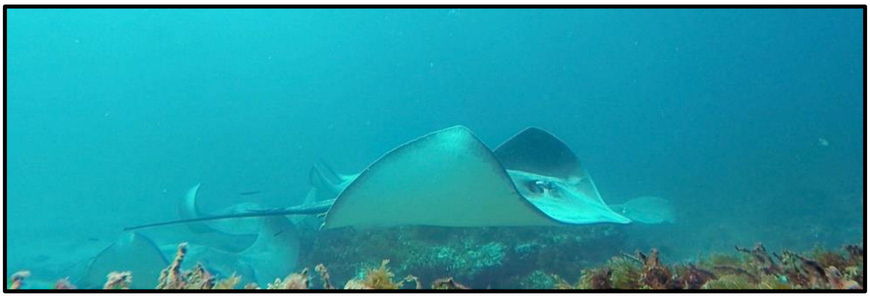
Ecology of Elasmobranch Cleaning Stations and the Effects of Tourism Activities in Bateman Bay, Ningaloo Reef



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DECLARATION

I declare that unless otherwise stated, this thesis is my own account of my research and contains as its main content, work which has not been previously submitted for a degree at any tertiary education institution.

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ABSTRACT

Fish cleaning in the marine environment is a mutualistic interaction where one participant, the cleaner, removes parasites, scales and mucus from the other participant, the client at sites called cleaning stations. Most studies of cleaning station client communities have focused on ray-finned fish while elasmobranchs have received less attention. As wildlife tourism commonly targets cleaning stations as sites to swim with manta rays and sharks, there is a need to improve understanding of how elasmobranchs use cleaning stations. Additionally, little work has been done to assess if and how tourism has impacts on manta rays or their ecosystems. A resident population of manta rays forms the basis of a manta ray tourism industry Bateman Bay, Western Australia which uses manta ray and shark cleaning stations as sites for interactions. This makes Bateman Bay an ideal area to address the current gaps in understanding of elasmobranch cleaning station use and the effects tourism may have on manta ray cleaning behaviour.

This study assessed the species composition and cleaning behaviours of the client community of the Point Maud and North Reef cleaning stations in Bateman Bay, Western Australia. Focus was given to the visitation frequency and cleaning behaviours of elasmobranch clients. The frequency of boat traffic and tourist presence at these sites and the proximity of manta ray tour interactions to cleaning stations was also studied. Using a remote underwater video system, 413 cleaning events involving 45 client species from 22 families including ray-finned fish, elasmobranchs and turtles were observed. Scaridae, Carcharhinidae, Labridae, Lethrinidae and Mobulidae clients contributed to 77.97% of the observed cleaning events. Differences in client community composition appeared to be driven more by season than site.

Visitation rates and cleaning behaviours varied between elasmobranch families. Sharks and manta rays had the highest visitation rate for Point Maud in autumn, stingrays were the most frequent elasmobranch client at North Reef. No elasmobranch cleaning events were observed in winter. Manta ray cleaning events had the longest average duration, followed by stingrays and sharks. Manta rays were most frequently observed circling around cleaning stations while sting rays and sharks more commonly cruised past the cleaning stations.

Boat traffic and tourist presence was more frequent at the Point Maud than North Reef. Of the observed tourist interactions, 16% occurred with cleaning manta rays. The behaviours of two manta rays before and during the interactions suggest that manta rays change their cleaning behaviours in response to tourists.

This study showed that the Point Maud and North Reef cleaning stations supports a diverse range of clients. The high contribution of families valued for tourism and for recreational fishing to the client community at these sites suggests their function is important in maintaining the ecological, social and economic values of Bateman Bay. As such, protecting megafauna cleaning stations in Bateman Bay may help sustain the tourism industry and recreational fishing in the area. The results of the boat traffic and tourist presence data suggest that making the code of conduct a condition of tour operator licenses, which has been recommended in other studies, could assist in reducing the impacts of tourism on manta ray cleaning behaviours.

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List of Abbreviations and Acronyms

CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora

MDS: Multi-Dimensional Scaling

NMP: Ningaloo Marine Park

NRA: North Reef in autumn

PMA: Point Maud in autumn

PMW: Point Maud in winter

RUV: Remote Underwater Video

1 Introduction

Ecological relationships are the interactions within and between species in an ecosystem; one example of this is cleaning mutualism. Cleaning occurs when one participant, the cleaner, removes parasites from another participant, the client (Limbaugh, 1961). Cleaning mutualism occurs between many fish species in marine environments at sites called cleaning stations (Losey, 1972). It is thought that the mutualism originated in tropical coral reef ecosystems, but also occurs on temperate reefs (Baliga & Law, 2016). As client fish are unable to remove all parasites by themselves, the benefit of allowing another organism to do so is reduced risk of disease and slowed growth rates for the client (Clague et al., 2011). The cleaner benefits from a rich untapped food source that repeatedly comes to them (Poulin & Grutter, 1996). Both participants therefore should receive mutual benefit, however due to cleaners consuming scales and mucus produced by the client, the mutually beneficial nature of the interaction has been questioned (Grutter & Bshary, 2004). Despite this, it has been demonstrated that there are clear biological and ecological benefits to the presence of cleaning stations on coral reefs.

The primary benefit of biological benefit of cleaning appears to be parasite control. Cleaning mutualism helps reduce parasite loading on clients and consequently ensures client growth and maturation age are not slowed and decreases disease risks (O'Shea et al., 2010; Clague et al., 2011; de Souza et al., 2014). However the presence of cleaners also appears to reduce stress levels in client fish (Bshary et al., 2007) Cleaning stations also have ecological importance. The presence of cleaner fish appears to reduce predation rates, acting as safe havens. Additionally, cleaning stations are associated with higher fish diversity and abundance, but the driver is somewhat unclear (Grutter et al., 2003; Arnal et al. 2002). Studies of cleaning station communities and cleaning behaviours have often focused on ray-finned fish compared to other clients such as sharks and rays (Subclass: Elasmobranchii) or turtles. This may reflect the fact that ray-finned fish cleaning stations are more common than their megafauna counterparts. However, as there is growing interest in using cleaning stations as sites for wildlife tourism, particularly for manta ray tourism, there is a need to better understand elasmobranch use of cleaning stations.

Manta ray tourism is a wildlife tourism industry that is rapidly growing in popularity due to several aspects of manta ray biology and ecology. Manta rays have a tendency to develop site affinities with cleaning stations and feeding grounds, making them a reliable focal species to work with as a tour operator (Couturier et al., 2011; O'Malley et al., 2013). Their large size and perceived friendly nature makes them popular with tourists seeking memorable wildlife interactions (Couturier et al., 2012; Hausmann et al., 2017). This has resulted in manta ray tourism becoming a valuable industry that can be used as a conservation strategy against overfishing, which is causing population declines across the global distribution of manta rays (O'Malley et al., 2013; Dulvy et al., 2014). While manta ray tourism has created economic incentives to introduce stronger legal protection for these vulnerable species, it is not without its own impacts (Marshall et al., 2011a; Marshall et al., 2011b; Venables et al., 2016).

There has been limited research focus on the ecological and behavioural impacts of manta ray tourism. This is most likely for similar reasons to wildlife tourism impacts in general receiving limited focus. There have been two key explanations for this. Firstly, there is a perception that wildlife tourism is inherently sustainable secondly that the impacts of wildlife tourism are difficult to study (Roe et al., 1997; Bejder et al., 2009; Rushen, 2000). Despite this, almost all reports of tourism impacts on manta rays mention that cleaning station behaviour is affected. This ranges from manta rays "playing" in the exhaust bubbles of divers to populations abandoning cleaning stations entirely for two years (de Rosemont, 2008; Kitchen-Wheeler, 2013). This suggests a need for a better understanding of how manta rays use cleaning stations and how to manage tourist interactions at these sites.

Bateman Bay in Western Australia, located on Ningaloo Reef, supports a resident population of manta rays (McGregor et al., 2011). There are cleaning stations in Bateman Bay utilised by both manta rays and sharks which makes the area an ideal site to further study elasmobranch use of cleaning stations (Daw, 2009; Speed, 2011). A manta ray tourism industry also operates in the area under a voluntary code of conduct designed to minimize the impact of tourism on manta rays (Daw, 2009; Venables et al., 2016). However, even with compliance to the code, there still appear to be short term impacts on manta ray behaviours, including cleaning (Venables, 2013). Additionally, while preliminary work studying the general fish communities at manta ray cleaning stations has been conducted, there are still gaps in our understanding of client composition and behaviours at these sites (Ashe, 2016).

This literature review commences with a brief discussion on cleaning mutualism. This is followed by an overview of cleaning station function and the biological and ecological roles cleaning stations play in reef ecosystems. The link between cleaning stations and wildlife tourism will be identified, particularly focusing on manta ray tourism. In this section, the nature of manta ray tourism, and what is known about its benefits and costs to ecosystems will be reviewed. Finally, elasmobranch use of cleaning stations and manta ray tourism on the Ningaloo Reef, Western Australia is described and the limitation of the current state of published literature explained. The review concludes with an identification of the gaps in current understanding of elasmobranch cleaning station use and tourism impacts while highlighting the opportunity Ningaloo Reef provides to address them.

1.1 Cleaning Mutualism

Ecological relationships are the interactions within and between species in an ecosystem, one example of this is cleaning mutualism. Cleaning mutualism is wide spread through marine environments with many species reported to participate in the interaction. Cleaning interactions occur commonly among marine fish. While it is thought that the mutualism originated in coral reef ecosystems, it is now seen in tropical and temperate waters (Baliga & Law, 2016). As fish are unable to remove all parasites by themselves, the benefit of allowing another organism to do so is clear in that it avoids the health consequences of high parasite loading, while the cleaner benefits from a food source that comes to them with minimal competition from other fish (Poulin & Grutter, 1996). The symbiosis typically involves a small cleaning fish removing ectoparasites, diseased tissue mucus or scales from a co-operating fish known as a client (Cote et al., 1998; Poulin & Grutter, 1996). A client fish will pose at a cleaning station and a cleaner fish will swim close to inspect the client, picking at the body surface, sometimes entering the client's mouth and gill chamber (Figure 1) (Losey, 1972). Cleaners can be obligate or facultative.

Obligate cleaners use cleaning as their main feeding strategy throughout their lives while facultative cleaners clean during the juvenile stage of their life and have a broader diet (Côté, 2000). Obligate and facultative cleaners have a complimentary role in reef communities, as they appear to have different clients (Francini-Filho and Sazima 2008). There are several hypotheses as to how this relationship evolved.

Figure 1: Example of a grey reef shark (*Carcharhinus amblyrhynchos*) posing to be cleaned in a tail stand position and with its mouth open while being cleaned by two cleaner wrasse (*Labroides dimidiatus*).

While the evolution of cleaning mutualism in aquatic environments is unclear, cleaners have arisen from a diverse range of taxonomic groups. It is thought that cleaning, since it is widespread throughout marine and freshwater environments, may have developed through convergent evolution of cleaning organisms and coevolution of cleaners, clients and ectoparasites (Gorlick et al., 1978). This relationship possibly developed in response to cleaning becoming a viable feeding strategy after a potential explosion of ectoparasite diversity or population increase. Alternatively, cleaning could have arisen when rapid climate change in the late Oligocene or early Miocene restructured marine ecosystems, creating space for new feeding strategies (Baliga & Law, 2016). Currently, there are over 130 species of fish and crustaceans that are known to act as cleaners. (Johnson et al., 2010). One of the most well studied groups of cleaners are fish of the genus *Labroides*, which are obligate cleaners belonging to the Labridae family (Johnson et al., 2010). The Labridae are a family of fish with at least 58 species that clean, either facultatively or obligately at some point in their life history (Baliga & Law, 2016). Phylogenetic analysis suggests that the evolution of cleaning behaviours as a feeding strategy is relatively recent in labrids, with the earliest transitions occurring within the last 20 million years (Baliga & Law, 2016). Given that cleaning behaviours may have evolved as a novel feeding strategy, and the lack of quantification of the benefits obtained by the participants, whether or not the relationship is truly mutualistic has been questioned (Poulin & Grutter, 1996).

Diet analysis of cleaner fish has cast doubt on cleaning interactions being entirely mutualistic. Historically, it was perceived that there were clear net positives for both participants. The cleaner benefits by food delivery into its territory while client reduces its parasite loading (Hay et al., 2004). Gut analysis of cleaner fish have found client tissue such as scales and mucus shedding doubt on the mutualistic nature of the association (Grutter & Bshary 2003; Losey 1972). This may partly be due to mucus being a more reliable food source than ectoparasites, which vary in size and abundance seasonally (Arnal et al. 2001). If given a choice and no resistance from the client, cleaners will preferentially eat the client’s mucus rather than parasites, this is known as ‘cheating’ (Bshary & Grutter, 2002). Cheating can often be identified by the client jolting during the interaction (Bshary & Grutter, 2002). The energetic costs to the client of producing new scales and mucus suggests that the interaction may not have an equally mutual benefit

(Grutter & Bshary 2003). Based on the evidence of that cleaner fish consume more than just parasites, it was posited that cleaning was potentially one-sided exploitation of the client by the cleaner (Poulin & Grutter, 1996).

However, there is some evidence that cleaning may approximate a mutually beneficial relationship. If the abundance of parasites on the client is sufficient, the cleaners may consume more parasites than mucus or scales resulting in an approximately mutual benefit (Grutter & Bshary 2003). There is also some evidence that clients regulate the interactions to benefit them as well. It appears that clients control cheating cleaners by chasing the cleaner or leaving the cleaning station as the number of times a client jolts decreases after chasing a cleaner (Bshary & Grutter, 2002). Regardless of the true nature of the relationship, there is a large body of literature suggesting that the sites where cleaning mutualism occurs on reef ecosystems are critical habitat for the health of the reef community.

1.2 Cleaning Stations

Cleaning stations are sites on reefs where cleaning mutualism occurs, these sites can be identified by the presence of cleaners and the posing behaviours of clients (Limbaugh, 1961). Cleaning stations are usually prominent portions of structurally complex reef that provides shelter for cleaner fish (Hay et al., 2004; Wheeler et al., 2013). However, the population density of the cleaner fish *Labroides dimidiatus* on atolls in French Polynesia was not correlated with substrate type suggesting that the location of cleaning stations is not only driven by reef structure (Arnal et al., 2002). At cleaning stations, client fish will display or pose for the cleaner fish in an attempt to initiate a cleaning interaction (Losey, 1972). While posing significantly increases the probability of a fish being cleaned, not all species of clients display posing behaviours and not all individuals of the same species will pose (Cote et al., 1998). The duration of cleaning events can be extremely variable (Arnal et al., 2001). This may be related to the cleaner's preferences. Francini-Filho et al. (2000) observed that cleaner fish appeared to prefer non-dangerous, mostly planktivorous species while dangerous piscivorous species were rarely cleaned. It has also been observed that cleaner fish show preferences to larger clients (de Souza et al., 2014). Grutter (1995) found that cleaning events with larger clients were more frequent and longer than smaller individuals of the same species. Ectoparasite load and non-parasitic copepod load on clients has also been found to influence client visitation rate (Arnal et al. 2001; Cheney & Côté 2001). Due to the health consequences of parasite load on clients, cleaning stations play a role in maintaining the health of reef communities.

1.2.1 Biological Importance

The main biological benefits of cleaning for clients are a result of reduction in parasite load but there also appear to be other benefits such as reduced stress levels in clients. Consequences of high parasite loads on fish include slower growth rates, delayed maturation age, reduced respiratory efficiency, skin disease, increased mortality rates and anaemia (de Souza et al., 2014; Oliver et al., 2011). As the basis of cleaning mutualism is the removal of parasites, it is unsurprising that the presence of cleaner fish has a strong effect on parasite loads in their clients (Hay et al., 2004). Although it lacked controls, a study conducted in the British West Indies, found that removal of cleaners from the reef reduced the number of fish present while the abundance of parasites on the remaining fish increased (Limbaugh, 1961). More recently, a laboratory study found that after eight days, infection of monogenean parasites on dusky grouper (*Epinephelus marginatus*) was significantly higher on individuals which did not have access to cleaner fish compared to those that did (de Souza et al., 2014). A long-term consequence of high parasite loads appears to be reduced growth rates. An eight-year field study showed that damselfish (*Pomacentrus moluccensis*) on reefs where cleaners were consistently removed had higher parasite loads and were on average smaller than individuals on control reefs (Clague et al., 2011). Therefore, there are biological benefits in having access to cleaner fish in terms of growth and reduction in parasite load. Cleaner fish also appear to have the ability to regulate stress in client fish, as their presence can reduce cortisol levels in captured and transported client species (*Chromis dimidiate* and *Pseudanthias sqamipinnis*) (Bshary et al., 2007). Although this study was laboratory based and if this effect occurs in the wild has not been tested, it nonetheless suggests there may be physiological benefit to clients in cleaning mutualism. In addition to biological benefits, cleaning stations appear to have broader ecological importance.

1.2.2 Ecological Importance

While cleaning stations facilitate mutualism, there is also evidence to suggest that there are reduced rates of predation at cleaning stations. It is common for a cleaner fish to enter the mouth of its client during a cleaning event and while there are some reports of clients predating on their cleaners, it is uncommon (Losey 1972; Francini-Filho et al. 2000). It appears that obligate cleaner species are almost never predated on, whereas facultative cleaners are less immune from predation (Trivers, 1971). Immunity from predation in cleaners appears to have extended into reduced rates of predation at cleaning stations overall. In a laboratory study, it was found that the presence of a cleaner fish resulted in nearby fish not involved in the interaction experiencing less aggressive chases from piscivorous clients (Cheney et al. 2008). The rate that piscivorous clients chased prey was negatively correlated with the amount of tactile stimulation given to the predator by the cleaner. This study concluded that cleaning stations may act as safe havens from predators for some species of fish. In addition to the effects cleaning stations have on predation rates, there is also considerable evidence that cleaning stations act as a locus of fish diversity and abundance.

Cleaning stations are known to have an ecological importance in terms of aggregation of a diverse range of clients, but there is debate over what drives the correlation between cleaner presence and client diversity. Slobodkin & Fishelson (1974) found that species diversity was highest at cleaning stations compared to other parts of the same reef and attributed this to the presence of cleaner fish (the client attraction hypothesis). In response, Gorlick et al. (1978) pointed out that while the species diversity at cleaning stations could be due to the presence of cleaners, it was not necessarily the only attributable reason for diversity. Gorlick et al. (1978) went on to suggest two additional hypotheses that could explain the diversity of species at cleaning stations; that cleaners were attracted to these areas because of high client diversity (the cleaner attraction hypothesis) or that both cleaners and hosts were attracted to that habitat in response to a common factor or factors (the habitat attraction hypothesis). It was suggested that these factors could include food availability, reef geometry and subreef shelter (Gorlick et al. 1978). More recent studies have found evidence for the client attraction and cleaner attraction hypotheses.

While there has been evidence both for cleaners choosing areas of the reef and cleaners attracting a diverse range of clients, there appears to be stronger evidence for the latter hypothesis. Arnal et al. (2002) found a positive correlation between cleaner fish density and fish species richness. The study concluded that cleaner fish appeared to choose habitat based on species diversity due to a lack of data showing that cleaner fish increased client fish abundance. However, this study did not use experimental manipulation to validate its findings. Studies where cleaner fish have been removed from reefs have found more evidence to suggest that cleaning stations drive species diversity. A cleaner removal study found that when cleaner fish are absent from the reef, the diversity of mobile fish declines while the diversity of resident fish does not appear to be impacted (Grutter et al. 2003). It was concluded that the highly mobile fish tend to be larger and may have greater impacts on the overall reef ecosystem and that fish may choose reef patches based on the presence of cleaners. Bshary (2003) observed natural fluctuations in cleaner fish presence and absence as well as experimentally removing and adding cleaner fish to reef patches. In the short term, cleaner fish presence does not affect fish abundance or diversity, but over four to twenty months the disappearance of cleaners results in a significant decline in fish diversity. Conversely, adding cleaner fish increased diversity within weeks. Concurrent with Grutter et al. (2003), Bshary (2003) observed that the effects of cleaner addition and removal were stronger on the diversity and abundance of mobile species compared to resident species.

Cleaning station community composition has been well studied but some client groups have not received as much research attention as others. The community composition of cleaning stations has been studied using diver survey and remote underwater video methods or a combination thereof (Oliver et al., 2011; O’Shea et al., 2010; Sazima et al., 2000; Slobodkin & Fishelson 1974). Client species are most commonly ray-finned fish but sharks, rays and turtles have also been reported to be cleaned at cleaning stations (Grossman et al., 2006; Sazima et al., 2004; Oliver et al., 2011; Sazima & Moura 2000; O’Shea et al., 2010). More is known about ray-finned fish use of cleaning stations than elasmobranchs or turtles. Forty papers that studied cleaning station communities or client behaviours were reviewed; while not exhaustive indicates that elasmobranch cleaning station use has not been well studied (Table 1). While studies that included ray-finned fish clients tended to include behavioural data, most elasmobranch and turtle studies report that these animals use the cleaning stations without providing detailed data on how.

This bias most likely reflects the relative abundance of cleaning stations for reef fish than cleaning stations that are visited by turtles or elasmobranchs. It could also be due to studies not reporting the presence of client groups outside of their focus. The popularity of manta rays tourism, which commonly uses cleaning stations as a site for tourist interactions with rays and sharks, is increasing (Daw, 2009; Rohner et al., 2013; Venables, 2013). In some locations, such as the Maldives, most manta ray tourism is based on manta rays predictably visiting cleaning stations (Anderson et al., 2011; Kitchen-Wheeler, 2013). This suggests a need for more research on how elasmobranchs use cleaning stations to inform management practices of these tourism activities as cleanings stations are critical habitats for maintaining the health of fish communities.

Table 1: Number of studies including different client groups of reef cleaning stations. Studies could focus on the cleaning behaviours of individual client species or study the community composition of clients. Studies were found using the following search terms: “Cleaning stations AND diversity”, “Cleaning stations AND composition”, “Cleaning stations AND turtles”, “Cleaning stations AND sharks”, “Cleaning stations AND rays”.

Type of Client	Number of Studies	References
Ray-Finned Fish	26	Losey 1972; Slobodkin and Fishelson 1974b; Losey 1979; Grutter 1994; Grutter 1997; Grutter and Poulin 1998; Sazima et al. 1999; Francini-Filho et al. 2000; Sazima et al. 2000; Arnal et al. 2001; Cheney and Côté 2001; Gasparini and Floeter 2001; Bshary and Grutter 2002; Grutter and Bshary 2003; Bshary et al. 2007; Francini-Filho and Sazima 2008; Clague et al. 2011; Waldie et al. 2011; Huebner and Chadwick 2012; Titus et al. 2015; Quimbayo et al. 2017a; Quimbayo et al. 2017b
Sharks	9	(Sazima et al. 2000; Gasparini and Floeter 2001; Siefert 2001; Whitney and Motta 2008; O’Shea et al. 2010; Oliver et al. 2011; Wheeler et al., 2013; Quimbayo et al. 2017; Quimbayo et al. 2017
Rays	8	Snelson et al. 1990; Marshall 2008; Deakos 2010; O’Shea et al. 2010; Kitchen-Wheeler 2013; Meekan et al. 2016; Quimbayo et al. 2017
Turtles	4	Gasparini and Floeter 2001; Sazima et al. 2004; Grossman et al. 2006; Quimbayo et al. 2017
Total	40	

Based on the literature reviewed, it is evident that cleaning stations are critical habitats. Cleaning stations play an important role in maintaining the health of individual fish and have effects on community diversity, abundance and predation rates. There has also been a gap identified in understanding how elasmobranchs utilize cleaning stations. The review will now introduce manta ray tourism as this industry often relies on cleaning stations as sites for interactions. The reasons for the popularity of manta ray tourism, the economic value of the industry and its use as a conservation strategy in response to overfishing will be discussed. Following this, the recognition of the need for more research on the impacts of wildlife tourism on manta rays and a discussion of the potential reasons why there is a lack of research in this area will be discussed.

1.3 Manta Ray Tourism

Manta ray tourism is a form of wildlife tourism where participants snorkel or SCUBA dive with manta rays *(Mobula alfredi* and *Mobula birostris,* Subclass: Elasmobranchii, Family: Mobulidae), and depending on the nature of operations can be considered ecotourism. In recent decades, the non-consumptive wildlife tourism industry has grown rapidly on a global scale, and manta ray tourism is no exception (Green & Higginbottom 2000; O'Malley et al. 2013). Wildlife tourism is a term used to describe tourism based on visitors interacting with non-domesticated or wild animals in their natural environment or in captivity (Newsome et al., 2005). For an activity considered ecotourism, the industry or operator should focus on not degrading the ecosystem they are using by operating in an environmentally sustainable manner (Sirakaya et al., 1999; Wight, 1993). Additionally, an ecotourism operation should ideally include an element of learning that aims to change visitor's behaviour through providing enlightening experiences and interpretation (Wight 1993; Garrod & Wilson 2003). To conduct tours in an environmentally sustainable way, operators need to manage the way they use the ecosystem and interact with manta rays. The level of management across operations in 31 countries known to conduct manta ray tourism varies (O'Malley et al., 2013).

Manta ray tourism is a form of wildlife tourism that can be considered ecotourism depending on the practices of the tour operator as the industry is often self-managed. Manta ray tourism primarily involves viewing, photographing and in some places touching manta rays while swimming with them by snorkelling or SCUBA diving. Operations have been identified in 31 countries, with varying levels of management to ensure environmental sustainability (O'Malley et al., 2013). Government involvement in management of manta ray tourism is rare and often has minimal monitoring or enforcement (Needham et al., 2017; Venables et al., 2016). As such, dive centres or conservation organisations usually take responsibility for industry management to ensure the long term sustainability of the manta ray tourism industry (Venables et al., 2016).

Manta rays are popular with tourists due to aspects of their biology and ecology. Manta rays have a circumglobal distribution in tropical and subtropical coastal seas. The reef manta ray (*M. alfredi*) is the more common species, and is often found closer to shore than the larger oceanic manta ray *(M. birostris*) (O'Malley et al., 2013). Manta ray size is measured as the distance from wing tip to wing tip (disc width) (Compagno, 1999; Marshall et al., 2008). *M. birostris* has a maximum disc width of 7 meters and *M. alfredi* has a maximum recorded disc width of 5.5 meters (Marshall et al., 2009). Tourists commonly express a desire to interact with large species, so the size of manta rays has made them a desirable target species for wildlife tourism (Giglio et al., 2015; Hausmann et al., 2017). The popularity of manta rays with tourists is also due to their perceived curious and friendly nature. This perception is likely caused by reports of manta rays approaching divers, appearing to enjoy the interaction and allowing divers to touch them and staying to interact with the divers for a long period of time (Rodger et al., 2010). It has been shown that manta rays exhibit site affinities and fidelities to certain sites to for feeding, cleaning and mating (Dewar et al., 2008; Couturier et al., 2011; Germanov & Marshall 2014; Deakos, 2010). These site fidelities and affinities make manta rays a reliable focal species for tour operators to locate. One example of this is a tour operator in Indonesia where visiting a manta ray cleaning station is a key aspect of their tour due to the predictability of their occurrence (O'Malley et al., 2013). These aspects of manta ray biology and ecology have made these animals increasingly popular to interact with, which has assisted in their conservation in response to population declines. Population declines have occurred due to the slow life history of manta rays being incompatible with targeted fisheries.

While manta rays are popular with tourists, they are also the target of fisheries that catch the animals for their gill-plates. Manta rays are K-selected organisms with a very slow life-cycle (Alava et al., 1997). It is estimated that they reach sexual maturity at 6 years old with females giving birth to one to two pups every two to three years (Dulvy et al., 2008; Homma et al., 1999). These life history characteristics make them very susceptible to overexploitation through fishing (Croll et al., 2015; Dulvy et al., 2014). As planktivores, manta rays have gill-plates that filter out plankton from the water column. In Chinese markets, the value of manta ray gill-plates have an average value of US$277-329 per kg, but have been reported to be sold for up to US$680 per kg (O'Malley et al., 2017; IUCN 2013). An adult manta ray yields 5-7kg of dried gills, making manta ray fisheries more lucrative than the shark fin trade (Couturier et al., 2012). The draw of a lucrative market coupled with the slow reproduction rate of manta rays has already lead to population declines across India, French Polynesia, Mexico and Japan (Homma et al., 1999; Couturier et al,. 2012; Mohanraj et al,. 2009). These declines resulted in the listing of manta rays as vulnerable to extinction in 2011 on the IUCN Red List of Threatened

Species (Marshall et al., 2011a; Marshall et al., 2011b). In response, conservation research has proposed manta ray based wildlife tourism as a non-extractive and more sustainable use of manta ray populations.

Manta ray tourism has been shown to be economically more valuable than targeted fisheries and has become a successful conservation strategy. Economic impact studies have evaluated the global value of manta ray tourism, as well as focused studies of economic impacts in the Maldives and Mozambique. It is estimated that globally, the manta ray tourism industry creates US$73 million annually in direct revenue[1] and US$140 million annually in direct economic impact[2] (O'Malley et al., 2013). In Mozambique it was estimated that manta tours were worth US$10.9 million per year in direct revenue to operators with a direct economic impact of US$34.0 million per year (Venables et al., 2016). The estimated direct revenue in the Maldives was US$8.1 million per year between 2003 and 2006 (Anderson et al., 2011). Venables et al. (2016) also noted that their estimate placed the value of the tourism industry in Mozambique alone to almost equal that of the worldwide market value of mobulid gill plates, which is estimated to be US$11.3 million per year. As such, the value of tourism has provided an economic incentive to protect both manta ray species.

The main strategy for conservation for manta rays in response to the value of tourism has been to increase legal protection. In 2013, Manta rays were listed on the Convention on

[1] Direct revenue refers to the revenue generated by the manta ray dive tours without associated expenditures.

[2] Direct economic impact refers to expenditures on manta ray dives and associated expenditures such as lodging, food and local transportation attributed to manta ray diving.

International Trade in Endangered Species of Wild Fauna and Flora (CITES) II, which aims to ensure that the international trade of specimens does not threaten their survival. While trade of manta rays is not banned under this convention, it requires that trade must be controlled in order to avoid use of manta rays that can inhibit the species survival (CITES 2016). Manta rays have also been given legal protection in regional, national and state laws that have been introduced across the globe. Laws prohibiting the catch or trade of one or both manta species have been passed in one region (The European Union), six countries (Ecuador, Mexico, Philippines, Maldives, New Zealand and Australia), two US States (Hawaii and Florida), two US Territories (Guam and the Commonwealth of the Northern Mariana Islands), the state of Yap, Federated States of Micronesia (O'Malley et al., 2013). However, while there has been increased legal protection against extractive use of manta rays, there has been limited research on the impacts tourism may have on manta rays.

One reason that the impacts of manta ray tourism on the focal species has not been well researched is the perception that it has no significant impact. Newsome et al., (2005) recognised this as one of the main barriers to studying wildlife tourism. Wildlife tourism can deliver significant benefits to animals and ecosystems in terms of better conservation measures, as it has for manta rays (Altmann, 2016). However, the benefits will not be fully realised if the negative impacts of wildlife tourism go unresearched. Without research on tourism impacts on wildlife, appropriate management strategies to mitigate these effects cannot be put into place (Anderson et al., 2011). Scientists have often been more concerned with conservation rather than the impacts of tourism. Ecotourism, including wildlife based ecotourism, is often considered to be inherently sustainable (Roe et al., 1997). For example, some manta ray tour operators do appear to believe there is no negative impact caused by their activities despite observations of declining manta ray numbers (Anderson et al., 2011). Newsome et al. (2005) also recognised a second barrier to studying wildlife tourism, which is the difficulty of quantifying impacts and attributing them to tourism activities.

There can be high levels of complexity and high costs associated with studying the impacts of tourism (Newsome et al., 2005). To successfully study the impacts of tourism, short- and long-term data sets are needed in addition to an understanding of impacts on both the focal species population and the broader ecosystem (Roe et al., 1997). While seemingly less difficult than studying long term impacts, short term impacts present their own complexities (Bejder, Samuels, Whitehead, Finn, & Allen, 2009; Rushen, 2000). Short term behavioural responses of focal species have been studied using methods including observation and filming of interactions and using tagging to monitor fine scale movements (Venables 2013; Beale & Monaghan 2004; Huveneers et al. 2013; Fitzpatrick et al. 2011). There is a diverse range of interactions between humans and wildlife associated with wildlife tourism depending on the type of activity occurring. There is also an equally diverse range of ways wildlife can be affected (Bejder et al., 2009). Furthermore, individuals of the same species may react differently to the same type of interaction (Rodger et al., 2010). For manta ray tourism in particular, there can be difficulties in attributing behavioural responses of manta rays to tourism, as other factors such as oceanographic changes or the presence of fisheries can also influence their behaviours (Rohner et al., 2013). Regardless of these difficulties, there is evidence that manta ray tourism does effect manta ray behaviour, particularly at cleaning stations.

Responses of manta rays to tourist presence at cleaning stations have been reported in several locations. Kitchen-Wheeler (2013) observed that when divers are present at cleaning stations, the majority of observed manta rays appear to be attracted to diver’s exhaust bubbles, hovering in them. This behaviour is thought to dislodge skin and parasites, which could be considered a positive outcome from the interaction. However, reports of negative effects of tourism on manta rays are more commonly reported. A cleaning station in Bora Bora, French Polynesia, that was historically known to be frequented by manta rays was abandoned; this is thought to be due to high tourism pressure (de Rosemont, 2008). Manta ray sightings have also been observed decrease during times of relatively high amounts of tourism activities on cleaning station reefs in Mozambique (Rohner et al., 2013). The problem of increased boat traffic and number of divers appears to be recognised by tourists and stakeholders. Surveys found that some individuals thought increased regulation of tourism was required to protect both marine species and the tourism industry (Venables et al., 2016). In Coral Bay, Australia, manta rays have been observed to shorten their cleaning station visit duration and depart cleaning stations in response to vessels driving over these sites and snorkelers diving down to manta rays engaging in cleaning behaviours (Daw, 2009; Venables, 2013). These observed impacts, coupled with limited knowledge of how manta rays, and elasmobranchs in general, use cleaning stations in the absence of tourists makes it necessary to start addressing these gaps to inform management. As Ningaloo Reef in Western Australia supports a manta ray population that is only influenced by environmental processes and tourism and is part of a marine protected area, this site may be a suitable location to start addressing these gaps.

1.4 Ningaloo Marine Park

The Ningaloo Marine Park (NMP) is located on the coast of central-western Australia and aims to facilitate conservation and recreation within the Ningaloo Reef system. The reef is one of the world’s longest fringing reef systems and is approximately 1300 km from the nearest city, Perth (Kobryn et al., 2013). Despite its remoteness, the NMP is a popular tourist destination for wildlife interactions. The NMP consists of both state and federal protected areas covering a total area of 263,343 ha and 232,600 ha respectively (Department of Conservation and Land Management 2005; Commonwealth of Australia 2002). Both the state and federal jurisdictions are managed by the state government through a Memorandum of Understanding (Commonwealth of Australia 2002). The NMP supports a variety of tourism industries, receiving approximately 200,000 visitors a year (Smallwood et al., 2012). As a fringing reef, Ningaloo has a close proximity to shore and for many tourists, snorkelling is one of the main reasons for visiting (Jones et al., 2010). One of the major accommodation hubs in the Ningaloo region is Coral Bay. For visitors to Coral Bay, participating in wildlife interaction tours is more important than for visitors to any other sub-region of the park (Jones et al., 2010). The Coral Bay region supports a high diversity of marine life (Fitzpatrick and Penrose, 2002) and tour operators offer the opportunity to interact with whale sharks, turtles, manta rays and reef sharks (Catlin & Jones, 2010; Department of Conservation and Land Management, 2005; Rodger et al., 2010). Manta rays receive the highest demand as a focal species due to their presence all year round, while reef shark interactions at cleaning stations are included as part of manta ray tours (Daw 2009; Wheeler et al., 2013).

1.4.1 Manta Ray and Shark Populations of Ningaloo

Coral Bay and Bateman Bay supports elasmobranch populations that are known to use sites in the area for cleaning. Over 900 individual manta rays have been photographed in the region (McGregor, pers. comm.). There appears to be a core population of resident manta rays while other individuals exhibit seasonal and roaming visitation patterns (McGregor et al., 2011). Bateman Bay in particular is likely to be important for this population as it is a site where manta rays are found feeding, breeding and cleaning (Daw, 2009). Despite some studies being conducted on habitat use of manta rays in Coral Bay, their use of cleaning stations and the impacts that tourism may be having on their cleaning behaviours is still poorly understood (Ashe, 2016). These bays are also important for shark communities. There are known aggregation sites, nurseries and cleaning stations used by several species of reef shark (*Carcharhinus melanopterus, C. amblyrhynchos, Triaenodon obesus* and *Negaprion acutidens*) (Speed, 2011; Wheeler et al., 2013). The lagoon of Ningaloo Reef in Bateman Bay has been identified as an important site for manta ray feeding, breeding and cleaning. There are several cleaning stations known to manta ray tour operators that are frequented by manta rays and grey reef sharks (*C. amblyrhynchos)*, and get used as sites for interactions with these species (Wheeler et al., 2013; Daw 2009).

1.4.2 Manta Ray Tourism in Coral Bay

The manta ray tourism industry in Coral Bay is still relatively young and initially started out as a part of the whale shark tours that operate in the same area. In the early 1990s whale shark tour operators started conducting manta ray interaction swims after interacting with whale sharks and has grown considerably since then (Venables, McGregor, et al., 2016) (Figure 2). The industry has expanded and currently includes five vessels with a combined capacity of 139 passengers per day, and an estimated 12,000 passengers per year on tours (Daw, 2009; Venables, 2013). Currently, no specific license is required for operators to conduct manta ray tours (Daw, 2009). Tours depart daily and use a spotter plane to locate manta rays in Bateman Bay for tourist interactions (Daw & McGregor, 2008). Manta rays, particularly resident individuals, may be exposed to high tourist pressure due to their constant presence, as opposed to the whale sharks, which have a seasonal occurrence (Department of Conservation and Land Management, 2005; Rodger et al., 2010). Although the 2005 management plan for NMP reported no observed impacts from manta ray tourism, observations of operators and tourists have suggested otherwise.

In the early 2000s, concern was raised about the potential for manta ray tourism disturbing important behaviours such as feeding, cleaning and mating. It was thought that inappropriate vessel operation and pressure from large groups in the water may be causing manta rays to alter their behaviour. In addition to this, concern for tourist's wellbeing were raised after manta rays reportedly rammed and breached upon snorkelers (Daw, 2009; Daw & McGregor, 2008). In response a voluntary code of conduct developed by the Department of Environment and Conservation in consultation with tour operators was introduced in 2003 and revised in 2008 (See Venables (2016) for an outline of the code of conduct). While the implementation of mandatory compliance to the code of conduct as a licence condition has been recommended, it is yet to be implemented (Venables, McGregor, et al., 2016). Venables (2013) found that, despite operators complying with the code of conduct, over one third of manta rays interacted with exhibited a behavioural change in response to snorkelers. Responses included immediate avoidance, termination of feeding behaviours or departing cleaning stations. If manta rays cannot be found anywhere else in the bay, tour operators will periodically check manta ray cleaning stations during the day (Daw, 2009). This may put extra pressure on these critical habitats and their broader client community in addition to the manta rays. However, the reliable appearance of manta rays in Bateman Bay appears to be more significantly driven by food availability than cleaning needs, since most tourist interactions occur with manta rays that are cruising or feeding in the bay (Venables, 2013).

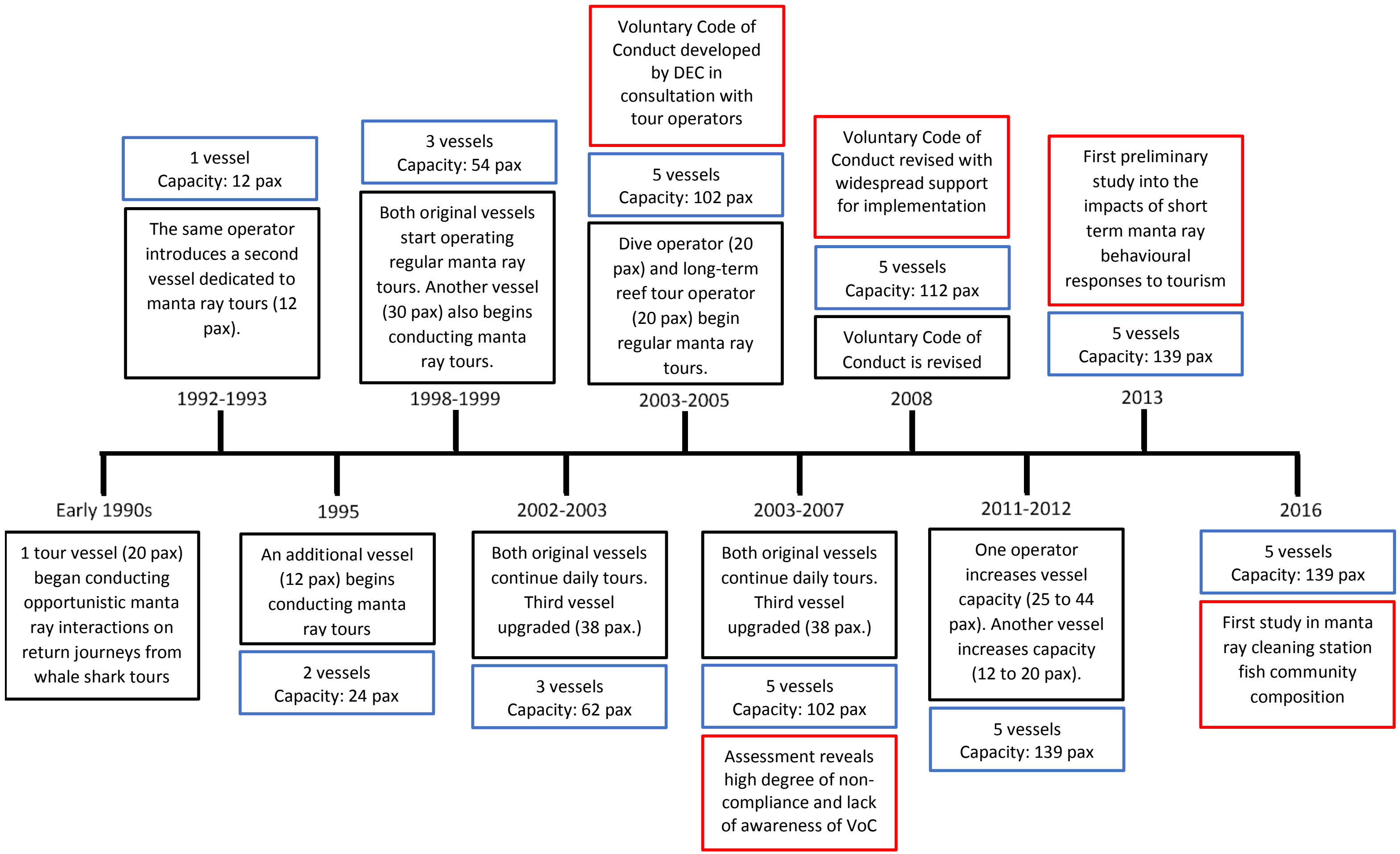

Figure 2: Development and management history of the manta ray tour industry development in Coral Bay. Adapted from Venables (2013) with added information from Daw (2008), Venables et al. (2016) and Ashe (2016).

Conclusion

Cleaning mutualism and cleaning stations play a fundamental role in maintaining the health and diversity of coral reef ecosystems. Cleaning mutualism helps control parasite loading on clients while providing cleaners with a novel feeding strategy and near-immunity from predation. Cleaning stations can act as safe havens and are sites of species diversity and abundance on coral reefs. Current reviewed literature suggests that there is a bias towards ray-finned fish in terms of our understanding of client communities and behaviours at cleaning stations compared to elasmobranchs. There is a need to address this gap as the popularity of wildlife tourism at cleaning stations increases. This is largely due to manta ray interaction tours relying on manta rays predictably visiting cleaning stations. The popularity of manta ray tourism has benefitted manta rays in creating economic incentive for legal protection of these animals. However, it is evident that manta ray tourism does have impacts on these animal's behaviours, particularly at cleaning stations.

Bateman Bay on the Ningaloo Reef in Western Australia is an ideal site to address the identified gaps in understanding of elasmobranch cleaning station use and the effects of tourism on cleaning stations. This is largely due to Ningaloo supporting a resident population of manta rays and sharks that are known to visit cleaning stations in the area. Furthermore, there are no active fisheries in Bateman Bay and the manta ray tourism industry is relatively well managed and self-regulated.

The aims of this study are to use remote underwater video techniques to evaluate the species composition of and behaviours of clients utilizing cleaning stations known to be used by manta rays in Bateman Bay, Western Australia. This study, while including ray-finned fish, aims to improve understanding of the visitation frequency and cleaning behaviours of elasmobranchs. The proximity of manta ray tourism to these cleaning stations, the frequency of boat and tourist presence at cleaning stations and the effect of tourist presence on manta ray cleaning behaviours will also be evaluated to assess the present risks the tourism industry in Bateman Bay poses to manta ray behaviour at cleaning stations.

2 METHODS

2.1 Site Description

This study was conducted at Ningaloo Reef on the central-west coast of Australia. Ningaloo Reef is a 280 km discontinuous fringing reef with the lagoon varying between 200 m to 7 km in width (Cassata & Collins, 2008). The study sites were located in Bateman Bay (23° 03’S: 113° 46’ E), which is found on the central sector of Ningaloo Reef (Figure 3). The Ningaloo Reef is spans both north and south of the Tropic of Capricorn and displays both temperate and tropical characteristics. The region has a semi-arid climate with an annual rainfall of 260 mm which mostly falls in the summer and autumn months (Bureau of Meterology, 2017). This rainfall is largely due to extreme events associated with tropical cyclones (Fitzpatrick & Penrose, 2002). Temperatures are highest in the summer months and lowest in the winter months (Bureau of Meterology, 2017).

Ningaloo Reef has a diverse range of benthic habitats that supports a high diversity of reef organisms (Fitzpatrick & Penrose, 2002; Hutchins, 2001; Kobryn et al., 2013; van Keulen et al., 2008). The Leeuwin and Ningaloo Currents disperse coral larvae and assist in retaining planktonic biomass in the Ningaloo ecosystem, which is believed to influence the system’s biodiversity (Taylor & Pearce, 1999). The Leeuwin Current flows north to south over the shelf break, transporting northern warm, low salinity tropical waters to the reef edge (D’Adamo & Simpson, 2001). The current is at its strongest during austral winter (Waite et al., 2007). The Ningaloo Current is a counter current that flows south to north on the inner shelf, flowing strongest between September and mid-April (Taylor & Pearce, 1999). It is thought that the Ningaloo Current provides nutrient rich waters to the reef (D'Adamo & Simpson, 2001). The circulation and transport of water within Ningaloo Reef's lagoon is primarily driven by wave-pumping of water over the reef crest while prevailing winds and sea breezes tend to drive nearshore waters northwards (Hearn & Parker, 1988). The tides are semi-diurnal with a maximum range at springs of approximately 2 m (D'Adamo & Simpson, 2001).

Bateman Bay is a large sandy embayment north of Coral Bay between Point Maud and Bruboodjoo Point. It is approximately 20 km long and extends approximately 5 km between the shore and reef crest (Fitzpatrick & Penrose, 2002). The bay is open to the ocean due to the Cardabia Passage, a 5 km wide and 30 m deep gap in the reef, which allows swell to wash into the lagoon. The gap allows nutrients and plankton to enter the bay and may be a driver in aggregations of planktivorous megafauna such as manta rays that are regularly found in the area (Fitzpatrick & Penrose, 2002).

This consistent presence of megafauna in Bateman Bay is marketed as key element of tours operating from the Coral Bay town site. Tour activities include manta ray, whale shark and humpback whale interaction tours as well as coral viewing glass bottom boat tours. Due to the presence of a resident manta ray population, the tours occur all year round but number of tourists peaks in April and July, coinciding with school holidays (Daw, 2009). The interactions between tourists and manta rays usually occur between 10:30am and 12:30pm each day, although this can vary (F. McGregor, pers. comm.).

Annually, the Ningaloo Coastal Region, which includes Coral Bay, attracts approximately 179, 400 overnight visitors with an annual total expenditure of $AUD 141 million (Jones et al., 2010). The demographic of tourists visiting Coral Bay is younger than visitors to other parts of Ningaloo, with the majority of visitors being families (Jones et al., 2010). Almost 60% of visitors to Coral Bay are residents of Western Australia. Most visitors stay for less than 8 days, partly due to limited accommodation and high demand making staying in Coral Bay expensive compared to other tourism areas on Ningaloo Reef (Jones et al., 2010).

Figure 3: Map of Bateman Bay identifying the location of the two cleaning station study sites in relation to Coral Bay. Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES Airbus DS, USDA, USGS, AeroGRID, IGN and the GIS User Community.

2.1.1 Point Maud Cleaning Station

The Point Maud Cleaning Station is located within the Maud Sanctuary Zone of the Ningaloo Marine Park, approximately 0.5km from the shore. The site is 8.5 m deep and has a predominantly north-flowing current. The cleaning station is composed of a large *Euphyllia* colony and two smaller mixed species coral bommies next to the *Euphyllia* colony (Figure 4). Macroalgae coverage, predominantly *Sargassum* sp., on the cleaning station fluctuates seasonally (Figure 5). The algal coverage is moderate in March, highest in May and lowest in August. This site may experience relatively frequent boat traffic compared to the second site, North Reef. Point Maud is located near a boating channel and is closer to the Coral Bay boat ramp than North Reef. This cleaning station has been referred to as Point Maud North in previous studies, to minimise confusion with another cleaning station being present nearby to the south (Ashe, 2016). The southern cleaning station was not included in this study.

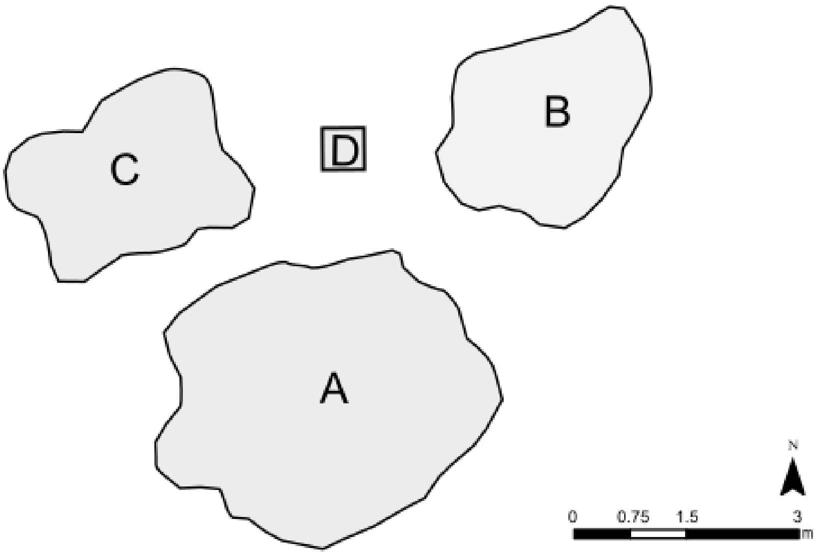

Figure 4: Diagram of an aerial view of the Point Maud cleaning station. A = Euphyllia colony, B and C = Mixed species coral bommies, D = Sinter block where the RUV was placed. Shape of reef and scale is approximate.

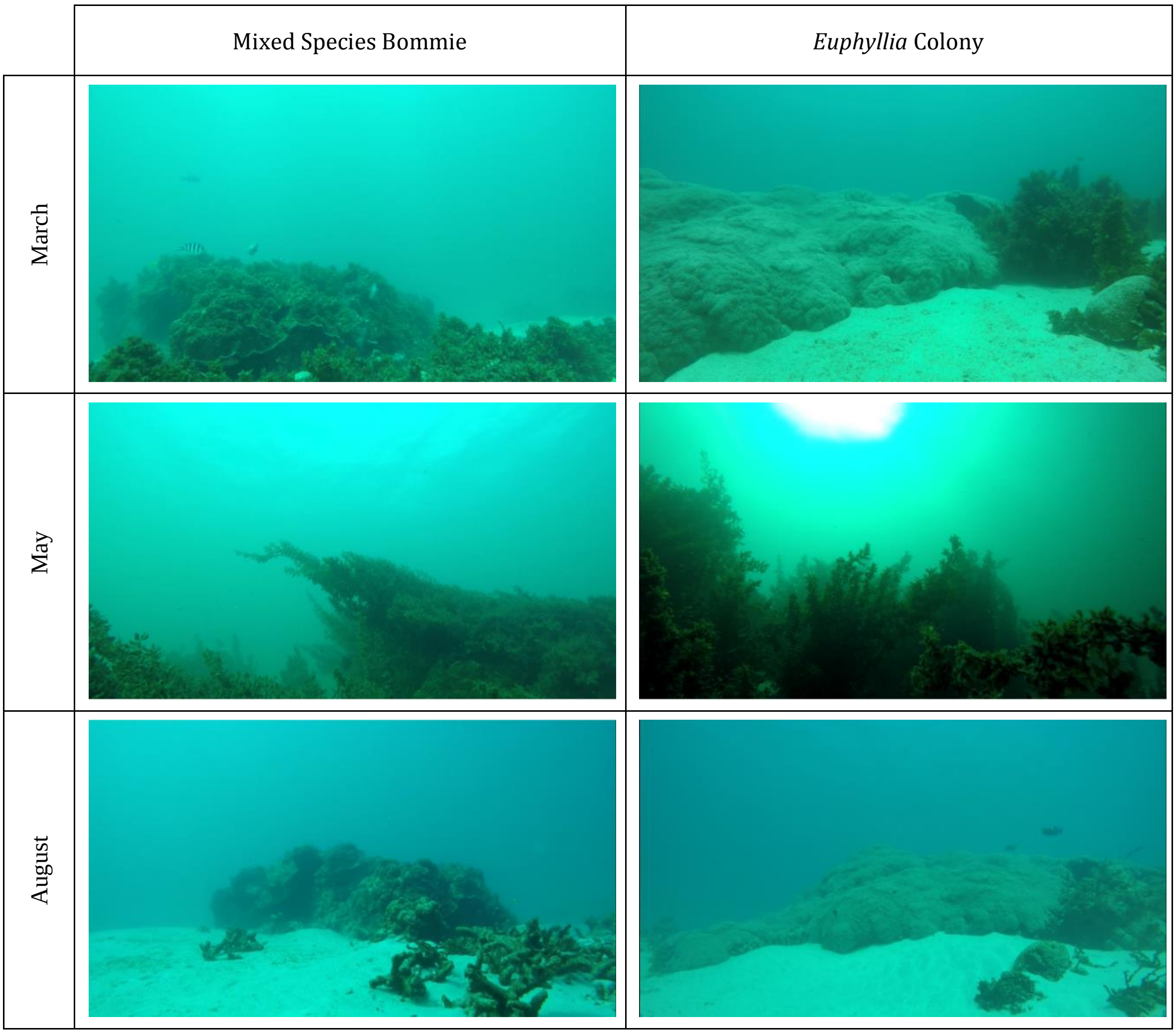

Figure 5: Images of the Point Maud cleaning station showing seasonal change in algal coverage. The mixed species bommie in the images is labelled at B in Figure 2.

2.1.2 North Reef Cleaning Station

The North Reef Cleaning Station is located on the northern side of the Cardabia Passage, approximately 4.6km from shore. The site is 5 m deep and has a predominantly north-flowing current. The cleaning station is located on a raised limestone outcrop near a coral reef structure (Figure 6). This site experiences relatively low frequency of human presence as it is far from any boating channels and the boat ramp. The main reason for human activity at this site is manta ray tourism when manta rays cannot be found in the southern end of Bateman Bay. Due to dependence on commercial tour operators, this site was only visited in May. As such, North Reef was sampled in autumn and not winter. In May, this site has a moderate cover of macroalgae of mixed species (Figure 7).

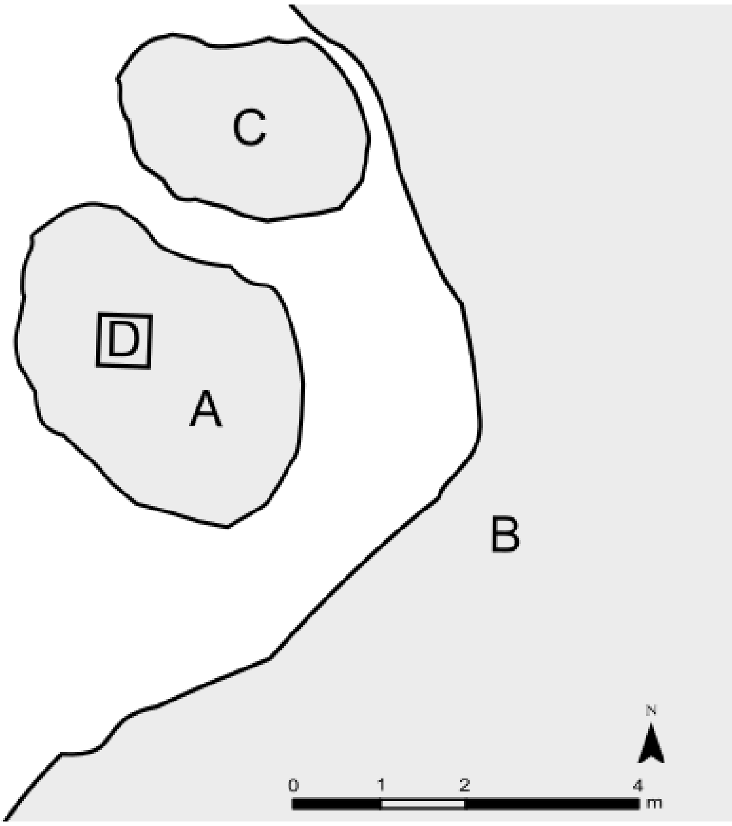

Figure 6: Diagram showing an aerial view of the North Reef Cleaning Station. A = The limestone outcrop where most cleaning activity occurs, B = Nearby low-lying reef, C= Another limestone outcrop, D = Location where the RUV system was placed. Shape of reef and scale is approximate.

Figure 7: Images from all three camera positions at the North Reef cleaning station. This site was only sampled in May, so no seasonal changes in algal coverage were documented. In the background of the first and third images, the low-lying reef can be seen, while the second camera faces the open sand

2.2 Data Collection

Sampling was carried out in March, May and August 2017. Point Maud was sampled in March, May and August while North Reef was only sampled in May. However, the data collected at Point Maud in May was not included due to the high *Sargassum sp.* coverage at the site obscuring any cleaning activity (Figure 5). Data was collected using a remote set up of GoPro Hero and Hero4 cameras. The cameras were used on the wide-angle setting. On this setting, the cameras had a horizontal field of view of 118 degrees and a vertical field of view of 69.5 degrees (GoPro Inc., 2017). During the March sampling period, two cameras were used, separately attached to dive weights. A fixed plate of either 3 or 4 cameras was used after the March sampling period, to minimise blind spots (Figure 8). At the Point Maud cleaning station, cameras were placed on a sinter block in the sand in between three coral bommies that form the cleaning station. At the North Reef cleaning station, cameras were placed in a central position on bare limestone.

Figure 8: The three-camera remote underwater video camera system. The cameras are mounted 120 degrees apart. On the four-camera system, they were mounted 90 degrees apart.

The cameras were deployed by snorkelling from Ningaloo Marine Interaction's manta ray tour vessel, *Utopia*, at approximately 10:30am prior to manta ray tour interactions beginning each day. Deployment time and location were opportunistic, being based on how the manta ray tour was being conducted each day. On several occasions in March, cameras were also deployed at 2:00pm on return of the tour vessel and retrieved later in the afternoon. In May, cameras at the North Reef cleaning station were deployed from a research vessel before tour vessels arrived.

During the manta ray interaction swims, in-water observations of the manta ray's behaviours were recorded in addition to GPS locations of each interaction. Observations included the behaviour the manta ray was engaged in at the start of the interaction and if this behaviour changed. Additionally, the number of manta rays in the bay sighted by the spotter plane pilot were recorded.

2.2.1 Video Analysis

The video files were viewed in *Adobe Premiere Elements 12*. This gave the ability to watch every camera's video files synchronously (Figure 9). Timing was started once the cameras were settled and continued until half the cameras stopped recording due to low battery power or until they were retrieved. Boat noise or the presence of tourists were recorded if engines could be clearly heard or if a person was visible in the field of view. Only one observer analysed the videos to keep species identification and behaviour categories as consistent as possible. Through the observations of the videos generated data on client community species and family contribution, the number of cleaner fish attending clients, the behaviour of clients and the duration of clients were analysed.

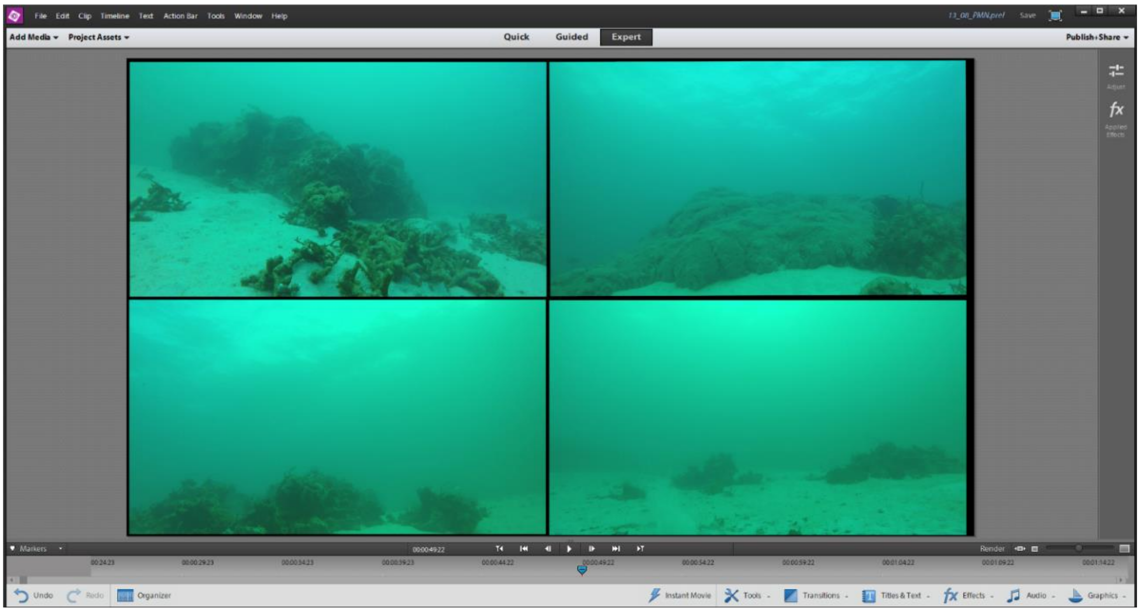

Figure 9: Screen capture illustrating how Adobe Premiere Elements 2 was used to view the video data.

2.2.1.1 Client Species and Families

Clients were defined as marine fauna that was attended by cleaner fish. To be attended, the cleaner fish had to be picking at the body surface of the client (Losey, 1972). Client species and families were identified using Allen (2009), Last et al. (2009) and Froese and Pauly (2017). If a cleaner fish swam close to a potential client but either the cleaner or client withdrew, the interaction was not counted or identified.

2.2.1.2 Client and Cleaner Behaviours

As recommended by Martin and Bateson (1986), preliminary in-water observations and RUV deployments were conducted at Point Maud before the commencement of the study to assess general behaviour patterns of client species. The observations taken in this period confirmed that behaviour categories adapted from Marshall (2008), Venables (2013) and Ashe (2016) could be used. The behaviour categories in this study describe the client's movement path and the cleaner's behavioural state and were entered as a fourletter code, combining the behaviour of the client and the cleaner (Table 2 & Table 3). These categories describe the behaviour seen for the majority of the interaction. If a client was seen to be circling for most of the interaction, but briefly paused to hover, the interaction would be described as circling.

Table 2:Description of each client fish behaviour category observed during video analysis.

Movement	Description	Code
Cruising	Client fish moves in an approximately linear path over or around the cleaning station while being cleaned.	CR
Circling	Client fish moves in an approximately circular path around the cleaning station while being cleaned.	CI
Hovering	Client fish slows down and is near stationary over a particular spot while being cleaned (Current may move client while this occurs).	HO
Feeding	Client fish is actively feeding on the benthos while cleaner fish attends to them.	FE

Table 3: Description of cleaner fish behaviour categories observed during video analysis.

State	Description	Code
Cleaning	Cleaner fish is actively picking at client fish's body surfaces	CL
Not Cleaning	Cleaner fish are not attending client (Category only used for rays and sharks)	NC

2.2.1.3 Duration of Cleaning Events

The duration of a cleaning event was defined as the period of time from when physical contact between a cleaner and client fish begins until either the cleaner or client withdraws (Sazima et al., 1999). If a ray-finned fish or shark was being cleaned and left the field of view and returned within 10 seconds the cleaning interaction was assumed to have been continuous. If a manta ray or turtle was being cleaned and left the field of view and returned within 5 minutes, it was considered to have been a continuous cleaning event. These intervals were based on the average cleaning time for each client group.

2.2.1.4 Cleaner Fish Counts

Marshall (2008) provided counts of cleaner fish attending manta ray clients and identified cleaners to species level to determine relative involvement of cleaner species. Unfortunately, the small size of the cleaner fish made it hard to consistently identify cleaners to species level on video files. As such, cleaners were counted, and species were identified where possible. The counting method used was Max N to avoid repeatedly counting the same cleaners if they left and re-entered the field of view during a cleaning interaction (Harve et al., 2007).

2.2.2 Manta Ray Tourist Interaction Data

The location of each manta ray tour interaction that was observed and the number of manta rays interacted with was recorded. Additionally, in-water observations were made to discern the behavioural state of the manta rays being interacted with (Table 4). Four manta ray tour interactions that occurred at Point Maud or North Reef while the RUV system was recording, the video data was analysed using the behaviour categories that introduced previously (Table 2). However, behaviours were described on a finer resolution. Instead of only describing the dominant movement pattern, the amount of time hovering, circling, cruising was recorded. For each manta ray that was interacted with, its duration of each behaviour category in the 15 minutes prior to the tour interaction starting and the time during the interaction were recorded.

Table 4: Description of manta ray behaviour states observed during manta ray tour interactions.

State	Description
Feeding	The mouth of the manta ray is wide open, cephalic lobes unfurled, gills flared.
Cruising	Mouth closed, or slightly open, cephalic lobes rolled or slightly unfurled, gills not flared.
Cleaning	Manta ray being attended to by cleaner fish.

2.3 Data Analysis

All univariate analysis was conducted using R Studio while all multivariate analysis was conducted in PRIMER 6. The geospatial analysis was conducted in ArcMap.

2.3.1 Evaluation of the RUV System

The success of the aim to develop and deploy a multi-camera RUV system was evaluated by comparing the number of successful and unsuccessful deployments. The RUV system's ability to capture manta ray cleaning events and the presence of boats and tourists was evaluated by comparing the RUV data against the tour operator's logbook data. As the logbook data only reports the location of the interactions and the number of manta rays observed, only manta ray cleaning events could be evaluated. The number of observations of manta rays at Point Maud or North Reef recorded by the RUV system and logbooks were compared. Additionally, the number of manta rays observed by the RUV system and logbooks were compared for each day of RUV deployment when tours occurred while manta rays were present at the cleaning stations.

2.3.2 Overall Client Species Composition

The number of cleaning events for all client species per deployment were counted. This data was square root transformed and a Bray-Curtis resemblance matrix was produced. The similarity of client species composition at Point Maud in autumn and winter and North Reef in autumn were analysed using ANOSIM and SIMPER techniques.

Proportional contribution to client communities were evaluated for all cleaning events observed and for each site and season of deployment. This was done by calculating what percentage of cleaning events each client family contributed to the total number of cleaning events. By ranking families by their percentage contribution, a cumulative contribution was also calculated to evaluate which families cumulatively made up the majority of clients overall and by each site and season.

2.3.3 Visitation Frequency of Elasmobranchs

The visitation frequency of elasmobranchs observed cleaning or not cleaning at each site and deployment period was analysed by calculating a visit per hour measure. This was done by counting the total number of visits of each elasmobranch species during each deployment and dividing by the number of hours the cameras recorded for during that deployment. Average visitation frequency was then calculated for each elasmobranch family per site and season of deployment. Only one elasmobranch cleaning event was observed in winter at Point Maud and this was excluded from analysis due to lack of replicates. Comparisons of average visitation frequency between Point Maud and North Reef in autumn were tested using a Wilcoxon rank sum test as the data was not normally distributed after transformations were conducted. Manta ray clients were identified to individual level using their ventral markings and a photo-identification database (McGregor, 2012).

2.3.4 Duration of Elasmobranch Cleaning Events and Number of Cleaners Attending to Clients

Durations of cleaning behaviours were averaged for each elasmobranch family during each deployment period. As the data was strongly skewed to the right and transformations could not provide a normal distribution, a Wilcoxon rank sum test was used to test for statistical differences in the average duration of Mobulidae and Dasyatidae cleaning events. No comparison could be made with the duration of Carcharhinidae cleaning events as this family was only observed to engage in cleaning behaviours in autumn at Point Maud. A Kruskal Wallis H test was used to test if there was a difference in the median duration of cleaning events for each elasmobranch family. The same procedures were used to evaluate the relationship between elasmobranch family, site and Max N of cleaner fish.

2.3.5 Elasmobranch Cleaning Behaviours

The behavioural preferences of elasmobranchs were evaluated by calculating the proportional frequency of each cleaning behaviour type observed out of all cleaning events for each elasmobranch family (Table 2). These proportions were then analysed using a Chi-Square test for independence to evaluate if there was a relationship between proportion of cleaning behaviours and elasmobranch family. Following this a Chi-Square Goodness of Fit test was conducted for the behaviours observed within each family to evaluate if the behaviour preferences were statistically significant.

2.3.6 Evaluating Boat and Tourist Presence at Cleaning Stations

The frequency of engine noise and tourist presence at each site during each season that was sampled were calculated by calculating the number of times engine noise could be heard or tourists were visible in the camera's field of view per hour, similar to visitation frequency of elasmobranchs. The proportion of disturbed time at each site was evaluated by dividing the number of disturbed minutes by total deployment time. The number of cleaning events per hour for disturbed and non-disturbed was calculated in the same way that the elasmobranch visits per hour were calculated.

Using the locations of manta ray tourist interactions and the locations of the cleaning stations, the distance from each tourist interaction that was observed to North Reef and Point Maud was calculated using the Point Distance function of ArcMap.

The proportion of interactions that occurred when manta rays were engaging in cleaning, cruising, feeding and courtship behaviours was also evaluated. This provided the ability to analyse the percentage of manta ray tour interactions that could affect cleaning behaviours of manta rays and the overall cleaning station client communities.

2.3.7 Effect of Boat and Tourist Presence on Manta Ray Behaviour at Cleaning Stations

Analysing the effect of boat and tourist presence on manta ray behaviour at cleaning station was done by adapting the methods of Venables (2013). The proportion of behaviours seen before and during tourists arrived at the cleaning station were compared using a Chi-Square test. In the test, the observed proportions were those seen in while tourists were present, and the expected proportions were those observed when tourists were not present.

3 RESULTS

3.1 Use of RUVs to Observe Cleaning Events

A total of 33.5 hours of video data was recorded over 17 successful deployments[3], capturing 413 cleaning events. Six of these deployments were at Point Maud in autumn, four at North Reef in autumn and seven at Point Maud in winter. The camera system was improved over the course of the study. Consequently, deployments at Point Maud in autumn used two cameras which had a limited horizontal field of view compared to subsequent deployments using more cameras (Table 5). Despite the limited field of view, the cameras faced the areas of the cleaning station that received the most activity, based on comparison of footage with four cameras. Deployments at North Reef used a three-camera system and deployments at Point Maud in winter used a four-camera system.

Table 5: Comparison of the horizontal field of view and the size of gaps or overlap in the field of view of each RUV system.

Number of Cameras	Horizonal Field of View (degrees)	Gap Between Cameras (degrees)	Overlap Between Field of View (degrees)
2	236	62	-
3	354	2	-
4	472	-	28

[3] Two deployments at Point Maud in autumn failed due to cameras falling from their original position shortly after deployment. One deployment at North Reef in autumn failed due to the positioning of the cameras causing algae to obscure the field of view.

All RUV data, regardless of number of cameras was included in the analysis unless the deployment was unsuccessful. The RUV data using two cameras was still considered useable as the field of view included the areas of the cleaning station that had the highest amount of cleaning activity. However, when interpreting the results, there is potential for the Point Maud autumn providing underestimates of number of interactions was considered. The difference between the three- and four-camera system was relatively minimal as there was only a 2° gap between each of the three cameras (Table 5). This contributed to a horizontal blind-spot of 3 cm for every meter away from the camera. Given that all client species were larger than 3c m in length, it is unlikely that an event occurred without being observed on the three-camera system.

3.2 Client Species Composition

In the total 413 cleaning events observed, 45 species from 22 families were identified as clients (Table 6). Most of these species teleosts or elasmobranchs, however one species of marine turtle, *Chelonia mydas*, was also observed being cleaned at Point Maud. The most diverse client families were Scaridae, Labridae and Acanthuridae. The highest client diversity was recorded at North Reef in autumn with 25 species observed engaging in cleaning behaviours. This was followed by Point Maud with 24 species in autumn and 16 species in winter observed engaging in cleaning behaviours. By combining site and season factors for each deployment, a one-way ANOSIM test showed that differences in species composition and abundance of clients was greater between categories than within categories. ($P = 0.01$, $R = 0.637$) (Figure 10).

One-way SIMPER analysis showed that the client species composition was most similar at Point Maud and North Reef in autumn (89.35% average dissimilarity). Point Maud in winter and North Reef in autumn had the least similar client species composition (91.83%

dissimilarity). The difference in client species composition at Point Maud in autumn and winter fell between these two comparisons, with an average dissimilarity of 90.74%.

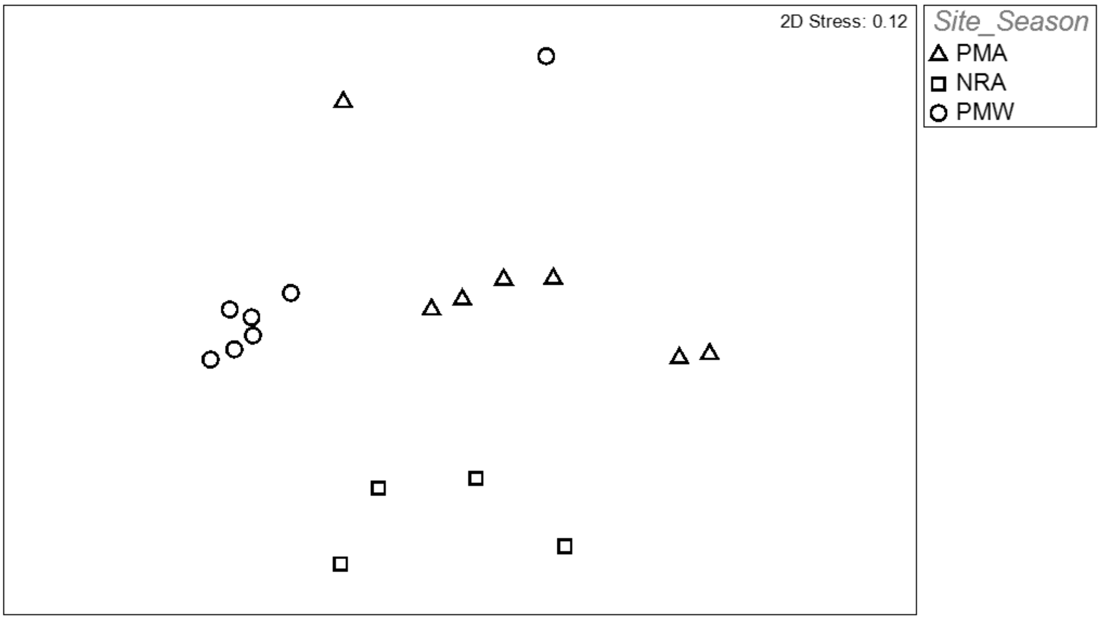

Figure 10: MDS plot of client species composition and abundance data categorized by the site and season of each deployment. Deployments during winter at Point Maud had higher within-group similarity compared to Point Maud in autumn and North Reef in autumn. The stress value of 0.12 indicates that this plot is a reasonable representation of the resemblance matrix. PMA = Point Maud in autumn, NRA = North Reef in autumn, PMW = Point Maud in Winter.

Table 6: List of all client species identified and which site and seasons they occurred in. NRA = North Reef in autumn, PMA = Point Maud in autumn, PMW = Point Maud in winter.

Family	Species	Occurrence		
		NRA	PMA	PMW
Acanthuridae	*Acanthurus grammoptilus*			●
	Naso hexacanthus	●		
	Naso unicornis	●	●	
	Zebrasoma scopas		●	
Apogonidae	*Apogon aureus*	●		
Balistidae	*Melichthys niger*			●
	Sufflamen chrysopterum	●		
Carcharhinidae	*Carcharhinus amblyrhynchos*		●	
	Triaenodon obesus		●	
Chaetodontidae	*Chaetodon lineolatus*			●
	Chaetodontidae sp.		●	
Cheloniidae	*Chelonia mydas*		●	●
Dasyatidae	*Dasyatis thetidis*	●		
	Pastinachus atrus		●	●
	Pastinachus sephen	●		
Diodontidae	*Diodon hystrix*	●		
Haemulidae	*Diagramma labiosum*		●	
Labridae	*Cheilinus trilobatus*	●		
	Choerodon schoenleinii	●		
	Coris aygula	●	●	
	Gomphosus varius		●	
	Hemigymnus melapterus		●	●
	Thalassoma lunare	●	●	
Lethrinidae	*Lethrinus nebulosus*	●	●	
	Lethrinidae sp.		●	
Lutjanidae	*Lutjanus carponotatus*	●	●	
	Lutjanus lemniscatus	●		
	Lutjanidae sp.	●		
Mobulidae	*Mobula alfredi*	●	●	
Mullidae	*Parupeneus indicus*	●		
Myliobatidae	*Myliobatidae sp.*		●	
Nemipteridae	*Scolopsis bilineata*		●	●
Pomacentridae	*Neoglyphidodon melas*	●		
	Pomacentridae sp.		●	
Scaridae	*Chlorurus bleekeri*			●
	Chlorurus sordidus			●
	Scarus frenatus			●
	Scarus ghobban	●		
	Scarus prasiognathos		●	
	Scarus psittacus	●		
	Scarus rivulatus	●		●
	Scarus schlegi		●	●
	Scaridae sp.	●	●	●
Tetraodontidae	*Arothron hispidus*	●		
	Arothron stellatus			●
Total Number of Species	45	23	22	14

3.3 Client Family Contribution

Overall, the top five ranked families by percent contribution to total number of cleaning events observed were the Scaridae (52.06%), Carcharhinidae (7.02%), Labridae (7.02%), Lethrinidae (6.30%) and Mobulidae (5.57%) (Table 7). Together these families made up 77.97% of all observed cleaning events. However, the order of ranking and the families present changed with site and season.

The top five families ranked by percent contribution to total number of cleaning events at North Reef in autumn were the Lethrinidae (24.36%), Scaridae (19.23%), Lutjanidae (16.67%), Dasyatidae (10.26%) and Mobulidae (8.97%) (Table 8). Cumulatively these families made up 79.49% of all cleaning events observed at North Reef in autumn.

At Point Maud in autumn, the top five ranked families at Point Maud in autumn were the Carcharhinidae (23.77%), Labridae (16.39%), Mobulidae (13.11%), Scaridae (11.48%) and Acanthuridae (9.02%) (Table 9). Cumulatively these families made up 73.77% of all the cleaning events observed at Point Maud in autumn.

Point Maud in winter had the most skewed family composition of all the site-season categories (Table 10). The top five ranked families were the Scaridae (87.32%), Cheloniidae (7.51%), Labridae (1.41%), Acanthuridae (0.94%) and Nemipteridae (0.94%). Cumulatively, these families made up 98.12% of the cleaning events observed at Point Maud in winter.

3.4 Overall Cleaning Behaviours

Across all families the most common cleaning behaviour for clients was hovering (49.39% of call cleaning events) followed by cruising (41.86% of all cleaning events), circling (5.33% of all cleaning events) and feeding (2.42% of all cleaning events) (Table 7). Most families exhibited a preference for either cruising or hovering behaviours. Only the Tetradontidae exhibited circling, cruising and hovering behaviours equally. The Acanthuridae family hovered for most cleaning events, but when Acanthuridae individuals did not hover, they exhibited cruising and feeding behaviours in an equal number of cleaning events. The only clients to show a clear preference to circling were the Mobulidae and Dasyatidae, but as previously mentioned the Tetradontidae were also observed circling around the cleaning station while being cleaned.

3.5 Overall Cleaning Event Duration and Number of Cleaners

The average duration of a cleaning event was 0.92 minutes. Megafauna families had the top three highest average durations of cleaning event, with the exception of the Carcharhinidae family. Of the megafauna families, the Mobulidae had the highest overall average of cleaning event duration (10.32 minutes ± 3.27 SE) followed by the Cheloniidae (3.21 minutes ± 0.66 SE), Dasyatidae (0.87 minutes ± 0.31 SE) and Carcharhinidae (0.13 minutes ± 0.01 SE). Cleaning events where the client exhibited circling behaviours had the longest duration ($\bar{x} = 10.35$ minutes ± 3.42SE), this was followed by hovering clients ($\bar{x} = 0.51$ minutes ± 0.09 SE), feeding clients ($\bar{x} = 0.46$ minutes ± 0.11 SE) and cruising clients ($\bar{x} = 0.37$ minutes ± 0.07 SE). However, duration by cleaning behaviour is confounded by family as the only families observed to circle were the Mobulidae, Dasyatidae and Tetradontidae and the only clients observed to feed while being cleaned were the Scaridae and Acanthuridae.

A similar trend was seen in the number of cleaners attending to clients. The top three families for average number of cleaners were once again megafauna families, the Mobulidae (10.39 cleaners ± 1.03 SE), Cheloniidae (6.65 cleaners ± 0.52 SE) and the Dasyatidae (5.00 cleaners ± 0.73 SE). The other megafauna family, the Carcharhinidae

(1.33 cleaners ± 0.13 SE) was ranked fifteenth highest for average number of cleaners. Species seen engaging in cleaning were predominantly *Labroides dimidiatus* and *Thalassoma lunare*. *Heniochus* sp. was observed cleaning manta ray clients at North Reef. *Acanthuridae sp.* individuals were also observed cleaning turtle clients at Point Maud.

Table 7: Client families ranked by their percentage contribution to the overall number of clients across all sites and seasons. N is the number of individuals observed engaging in cleaning behaviours during the study. Sp Div. = The diversity of species within the family acting as cleaning station clients. Behaviours lists the types of movement each client family were observed doing while being cleaned (CI – Circling, CR – Cruising, FE – Feeding, HO – Hovering), ordered by how common each behaviour was. Duration lists the average length of cleaning event ± standard error. Number of Cleaners lists the average Max N of cleaner fish attending clients ± standard error. %C describes the percent contribution each family made to the total number of cleaning events observed. %CC is the cumulative percentage each family made to the total number of cleaning events, starting with the highest contributing family.

Overall											
Family	N	Sp Div.	Behaviours	Duration (minutes)			Number of Cleaners			%C	%CC
Scaridae	215	10	HO, CR, FE	0.27	±	0.02	1.33	±	0.04	52.06	52.06
Carcharhinidae	29	2	CR, HO	0.13	±	0.01	1.33	±	0.13	7.02	59.08
Labridae	29	6	CR, HO	0.18	±	0.02	1.14	±	0.08	7.02	66.10
Lethrinidae	26	3	CR, HO	0.34	±	0.08	1.00	±	0.00	6.30	72.40
Mobulidae	23	1	CI, CR, HO	10.32	±	3.27	10.39	±	1.03	5.57	77.97
Cheloniidae	22	1	CR, HO	3.12	±	0.66	6.65	±	0.52	5.33	83.29
Acanthuridae	15	5	HO, CR = FE	0.32	±	0.05	1.33	±	0.13	3.63	86.92
Lutjanidae	15	3	HO, CR	0.30	±	0.08	1.33	±	0.16	3.63	90.56
Dasyatidae	11	2	CI, CR	0.87	±	0.31	5.00	±	0.73	2.66	93.22
Nemipteridae	9	1	HO, CR	0.24	±	0.05	1.00	±	0.00	2.18	95.40
Haemulidae	5	1	CR, HO	0.16	±	0.02	1.00	±	0.00	1.21	96.61
Tetraodontidae	3	2	CI = CR = HO	0.21	±	0.06	1.00	±	0.00	0.73	97.34
Apogonidae	2	1	CR	0.12	±	0.05	1.00	±	0.00	0.48	97.82
Balistidae	2	2	HO	0.33	±	0.11	1.50	±	0.50	0.48	98.31
Chaetodontidae	2	2	HO	0.14	±	0.06	1.50	±	0.50	0.48	98.79
Pomacentridae	2	2	CR	0.05	±	0.00	1.00	±	0.00	0.48	99.27
Diodontidae	1	1	CR	0.05	±	-	1.00	±	-	0.24	99.52
Mullidae	1	1	CR	0.10	±	-	1.00	±	-	0.24	99.76
Myliobatidae	1	1	CR	0.15	±	-	3.00	±	-	0.24	100
Total	413	47	CI, CR, FE, HO	0.92			2.24			100	100

Table 8: Client families ranked by their percentage contribution to the clients of the North Reef cleaning station in autumn. N is the number of individuals observed engaging in cleaning behaviours. Sp Div. = The diversity of species within the family acting as cleaning station clients. Behaviours lists the types of movement each client family were observed doing while being cleaned (CI – Circling, CR – Cruising, HO – Hovering), ordered by how common each behaviour was. Duration lists the average length of cleaning event ± standard error. Number of Cleaners lists the average Max N of cleaner fish attending clients ± standard error. %C describes the percent contribution each family made to the total number of cleaning events observed. %CC is the cumulative percentage each family made to the total number of cleaning events, starting with the highest contributing family.

North Reef – Autumn							
Family	N	Sp Div.	Behaviours	Duration (minutes)	Number of Cleaners	%C	%CC
Lethrinidae	19	1	CR, HO	0.31 ± 0.07	1.00 ± 0.00	24.36	24.36
Scaridae	15	6	CR, HO	0.35 ± 0.07	1.40 ± 0.16	19.23	43.59
Lutjanidae	13	3	HO, CR	0.26 ± 0.06	1.38 ± 0.18	16.67	60.26
Dasytidae	8	2	CR, CI	1.02 ± 0.41	4.63 ± 0.73	10.26	70.51
Mobulidae	7	1	CI, CR = HO	1.26 ± 0.65	8.86 ± 1.28	8.97	79.49
Labridae	6	4	CR	0.23 ± 0.06	1.00 ± 0.00	7.69	87.18
Acanthuridae	2	2	HO	0.15 ± 0.02	1.50 ± 0.50	2.56	89.74
Apogonidae	2	1	CR	0.12 ± 0.05	1.00 ± 0.00	2.56	92.31
Tetraodontidae	2	1	CI = HO	0.26 ± 0.08	1.00 ± 0.00	2.56	94.87
Balistidae	1	1	HO	0.22 ± -	2.00 ± -	1.28	96.15
Diodontidae	1	1	CR	0.05 ± -	1.00 ± -	1.28	97.44
Mullidae	1	1	CR	0.10 ± -	1.00 ± -	1.28	98.72
Pomacentridae	1	1	CR	0.05 ± -	1.00 ± -	1.28	100.00
Carcharhinidae	-	-	-	-	-	-	-
Cheloniidae	-	-	-	-	-	-	-
Nemipteridae	-	-	-	-	-	-	-
Haemulidae	-	-	-	-	-	-	-
Chaetodontidae	-	-	-	-	-	-	-
Myliobatidae	-	-	-	-	-	-	-
Total	78	25	CI, CR, HO	0.34	2.06	100	100

Table 9: Client families ranked by their percentage contribution to the clients of the Point Maud cleaning station in autumn. N is the number of individuals observed engaging in cleaning behaviours. Sp Div. = The diversity of species within the family acting as cleaning station clients. Behaviours lists the types of movement each client family were observed doing while being cleaned (CI – Circling, CR – Cruising, HO – Hovering), ordered by how common each behaviour was. Duration lists the average length of cleaning event ± standard error. Number of Cleaners lists the average Max N of cleaner fish attending clients ± standard error. %C describes the percent contribution each family made to the total number of cleaning events observed. %CC is the cumulative percentage each family made to the total number of cleaning events, starting with the highest contributing family.

Point Maud - Autumn										
Family	N	Sp Div.	Behaviours	Duration (minutes)			Number of Cleaners			%C	%CC
Carcharhinidae	29	2	CR, HO	0.18	±	0.01	1.33	±	0.13	23.77	23.77
Labridae	20	4	CR	0.16	±	0.02	1.20	±	0.12	16.39	40.16
Mobulidae	16	1	CI, CR, HO	14.28	±	4.37	11.06	±	1.36	13.11	53.28
Scaridae	14	3	CR, HO	0.18	±	0.03	1.07	±	0.07	11.48	64.75
Acanthuridae	11	3	HO, FE, CR	0.38	±	0.06	1.36	±	0.15	9.02	73.77
Lethrinidae	7	3	CR, HO	0.42	±	0.24	1.00	±	0	5.74	79.51
Nemipteridae	7	1	HO, CR	0.27	±	0.06	1.00	±	0	5.74	85.25
Cheloniidae	6	1	HO, CR	2.75	±	0.74	6.33	±	0.67	4.92	90.16
Haemulidae	5	1	CR	0.16	±	0.02	1.00	±	0	4.10	94.26
Dasytidae	2	1	CI = CR	0.59	±	0.38	7.00	±	3.00	1.64	95.90
Lutjanidae	2	1	HO	0.60	±	0.50	1.00	±	0	1.64	97.54
Chaetodontidae	1	1	HO	0.08	±	-	1.00	±	-	0.82	98.36
Myliobatidae	1	1	CR	0.15	±	-	3.00	±	-	0.82	99.18
Pomacentridae	1	1	CR	0.05	±	-	1.00	±	-	0.82	100
Tetraodontidae	-	-	-		-			-		-	-
Apogonidae	-	-	-		-			-		-	-
Balistidae	-	-	-		-			-		-	-
Diodontidae	-	-	-		-			-		-	-
Mullidae	-	-	-		-			-		-	-
Total	122	24	CI, CR, FE, HO		1.45			2.74		100	100

Table 10: Client families ranked by their percentage contribution to the number of clients observed at Point Maud in winter. N is the number of individuals observed engaging in cleaning behaviours during the study. Sp Div. = The diversity of species within the family acting as cleaning station clients. Behaviours lists the types of movement each client family were observed doing while being cleaned (CI – Circling, CR – Cruising, FE – Feeding, HO – Hovering), ordered by how common each behaviour was. Duration lists the average length of cleaning event ± standard error. Number of Cleaners lists the average Max N of cleaner fish attending clients ± standard error. %C describes the percent contribution each family made to the total number of cleaning events observed. %CC is the cumulative percentage each family made to the total number of cleaning events, starting with the highest contributing family.

Point Maud - Winter											
Family	N	Sp Div.	Behaviours	Duration (minutes)			Number of Cleaners			%C	%CC
Scaridae	186	7	HO, CR, FE	0.27	±	0.02	1.34	±	0.04	87.32	87.32
Cheloniidae	16	1	CR, HO	3.26	±	0.88	6.79	±	0.70	7.51	94.84
Labridae	3	1	CR, HO	0.19	±	0.02	1.00	±	0.00	1.41	96.24
Acanthuridae	2	2	CR = HO	0.15	±	0.07	1.00	±	0.00	0.94	97.18
Nemipteridae	2	1	HO	0.13	±	0.03	1.00	±	0.00	0.94	98.12
Balistidae	1	1	HO	0.43	±	-	1.00	±	-	0.47	98.59
Chaetodontidae	1	1	HO	0.20	±	-	2.00	±	-	0.47	99.06
Dasytidae	1	1	CR	0.25	±	-	4.00	±	-	0.47	99.53
Tetraodontidae	1	1	CR	0.12	±	-	1.00	±	-	0.47	100
Carcharhinidae	-	-	-		-			-		-	-
Lethrinidae	-	-	-		-			-		-	-
Mobulidae	-	-	-		-			-		-	-
Lutjanidae	-	-	-		-			-		-	-
Haemulidae	-	-	-		-			-		-	-
Apogonidae	-	-	-		-			-		-	-
Pomacentridae	-	-	-		-			-		-	-
Diodontidae	-	-	-		-			-		-	-
Mullidae	-	-	-		-			-		-	-
Myliobatidae	-	-	-		-			-		-	-
Total	213	16	CR, HO, FE		0.56			2.12		100	100

3.6 Elasmobranch Use of Cleaning Stations in Bateman Bay

The Mobulidae, Carcharhinidae and Dasyatidae families of the Elasmobranchs were observed using the North Reef and Point Maud cleaning stations[4]. A total of 78 elasmobranch visits to the two cleaning stations was observed. Of these 78 visits, 61 resulted in cleaning events. Five species of elasmobranchs engaged in cleaning behaviours while seven species were observed cruising through the cleaning stations. Forty-seven elasmobranch cleaning events occurred at Point Maud in autumn, 13 at North Reef in autumn and one at Point Maud in winter.

One Mobulidae species, *Mobula alfredi*, was observed engaging in cleaning behaviours at North Reef and Point Maud during autumn deployments. Mobulidae clients were observed engaging in cleaning behaviours 5 times at North Reef and 16 times at Point Maud While *M. alfredi* was observed at Point Maud in winter, individuals were not seen engaging in cleaning behaviours. Using photo-identification methods, 13 *M. alfredi* individuals were identified. Five individuals were only seen once over the course of the study. Seven individuals were observed to leave the cleaning stations and return multiple times within one deployment. Only one individual was seen to revisit a cleaning station over two deployments. The revisitation occurred at Point Maud in autumn. No individuals visited both Point Maud and North Reef within the times that cameras were deployed.

[4] One Myliobatidae species was only observed once at Point Maud and was excluded from analysis due to lack of replicates.

Carcharhinidae species were only observed at Point Maud. *Carcharhinus amblyrhynchos* and *Triaenodon obesus* were observed to exhibit cleaning behaviours in autumn. In this period, 29 Carcharhinidae cleaning events were observed. An additional two species, *Negaprion acutidens* and *Loxodon macrorhinus* were observed cruising past this cleaning station but did not engage in cleaning behaviours. No carcharhinid cleaning events were observed in winter.

Two species of the Dasyatidae family, *Pastinachus sephen* and *Dasyatidis thetidis* were observed engaging in cleaning behaviours at North Reef. *P. sephen* was also observed being cleaned at Point Maud in autumn and winter. Dasyatidae individuals were observed engaging in cleaning behaviours eight times at North Reef in Autumn, two times at Point Maud in autumn. One *P. sephen* cleaning event was observed in winter at Point Maud and was excluded from analysis due to lack of replicates.

3.6.1 Visitation Frequency

The distribution of visitation frequency for cleaned and non-cleaned elasmobranchs engaging in cleaning interactions or cruising past the cleaning stations varied between site and by season ($H = 57.695$, $df = 16$, $P = <0.001$) (Figure 11). The highest visitation frequency for the Mobulidae engaging in cleaning behaviours occurred in autumn at Point Maud ($\bar{x}$=1.67 individuals per hour ± 1.12 SE), followed by North Reef in autumn ($\bar{x}$=0.75 individuals per hour ± 0.48 SE). No Mobulidae cleaning events were observed at Point Maud in winter. However, Mobulidae were seen passing cleaning stations without being cleaned most frequently at Point Maud in winter ($\bar{x}$=0.57 individuals per hour ± 0.43 SE). Non-cleaning Mobulidae were also observed at Point Maud in autumn ($\bar{x}$=0.17 individuals per hour ± 1.12 SE) and at North Reef in autumn ($\bar{x}$=0.25 individuals per hour ± 0.25 SE).

The visitation frequency for Dasyatidae species engaging in cleaning behaviours was higher at North Reef in autumn ($\bar{x}$=1.25 individuals per hour ± 1.25 SE) compared to Point Maud in autumn ($\bar{x}$=0.17 individuals per hour ± 0.17 SE) with no Dasyatidae cleaning events observed in winter at Point Maud. Dasyatidae species were only observed cleaning at North Reef, no passes of the sites were made without cleaner fish attending to Dasyatidae individuals. Individuals were observed not engaging in cleaning behaviours at Point Maud in winter ($\bar{x}$=0.14 individuals per hour ± 0.14 SE) but not in autumn.

Carcharhinidae cleaning events were only observed at Point Maud in autumn ($\bar{x}$=2.33 individuals per hour ± 1.06 SE). Carcharhinidae species were also observed passing the cleaning station without engaging in cleaning stations. This occurred most frequently at Point Maud in autumn ($\bar{x}$=9.33 individuals per hour ± 1.50 SE) followed by Point Maud in winter ($\bar{x}$=4.43 individuals per hour ± 1.89 SE). No Carcharhinidae species were observed at North Reef.

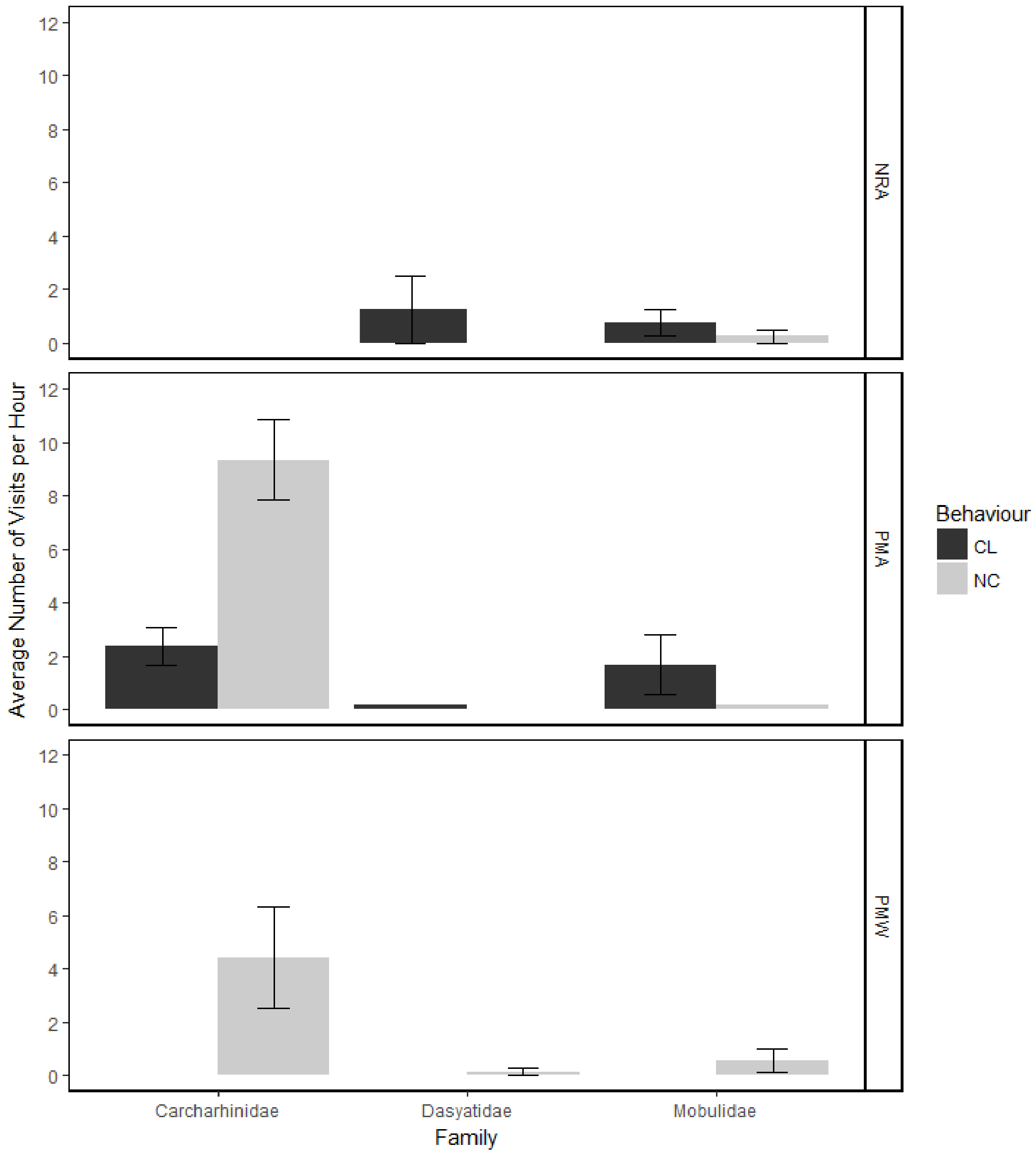

Figure 11: Average number of visits per hour for the elasmobranch families observed at each site and season. NRA = North Reef in autumn, PMA = Point Maud in autumn, PMW = Point Maud in winter. CL = Cleaned, NC = Not Cleaned. Error bars = standard error.

3.6.2 Duration of Elasmobranch Cleaning Interactions

The duration of cleaning events differed between elasmobranch families and by site and season of observation (Figure 12). Carcharhinid clients at Point Maud in autumn had the lowest mean cleaning event duration for any elasmobranch group ($\bar{x}$ = 0.13 minutes ± 0.23 SE). Dasyatidae clients had a higher mean duration of cleaning events at North Reef in autumn ($\bar{x} = 1.02$ minutes ± 0.41 SE) compared to Point Maud in autumn ($\bar{x} = 0.59$ minutes ± 0.38 SE). One Dasyatidae cleaning event was observed at Point Maud in winter that lasted for 0.25 minutes.

Mobulidae clients had the longest duration of cleaning events. The duration of cleaning events for Mobulidae clients was higher at Point Maud ($\bar{x} = 14.29$ minutes ± 17.46 SE) in autumn compared to North Reef in autumn ($\bar{x} = 2.06$ minutes ± 0.90 SE). The duration of Mobulidae cleaning events were found to be statistically different using a Wilcoxon rank sum test (P = 0.04, W = 15). Both the longest (61.35 minutes) and shortest (0.23 minutes) manta ray cleaning behaviours were observed at Point Maud.

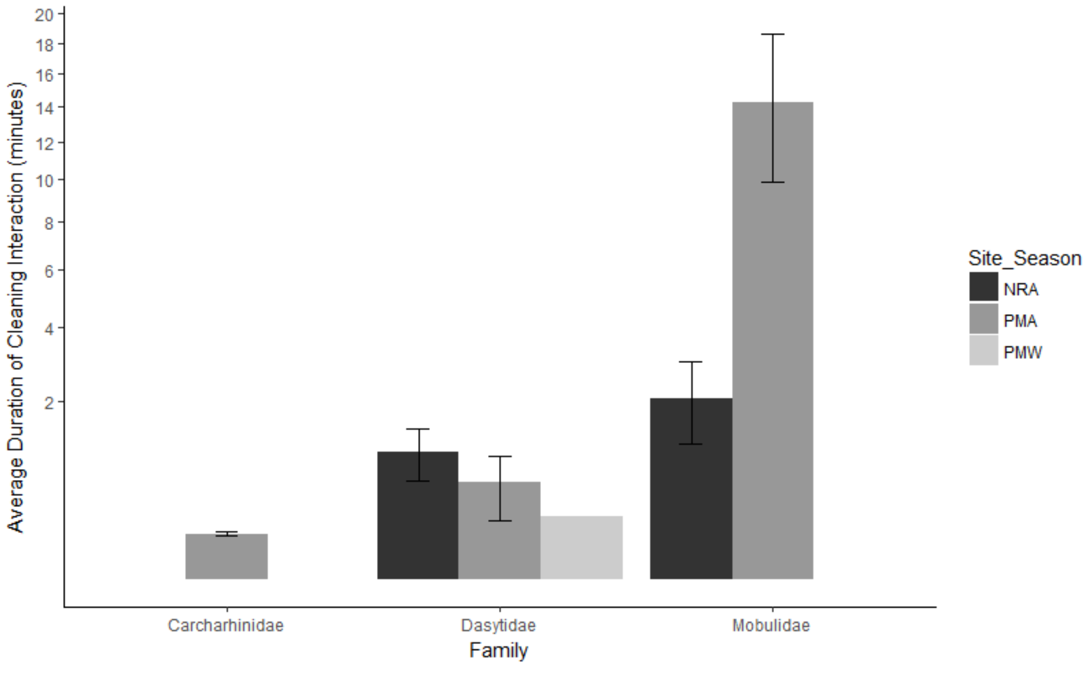

Figure 12: Mean duration of cleaning events for three elasmobranch families at each site and season where they were observed. Error bars represent standard error.

3.6.3 Behaviour Preferences

The relationship between family and type of cleaning behaviours exhibited was found to be significantly different (χ^2=28.91, df = 4, P = <0.001) (Figure 13). A total of 61 elasmobranch cleaning events were observed. Of these events, 29 had Carcharhinidae clients, 21 had Mobulidae clients and 11 had Dasyatidae clients. For all families of elasmobranchs observed, a Chi-Square Goodness of Fit test indicated that there was a statistically significant difference in the percentage of time spent engaging in different cleaning behaviours (P = 0.05, df = 2). Carcharhinidae species most frequently displayed cruising cleaning behaviours (86.2% of cleaning events) (χ^2=15.22, df = 1, P = 0.001). The only other cleaning behaviour that Carcharhinidae species were observed engaging in were hovering behaviours (13.79%). A higher proportion of Dasyatidae species (63.64%) displayed cruising behaviours than circling behaviours (36.36%) but this was not found to be statistically different (χ^2=0.8182, df = 1, P = 0.366). Dasyatidae species were not observed engaging in hovering behaviours. Mobulidae species showed a preference for circling behaviours, which accounted for 71.43% of cleaning interactions observed (χ^2=17.297, df = 2, P = <0.001). The next most common behaviour was cruising, which accounted for 19.05% of Mobulidae cleaning events and hovering, which occurred in 9.52% of Mobulidae cleaning events.

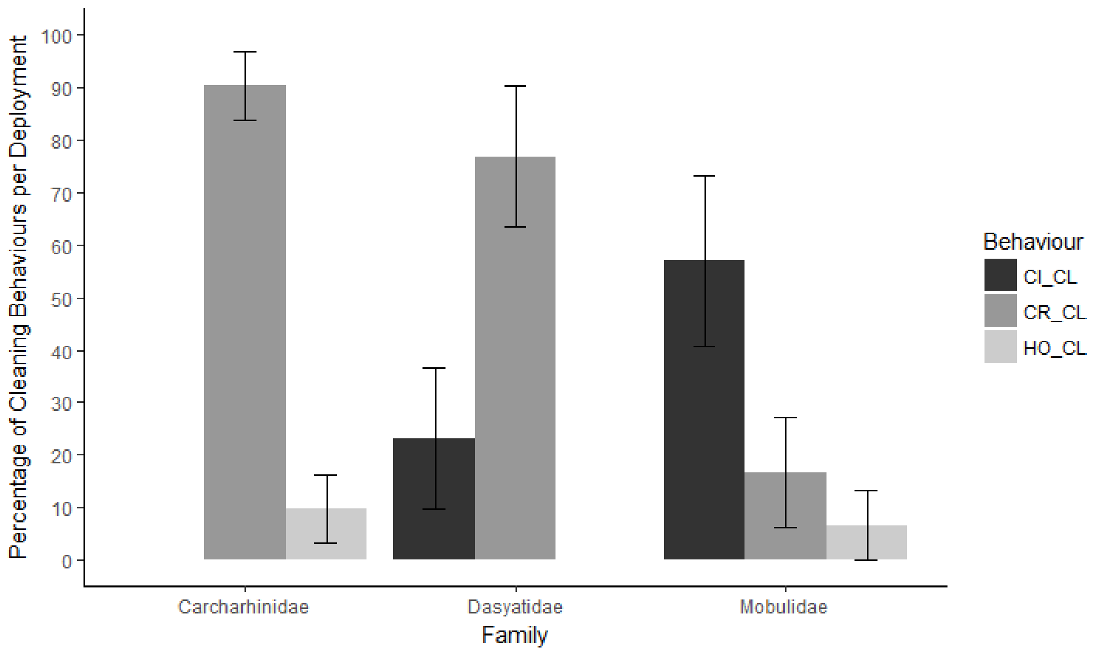

Figure 13: Mean percentage of cleaning behaviours systems at cleaning stations in Bateman Bay observed for three elasmobranch families. Error bars represent standard error.

3.6.4 Number of Cleaner Fish to Clients

As with duration of cleaning events and cleaning behaviour preferences, elasmobranch families were attended by differing numbers of cleaner fish (Figure 14). The number of cleaners attending each elasmobranch family was statistically different (H= 48.809, P=<0.0001, df = 2). This difference was unlikely to be driven by site or season as there was not a statistical difference between these factors (H = 5.448, P = 0.06, df = 2). Carcharhinid clients at Point Maud in autumn had the lowest average Max N of cleaner fish (median = 1 cleaners per client, $\bar{x}$= 1.33 cleaners per client, ± 0.13 SE). Dasyatid clients had the most cleaners attend to them at Point Maud in autumn (median = 7 cleaners per client, $\bar{x} = 7.00$ cleaners per client ± 3 SE), followed by North Reef (median = 5 cleaners per client, $\bar{x} = 4.63$ cleaners per client ± 0.73 SE) and Point Maud in winter ($\bar{x} = 4.00$ cleaners per client, n = 1). Mobulid clients consistently had the highest average Max

N of cleaners attend to them compared to other elasmobranch clients. Like Dasyatids, Mobulids received a higher Max N of cleaners at Point Maud in autumn (median = 11.5 cleaners per client, $\bar{x} = 11.06$ cleaners per client ± 1.36 SE) than at North Reef in autumn (median = 8 cleaners per client, $\bar{x} = 9.20$ cleaners per client ± 1.83 SE).

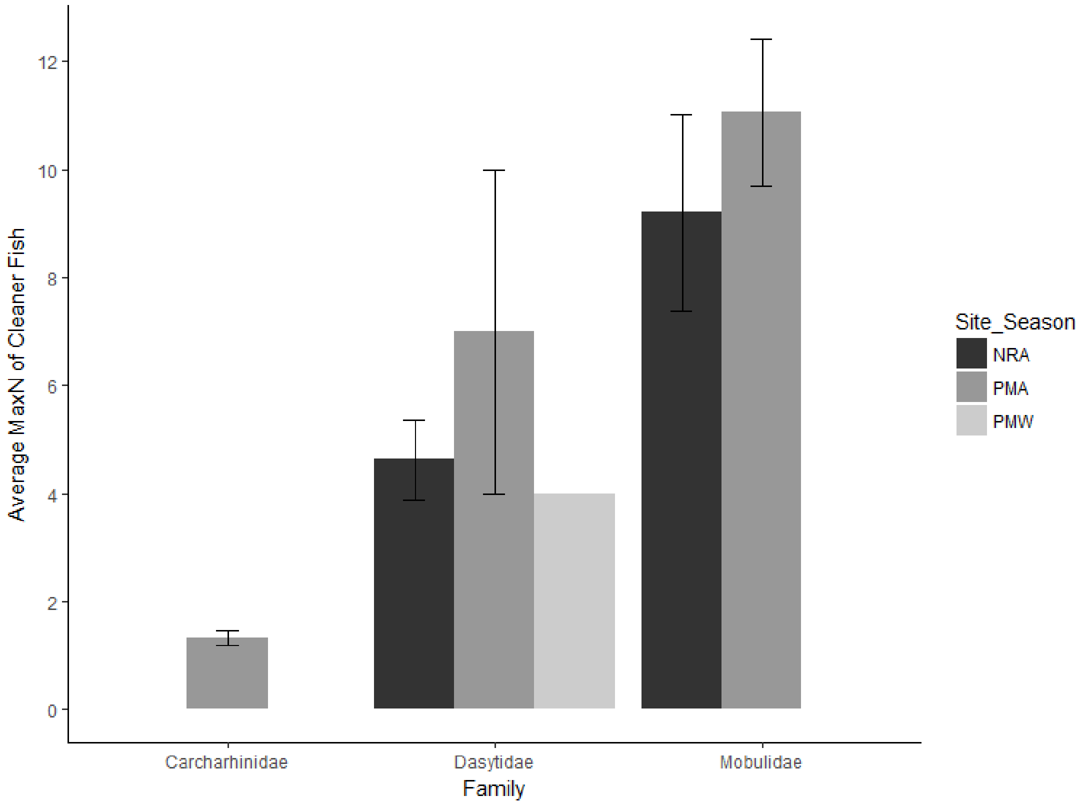

Figure 14:Mean number of cleaner fish Carcharhinidae, Dasyatidae and Mobulidae families by the site and season of observation. Error bars represent standard error.

3.7 Boat and Tourist Presence at Cleaning Stations

The RUV systems were capable of detecting engine noise and the presence of tourists at each cleaning station. However, if tourists were not permitted to duck dive at the cleaning stations, it was hard to detect their presence at Point Maud due to the depth of the site. Of the 33.5 hours of recording, 4 hours had detectable engine noise and 0.69 hours had tourists visible at the cleaning stations.

Engine noise was heard at least once during every deployment throughout the study, but this was often related to deployment or retrieval of the RUV. Noise could be heard even when manta rays were not present at the cleaning stations, suggesting that some of the engine noise was not manta ray tourism related. Engine noise was most frequently heard at Point Maud. The frequency of boat presence at Point Maud was highest in winter ($\bar{x}$= 2.04 occurrences per hour ± 0.55 SE), then Point Maud in autumn ($\bar{x}$= 1.87 occurrences per hour ± 0.34 SE), compared to North Reef in autumn ($\bar{x}$= 1.69 occurrences per hour ± 0.66 SE).

Of the four deployments of the RUV system at North Reef in autumn, snorkelers were observed in one and SCUBA divers were observed in two. Snorkelers were only observed at the cleaning stations when manta rays were present, but the SCUBA divers were observed when manta rays were not present. The snorkelers and divers spent an average of 5.58 minutes ± 2.81 SE at the cleaning station. In comparison, of the five deployments at Point Maud in autumn, snorkelers were observed once, staying at the cleaning station for 13.70 minutes. No SCUBA divers were observed at Point Maud.

3.7.1 Manta Ray and Tourist Presence Validation

The presence of manta rays and tourists at the cleaning station study sites as observed by the RUV system can be validated against the log book data collected by the tour operator that the RUVs were deployed through (Table 11). At least one manta ray was detected on eight of the seventeen deployments made over the course of the study. In comparison, the log book data recorded 7 tour interactions with manta rays at the two cleaning stations out of a total 25 tourist interactions with manta rays. The RUV system had three recordings of manta rays present at the cleaning station without being recorded in the logbook. Conversely, out of seven tourist interactions at the cleaning stations, the RUV system detected two. The other five are only known due to the log book entries.

Table 11: Comparison of the number of RUV deployments or tour operator log book entries where manta rays were observed at Point Maud or North Reef.

	Number of Days Manta Rays Present at Cleaning Stations	Number of Days Tourists Present at Cleaning Stations
Log Book Only	2	5
RUV Only	3	0
Log Book and RUV	5	2
Total	10	7

The consistency between the number of individual manta rays counted in the RUV data compared to the log book data varied (Figure 15). Of the 17 successful deployments, eight RUV deployments occurred when manta rays were present at Point Maud or North Reef while tours were being conducted. Of these deployments, two detected the same number of manta rays at the cleaning station as observed by the tour operator. A further two deployments recorded manta rays that were not recorded in the logbook. This was a result of manta rays being interacted with away from the cleaning stations. The remaining four deployments, while detecting manta rays, provided an under-estimate of manta rays in the area compared to the observations of the tour operator. However, on these days, manta rays were dispersed around Point Maud rather than aggregated at the cleaning station.

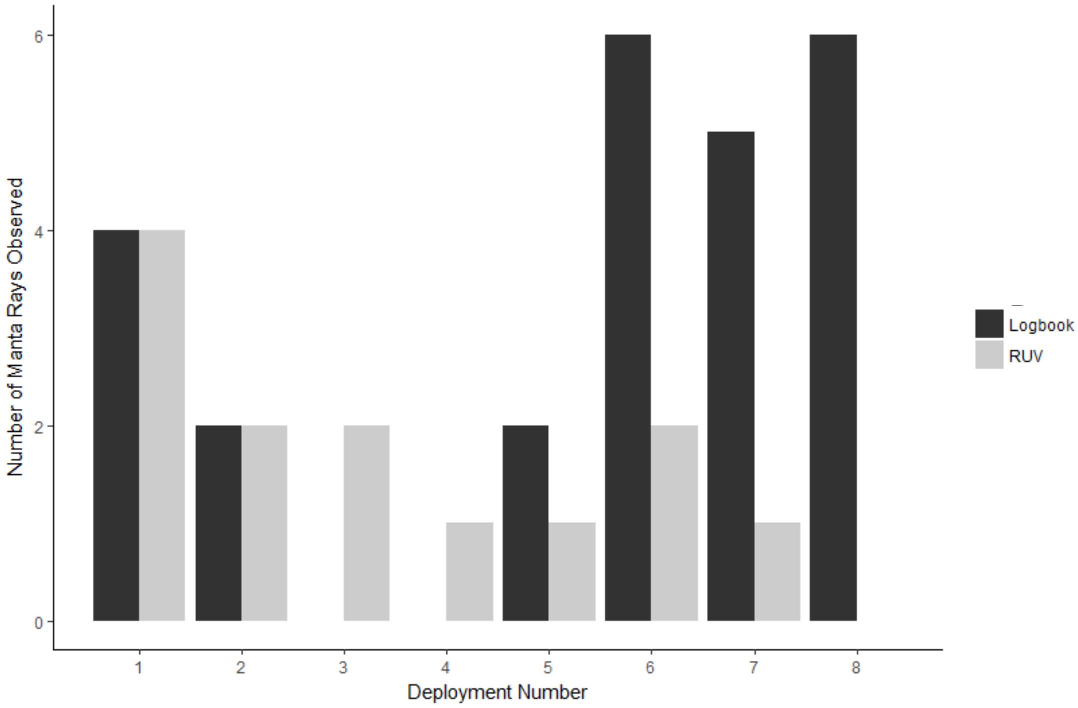

Figure 15: Number of manta rays observed at Point Maud or North Reef by the RUV system compared to the number observed by the tour operator. Deployments 1 and 2 occurred at Point Maud in autumn. Deployments 3 to 5 occurred at North Reef in autumn. Deployments 6 to 8 occurred at Point Maud in winter.

3.7.2 Proximity of Manta Ray Tourism to Cleaning Stations

A total of 25 manta ray tourist interaction swims were observed. 13 of these interactions occurred in autumn and 12 in winter. During these interactions, tourists swam with mantas while they were engaging in cleaning, cruising and feeding behaviours. There was a statistically significant difference in the proportion of behaviours manta rays were engaging in during tourist interactions ($\chi^2 = 37.418$, df = 2, P = <0.0001). The most common behaviour for manta rays to be exhibiting during interactions was feeding (44%), followed by cruising (40%) and cleaning (16%). Tourists interacted with cleaning manta rays at Point Maud twice and at North Reef and Oyster Bridge once.

Most of the tourist interactions occurred in the southern half of Bateman Bay, in closer proximity to the Point Maud cleaning station than the North Reef cleaning station. Two-

Way ANOVA testing showed that the average distance from cleaning stations to locations where manta rays were being interacted with as part of tours were statistically different between sites and season (P = 0.02, F = 10.732) (Figure 16). Most manta ray interaction swims occurred closer to the Point Maud cleaning station ($\bar{x}$=4.10 km from cleaning station ± 0.69 SE) compared to the North Reef cleaning station ($\bar{x}$=6.63 km from the cleaning station ± 0.54 SE). Interactions tended to occur closest to Point Maud in winter ($\bar{x}$=2.5 km from the cleaning station ± 0.73 SE) with four of the 12 observed interactions occurring less than 0.2 km from the cleaning station. However, in these interactions no manta rays were observed engaging in cleaning behaviours despite making multiple passes of the cleaning stations.

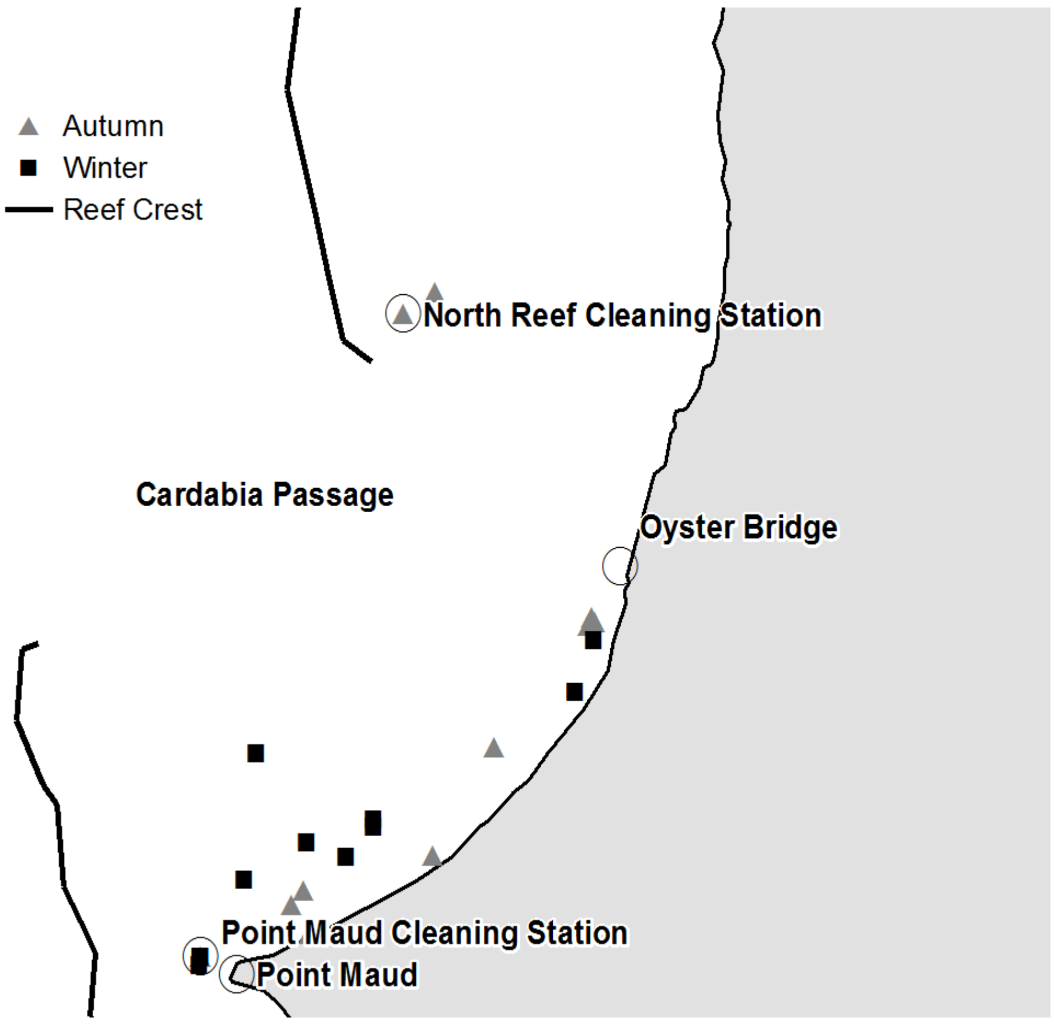

Figure 16: Map showing the location of manta ray tourist interactions in Autumn and Winter. Coastline data is GEODATA COAST 100K 2004 (Geoscience Australia).

3.7.3 Effect of Tourist Presence on Manta Ray Cleaning Behaviours

The RUV system captured interactions between four manta rays and tourists over two separate interactions. This allowed for a preliminary analysis of the effects that the presence of tourists may have on manta ray cleaning behaviours (Figure 17). Two of the manta rays were present at the Point Maud cleaning station prior to tourists arriving. The third manta ray arrived at Point Maud while the previous two were still present. Tourists were present at the cleaning station for 16.83 minutes. The third manta ray was still present after the interaction. The fourth interaction occurred at North Reef where the manta ray arrived at the cleaning station while being followed by tourists. This interaction lasted for 9.65 minutes. The tour group continued to follow the manta ray as it left the cleaning station. The RUV system was collected at the conclusion of these interaction meaning that manta ray behaviours after the interactions could not be observed.

The first manta ray did show a significant change in behaviour (χ^2 = 4.603, df = 1, P = 0.032). The proportion of time spent hovering over the cleaning station dropped from 30.50% to 6.56%. While this is a significant change, the presence of tourists did not cause this individual to stop cleaning or leave the cleaning station. While the Chi-Square Goodness of Fit test found no statistically significant change in the second manta ray's cleaning behaviours (χ^2 = 0.713, P = 0.398, df = 1), it did stop cleaning and left the cleaning station during the tourist interaction. Whether this was due to the presence of tourists or not cannot be conclusively established.

The occurrence of a behaviour change in the third and fourth manta rays could not be analysed due to the lack of data on their behaviour prior to the interactions starting. It is worth noting that the third manta ray stayed at the cleaning station after tourists left. Conversely, the fourth manta ray left the cleaning station during the interaction after 9 minutes.

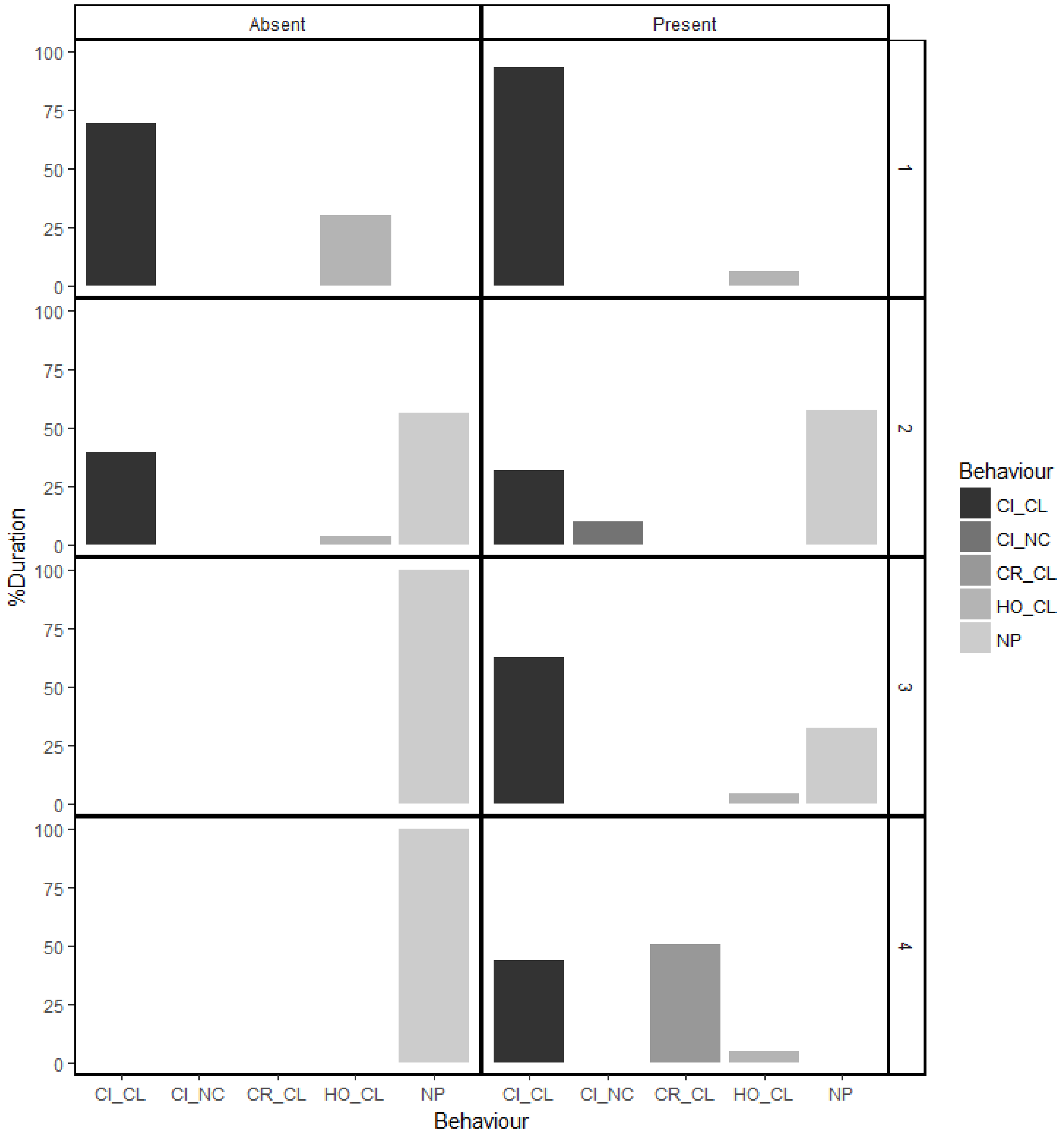

Figure 17: Comparison of the proportion of behaviours exhibited by four manta rays when tourists are absent or present at cleaning stations. CI_CL = Circling while being cleaned, CI_NC = Circling without being cleaned, CR_CL = Cruising while being cleaned, HO_CL = Hovering while being cleaned, NP = Not present at the cleaning station.

4 DISCUSSION

4.1 Evaluation of Multi-Camera RUV Method

This study developed a multi-camera RUV method that could simultaneously record and analyse video data from 2 to 4 cameras, providing near 360-degree coverage of study sites. The maximum battery life of three hours was enough to study how cleaning stations in Bateman Bay are used during the peak period of tourism activity each day. The camera system was continuously improved between data collection periods based on analysis of the previous period's data. The two-camera system had a limited field of view, so data from Point Maud in Autumn may provide underestimates of cleaning activity and client diversity. For the aims of this study, four cameras and a near 360-degree field of view was optimum, but for other studies, such coverage may not be necessary. Single camera RUV systems have been used to study cleaning stations previously (Oliver et al. 2011; Sazima, Moura, and Sazima 1999; Quimbayo et al. 2017) but multi-camera systems do not appear to be commonly used (Mallet & Pelletier, 2014). However, while they do not appear to have been used in cleaning station studies, they have been used in other ecological studies (González-Rivero et al., 2014; Holmes et al., 2013; Jackson et al., 2006; Mills et al., 2005).

The advantage of the multi-camera system was the near complete coverage of the cleaning station, reducing the potential for clients to leave the field of view before cleaning events ended. This method was able to capture a rich data set by monitoring the community composition and cleaning behaviours of client species at cleaning stations in Bateman

Bay. The video data was used to study how different clients used the study sites by analysing visitation frequencies, duration of visit and number of cleaner fish attending to clients. The method was also able to capture boat noise and tourist presence at the cleaning stations.

The RUV system was very effective at detecting engine noise from boats, but it did not always manage to capture tourist presence at the cleaning stations. This was established by comparing observations of tourists at the cleaning stations recorded in the RUV data with the tour operator's logbook data. This was particularly an issue at the deeper site, Point Maud. This was partly due to lighting from the sun obscuring the presence of snorkelers or the camera angles being too low to see the surface. Solutions to this issue could be to use cameras with fish eye lenses to capture a wider vertical field of view or add another camera that is always tilted towards the surface. Alternatively, a 360-degree camera in a domed housing could be used to achieve the same result. Another issue was the battery life running out before tourists arrived at the cleaning stations in the late afternoon.

This system's presence on the cleaning station did not appear to affect the behaviours of most clients. Some fish species would investigate the cameras, and on two occasions the cameras were bitten and pushed over by turtles, resulting in unsuccessful deployments. Within 10 minutes of deployment the rate of cleaning events stabilized to approximately the rates observed in subsequent hours of recording. This suggests that deploying the cameras had a minimal effect on the overall data set given that most deployments lasted for 3 hours.

4.2 Cleaning Station Ecology

4.2.1 Client Composition of Cleaning Stations in Bateman Bay

This study aimed to improve understanding of the client species and family composition of cleaning stations used by manta rays in Bateman Bay. At the two cleaning stations studied, 45 species from 22 families were identified. The diversity of species was highest at North Reef and Point Maud in autumn and lowest at Point Maud in winter. Most of these species were ray-finned fish, but rays, sharks and turtles were also observed using these sites for cleaning purposes. The most common species overall was an unidentified Scaridae species and *Scarus schlegi*. This is largely due to the client composition being dominated by Scaridae clients in winter at Point Maud. The next most common species were *Carcharhinus amblyrhynchos*, *Mobula alfredi* and *Lethrinus nebulosus*. This result is expected given that the site was selected as a known *M. alfredi* cleaning station and that Scaridae, Carcharhinidae and Lethrinidae species are abundant in the area (Speed 2011; Ashe 2016; Westera et al. 2003).

A survey of Bateman Bay's marine fauna identified 343 species of fish, including elasmobranchs, and three species of turtle in the area (Fitzpatrick & Penrose, 2002). The present study therefore observed 12.83% of the known fish species and 33.33% of turtle species in the area utilizing these cleaning stations. Ashe (2016) observed 144 species, including ray-finned fish, elasmobranchs and turtles, in the vicinity of manta ray cleaning stations in Bateman Bay[5]. Only 30 of these species engaged in cleaning events. Therefore, it may be that not all the fish and species observed by Fitzpatrick and Penrose (2002) in Bateman Bay utilize the habitats near manta ray cleaning stations and an even smaller proportion use these habitats to solicit cleaning services. The diversity at these two cleaning stations is relatively high compared to results from other studies of cleaning station client species composition (Table 12). This may be due to this study reporting all clients regardless of taxonomic group. Other studies may have had other clients visiting and did not report them due to the aims of the study.

The differences in diversity of clients at the two cleaning stations may be attributable to differences in the general fish communities of Bateman Bay. Some species at North Reef are not known to be present elsewhere in the Bay, which could explain why the diversity was observed to be highest there (Fitzpatrick & Penrose, 2002). However, the survey also observed that the Maud sanctuary zone, which the Point Maud cleaning station is part of, had the highest diversity of reef fish in Bateman Bay. If client species composition reflects that of the general composition of the area, it would be expected that Point Maud would have had the highest diversity. There is a possibility that the diversity of species at Point Maud in autumn may be an underestimate due to the two-camera system potentially missing cleaning events outside its field of view. Additionally, Fitzpatrick and Penrose (2002) used baited RUVs. These two reasons could explain the dissonance between the present study's results and that of Fitzpatrick and Penrose (2002).

[5] Ashe (2016) studied different manta ray cleaning stations to the present study. Ashe (2016) studied two cleaning stations near Point Maud and a cleaning station near Oyster Bridge. This study focused on the general community present at the cleaning stations but did not specify which species acted as clients.

Client species composition and abundance appears to be primarily driven by season rather than site, as species composition was more similar between Point Maud and North Reef in autumn than Point Maud in autumn and winter. Seasonal shifts in composition of the general fish community could explain this, but most species that were cleaned in autumn were still present in the area in winter. The effect of season on client composition could be driven by seasonal changes in parasite composition. Alternatively, this effect could be a combination of fish community composition shifts and changes in parasite abundance (Grutter, 1994; Kennedy, 1975).

Table 12: Taxonomic diversity of client species and families recorded in other studies of client communities and the present study, ranked by number of species.

Reference	Species (N)	Family (N)	Classes	Location
Quimbayo et al. (2017a)	19	-	Ray-finned fish and Elasmobranchs	Tropical eastern Pacific, number of sites not disclosed.
Ashe (2016)	144	37	Ray-finned fish, Elasmobranchs, turtles and cetaceans	Bateman Bay, central-west Australia, 3 cleaning stations
Slobodkin and Fishelson (2017)	47	19	Ray-finned fish	Eilat, Israel, 13 cleaning stations
Present Study	**45**	**22**	**Ray-finned fish, elasmobranchs and turtles**	**Bateman Bay, central-west Australia, 2 cleaning stations**
Sazima et al. (2000)	34	16	Ray-finned fish	South-eastern Brazil, 3 cleaning stations
Titus et al. (2015)	-	16	Ray-finned fish	Utila, Honduras, 2 cleaning stations
Cote et al. (1998)	30	-	Ray-finned fish	Barbados, West Indies, 12 cleaning stations
Quimbayo et al. (2017b)	23	15	Ray-finned fish, sharks and sea turtles	Atoll in south Atlantic, 7 cleaning stations
Sazima et al. (1999)	23	19	Ray-finned fish	Abrolhos Archipelago, Brazil, 2 cleaning stations
Quimbayo et al. (2017a)	19	-	Ray-finned fish and Elasmobranchs	Tropical eastern Pacific, number of sites not disclosed.
Francini-Filho et al. (2000)	19	-	Ray-finned fish	Fenando de Noronha Archipelago, Brazil, 4 cleaning stations
Grutter et al. (2003)	12	-	Ray-finned fish	Lizard Island, Great Barrier Reef, 2 cleaning stations
O'Shea et al. (2010)	5	3	Elasmobranchs	Osprey Reef, North east Australia, 1 cleaning station

4.2.2 Contribution of Families to Client Community

The most common client family was the Scaridae, which contributed more than 50% cleaning events observed. Almost all the Scaridae cleaning events occurred in winter at Point Maud, which contributed to the difference in species composition between seasons. This is unsurprising given that Scaridae species make up a large proportion of the general community at this site (Ashe, 2016). The other major contributing client families were the Carcharhinidae, Labridae, Lethrinidae and Mobulidae, but each of these families all contributed less than 10% to the overall number of cleaning events.

The client composition data suggests that these cleaning stations are important to species that are targeted by tourism and fishing activities. The sites were selected based on the knowledge they were used by tour operators to interact with manta rays, so it is unsurprising that they contributed a high percentage of the client composition. Carcharhinidae and Cheloniidae families are also families valued for tourism activities and contributed highly to the overall client composition (Department of Conservation and Land Management, 2005). These three families often ranked in the top five contributing families to client composition in each site and season category. This suggests that these families may rely on these cleaning stations in order to manage parasite infection. This means that the continued function of the cleaning stations in Bateman Bay should be of interest to the Coral Bay tourism industry.

Analysis of the ray-finned fish community using the cleaning stations suggests that these sites are also important for species targeted by fishers. Westera et al. (2003) identified that the *Cheorodon spp., and* Lethrinidae, Serranidae, Lutjanidae, Haemulidae species are commonly targeted for recreational fishing in the Ningaloo Marine Park. All of these groups except the Serranidae were observed engaging in cleaning behaviours at least once at Point Maud or North Reef. This suggests that the cleaning stations also provide an ecological service to improve health of fish stocks used for recreational fishing in Bateman Bay.

4.2.3 Client Behaviours

The most common behaviour for clients was hovering. Hovering clients were often posing in either a head or tail stand position. It has been found that posing increases the probability of a client being cleaned (Cote et al., 1998), which may explain why this was the most common behaviour. Cote et al., (1998) also found that not all species pose and not all individuals in the same species pose. While this study only concerned ray-finned fish, the present study suggests the same trend is evident in elasmobranchs and turtles. The next most common client behaviour was to cruise over the cleaning station. In most of these interactions the cleaner would approach the client and begin inspecting, the client would then either slow down to be cleaned or speed up to leave the station. This therefore may represent the cleaners opportunistically approaching potential clients which happen to be passing the station as they move around the reef. For clients observed to be feeding while being cleaned, it may be that these clients were feeding in the area and the cleaners opportunistically attend them. Circling was only seen in three families, the Mobulidae, Dasyatidae and Tetradontidae. Circling may be used by clients that struggle to hover but require cleaning, as the Mobulidae and Dasyatidae have negative buoyancy. On occasions when these families hovered, they sank before resuming a circling movement pattern. Only one circling event in the Tetradontidae was observed so it is hard to attribute a reason to this behaviour.

4.2.4 Duration of Events and Number of Cleaners

While most cleaning events lasted less than a minute, the duration of cleaning events client varied considerably. Durations ranged between less than five seconds to over an hour. There was considerable variation in the duration of cleaning events between families. This supports Arnal et al., (2002), who also reported great variation in the duration of cleaning events. Ray-finned fish and shark clients tended to have a shorter duration of cleaning events compared to rays and turtles. It is unclear why this is, but it may be related to the larger surface area of rays and turtles taking longer to clean. It could also be related to the number of parasites on the client or their physiology and morphology. The duration of a cleaning event was longest when clients circled around the cleaning station or hovered while it was shortest when clients cruised by the station. This is confounded by the only families exhibiting circling behaviours, the Mobulidae, Dasyatidae and Tetradontidae, being mostly large species.

4.2.5 Number of Cleaners Attending Clients

Similar to duration of cleaning events, the number of cleaners attending clients varied between families. The number of cleaners attending a client ranged between 1 and 20, with most cleaning events only involving one cleaner. Shorter cleaning events tended to have fewer cleaners attending the client, but this may reflect the size of the client. It is known that cleaners show a preference to larger clients of any given species (Grutter 1995). Therefore, it would make sense that the largest clients, the rays, would have the highest number of cleaners attending them as they provide the largest surface area for cleaners to clean. One exception to the trend of larger clients having the longest duration and highest number of cleaners is the shark clients. Sharks frequently only had a single cleaner attend to them, despite being part of the megafauna client category. This may be related to their trophic class as a predator, since cleaners appear to prefer non-predatory clients, in addition to sharks seldom slowing down as they passed the cleaning station (Francini-Filho et al., 2000).

While the species of cleaners could not always be discerned in the video data, some species could be identified. *Labroides dimidiatus* and *Thalassoma lunare* were the most commonly observed cleaners. *Acanthuridae* and *Heniochus* species were also occasionally observed cleaning. *L. dimidiatus* and *T. lunare* have been observed to act as cleaners at manta ray cleaning stations previously (Marshall 2008; Kitchen-Wheeler 2013; O’Shea et al. 2010). These species are also known to clean sharks at a cleaning station in the Coral Bay area (Wheeler et al. 2013). Acanthuridae and *Heniochus* species, while not as common, have also previously been reported to act as cleaners (Hobson 1969; Grutter 2002).

4.2.6 Elasmobranch Use of Cleaning Stations in Bateman Bay

This study particularly focused on the use of cleaning stations by elasmobranch clients. While elasmobranchs were observed cruising past the cleaning station without being cleaned, most visits resulted in a cleaning event. Seven species of elasmobranch were observed, five of which engaged in cleaning events. The five species that engaged in cleaning behaviours were two shark species (*Carcharhinus amblyrhynchos*, *Triaenodon obesus*), one Mobula ray species (*Mobula alfredi*), and two stingray species (*Pastinachus sephen*, *Dasyatis thetidis*). The two elasmobranch species that were not cleaned were both sharks (*Negaprion acutidens* and *Loxodon macrorhinus*). Cleaning was more frequent in autumn at Point Maud and North Reef compared to Point Maud in winter, which is congruent with the overall trend of cleaning station activity for all client species. Only one elasmobranch cleaning event was observed in winter. Visitation frequency for cleaned and non-cleaned elasmobranchs varied by site, season and elasmobranch family.

4.2.6.1 Manta Ray Cleaning Behaviours

Manta rays were observed engaging in cleaning behaviours at Point Maud and North Reef in autumn. The highest frequency of manta ray visitation was at Point Maud in autumn. This suggests that the concerns that have been raised of potential abandonment due to tourism have not yet materialised (McGregor pers comms, Daw, 2009; Venables, 2013). However, it cannot be said if the number of manta rays visiting these sites has decreased over time. Manta rays were observed at both cleaning stations and at Point Maud in autumn and winter, however they only cleaned during autumn. Visitation frequency was highest at Point Maud in autumn and lowest at Point Maud in winter.

Using photo-identification, manta rays were identified to an individual level. Several manta rays revisited the Point Maud cleaning station in autumn within two days of their first observed visit. However, within the scope of this study, revisits within a temporal scale of days is the only pattern that could be reliably observed. Revisitation by manta rays has been known to occur within days, months and years using photo-identification studies (O'Shea et al. 2010; Couturier et al. 2011; Dewar et al., 2008).

The mean duration of a cleaning event was 10.32 minutes, with the shortest duration lasting less than a minute and the longest lasting for 61 minutes. On one occasion a manta ray had been at the Point Maud cleaning station in autumn for 24.82 minutes when the RUV system's battery ran out. Therefore, it is hard to say how long that cleaning event lasted in total. In comparison to other studies, these durations are relatively short but fall within the reported ranges. Kitchen-Wheeler (2013) reported the most similar range in cleaning duration with manta rays in the Maldives spending between 5 and 75 minutes being cleaned. It was also noted by Kitchen-Wheeler (2013) that manta rays were only attended by cleaners for a small proportion of their visit to the cleaning stations. In comparison, manta rays at Point Maud and North Reef were cleaned near continuously during visits, although this may be due to lower number of manta rays present at cleaning stations in Bateman Bay compared to the Maldives. O'Shea et al., (2010) reported manta rays cleaning at a seamount for between 5 minutes to 5 hours. Using acoustic tagging methods, Marshall (2008) found that manta rays spent a mean time of 119.4 minutes at reefs with cleaning stations, but it is unclear if the manta rays cleaned during this time. From these studies it is evident that RUV system that can record for more than three hours may be necessary to monitor the full range in cleaning events for manta rays.

The most common behaviour for a manta ray to exhibit while cleaning was circling, followed by cruising or hovering. These behaviours are consistent with observations in other studies of manta ray cleaning behaviour in the Maldives and Mozambique suggesting these behaviours are consistent across the species (Kitchen-Wheeler, 2013; Marshall, 2008). It is worth noting that cruising past cleaning stations was not reported by Kitchen-Wheeler (2013) or Marshall (2008) but was reported in Daw (2008) in response to tourist presence. Manta rays were attended by the highest number of cleaner fish for any elasmobranch client. This also appears to be consistent with manta ray cleaning events in other reef ecosystems (Kitchen-Wheeler, 2013; Marshall, 2008).

Their long visit duration, combined with circling behaviours and high number of cleaner fish suggest that manta rays are intentionally visiting cleaning stations in Bateman Bay to solicit cleaning services. However, in winter at Point Maud, the presence of non-cleaned manta rays is likely to be attributable to a crab spawning event that occurs in August (F. McGregor pers. comms). The manta rays observed on the RUV system did not slow down as they cruised past the cleaning station. In-water observation of manta rays and plankton sampling in the area in August suggested they were cruising in the area waiting for the plankton bloom or feeding on the available plankton once the spawning event occurred (F. McGregor pers. comm., A. Thornton unpublished data).

4.2.6.2 Shark Cleaning Behaviours

Sharks were observed frequently at Point Maud but not at North Reef. Most sharks that visited the cleaning station cruised past without slowing down and were not cleaned. The most common shark species, and only shark clients, observed were *C. amblyrhynchos* and *T. obesus*. This is unsurprising as these species are considered two of the three most abundant reef shark species in the Indo-Pacific region (Last et al., 2009). Visitation frequency was highest for non-cleaned sharks at Point Maud in autumn, this was also the only season and site that sharks were observed being cleaned. Sharks were still observed in winter at Point Maud, but they were not being cleaned. No sharks were observed at the North Reef cleaning station. The average duration of cleaning events was 7.9 seconds with a range between 4 seconds and 19 seconds.

The most common behaviour for shark clients was to cruise over the cleaning station, but some clients would hover. Some *C. amblyrhynchos* individuals would adopt a vertical tail-stand pose that has been observed another cleaning station in Coral Bay and in other reef ecosystems (Wheeler et al., 2013; O'Shea et al., 2010). No *T. obesus* individuals were observed posing as all cleaning events occurred as they cruised over the cleaning station. Posing does not appear to be common for the species, but they have been observed to rest on reefs to be cleaned (O'Shea et al., 2010; Whitney & Motta, 2008). Most sharks only received one cleaner fish that would swim up from the cleaning station to meet the shark.

The high number of sharks at Point Maud compared to North Reef may be attributable to its close proximity to a known reef shark aggregation site in Skeleton Bay, slightly south of Point Maud (Speed, 2011). This reef shark aggregation site tends to have higher numbers in summer, which may explain why more sharks were seen in early autumn than mid-winter deployments (Speed, 2011). Sharks seen at Point Maud may have been travelling to the Skeleton Bay aggregation site, explaining the tendency for the sharks to cruise from the north to south.

The short duration of cleaning events may be due to the cleaning event happening incidentally on their travel path. However, a duration for shark cleaning events between five to ten seconds has also been reported by O'Shea et al., (2010), so the short duration of cleaning event may be typical of sharks. Sazima & Moura (2000) reported that most cleaning events for the shark *Carcharhinus perezi* lasted for a minute. Additionally thresher sharks (*Alopias pelagicus*) have been observed to clean for up to 23 minutes, so there is evidence to suggest that sharks do clean for longer periods of time (Oliver et al., 2011). The low variance in shark cleaning event duration supports the idea that short duration is typical for sharks, at least at Point Maud. The relatively low frequency of shark cleaning events compared to number of sharks that were not cleaned may also be attributable to the presence of another cleaning station nearby that is known to be significant for *C. amblyrhynchos* clients (Wheeler et al., 2013). If this site is nearby, sharks may have a preference to it over Point Maud due to a more reliable and faster current (Wheeler et al., 2013).

4.2.6.3 Stingray Cleaning Behaviours

Across the literature, there are very few reports of cleaning behaviours in sting rays (Meekan et al., 2016; Snelson et al., 1990; Quimbayo et al., 2017). The present study observed stingrays engaging in cleaning behaviours at both sites and during autumn and winter at Point Maud. Visitation frequency was highest at North Reef and Point Maud in autumn, with only one stingray cleaning event observed in winter at Point Maud. The average duration of stingray cleaning events was 1.02 minutes, with a range of 0.08 minutes to 3.26 minutes. Cleaning durations of up to 26 minutes have been reported in stingrays (Snelson et al., 1990). It is possible that the durations observed in the present study are an underestimate due to individuals settling behind coral bommies out of the field of view while being followed by cleaners.

Stingrays did not exhibit a clear behaviour preference. However, most stingrays cruised over the cleaning station while a few individuals circled around the cleaning station. Circling behaviours have also been reported in cleaning sting rays in addition to posing on the seafloor, but no posing was observed in the present study (Snelson et al., 1990).

On average, stingray clients had four cleaners attending them. On one occasion at North Reef when the RUV system was collected, a school of 12 stingrays were observed buried in the sand nearby the cleaning station. In the RUV video data of this deployment, the stingrays cruised over the cleaning station and were cleaned while heading towards the bare sand patch. This suggests that the cruising cleaning behaviours may have been a result of the school heading to the sand patch rather than actively seeking out cleaning services. However, the circling behaviours observed in some stingray clients, and the maximum duration of cleaning events of 3.26 minutes provides evidence that some stingray clients were actively seeking out cleaning services.

4.3 Boat and Tourist Presence at Cleaning Stations

Despite deployments occurring during peak tourism operation time, most of the video data did not have boats or tourists present at the cleaning stations. Boats engine noise could be detected for 12% of the total video time and tourists were present for 2% of the total video time. Engine noise was more frequently heard at Point Maud than at North Reef. Given the proximity of the Point Maud cleaning station to a boating channel and the far distance of North Reef from the boat ramp, this is unsurprising. The amount of boat traffic at Point Maud could raise concern due to observations that vessels operating at excessive speed and manoeuvring inappropriately around manta rays has been shown to alter manta ray behaviour (Daw, 2009). However, the code of conduct states vessels should not go nearer than 30m to known manta ray cleaning stations, and this may be helping to avoid vessels disturbing cleaning stations. Fish at the cleaning stations did not appear to show observable responses to the presence of engine noise, despite loud noises being known to cause stress responses in fish (Bowles, 2012; Slabbekoorn et al., 2010). This may be a results of fish habituating to engine noise, after many years of being exposed to engine noise, fish may no longer associate the noise with danger (Bowles, 2012). Alternatively, it is possible that the volume of the noise was not loud enough to warrant a response from the fish as the site is quite deep and it was rare for boats to travel directly over the cleaning stations.

Tourist and diver presence was more frequent at North Reef than Point Maud based on the RUV. However, the tour operator log book data suggests more interactions occur at Point Maud. This difference may be attributable to deployments at North Reef only being possible when tour operators or research divers would be going to North Reef, while the tour operators pass Point Maud every day. Validation of the RUV data against the tour operator’s log books show that some tourist interactions at Point Maud were not captured by the video data, potentially skewing results. Even with the interactions from the log book considered, the number of interactions occurring at cleaning stations in Bateman Bay is relatively low. Most tourist interactions during the study occurred in the southern half of Bateman Bay relatively close to the shore. In the observed tourist interactions with manta rays, 44% of these interactions occurred with manta rays that were feeding, 40% with manta rays that were cruising and 16% were with cleaning rays. These results are very similar to the findings of Venables (2013), who reported 49% of tourist interactions with manta rays occurred when they were feeding, 30% when cruising, 7% engaging in courtship behaviours and 14% while cleaning, in Bateman Bay. Tourist presence always coincided with manta rays being present at the cleaning station. As such, if manta rays were not cleaning there was no need for tourists to visit the cleaning stations.

4.3.1 Effect of Tourist Presence on Manta Ray Cleaning Behaviours

The RUVs recorded tourist interactions with four manta rays. Three of these manta rays were interacted with simultaneously at Point Maud in autumn. The fourth manta ray was interacted with in autumn at North Reef. Two of the manta rays interacted with at Point

Maud in autumn were present at the cleaning station prior to the interaction occurring. This meant that changes in the behaviour of these two individuals could be analysed. The first manta ray continued to clean but reduced the amount of time it spent hovering above the cleaning station in favour of large circling patterns. The second individual stopped cleaning and left the station approximately three-quarters of the way through the interaction. During the interaction at North Reef, the manta ray predominantly exhibited cruising behaviours. It swam in long lines passing the cleaning station, stopping to hover for a very short time before continuing its cruising behaviour.

It should be noted that during the interaction at Point Maud, tourists were permitted to duck dive down to the cleaning station near the end of the interaction. Duck diving at cleaning stations goes against the code of conduct but was allowed by the operator on this occasion to see if a behavioural response was observable. Tourists complied with the code of conduct at North Reef, but the manta ray's cruising behaviour was considered to be a response to tourist presence. It has been observed that during tourist interactions at cleaning stations in Bateman Bay, some manta rays do not stop at cleaning stations but rather continue past and leave without cleaning (Daw, 2009). The manta ray did clean at North Reef, but the duration of cleaning was shorter than the average length of cleaning events for manta rays observed in this study. While not conclusive, the combination of the cruising behaviour and shorter duration of cleaning event does suggest that tourist presence did affect the cleaning behaviour of the manta ray.

Departure from cleaning stations in response to tourists has been observed in other studies. Kitchen-Wheeler (2013) observed that the approach of SCUBA divers to cleaning stations in the Maldives was often associated with manta rays leaving the site. Venables (2013) also observed that the presence of snorkelers at cleaning stations in Bateman Bay caused manta rays to depart cleaning stations. The most extreme case of this was total abandonment of a cleaning station for two years by manta rays in French Polynesia (de Rosemont, 2008). While it was mentioned that other factors could have been the cause of the abandonment, high tourism pressure was considered to be one of the main factors.

4.4 Considerations for Future Research

For studies aiming to study client composition and behaviours at cleaning stations or the effect of tourism at critical sites, a multi-camera or 360-degree camera RUV system will minimise the potential for events occurring outside the field of view of the camera. However, the system was limited by the length of battery life of the RUV system and cleaning stations were only monitored during the middle of the day. While the maximum battery life of three hours was enough to study how cleaning stations in Bateman Bay are used during the peak period tourism activity during the day, it was not enough to detect diurnal patterns. Diurnal patterns have been detected in client species composition and cleaning event duration as well as cleaning station visitation patterns of elasmobranchs (Sazima et al., 2000; O’Shea et al., 2010; Speed, 2011).

Future research on cleaning stations in Bateman Bay could utilize methods from other studies to monitor diurnal patterns. O’Shea et al., (2010) used a system that was capable of recording for 12-hour periods and was used to detect diurnal and tide-related patterns in cleaning station use. Alternatively, repeated deployments of a RUV system as in Oliver et al., (2011) could be done to collect diurnal pattern data at seamount cleaning stations. By using a similar method, tide-related and diurnal patterns in client composition, visitation frequency and behaviours in Bateman Bay could be studied. This would assist in developing a better understanding of how cleaning station use during peak tour operation time compares to other times of day. Of particular interest is to assess if manta rays return to cleaning stations after departing the sites in response to tourists.

Another area for future research identified in this study is investigation of what is driving the seasonal shifts in client composition. This could potentially involve studies of the broader fish community and parasite abundance on clients. It would also be valuable to study more cleaning stations in the area over a longer time period to collect data on the temporal and spatial differences in cleaning station communities.

4.5 Management Implications

As a management tool, RUV systems can help to monitor species composition and behaviours at habitats of interest. RUV methods also present an opportunity to monitor the presence of boats and tourists and the ability to capture data about interactions between wildlife and tourists at sites of interest, such as manta ray cleaning stations. Without modifications the RUV system used in this study may struggle to capture these events if tourists stay on the surface as the code of conduct suggests. As such, if this system was to be used as a management tool it is recommended that it is used in tandem with a logbook system or another method of in-water validation to provide more reliable results.

Ensuring the continued function of these cleaning stations may be important for maintaining the ecological and social values of Bateman Bay. This is due to species valued for both tourism and recreational fishing activities in Bateman Bay are using the Point Maud and North Reef cleaning stations. While Point Maud is already within a sanctuary zone, North Reef is not. Including known manta ray cleaning stations as sanctuary zones may be a good strategy to ensure the continued functionality of these sites. As Lethrinidae and Lutjanidae species contributed to 41% of the cleaning events observed at North Reef, the cleaning station's function may be vulnerable to fishing pressures. It has been shown that there are high rates of compliance with zoning rules among recreational fishers in Ningaloo Marine Park, including North Reef into a sanctuary zone may help avoid the cleaning station's function being affected by fishing activities (Smallwood & Beckley, 2012). However, its remote location from the boat ramp may already be reducing this risk.

By comparing the present study's data with that of Venables (2013), it appears that there has not been a change in the proportion of tourist interactions with manta rays at cleaning stations. Venables (2013) reported that 14% of observed manta rays during tourist interactions were engaging in cleaning behaviours, compared to 16% in the present study. This would suggest that the voluntary code of conduct appears to be managing the industry well enough to not cause manta rays to abandon cleaning station usage while tours are occurring. But while only a small proportion of tourist interactions occur at or near cleaning stations, it is important to carefully manage these interactions as there is a high cost to the consequences. Anecdotally, there may be an overall decline in the number of manta rays present in Bateman Bay according to tour operators (F. McGregor pers comm). During the fieldwork for the present study, there were three occasions where no manta rays could be found in the area by the spotter plane used by the manta ray tour operators, which may lend some evidence to the anecdote. However, analysis of long-term data is needed to detect any overall trends in manta ray abundance. Additionally, this perceived decline may be associated with complex environmental factors, such as fluctuations in plankton abundance, as well as the effects of tourism on manta ray behaviours (F. McGregor, pers comm).

While only a small number of tourist interactions occurred with cleaning manta rays, it was evident that there was a behavioural response that ranged from changing movement patterns to departure from the cleaning station. These responses appeared to be more pronounced when tourists were not required to comply with the code of conduct.

Therefore, there may be a need for better enforcement of the code of conduct or mandatory compliance to the code of conduct as a license condition. It has been recognised that interactions with manta rays at cleaning stations can be done sustainably, but this relies on appropriate training for the tour guides and a culture in the tour company that promotes sustainable behaviours of guides and tourists (Daw, 2009). As such, training for guides on understanding manta ray behaviour may also be beneficial in reducing the impacts of manta ray tourism.

5 CONCLUSION

This study aimed to use remote underwater video methods to develop a better understanding of the ecology of manta ray cleaning station client communities of Bateman Bay. In addition to studying the general client community, the study also focused on elasmobranch use of cleaning stations and the effects of boat and tourist presence on these sites.

Analysis of the species and family composition showed that the Point Maud and North Reef cleaning stations are used by ray-finned fish, elasmobranchs and turtles. The diversity of clients only reflected a small percentage of the known diversity in the area but was relatively high compared to that of other studies. It was already known that the sites studied are valuable for tourism due to manta rays using the cleaning stations. This study showed that these cleaning stations are also used by turtles and sharks which are also valued for tourism as well as several species of ray-finned fish valued for recreational fishing. The most common cleaning behaviours were hovering and cruising. This may reflect that posing increases the chance of being cleaned while cleaners may be opportunistically cleaning fish that pass by the cleaning station. The duration of cleaning events was highly variable, but it appears that the size of the client is a factor. Size also appears to influence the number of cleaners a client will receive. This suggests that these cleaning stations are important for the long-term sustainability of tourism and fishing activities in the Ningaloo Marine Park.

Multivariate analysis suggests that species composition was more strongly driven by season than site. Whether this was due to seasonal shifts in general species composition of the area or seasonal changes in parasite abundance is a potential area of future research. A longer-term study of seasonal client species composition would help to evaluate if this trend continues in spring and summer and is consistent at other cleaning stations in Bateman Bay.

Elasmobranchs were frequent clients of Point Maud and North Reef in autumn. Most elasmobranch visitors to the cleaning stations were attended to. Manta rays spent the longest time cleaning and received the highest number of cleaners, commonly circling around the cleaning stations. Sharks were the most frequent visitors to Point Maud in autumn but had the shortest cleaning event duration and lowest number of cleaners attend them of any elasmobranch. Stingrays were more frequently observed cleaning at North Reef than Point Maud. The duration of stingray cleaning events fell between sharks and manta rays as did the number of cleaners they received. Most stingray clients cruised past the station, but some did circle. These differences in use of cleaning station by family suggest that manta rays are intentionally visiting these sites to solicit cleaning services while most shark and stingray clients are passing by and happen to be cleaned.

Analysis using RUV data showed that boat presence was most frequent at Point Maud. The RUV data and tour operator logbook data revealed that Point Maud also has more tourist interactions occurring at or near this site than North Reef in autumn and winter. This is most likely due to Point Maud's closer proximity to a boat channel and boat ramp than North Reef. This study did not record enough tourist interactions at cleaning stations to conclusively state whether this impacts the function of the Point Maud and North Reef cleaning stations. However, it was observed that the presence of tourists at cleaning stations appears to affect the movement patterns of cleaning manta rays. The arrival of tourists to the cleaning stations was also associated with manta rays departing the site.

Based on the results of this study, it is evident that manta ray cleaning stations in Bateman Bay provide ecological values and may help sustain the social and economic values of tourism and recreational fishing. As such, it is recommended that options to protect these sites are considered, such as establishing a no-take zone around the currently unprotected North Reef cleaning station. Additionally, it is recommended that enforcement of the code of conduct as a mandatory license condition be considered to help minimize the impacts of tourism on manta ray cleaning behaviours.

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