Effects of time of day and proximal mangrove coverage on juvenile fish and cephalopods in seagrass

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ABSTRACT

Seagrass beds play an important roll for fish and cephalopods as they act as feeding areas, food sources, nurseries and shelter. There is a growing need to understand the ecology of these environments, how they relate to the habitats around them, how they are used differently over the diel cycle and how they support fisheries. This study tested the effects on fish and cephalopod in seagrass beds in Moreton Bay. Specifically, it investigated the differences of these assemblages in seagrass habitats (a) proximal to different levels of mangrove coverage, and (b) at dusk compared to dawn. A review of the literature suggested that there was likely to be greater species richness and abundances in seagrass proximal to higher levels of mangrove coverage and there would be greater species richness and abundances at dusk than dawn. This study found that there was significantly higher species richness of fish and cephalopods in seagrass beds proximal to areas with lower mangrove coverage but there was no significant difference in abundances. This correlation is likely to be attributed to the location of the sites within the estuary, which may be contributing more strongly to the nekton assemblages in the seabed than the proximal mangroves. Additionally, this study found that there was a significantly greater abundance of fish and cephalopods at dusk than dawn, but species richness was not significantly different. Both dawn and dusk are recognised as active periods and it was theorised that the greater levels of oxygen in the water column at dusk (due to diurnal primary production) could lead to greater activity within, and use of, seagrass beds at dusk than dawn. This research is the important first step in a highly topical potential study on the impacts of proximal habitats, location within the estuary and time of day on seagrass nekton.

Keywords: Seagrass, nekton, diel, mangroves, fish, cephalopod, estuary.

INTRODUCTION

Seagrass beds play an important roll in defining local fish assemblages, as they are used as feeding areas, for food, as nurseries and as shelter from predators (Jackson et al. 2001; Kopp et al. 2007; Ogden 1980; Parrish 1989; Pollard 1984; Thayer et al. 1984). The focus on understanding the ecology of seagrass habitats has grown as awareness increases of their valuable contribution to fisheries (Jackson et al. 2001; Gillanders 2006; McArthur et al. 2003). The ability of seagrass beds to stabilise sediment, remove excessive nutrients from the water column and act as a carbon sink has also lead to an increased focus on seagrass in the literature in the last few decades (Mellors et al. 2002).

In Queensland and in Moreton Bay in particular, there are seagrass beds that have been found to be resilient to the large sediment loads and nutrients emitted from the Brisbane River (Maxwell et al. 2014). Prior research in nekton assemblages in seagrass in Moreton Bay has included looking at the prawn and fish assemblages in seagrass beds compared to unvegetated areas (Skilleter et al. 2005). This study will focus on fish and squid assemblages in seagrass beds. The use of seagrass by nekton is highly complex and depends on many factors (Connolly & Hindell 2006). This study seeks to help understand how the use of seagrass beds by nekton is affected by (a) the level of proximal mangrove coverage, and (b) the time of day.

The effects of surrounding habitats on nekton in seagrass are highly complex (Hammerschlag & Serafy 2010; Jelbart et al. 2007). Studies suggest that surrounding ecosystems (e.g. mangroves, saltmarshes, mudflats) greatly affect nearby seagrass nekton assemblages (Kopp et al. 2010; Honda et al. 2013; Laegdsgaard & Johnson 2001). Dorenbosch et al. (2006) found that, in East Africa, nearby coastal ecosystems such as coral reefs and mangroves increased fish species richness and abundance on proximal seagrass beds. This correlation is well established on other parts of the world, including Moreton Bay (Butler & Jernakoff 1999; Skilleter et al. 2005). The role of mangroves as nursery habitats also leads to a greater species richness and abundance of fish in seagrass beds close to mangroves (Nagelkerken et al. 2002).

Studies on the changes in nekton assemblages in seagrass beds over the diel cycle have primarily focused on comparing night and day (Krumme et al. 2005; Sogard et al. 1989; Gray et al. 1998). However the differences between dusk and dawn (where the amount of light is similar) has not been investigated extensively. Generally dusk and dawn are considered to be very active periods as they are the intercept of behaviours from nocturnal and diurnal animals (Sogard et al. 1989; Pelicice et al. 2005). In general, higher nekton abundance and species richness is recorded at dusk than dawn (Krumme et al. 2005). This study will seek to compare the differences in fish and cephalopod assemblages in seagrass beds at dawn and dusk at two different locations in Moreton Bay.

The aim of this study was to investigate the differences of fish and cephalopod assemblages in seagrass habitats (a) proximal to different levels of mangrove coverage, and (b) at dusk compared to dawn. The following two hypotheses were tested: (1) species richness and abundance would be significantly greater in seagrass beds proximal to areas with high mangrove coverage compared to seagrass beds proximal to areas with low mangrove coverage, and (2) species richness and abundance would be significantly greater at dusk than dawn.

METHODS

STUDY SITES

This study was undertaken on the northwestern point of North Stradbroke Island in Moreton Bay, Queensland (Figure 1). Moreton Bay has extensive beds of seagrass and North Stradbroke Island's western coast has varying levels of mangrove coverage along it. Two sites were sampled; with five replicate samples being taken each at dusk and dawn (a total of 10 replicate samples taken at each site). Site A was a seagrass bed proximal to an area with high levels of mangrove coverage (>80% coverage) and Site B was a seagrass bed proximal to an area with low levels of mangrove coverage (<15% coverage). Seagrass sites were selected based on the per cent coverage of mangroves along the proximal shoreline, using Google Earth (2008) (Figure 2). The samples were taken from seagrass beds approximately 100m from the shoreline.

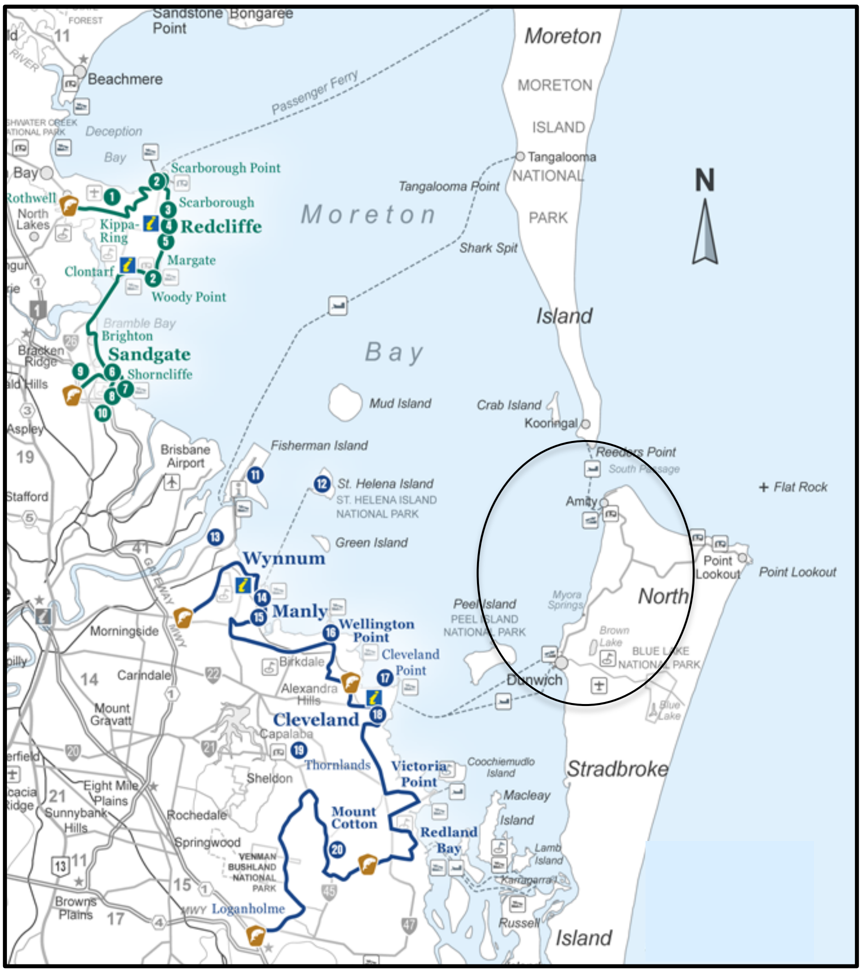

Figure 1: Map of Moreton Bay

(Source: RACQ 2012)

Figure 2: Map of subject sites on North Stradbroke Island

(Source: Google Earth 2008)

Technique Used

For each replication, a 10m, 1.5mm mesh seine net was pulled approximately 15m along the seagrass bed, with the ends of the net being held approximately 6m apart. This resulted in an area approximately $90m^2$ being sampled with each replicate. The seine net was designed to catch juvenile fish and cephalopods. The samples were taken at dawn and dusk over 2 days, which coincided with low tide. Care was taken to ensure that there was no overlap in the areas being sampled each time. Samples were taken in knee-deep water from seagrass beds of *Zostera muelleri* with similar shoot structures and densities. The contents of the seine net were then emptied into aerated buckets, organisms were identified and recorded and released immediately to minimize mortality rates. Nekton that could not be identified immediately was photographed, recorded and released, and identified at a later point in time.

Statistical Analysis

The statistical packages IBM SPSS Statistics Version 20 and Primer Version 6.1.13 were used to statistically analyse the data.

Results

In total 30 individual fish and squid species were caught and identified as well as *Sepiadariidae spp., Ostraciidae spp., Arothron spp.,* and *Gobiidae spp.,* which were grouped by family due to the difficulty of identifying the juvenile stages of these organisms (Table 1).

Table 1: A summary of fish and squid species caught

Scientific Name	*Common Name*
Sepiadariidae spp.	Squid
Ostraciidae spp.	Cow fish
Arothron spp.	Pufferfish
Gobiidae spp.	Goby
Sepioloidea lineolata	Striped pyjama squid
Gerres subfasciatus	Silver biddy
Repomucenus macdonaldi	Dragonet
Monocanthus chinensis	Fan bellied leatherjackets
Pseudorhombus jenynsii	Smalltooth flounder
Centropogon australis	Fortescue
Urocampus carinirostris	Hairy pipefish
Pelates sexlineatus	Six lined trumpeter
Acanthopagrus berda	Pikey bream
Hippicthys penicillus	Beady pipefish
Sillago maculate	Trumpeter whiting
Leptoscarus vaigiensis	Seagrass parrotfish
Suggrundus jugosus	Mud flathead
Atherinomorus vaigiensis	Ogilby's hardyhead
Syngnathoides biaculeatus	Double ended pipefish

Strongylura leiura	Longtom
Tetractenos hamiltoni	Common toadfish
Hippocampus kuda	Seahorse
Synanceia horrida	Estuarine stonefish
Sphyraena obtusata	Striped sea pike
Siganus fuscescens	Dusky rabbitfish
Petroscirtes lupus	Brown sabertoothed blenny
Hemiramphus robustus	Three-by-two garfish
Halichoeres nebulosus	Cloud wrasse
Parachaetodon ocellatu	Ocellate coralfish
Acanthopagrus australis	Yellowfin bream
Apogon limemus	Sydney cardinalfish
Fistularia petimba	Rough flutemouth
Torquigener pleuroglamm	Weeping toadfish
Pegasus volitans	Slender seamoth

Due to the presence of two variables (mangrove coverage and time of day) a multivariate analysis, specifically a PERMANOVA, was conducted to investigate the differences in fish assemblages. The interaction between mangrove coverage and time of day was found to be not significantly significant (p=0.167). However, individually, the two variables were found to be significantly significant: mangrove coverage (p=0.001) and time of day (p=0.046). A binomial presence/absence analysis was then used, as the variation in species abundance was not comparable. This analysis also showed that both variables, mangrove coverage and time of day, were significantly significant in affecting the fish assemblages (p=0.001 and p=0.009, respectively).

Multidimensional Scale (MDS) Plots were used to visually investigate the influence of proximal mangrove coverage (Figure 3) and time of day (Figure 4) on fish assemblages. For both MDS Plots, the stress level was considered to be acceptable (0.09). Figure 3 indicates there is clear separation in the fish assemblages recorded at Site A, with low mangrove coverage, and Site B, with high mangrove coverage. Although less apparent, figure 4 also shows a difference in fish assemblages recorded at dusk and dawn.

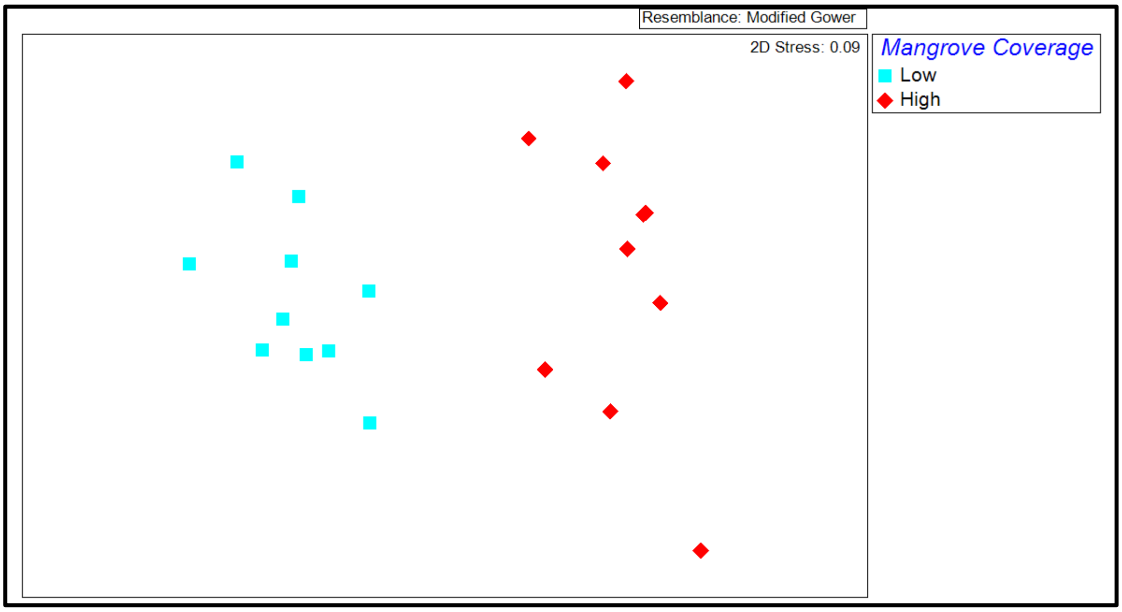

Figure 3: MDS Plot of fish assemblages in seagrass beds proximal to different levels of mangrove coverage

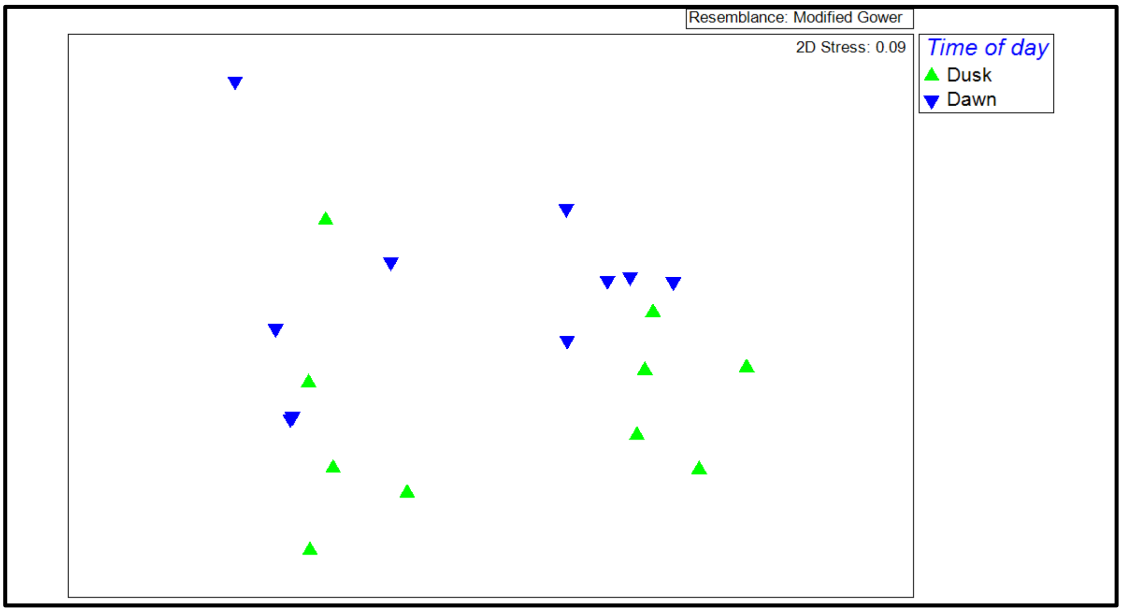

Figure 4: MDS Plot of fish assemblages in seagrass beds at dusk and dawn

Having established that fish assemblages were different at the two sites proximal to different levels of mangrove coverage as well as different between the two times of day, species richness and abundance were looked at individually, to better understand what factor was driving the difference.

Univariate analyses were undertaken to investigate the following:

1. Species richness on seagrass beds proximal to low and high levels of mangrove coverage.
2. Abundance on seagrass beds proximal to low and high levels of mangrove coverage.
3. Species richness on seagrass beds at dawn and dusk.
4. Abundance on seagrass beds at dawn and dusk.

5. The differences in the abundances of the most common nekton species on seagrass beds proximal to low and high levels of mangrove coverage.
6. The differences in the abundances of the most common nekton species on seagrass beds at dawn and dusk.

SPECIES RICHNESS AND MANGROVE COVERAGE

Exploratory data analyses were conducted to investigate the assumptions for an ANOVA. Having established all assumptions were met an ANOVA was conducted. Species richness was found to be statistically significantly greater in seagrass beds proximal to areas with low mangrove coverage (p=0.026) (Figure 5).

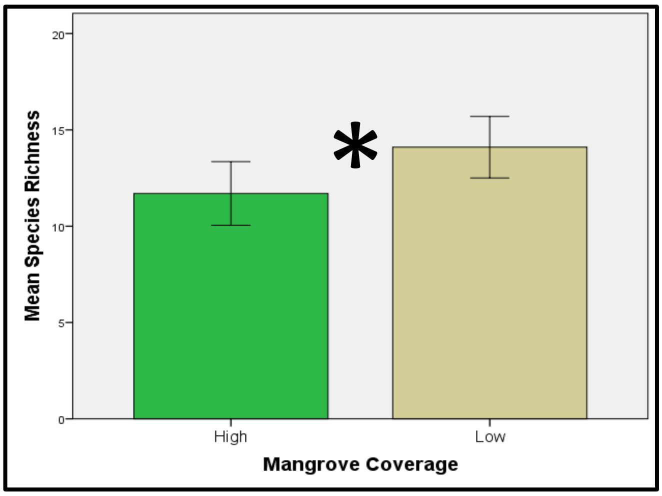

FIGURE 5: SPECIES RICHNESS IN SEAGRASS BEDS PROXIMAL TO AREAS WITH HIGH AND LOW MANGROVE COVERAGE

ABUNDANCE AND MANGROVE COVERAGE

There was found to be no statistically significant difference in abundance in seagrass beds proximal to areas with differing levels of mangrove coverage (p=0.835).

SPECIES RICHNESS AND TIME OF DAY

There was found to be no statistically significant difference in species richness at dusk and dawn (p=0.083)

ABUNDANCE AND TIME OF DAY

Exploratory data analyses were conducted to investigate the assumptions for an ANOVA comparing the abundance at dusk and dawn. A Lavene's Test using the original data found that the assumption of homogeneity of variance was not met. Similarly, a Lavene's Test using the log-transformed data found no homogeneity of variance. Therefore, the assumption of homogeneity of variance was violated and it was decided that it was necessary to halve the alpha to account for the lack of homogeneity of variance (significant is p<0.025). An ANOVA was conducted and abundance was found to be statistically significantly higher at dusk than dawn (p=0.022) (Figure 6).

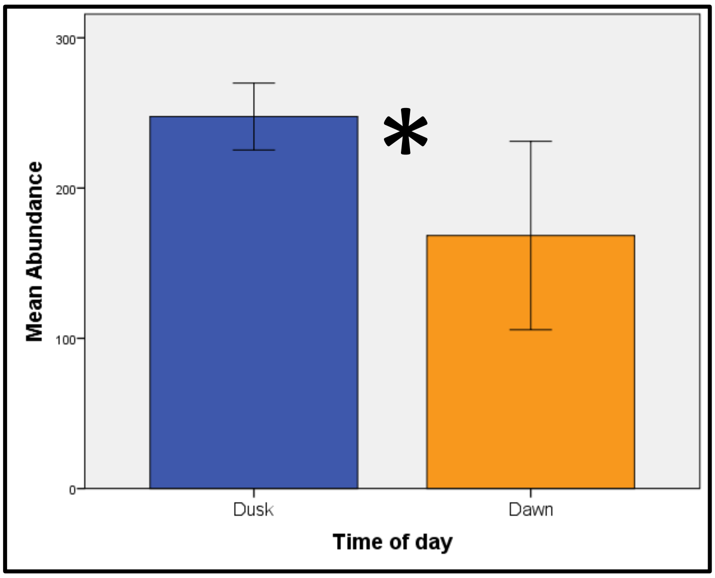

FIGURE 6: ABUNDANCE IN SEAGRASS BEDS AT DUSK AND DAWN

ABUNDANCE OF COMMON SPECIES AND MANGROVE COVERAGE

A univariate analysis was also conducted comparing the mean abundance of several of the most common species in seagrass beds proximal to high and low levels of mangrove coverage. The assumptions were tested for each species. The study showed that there were significantly greater abundances of the *Petroscirtes lupus* but lesser abundances of *Pelates sexlineatus* in seagrass beds proximal to areas with high mangrove compared to those proximal to low mangrove coverage (Figure 7).

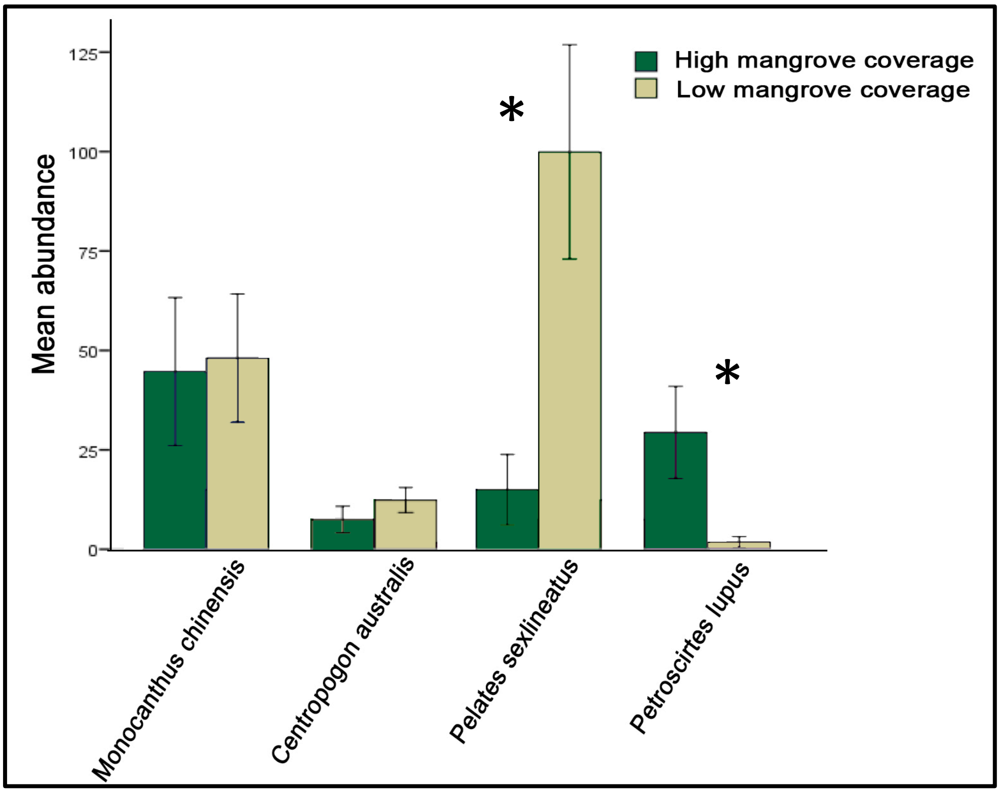

FIGURE 7: ABUNDANCE OF COMMON SPECIES IN SEAGRASS BEDS PROXIMAL TO AREAS WITH HIGH AND LOW MANGROVE COVERAGE

Abundance of common species and time of day

A univariate analysis of the common species comparing their abundances at dawn and dusk found that there was a significantly greater abundance of *Monocanthus chinensis* at dusk than dawn (Figure 8). The assumptions were tested and met.

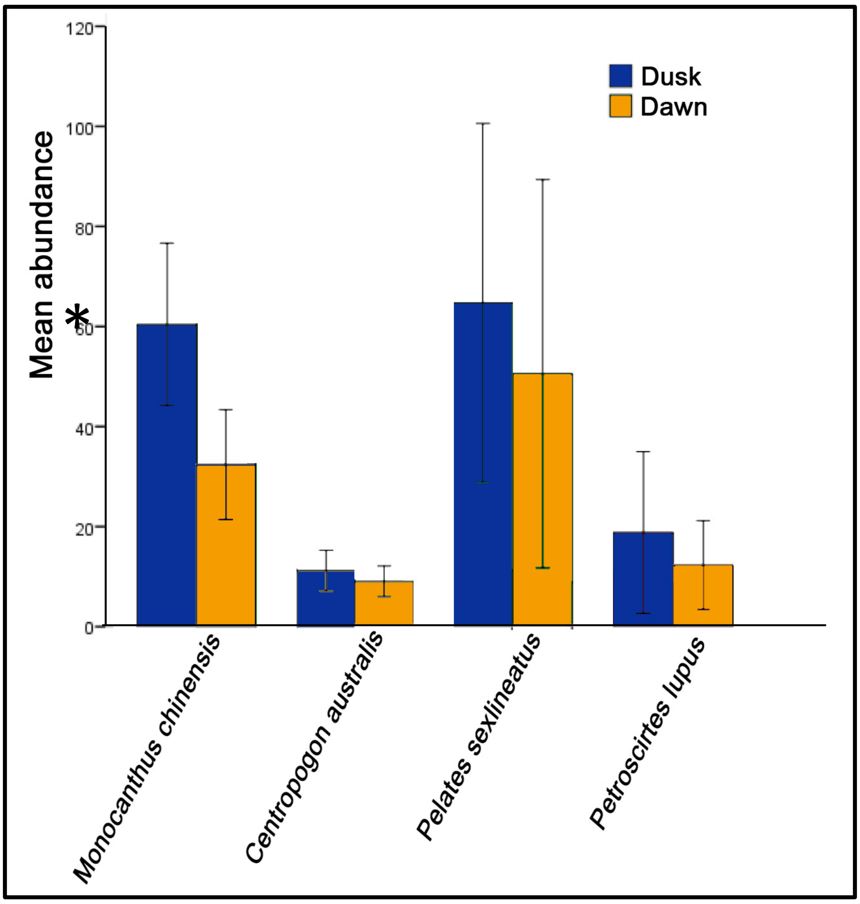

Figure 8: Abundance of common species in seagrass beds at dusk and dawn

Discussion

The results of this study were not supportive of either of the two hypotheses. Firstly, significantly greater species richness was found in seagrass beds proximal to areas with low mangrove coverage compared to high mangrove coverage and there was also no significant difference observed in fish and cephalopod abundances between these two locations. Secondly, there was a significantly greater abundance of fish and cephalopods in seagrass beds at dusk than dawn, but species richness was not significantly different between these times. There are several reasons why this could be the case, each which could be investigated in a potential subsequent study. Firstly, it is likely that more replications could lead to decreased variation, and increased accuracy in the results across both hypotheses. Secondly, there are some other factors that could be contributing to the results not being supportive of each hypothesis.

For example, the geography and the hydrology of the estuary could have been having a greater influence on the nekton assemblages in the seagrass beds than the mangroves themselves. Butler and Jernakoff (1999) argue that, although there are many factors that can contribute to nekton assemblages in seagrass beds, the location within the estuary has the greatest influence. The location within an estuary can determine the sediment, the exposure to predation and other threats, the availability of nutrients, the seagrass structure and the accessibility of the site to specific aquatic species (Butler and Jernakoff 1999). Site A, with lower proximal mangrove coverage, is located in a small bay, where a sink effect could be in action. It is possible that the larvae-laden, oceanic waters come into the estuary around the northern point of North Stradbroke Island, travel through the Rainbow Channel and collect in the bay north of Dunwich, where site A is located (Figure 9). Similar instances of this effect have been observed and described in the literature all over the world (Dame & Allen 1996; Chernova & Primakov 2011; Murphy & Iken 2014). Using more sample sites, dispersed throughout Moreton Bay, could help to better understand the relationship between nekton assemblages in seagrass beds, proximity to mangroves as well as location within the estuary.

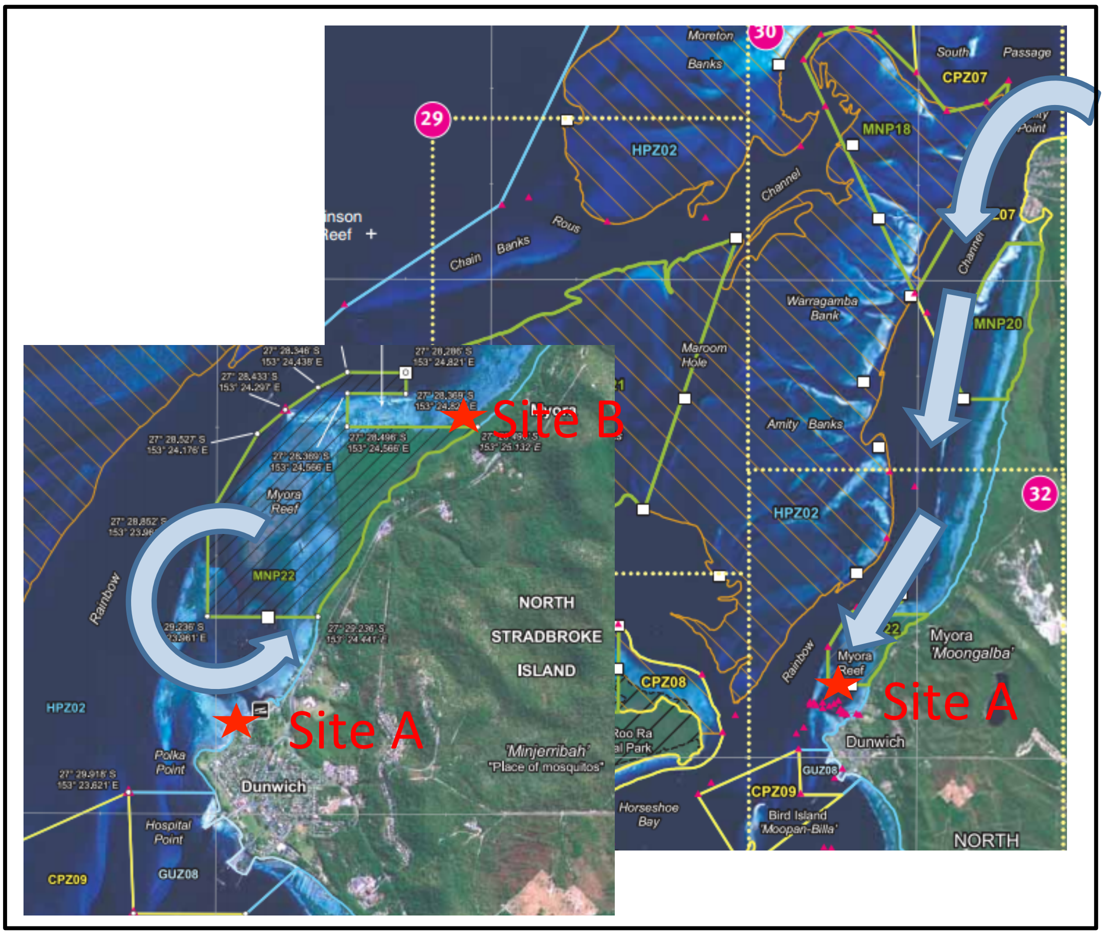

FIGURE 9: DIAGRAM OF SINK EFFECT AT SITE A

This study did find a higher abundance of fish and squid at dusk than dawn (although species richness was not significantly different). This could be due to the fact that there is a higher level of oxygen in the water column from primary production throughout the day, which is thought to influence organism behaviours (Yarbro & Carlson 2008). These periods are also known to be incredibly active as they are the times that a shift change occurs in the behaviours of nocturnal and diurnal species (Helfman 1996). This research is the important first step in a highly topical potential study on the impacts of proximal habitats, location within the estuary and time of day on seagrass nekton.

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