), (Kefford, 1998), (Horrigan, 2005) with macroinvertebrates exhibiting high sensitivity towards changes in salt levels (Hart, 1990).

Salinity has the largest effect on invertebrate species mainly through the relationship between the salinity conditions and osmoregulatory physiology within the invertebrate species (Withers, 1992) Saline lake water however has also shown to have higher toxicity than the equivalent prepared saline solution under laboratory conditions (Kefford, 2000), and as such other factors in the saline systems may be jointly responsible for the reduced taxon richness, including physical habitat and ionic composition (Pinder, 2005).

Aquatic larvae of highly mobile species, including several species of the Diptera order, were found to be significantly higher in proportion in the less saline conditions found in the Cow Swamp. As these species show reduced survival and developmental rates in more saline habitats (Carver, 2009), it is likely the increased presence in the more freshwater systems is due to preferential behaviour patterns and avoidance of the more saline sites.

Past sampling and collection of data in Australian systems has also shown a significant relationship between salinity and aquatic organisms present (Brim-Box, 2014) although the differing salinities accounted for less than 7% of variation in the collected data. By comparison, changes in salinity account for 92% of the variation in taxon richness in the sampled sites.

The reduced taxon richness and numerical dominance of a few key species in more saline environments has been documented in the past (Williams, 1999), (Kefford, 2012), (Hart, 1990) and it appears that the same effect has been demonstrated in this field study.

Effects of Water Colour on Taxon Richness

Water colour was variable within the different sample sites, with the highest colour readings in Cow Swamp. These greatly increased readings were likely related to tannin leeching from the leaves and biological material dropped from melaleuca trees living within the aquatic environment (Growns, 1992).

Highly coloured waterbodies have been shown to have lower numbers of each individual species, but higher numbers of rare taxa (Growns, 1992). This coincides with the field sample data, which shows low abundance compared with Dune and

Town Swamps, yet higher alpha and beta diversities, which coincide with the diversity both within and between the samples. These higher diversities indicate a larger number of unique taxa, and include several relatively rare species unidentified in the three other surveyed sites, including several species of Arachnida water fleas and Insecta species.

Water colour has also been shown to be a good indicator of dissolved organic carbon content and is often used as a surrogate measurement (Wallage, 2010), which provides food for detritivores and planktonic species. Water colour may also indicate higher levels of decaying plant material, which likely provide microhabitats and a food supply for shredder invertebrate species, which also provides a more diverse pathway for carbon and energy to be transferred to secondary producers (Bohman, 2001), allowing for more diverse conditions which have been shown to lead to greater beta diversity within invertebrate communities (Astorga, 2014). This may have been a contributor to the taxonomic richness and relationship with colour within the samples collected at each site in this field trip, as colour was shown have a significant, positive effect on taxon richness. In particular, Cow swamp had a large bed of detritus and decaying plant matter, with town swamp also supporting a layer of organic material and aquatic plants.

Other significant factors of Taxon Richness

The increased taxon richness in Cow Swamp may also be attributed to more the more varied and developed food chain, with a large number of first order predators (Corixidae, Anostraca), second order predators (Hirudinea) and parasitic organisms (Eylaidae, Limnesiidae) present. These species make up a much larger proportion of the total invertebrate sample in this less saline water, with predator species making up less than 2% of the total sample in the saline samples. This is likely due to the greatly reduced diversity in the more saline conditions, as described previously by (Brim-Box, 2014), (Piscart, 2005) and (Pinder, 2005), where many of the species upon which higher order invertebrates feed were absent. The absence of these species may be attributable to the decreased diversity of lower order species, due to the adverse saline conditions.

Another environmental variable affecting the higher taxon richness of invertebrates in the Town Swamp and Cow Swamp sites may be the increased vegetation present in the aquatic environment, which has been shown to have a positive relationship with increased invertebrate life. In particular, many species of Insecta larvae favour environments with high levels of sediment and submerged plant life (Davis, 1999), which were largely absent from the Dune Swamp and Sandy Cape Lake locales.

Diversity Indices

Cow Swamp showed the highest alpha and beta diversity values for the total sample, at 0.943 and 1.102, when compared with the other more saline environments. This would indicate higher levels of taxon richness within the water body, as would be expected given the comparative water quality, and from data gathered in previous studies (Williams, 1999),(Kefford, 1998), (Hart, 1990), (Brim-Box, 2014). Of note however, Town Swamp showed a lower alpha and beta diversity index than Dune Swamp, which would be unexpected given the negative relationship between taxonomic richness and salinity.

Invertebrate Species Identification and Location within Samples

There were no samples of Calanoida identified in the Town Swamp site. This is of particular interest because this family of invertebrates shows relatively high tolerance and adaptability to salinity (Cervetto, 1999) and was present in significant quantities in the hyper-saline Sandy Cape environment, moderately saline Dune Swamp and freshwater Cow Swamp. That Calanoids make up a significant proportion of invertebrate numbers in Cow Swamp, as has been reported in the past (Growns, 1992), where they tended to dominate highly coloured water. Contrary to expectations and findings from Growns et al (Growns, 1992), Calenoida species continued to be relatively dominant in the less coloured sites when compared with Cyclopoida species, which would be expected to dominate in the less-coloured wetlands (Growns, 1992). This may be due to a higher susceptibility to saline conditions within the Cyclopoida family (Cervetto, 1999).

This finding may also be due to a variety of other factors, including the increased water flow that was observed in the Town Swamp region, as the Calanoida family are primarily filter feeders that feed off planktonic microorganisms (Gooderham, 2002) and zooplankton are quickly eliminated from shallow streams or rivers <1m in depth (Walks, 2004) as was the case for the Town Swamp site. It may also be due to the relative impermanence of the Town Swamp site, as this waterbody is known to dry out during the summer months. As Calanoida also lack adaptations to survive periods in which the water source dries out (Gooderham, 2002), their absence in this system may be explained through simple incompatability with the system.

Highly variable levels of salinity in the system may also be a cause, as Calanoida have shown poor survival rates in cases where salinity rises by 10-15% in a short period of time. Due to poor adaptability to highly variable salinity (Cervetto, 1999) these organisms may not survive the initial hydration and consequent low salinity levels during the initial period of rainfall.

The high levels of Chydoridae found within the Town Swamp region may be attributed to the impermanence of the Town Swamp site. Cladocerans are well adapted to dry periods with eggs which are tolerant to drying (Davis, 1999) and which can survive during the summer months recolonizing the Town Swamp site once the area is rehydrated. The relatively high proportion of Chydoridae may also be partly due to the lack of Copepod species, such as Calenoida, at the Town site as Copepods are a significant predator species and their presence has been shown to have an inverse correlation to Cladoceran abundance. (Adamczuk, 2013)

In the field study, Leptodora had particularly high predation pressure on the Cladoceran species, and the increased presence of Leptodora and Copepods in the Cow Swamp were likely also to be responsible for the reduced proportions of Chydoridae at this site (Adamczuk, 2013).

Crustacean species, particularly Ostracods and Ilyocriptidae, were the dominant species at all four sites. Ostracods show a higher numerical proportion under high and super saline conditions, with a 72% distribution of total sampled invertebrates in the hyper-saline Sandy Cape Lake site. Ilyocriptidae were also capable of surviving the saline environment, at 20% of the numerical distribution. Ilyocriptidae appeared to be more successful in moderately saline conditions and were in a higher proportion relative to Ostracods in these conditions. The relative abundance of Ostracods and ilyocriptidae however remained relatively constant in the saline conditions of the

Town, Dune and Sandy Cape sites, with 90, 89, and 92 percent of all invertebrate samples collected These data represent and agree with data regarding the dominance of Crustacea in saline conditions (Hart, 1990), (Pinder, 2005). These proportions were highly conserved between sites, which may indicate competition between the two dominant species, with Ilyocriptidae more competitive in areas of low to moderate salinity.

The lower proportion of Ostracod and Ilyocriptidae, of 55%, in the Cow Swamp area likely represents increased competition for resources from other species and higher levels of predation, as the reduced need for osmotic regulation (Withers, 1992) allows for higher species richness, as has been observed in several aquatic systems within Australia (Bunn, 1992).

Pomatiopsidae is a species of the Mollusca class which is found primarily in salt lakes (Davis, 1999), and was present in both moderately saline and hyper saline conditions in the field study. It wasn't present in the freshwater Cow Swamp, as would be expected for a halophilic organism (Williams W. , 1980).

The Crustacea group has proven to be the most tolerant of saline conditions in past samples undertaken throughout Australian water systems (Hart, 1990) with Insecta class species controlling the majority of freshwater samples. As such, the comparative dominance of the Crustacea in the moderately and hyper-saline sites is unsurprising. The small number of insect species is however of some concern in the Cow Swamp site, as it would be expected that insect species, particularly Diptera larvae, would have a higher overall numerical proportion of the Cow Swamp sample due to the freshwater nature of the water body.

Abundance data and lack of Significant Relationships

The abundance data collected shows high variability and a very high abundance for the Town Site. While Ostracods and Ilyocryptidae may have shown increased populations, due to higher eutrophication from surrounding farmlands and fertiliser use (Davis, 1999), it is unexpected that this would have had such a pronounced effect. The relatively inconsistent hydrological pattern as is experienced at Town Swamp would be expected to lead to lower abundance and taxon richness (Waterkeyn, 2008). Due to the high variability of the abundance data, as well as the large number of outlier values within the data, it is likely that there were errors and inconsistencies in the data collection. Town swamp micro-invertebrate samples may have been incorrectly counted, and with the multipliers for the divided samples, this may have led to the greatly inflated counts, particularly for the Ostracod and Ilyocryptidae invertebrates which are largely contained to the micro-invertebrate samples. Further collection and analysis of specimens in the field, with greater depth and accuracy, would therefore be recommended in order to gain a greater and more accurate understanding of the invertebrate abundance in the sample sites.

The finding that abundance was much higher with regards to colouration, and substantially lower in the more coloured Cow Swamp, may be partly due to the decreased light level available to the primary producers, as theorised by Growns et al. (Growns, 1992) If this was the case, any significant relationship between colour and abundance may have been invalidated by the atypical relationship between abundance and colour within Cow Swamp.

Future Recommendations

While several measures of water quality were gathered and assessed against taxon richness and abundance within the sample sites, abundance showed high variance, with several outliers and the significant relationship between abundance and site explaining only 42% of the variance. This indicates poor fit and that other factors have contributed to relative abundance. In particular, nutrient enrichment is increasingly a concern for wetland ecosystems, and may have a large contribution to species abundance. It is therefore recommended that future samples would use improved equipment and methodology to provide better data collection.

Study and maintenance of the vegetation in and surrounding the wetland ecosystems is also recommended, as wetlands containing high levels of these species are increasingly rare and have suffered the greatest damage from European colonisation, particular in regards to removal of waterside vegetation (Davies, 2010), (Growns, 1992). As such, these unique ecosystems are under particular threat from changing environmental conditions.

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Report 4

An investigation of macroinvertebrate communities in saline wetlands surrounding Jurien Bay

Abstract:

The purpose of this study was to investigate the effects of higher levels of salinity has on macro invertebrate richness. The investigation was focused on four wetlands in the Jurien Bay region two of which were saline, one hyper saline and the fourth fresh water. Samples were taken with sweep nets over a distance of ten metres and repeated three times. The samples were sorted into jars separating macro invertebrates bigger than 2mm from the smaller ones <2mm. The samples were identified back at the lab using a microscope and taxonomic books related to macro invertebrates. Data was then compiled into one data sheet for statistical analyses. The main findings of this study were that higher levels of salinity in wetlands effects the diversity of macro invertebrate communities and that whether the wetland is perennial or intermittent will effect salinity levels. Because intermittent wetlands dry out during summer their salinity levels rise over time. Perennial wetlands stay wet all year round stopping salinity levels from rising due to drying. Salinity affects macro invertebrate diversity as some species such as crustaceans thrive in highly saline environments as they're salt tolerant and some species can't survive in these saline environments these are our non-salt tolerant species. Due to the change in climate in the south west of Western Australia and the decline in rainfall and hence increase in salinity, wetlands across the region will continue to be affected by this phenomenon causing their communities of macro invertebrates to decline in species richness.

Introduction:

Jurien Bay is located approximately 200km north of Perth in the southwest corner of Western Australia, it is a Mediterranean climate and is known for its high levels of biodiversity and is considered to be one of the most bio-diverse regions in the world (Chalmers & Davies, 1983). An important part of its ecology is wetlands. Wetlands are a highly crucial piece of the puzzle known as our environment. They protect absorb pollutants and keep our water quality high (Odum, 2000). These regions also harbor high diversity of flora and fauna, much of which is endemic (Hall et al., 2004). A wetland is essentially an area of land that is saturated with water, either perennially or intermittent (Moore, 2001). Currently wetlands are considered to be under massive threat from the phenomenon known as global warming. With the current global increase of average temperature our intermittent wetlands are seeing to be around for reduced periods of time and with lesser volumes. Meanwhile our perennial wetlands are decreasing in size (Irwin, 2009). One of the primary problem with this presents us with is with a decrease in volume of water we have an increase in potency of contaminants. With lager volumes of water these contaminants are see to be more dilute and thus less harmful to the highly adapted species that live within (Ladewig & Asquith, 2012). One of the primary contaminants is salt; this is primarily an issue in intermittent wetlands, as salts tend to accumulate in these low-lying regions washed in from soils around being deposited in the wetland. Due to the fact of their seasonality this highly affects the wetland as volumes and therefore salt concentrations vary significantly allowing only highly adapted species that can exist in such variable conditions present. Majority of these intermittent wetlands are also seen to be shallow allowing for greater heat to be absorbed so a higher frequency of temperature swings are observed opposed to our deeper perennial wetlands which typically have more stable temperatures. The accumulation of problems caused from global warming creates a volatile and unpredictable environment for the species that exist here (Mitsch & Gosselink, 1993). Especially those of which are endemic. Other primary threats to our wetlands exist as human disturbance, use for recreational activities and water run off and particularly the encroachment of urban development. Run offs bring in chemicals and various other substances that can cause a possible catastrophe for species and possible eutrophication, inedible depriving the fauna of oxygen and denuding the aquatic species of life. Another threat is from agriculture; typically from livestock trampling the flora primarily affecting smaller species of plants this then inhibits the species that live within this region by inhibiting the quantity of habitats. With a growing mining industry wetlands are being encroached on, in the Jurien Bay region it was for the lime industry the primary problems caused by this are potential run off, clearing of land possibly causing dry land salinity to run off of chemicals used in the process of mining and dust kicked up by trucks, covering the vegetation in dust reducing photosynthesis (Battisti et al., 2008). However we hypothesize that the major effector of our wetlands ecology is salinization causing a decrease in macro invertebrate species diversity.

Method

Site description

Site name: <u>Town Swamp</u>

Coordinates: -30.290504 Lo115.052202

Hydrology: intermittent.

Salinity level: saline.

Sediment: sandy.

Flora: Eucalyptus and Salt Bushes.

Fauna: Seagulls and Oyster Catchers.

Figure 1. An aerial picture of Town Swamp taken from Google Maps as a screen shot.

Out of all four wetlands Town Swamp was located the closest to town and was the most affected by humans. Being an intermittent wetland Town Swamp was shallow with a sandy bottom. The water was saline which would also be due to its seasonal drying out during summer. The geology of the land around the lake consisted of lime stone and sandy soil. During summer when the wetland dries out the dry surface is used as a race track with evidence of activity showing in the form of an old rusted car. The wetland is also located close to a lime stone track with power lines running along it.

Site name: <u>Dune Swamp.</u>

Coordinates: -30.20945 Lo115.00778

Hydrology: intermittent.

Water: saline

Sediment: sandy.

Flora: Salt Bush/Salt Tolerant Shrubs

Fauna: Various seabirds (eg gulls)

Figure 2. An aerial picture of Dune Swamp taken from Google Maps as a screen shot.

Out of all the four sites Dune Swamp was the smallest in diameter. Dune Swamp is an intermittent wetland with a shallow sandy bottom. The wetland had saline water which would be amplified with its drying during summer. The geology surrounding Dune Swamp was sandy and lime stone with fine clay like waterlogged sediment in the immediate surroundings. The wetland was positioned in a low point with sand dunes to the south and salt flats to the north. Dune Swamp is located close to a road that accesses a camp site and a lime mine.

Site name: <u>Sandy Cape Lake</u>.

Coordinates: -30.207632 Lo115.010183.

Hydrology: intermittent.

Water: hyper saline.

Sediment: sandy fine sediment (contains lime)

Flora: small salt adapted shrub.

Fauna: Various seabirds (eg gulls)

Figure 3. An Aerial picture of Sandy Cape Lake taken from Google Maps as a screen shot.

Out of all four wetlands Sandy Cape Lake was the largest in diameter. Sandy Cape Lake is an intermittent wetland with a shallow fine sandy bottom. The water at Sandy Cape Lake was hyper saline which would be due to its intermittency in drying out during summer. The geology of Sandy Cape Lake included fine sand and lime stone. Out of the four wetlands Sandy Cape Lake is the second most affected by human activity having a lime mine on the northern side of the wetland and an access road to a camp site and the mine to the south. Sandy Cape Lake and Dune Swamp were very closely located to each other being split only by a thin stretch of land and road.

Site name: <u>Cow Swamp</u>.

Coordinates: -30.254988 Lo115.150152.

Hydrology: perennial.

Water: fresh.

Sediment: organic matter.

Flora: Paper Bark, Banksias and Sedge Reeds.

Fauna: Emu

Figure 4. An aerial picture of Cow Swamp taken from Google Maps as a screen shot.

Out of the four wetlands Cow Swamp was the one wetland that was perennial, meaning its body of water does not dry out during summer. Cow Swamp was the deepest of the four wetlands with a bottom made up of organic sediment. The water of the wetland was fresh with a Tannin colour from the Melaleuca trees surrounding the wetland. The geology of the land surrounding the wetland included sand and lime stone, but most of the surrounding earth was covered with grass for grazing. Cow Swamp had a low level of human activity along with Dune Swamp in comparison with the other two wetlands.

Materials list

Materials used:

- Waders
- Spoons
- Splitter
- Pipettes
- Net
- Tray
- Sample jars
- Microscopes
- Petri dish
- Tweezers
- Prods
- DI water
- Ethanol
- Dissolved oxygen (DO) metre
- Salinity metre
- PH metre

Procedure

Site sampling procedure:

For all four sample sites the following procedure was completed to obtain the samples: (each step was repeated 3 times)

1. Completed a ten metre sweep moving sweep net up and down through the water column.
2. Sample was then cleaned from the net into a tray.
3. Pipettes were then used to remove any macroinvertebrate 2mm and above in size and placed them into sample jars for identification back in the lab.
4. The remainder of the sample was then split using a splitter jug to a faction of 1/18 of the original volume and placed into sample jars for identification back in the lab.
5. A sample for the level of dissolved oxygen was taken and recorded using a DO metre.

Laboratory identification procedure:

For all four sites the three samples from each were analysed back in the laboratory to identify the individual macroinvertebrate species by completing the following procedure.

1. Samples of larger macroinvertebrates (>2mm) were removed from jars into Petri dish using pipette.
2. Macroinvertebrates were individually identified using a microscope and taxonomic identification books (Davis, J. A. et al 1997, Miller L.J. 2003 Williams, W.D. et al 2002).
3. The first two stages of the procedure were then repeated for the samples of macroinvertebrates <2mm in size.

Process taken for statistical analyses of data

Graphs: the following graphs were constructed to compare and analyse the data from the wetlands.

Bar graph:

- Mean salinity of four wetlands.
- Mean taxon richness of four wetlands.

Line graph: comparing correlations between the following variables.

- Total macroinverbrate taxa and salinity.
- Total macroinverbrate taxa and turbidity.
- Total macroinverbrate taxa and temperature.
- Total macroinverbrate taxa and dissolved oxygen.
- Total macroinverbrate taxa and pH.

- Total macroinverbrate taxa and colour.

Statistical tests: the following statistical tests were conducted to analyse the data from the wetlands.

- Six T-tests comparing taxa between the four sites.
- An ANOVA test comparing difference between wetlands for mean taxon richness.
- An ANOVA test comparing the difference between wetlands for salinity.
- Values for similarity coefficients for similarity of taxa between the four sites were calculated.

Results:

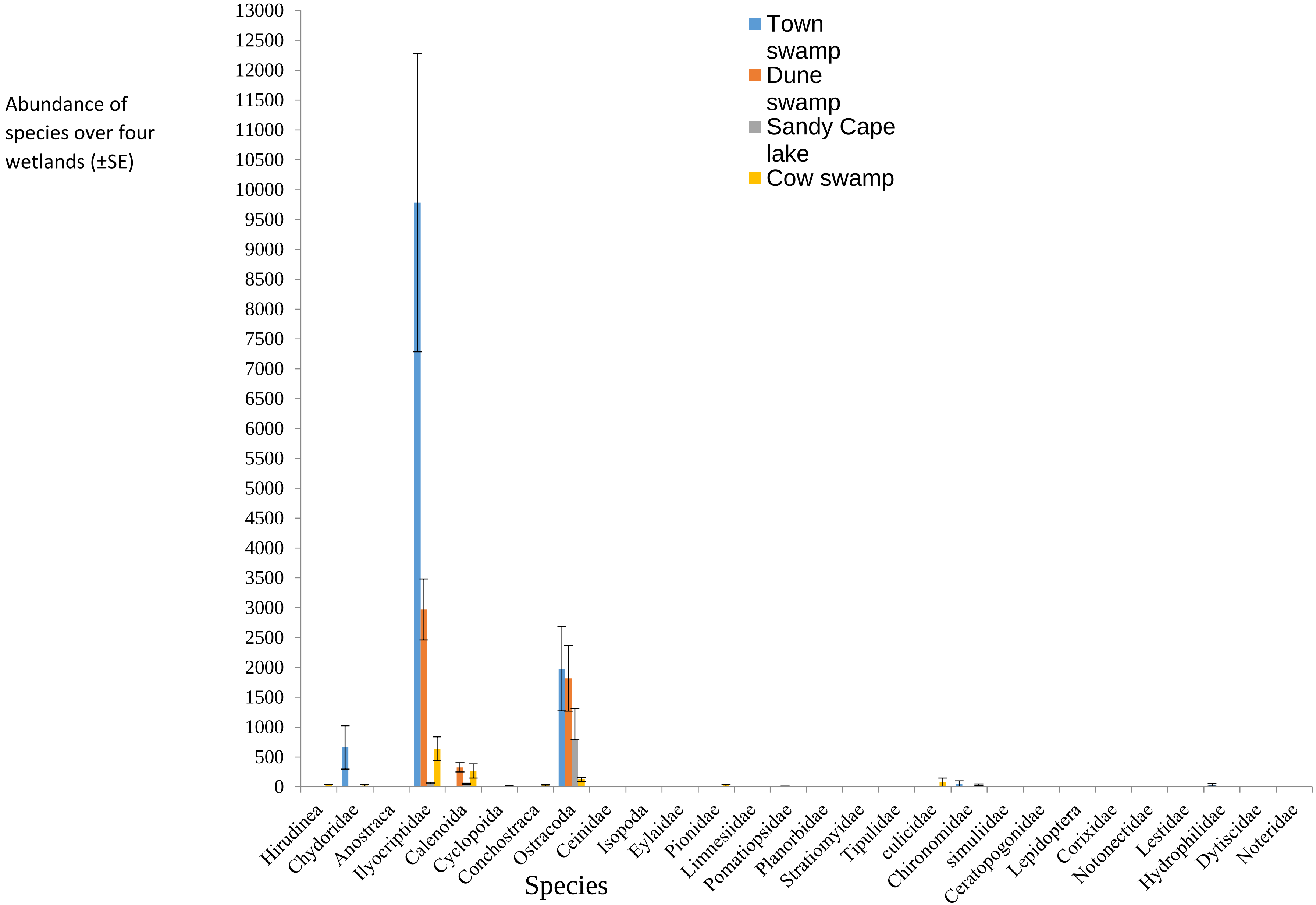


Figure 5. Abundance of all species across the four wetlands in the Jurien Bay region collected using a sweep net. N=23 readings per wetland. Data are means ± 1 standard error.

Mean Salinity (±SE)

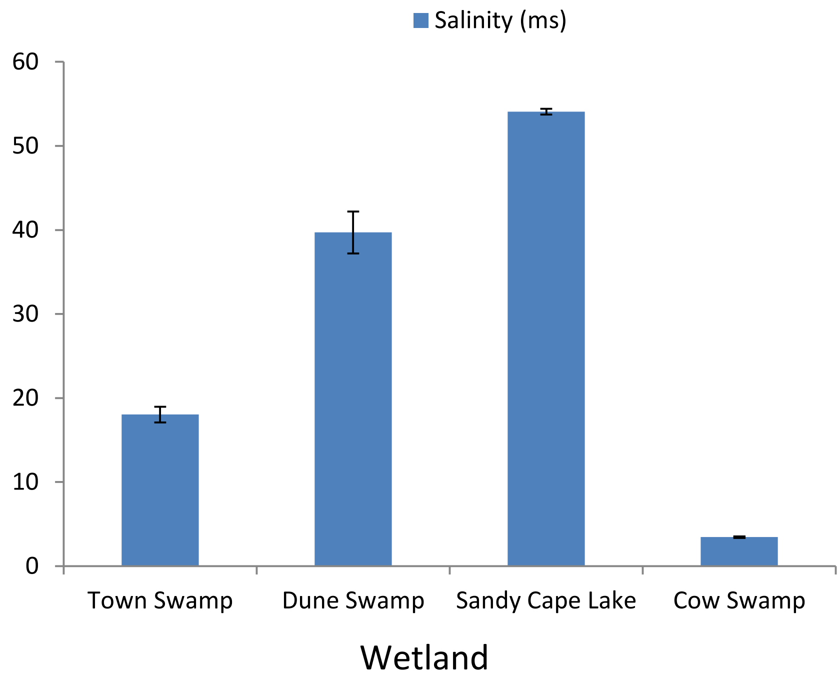
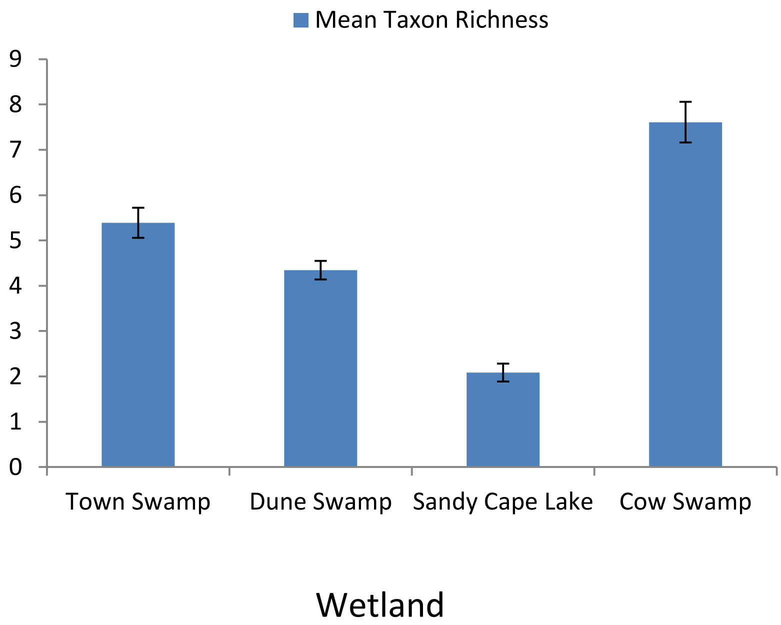


Figure 6. Mean salinity of four wetlands in the Jurien Bay region collected using a conductivity meter. N=8 readings per wetland. Data are means ± 1 standard error.

Mean Taxon Richness (±SE)



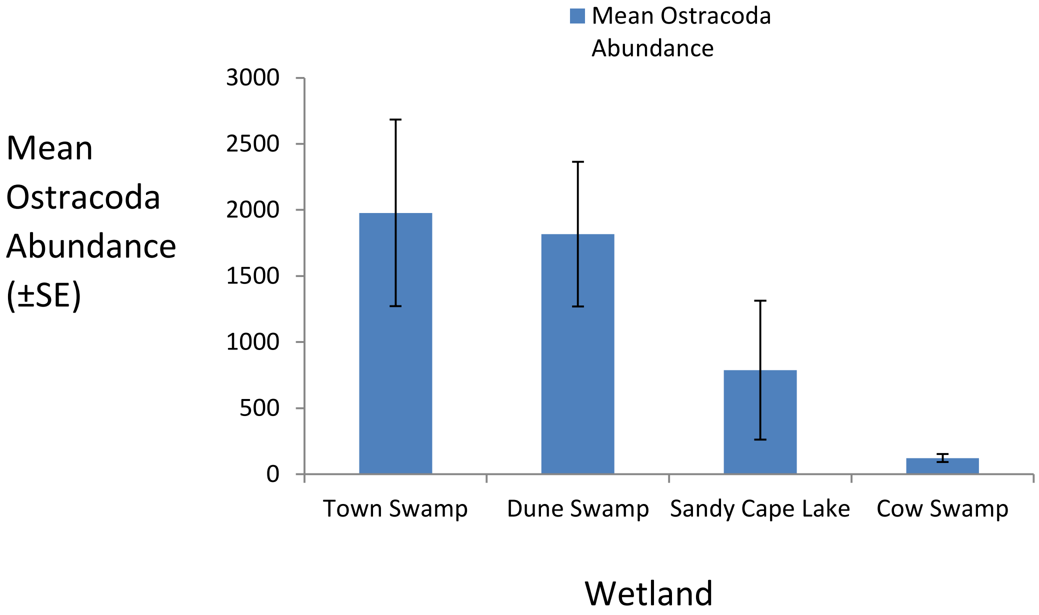


Figure 8. Mean abundance of Ostracoda in four wetlands in the Jurien Bay region collected using a sweep net. N=23 readings per wetland. Data are means ± 1 standard error.

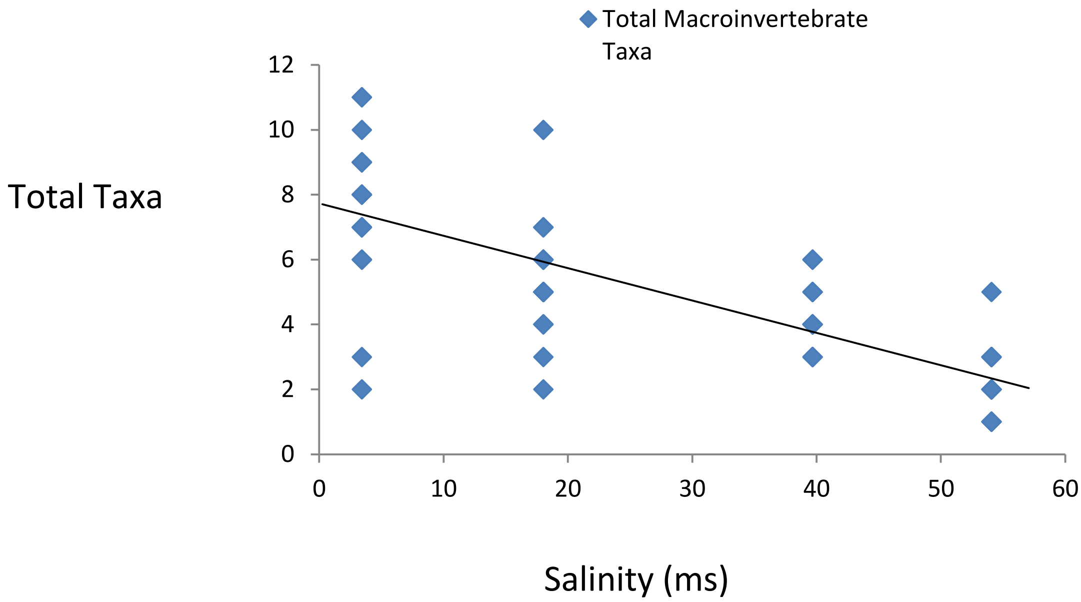


Figure 9.Correlation between Total macroinverbrate taxa and salinity (ms) in a 10m sweep, at four wetlands in the Jurien Bay region in the month of August. The equation of the line is y=0.0997x + 7.7303 and the R^2 value is 0.617.

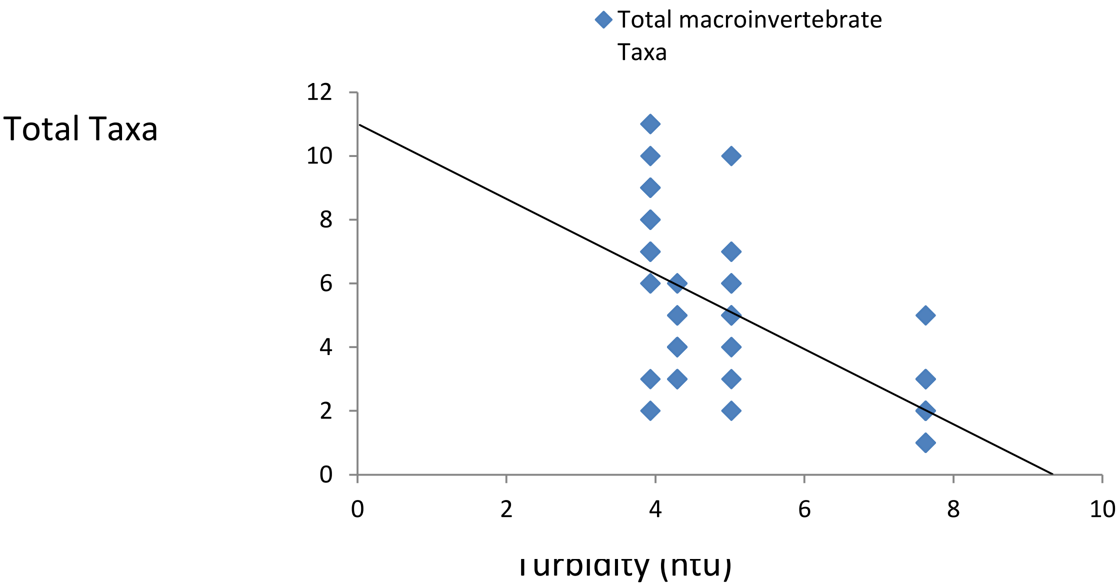


Figure 10. Correlation between Total macroinverbrate taxa and turbidity (ntu) in a 10m sweep, at four wetlands in the Jurien Bay region in the month of August. The equation of the line is y= -1.177x + 11 and the R^2 value is 0.475.

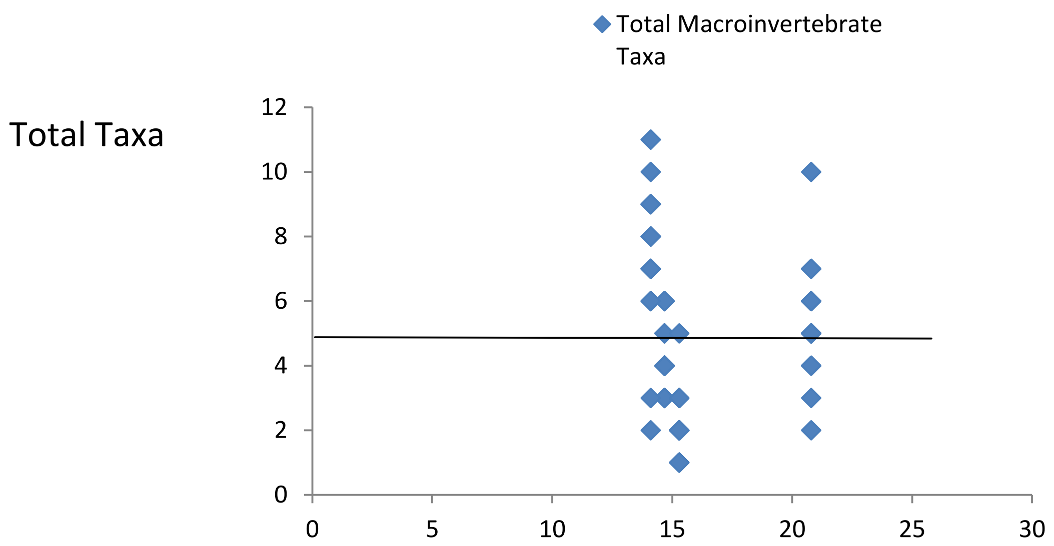


Figure 11. Correlation between Total macroinverbrate taxa and temperature (°C) in a 10m sweep, at four wetlands in the Jurien Bay region in the month of August. The equation of the line is y= -0.001x + 4.882 and the R^2 value is < 0.001.

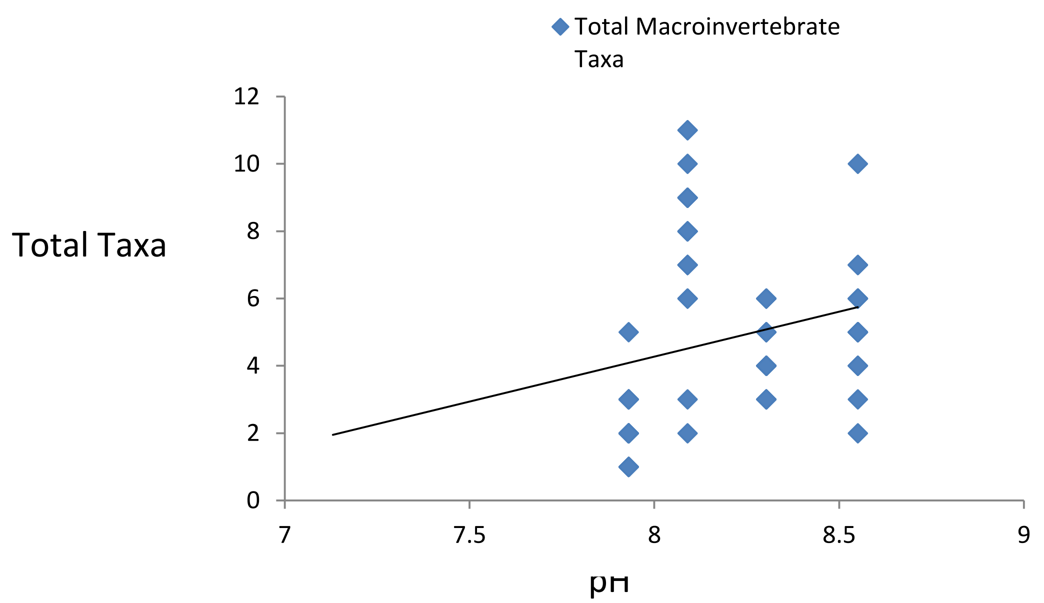


Figure 12. Correlation between Total macroinverbrate taxa and pH in a 10m sweep, at four wetlands in the Jurien Bay region in the month of August. The equation of the line is y= -2.676x -17.13 and the R^2 value is 0.063.

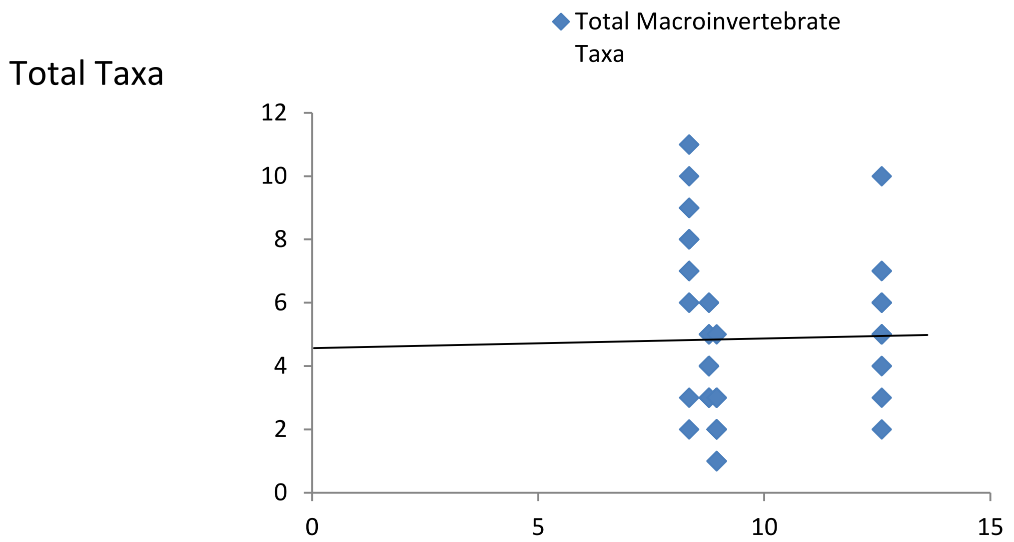


Figure 13. Correlation between Total macroinverbrate taxa and dissolved oxygen (ppm) in a 10m sweep, at four wetlands in the Jurien Bay region in the month of August. The equation of the line is y= -0.03x + 4.564 and the R^2 value is < 0.001.

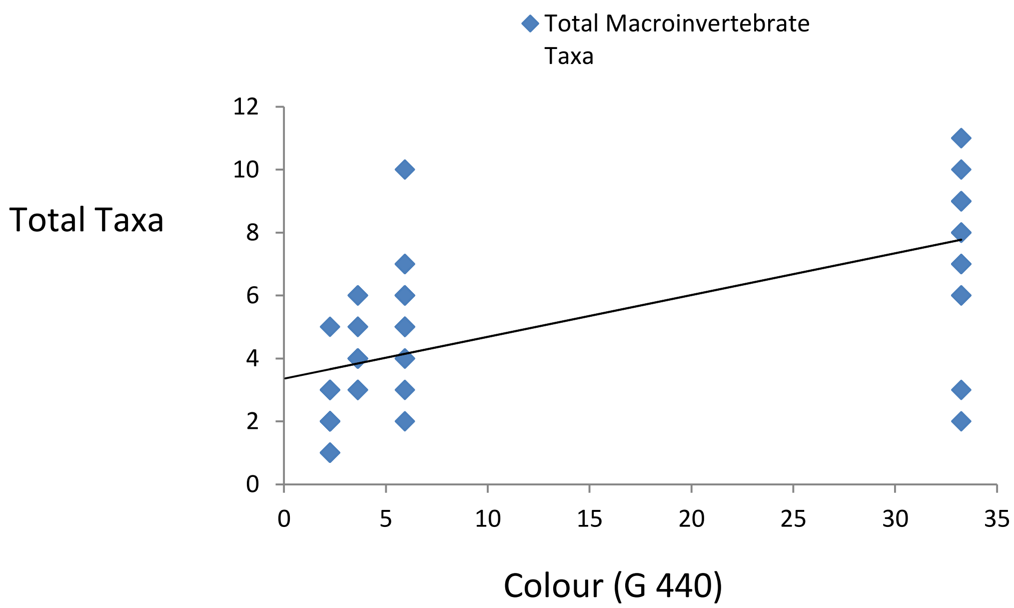


Figure 14. Correlation between Total macroinverbrate taxa and colour (G 440) in a 10m sweep, at four wetlands in the Jurien Bay region in the month of August. The equation of the line is y= -0.132x + 3.362 and the R^2 value is 0.47.

Table 1. Means for temperature, dissolved oxygen, pH, salilinty, turbidity and colour at the four sampled wetlands in the Jurien Bay reigon in the month of August.

	Temperature (^oC)	**Dissolved Oxygen (ppm)**	**pH**	**Salinity (ms)**	**Turbidity (ntu)**	**Colour (G 440)**
Town Swamp	20.81	12.6	8.52	18.04	5.02	5.93
Dune Swamp	14.69	8.78	8.3	39.7	4.29	3.63
Sandy Cape Lake	15.3	8.95	7.93	54.08	7.63	2.26
Cow Swamp	14.11	8.34	8.1	3.45	3.93	33.25

Table 2. Difference between mean taxon richness at four wetlands in the Jurien Bay region in the month of August, using a independent samples t test.

Table 3. Similarity Coefficient values between all four wetlands in the Jurien Bay region, using the similarity coefficient formula.

Wetland	**Mean**	**Standard deviation**	**t**	**df**	**Sig value**
Town Swamp Dune Swamp	5.41 4.35	1.62 0.98	2.67	43	0.152
Town Swamp Sandy Cape Lake	5.41 2.09	1.62 0.95	8.43	43	0.059
Town Swamp Cow Swamp	5.41 7.61	1.62 2.15	-3.86	43	0.299
Dune Swamp Sandy Cape Lake	4.35 2.09	0.98 0.95	7.94	44	0.407
Dune Swamp Cow Swamp	4.35 7.61	0.98 2.15	-6.62	44	0.019
Sandy Cape Lake Cow Swamp	2.09 7.61	0.95 2.15	-11.28	44	0.007

Town Swamp vs Dune Swamp	0.583
Town Swamp vs Sandy Cape Lake	0.572
Town Swamp vs Cow Swamp	0.471
Dune Swamp vs Sandy Cape Lake	0.632
Dune Swamp vs Cow Swamp	0.533
Sandy Cape Lake vs Cow Swamp	0.414

Table 4. The difference between wetlands for mean taxon richness using an ANOVA test.

	df	**F**	**Significance**
Between Groups	3	53.802	> 0.000
Within Groups	88		
Total			

Table 5. The differences between all wetlands in the Jurien Bay region for salinity using an ANOVA test.

	df	**F**	**Significance**
Between Groups	3	2.658E + 32	> 0.000
Within Groups	88		
Total			

There were 28 different species identified in the four wetlands (see figure 5), the Ilycriptidae species was by far the most abundant with an average of over 9000 species identified in Town Swamp and around 3000 in dune swamp. The Ostracoda species were also extremely abundant with 1500-2000 individuals found at both Town and Dune Swamps (see figure 5).

The mean taxon richness found at each wetland differs greatly (see figure 7).The bar graph shows a fairly unsymmetrical distribution of the values, Cow Swamp has the highest mean taxon richness at 7.6 with Town Swamp following next at 5.4. Sandy Cape Lake has the lowest mean taxon richness at 2.08 and Dune Swamp the seconded lowest at 4.34.The mean salinity level differs at each of the four wetlands found in the Jurien Bay (see figure 6). As it is clear from the roughly bell shaped bar graph, Sandy Cape Lake has the highest salinity level at around 54 ms while Cow Swamp has the lowest salinity level at 3.45 ms, between these two wetlands is Dune swamp at 39.7 ms and Town Swamp at 18 ms. The difference in salinity between Cow Swamp and Sandy Cape Lake is 50.55. Ostracoda are seen as key indicator species for salinity (see figure 8), from the bar graph the data is skewed towards the left with Town and Dune Swamp having a mean abundance of 1500+. While Cow Swamp has a small mean abundance of 122.5.

From the results between the relationship of salinity and total taxa (see figure 9) a negative line is created with a correlation coefficient of the graph is 0.617, this shows that there is a moderately strong relationship between total taxa found at wetlands and salinity levels at wetlands.

Turbidity can play a large factor in an aquatic organism's environment, the data produces a negative relationship with a correlation coefficient of 0.475 showing that there is a moderately weak relationship between these two factors (see figure 10).

The factors temperature, dissolved oxygen and pH (see figures 11, 12 and 13) all produce scatter graphs with correlation coefficient values of < 0.07, indicating that there is no relationship between these three factors and total taxa found.

From the results collected colour produces a positively directed line with a correlation coefficient of 0.47 which displays a moderately weak relationship between the two factors (see figure 14)

The factors temperature, dissolved oxygen, turbidity, colour, pH and salinity all play important roles in taxa abundance and diversity (see table 1). Town Swamp has the highest temperature with around 5^{o}C above the other wetlands and the highest dissolved oxygen at around 3.5 ppm above the other wetlands as well as the highest pH level. Salinity varies across the table with Cow Swamp having the lowest and Sandy Cape Lake having the highest. Sandy Cape Lake has the highest turbidity at 7.63 while Cow Swamp has the lowest at 3.45. Cow Swamp has by far the highest colour reading at 33.25 which is more than 6 times the closest colour reading which was a Town Swamp.

The mean taxon richness difference between wetlands greatly varies (see table 2), from the table the Sig values between the sites, Town Swamp and Dune swamp, Town Swamp and Sandy Cape Lake, Town Swamp and Cow Swamp, Dune Swamp and Sandy Cape Lake are greater than 0.05 meaning that there is no significant difference between taxon richness at a 5% significance. However the difference in taxon richness between Dune swamp and Cow Swamp, Sandy Cape and Cow Swamp is significant at 5% as the sig values are less than 0.05.

The similarity coefficients represent the value for the similar amount of species found between the four wetlands (see table 3). The wetlands with the most similar species were Dune Swamp and Sandy Cape Lake at a value of 0.632, the sites with the least similar species were Sandy Cape Lake and Cow Swamp at 0.414.

The difference between wetlands for mean taxon richness and salinity (see tables 4 and 5) are significant at a 5% significant value as there significant values are both > 0.000, meaning that both salinity and mean taxon richness differs across all four wetlands.

<u>Discussion:</u>

From the findings in the results we can see that both mean taxon richness and salinity greatly differs between the four wetlands (see tables 4 and 5), the ANOVA outputs for both these factors produced a significance value of < 0.000, meaning that there is not a lot of similarity between all wetlands for these factors. From the results we can also see that the Sandy Cape Lake, Dune Swamp and Town Swamp have much higher salinity levels than Cow Swamp (see table 1). The main reason for this difference in salinity is most likely the fact that Town Swamp, Dune Swamp and Sandy Cape Lake are all intermittent wetlands while Cow Swamp is a perennial wetland (Moore, 2001). The constant drying out of the other three wetlands drastically raises the salinity level when compared to Cow Swamp which does not dry out (Mitsch & Gosselink, 1993).

The effect of this salinity can be observed through taxon richness as Sandy Cape Lake has the highest salinity but the lowest taxon richness and that Cow Swamp has the lowest salinity but the highest taxon richness (see figures 6 and 7). This provides us evidence that salinity plays a negative effect on taxon richness. As mentioned above Cow Swamp had the highest taxon richness, and when compared using an independent t samples test for taxon richness with Sandy Cape Lake and Dune Swamp the results showed that these wetlands were extremely different as both significance values were < 0.02 (see table 2). The differences between these values for taxon richness can be directly related to salinity as Sandy Cape Lake and Dune Swamp had the highest salinity levels (see figure 6). These high levels of salinity have had a direct effect on the two wetlands as they had the two lowest mean taxon richness values (see figure 7).

The number of similar species is also key to understanding the effects of salinity on these environments (Gower, 1971). Using a similarity coefficient function (see table 3) Cow Swamp and Sandy Cape Lake had the least similar species between them with a value of 0.414, this is likely due to the extreme difference in salinity. Sandy Cape Lake and Dune Swamp had the most similar species between them with a value of 0.632 (see table 2), this high value in similarity of species is most likely due to the close proximity of the two wetlands as well as the similar salinity levels. These results provide evidence that salinity also plays a role in what type of species can live within the wetland.

Crustacea thrive in saline environments compared to Insecta which causes the large numbers of both Ostracoda and Ilycriptidae in the four wetlands (see figure 5). Ostracoda are seen as a key indicator species for salinity, as they are more comfortable in saline environments and thrive in such environments (Whatley & Maybury, 1990). From the results Ostracoda had both high numbers in Town Swamp and Dune Swamp but with slightly less abundance in Sandy Cape Lake (see figures 5 and 6). This species had their lowest abundance in Cow Swamp, indicating there preference of saline conditions.

The scatter graph between salinity and total taxa reinforces all of the above (see figure 9), as it was the highest correlation coefficient value in the results section at 0.617, this value suggests that there is a moderately strong relationship between these two factors. This correlation coefficient value provides final evidence that salinity has a negative effect on taxon richness.

Turbidity was another factor sampled in the field and analyzed in the results, the correlation coefficient value between taxon richness and turbidity is 0.475 (see figure 10), this indicates that there a moderately weak relationship between the two. The line produced by the graph is negative, so as turbidity increases taxon richness decreases. This is most likely due to high turbidity results in decreased water quality as well as less light penetration in the water column resulting in less photosynthetic organisms (Odum, 2000). The extremely high value of 7.63 for Sandy Cape Lake is mostly likely due to the mining processes at this site which result in a lot more water disturbance (Battisti et al, 2008).

The values for temperature, pH and dissolved oxygen did not vary greatly between the wetlands (see table 1). This lack of variability therefore meant that these factors had very little effect on taxon richness, the correlation coefficients produced between these factors and mean taxon richness produced low values of < 0.07 (see figures 11, 12 and 13). These values indicate that there is no relationship between them and taxon richness.

Colour produced a positive line with a correlation coefficient value of 0.47 (see figure 14). This graph indicated that there is a moderately weak relationship between colour and taxon richness, as colour rises so does taxon richness. Cow Swamp had a much higher value for colour (see table 1) this is most likely due to the tannins in the water produced by vegetation around the wetland. This deep colour would most likely provide macroinvertebrates with protection from larger predators (Scholz, 2011).

Conclusion:

Our hypothesis appeared conclusive with an increase in salinity directly affecting species richness. This is a major factor specifically in wetlands as they're low lying water bodies hence salt is seen to accumulate and is not flushed out. This is a further problem when it comes to intermittent wetlands, which are seen to have a high level of salinity due to their typically lesser volumes of water, and thus increased levels of salinity (Ladewig, & Asquith, 2012). These intermittent wetlands become home to more saline tolerant species such as crustaceans (Whately & Maybury, 1990). In comparison to our perennial wetlands which are seen to host a greater diversity of species due to the reduced levels of salinity. However with an increase in global temperatures due to the global warming phenomenon and decreased levels of rainfall we'd expect to see an increase in salinity levels across our wetlands of the south-west region of WA, posing a great threat for our macro-invertebrate richness even posing a potential threat for our perennial wetlands decreasing there volume with greater significance in the summer months hence increasing salinity (Irwin, 2009). However other factors are also contributors and cannot be ignored, turbidity effects light penetration and thus the amount of algae present, thus when the base food of a system is reduced one would expect the rest of the food chain to be affected reducing species richness (Odum, 2000). Colour is another potential competitor providing cover from predators allowing greater diversity (Scholz, 2011). However according to our dataset salinization is the major contributor to a reduced level of species richness amongst wetlands of the Jurien Bay region.

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Report 5

Macroinvertebrate Communities in the Coastal Wetlands of Jurien Bay

Abstract

Macroinvertebrates and water qualities were sampled at four wetlands in Jurien Bay of Western Australia in August of 2015. Three sweeps were taken at each wetland and water qualities were measured with the appropriate equipment. The macroinvertebrates taken from the sweeps were then keyed out to family and counted. Various analyses were done in order to test whether salinity had any effect on the abundance of species in the wetlands. An Analysis of variance was conducted between salinity levels and the taxon richness. This test produced results to suggest that as the wetlands became more saline the abundance of families reduced. Co-efficient of similarities was performed and gave results that were expected. Sandy Cape Lake and Co Swamp were the least similar due to the fact that Sandy Cape Lake had the greatest salinity level and Cow Swamp is a freshwater wetland with the least amount of salinity. The changes in abundance of families between wetlands can be explained by the water qualities.

Introduction

Wetlands are areas of land that are wet for at least part of the year (Kalman, 2003). Some wetlands are covered all year round with water others are underground for part of the year. Wetlands can either be naturally occurring or manmade. They form when rainwater or groundwater collect in an area on the ground. Wetlands in the Swan Coastal Plain are unique and are a dominant feature of Perth. The wetlands are important for their wildlife conservation as well as their social values. The wetland areas are of high biological productivity and directly or indirectly support most of the wildlife of the Swan Coastal Plain (Davis, 1987). Wetlands are highly individual habitats and the flora and fauna present are often very unpredictable (Friday, L.E. 1987). Wetlands are home to many plants and animals including macroinvertebrates. Macroinvertebrates are described as having no backbone and are seen with the naked eye. Most macroinvertebrates are very small but also can be quite large, such as freshwater crayfish (Water and Rivers Commission, 2001). The study of macroinvertebrates is very important, as they are an essential part of wetland food chains. They form part of two interconnected food chains: the grazing food chain and the detrital food chain (Davis, 1987).

The macroinvertebrates rely on water quality for survival as they live in the water for all or most of their lives. If the water quality changes then the community of macroinvertebrates may also change.

Therefore the richness of macroinvertebrate communities may be dependant on the water qualities (Water and Rivers Commission, 2001). Environmental modifications can alter the macroinvertebrate communities. The Turbidity of the water can be exaggerated by poor catchments. When water is highly turbid, the light cannot penetrate as easy which affects photosynthesis of the plants and can also increase the temperature of the water. Salinity is a problem in the water bodies of South-west Western Australia. All macroinvertebrates have different levels of tolerance to levels of salinity. Studies have shown that crustaceans are more tolerant to rising salinity levels than the insects are (Water and Rivers Commission, 2001). Studies suggest that coloured wetlands support lower levels of macroinvertebrates, although the reason why are not clear. It could be that colour reduces the light levels and wavelengths available to the primary producers (Growns et al. 1992).

The aim of this study was to test whether water quality had an effect of the abundance of macroinvertebrates, particularly salinity. From This study it is predicted that the total taxon of families will be greater in the freshwater wetland and where the water is less coloured. An abundance of crustacean families will be found in the saline wetlands.

Methods

Four wetlands were sampled for physio-chemical parameters and aquatic macroinvertebrates. Three of the wetlands were saline and these included Town Swamp (Lat -30.290504, Long 115.052202), Dune Swamp (Lat -30.20945, Long 115.00778) and Sandy Cape Swamp (Lat -30.207632, Long 115.010183). The last wetland visited is a freshwater wetland called Cow Swamp (Lat -30.254988, Long 115.150157)

Figure 1. Top from Left to Right: Town Swamp and Dune Swamp. Bottom from Left to Right: Sandy Cape Swamp and Cow Swamp. Pictures taken by Emily Gannon in August 2015 at Jurien Bay.

Field Sampling:

Sampling was conducted in August 2015 at four Jurien Bay wetlands (Figure 1.) At each swamp in groups of 3 people, 3 random sweeps were taken along a 10 meter transect in various areas of the swamp. The contents of each sweep were then placed into a white tray and 1.2 litres of swamp water was poured through the net into the white tray. All Large invertebrates were taken out using a spoons and pipets and placed into a vial containing 70% ethanol. When all the large invertebrates were taken a sample splitter was used to reduce the remaining water to 1/32 and this was then poured into a separate vial and topped up with ethanol. Each vial was then labelled with the names of the collectors, the swamp name and the date. This method was repeated for each of the four swamps and each swamp had a total of 6 vials.

After the invertebrate sample a Dissolved oxygen meter was used to measure the dissolved oxygen and the temperature of the water. This was done in 3 sections of each lake and the average number was used.

Laboratory Analysis:

While out in the field a large bottle of Swamp water from each of the four swamps was filled. In the laboratory a small sample of each swamp was taken and conductivity meter was used to determine the level of salinity in the water. Next a spectrophotometer was used to determine the colour of the sample. The colour was measured at 440nm and the figure was then multiplied by 2.303 x 100 to give an absorption reading. Turbidity was then measured on unfiltered water spectrophotometrically. All the water quality data was then entered into an excel spreadsheet.

For the invertebrate analysis, each group member took one sweep (2 vials; big and small sample) from each swamp to identify. The samples were identified and counted using stereomicroscopes and the available keys. The count of invertebrates that were in the sample that was split had to be multiplied out depending on the number of times it was split (32). The data for each swamp was then entered into an excel spreadsheet.

Data Analysis:

Excel was used for all data analysis. Firstly bar graphs were produced to show the mean abundance of each type of invertebrate for each swamp. The most abundant families were plotted on one graph and the least abundant families were plotted on another. Secondly two ANOVA test were carried; one to test whether the mean salinity readings were the same between all sites and one to test whether the mean taxon richness was the same between all sites. A regression analysis was then done to test whether there is any correlation between the salinity level and the amount of different families found at each site. A table with the mean figures of each water quality at each site was then produced. Lastly a similarity co-efficient table was produced.

Results

Town Swamp and Dune Swamp is where the most abundant families were found (Figure 2.). Chydoridae (only found at Town Swamp), Ilyocriptidae and Ostracoda (both found in Town Swamp and Dune Swamp) were the three most abundant families.

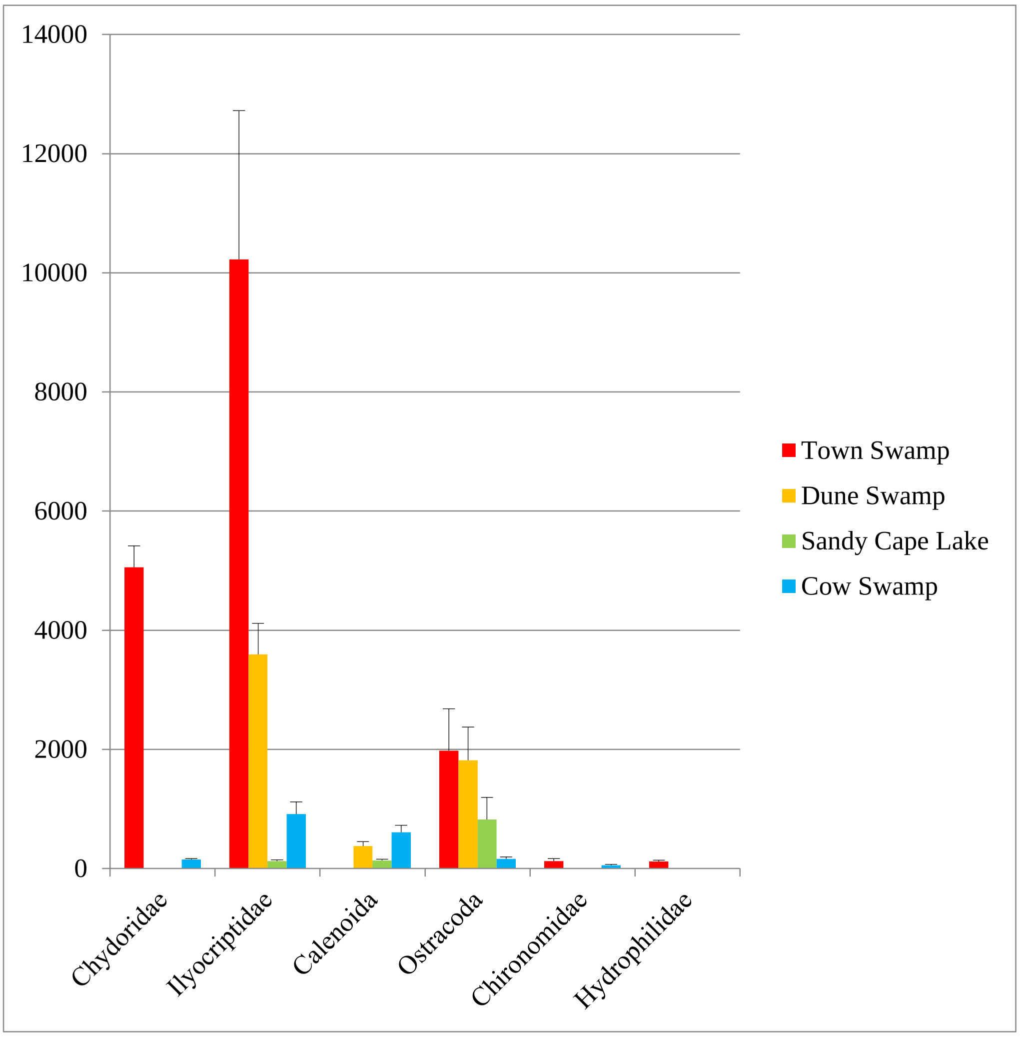

Figure 2. The mean count of the most abundant invertebrates sampled in Jurien Bay wetlands in August 2015.

Of the least abundant invertebrate families found in Jurien Bay (Figure 3.) majority were only found in Cow Swamp. These families include Hirudinae, Cyclopoida, Conchostraca, Eylaidae, Pionidae, Limnesiidae, Corixidae, Notonectidae and Noteridae.

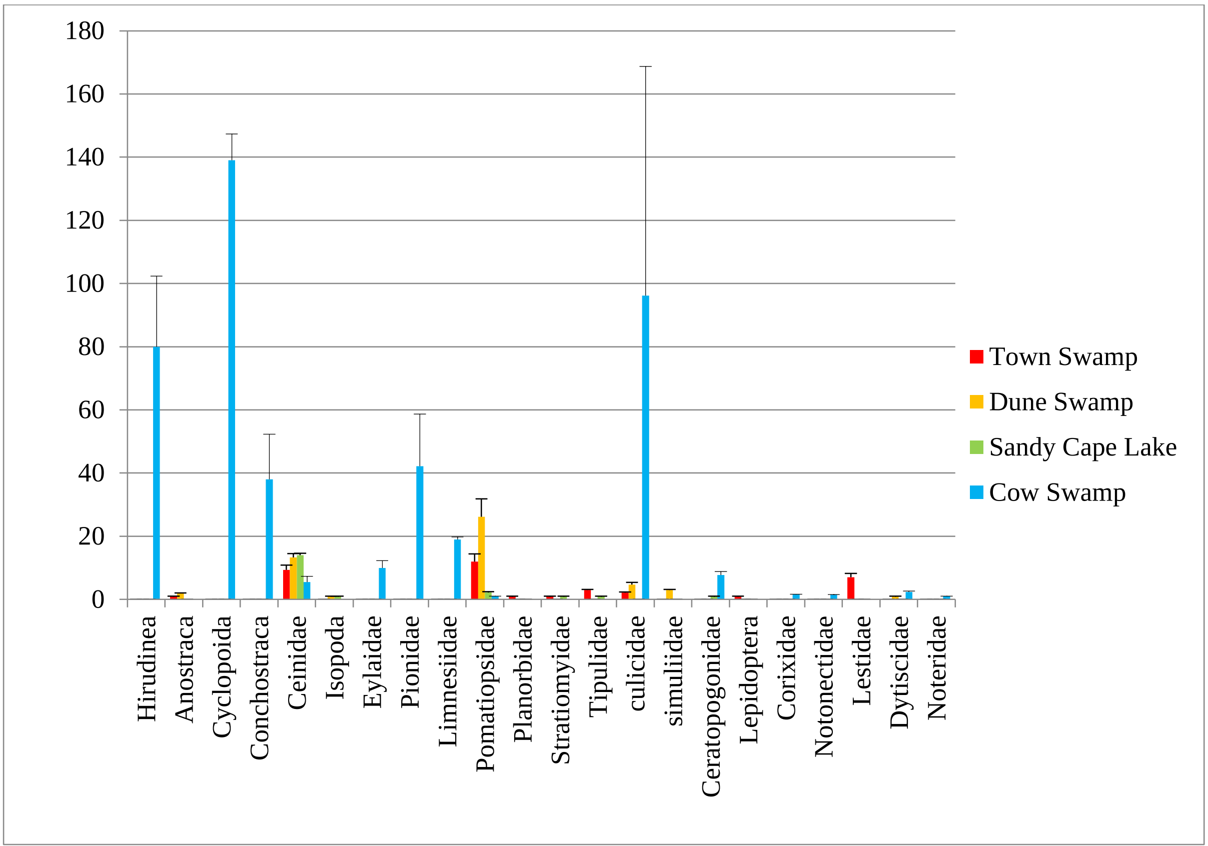

Figure 3. The mean count of the least abundant invertebrates sampled in Jurien Bay Wetlands in August 2015.

The Salinity level difference between the four sites was tested using an ANOVA test (Table 1.) with the hypothesis being:

H_0: μ1= μ2= μ3= μ4

H_1: at least two means are different

(Where μ1 is the mean salinity level at Town Swamp, μ2 is the mean salinity level at Dune Swamp, μ3 is the mean salinity level at Sandy Cape Lake and μ4 is the mean salinity level at Cow Swamp)

As the P-value (<0.0001) was less than the 0.05 significance level, H_0 was rejected and it can be concluded that there is significant evidence to say there is a difference between the mean salinity levels between the four Swamps. Looking at the summary table it can be seen that Sandy Cape

Swamp had the highest mean reading of salinity at 54.075ms. Cow Swamp had the lowest reading of 3.45ms. Town Swamp and Dune Swamp sat in between readings of 18.044ms and 39.7ms respectively.

Table 1. Results of a single Factor ANOVA Test of the mean salinity levels between the four Jurien Bay swamps.

SUMMARY

Groups	Count	Sum	Average	Variance
Town Swamp	8	144.35	18.04375	6.945141071
Dune Swamp	8	317.6	39.7	49.27714286
Sandy Cape Lake	8	432.6	54.075	0.870714286
Cow Swamp	8	27.6	3.45	0.085714286

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12127.63	3	4042.54362	282.800604	4.92805E-21	2.946685
Within Groups	400.251	28	14.29467813			
Total	12527.88	31				

A second ANOVA test was done to test the difference between mean taxon richness between the four swamps using the hypothesis:
H0: The mean taxon richness does not vary between swamps.

H1: The mean taxon richness varies between swamps.

As the P-Value (<0.0001) is less than the 0.05 significance level, H_0 is rejected and therefore there is significant evidence to suggest that the mean taxon richness varies between the four swamps. From the output in Table 2, the greatest mean total taxon was observed in Cow swamp, with an average of 7.6 different families found. The lowest mean number of families was observed in Sandy Cape Swamp with only 2.08 found.

Table 2. Results of a single Factor ANOVA Test of the mean total taxon at the four Jurien Bay wetlands.

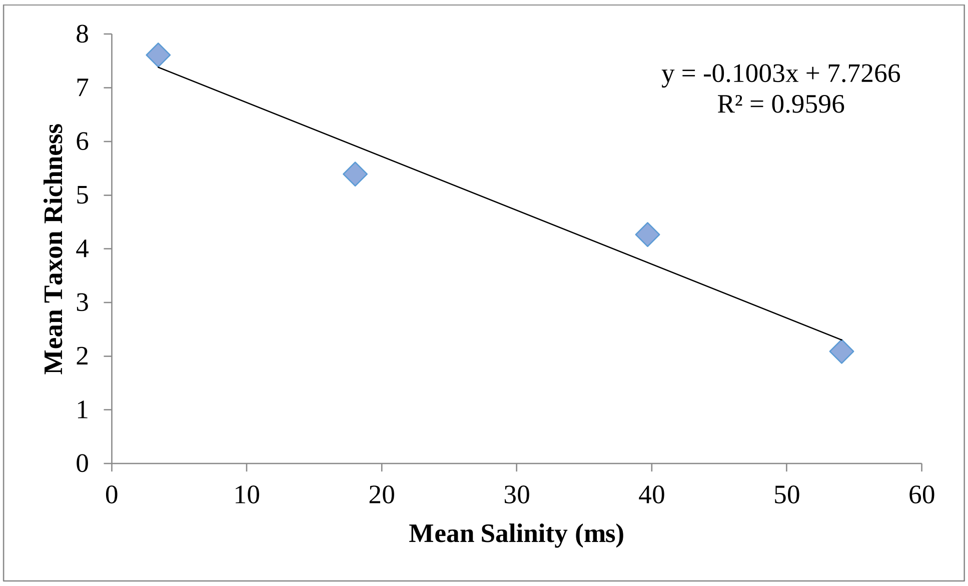

Figure 4. The correlation between mean salinity reading and mean taxon richness of the four swamps in Jurien Bay.

SUMMARY				
Groups	Count	Sum	Average	Variance
Total Taxa - Town	23	124	5.391304	2.521739
Total Taxa - Dune	23	98	4.26087	0.928854
Total Taxa - Sandy	23	48	2.086957	0.901186
Total Taxa - Cow	23	175	7.608696	4.612648

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	365.337	3	121.779	54.33877	5.72E-20	2.708186
Within Groups	197.2174	88	2.241107			
Total	562.5543	91				

A linear regression analysis (Figure 4. and Table 3.) was performed to analyse the relationship between the mean salinity level and the mean taxon richness. The hypothesis that was tested was:

H_0: B1 = 0 (There is no linear relationship between salinity and taxon richness)

H_1: B1 $\neq$ 0 (There is a linear relationship between salinity and taxon richness)

As the P-Value (0.02) is less that the 0.05 significance level H_0 is rejected. Therefore there is significant evidence that there is a linear relationship between the mean salinity level and the mean taxon richness. The results show a negative linear relationship between the two variables; the more saline the wetland is the less families of invertebrates are present.

Table 3. Results from a linear Regression between Mean salinity and mean taxon richness.

Regression Statistics	
R Square	0.95963
Adjusted R Square	0.93944
Total number of observations	4
Mean Taxon Richness = 7.7266 – 0.1003 * Mean Salinity	
ANOVA	
P-Value	0.02039
Coefficients	
Intercept	7.72659
Mean Salinity	-0.10027

Water qualities (Table 4.) were tested at each site. Temperature and dissolved oxygen was approximately even between Dune Swamp, Sandy Cape Swamp and Cow Swamp (14-15°C and 8ppm) but was greatly increased at Town Swamp (20°C and 12.6ppm). The pH reading was also the greatest at Town Swamp. There was not much difference between the turbidity readings at all four wetlands but Cow Swamp being the least. Cow Swamp had the largest colour reading (33.25) compared to all other wetlands (between 2 and 6).

Table 4. The mean water quality readings of the four wetlands in Jurien Bay.

	Wetland			
Water Quality	**Town Swamp**	**Dune Swamp**	**Sandy Cape Swamp**	**Cow Swamp**
Temperature (°C)	**20.81**	**14.69**	**15.30**	**14.12**
Dissolved Oxygen (ppm)	**12.60**	**8.78**	**8.95**	**8.34**
pH	**8.52**	**8.30**	**7.93**	**8.09**
Turbidity (ntu)	**5.02**	**4.29**	**7.63**	**3.93**
Colour (G 440)	**5.93**	**3.63**	**2.26**	**33.25**

Comparing the similarity of the four wetlands was done using the similarity coefficients (Table 5.) The results show that the two wetlands that were the most similar in regards to taxon richness were Sandy Cape Swamp and Dune Swamp with a similarity co-efficient of 0.6. The two wetlands that were the least similar were Sandy Cape Swamp and Cow Swamp.

Table 5. Similarity Co-efficient results between the four Swamps in Jurien Bay.

	Town Swamp	Dune Swamp	Sandy Cape Swamp	Cow Swamp
Town Swamp	**1**	**-**	**-**	**-**
Dune Swamp	**0.56**	**1**	**-**	**-**
Sandy Cape Swamp	**0.52**	**0.60**	**1**	**-**
Cow Swamp	**0.47**	**0.50**	**0.41**	**1**

Discussion

The most abundant families found in Jurien Bay wetlands were Chydoridae, Ilyocriptidae and Ostracoda. The two wetlands that these were the most abundant in were Town Swamp and Dune Swamp, two of the saline wetlands. The 3 most abundant families fall under the crustacean sub phylum, which according to studies, is most tolerant to saline environments. The high count of Ilyocriptidae in Town Swamp (10,226) and Dune Swamp (3,595) could be explained by the colour theory (Growns et al. 1992). As these two wetlands were of low coloured it could explain why there is a high number of this invertebrate. Of the least abundant invertebrates found the majority of families were found in Cow Swamp, this could explained by the salinity level. Many invertebrates are not able to survive in high salinity levels and as Cow swamp is a freshwater wetland the salinity levels are a lot lower than the three other wetlands. The difference in salinity and in the taxon richness was shown in the two ANOVA tests (Table 1 and 2).

A negative linear relationship between mean salinity level and mean taxon richness concluded that as the water in a wetland becomes more saline the amount of different families in that wetland decreases. Again this is justified by the fact that all invertebrates survive in different water qualities. Some invertebrates are more tolerant to salt than others. In this case majority of families found survived better in a freshwater environment.

The water qualities of each four lakes were tested and the turbidity of Cow Swamp was the lowest which could explain why the temperature of Cow Swamp was also the lowest. As the turbidity levels increase so can the temperature (Water and Rivers Commission, 2001) as the heat cannot escape. The results do not stay true to this statement with Town Swamp and Sandy Cape Swamp as Town Swamp had the highest water temperature but the turbidity level was lower than Sandy Cape Swamp, which had the highest reading for turbidity.

The two most similar wetlands were Dune Swamp and Sandy Cape Swamp with a similarity co-efficient of 0.6. These two wetlands also had the two highest salinity readings, which would suggest why they are the most similar in taxon richness. Having a higher salinity level means a less diverse macroinvertebrate environment (Figure 4.) Sandy Cape Swamp and Cow Swamp were the least similar with a co-efficient of 0.41. Sandy cape swamp had the highest salinity level whereas Cow swamp is a freshwater wetland therefore having the least amount of salt. Again the salinity level can explain why there is a difference between two wetland’s taxon richness. Overall the results conclude that the water quality of a wetland can alter the diversity of macroinvertebrate families.

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Report 6

Salinity affected coastal wetlands, play a key role in the types of Aquatic Invertebrate communities found in Jurien Bay, Western Australia

Abstract

Aquatic invertebrate abundance and richness, as well as community dynamics; are controlled by the quality of the water (salinity, colour, turbidity, etc. of the water in coastal wetlands), which is further influenced by climate factors, human and tourism use impacts on Jurien Bay. The proximity to the coast is one of the main causes of salinity levels of the wetlands; potentially altering the compositing of invertebrate communities. We used a sampling net along a ten metre transect to stir up the substrate which collect the invertebrates. Repeating this three times in four different wetlands; we grouped the invertebrates, identified them and analysed the patterns. What was found was higher salinity levels in wetlands with closer proximity to the coast, and this is turn influenced a lower aquatic invertebrate diversity and richness. Further research is needed to be focused on aquatic invertebrate ecosystems and their adaptations of the regulation of salt.

Introduction

Jurien Bay is a coastal town located in the Wheatbelt region of Western Australia, 220 kilometres north of Perth facing the Indian Ocean (Holloway, 2006). Jurien Bay is a warm, Mediterranean Climate, with seasonal rainfall usually in the winter, and sometimes receiving storm cells of cyclones further up north in Western Australia (Holloway, 2006). The fast growing economy based on fishing, aquaculture and tourism, and its close distance to Perth and a popular holiday destination; there has been a lot of urban development and human impact pressure on the current natural environment (Holloway, 2006). Due to the close proximity to the coast, one of the most direct influences to the biodiversity of flora and fauna found in Jurien Bay is salinity. In particular, there is little diversity and richness in aquatic invertebrate taxa found in Jurien Bay's local wetlands (Growns JE, 1992). Salinity is a factor that is of some significant importance to the balance of the ecological world (MA, 1985). It influences the type of organisms that live in a body of water, and their ability and adaptation to the amount of salt their body can tolerate (MA, 1985). Salinity is the amount of dissolved salt content in a body of water, and influences the types of plants that grow in a body of water: therefore directly influencing the type of organisms that share that water body that the plants live in (Sim LL, 2013). Aquatic invertebrates have different salt tolerances, many species such as the Culicidae, or mosquito larvae have no choice to intake salt ions during absorption of nutrients, so therefore osmoregulation allows for the excretion of salts (Bunn SE, 1992). Continuous flowing water replenishes the water body with oxygen and nutrients, adding a high amount of dissolved oxygen, and increases habitat diversity (LE, 1987). Several taxa are adapted to maintaining their position, and filter-feeders can take use of incoming water currents for food, using little energy (Wallace, 1996). However, this is not the case for wetlands in Jurien Bay. These wetlands, depending on how deep or shallow the water is, are only rarely replenished by seasonal rain (Holloway, 2006). The rest of the year, the water is still and food sources run low. Plants and animals only have a specific tolerance to salt content in a body of water, and so this adds to the pressure of survival rates and animal diversity found in each wetland.

Using a sampling method to comprise a quantitative description of the invertebrate fauna and water quality factors of four different coastal wetlands; together will answer the aim of this paper to examine how salinity influences the invertebrate communities of coastal wetlands located in Jurien Bay, Western Australia.

Methods

Study Sites

The 4 wetlands chosen for this study were representative of the different water quality statuses and biodiversity hotspots known to be located in the wetlands of the coastal area of Jurien Bay. Three locations were chosen to contain saline wetlands, Town Swamp (-30.20945 S, 115.00778 E), Dune Lake (-30.207632 E, 115.010183 S) and Sandy Cape Lake (-30.290504 S, 115.052202 E). And one final freshwater wetland; Cow Swamp (-30.254988 S, 115.150157 E). Town Swamp was surrounded by thick, low lying scrub of saltbush that covers about 34% of the wetland. Shallow water, islands of higher land in the centre, intermittent, human impacted during the summer due dried up water, there isn't much shade or wind protection, sandy and muddy substrate. Dune Lake is a small, saline lake that is also intermittent (dries during summer). There is a large, high rise sand dune on the south east end of the wetland, but the western side isn't protected on the western side. Shallow water, surrounded by salt bush, Indian Ocean to the west, contains a clay-type substrate, and there is a dirt road on the north side but contributes minimal human impact, and groundwater contributes to the water level. Sandy Cape Lake, which is located near a Gypsum mine to the North West. It is characterised by its shallow, extremely saline water; surrounded by dense saltbush also with islands of vegetation throughout the middle, very windy with little wind protection, sandy, and there is wave foam that forms on the southern end. The freshwater wetland of Cow Swamp has very deep water, and dense assemblages of Melaleuca surrounding the majority of the edge of the wetland. The wetland is in a livestock area, so it is impacted by cow manure and trampling.

Physiochemical variables

Three 10 meter transect sweep sites were conducted at each wetland. Each one was approximately five metres further out than each other; from the shore of the wetland. With the three different sweep sampling sites, the water testing could be recorded and repeated 3 times to calculate an average of the overall wetland. These water samples were taken to the laboratory and recorded for temperature, in degrees Celsius. Dissolved oxygen, measured as parts per million. pH, salinity measured in milli siemens. Also, one sample of water was taken from each wetland to calculate an average over all three transect samples, which was measured for Turbidity (NTU – Nephrelometric Turbidity Units), and Colour (Gilvin; A=440nm). Since there were three transect samples over each of the four wetlands, this allowed for analyses replicated three time for each wetland to reduce the risk of loss of a sample. The condition of each wetland was determined from the totals of conductivity, dissolved oxygen, pH, temperature, colour and turbidity.

Aquatic Invertebrates

The aquatic invertebrate samples were collected with a long length sweep net. The net was used to stir up any invertebrates from the surface of the substrate through the water column, moving the net up and down, over a transect line of ten metres. Three different sweeps were collected along a transect extending from the area of the wetland with the most vegetation, about approximately 5 – 10 metres outwards towards the middle of the wetland which was just outside the shallow waters with the most aquatic vegetation, and finally another approximately 5 – 10 metres further out in the middle of the wetland with a much clearer water column and less aquatic vegetation.

Once each individual sweep was collected, the sampled were processed in the field by placing the contents of the net into a white tray. The invertebrates were washed through the net with one litre of water collected from the surface of the water column from that wetland.

The sorting tray was searched and the invertebrates were split into two groups according to their sizes. The macroinvertebrates and the microinvertebrates. The macros were identified to being larger than 1 – 2 cm, and anything smaller in length were the micros. The macroinvertebrates were collected individually and places in a vial with 70% ethanol. The remaining microinvertebrates were reduced in their numbers using a sample splitter down to 1/16 and 1/32, and then placed in a separate vial with 70% ethanol. This was repeated three times, with the three different transects throughout the four individual wetlands. That's twelve sweeps in total, and 24 samples of invertebrates; 12 macro and 12 micro. All invertebrates in the samples were identified to family level and counted using stereomicroscopes and available keys. The microinvertebrate sub-samples were multiplied by how many times the sample was split in the field (either by 1/16 or 1/32). Results were expressed as number of animals per 10 metre transect.

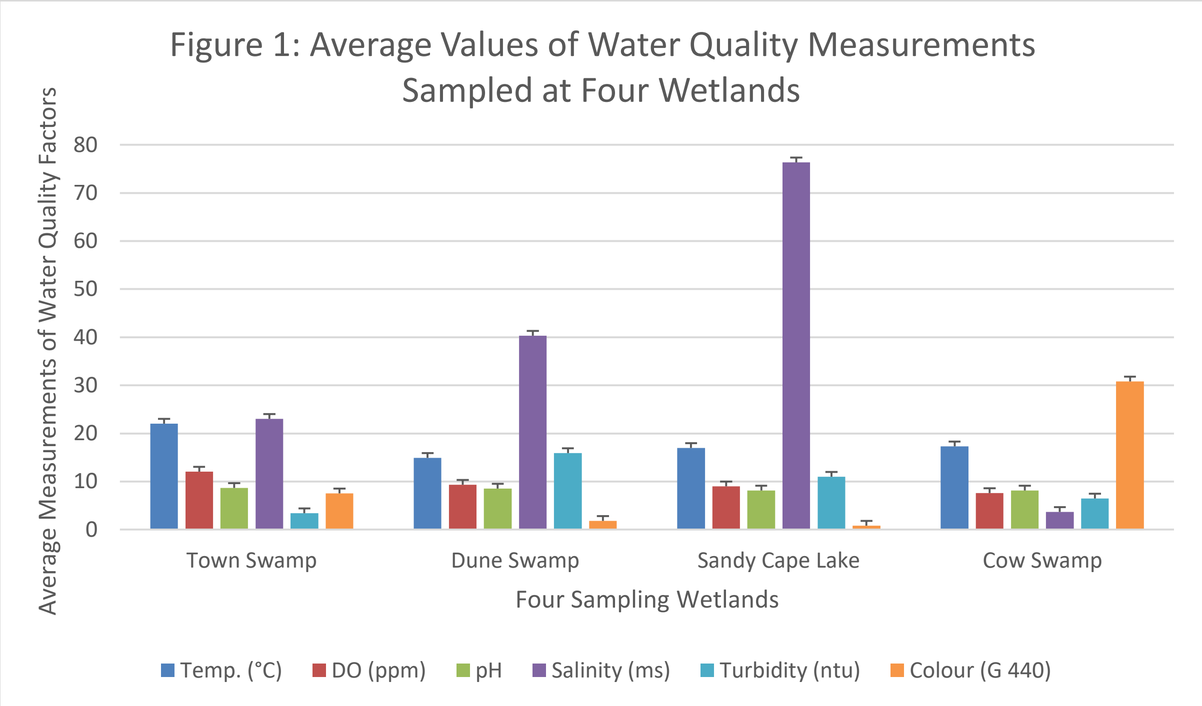
Data Analysis

The numbers of different micro and macroinvertebrate family groups were entered into Excel spreadsheets and compared across the four different wetlands in concern to what invertebrates were found in what wetlands, and more importantly the number of taxa found in each wetland. The number of taxa and abundance was then compared between groupings of the four wetlands on the basis of water quality indices that determine how salinity affected the wetland is.

Results

Water Quality

Figure 1, showing the average values taken from 12 samples of water quality measurements from each of the four wetlands. Data are means ± standard error.



Figures compare the water quality values between each sampling wetland. Figure 1 gives a summary of comparing averages in water quality, represented in a bar graph. As shown, the measurements of temperatures stay about the same for the four wetlands, roughly staying around the values of 15 to 20 degrees Celsius. Dissolved oxygen for all of the wetlands also stay at roughly 10 parts per million, as well as pH staying at around about the same value of 10 for all of the four sampled wetlands. However values changed when it came to measuring salinity, turbidity and colour. Salinity rapidly decreased in each wetland that got closer to the coast of Jurien Bay, from roughly 25 to 80 milli siemens moving from the sampling sites of Town Swamp, Dune Lake and then Sandy Cape Lake. However once we moved further inland and away from the coast to the sampling site of Cow Swamp, the salinity average measurement of the water rapidly decreased to roughly less than 15 milli siemens. Average measurements for turbidity were the lowest for the sampling sites of Town Swamp and Cow Swamp. Colour measured to be very low values for Town Swamp, and Dune and Sandy Cape Lakes, and then significantly higher at Cow Swamp.

Taxon Richness

Figure 4: The mean counted aquatic invertebrate taxa sampled at the four wetlands. Data are means ± 1 standard error.

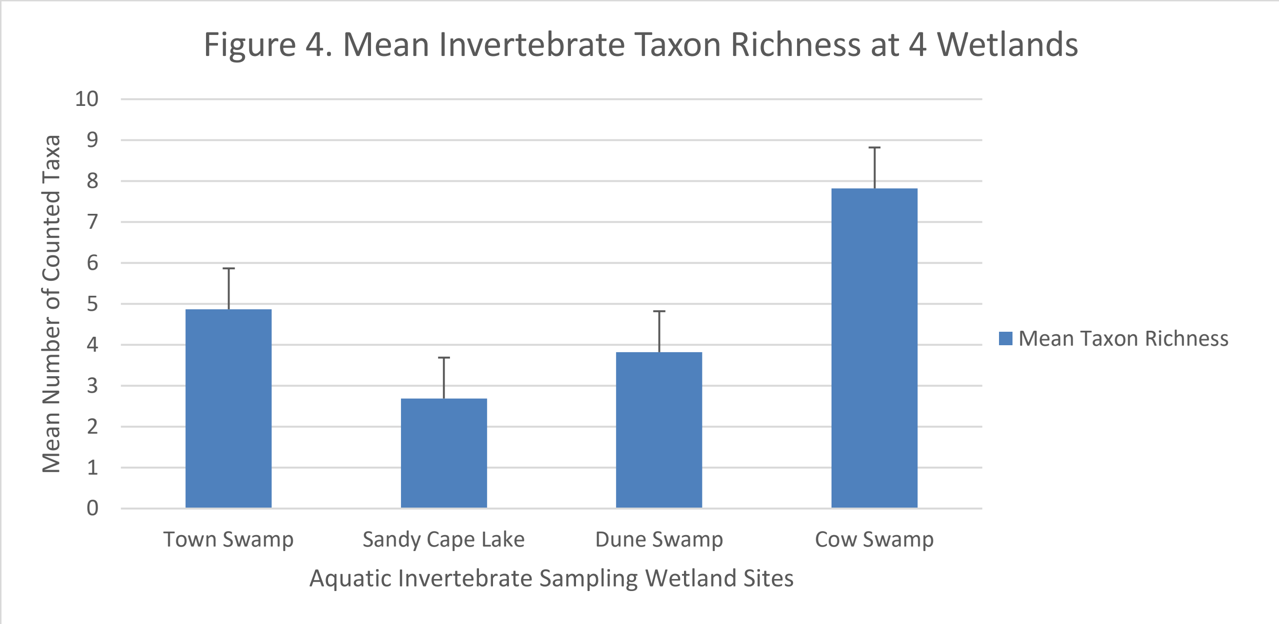
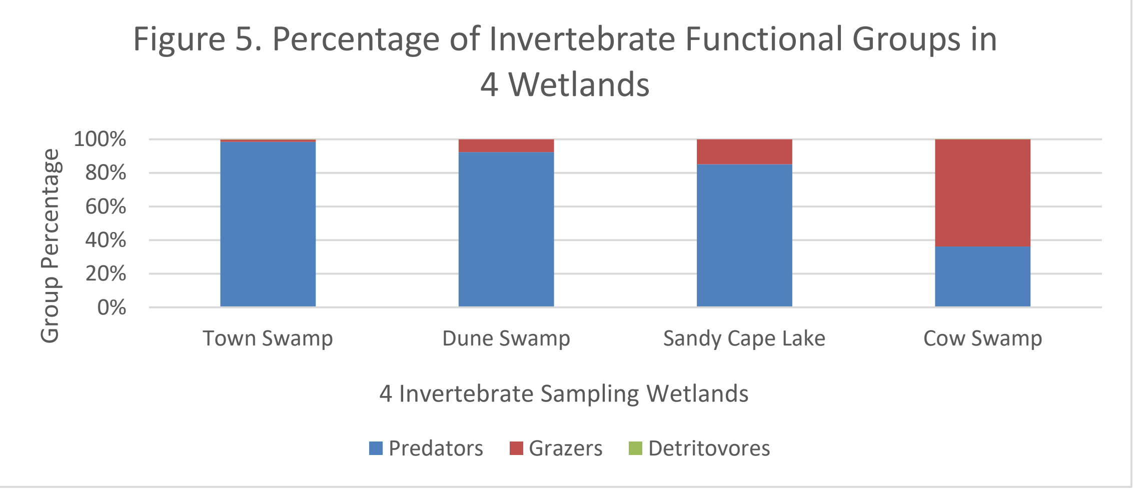


Figure 4 shows, that during our sampling methods, we repeated several tests of counting how many aquatic invertebrate families were recorded being found at each of the four wetlands. Out of all of the four wetlands, there were 21 recorded invertebrate families sampled. Along with identifying what aquatic invertebrate families were found and counting how many were in each sample, we noted down how many of the group of families occurred in each wetland. From this we could see how rich the invertebrate taxa is in each of the wetlands. Town swamp was moderately taxa rich with up to 5 different aquatic invertebrate families found. That richness started to decrease as we moved closer to the coast at sites Sandy Cape Lake and Dune Swamp, being less than 5 taxa groups found. The richness rapidly increased as we moved to the inland site of Cow Swamp, where the aquatic invertebrate count was about 8 families found, and showing the difference in taxa richness.

Functional Groups

Figure 5: Aquatic Invertebrates grouped into their functional groups and what percentage they made up in each wetland.



During our sampling of the aquatic invertebrates, they were placed into functional groups of predators, grazers and detritovores. The numbers were counted and processed how much of that group made up each wetland, and turned it into a percentage. As shown in figure 5, as you move from Town Swamp to Cow Swamp, the percentage of predators becomes less, from over 90% to less than 40%. As the predators dropped the percentage of grazers rapidly increased from less than 10% to nearly 70%. There is very little eveness in functional group percentage, apart from Cow Swamp which shows the greatest eveness in functional groups that make up that wetland.

Aquatic Invertebrates

Figures 6 to 10, show the counted mean abundance of aquatic invertebrate families sampled at four wetland sites. Each figure has a shorter y-axis scale, portraying the larger diversity of numbers in invertebrate families. The maximum scale numbers on each figure go down from 6500, 3000, 1000, 500 and 100. Means are ± standard error.

Figure 6. Mean Abundance of Invertebrate Family Numbers at Four Wetland Sampling Sites

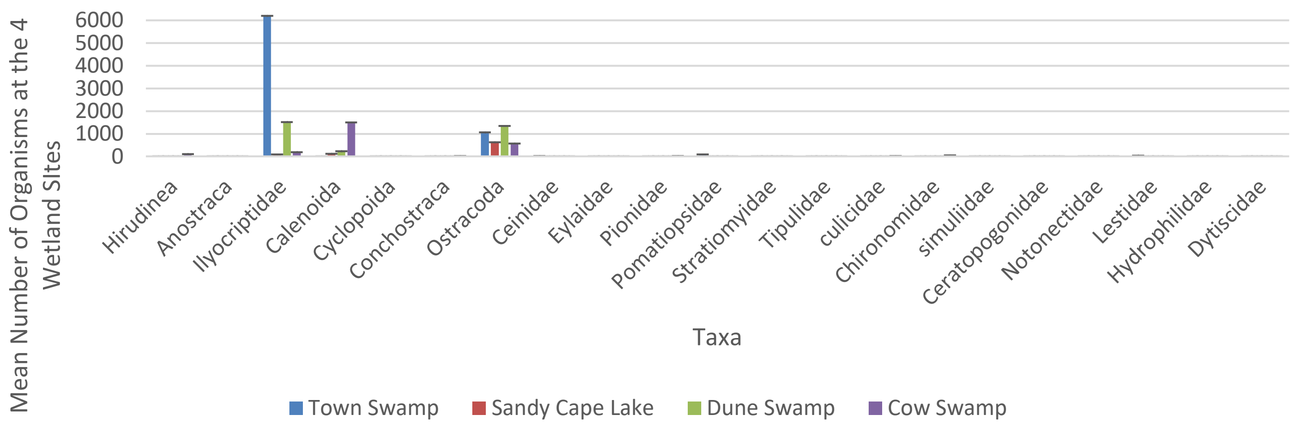


Figure 7. Mean Abundance of Invertebrate Family Numbers at Four Wetland Sampling Sites

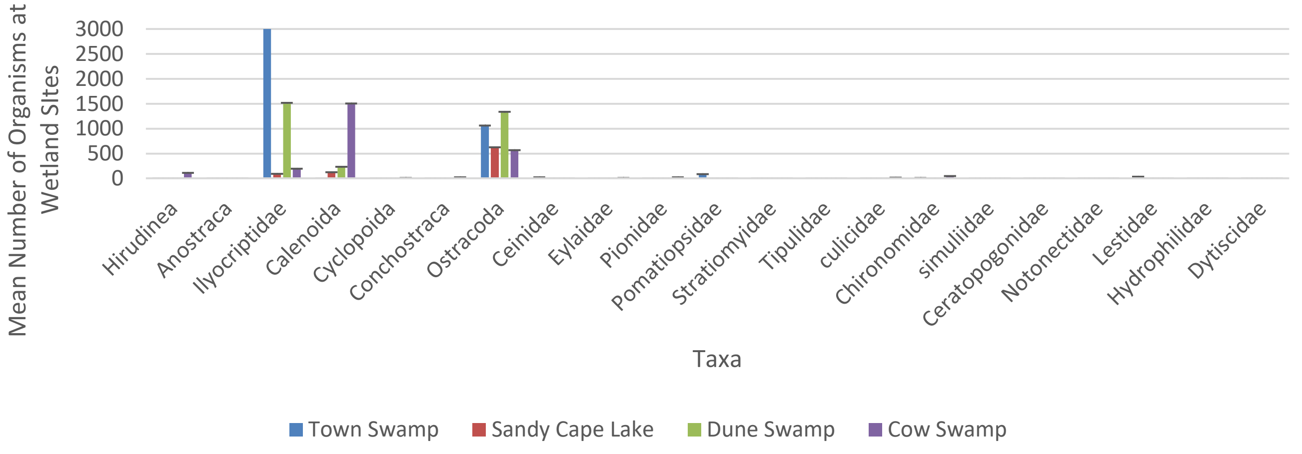


Figure 8. Mean Abundance of Invertebrate Family Numbers at Four Wetland Sampling Sites

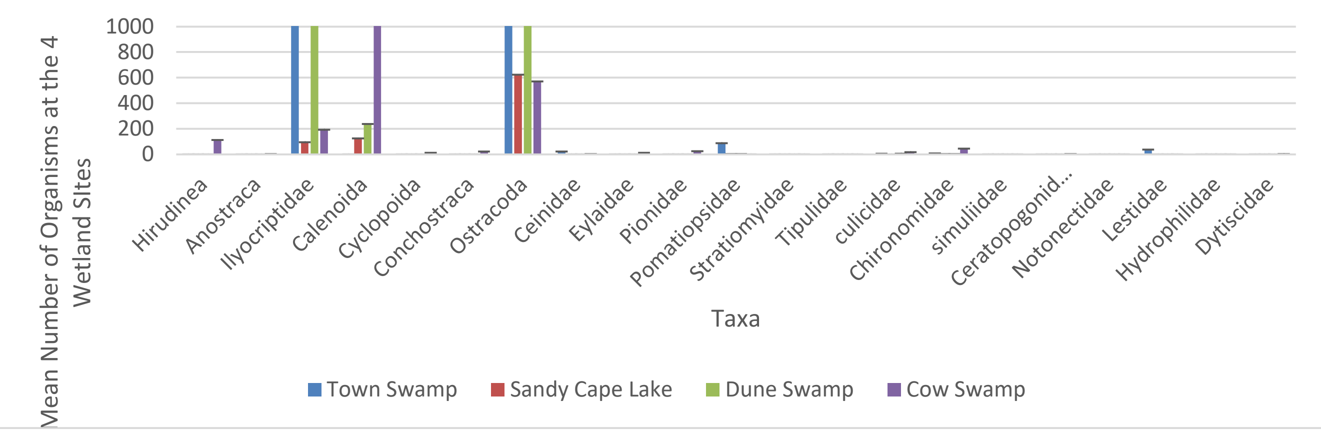


Figure 9. Mean Abundance of Invertebrate Family Numbers at Four Wetland Sampling Sites

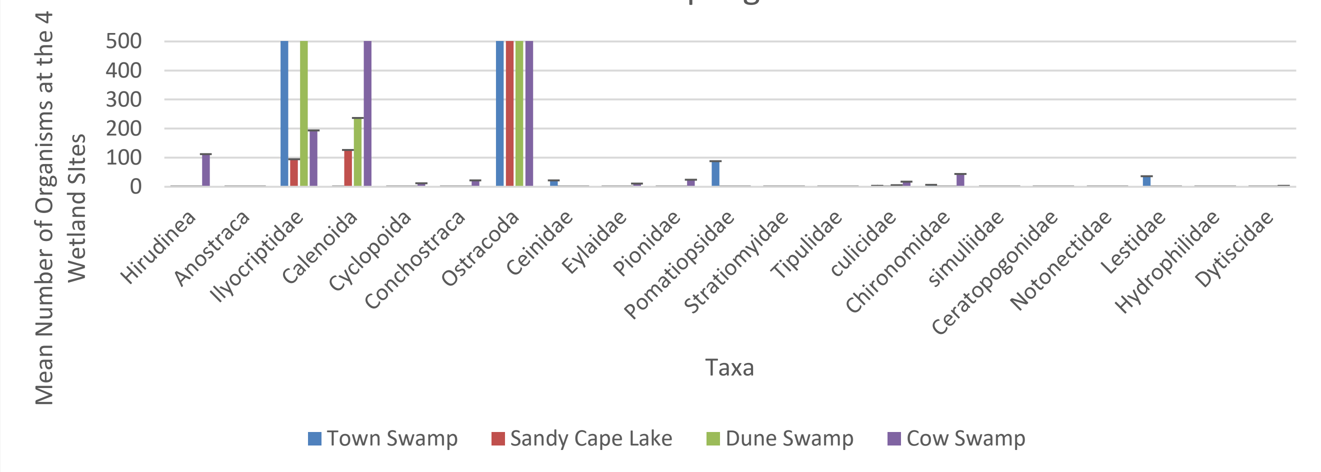
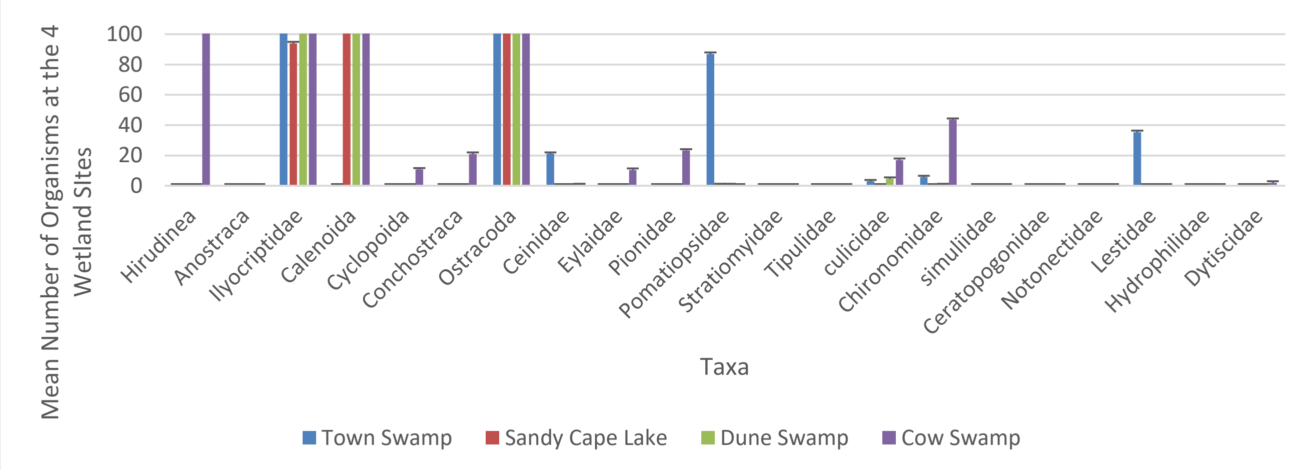


Figure 10. Mean Abundance of Invertebrate Family Numbers at Four Wetland Sampling Sites



The figures above show an overall representation of the types of invertebrates that were sampled in the four wetlands and their occurrence in the other types of wetlands; so their average abundance out of the four sampled wetlands. As seen above, each wetland was different in terms of water quality and salinity. Each invertebrate family was faced with different salinity challenges depending on which wetlands they lived in. Out of 24 repeated invertebrate samples of identification and counting for each wetlands, 21 different aquatic invertebrate families were identified throughout the four wetlands. The figures were repeated five times in the results because the average numbers counted for each family were very high compared to lower numbers counted for different families found in different wetlands. In other words, there were higher densities for a particular aquatic invertebrate found in one wetland, and it wasn't the same occurrence for other species. This example is shown in figure 6, where the Scruds (Ilyocrptida) reached a maximum count of nearly 6500 in the Town Swamp, and were found in significantly lower numbers of about 1500 in Dune Swamp and then far lower numbers below 1000 found in Sandy Cape Lake and Cow Swamp. Looking at the figure representing the bigger picture, it is noticeable that the Calenoida and the Ostracoda have numbers almost reaching numbers 1500, again showing high aquatic invertebrate density but low abundance and diversity. The other four figures, (7, 8, 9 and 10) are merely just to show the abundance of the low numbers of aquatic invertebrates, and the diversity of organisms in each wetland. It is really at figure 10 where you can clearly identify the differences in invertebrate abundance between wetlands. Cow Swamp received the highest abundance of organisms, with numbers (mostly small numbers) in almost every sampled family, except for the Crane Fly (Tipulidae) and the Damselfly (Lestidae). Cow Swamp was identified containing an abundance of aquatic invertebrates with low densities and high diversity. However with Town Swamp, Dune Lake and Sandy Cape Lake; there wasn't a high abundance of invertebrate families. The figures 7 to 9 show that those wetlands either had a very high or very low density for only a small number of aquatic invertebrate families. This shows the wetlands low richness, diversity and evenness.

Discussion

The aim of this paper was to investigate how salinity influences the aquatic invertebrate communities of coastal wetlands off Jurien Bay, Western Australia. We collected several groups of data to draw relationships between the quality of the water; and the aquatic invertebrate abundance, diversity and richness of each of the four coastal wetlands. Salinity does have an effect on aquatic invertebrates and community structure (SA, 1981). From our water quality measurements, we found that there were higher salinity levels in Sandy Cape Lake. And then significantly lower levels in Cow Swamp. This reflects on the fact that Sandy Cape Lake has a closer proximity to the shore of Jurien Bay, and there is less protection from weathering and terrestrial plants to absorb water. This is also the explanation of the little colour found in Sandy Cape Lake, compared that with a higher absorption coefficient in Cow Swamp. Taxon richness calculations was simply counting the number of families of aquatic invertebrates found in each wetland. The lowest richness was found in Sandy Cape Lake, followed by the highest found in Cow Swamp. This follows on from the salinity measurements and its influences on aquatic invertebrates. Sandy Cape Lake which had the highest salinity reading, had the lowest count in taxon richness, this may be due to the fact that some aquatic organisms don't have the adaptations to regulate salt concentrations throughout their bodies. Cow Swamp with the lowest salinity reading contained the highest taxon richness. The aquatic invertebrates were identified into functional groups of predators, detritivores and grazers to look at community structure. Moving from Town Swamp to Sandy Cape Lake with the increasing salinity levels, one group would significantly outnumber the other, usually the predators. Moving to Cow Swamp with lower salinity meant a more even distribution of invertebrate groups. Through more calculations, this was not as expected due to bad research. The results should have been found differently in a sense that there should have been a higher count in detritivores and a more even amount of each group for Cow Swamp. However the low numbers of grazers in Sandy Cape Lake was expected due to the salt content causing a shortage of food for grazers. We counted the number of each invertebrate family from 24 repeated samples and calculated averages of each family from each wetland. What was found was there to be a high density of one or two families in the one lake, and then an even low count of almost all the invertebrate families in another lake, which was Cow Swamp with the lowest salinity levels. There was a higher density in Town Swamp and lower in Cow Swamp which overall had the greatest diversity and invertebrate abundance. However the results were hard to calculate due to the fact that the minimum and maximum of average counts of invertebrates were so far apart. In other words, there were either high density or very low densities of invertebrates. The graph was visually hard to compare. However the higher diversity in Cow Swamp was a good indicator of high biodiversity due to less salinity in the wetland.

The general frequency throughout the results is in agreement that salinity influences aquatic invertebrates in coastal wetlands; the higher the salinity content decreases the average number of families and the diversity of invertebrates (Comission, 2001). Some results were out of expected range, this would be due to incorrect sampling methods and a poor calculation of statistical outputs. The limitations of this research included factors like uneven sampling due to the study site already been human impacted on by trampling, little data recorded about the study site and its surroundings, the water being washed through the invertebrates was taken from the wetland and may have contained more invertebrates. There was dirt and other particulates in our sampling tray and macro invertebrates could have been missed. During identifying, the invertebrates could have been miscounted. The main issue of this paper was due to the fact that I had no group members working on it with me, I didn't have enough time to research enough to calculate more statistical outputs and summary data to strongly support my argument. And more accurately there wasn't enough maximum words to give more details about salinity and more specifically the invertebrates themselves. More time needs to be put into more background knowledge and statistical data summaries.

Conclusion

The type of function and salt tolerance levels of each family of sampled invertebrate was not well understood for this paper. However the findings of this paper can conclude that aquatic invertebrates found in Jurien Bay wetlands do not have a high tolerance to salinity, because salinity is one of the causes of their diversity and abundance. The high salinity wetlands tended to have invertebrates locate in high densities to find food. Whereas the lower salinity wetlands had a more even numbered distribution of invertebrates with higher taxon diversity and richness, due to better water quality leading to more food. The implications were simply uneven data due to the site already previously sampled and not enough knowledge on aquatic invertebrate families and statistical analysis. More relationships need to be drawn to invertebrate communities and salinity.

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Report 7

Investigating the link between salinity and macroinvertebrate richness in wetlands surrounding Jurien Bay

Abstract

Due to an old and flat landscape, the soils and subsequently the wetlands of south-west of Western Australia have become progressively more saline. The salinity in the water bodies and a variety of other abiotic environmental factors have forced its inhabitants to become more tolerant to these variables. This paper will explore whether different salinity levels affect the species diversity and/or richness of the macroinvertebrate community within wetlands.

Macroinvertebrates and water quality measurements were sampled at 4 wetlands near Jurien Bay, Western Australia, in August 2015. Using statistical analysis, comparisons of species diversity were made among the wetlands. Correlations between water quality parameters and the macroinvertebrate community were hypothesized, and a linear regression between salinity and the mean species diversity was calculated.

The species diversity and richness varied greatly among the wetlands. A negative correlation between salinity and the mean of species taxa found was apparent, whilst other water quality parameters did not appear to have any obvious effects on species diversity. The most taxa of macroinvertebrates were found in the freshwater wetland. The most saline water body was, correspondingly, the least diverse. Furthermore, the data suggests that the highest species richness can be found in moderately saline wetlands. Salinity levels therefore do affect macroinvertebrate communities in wetlands. The more saline the water body, the lower the species diversity and the higher the species richness.

Introduction

Salinity is a major factor affecting the flora and fauna in south west Western Australia (SWWA). Salt has accumulated in the soil profiles and the groundwater in SWWA for hundreds of thousands of years due to its old and flat landscape (Halse *et al.* 2004). In the semi-arid inland regions, deposits of aerosol marine salt resulted in an even more saline soil profile, as the evapotranspiration greatly exceeds the precipitation in these areas (Bunn & Davies 1992; Pinder *et al.* 2004). The increased soil salinity subsequently contributed to the inland wetlands to become progressively saline. The historical prevalence of natural salt in the wetlands of SWWA eventuated in unique ecosystems with endemic, more salt tolerant flora and fauna, however, increased secondary salinisation has resulted in associated loss of freshwater habitats and biodiversity (Halse *et al.* 2004). Climate change is an additional factor which is very likely to cause further loss of wetlands, especially temporary wetlands as they rely on the weather conditions and rainfall (Sim *et al.* 2013). Although wetlands in SWWA display a higher degree of endemism compared with similar ecosystems elsewhere, their biota is largely determined by fluctuation of salinity and permanence (Brock 1985). As many of the wetlands in SWWA are intermittent, the inhabitant flora and fauna, particularly macroinvertebrates which assist in maintaining the water quality of a wetland (Chambers & Davis, 1989), have become tolerant to more variable environmental conditions (Water and Rivers Commission, 2001).

The coastal wetlands of Jurien Bay create important ecosystems that contain an enormous diversity of aquatic macroinvertebrates (Pinder *et al.* 2004), over 1000 aquatic species were identified in a study conducted by Halse *et al.* in the Wheatbelt region (2004). The Mediterranean climate in the region, characterised by dry, hot summers and mild, wet winters, imposes a seasonal pattern on the aquatic fauna, and generates high community persistence (Bunn & Davies 1992). Periods of wetland drying are associated with increased salinity, forcing less tolerable species to disperse, or to become dormant during periods of drought (Sim *et al.* 2013). In general, wetlands with high salinity have low species diversity (Brock 1985, Halse *et al.* 2004). The purpose of this paper is to determine if salinity is a limiting factor on the diversity of macroinvertebrate communities in wetlands near Jurien Bay.

Methods

Sampling sites

Quantitative sampling of macroinvertebrates was limited to four sites near Jurien Bay: Town Swamp, Sandy Cape Lake, Dune Swamp, and Cow Swamp, the only perennial and freshwater wetland sampled.

Town Swamp is a shallow water body, with sandy substrate and filled with silt. It is surrounded by salt bushes (for about one metre from the water) and taller shrubs, providing habitat for a lot of aquatic birds, for example silver gulls, stilts and ducks. Town Swamp used to be a dump site for the town. An old car wreck in the middle and a lot of rubbish inside the water are evidence for past and present human disturbance.

The water in Sandy Cape Lake is very shallow and clear. Its substrate is dominated by sand (1-4mm) and silt (<1mm). Large formations of salt crystals were dispersed inside the water and along the shoreline. Salt tolerant succulents immediately surrounded the water (for about one metre) before a variety of native shrubs started to dominate. Human disturbance in the area is evident, ranging from pollution to a large gypsum mine north of the sampling area.

The shallow water at Dune Swamp contains fine clays and silt with a lot of fine, “hair like” algae. Salt bush and other low lying shrubs surround the wetland on a substrate that is a combination of clay, silt (<1 mm) and sand (1-4 mm), saturated with water. Approximately five metres away from the shore, the ground is drier, and native bushes become the dominant feature of the landscape. A number of aquatic birds were present at the time of sampling. Human disturbance (e.g. pollution and old oyster racks from oyster farming) were obvious, but not abundant.

Cow Swamp is a quite deep perennial wetland, filled with muddy clay. The water is stained due to the wetland’s fringing vegetation which mainly consists of small, low lying melaleucas. The trees and their partially or fully submerged roots provide shade and habitat for aquatic fauna as well as small birds.

Figure 3 and 4: Images of Sandy Cape Lake (sources: Google Earth (figure 3) and M. DeGuzman (figure 4))

Figure 5 and 6: Images of Dune Swamp (sources: Google Earth (figure 5) and K. Horley (figure 6))

Wetland	Latitude	Longitude
Town Swamp	-30.290504	115.052202
Sandy Cape Lake	-30.207632	115.010183
Dune Swamp	-30.20945	115.00778
Cow Swamp	-30.254988	115.150157

Sampling of macroinvertebrates

The four wetlands were sampled for macroinvertebrates at one occasion only, in August 2015. Semi-qualitative samples were taken randomly by 22 students (n=22), each student collecting one sweep sample at all four wetlands. Macroinvertebrates were collected by vigorously moving a sweep net up and down the water column along a 10 m transect. Using 1 litre of water, the contents of the net were emptied into a sorting tray. All organism above 2 mm were removed and placed in a vial using a spoon or pipette. A splitter bucket was then used to reduce the sample to 1/16 or 1/32 which was then poured into a separate vial. Both vials were filled up with 70% ethanol and taken to the laboratory where the macroinvertebrates were identified to family level, with the exception of Ostracoda which were identified to subclass level only (for the purpose of this study Ostracoda will be referred to as a family). The number of individuals of each family were counted, either by counting the larger samples directly, or by multiplying up the sub sample (by how many time it was split before), and recorded.

Water quality

Water temperatures and measurements for dissolved oxygen were recorded at each wetland (3 measurements per student, calculated into a mean). Further water samples were taken from the wetlands to the laboratory where the pH, salinity, turbidity, and colour of the samples were measured and recorded.

Analysis of data

Mean values and standard deviations of the temperature, dissolved oxygen, pH, salinity, turbidity and colour of the water were calculated for each wetland. The mean and the total number of families, as well as the total abundance of each family were also calculated for all sites, enabling the determination of the similarity coefficients between wetlands (similarity = [2 x (families in both wetlands)] / [(families in wetland 1) + (families in wetland 2)]. A t-Test, ANOVA, and linear regression have been carried out to determine differences and correlation between the wetlands, the mean taxa found, and the salinity at each wetland.

Results

Water quality

The means and standard deviations of the water quality parameters from the four sampled wetlands are given in table 1 (talking about any water quality data will refer to these mean values unless stated otherwise). Except for the pH which was similar at all wetlands, ranging from 8.11 at Cow Swamp to 8.68 at Town Swamp, all parameters showed considerable variation among the sampled sites. The most significant difference between the wetlands was the salinity. Sandy Cape Lake was the most saline (76.33 ms) and Cow Swamp was the least saline (3.67 ms). Another remarkable variation was seen with the water colour due to Gilvin (measured at 440 nm), ranging from 0.81 at Sandy Cape Lake o 30.8 at Cow Swamp. Temperature ranged from 14.93 °C at Dune Swamp to 22.01 °C at Town Swamp, dissolved oxygen (DO) ranged from 7.63 ppm at Cow Swamp to 12.05 ppm at Town Swamp, and turbidity ranged from 3.41 ntu at Town Swamp to 15.91 ntu at Dune Swamp. Although the data does not indicate any correlation between the water quality parameters, it suggests that Sandy Cape Lake and Dune Swamp are the most similar in regards to their water chemistry.

Table 1: Mean and standard deviation for water quality parameters in 4 sampled wetlands (n=22) (sampled in August 2015 near Jurien Bay, WA); Units: Temperature (°C), Dissolved oxygen (DO) (ppm), Salinity (ms), Turbidity (ntu), Colour (G 440 nm)

	Town Swamp	Sandy Cape Lake	Dune Swamp	Cow Swamp
Temperature				
$\bar{x} \pm SD$	22.01 ± 3.48	16.97 ± 3.08	14.93 ± 2.69	17.34 ± 3.75
DO				
$\bar{x} \pm SD$	12.05 ± 2.83	9.01 ± 1.55	9.31 ± 1.88	7.63 ± 1.52
pH				
$\bar{x} \pm SD$	8.68 ± 0.21	8.13 ± 0.23	8.52 ± 0.19	8.11 ± 0.18
Salinity				
$\bar{x} \pm SD$	23.01 ± 4.86	76.33 ± 11.27	40.30 ± 7.91	3.67 ± 0.34
Turbidity				
$\bar{x} \pm SD$	3.41 ± 1.30	11.00 ± 1.96	15.91 ± 6.57	6.48 ± 5.10
Colour				
$\bar{x} \pm SD$	7.52 ± 1.88	0.81 ± 0.52	1.80 ± 0.82	30.80 ± 0.46

Macroinvertebrate fauna

A total of 21 macroinvertebrate taxa were collected from the four sampled sites (Table 2). The mean taxa found were significantly different in each wetland ($P < 0.001$; table 3). The most taxa were found at Cow Swamp where 19 families were identified. Sandy Cape Lake and Dune Swamp where a total of 7 families were found, were the least diverse. However, Town Swamp only showed a slightly higher diversity with a total of 9 collected families. The similarity coefficients between the sampled wetlands suggest that Sandy Cape Lake and Dune Swamp are the most similar in regards to the same type of families found within each. At the same time, both are the most different in contrast to the Cow Swamp (table 4).

Table 2: Mean Abundance of macroinvertebrate taxa for four wetlands sampled in August 2015 near Jurien Bay, WA

		Town Swamp	Sandy Cape Lake	Dune Swamp	Cow Swamp
	Total No. of taxa	9	7	7	19
Annelida	Hirudinea	0.00	0.00	0.00	111.32
Crustacea	Anostraca	0.05	0.00	0.00	0.14
	Ilyocriptidae	6545.91	93.86	1516.00	192.59
	Calenoida	0.00	125.18	235.82	1507.91
	Cyclopoida	0.00	0.00	0.00	10.71
	Conchostraca	0.00	0.00	0.00	21.00
	Ostracoda	1116.91	621.86	1339.86	569.14
	Ceinidae	21.09	0.00	0.00	0.27
Arachnida	Eylaidae	0.00	0.00	0.00	10.36
	Pionidae	0.00	0.00	0.00	23.18
Mollusca	Pomatiopsidae	86.86	0.27	0.32	0.05
Insecta	Stratiomyidae	0.05	0.00	0.00	0.05
	Tipulidae	0.00	0.00	0.05	0.00
	Culicidae	2.91	0.05	4.59	17.00
	Chironomidae	5.68	0.09	0.27	43.50
	Simuliidae	0.00	0.00	0.00	0.09
	Ceratopogonidae	0.00	0.00	0.00	0.18
	Notonectidae	0.00	0.00	0.00	0.05
	Lestidae	35.41	0.05	0.00	0.00
	Hydrophilidae	0.00	0.00	0.00	0.09
	Dytiscidae	0.00	0.00	0.00	1.91

Table 3: Results of one-sample t-Test (SPSS) between the mean taxa found at each wetland sampled (sampled in August 2015 near Jurien Bay, WA)

Wetland	n	Mean No. of taxa	T	Significance
Town Swamp	22	4.95	19.791	0.000
Sandy Cape Lake	22	2.64	17.015	0.000
Dune Swamp	22	3.86	23.404	0.000
Cow Swamp	22	7.82	24.441	0.000

Table 4: Similarity coefficients of families found in 4 sampled wetlands (sampled in August 2015 near Jurien Bay, WA)

	Town Swamp	Sandy Cape Lake	Dune Swamp	Cow Swamp
Town Swamp	1			
Sandy Cape Lake	0.750	1		
Dune Swamp	0.625	0.857	1	
Cow Swamp	0.571	0.462	0.462	1

Linear regression analysis (SPSS) showed a negative correlation between salinity and the mean taxa found at the sampled wetlands, the higher the salinity of a wetland, the lower the mean of the total macroinvertebrate taxa (figure 9). The mean taxa found at each site varied significantly when compared with the salinity in each wetland (ANOVA: $F_{3, 84} = 90.573$; $P < 0.001$)

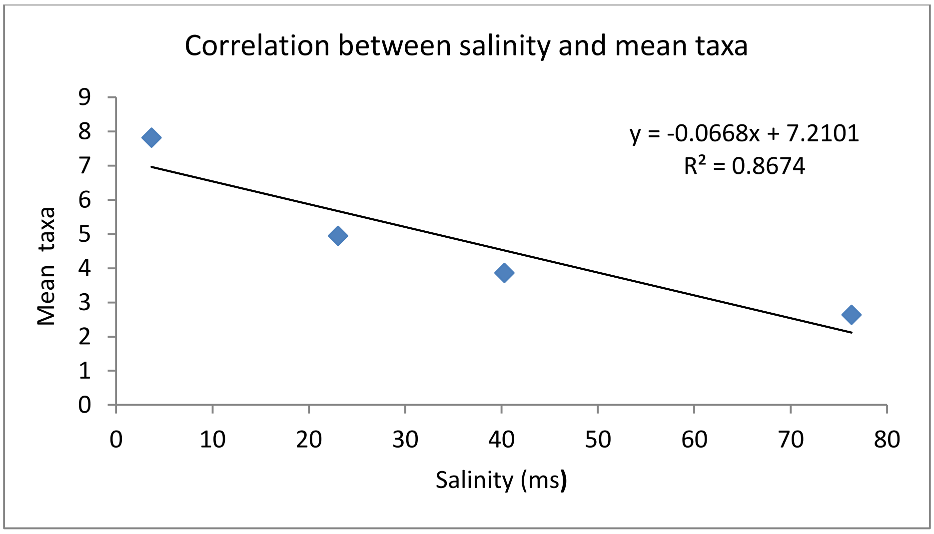

Figure 9: Correlation between the salinity and the mean of the total taxa found in each wetland (sampled in August 2015 near Jurien Bay, WA)

Further calculations showed that the mean abundance of each family varied substantially amongst the wetlands (table 2). Compared to the other three wetlands, Cow Swamp had the highest species abundance in general (figure 10 and figure 11). The crustaceans were most abundant in Town Swamp and Dune Swamp which were moderately saline wetlands, but less abundant in Sandy Cape Lake, the most saline water body sampled. Most insects and arachnids, the least abundant taxa overall, were found at the freshwater Cow Swamp. In general, it is apparent that the saline water bodies were less diverse, but tended to have higher species richness.

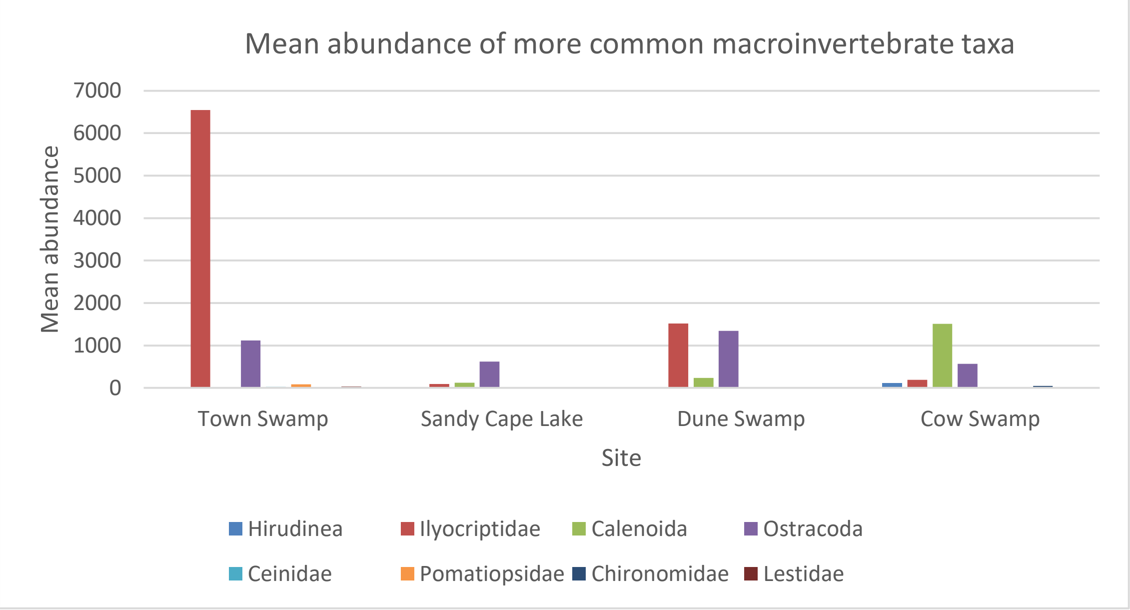

Figure 10: Mean abundance of more common macroinvertebrate taxa, sampled at four wetlands (Town Swamp, Sandy Cape Lake, Dune Swamp and Cow Swamp) in August 2015 near Jurien Bay, WA

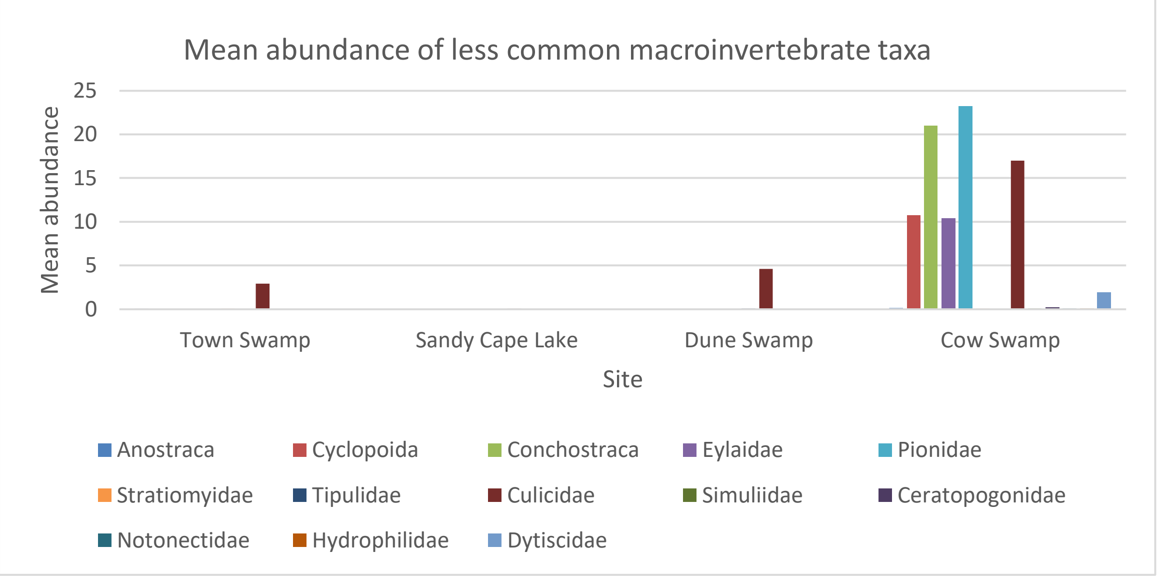

Figure 11: Mean abundance of more common macroinvertebrate taxa, sampled at four wetlands (Town Swamp, Sandy Cape Lake, Dune Swamp and Cow Swamp) in August 2015 near Jurien Bay, WA

Discussion

Chemical factors of the water, including conductivity, turbidity, pH levels, temperature, dissolved oxygen and colour, have been suggested to have an influence on faunal community structure and diversity in wetlands (Growns *et al.* 1992; Sim *et al* 2013). High acidity and constant temperature fluctuations, for example, may result in the loss of sensitive macroinvertebrates and a decrease in diversity (Waters and Rivers Commission 2001). In this study however, the only correlation found was between species diversity and salinity. Other water quality parameters showed great fluctuations, possibly because the samples were collected at different times of the day, which prevented the determination of correlations. These fluctuations also explain the overall variation of species between the different wetlands (Friday 1987). Dune Swamp and Sandy Cape Lake had very similar water quality parameters, which explains the similarity in their species composition (Friday 1987).

Macroinvertebrates have varying tolerance to levels of salinity (Waters and Rivers Commission, 2001). Cow Swamp had the highest species diversity of the four wetlands, due to its low salinity (Brock 1985; Halse *et al.* 2004). Another influencing factor is the extensive fringing vegetation found at Cow Swamp which provides food and shelter for macroinvertebrates, resulting in greater diversity and populations (Friday 1987). Grown *et al.* argue that the "greatest number of species occurs where the habitat is most diverse" (1992). Crustaceans are known to be more tolerant in high salinity than other taxa (Pinder *et al.* 2004), which explains their highest abundance at Town Swamp and Dune Swamp. The data collected suggests however that if the conditions are too saline (like Sandy Cape Lake) the abundance of crustaceans starts to decline. This supports the general theory, proposed by Halse *et al.* that high salinity leads to diversity loss (1981). The most arachnids and insects were collected at Cow Swamp, likely because they are a saline sensitive class (Pinder *et al.* 2004).

Although the wetlands were only sampled on one occasion, two clear trends already emerged. In agreement with studies by Brock (1985), Halse (1981), Pinder *et al.* (2004), species diversity decreased in the wetlands as the salinity increased. Within the saline water bodies, species richness was greatest in moderate salinity which correlates with findings by Balla & Davis (1995). Therefore, salinity is a clear determinant of the community composition and abundance of macroinvertebrate taxa.

Acknowledgements

The sampling was carried out during a field trip to Jurien Bay, organised by staff from Murdoch University. We would like to thank the other students who have helped with the sampling to compile the data which this paper is based on. We would also like to thank Peter O'Toole and Scott Strachan for leading the project, and especially for assisting with the identification of the macroinvertebrates. All members of the group collected and identified the macroinvertebrates on camp, and analysed and interpreted the data at Murdoch University. Brianna is thanked for writing the draft for the introduction, the draft for the methods was written by Jack, and the results by Katja, however, everyone has contributed to changes to prepare the final paper.

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Report 8

Investigating the effect of salinity of aquatic macroinvertebrates at Jurien Bay.

Abstract

Many wetlands in Australia have their own specific aquatic macro-invertebrates due to the different conditions of water quality. Aquatic macro-invertebrates are good indicators of water quality, their survival are very important for a wetland. There are four wetlands (Town Swamp, Dune Swamp, Sandy Cape Swamp and Cow Swamp) we were examined in this field-trip, they are all located at Jurien Bay in Western Australia. It was hypothesised that the distribution of macro-invertebrates in saline wetland will be much more different with freshwater wetland in terms of the salinity and other environmental factors. Macro-invertebrates and water sample were collected from four wetlands in each group. Cow Swamp showed a significant higher response in biodiversity while Town Swamp had the higher abundance of species. The results for the wetlands were unexpected but may be exaplained by different environmental factors such as temperature, colour and turbidity.

Introduction

Aquatic macro-invertebrates are small invertebrate animals (lack a backbone) that live in water but which are large enough to be seen with our naked eye. There are many different types of them include insects, crustaceans, molluscs, arachnids and annelids. Some of them can be quite large such as crayfish but most of them are very small. According to United States, Environmental Protection Agency (2012), Aquatic macro-invertebrates are good indicators of stream quality because they are affected by the physical, chemical, and biological conditions of the stream. Moreover, some of them are a very intolerant of pollution so they can show the impacts and degradation from habitat loss. Therefore their survival is related to the water quality. If there is a change in the water quality, it may also change the macro-invertebrate community. Due to their variability in sensitivity to the aquatic environment, macro-invertebrates make good biological indicators. We can find out how healthy a waterway is by sampling macro-invertebrate communities as a result of looking at the types and numbers of animals presented.

Macro-invertebrate lives in different part of water body, such as water's surface, in water itself, or on the bottom. However, Water and Rivers Commission (2001) mentions that vegetation around the waterbody is one of the key element provides an environment to macro-invertebrate, such as aquatic plants and native trees. Aquatic plants can balance the water of temperature, light and water flow. In addition, native trees and shrubs also provide shade which can reduce the extreme temperature and prevent from erosion as nutrient filters. Moreover, leaf litter is a part of food for macro-invertebrates, or the bacteria and fungi which cause it to decompose.

Salinity is a major problem of waterbodies in the south-west of Western Australia (Water and Rivers Commission, 2001). Therefore, macro-invertebrates are useful as indictors of change in the aquatic systems because they have an ability of tolerances to different levels of salinities.

The purpose of this report is to determine how the salinity and other environmental factors influence the structure and function of macro-invertebrate communities in coastal wetlands at Jurien Bay. The distribution of macro-invertebrate communities of three saline wetlands, Town Swamp, Dune Swamp and Sandy Cape Swamp were assumed to be different to the freshwater wetland, Cow Swamp.

Methods

Each site of invertebrates have been sampled semi-qualitatively using a sweep net along a 10 meters transect by every member of the group to enter water. The sampling technique was bouncing the net backwards over the bottom to stir up the sediment, and then scoop it forward. Repeated to bounce and collect the debris back into the net. This way can be collected the majority of the maro-invertebrates species and different types of them. There were two parts of sampling of each site: Firstly, all the maro-invertebrates have removed and placed into a vial containing 70% ethanol. Secondly, the sub-sample has placed in a separate vial containing 70% ethanol through a 250 micron sieve of excess water washing. After the sampling, identification work is very important in order to record what we have found. So we have used an identification key book to accurately identify and observed it under the microscope what species were they.

Moreover, water quality is a prime determinant of what can live in an aquatic ecosystem. So we have collected some water samples from each site in order to do the laboratory analysis of water samples. Several environmental parameters determine the water quality, including turbidity, colour, temperature, light, pH and dissolved oxygen have been recorded from each site.

Picture 1: Sub-sample sampling through a sample splitter.

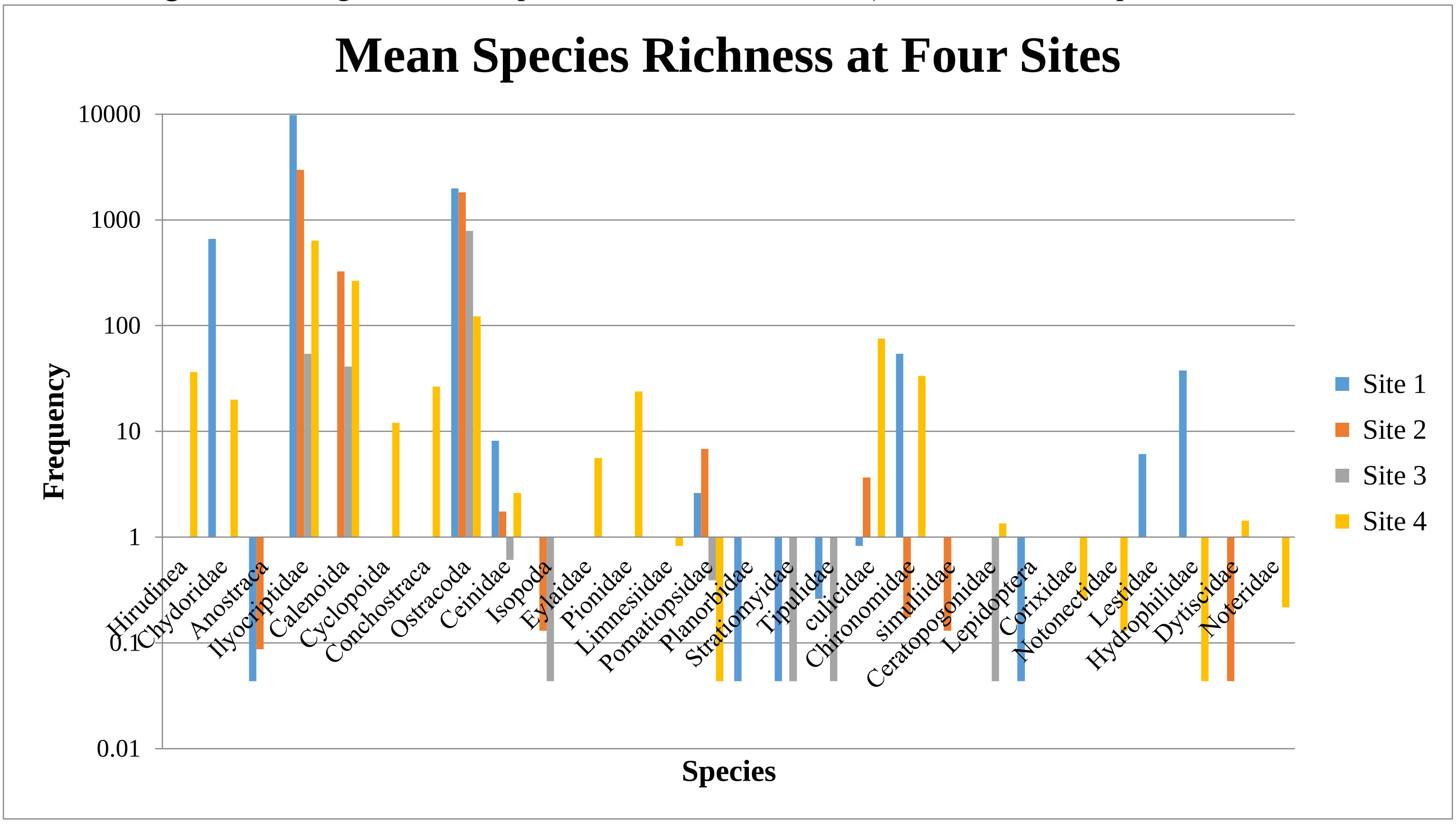
Results

Table 1 The mean water quality at four coastal wetland.

	Temp. (°C)	Dissolved Oxygen (ppm)	pH	Salinity (ms)	Turbidity (ntu)	Colour (G 440)
Town Swamp	21.71	14.28	8.56	17.04	4.14	6.02
Dune Swamp	22.88	13.58	8.53	16.42	4.09	6.09
Sandy Cape Lake	22.56	13.14	8.46	16.90	4.39	5.88
Cow Swamp	21.99	13.40	8.52	17.10	4.41	5.98

The conditions of water quality found in each site are shown in Table 1. The range of all these parameters over the four wetlands is apparent: for example, the number of temperature ranges from 21.71°C to 22.88°C; pH from 8.46 to 8.8.56; Dissolved Oxygen from 13.14 ppm to 14.28 ppm; Salinity from 16.42 ms to 17.10 ms; Turbidity from 4.09 ntu to 4.41 ntu; Colour from 5.88 to 6.09.

Figure 1 Average number of species richness at four sites. (Site 1: Town Swamp; site 2:



Dune Swamp; site 3: Sandy Cape Lake; site 4: Cow Swamp)

The histograms give a clearer overall impression of the locations, spreads and shapes of the set of data. Visually, the proportion of marco-invertebrate at Town Swamp appears to be greater among species than other wetlands. Since the species richness at Town Swamp appears to be greater than other wetlands, we would expect that the mean richness of species is generally richest at Town Swamp.

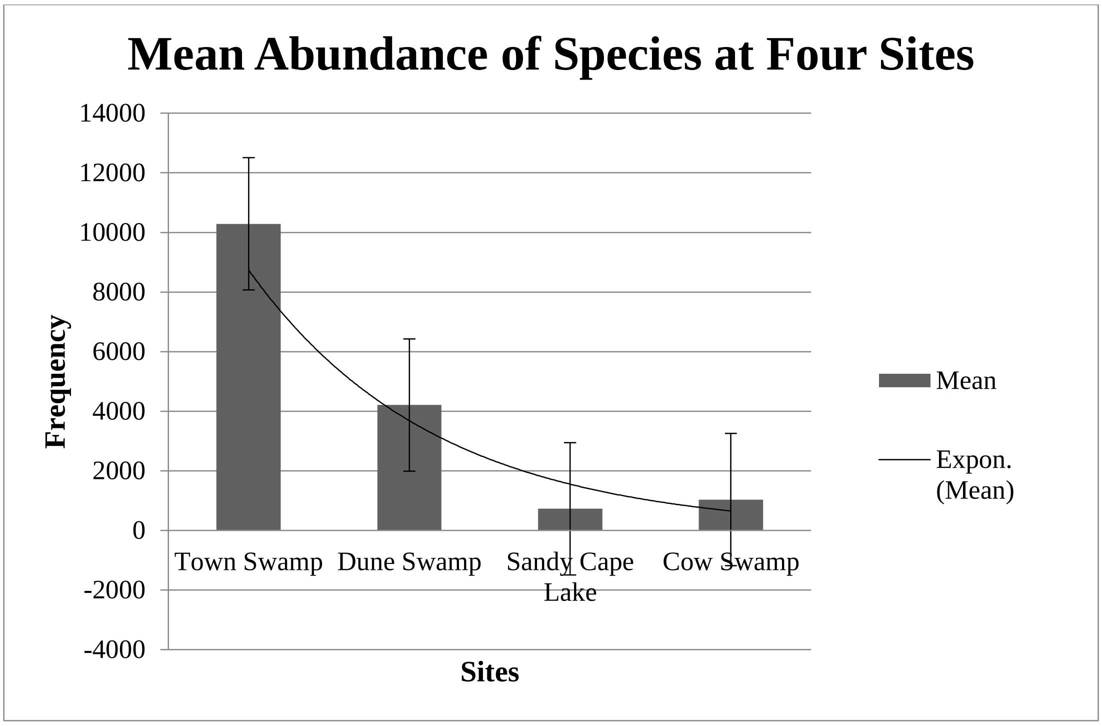


Figure 2 Average number of species abundance at four sites.

The histograms give a clearer overall impression of the locations, spreads and shapes of the set of data (Tend to be negative). Visually, the proportion of marco-invertebrate at Town Swamp appears to be greater among species than other wetlands. Since the species abundance at Town Swamp appears to be greater than other wetlands, we would expect that the mean abundance of species is generally greatest at Town Swamp. However, Sandy Cape Lake has the lowest abundance of species.

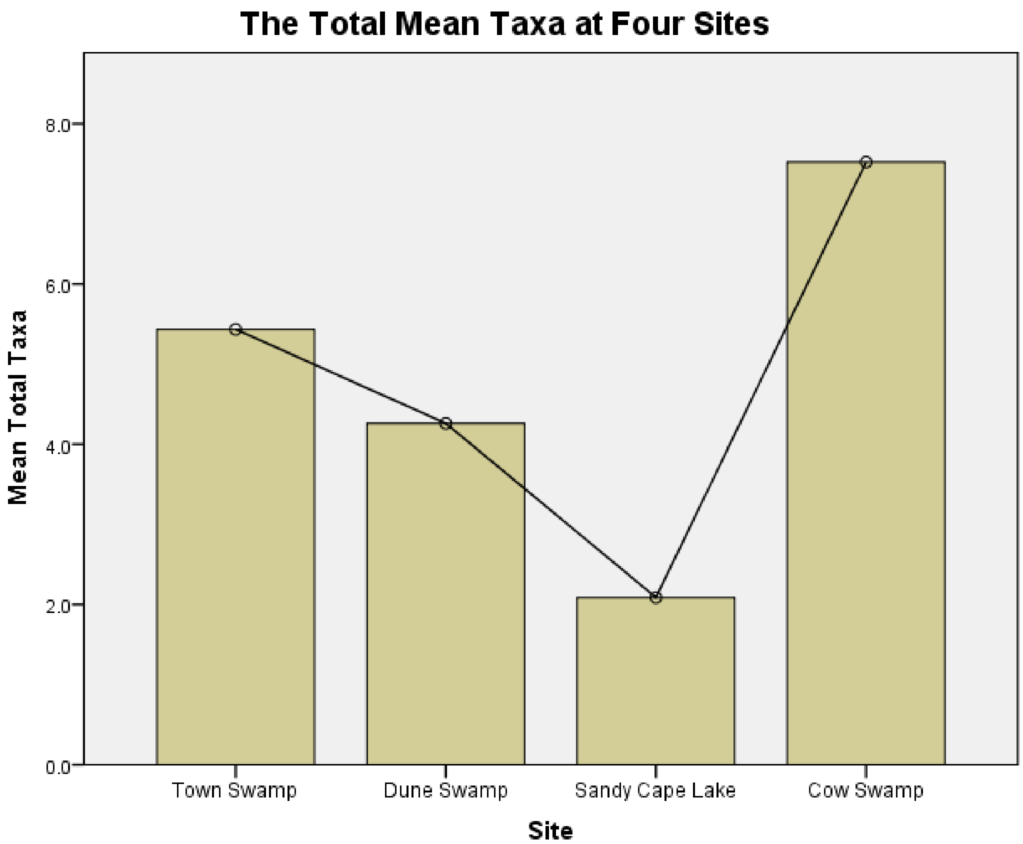


Figure 3 Average number of species taxa at four sites.

Visually, the taxa proportion of marco-invertebrate at Cow Swamp appears to be greater among species taxa than other wetlands. Since the species taxa at Cow Swamp appears to be greater than other wetlands, we would expect that the mean taxa of species is generally greatest at Cow Swamp where is achieved a higher biodiversity site.

Descriptives

Total Taxa

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Town Swamp	23	5.435	1.6188	.3375	4.735	6.135	2.0	10.0
Dune Swamp	23	4.261	.9638	.2010	3.844	4.678	3.0	6.0
Sandy Cape Lake	23	2.087	.9493	.1979	1.676	2.497	1.0	5.0
Cow Swamp	23	7.522	2.0642	.4304	6.629	8.414	2.0	11.0
Total	92	4.826	2.4522	.2557	4.318	5.334	1.0	11.0

Table 2 General data descriptive analysis from four sties.

	Sig. (2-tailed)	Mean Difference
Total Taxa of of Town Swamp & Dune Swamp (Equal variances not assumed)	0.005	1.1739
Total Taxa of of Sandy Cape Lake and Cow Swamp (Equal variances not assumed)	0	5.43

Table 3 Independent samples test with 4 sites from SPSS.

ANOVA

Total Taxa

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	355.565	3	118.522	54.421	.000
Within Groups	191.652	88	2.178		
Total	547.217	91			

Table 4 ANOVA data between groups and within groups

The two-tailed test of Town Swamp and Dune Swamp of total taxa for difference in the mean abundance has a P-value of 0.005, which is significant at a 5% level. Assuming that the group was randomly sampled from Town Swamp and Dune Swamp respectively, the data provide significant evidence that the mean abundance in total taxa differs according to 2 sites. From the data it appears that the mean abundance in Dune Swamp exceeds that in Town Swamp by an estimated 1.17 per species.

The two-tailed test of Sandy Cape Lake and Cow Swamp of total taxa for difference in the mean abundance has a P-value of 0, which is significant at a 5% level. Assuming that the group was randomly sampled from Sandy Cape Lake and Cow Swamp respectively, the data provide significant evidence that the mean abundance in total taxa differs according to 2 sites. From the data it appears that the mean abundance in Cow Swamp exceeds that in Sandy Cape Lake by an estimated 5.43 per species.

From Table 4, the F-ratio of 54.4 gives a P-value of 0 for the test of equality of means, providing significant evidence that mean taxon richness differs under Cow Swamp (assuming $\alpha = 0.05$). Sample mean of three saline wetland indicate that mean taxon richness has decreased.

Discussion

A wetland does required awareness of the variability and interactions between physical, chemical and biological parameters. When we look at the different environmental factors, they are the key evidences to reflect how the conditions of water quality generally as well as to identify is the environment suitable for different marco-invertebrate. Colour and turbidity are the measurement of suspended solids and describing the factors that is impacting the water column, such as yellow or green blooms, algal cells and clay. The colour conditions of Town Swamp and Dune Swamp were slightly higher than Sandy Cape Lake and Cow Swamp Table 1). It was indicated that two wetlands might occur more organic matters and is caused by decomposed vegetation which can affect the colour like yellow or tea-coloured. However, the level of turbidity at Town Swamp and Dune Swamp were slightly lower than others. It indicates that Sandy Cape Lake and Cow Swamp where the turbidity were higher which less light is available for photosynthesis and lead to the aquatic system decreased. Increase in turbidity may cause by land clearing that results in erosion, such as urbanisation of roads and drains. Temperature is an important factor when conditions change. According to the result, the temperature of Dune Swamp and Sandy Cape Lake were slightly higher than others. Increasing water temperature is caused by clearing trees decrease shading and lead to the growth of algal.

In the fieldtrip, salinity is the major factor that we were looking for. It describes the salt concentration of the water. In fact, Cow Swamp is supposed to be a freshwater wetland, but it is the most likely the higher level of salinity from the four wetlands. The removal of native, perennial, deep-rooted vegetation and its replaced by shallow-rooted annual species around the wetland can be a fact of increasing the salinity. The loss of deep-rooted vegetation reduces the amount of evapotranspiration and the surface capture of rainwater and it is causing increased run-off. These changes cause groundwater column to rise and leading to the surface salt stored in the soil. It is known as secondary salinization. Secondary salinization is widespread in Australia, especially in south-western Australia (Calver M, 2009). It kills freshwater organisms and reduces biodiversity and it might only allow some organisms which is high salinity tolerance to survive.

When we compare with figure 2 and 3, despite the species abundance in Cow Swamp was nearly lowest, it has achieved the highest level of species taxa (higher biodiversity). Aquatic macro-invertebrates are good indicators of water quality, which can reflect the water quality directly. Macro-invertebrates community diversity is usually reduced by different specific conditions, such as dragonflies and damselflies can be tolerant of salinity but are harmed by other pollutants. The response of macro-invertebrates can vary enormously because some animals can act as specific changes in the water conditions. Therefore, Cow Swamp has the most healthy condition of water quality which is occuring the highest biodiversity of macro-invertebrates. It is allowed to indicate different kind of pollutants and the level of salinity comprehensively.

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Student investigations into the effect of salinity of macroinvertebrate diversity in wetlands surrounding Jurien Bay

MURDOCH UNIVERSITY
PERTH, WESTERN AUSTRALIA

Contents

Summary

The Murdoch University Ecology camp was undertaken from the 28th August until 1st of September 2016 at Jurien Bay. 19 students were involved with sampling macroinvertebrates over this period and three reports were written using the collected data (which can be viewed in the following document). The aim of the project was to assess whether salinity had an effect on macroinvertebrate diversity in wetlands surrounding Jurien Bay.

Four wetlands surrounding Jurien Bay were selected for sampling and measurements for pH, salinity, turbidity and color. The results showed that while there were differences between pH, turbidity and color they were likely to have a limited effect on macroinvertebrate diversity. However, there was considerable variability in salinity in the wetlands, with salinities ranging from brackish (Cow Swamp ~1440.9 ppm) to a brine (Sandy Cape Lake ~41287 ppm).

Macroinvertebrates were collected from each of the four wetlands. Over this period of sampling 37 families of aquatic macroinvertebrates were collected from the four wetlands. The results indicated macroinvertebrate richness was greatest in the fresher wetland (Cow Swamp) and diversity decreased with increasing salinity (lowest in Sandy Cape Lake). Crustaceans were abundant in each of the wetlands with ostracods (Family: Cyprididae), cladocerans (Family: Ilyocryptidae) and copepods (Calanoida and cyclopoida) being the most common macroinvertebrate encountered, which is unsurprising given the salinities measured in the wetlands. The greatest diversity and a higher proportion of insects were found in the fresher wetlands, a trend that is consistent with the literature. A more detailed explanation of these findings can be found in the following student reports.

This field work provides a valuable opportunity for students to get out in the field and gather real world experience in regards to environmental science and aquatic ecology. It allows them to consolidate the theories behind their studies and provide valuable insight into how fieldwork is completed.

Report 1

Salty Problems: Wetland invertebrates respond to human activity in Jurien Bay

Introduction

Wetlands are areas consisting of frequently or permanently saturated soils, that are home to many species of macroinvertebrates. There are different types of wetlands, and these can include; swamps, marshes, billabongs, lakes, lagoons, saltmarshes, mudflats, mangroves, shallow reefs, and in rarer instances, boglands or peatlands (1). They play an important role in the natural environment, reducing flood impacts, absorbing pollutants, improving water quality, as well as being a habitat for supporting a diverse range of plant and animal species, many of which are endemic to certain areas. (2). Wetlands can change under certain climatic conditions. For example, they can gradually fill in or dry up during warmer seasons, or expand after long periods of rainfall. Changes in Australia's climate can impact wetlands through rates of evaporation and recharge, and thus influence water quality. It is evident that in Australia average temperatures have risen by up to 1.5°C, and average rainfall catchments are reaching both positive and negative extremes not seen during the 1900's (17). Humans have had a dramatic effect by altering conditions which support wetlands, draining, dumping and filling in wetlands, all causing a decrease in species richness and abundance (4).

A healthy and sustainable wetland is dependent upon sound structure, water quality, substrate, carrying capacity, groundwater storage, nutrient cycling and biomass production. High species richness (alpha diversity) and abundance generally equate to a healthy wetland (18, 4). Beta diversity of invertebrates is the variation in species composition among sites in a geographic area and gives information about the health of the region (19).

The macroinvertebrate communities of Western Australia's wetlands are varied across the State and due to climatic drying effects, especially during Summer time and extended droughts, there is a high tolerance to a mixture of environmental conditions. Many have life cycles that allow for survival of the species during extreme conditions (5). Some Macroinvertebrates are endemic to wetlands in the southwest of Western Australia, as a result of these ever changing conditions. Invertebrates can also be used as bioindicators for ecosystem health (16) but there is still a certain lack of specific information on how many invertebrates are affected by factors such as salinity (14). There are multiple ways for classifying macroinvertebrates, and an alternative to using the taxonomic group is the functional feeding group, which classifies macroinvertebrates by their behavioral mechanisms of food acquisition.The 3 main functional feeding groups which a macroinvertebrate can be classified as are:

- **Detritivores**

  -Shredders which consume organic matter and convert it into finer particles (e.g. amphipods, isopods, caddisfly larvae) -Scrapers which feed on algae and organic matter attached to stones (e.g. snails, mayfly larvae)
- **Grazers** **-**

  Collectors/Filter feeders which feed on fine organic particles left by shredders and other processes (e.g. mayfly nymph, mussels, water fleas, some fly larvae and worms).
- **Predators** consume live prey such as shredders, scrapers and collectors/filter feeders (e.g. dragonfly and damselfly larvae, adult beetles, beetle larvae, some midge larvae, some stonefly larvae). (5 and 6)

Jurien Bay was chosen as the site for this study due to its many different wetland areas with a variety of physical and chemical influences, which can then be analysed. It is a small coastal township, located on the coastal plain of Western Australia at 30.31° S 115.03° E (9). Figure C gives its position in relation to the rest of WA. It lies approximately 2m above sea level, and experiences a mediterranean climate. Temperatures range from max. 30.9°C and min. 18°C in Summer to max.

19.5°C to min. 9.3°C in Winter. Annual rainfall is 551.7mm and there is a predominant wind of south to south-easterly (10). According to studies, there is an overall decline in the average rainfall of the Jurien Bay area, and the south-west of Western Australia overall (18). Figure 1. shows the rainfall decile for Australia, with Jurien Bay being in the 'below average' area. Wetlands along this coastline may be saline or freshwater.

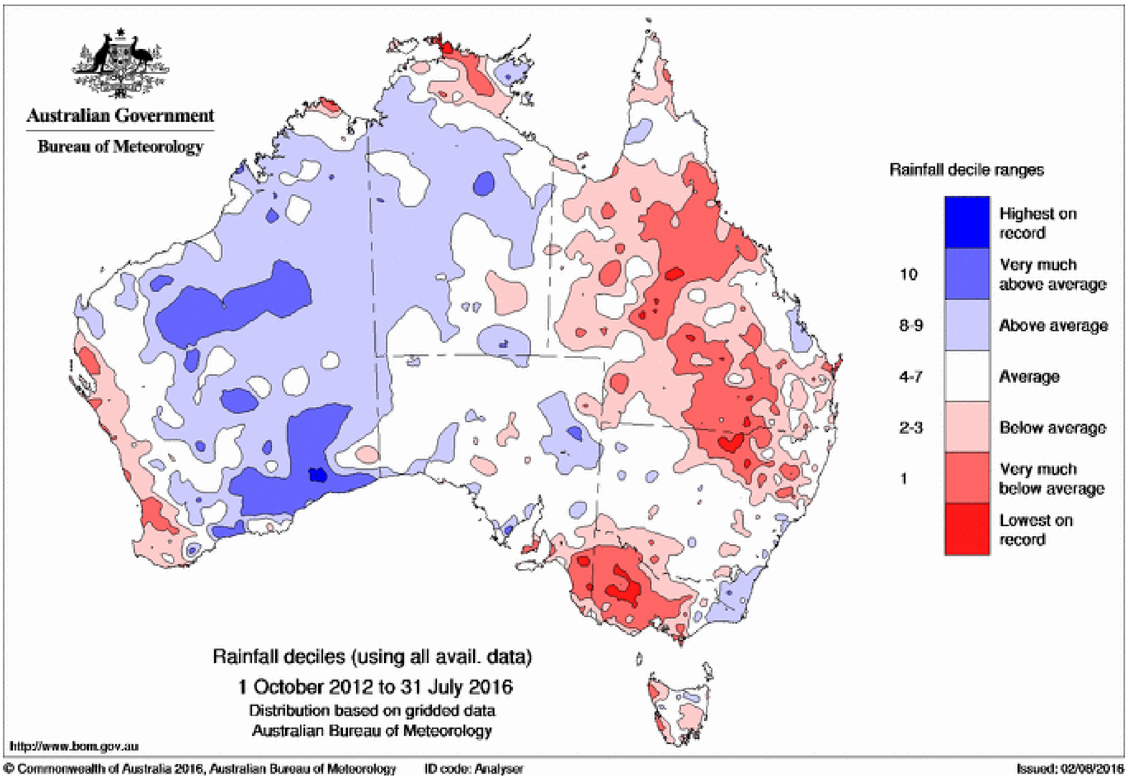

Figure 1. Rainfall decile for Australia from October 2012 to July 2016, using all available meteorological data. Jurien Bay is found in the 'below average' to 'very low below average' zone (18)

Studies show that the salinity levels of a wetland can greatly influence invertebrate community structure (Pinder) and lead to general modification of vegetation, loss of food resources and changes in predatory pressures. These changes will typically become apparent at levels of salinity greater than 1000 ppm and indicate that as salinity increases [in wetlands] there is a loss of diversity (14).

Salinity can be varied in 2 different ways, primary being naturally occurring saline levels (seasonal, annual, leaching effects etc.) and secondary being human induced (dumping, mining, draining) (15).

A classification of salinity levels is often referred to as an aid in describing water quality, and is given in Table 1.

Table 1. Shows classifications of water from their levels of salinity. This is expressed in mg/L, which is equal to ppm (parts per million). **(12)**

Salinity status	Salinity (milligrams of salt per litre)	Description and use
Fresh	< 500	Drinking and all irrigation
Marginal	500 –1 000	Most irrigation, adverse effects on ecosystems become apparent
Brackish	1 000 – 2 000	Irrigation certain crops only; useful for most stock
Saline	2 000 – 10 000	Useful for most livestock
Highly saline	10 000–35 000	Very saline groundwater, limited use for certain livestock
Brine	>35 000	Seawater; some mining and industrial uses exist

The aim of this experiment is to determine a relationship between family abundance and salinity. The hypothesis is that the wetlands of Jurien Bay with a high salinity will have a lower family richness than those with a lower salinity .

Method

Background

The 4 sampling sites were:

- Town Swamp (30°29’05”04 **S** 115°05'22”02 **E**)

Town swamp is named due to its proximity to the town of Jurien Bay. It is a long ovoloid shape approximately 150x25m in size, lying in an east-west direction and being around 0.4m at its deepest (large amount of rainfall prior to time of measurement). This is a saline wetland.

There is a high amount of modification to this intermittent swamp, as a result of cars being driven over the dry surface during Summer, and human rubbish being left in it. It was also used as a town dump previously. In the middle of this swamp is an abandoned car.

The vegetation growing beside it is a large variety of tall trees (eucalyptus and others), many bushes and reeds, and there is filamentous algae present. Refer to Figure 2.

Figure 2. A photograph of a small section of Town Swamp. Photo by Dallas Campbell, August 2016

- Dune Swamp (30°20’94”5 **S** 115°00’77”8 **E**)

Dune Swamp is positioned very close to the Sandy Cape Swamp, and they are separated by Sandy Cape Rd. It lies in a curved shape, with a tapered end closest to the road and is about 150m in length. At its deepest it is approximately 0.4m (large amount of rainfall prior to time of measurement).

There is very little protection afforded to this area from wind, and certainly on the days of sampling, there was a great amount of wind disturbance.

Cars are ridden over a mostly dry surface during Summer, and rubbish is left in and beside it.

Vegetation was made up of rough scrub and bushes, reeds and low lying plants. Filamentous algae is present. Refer to Figure 3.

Figure 3. A photograph of Dune Swamp. Photo by Dallas Campbell, August 2016

- Sandy Cape Swamp (30°20’76”32 **S** 115°01’01”83 **E**)

The Sandy Cape Swamp, as mentioned before is situated opposite Dune Swamp. Hence, they share similar vegetation and wind disturbance. Depth is approximately 0.5m (large amount of rainfall prior to time of measurement). This swamp is also much larger than Dune swamp, reaching to almost 300m length, and lying alongside it is a lime quarry (resembles white dunes). This impacts its salinity content as lime is constantly being added when the stone crumbles down embankments and into the water. Vegetation was very similar to Dune Swamp and filamentous algae was present.

- Cow Swamp (freshwater) (30°25’49”88 **S** 115°15’01”57 **E**)

Cow swamp is located somewhat inland in comparison to the other wetlands. Due to a large amount of rainfall prior to measurement, this wetland has spread out to a much larger coverage than normal, approximately 50m from its usual border (as stated by demonstrator Peter O’Toole) and the large amount of melaleuca trees growing within it make it difficult to estimate size. The trees also result in a tanin stained effect, browning the water. There is a maximum depth of 1m. This swamp lies on farmland and is subsequently modified by local cows walking beside and in the water. Vegetation includes many melaleuca trees (growing beside and in the swmp), many different grasses (due to cleared nature of farmland) and wildflowers are proliferate in the immediate vicinity. Filmentous algae is present and the water’s edge lies over farm weeds and grasses (not marine in nature). Refer to Figure 4.

Figure 4. A photograph of Cow Swamp. Photo by Dallas Campbell, August 2016

The weather at Jurien Bay prior to and during sampling included an August rainfall of 79.4mm, and temperatures with mean highs of 19.4°C and lows of 8.6°C (11).

Sampling

The Salinity of each wetland was measured from a small arc just off the water's edge, at 3 different points using an electrical conductivity meter and each measurement being roughly 5-10m apart. The Conductivity metre was set to measure the conductivity in millisiemens, so the data then had to be converted into parts per million by multiplying it by 640. A small sample of the water was taken in the empty plastic bottle, and was later used for water quality testing back in the lab.

The macroinvertebrate samples were taken using the sweep nets. A person from each pair would put on the waders, and drag the sweep net across the bottom of the wetland for roughly 10m. If at first glance the sample contained copious amounts of sand, enough to fill the collection tray, then the sample was retaken. The contents of the sweep nets were placed into the collection trays, and the forceps were used to place as many visible macroinvertebrates into the the macro sample cups. A piece of waterproof paper, after writing the name date and location was placed in each sample cup for later identification of the samples. Once all of the visible macroinvertebrates had been placed into the macro sample cup, the remaining sample was then split a number of times until it could fit into the micro sample cup. Each time the sample is split it represents a small fraction of the total sample. To get the remaining sample into the micro sample cup it, it was split enough times to represent a fraction of the sample, and the number required to multiply any macroinvertebrates found in the sample to represent to the total amount was written on the piece of paper along with the sampler's name the date and the location the sample was taken before being placed in the cup. This was mostly 32, but in some cases was 16 or 64.

After returning from each wetland, the water quality tests were conducted. There were a total of 3 tests needed to be performed in the lab on a water sample from each wetland. A pH test, a Colour test and a turbidity test. The pH of each sample was measured by calibrating the pH meter to 7, and some water from that wetland which was captured in the plastic bottle was poured into a beaker, and the pH was measured.

Colour was measured using a filtered sample (0.2 micron filter paper) read in a spectrophotometer at 440nm. Absorbance (measured in g440/m) was subsequently multiplied by 2.303x100 to give an absorption coefficient.

Turbidity was measured on unfiltered water, and compared to a reference solution of distilled water. This was completed using a spectrophotometer, and results were recorded in NTU (Nephrelometric Turbidity Units).

One at a time the Macroinvertebrates from each sample cup were placed into a petri dish and viewed under a microscope. Books with dichotomous charts and the assistance of a supervisor, (Peter O'toole) were used to identify the different macroinvertebrates in each sample. Each person identified and counted all of the macroinvertebrates in their samples and The data was recorded in a table on excel.

Results

The aim of our experiment is to determine a relationship between species richness and salinity and our hypothesis was Wetlands of Jurien Bay with a high salinity will have a lower species richness than those with a lower salinity .

The other water quality tests included colour pH and turbidity. Analysis of these results was done in excel using all of the data provided from the each pair of students who performed the water quality tests, and the averages were calculated. The results showed little variation of the pH in 3 out of the 4 wetlands, with their pH ranging from 8.17 and 8.75. Cow swamp being the exception, having a pH of 7.21. The salinity of the wetlands varied drastically. Sandy Cape Lake being the most saline at 41287.2 ppm and Cow swamp being the least saline at 1440.9 ppm. The turbidity also showed little variation in 3 of 4 the wetlands, having turbidites ranging between 17.10 NTU to 22.76 NTU, and Cow swamp had a very low Turbidity of 3.91 NTU. Colour varied considerably between all 4 wetlands, with colour ranging from 1.59 G440 to 30.41 G440.

Table 2: Shows the averages of the water quality tests done in each wetland.

	pH	**Salinity (ppm)**	**Turbidity (NTU)**	**Colour (G440)**
Town Swamp	8.75	6648.8	17.10	8.00
Dune Swamp	8.65	17362.4	22.76	3.77
Sandy Cape Swamp	8.17	41287.2	17.54	1.59
Cow Swamp	7.21	1440.9	3.91	30.41

As salinity is the factor being scrutinised, a column graph was generated in excel to help clarify the significance of these results, shown in in Figure 5. Cow swamp had the lowest salinity, at 1440.9 ppm. Next was Town swam, with 6648.8ppm, then Dune Swamp with 17362.4 ppm and lastly with the highest Salinity was Sandy Cape Swamp with 41287.2 ppm. The salinity results are significantly different, the standard errors are reasonably low, meaning there was not much spread in the data at each wetland, allowing the averages to be quite accurate and precise. The following table can then be made with salinity classifications.

Table 3. Showing wetlands and their salinity classifications.

Wetland	Salinity Classification
Town Swamp	Saline
Dune Swamp	Saline
Sandy Cape Swamp	Brine
Cow Swamp	Brackish

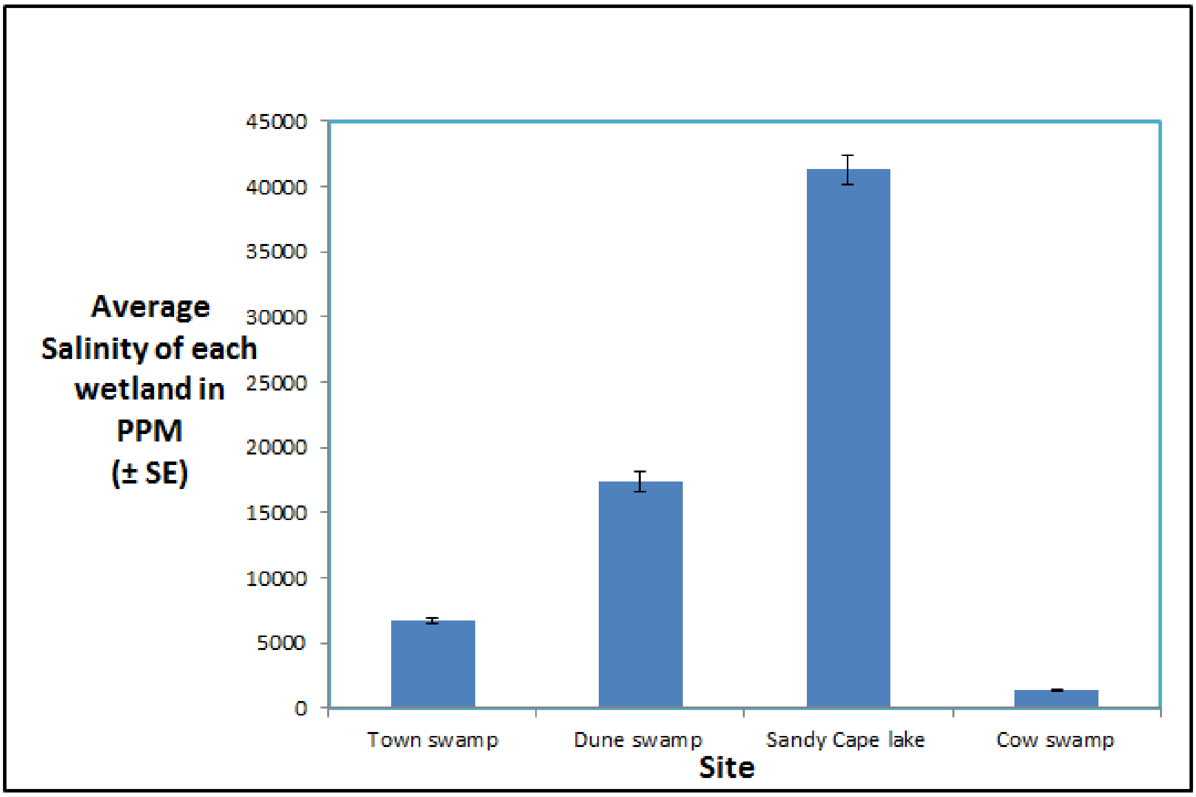

Figure 5: Column graph showing the average salinity (1 ± SE) of the 4 wetlands sampled.

The hypothesis for the experiment is, wetlands of Jurien Bay with a high salinity will have a lower family richness than those with a lower salinity. One of the ways in which the hypothesis was tested was to compare the family richness with the salinity. The family richness was counted from the data and SPSS was used to create a scatterplot to show family richness, against salinity. A linear regression line was then added to the scatterplot showing a strong negative correlation between the variables. As the salinity decreases the family richness increases, which supports our hypothesis.

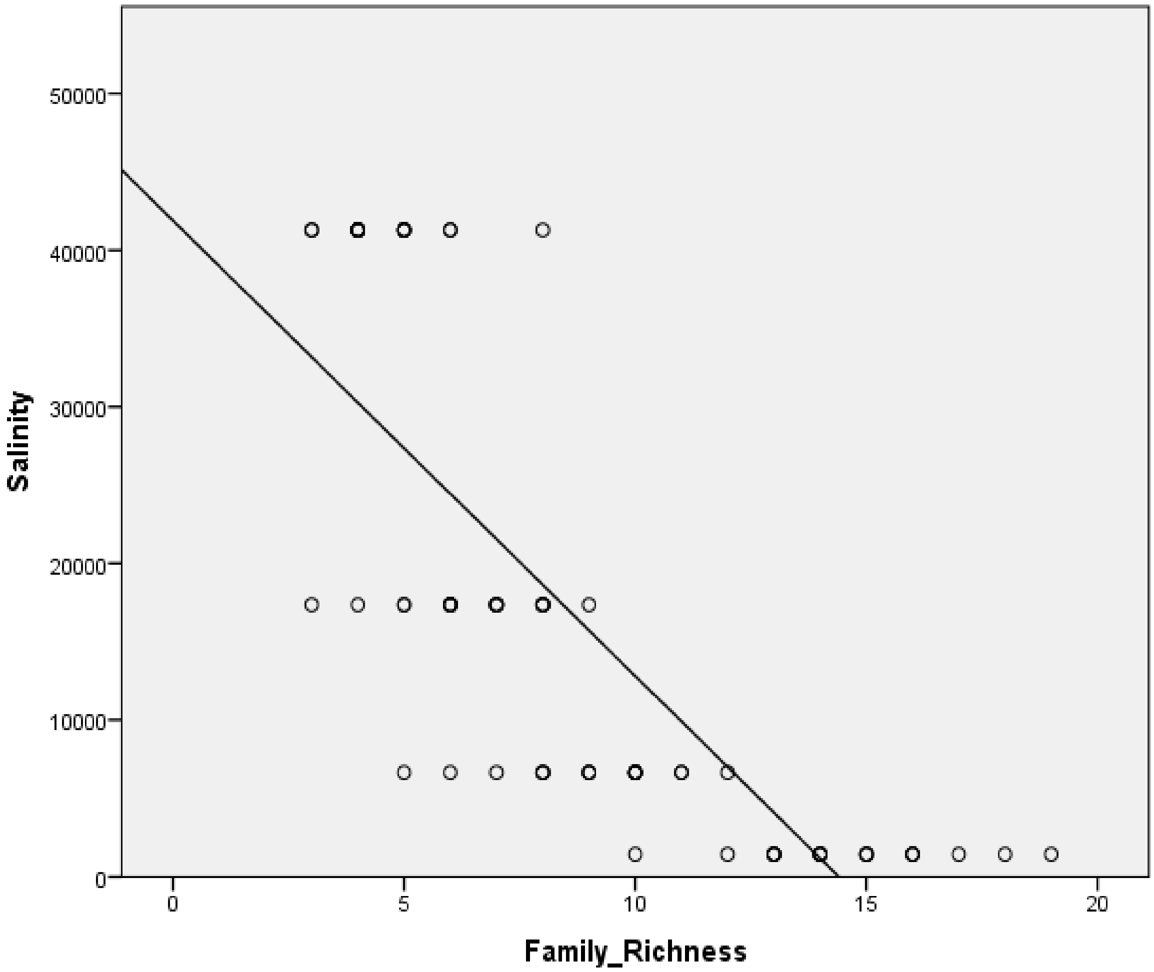

Figure 6: A Scatterplot with a linear regression line showing a strong negative correlation between Salinity in PPM and Family Richness. As the Salinity decreases the Family Richness increases. The R Squared value of the the regression line is 0.61 and the equation of the line is Y=41900-2190x. N=19 sweeps per sample.

In order to test the hypothesis and examine similarities between sites, a number of tests were run. Class Richness was found for each wetland (demonstrated in Table 3) with the Insecta Class having the highest richness (17 families), and also the highest variability across the sites. The Sorenson Similarity Index was found between sites for the 3 differing salinity types, given in Table 5. The two wetlands of a saline classification (Town and Dune swamps) had the highest similarity of 0.5. The lowest similarity was 0.24 between the saline and brine wetlands (Town and Sandy Cape swamps).

Table 4. Class Richness of the 4 sites, focusing on invertebrates of the Insecta, Crustacea and Mollusca Classes. N=19 sweeps per sample. Refer to appendix

Class	Town Swamp	Dune Swamp	Sandy Cape Swamp	Cow Swamp
Insecta	15	7	5	17
Crustacea	4	5	4	7
Mollusca	2	3	2	2

Table 5. Sorenson Similarity Index for paired sites with differing salinity. 1= completely similar, 0= no similarity.

Site 1 (salinity)	Site 2 (salinity)	Similarity Index
Town Swamp (saline)	Dune Swamp (saline)	0.5
Town Swamp (saline)	Sandy Cape Swamp (brine)	0.24
Cow Swamp (brackish)	Sandy Cape Swamp (brine)	0.31

Further testing on wetland similarity included a family from each functional feeding group, found in both the samples from Cow swamp and Sandy cape swamp, being selected to undergo independent-samples t tests. These 2 wetlands were selected because they had the highest and lowest salinity. The chosen families were: Predator- Dytiscidae (7), Grazer- Calanoida (8) and Detritivore- Ceinidae (13), and the outcome is shown in Table 6. The most significant p-value was 0.137 for the predator feeding group.

Table 6. Statistical differences between 2 sites, Sandy Cape Swamp and Cow Swamp, for each functional feeding group (single invertebrate family used for each test: Dytiscidae, Calanoida and Ceinidae) N=19 sweeps per sample.

Functional Feeding group	Site	Mean ± SE	T-statistic	Degrees of Freedom	P-Value
Predator (family: Dytiscidae)	**Sandy Cape Swamp**	**0.47 ± 0.328**	**-1.520**	**35.867**	**0.137**
	Cow Swamp	**1.16 ± 0.308**			
Grazer (family: Calanoida)	**Sandy Cape Swamp**	**344.05 ± 124.711**	**-4.379**	**27.382**	**0.000**
	Cow Swamp	**1509.63 ± 235.176**			
Detritivore (family: Ceinidae)	**Sandy Cape Swamp**	**0.63 ± 0.399**	**-2.994**	**18.000**	**0.008**
	Cow Swamp	**1081.840 ± 361.130**			

Discussion

The invertebrates of wetlands throughout the southwest of Western Australia are impacted by changing climate (9). Variations in normal temperatures and rainfall contribute to alterations in wetland salinity (14).

The results showed that sandy cape swamp had the highest salinity, at 41287.2 ppm. While cow swamp had the lowest salinity at only 1440.9 ppm. There was a strong negative correlation between species richness and the salinity of the wetlands. This can be attributed to the lime quarry beside the wetland, which leaches into the water and increases the ionic composition. This is an example of human activity affecting the wetland and is therefore considered secondary salinisation (15). All other wetlands of the study were impacted by human activity, but none to the same degree as Sandy Cape Swamp.

The similarity index between sites finds that there are a number of shared invertebrate families, and that the low similarity of Sandy Cape swamp to Town Swamp, is due to a small richness of invertebrates at the briny Sandy Cape Swamp. The reason that the brackish water of Cow Swamp and the briny water of Sandy Cape Swamp are more similar is inferred as being a result of Sandy Cape swamp having a very large family richness that nearly reached the total family richness for the 4 sites.

The P-value in independent-samples t tests for a predator in Sandy Cape lake against Cow swamp was above 0.05, showing that there was a significant difference in the number of predators between these 2 wetlands. These results infer that the functional feeding group of predators is negatively impacted by changes in salinity and consequently will affect the ecosystem. This is supported by research into the effect of high salinity on invertebrates (14). Insects, being important macroinvertebrate predators,are generally sensitive to salt as they have have soft-bodied and structurally simple larvae life stage (14). Further tests with other families would enhance the validity of this statement.

These results support our hypothesis that the wetlands of Jurien Bay with a high salinity will have a lower family richness than those with a lower salinity. The species richness decreased at a rather consistent rate up to Dune swamp which had the 2nd highest salinity. The decrease in species richness from dune swamp to sandy cape lake was miniscule, thus showing that after a certain salinity the decline will eventually cease.

This is supported by reports on salinisation, which find that as salinity levels increase in wetlands, there is a general reduction in salt-sensitive invertebrates, and what remains in the ecosystem is halophilic or salt-tolerant species which can adjust to a variety of salt levels (3) and that the rapid decline in invertebrate diversity will slow at approximately 10 000 ppm (15).

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Report 2

Aquatic Macroinvertebrate response to salinity levels in coastal wetlands at Jurien Bay

Introduction:

The effects of secondary salinity in Western Australia due to land clearing, urbanisation and agriculture are becoming clear. These effects are detrimental to wetlands and the aquatic organisms that live within them. “Aquatic macroinvertebrates communities have varying tolerances to different levels of salinity” (Water and Rivers Commission 2001) and thus are good indicators of wetland health.

Primary salinity is a natural part of ecosystems in Jurien Bay, a small town located on the coast of Western Australia and part of the wheatbelt. As a result, the macroinvertebrates and marine organisms of the region have adapted to this accordingly (Nielsen et al. 2003). Their tolerance to salinity levels has evolved after being exposed to low levels of flow during the summers causing an increase in salinity, which has led them to develop a tendency to avoid high salinity water levels or to develop a tolerance level, depending on the species (Nielsen et al. 2003). The land practice of grazing and crop growing has resulted in the removal of deep-rooted native trees and the replacement of shallow rooted crops or grazing pastures (Nielsen et al. 2003). This has caused the water table to rise in many regions of Western Australia and to bring along with it salt from deeper in the soil. As an effect when more water evaporates in warmer months, the salt remains in the water, and the process continues, increasing salinity levels. The alteration and interruption of normally interconnected wetlands have also reduced the amount of flow and flushing that would naturally occur, also contributing to the severity of this issue (Nielsen et al. 2003). When salinity reaches a certain amount the water becomes toxic to many aquatic macroinvertebrates, and this is why their species abundance and richness often a good indicator of wetland salinity and health (Water and Rivers Commission 2001). As a result, it is predicted that the aquatic macroinvertebrate species richness in the south-west region could be reduced by one-third due to increased secondary salinity, further changing natural ecosystems (Carver et al. 2009).

Aquatic macroinvertebrates are often used to test the effects of many factors of human effects such as physical disturbances and chemical pollution (Wetland Health Evaluation Program

2002). Physical disturbances can include processes such as weed invasion, salinization, climate change, and even groundwater abstraction (Central Midland and Coastal Advocate 2012). Aquatic macroinvertebrates are sampled to test the effects of anthropogenic influences such as secondary salinity on wetlands because they can be found in most wetlands and are directly exposed to these conditions for most of their (Wetland Health Evaluation Program 2002). The wide range of macroinvertebrates mean that they all have different tolerances, this means that the species present in a particular wetland can indicate the level and effects of environmental changes (WA Department of Water 2016). Macroinvertebrates are affected by salinity levels that are higher than 1000ppm, although information on this is limited and invertebrate salinity tolerance is likely to change during their lifetime and of course with different species (Nielsen et al. 2003).

There have been a few studies completed on macroinvertebrate richness in wetlands affected by salinity in the wheatbelt and the south-west in general. Although there hasn't been a sufficient amount of scientific reports published on how salinity affects aquatic macroinvertebrate richness in wetlands in Jurien Bay. Therefore, it is vital to gain this information as Jurien is a region that has been affected by secondary salinity.

The aim of this scientific study was to investigate how different salinity levels affect the composition and richness of aquatic macroinvertebrate communities at Jurien Bay. It is predicted that an increased in salinity in wetlands causes a corresponding decrease in species richness.

Method:

Procedure:

The survey was conducted at four wetlands in Jurien Bay, with the aim to gather sufficient water and macroinvertebrate samples to analyse back in the laboratory. Three of the wetlands, Town Swamp, Dune Swamp and Sandy Cape Lake, were located along the coast of Jurien Bay while the fourth, Cow Swamp was situated further inland.

The first site visited was Town swamp, where group members worked in pairs or threes to gather the required samples. Team members took turns to test the conductivity of water using an electrical conductivity meter and gathered macroinvertebrate samples along a 10-metre transect from two random locations via the use of a sweep net. While this team member was completing this process, another prepared the sample containers. This included two for macroinvertebrates and two for micro invertebrates for a total of fours samples from each wetland (containers labelled with pencil). There was a total of eight groups who collected eight water samples and 19 macroinvertebrate samples.

Sample containers were filled with 70% ethanol. After the team member had returned with the sweep net, the container was filled with 800ml of water which was poured over the net to successfully get the collected macroinvertebrates into one of two trays that were brought to the wetland. The second team member began selecting the macroinvertebrates from the first sweep while the first returned to the water to collect the second sweep. 800ml of water was again collected to move the invertebrates from the sweep net to the second tray and a general sample of water was also collected from the wetland in a bottle for water analysis at the campsite. Once both samples were in the trays both team members worked to collect macroinvertebrates from the tray in separate sample containers using tools such as forceps, slotted spoons and pipettes.

Once each pair had gathered enough macroinvertebrates to get an accurate estimation of macroinvertebrate richness and abundance in their sample, the sample was split to collect the micro-invertebrate sample from each sweep.

Analysing water sample:

The water samples from each wetland were analysed to determine the pH, colour (Gilvin) and turbidity.

Analysing aquatic invertebrates:

The macro- and micro-invertebrate samples were each examined individually under a microscope and each organism found were identified and abundance recorded. They were identified to the family taxonomy level using “A Guide to Wetland Invertebrates of Southwestern Australia” by Jenny Davis and Faye Christidis.

Site descriptions:

Figure 1: A panoramic view of Town Swamp

Photography: Jaylin O'Sullivan

Figure 2: A panoramic view of Dune Swamp

Photography: Jaylin O'Sullivan

Figure 3: A panoramic view Sandy Cape Lake

Photography: Jaylin O'Sullivan

Figure 4: A panoramic view Cow Swamp

Photography: Jaylin O'Sullivan

Table 1: Descriptions of each four wetland sample sites.

Wetland sample site	Description of wetland
Town Swamp	Town swamp is an intermittent wetland. It is clear from the view that this wetland experiences weed invasion as seen in Figure 1 and is a habitat for seagulls and common swamp birds such as ducks and swans. There is evidence that it dries out over summer as there is an old car body close to the centre of the wetland, and it was once used as a dumping ground by locals.
Dune Swamp	Dune Swamp is an intermittent wetland that is a breeding ground for birds that inhabit this region. Its landscape features dunes and saltbush is common in this area as seen in Figure 2. The wetland contains filamentous algae and appears to be a dumping ground. It is also likely that cars have driven through this swamp during drier months of the year.
Sandy Cape Swamp	Sandy Cape swamp is also dominated by saltbush as seen in Figure 3 and is affected by the lime quarry nearby that causes an increase in salinity levels.
Cow Swamp	This perennial wetland is over a metre deep at some points. It is a tannin wetland and contains sandy soil with a small amount of clay. This wetland features submerged trees such as paperbarks as seen in Figure 4 and is located in a field that cows often graze at.

Statistical Analysis:

Regarding data analysis, various graphs, T-tests, tables and ANOVA testing were conducted in Microsoft Excel. Graphs were used to display % composition of major phylum, mean taxa richness, total abundance and mean salinity of different wetland. Scatterplots were also used to display the correlation between salinity level and total abundance, pH levels and species richness, turbidity and species richness, water colour and species richness as well as the correlation between salinity level and species richness. ANOVA tests were completed to compare taxa composition of each wetland as well as comparing the salinity of each wetland. T-tests were completed to compare mean species richness and mean salinity of the four wetlands via the use of a table. A table was also used to compare the species similarity between four wetlands. All statistical analysis were performed using a significance value of 0.05 and assumed that the observations were normally distributed and independent.

Results:

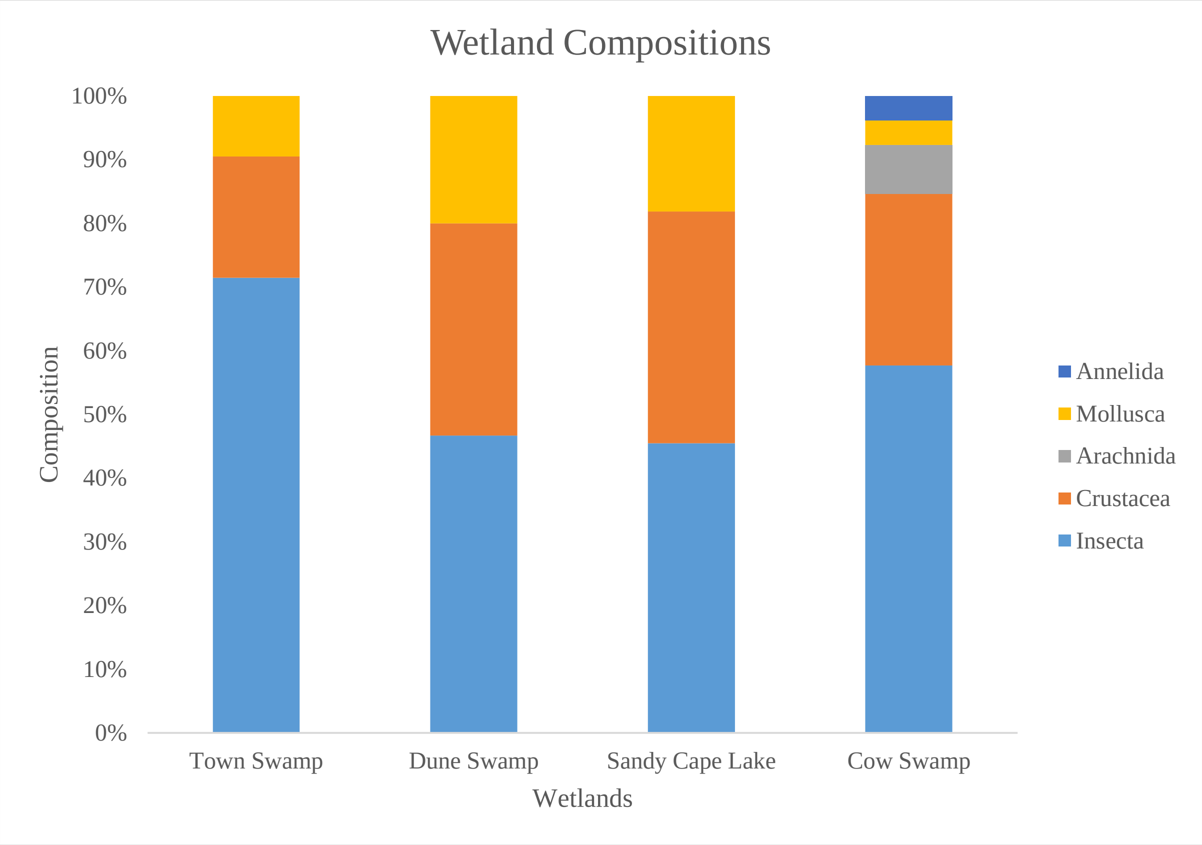

Figure 5: Stacked column graph showing the composition of the major invertebrate groups found at each wetland system based on taxa richness.

The dominant group of invertebrates found at all four locations was the Insecta, making up 71.43% of all taxa found at Town Swamp and 57.69% at Cow Swamp. Insecta, along with Mollusca and Crustacea were found in three of the four sites tested, while species of the Arachnida and Annelida were only located at Cow Swamp. Sandy Cape Lake displayed the lowest taxa richness with 11 species from three groups while Cow Swamp displayed the highest with 26 different species covering all five invertebrate groups.

An ANOVA test concluded that the taxa composition from site to site is not significantly different as the P-value of 0.76 (df=19) is higher than the significance value of 0.05.

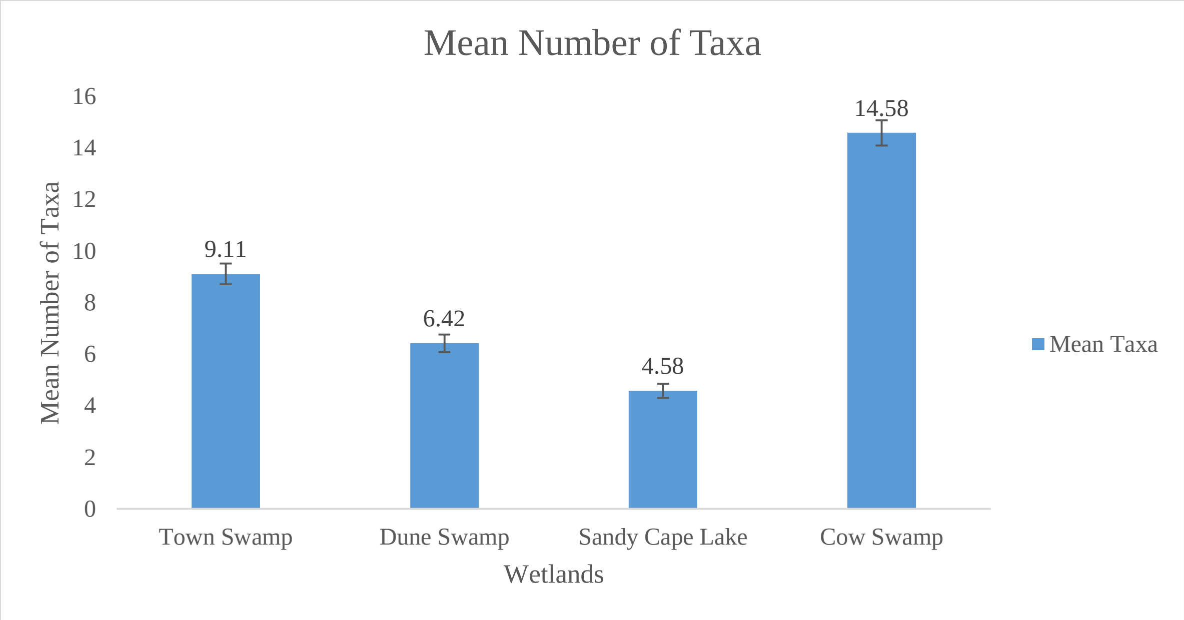

Figure 6: Column graph showing the mean taxon richness of each wetland.

The diversity of each wetland is illustrated by Figure 6, which shows the mean taxon richness of each site. Cow Swamp is evidently the most diverse (14.58 ± 0.49) and Sandy Cape Lake the least (4.58 ± 0.27).

T-tests were conducted between each site to compare the difference in taxon richness, and it was found that there are significant differences between all of the wetlands with all tests returning p-values below the significance value of 0.05. The highest difference was found between Cow Swamp and Sandy Cape Lake (t-statistic=-17.86, p-value=7.76012E-17, df=28) and the most similar between Dune Swamp and Sandy Cape Lake (t-statistic=4.22, p-value=0.0001, df=34).

Table 2: P(T<=t) two-tail value of multiple 2-tailed T-tests comparing the mean taxon richness of the four wetlands.

Town Swamp	1			
Dune Swamp	1.35754E-05	1		
Sandy Cape Lake	1.61829E-10	0.000173165	1	
Cow Swamp	3.71458E-10	7.74024E-15	7.76012E-17	1
	Town Swamp	Dune Swamp	Sandy Cape Lake	Cow Swamp

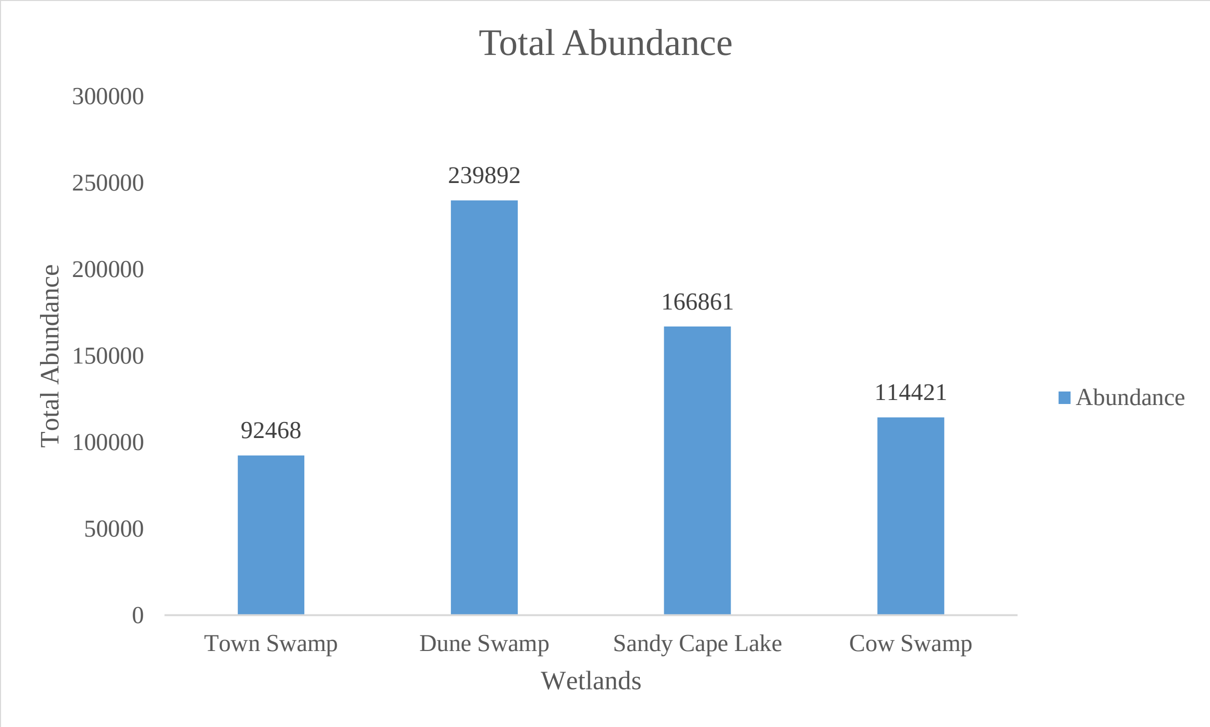

Figure 7: Column graph showing the total abundance of macroinvertebrates found in each wetland.

The results of an ANOVA test show that there is a significant difference in total abundance between the four wetlands with the p-value of 0.0445 (df:75), which is below the significant value of 0.05. Figure 7 shows that Dune Swamp has the greatest abundance with 239892 organisms found compared to the lowest, Town Swamp, with only 92468 organisms.

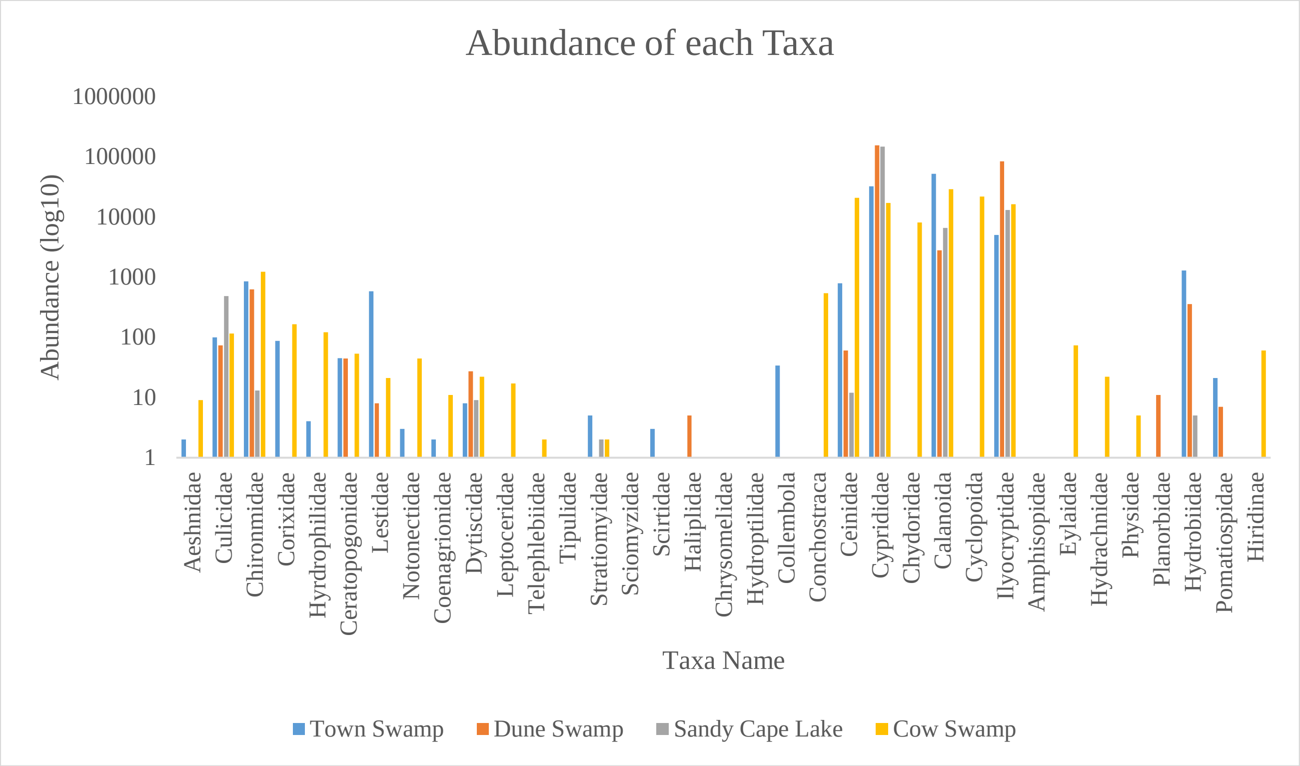

Figure 8: Column graph showing the number of individual organisms from each taxon that were found in each of the four wetlands.

Cyprididae was the most abundant species in three of the four wetlands and in total with 348452 individuals sampled. Other abundant species included Calanoida and Ilyocryptidae which are also in the Crustacea group. Of the Insectas, Chironmidae was the most abundant with 2700 sampled, most other species in the family were much rarer such as Tipulidae and Sciomyzidae which were only found once.

Table 3: Comparison index displaying percentage of taxa similarity between the four wetlands.

Town Swamp	1			
Dune Swamp	0.50	1		
Sandy Cape Lake	0.39	0.53	1	
Cow Swamp	0.48	0.33	0.28	1
	Town Swamp	Dune Swamp	Sandy Cape Lake	Cow Swamp

The comparison index in Table 5 shows that Dune Swamp and Sandy Cape Lake have the most numbers of taxon in common sharing a 53% commonality. However, Sandy Cape Lake also holds the lowest similarity with Cow Swamp, sharing only 28% of species.

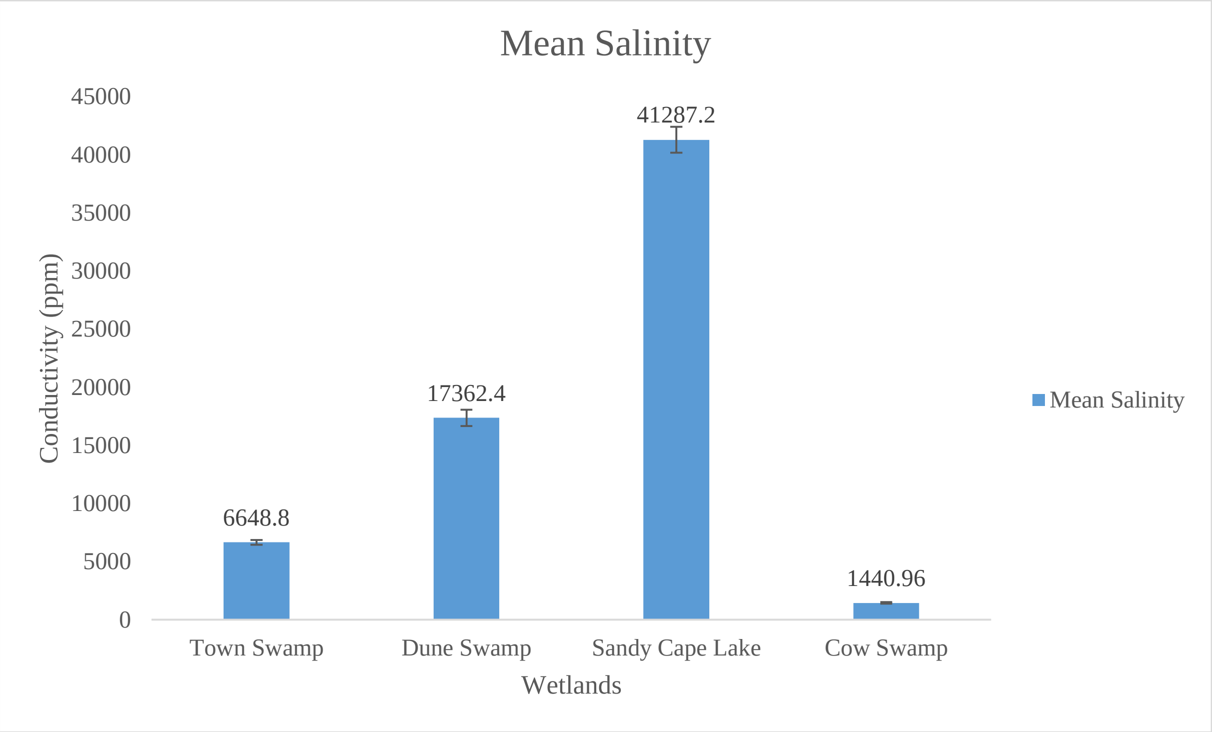

Figure 9: Column graph showing the mean salinity level (conductivity) of the four wetlands.

Figure 9 displays the large variation in relative conductivity of the four wetlands, Sandy Cape Lake being the most saline (41287.2 ± 1106.97) and the brackish wetland at Cow Swamp the least saline (1440.96 ± 73.71).

An ANOVA test returned a p-value of 1.88E-26 (df=31) which confirms the significant difference in the mean salinity level of the four wetlands. Further T-tests between each sites show that they are also significantly different to each other, with all comparisons returning p-value far below the significant value of 0.05.

Table 4: P(T<=t) two-tail value of multiple 2-tailed T-tests comparing the mean salinity of the four wetlands.

Town Swamp	1			
Dune Swamp	5.11235E-07	1		
Sandy Cape Lake	9.90564E-09	4.23088E-10	1	
Cow Swamp	1.98942E-09	9.3329E-08	3.36832E-09	1
	Town Swamp	Dune Swamp	Sandy Cape Lake	Cow Swamp

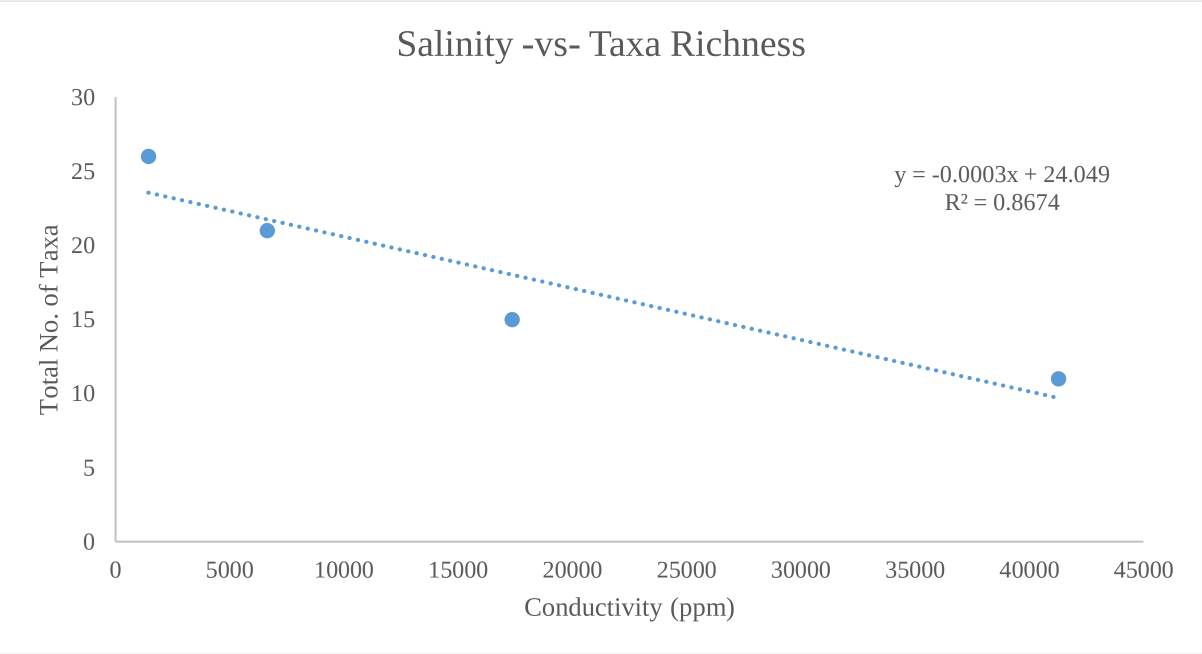

Figure 10: Scatter plot showing the correlation between salinity level and taxa richness.

The R^2 value of 0.8674 suggests a strong linear correlation between the salinity level of a wetland and its taxa richness. However, the p-value of 0.0687 is higher than the significant value of 0.05 so the relationship cannot be said to statistically reliable. Nonetheless, Figure 11 further affirms the inverse relationship and indicates that an increase in salinity results in a corresponding decrease in species richness.

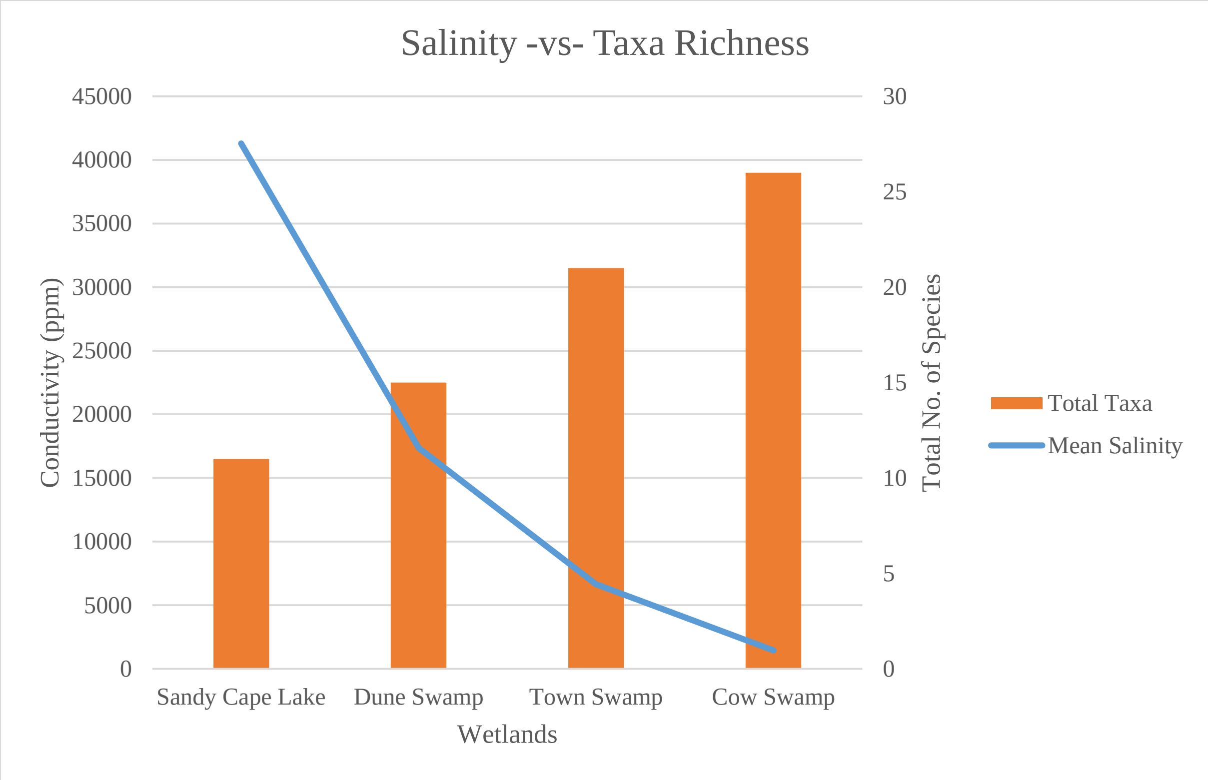

Figure 11: Column graph showing the inverse relationship between salinity level (conductivity) and taxa richness.

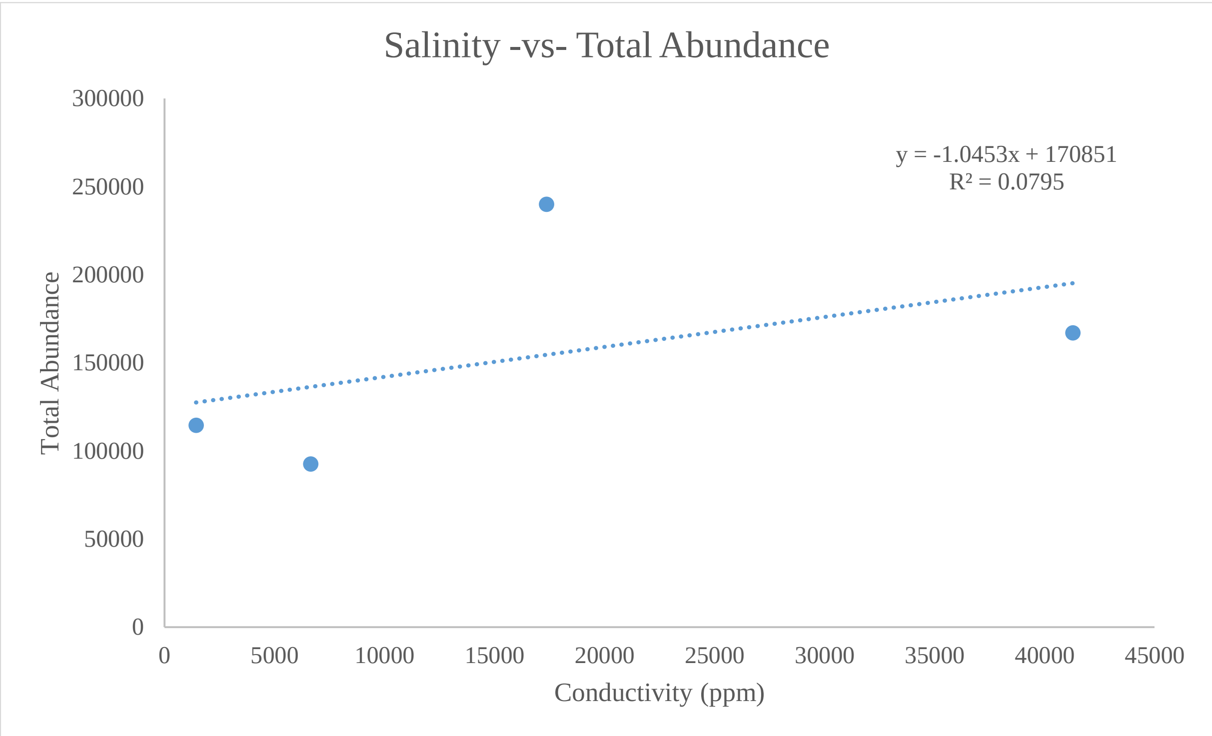

Figure 12: Scatter plot showing the correlation between salinity level and total abundance.

A regression analysis of the relationship between salinity level and total abundance returned an R^2 value of 0.0795 and P-value of 0.7179 which indicates that there is no correlation between these two variables.

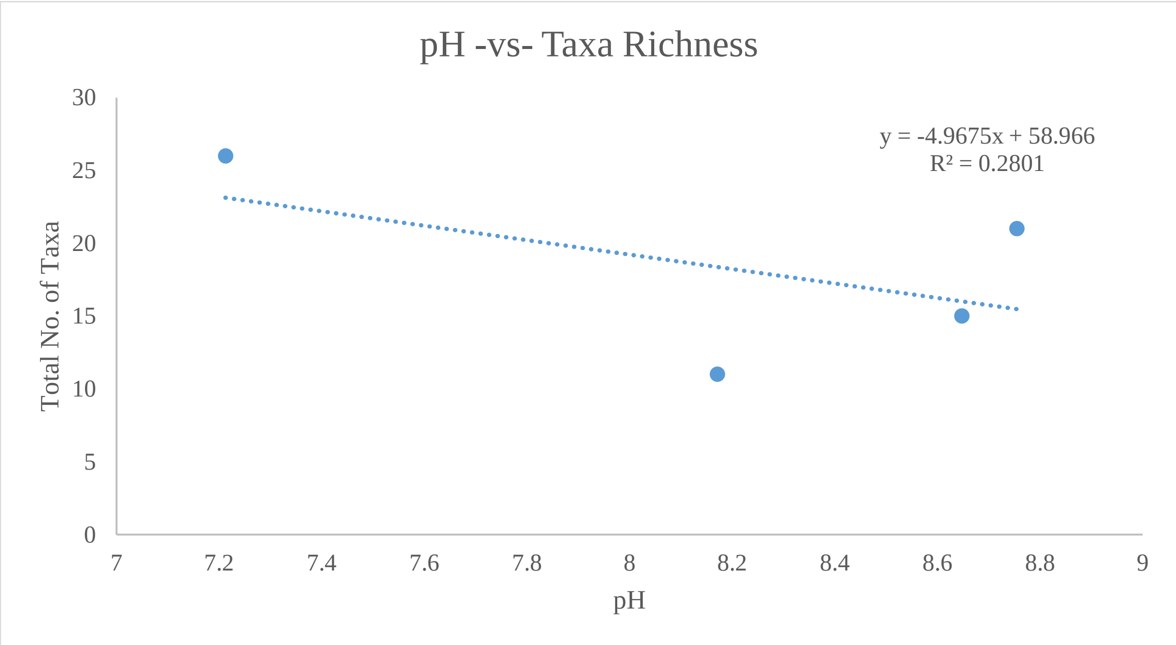

Figure 13: Scatter plot showing the correlation between pH level and taxa richness.

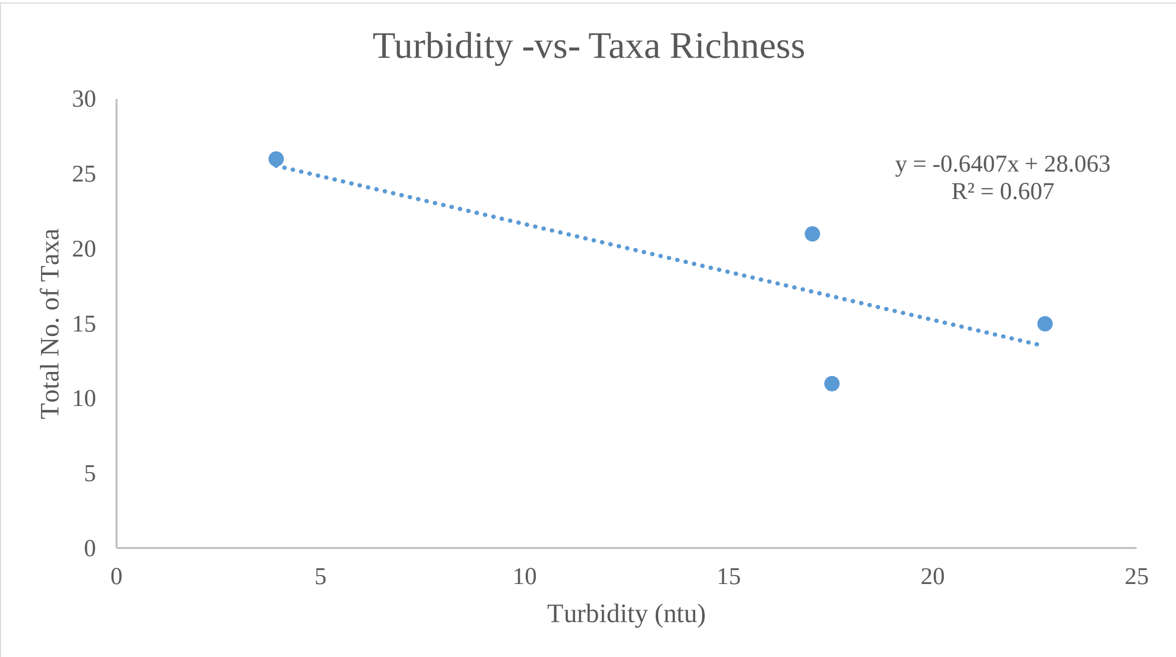

Figure 14: Scatter plot showing the correlation between turbidity and taxa richness.

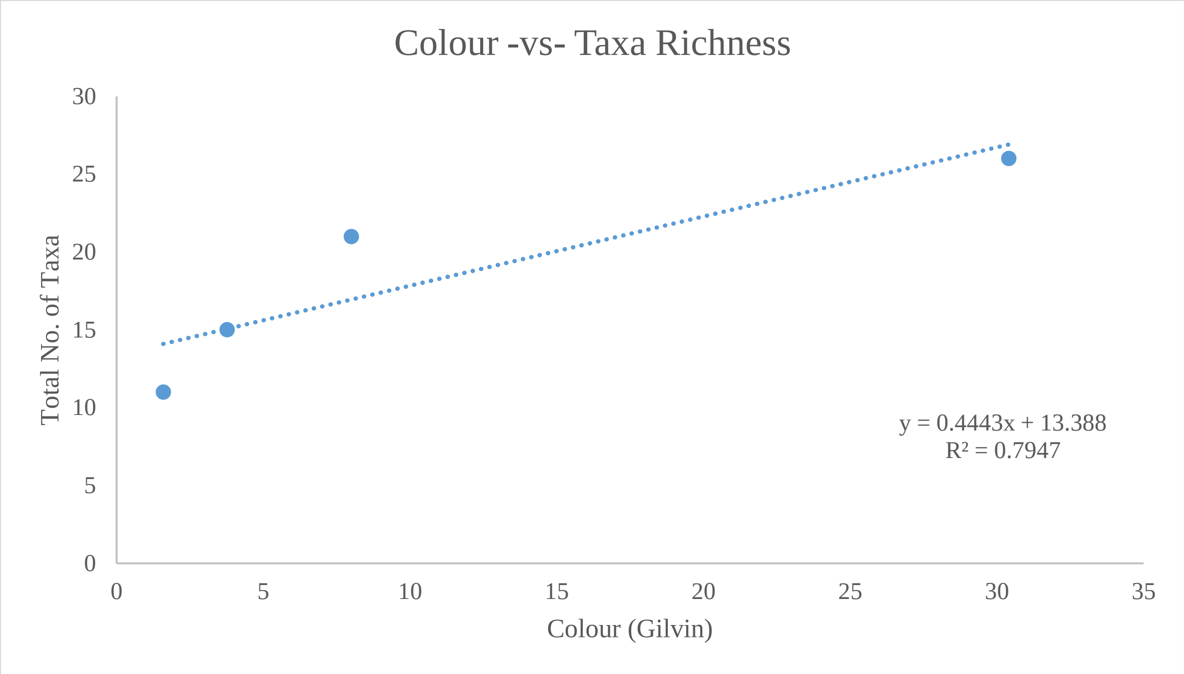

Figure 15: Scatter plot showing the correlation between water colour and taxa richness.

Besides the relationship between water salinity and taxa richness, other important physiochemical parameters were also sampled and tested. Linear regression analysis of pH, turbidity and water colour proved less correlated with species diversity. The pH level of the water has the weakest correlation with an R^2 of 0.2801 and P-value of .4701. Water turbidity and colour both displays a moderate correlation with R^2 values of 0.607 and 0.7947 respectively. However, they both returned P-values higher than the significant value of 0.05 (0.2209 and 0.1085) so cannot be said to be statistically reliable.

Discussion:

The aim of this scientific study was to investigate how different salinity levels affect the composition and richness of aquatic macroinvertebrate communities at Jurien Bay.

The overall results gathered from this study indicate that the aquatic macroinvertebrate family species richness does decrease as salinity levels increase. This finding was supported by the statistical tests completed including linear regression and data analysis that displays the correlation between salinity levels and taxa richness. Figure 10 shows a strong inverse relationship as supported by the R^2 value of 0.8674, however, the P value of 0.06 is marginally higher than the significant value of 0.05 so the inference cannot be accepted as statistically significant on its own. To support the argument, Figure 11 shows that taxa richness was higher in Cow Swamp which was the least saline wetland and decreased in a linear fashion as it transitioned to progressively more saline wetlands from Town Swamp, Dune Swamp to the most saline Sandy Cape Lake.

The salinity of the wetlands is displayed in Figure 9 which shows the clear differences in conductivity, which is confirmed by an ANOVA P-value of 1.88E-26. Sandy Cape Lake has a substantially higher level of conductivity than the other three site; it's mean conductivity of 41,287.2 ppm is higher than that of the average seawater conductivity of 32,000 ppm (Charnock et al. 2009). Based on the physical description of the sites, displayed in Table 1, one physical feature that stood out from the rest of the sites was the presence of a limestone quarry which would have drained into the wetland. This may be the major reason why this lake has such a substantially more saline than the other three wetlands. Dune Swamp and Town Swamp which follows Sandy Cape Lake in levels of conductivity could also be affected by a combination of a higher water table, aeolian salt deposits due to their positions along the coast and the seasonal drying of the swamps increasing the concentration of salt in drier months (Podmore 2009).

The Cow Swamp site was the least saline of those tested, with a mean conductivity of 1440ppm. This is just over the standard amount that could potentially minimise the aquatic macroinvertebrate species richness of a wetland (1000ppm) (Nielsen et al. 2003). Cow Swamp is located further east than the other three wetlands, therefore it would better insulated from the effects of aeolian salt deposits. It is also a perennial wetland, meaning the salt toxicity would not restrict macroinvertebrate development for larger taxa such as Annelida and Arachnida, which were only found in Cow Swamp as shown in Figure 5. Some taxa, specifically those of the Crustacea group, are abundant in all wetlands tested, which reflects their tolerance to high salinity levels (Szocs 2012). The disparity in the types of macroinvertebrates that can survive and thrive in different saline aquatic system can be seen in Table 5. Cow Swamp and Sandy Cape Lake only have 28% of taxa in common which highlights the different macroinvertebrate communities that have evolved and adapted to the environmental conditions.

The results gathered from this survey met the expected outcome because the salinity levels of certain wetlands such as Sandy Cape Lake become toxic to certain aquatic macroinvertebrate taxa preventing them from surviving in this environment. These results are also supported by similar surveys that were completed in the wheat belt, including Pinder (2005) which found that species richness in wetlands declined dramatically as salinity increased beyond 4100ppm**.** Halse made the observation that as salinity increases the number of species in a lake decreases, this trend was observed in multiple sites **(**Halse 1981) Lastly, Lyons' survey of Lake Eganu found that salinity has increased markedly in the last 70 years due to land clearing. As a result, the survey found that the richness of aquatic macroinvertebrate in the lake has decreased by about 80%. (Lyons et al. 2007).

This survey did indicate some clear trends although there were some limitations to this survey. A major limitation is the temporal scope of the survey which only provides a snapshot of the current wetland conditions. Another limitation was the small range of wetlands sampled, which only allowed insight into a single brackish site. Lastly, more biotic and abiotic data could be collected for analysis. Therefore, future surveys should take these points into considerations and be conducted over different seasons, include a larger, more varied range of wetlands and collect more physiochemical data.

Acknowledgement:

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Report 3

The influence of salinity on aquatic macroinvertebrate richness in coastal wetlands of Jurien Bay, Western Australia

Introduction

Saline water bodies are an intrinsic part of the Australian landscape, occurring throughout much of the coastal and inland areas of the continent (Brock M. A. 1985). Western Australia in particular has a high concentration of these waters, such as those in Jurien Bay, ranging from small perennial freshwater wetlands through to vast ephemeral salt pans (Brock M. A. 1985). This wide variety of wetland environments are home to an abundant and diverse range of aquatic invertebrate taxa and provide important habitat and food sources for many larger species such as birds and reptiles. Nowadays though, many wetlands are seeing progressively increasing levels of salinisation which is raising concerns of possible detrimental impacts upon the structure and function of these invertebrate communities, and therefore the ecosystem function of the wetlands themselves.

In Jurien Bay, as well as most other areas of Australia, most likely two greatest threats faced by wetlands in regard to increasing salinisation are dryland salinity and climate change. Dryland salinity is caused when deep rooted native vegetation is replaced with shallow rooted agricultural crops (Dept. of the Environment 2012). This allows groundwater levels to rise dissolving naturally occurring salts that are stored deep within the soil profile and bringing them to the surface (Dept. of the Environment 2012). When present at the surface they can have devastating impacts upon native vegetation as well as agricultural land, and cause toxicity within waterways. Climate change forecasts for Western Australia are for major decreases in rainfall and increases in temperature (Nielsen & Brock 2009). These changes will mean less inflow into wetlands and greater evaporation which will have the effect of lowering water levels and increasing relative salinity within wetland systems.

Wetlands are an extremely important part of the natural ecosystem providing habitat and breeding grounds for many native flora and fauna species, as well as being significant within the food chain providing a food source for larger species such as birds, reptiles and fish (Water & River Commission 2001). Invertebrate species form the basis of this food chain, however, concerns are that as salinity levels rise sensitive species will disappear leading to a breakdown of aquatic invertebrate communities severely impacting wetlands' ecosystem function (Water & River Commission 2001). Thus the aim of this study was to analyse the influence salinity has upon the macroinvertebrate communities within the coastal wetlands of Jurien Bay, Western Australia; the hypothesis being that as salinity levels increase taxa richness and abundance would decrease.

Methods

Sampling for this study took place at four wetlands of varying salinity, considered representative of the range of salinity levels experienced in coastal wetlands of Western Australia. Each wetland was sampled twice over a five-day period during August/September 2016, and analysed for their physio-chemical parameters and aquatic macroinvertebrate content.

Study Sites

For site locations See figure 1.

Cow swamp (30°15'20.39"S, 115° 8'59.01"E): Perennial, freshwater, approximately 1.6 ha, 100cm deep. Substrate – sandy clay or silt. Vegetation - *Melaleuca sp.* on shoreline, merging to pasture. Wildlife - wide variety of birdlife. Disturbance – wetland unfenced and situated in cattle farming pasture.

Town Swamp (30°17'28.15"S, 115° 3'11.32"E): Shallow, intermittent, saline, approximately 11 ha in size, 20 cm deep. Substrate - silty sand, some limestone outcropping present. Vegetation - filamentous algae in the waterway, *Sarcocornia sp.* and *Rhagodia baccata* on the shoreline merging to *Melaleuca sp.* and then *Eucalypt sp.* on higher ground. Wildlife - wide variety of birdlife, fringing vegetation likely habitat for amphibian and reptile species. Disturbance: highly modified, previously used as a waste disposal area, evidence of four-wheel-driving activity, many weed species.

Dune Swamp (30°12'34.78"S, 115° 0'27.23"E): Shallow, mostly intermittent, saline, approximately 2ha in size, 30 cm deep, small pool of permanent water (~100cm) towards the south eastern shoreline. Substrate - sandy silt. Vegetation - filamentous algae in waterway, *Sarcocornia sp.* and *Rhagodia baccata* on the shoreline, merging to *Melaleuca sp.* and then *Eucalypt sp.* and *Acacia sp.* on the south eastern sand dune. Wildlife - wide variety of birdlife, fringing vegetation likely habitat for amphibian and reptile species. Disturbance - mostly undisturbed, some evidence of four-wheel driving activity, minor weed disturbance.

Sandy Cape Lake (30°12'15.05"S, 115° 0'49.01"E): Shallow, intermittent, super-saline, approximately 180 ha in size, 30 cm deep. Substrate - sandy silt, evidence of salt surface crusting. Vegetation - *Sarcocornia sp.* and *Rhagodia baccata* on shoreline, merging to *Melaleuca sp.* and then *Eucalypt sp.* and *Acacia sp.* on higher ground. Wildlife – small amount of birdlife, fringing vegetation likely habitat for amphibian and reptile species. Disturbance – Major disturbance, lime mine on western side of wetland, evidence of four-wheel-driving activity, minor weed disturbance.

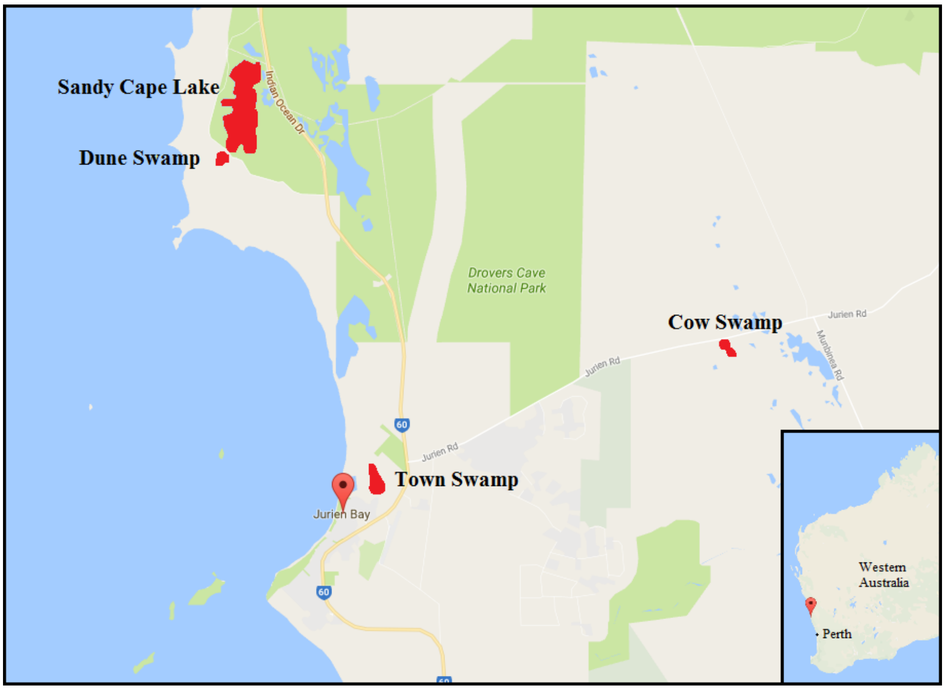

Figure 1: Study site locations (Google Maps 2016)

Physio-chemical and macroinvertebrate sampling

Each wetland was visited twice over a five-day period, providing a total of eight water and nineteen macroinvertebrate replicates for each wetland. For each replicate, water depth at the deepest point, and conductivity (mS) measurements were recorded. A water sample was then collected and taken back to the laboratory for analysis on pH, turbidity (NTU), and colour

($g440m^{-1}$). Conductivity and turbidity measurements were repeated three times for each sample to minimise false readings.

Macroinvertebrate sampling was carried out using a 250 micrometre mesh sweep net along a 10m transect moved vigorously in an up down motion from the surface to the substrate. The contents of the net were then washed into a sorting tray using 800 ml of water, where all large invertebrates were then manually removed and placed into a vial containing 70% ethanol. Following this a sample splitter was used to reduce the remaining sample down to $^{1}/_{32}$ as a record of any small invertebrates; the sample was then placed in a vial and topped with 70% ethanol. Laboratory processing of macroinvertebrate samples was carried out using stereomicroscopes with all invertebrates from both samples identified down to family level and counted. Keying was carried out using *The waterbug book* (Gooderham & Tsyrlin 2002), and *A guide to wetland invertebrates of southwestern Australia* (Davis & Christidis 1997).

Statistical Analysis

All statistical analysis was carried out using IBM SPSS Statistics 24, while all statistical tables and figures where produced using Microsoft Excel 2013. SPSS testing included: One-way ANOVA analyses on the difference in pH, salinity, turbidity, colour and taxon richness means between wetlands; Games-Howell post-hoc analysis performed on all ANOVA tests - Games-Howell was chosen as all wetlands showed unequal variance; and regression analyses performed on all correlations between physio-chemical parameters and taxon richness.

Results

<u>Physio-chemical Parameters</u>

Testing of environmental physio-chemical factors found considerable variation among wetlands for all testing parameters, results of which are shown in Figure 2. pH had a range of approximately 1.5 with Cow Swamp being the lowest at 7.2 and Town Swamp the highest at 8.7. ANOVA results found significant difference in pH readings, with post-hoc analysis revealing this was the case between all wetlands except Town Swamp and Dune Swamp. As expected salinity readings were found to have some of the largest differences ranging from nearly freshwater in Cow Swamp with an average of approximately 6.6ppt, up to highly saline conditions in Sandy Cape Lake at approximately 41.3ppt. ANOVA results found significant difference amongst salinity readings with post-hoc analysis revealing this to be true between all wetlands. Turbidity was found to have slightly less variation than salinity ranging from approximately 3.9ntu in Cow Swamp up to approximately 22.8ntu in Dune Swamp. ANOVA results showed there to be significant difference among readings, however post-hoc analysis revealed this to be the case only between Cow Swamp and Dune Swamp. Colour readings were found to have a large range, Sandy Cape Lake the lowest averaging approximately 1.6 and Cow Swamp the highest averaging about 30.4. ANOVA results found significant difference amongst colour readings with post-hoc analysis revealing this to be the case between all wetlands.

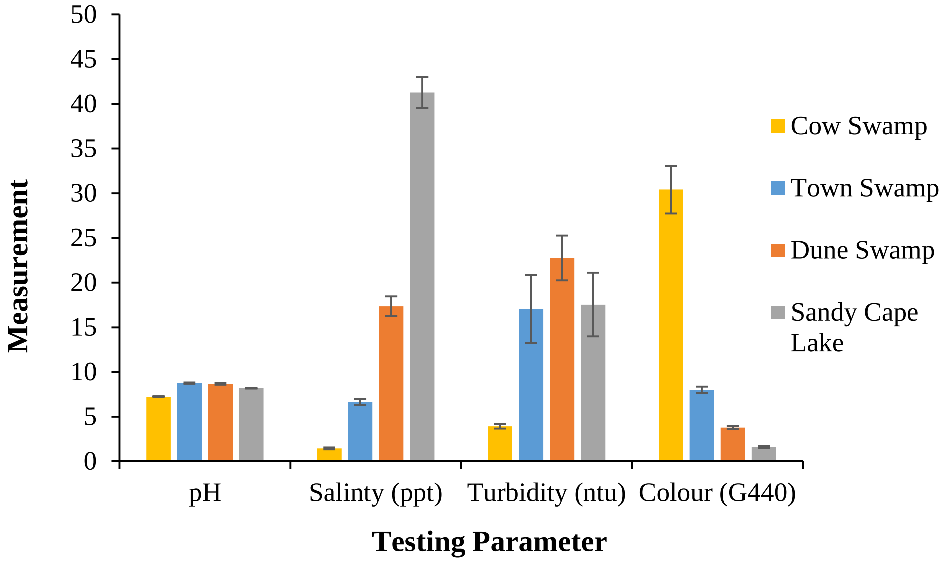

Figure 2: Means and standard errors for pH, salinity (ppt), turbidity (ntu) and colour (G440) at each wetland. For each parameter n=8 per wetland. ANOVA results were: pH: $F_{3,28}$ = 128.9, MS = 3.96, P = 0.000; Salinity: $F_{3,28}$ = 706.7, MS = 6114.31, P = 0.000; Turbidity: $F_{3,28}$ = 7.7, MS = 515.51, P = 0.001; Colour: $F_{3,28}$ = 96.9, MS = 1403.58, P = 0.000.

Macroinvertebrates

Macroinvertebrate analysis found there to be a total of 35 families recorded across all four wetlands, however taxa richness and abundance varied considerably between each. As can be seen from Figure 3 and Table 1 Cow Swamp recorded the highest taxa richness with a total of 26 and an average of ~18.9 families. This Then gradually decreased through Town Swamp then Dune Swamp and finally Sandy Cape Lake recording the lowest richness with a total of 11 and an average of ~5.9 families. ANOVA and post-hoc analysis found average family richness to be significant between all wetlands except Town Swamp and Dune Swamp. As for taxon abundance within families it generally followed the same pattern as family richness, being highest at Cow Swamp and lowest at Sandy Cape Lake.

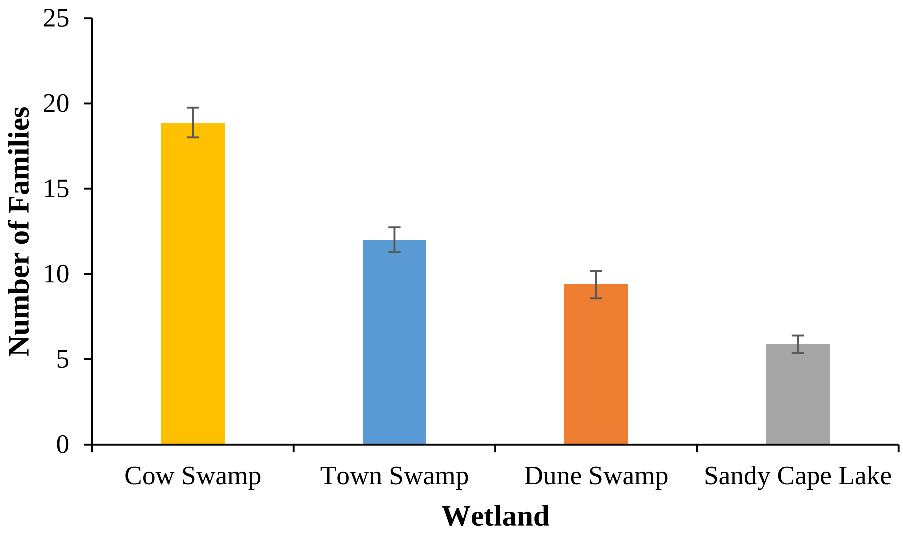

Figure 3: Average number of families recorded in each wetland. N = 8 per wetland. ANOVA results were: $F_{3,28}$ = 54.837, MS = 242.12, P = 0.000.

Physio-chemical and macroinvertebrate comparisons

Family richness and was compared to all four physio-chemical environmental factors in order to analyse what effect each was having upon taxa distribution. pH (Figure 4.1), salinity (Figure 4.2) and turbidity (Figure 4.3) all showed negative correlations with respective R^2 values of 0.3621, 0.6723 and 0.3379, while colour (Figure 4.4) showed a positive correlation with an R^2 of 0.7136. Regression analyses found all correlations to be significant ($\alpha = 0.05$) with all P-values < 0.005.

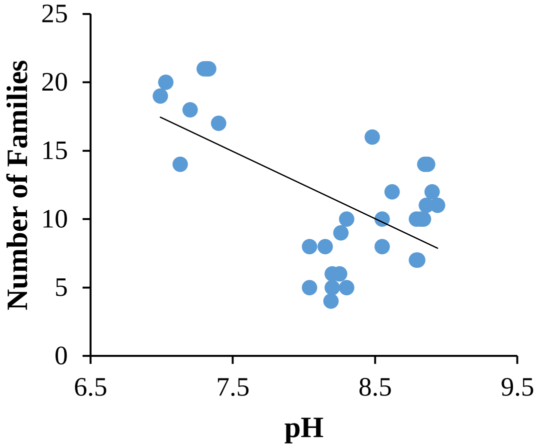

Figure 3.1: Correlation between pH and taxon richness (number of families) showing data for all four sites. The equation for the line is $y = -4.916\,x + 51.83$ with an R^2 of 0.3621; $n = 40$ samples. Regression analysis results were: $F_{1,30} = 17.03$, $t = 5.29$, P = 0.000.

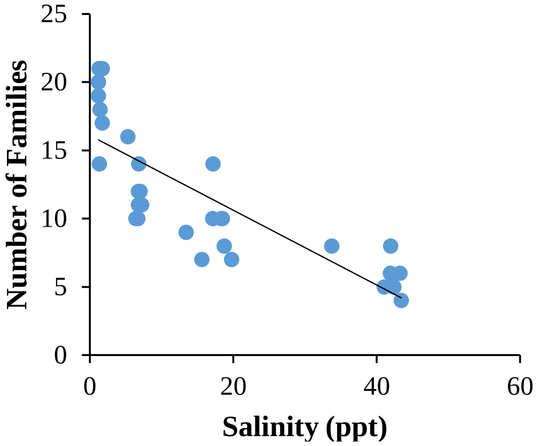

Figure 4.2: Correlation between salinity and taxon richness (number of families) showing data for all four sites. The equation for the line is $y = -0.274\,x + 16.10$ with an R^2 of 0.6723; $n = 40$ samples. Regression analysis results were: $F_{1,30} = 61.56$, $t = 20.30$, P = 0.000.

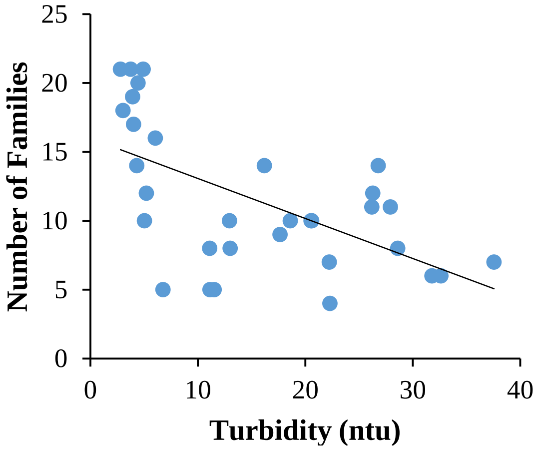

Figure 4.3: Correlation between turbidity and taxon richness (number of families) showing data for all four sites. The equation for the line is $y = -0.290\,x + 15.98$ with an R^2 of 0.3379; $n = 40$ samples. Regression analysis results were: $F_{1,30} = 15.31$, $t = 11.66$, P = 0.000.

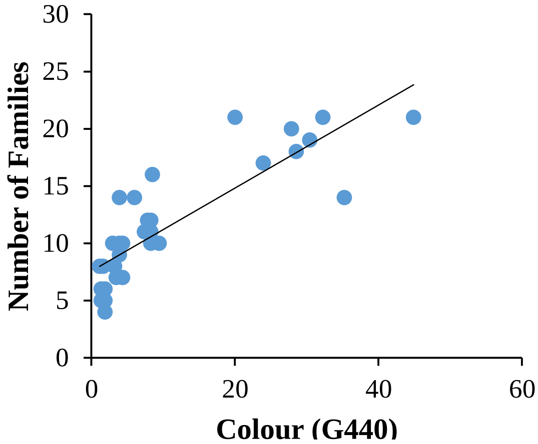

Figure 4.4: Correlation between colour and taxon richness (number of families) showing data for all four sites. The equation for the line is $y = 0.363\,x + 7.56$ with an R^2 of 0.7136; $n = 40$ samples. Regression analysis results were: $F_{1,30} = 74.77$, $t = 11.11$, P = 0.000.

Discussion

Results from this study support the original hypothesis, finding that an increase in salinity in Jurien Bays wetlands does lead to a reduction in aquatic invertebrate richness and abundance, however, other environmental physio-chemical factors also play a role in this observed decrease. Results found that taxa richness decreased significantly from Cow Swamp through to Town Swamp, followed by Dune Swamp and finally Sandy Cape Lake. All physio-chemical data measurements showed some degree of correlation to this reduction in taxa richness, however increasing salinity is most likely the most dominant cause. pH and turbidity, although statistically significant, showed only relatively weak correlations with R^2 values of ~0.36 and ~0.34 respectively, therefore neither are particularly effective at explaining the observed reduction, however both may still be partly accountable. Colour showed the strongest correlation to taxa richness with an R^2 of ~0.71, however, this correlation is most likely due to the increasing amount of fringing vegetation from Cow Swamp through to Sandy Cape Lake providing an increasing amount of habitat and therefore higher taxa richness. Considering these points, although salinity shows only moderately strong correlation with an R^2 of ~0.67, it is therefore the most likely reason for the observed changes in taxa richness between wetlands. This conclusion that increasing salinity reduces invertebrate richness also concurs with other studies such as Halse (1981).

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