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Oceanographic Factors on Coastal Aggregation of Reef Manta (*Mobula alfredi*) in The Manta Sandy, Raja Ampat, Indonesia

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Abstract

Reef Manta rays (Mobula alfredi) is an iconic species and under the IUCN Red List of Threatened Species it is classified as vulnerable. Although the decline of population has been reported due to their very high demand and economic value especially for their dried gill plates, they are present all year round at Manta Sandy, Dampier Strait, Raja Ampat, Indonesia. The appearance of M. alfredi may affected by environmental factors. Therefore, this study was aimed to determine the sighted frequency of M. alfredi and their related environmental factors during east and west monsoon. Underwater Visual Census (UVC) and camera trap (PhotoID) method were used to observe the appearance of M. alfredi. The remotely oceanographic data, such as sea surface temperature, chlorophyll-a, sea surface current and tidal data, in the same M. alfredi observation time were obtained from the web of www.oceancolor.gsfc.nasa.gov, www.Hycom.org, Geospatial Information Agency (GIA) and then analyzed using Seadas, Excel, and ArcMap (Geographic Information System). The results showed that during the west monsoon M. alfredi appeared more often (174 sighting) than in the east monsoon (5 sighting). Those appearances were connected with slightly warmer sea surface temperature and high value phytoplankton which is related to zooplankton. For planktivorous elasmobranch, lower sea surface current and high tidal value affect the distribution of zooplankton in those area, so give high feeding opportunity for M. alfredi. High sighted M. alfredi during west monsoon in Manta Sandy attract tourists, therefore regulation for their conservation need to be implemented.

Keywords: *M. alfredi, Photo Identification, SST, Chlorophyll-a, Manta Sandy*

Introduction

Raja Ampat Archipelago, located in West Papua of Indonesia, is a habitat of thousands species of reef fish and hundreds of hard coral reef species (White *et al.,* 2018; 2022) which become 67% part of described species in the world (McKenna *et al.,* 2002; Veron *et al,* 2009). It is also a very special habitat for a large population of manta rays (Mangubhai *et al.,* 2012), including Mobula rays, *Mobula alfredi* and *M. birostris*. As stated by Fox (2013), those archipelago has been designated as sanctuary for shark and ray in Southeast Asia. Couturier *et al.* (2012) and O' Malley *et al*. (2017) stated that due to their very high demand and economic value especially for their dried gill plates, along with increasing as target fishing (Sadili *et al*., 2015), and high retention in by-catch fisheries (Stevens *et al*., 2018a) have resulted in severe population declines of Mobulids, which greatly threaten their survival. Besides, there are also threats to mobulid population, especially which inhabit in the area where manta tourism activities develop (Anderson *et al*., 2010; Graham *et al.,* 2012) such as in Indonesia, the second-largest Mobulid tourism in the world after Maldives (O'Mallaey *et al*., 2013). Globally, Manta Rays have been assigned as vulnerable to extinction on IUCN Red List of Threatened Species (IUCN, 2011; Harris *et al*., 2020) and were in Appendix II list of CITES (CITES, 2013). While in Indonesia, *M. alfredi* and *M. birostris* have been fully protected in 2014 under Ministerial Decree of Marine Affairs and Fisheries No. 4/2014 (Ministry of Marine Affairs and Fisheries, 2014).

The reef manta ray, *M. alfredi* (Krefft, 1868) is one of the ocean's largest and commonly studied species, some of which were conducted in Hawaii (Deakos *et al*., 2011), the south-central Red Sea, Saudi Arabia (Braun *et al*., 2014), southern Mozambique (Carpenter *et al*., 2022), Australia (Couturier *et al*., 2011; 2014; Jaine *et al*., 2012, 2014; Armstrong *et al.,* 2019a), the south-west

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Pacific Ocean and south-east Indian (Amstrong *et al*., 2019), the eastern Pacific (Arauz *et al*., 2019), Maldives (Anderson *et al*., 2010; Harris *et al*., 2020), Philippines (Rambahiniarison *et al.,* 2016), and in Indonesia (McKenna *et al*., 2002; Ichsan and Awaluddin, 2013; Nurcahyo *et al*., 2016; Razak, 2017; Thovyan, 2018; Azizah *et al*., 2019; Setyawan *et al*., 2018; 2020). Setyawan *et al*. (2020) has studied and described the spatial ecology and demographics of *M. alfredi* in The Bird's Head Seascape (BHS) of West Papua, Indonesia, in which the largest population of the species was found in Raja Ampat, *i.e.* 1375 individuals recorded over 15 years and over 85% of appearances were in South East Misool and Dampier Strait MPA. These species are commonly distributed in coastal area (Kashwagi *et al*., 2011) and often visited their coastal aggregation sites (Courturier *et al*., 2012; Jaine *et al*., 2012). They do not only swim near the coast, but has also been observed in offshore coral reefs, rocky reefs, and seamounts areas. They occur along continental shorelines associated with high primary productivity (Deakos *et al*., 2011; Arauz *et al*., 2019), as they are planktonic feeder fishes, especially fed on zooplankton which makes them often seen in a high abundance of plankton sites (Nurcahyo *et al*., 2016).

Understanding the habitat use by vulnerable marine species such as *M. alfredi* is very essential in order to implement its management conservation strategies. It has been known that *M. alfredi* has a very patchy distribution (Harris *et al*., 2020) due to the preferences to specific environment. The small sub-populations are often found for short time in their aggregation sites (Jaine *et al*., 2014). Ichsan *et al*. (2013) suggest that the sighting of *M. alfredi* was affected by environmental factors such as lunar cycle that related to seawater characteristics. *M. alfredi* are plankton-feeders, so they have to be able to detect their very tiny prey in a dynamic and changing ocean (Sims *et al*., 2006) and commonly their movements are forced by the food resources availability (Anderson *et al*., 2011) and species-specific physiologies (Pillans, 2006). In addition, Rohner *et al.* (2013) mentioned that environmental, biological, and temporal variables of coastal aggregation sites determined the sightings of planktivorous elasmobranchs. Anderson *et al*. (2011) found that in Maldives, the migrations of M. alfredi subpopulation were affected by the South Asian Monsoon (SAM).

Manta Sandy, Raja Ampat is one of manta tourism destination known as Manta Site or Manta Mantra. It is located to the south of a large reef that is between Airborek Island and Mansuar Island towards the Dampier Straits west end. This site is very rich in plankton and also serves as a cleaning station (Razak, 2017). The objectives of this study are to reveal the oceanographic parameter related the sighting of *M. alfredi* in Manta Sandy during east and west monsoon. This research was also in line with Carpenter *et al*. (2022)'s suggestion that because the home range of *M. alfredi* population is usually large, it is important to understand the small-scale site within. The information will not be only useful for more understanding on their environment utilization and distribution, but also to develop local management strategies.

Materials and Methods

The study was conducted in Manta Sandy (Figure 1.), located in Regional Marine Protected Area of Dampier Strait which consist of 3 coastal area monitoring and management, including Gam and Mansuar Islands, Batanta Island, and Salawati Island (Conservation International Indonesia Program Raja Ampat, 2020). The observation of *M. alfredi* was carried out during July-August and November as representation of east and west monsoon, respectively. The oceanographic data, *i.e.* sea surface temperature, primary productivity (chlorophyll-a), current and tide data were obtained for the same period.

Underwater Visual Census (UVC) and camera trap method were used in this study to observe the appearance of *M. alfredi* in the Manta Sandy. UVC was conducted through scuba surveys lasted for average 30 min and in the ranged depth of 15-18 m in the early morning (at 08 am) and late afternoon (17 pm) along with placing the camera, which was set up a capture area of 4m^2 during 8 h observation time, at the eastern part of Manta Sandy area. By using camera trap, the unique gill-plate spot patterns in the ventral side of *M. alfredi* were taken as Identification photographs (photo-ID) to identify the individual (Kitchen-Wheeler, 2010). From these images, the individual sex could also be ascertained. The individual perspective determination in present study followed Harris *et al.* (2020), *i.e.* a confirmed photo-ID of an individual *M. alfredi* on a given observation day at Manta Sandy named as a sighting. Beside photo-ID, the individual behavioural activity was also taken, such as feeding, cleaning, cruising, or courtship. The dominated encountered activity was assigned as primary behaviour.

The data of *M. alfredi* sighting in Manta Sandy during the east (July-August 2018) and west (November-December 2018) monsoon were compared and analyzed using the Mann-Whitney test with the SPSS program and related to oceanographic condition of related monsoon. The oceanographic data in the same time with *M. alfredi* observation were taken from several resources. Sea surface temperature and chlorophyll-a parameter were obtained

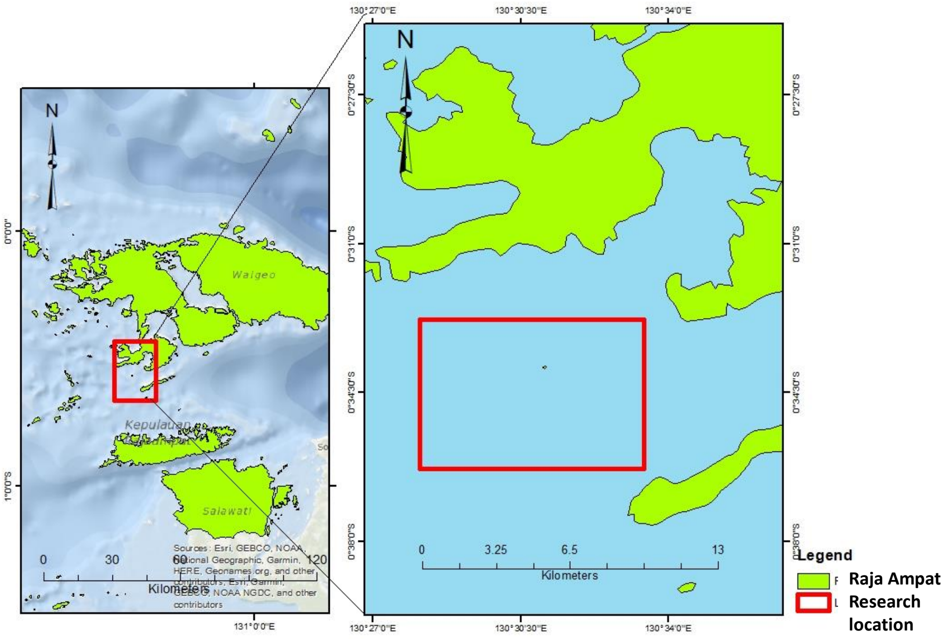

Figure 1. Study site of Manta Sandy, Raja Ampat

from the web of www.oceancolor. gsfc.nasa.gov, www.Hycom.org, Geospatial Information Agency, and then analyzed using Seadas, Excel, and ArcMap (GIS/Geographic Information System). Sea surface temperature and chlorophyll-a data modis level 3, four km were composite monthly to find out the monsoonal value of sea temperature and chlorophyll-a level. Additional data of direction and speed of surface currents and tidal data were taken from the web www.Hycom.org and were analyzed using Excel (Admiralty method) and ArcMap (GIS). Monsoonal current and tidal data were used to determine the distribution of surface currents and the changes during high and low tide. Database map of Raja Ampat Islands, West Papua was used as material for map design and layout.

Results and Discussion

The population of M. alfredi based on Photo Identification

There was a total of 215 sighting of 179 individually identified *M. alfredi* in Manta Sandy during present study, in which only 2.4% occurred during the east monsoon. Within identified *M. alfredi,* there were chevron and melanistic or black morph (Figure 2.). The black or white spots found on the area of the gill slits of the *M. alfredi*'s ventral side were used to identify individuals. Their identification using Photo ID showed black spots pattern on the ventral part of chevron-morph (Figure 1A.) and white spots on the black-morph individuals (Figure 1B.). Based on these differences, it was revealed that there were totals of 70 individuals as member of population in the Manta Sandy during west and east seasons, with a higher rate reappearance of each individual in the west monsoon (174) than in the east monsoon (5 appearance). Observation during 2004-2019 in 127 sites across the Bird's Head Seascape (BHS) in West Papua, Setyawan *et al*. (2020), also found more chevron appearance that black one.

Three female and two male was encountered during east monsoon, while during west monsoon 81.61 % (142) were female, 12.07% (21) were male, and the rest (6.32%), their sex could not be determined. It meant that the ratio of female and male was 6.8:1 compare to 1.58:1 of 2004-2019's observation in larger area in Raja Ampat (Setyawan *et al*., 2020). According Stevens *et al*. (2018a) the female mobulid species have larger disc widths than male, which is an adaptation to carry large pups. While in mature male, the claspers is enlarged, calcified and hardened, make it easier to distinguish from female. Like other elasmobranchs, male reef mantas are recognized to have lower site fidelity than females (Marshall *et al*., 2011; Whitney *et al.,* 2012; Setyawan *et al.,* 2018).

Of 179 individual, all (5 individual) were appeared once during east monsoon, but on west monsoon, they were sighted on the site more frequent, not only once (82.76%), but also twice (14.37%), three (2.3%), and four times (0.57%) a day (Figure 3.). The series observation carried out by Setyawan *et al.* (2018; 2020) in Raja Ampat revealed

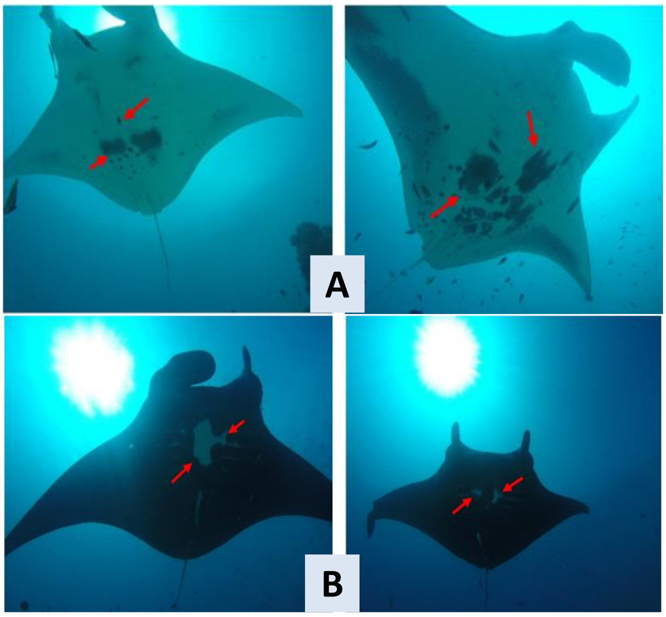

Figure 3. The colour pattern of *M. alfredi* sighted in Manta Sandy, chevron-morph (A) and black (melanistic)-morph (B) with specific black or white spots found on the ventral side

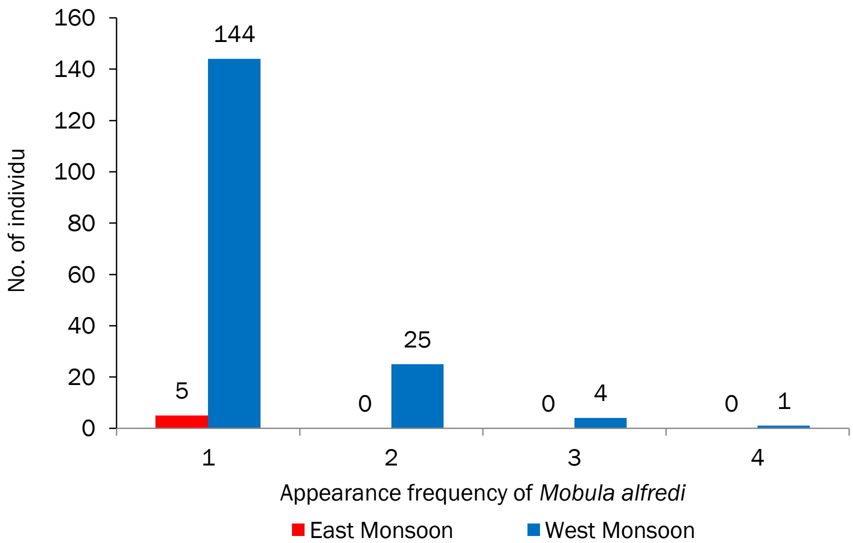

Figure 3. The presence frequency of *Mobula alfredi* during the east and west monsoon in the Manta Sandy Site

that individual *M. alfredi* showed to prefer revisiting the same site. Razak (2017) found a monthly trend of the appearance of *M. alfredi* in the same location during 2010-2016.

Oceanography parameter

The present study revealed that the frequency of *M. alfredi* presence during the west (November-December 2018 was significantly higher (P<0.05) than the east monsoon (July- August 2018). Same result was also encountered in Komodo Island during 2008-2012 (Ichsan *et al*., 2016). The factors that influence the emergence of this species in the site include water temperature (Dewar *et al*., 2008), seasonal water productivity (Luiz *et al*., 2009), and tides (Ichsan *et al*., 2013).

The results of depicted sea surface temperature in the west monsoon was slightly warmer (29.7-30.2°C) than the east monsoon 2018 (29.2-30.2°C) (Figure 4.). This points out that *M.*

alfredi are appeared more often in conditions when the waters around Manta Sandy are warmer although the appearance of *M. alfredi* in Raja Ampat seas could happened at temperatures ranging of 26-30°C (Dewar *et al*., 2008).

Monsoonal conditions affect the surface temperature of Raja Ampat seas. Mangubhai *et al.* (2012) fund that in Raja Ampat, the northwest monsoon was generally happened during November to April with winds emanating from the northwest, producing erratic strong wind and swell. During this period, sea surface temperatures (SSTs) are generally higher. Conversely, during May to October the southeast monsoon was occurred and the continuous strong southeast winds drive upwelling, which brought up the nutrient-rich and cooler water from a greater depth to the near-surface water upper layer, resulting high primary productivity in coastal areas (Susanto *et al*., 2006; Rykaczewski and Checkley, 2008). The optimum temperature range for the growth of phytoplankton in the water is 20-30°C (Lay *et al.*, 2019).

Putra *et al.* (2016) described that the zooplankton biomass and distribution could be predicted and driven by phytoplankton biomass. The distribution of phytoplankton biomass (chlorophyll-a) is highly dependent on sea surface temperature. Graham *et al*. (2012) and Papastamatiou *et al*. (2012) stated that the most important factor for foraging habitats and the spatial distributions of manta rays is the productivity blooms (related to the chlorophyll-a concentration) in inshore, coastal and coral reef ecosystems. The monsoonal climate controls During all year round, the climate of monsoon (east and west) regulate the spatial variation of resource (Radice *et al*., 2019), such as phytoplankton blooms, and influence the distribution seasonal manta ray (Anderson *et al.,* 2011). The results of observations of the distribution of chlorophyll-a in this study found that the value of chlorophyll-a in the west monsoon was much higher (1-2,5 $mg.L^{-1}$) than the East monsoon (0.25-0.75 $mg.L^{-1}$) (Figure 5.) which is similar with the sighting frequency of *M. alfredi* at the Mata Sandy site. Chlorophyll-a composition is affected by environmental condition and their physiological characteristics. It is suspected that in the east monsoon, upwelling tends happen in the area, leads to the stirring and spread process of nutrients. According to Razak (2017) the monthly data for seven years of 2010-2016 shows a significant difference of *M. alfredi* occurrences connected with abundance of plankton (Thovyan, 2018). This is indicating that abundance of plankton organisms is enough to support the survival of *M. alfredi* (Pratama *et al*., 2015). Putra *et al*. (2016) also stated that in the high productivity sites planktivorous megafauna, such as *M. alfredi,* have greater feeding opportunities compared to the areas with lower productivity. The relationship between biomass and abundance of plankton and the appearance of *M. alfredi* individuals also has been proven by Armstrong *et al.* (2019) where there are plentiful planktons during feeding.

Observations using satellite imagery showed the sea current condition of the west monsoon that occurs between November-December and the east monsoon that happens in July-August. The results revealed that the speed of sea current on its maximum during east monsoon, *i.e.* above 3.42 $m.s^{-1}$ and reached 0.15-0.95 $m.s^{-1}$ during west monsoon (Figure 6.).

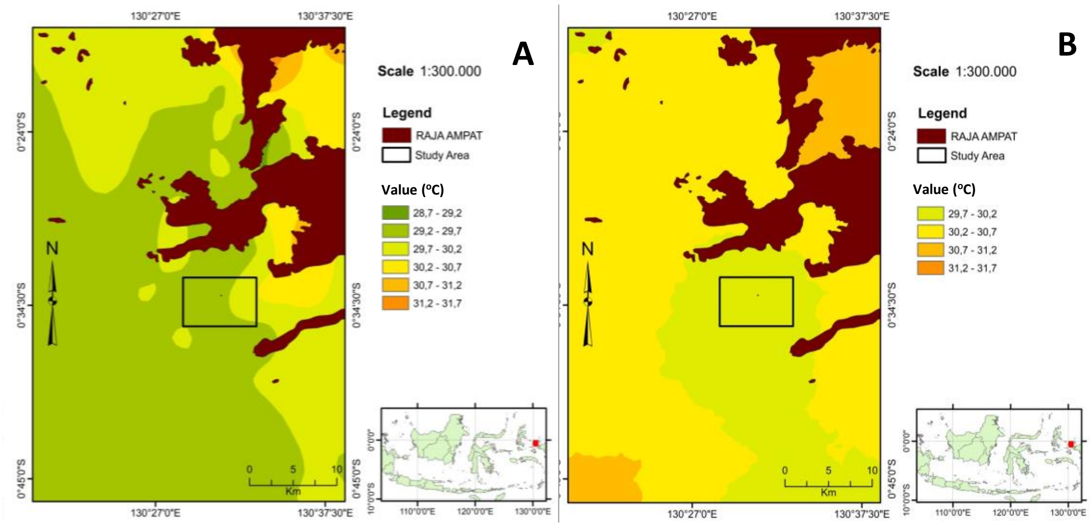

Figure 4. Sea Surface Temperature in The East (A) and West Monsoon (B) 2018 at the Manta Sandy - Raja Ampat Seas

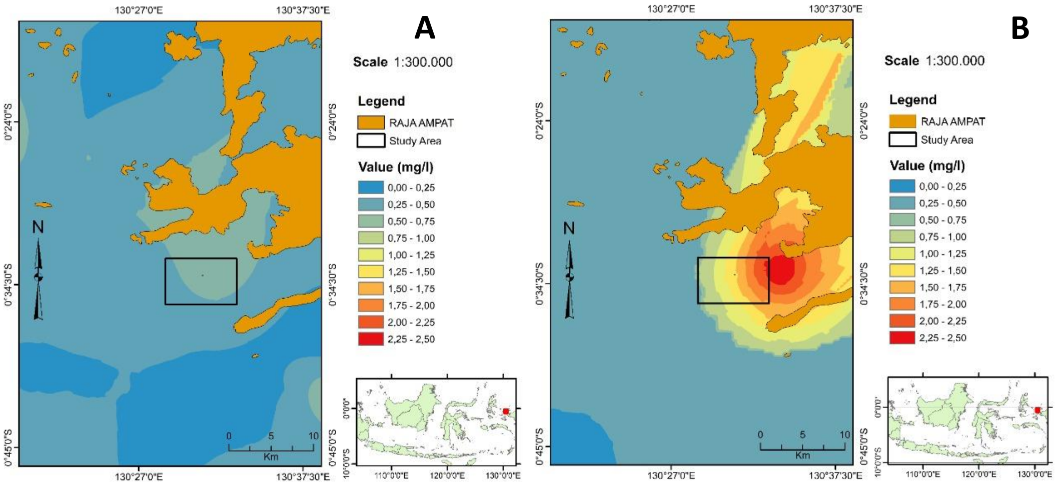

Figure 5. Chlorophyll-a in The East (A) and West Monsoon (B) 2018 at the Manta Sandy - Raja Ampat Seas

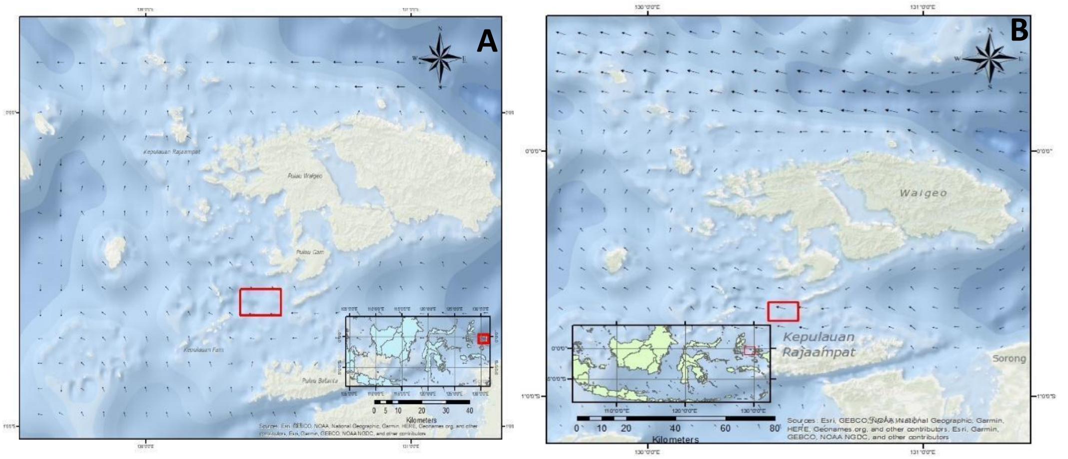

Figure 6. Distribution of the Surface Currents in the East (A) and West Monsoon (B) 2018 at the Manta Sandy-Raja Ampat seas

The high current velocity in the east monsoon resulted in the distribution of nutrients around Manta Sandy being unable to be distributed optimally. Changes in currents will help the mass transfer of water, then support the spread and horizontal migration of plankton, which is a food source for *M. alfredi.* This causes the presence of *M. alfredi* in Raja Ampat seas specifically in Manta Sandy in the east monsoon to be greatly lower compared to the west monsoon. During the warmer west monsoon of 2018, there were no upwelling in the study, therefore the mantas depend on the continuous strong currents in the Dampier Strait to bring about the zooplankton to their feeding location (Setyawan *et al*., 2018). *M. alfredi* is predicted to gather or aggregate in a location related to the presence of food, circulation patterns, temperature, water, mating behaviour, and body cleaning in the *cleaning station* (Dewar *et al*., 2008). Ware and Thomson (2005) state that the seasonal monsoons influence the distribution biomass of phytoplankton and associated with zooplankton and then associated with movement patterns of *M. alfredi*.

This study showed that there was differences in tidal condition between two monsoon observed. The tidal data processing results found that in the east season has got F value of 0.481, while in the west monsoon was 0.525. Both indicates the mixed semidiurnal tidal type. These tides have twice (high and low) tides a day. Tidal condition also influences the mean sea water level (MSL), in which the MSL of east monsoon was 122.5 cm and the west monsoon has 104.9 cm. While the lowest low water level (LLWL), during east and west monsoon show 16.4 and 14.7 cm, respectively. The high sighted of M. alfredi happened on west monsoon at highest high water level (HHWL) of 145.7 cm, and the lowest in east monsoon with 134.4 cm HHWL. Same result of Ichsan *et al*. (2013)'s study of *M. alfredi* in Komodo National Park and Jaine *et al*. (2012)'s Manta Rays study in Lady Elliot Island, in which the highest average appearance of manta is at high tide. In sheltered and shallow water's location, like in Manta Sandy, the tidal current brings about and accumulate the zooplankton in this area (Thums *et al*., 2010). Same condition also happens in Kilindoni Bay off Mafia Island, Tanzania, in which zooplankton accumulation was strongly affected by tidal currant and lead whale sharks to feed regularly (Rohner *et al*., 2015).

Diving and snorkeling with manta rays in their nature environment wild is a highly preferred tourism experience (O'Malley *et al.,* 2013). The high appearance of *M. alfredi* during west monsoon shown by present study in Manta Sandy, which is known as cleaning station for those species (Kasmidi and Gunadharma, 2017), have led to establish strong regulation for diving-tourists (Setyawan *et al*., 2018) for conservation purposes, such as code of conduct for diving tourist in those location need to be strictly obeyed. Because the disturbances come from tourisms visitors have proven to cause reef manta move away, reduce their fitness because of low feeding opportunity (Venables *et al*., 2016; Murray *et al.,* 2019), even have bad impact on their reproduction activity (Stevens, 2016; Stevens *et al*., 2018b). So for keeping high biodiversity of many species, one of which is *M. alfredi*, in Manta Sandy as part of Regional Marine Protected Area of Dampier Strait and the Raja Ampat MPA Network, White *et al.* (2022) has proven that the stake holders such as local community, regional government and non-governmental organization (NGO) have built a good cooperation to facilitate effective MPA in those area.

Conclusions

The dynamics of the *M. alfredi* appearance based on oceanographic observation during this study revealed that the highest *M. alfredi* sighted in Manta Sandy seas occurred in the west monsoon (November-December 2018). This supported by oceanographic condition, such as sea surface temperature, chlorophyll-a, surface currents, and tide level. The west monsoon showed warmer sea water, high primary productivity, low sea current and high highest high water level. The more appearance of *M. alfredi* during west monsoon the more attracted the tourist to come to the manta sandy.

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