Plankton abundance and community structure in reef manta ray (*Mobula alfredi*) feeding habitat in the Dampier Strait, Raja Ampat, West Papua, Indonesia

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Abstract. Reef manta rays (*Mobula alfredi*) are pelagic filter feeders, primarily feeding on zooplankton. Plankton plays an important role in marine food webs and can be used as a bioindicator to evaluate water quality and primary productivity. This study aimed to determine the community structure and abundance of zooplankton and phytoplankton at a *M. alfredi* feeding habitat in the Dampier Strait region of Raja Ampat, West Papua, Indonesia. Plankton samples were collected and environmental conditions were recorded during two sampling sessions, in March and in July 2017, respectively, from five *M. alfredi* feeding sites using a 20 μm plankton tow net. Plankton richness was found to be higher in March (272 ind L^{-1}±342) than in July (31 ind L^{-1}±11), which may be due to seasonal variations in ocean current patterns in the Dampier Strait. Copepods (Phylum Arthropoda) were the dominant zooplankton found in samples in both sampling periods. Microplastics were also present in tows from both sampling periods, presenting a cause for concern regarding the large filter feeding species, including *M. alfredi*.
Key Words: zooplankton, phytoplankton, feeding habitat, environmental conditions.

Introduction. The Raja Ampat Regency of the West Papua Province in Indonesia has one of the highest diversities of marine species in the world, making it a top priority for marine biodiversity conservation and fisheries management (Becking et al 2015; Larsen et al 2018; Mangubhai et al 2012; Runtuboi et al 2018; Tuhumena et al 2019). In order to safeguard this diversity, a network of six regional marine conservation areas, Kawasan Konservasi Perairan Daerah, KKPD (Huffard et al 2012) was created in Raja Ampat in 2007 (Mangubhai et al 2012). KKPD Dampier Strait, located in the central region of Raja Ampat covers an area of 336,200 ha (UPTD KKP Kabupaten Raja Ampat 2009). The waters of the Dampier Strait are nutrient-rich with high levels of productivity and support a diverse range of marine species and an abundance of biota (Boli 2014; Mangubhai et al 2012; Setyawan et al 2018).

Mobula alfredi (reef manta ray) belongs to the Mobulidae family. It can reach disc widths of up to 5.0 m and are commonly sighted in coastal waters and tropical archipelagos, around inshore reefs, lagoons and atolls (Marshall et al 2009; White et al 2018). *M. alfredi* face a range of anthropogenic threats including targeted fishing, by-catch, entanglement and boat strike and are consequently listed as "vulnerable to extinction on the International Union for Conservation of Nature (IUCN) red list of threatened species, as population declines have been reported worldwide (Marshall et al 2018; Rohner et al 2013). In 2014, *M. alfredi* received full protection status in Indonesia, based on the Decree of the Minister of Marine Affairs and Fisheries of the Republic of

Indonesia No. 4/KEPMEN-KP/2014 (Keputusan Menteri Kelautan dan Kelautan Republik Indonesia 2014).

M. alfredi are pelagic filter feeders, primarily feeding on zooplankton. *M. alfredi* feed using ram ventilation by opening their mouths and using their cephalic fins to direct water in, over their gills, allowing zooplankton to be filtered and enter into the digestive system (Couturier et al 2012; Nurcahyo et al 2016). Plankton are microscopic organisms that live in aquatic ecosystems; their movement and distribution within the water column is influenced by ocean currents and water movement (Tomas 1997). Phytoplankton are photosynthetic organisms which are important primary producers, whereas zooplankton are consumers, transferring energy up the marine food web (Odum 1993). Zooplankton includes larvae, crustaceans, small fish, molluscs and cnidarians and is a natural food source to larvae of aquatic organisms as well as some larger fauna, like *M. alfredi* (Couturier et al 2012). The quantification of diversity and structure of plankton communities in marine ecosystems can also be used to give an indication of the condition of the aquatic environment (Odum 1993).

Marine debris is described as persistent solids, produced or processed by humans, directly or indirectly, intentionally or unintentionally, disposed of or abandoned in the marine environment (NOAA Marine Debris Program 2013; Dewi et al 2015). Plastic, the dominant type of marine debris, is a synthetic organic polymer. Microplastics are plastics that have been broken down to particles <5 mm, due to heat, waves, ultraviolet light and bacteria in the ocean (Eriksen et al 2014). Microplastics are a widespread contaminant and are accumulating rapidly in the world's oceans (Gall & Thompson 2015; Worm et al 2017). Due to their extensive global distribution and to the nature of their feeding mechanisms, large marine filter-feeders are susceptible to ingesting microplastics, which have potentially negative impacts on the health of individuals (Germanov et al 2018).

The waters of the Dampier Strait are a critical habitat for reef *M. alfredi*, with a number of identified cleaning stations and feeding habitats (Perryman et al 2018; Perryman et al 2019; Setyawan et al 2018). Over 700 individuals have been photographically identified in this region to date (Tapilatu et al 2018). *M. alfredi* show a strong seasonality in their abundance in the Dampier Strait, with peak sightings occurring between November and May. At other aggregation sites, the spatial distribution and abundance of zooplankton have been identified as major drivers of *M. alfredi* occurrence (Armstrong et al 2016; Jaine et al 2012; Peel et al 2019). This study aims to compare the abundance and community structure of zooplankton at five different feeding sites in the Dampier Strait inside and outside of the *M. alfredi* sighting season peak.

Material and Method

Study site. Data were collected during March and July 2017 from five different sampling locations in the Dampier Strait, Raja Ampat of West Papua, Indonesia (Figure 1). These sites were selected based upon regular observations of *M. alfredi* feeding behavior.

Plankton sampling and environmental variables. Plankton sampling was conducted using the methods described in Sari et al (2014). Sampling was conducted between 07:00 and 12:00 AM, Eastern Indonesia Time (WIT). For each sampling month (i.e. March and July), three tows were conducted at each site on three consecutive days using a 20 μm plankton net with a 24 cm radius; 10 m net tows were deployed just below the surface of the water to simulate *M. alfredi* surface feeding behavior. Tows were conducted from the same starting point at each site. Samples were preserved by using Lugol and by being stored on ice. Plankton counts were obtained from three sub-samples of 1 mL from each tow. Sub-samples were placed in a Sedgewick-Rafter cell and they were observed under an Olympus CX31 microscope at 400x magnification. Environmental conditions were recorded at the time of sampling. Sea surface temperature was measured using a dive computer (Oceanic Geo 2) submerged from the vessel for 5 mins at each site, current velocity by measuring the time taken for a floating object to move 5 m on the surface of the water and light intensity was measured with a portable luxmeter (Hanna HI97500).

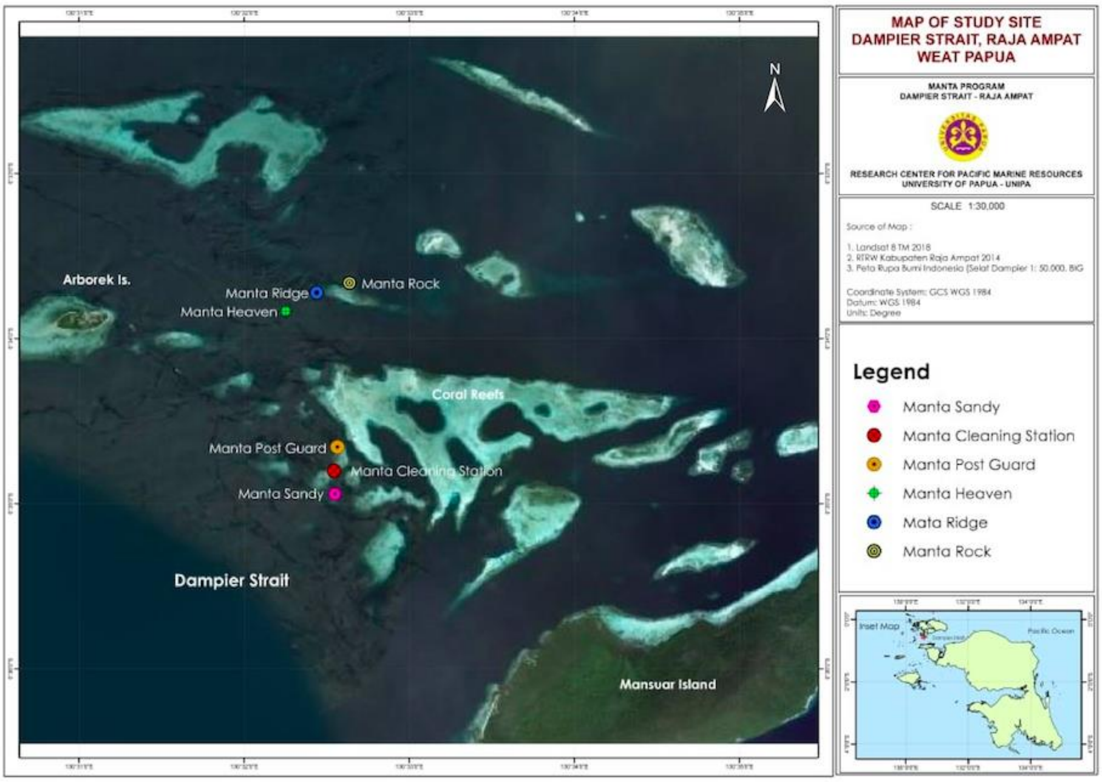


Figure 1. Map of study site and sampling locations in the Dampier Strait, Raja Ampat. Red dot on inset indicates the location of Dampier Strait in the Bird's Head Seascape, West Papua.

Plankton identification. Plankton was identified to genus where possible, by comparing key morphological characteristics to the following reference texts: Tomas (1997), Hutabarat & Evans (1986), and Yamaji (1979). Where identification to genus was not possible, individuals were identified to class, sub-class or order. In some samples there were substances or particles that could not be identified as plankton, many of which were subsequently confirmed to be microplastics. The structure of the plankton community can be described through general composition and three calculated indices: diversity index, uniformity index and dominance index. The following formulas were used to calculate measures of diversity, uniformity, and dominance.

Plankton abundance. Plankton abundance was calculated according to the following formula (Nugraha et al 2016):

$$N = n \, x \, \frac{A}{B} \, x \, \frac{C}{D} \, x \, \frac{1}{E}$$

Where:
A-number of grid squares on Sedgewick Rafter cell (1,000);
B-number of grid squares observed (300);
C-volume of filtered water sample (mL);
D-volume of observed sample (mL);
E-volume of filtered water (L);
N-plankton abundance (individual for zooplankton or cell for phytoplankton L^{-1});
n-the number of trained observers.
To determine the volume of water sampled the following formula was used (Fachrul 2007):

$$V = (\pi \, x \, r^2 \, x \, t)$$

Where:
V-volume of filtered water (m^3);

r-plankton net radius=0.24 m;
t-drawing distance=10 m.

Diversity index. The diversity index was calculated using the Shannon Index of Diversity formula (Agung 2016):

$$H' = -\Sigma^{S}_{i=1} Pi \ln Pi$$

Where:
H'-the index of diversity (Pi=ni/N);
Pi-number of genus-i divided by total number of individuals;
Ni-number of genus-I;
N-total number of individuals;
S-number of plankton genera.

According to Susanti (2010), the criteria H' to categorize the level of diversity can be interpreted as follows:
H' ≥ 3.0 = very high diversity
H' 1.6-2.99 = high diversity
H' 1.0-1.59 = moderate diversity
H' <1.0 = low diversity

Evenness index. The evenness index value was calculated to determine the distribution of individuals at the community level (Odum 1993) at each location and for each season. As described by Fachrul (2007), the Evenness index indicates whether the biota was distributed evenly or not; if the index value is relatively high then each type of biota exists in a uniform condition in the water.

$$E = \frac{H'}{H'\,max}$$

Where:
E-evenness index;
H'-index of genus diversity;
H'max-value of maximum species richness, Ln(S).

The Evenness Index (E) can be interpreted as follows:
E = 0.00-0.50, equity among genera is low, indicating a difference in the individual abundance of each genus.
E = 0.51-1.00, distribution among genera is relatively uniform (i.e. the number of individuals of each genus is relatively similar).

Dominance index. The dominance index value is used to indicate the degree to which certain genera numerically dominate a given sample. To examine the degree of dominance in the samples, the Dominant genus Index by Fachrul (2007) was used:

$$D = \sum_{i=1}^{S} \left(\frac{ni}{N}\right)^2$$

Where:
D-dominance index;
Ni-number of individual types of i;
N-total number of individuals.

Odum (1993) provided the following interpretation of dominance values from the formula: if the value of C is close to 0 (<0.5), then no genus is dominant, and if the value of C approaches 1 (≥0.5), then there is a dominant genus.

A Shapiro-Wilk test was conducted using SPSS Version 16 to determine whether the abundance, diversity, evenness and dominance data were normally distributed. Unless otherwise stated, reported values are mean ± standard deviation (SD).

Results

Plankton abundance and community structure. The abundance of both zooplankton and phytoplankton was higher at all study sites in March than July (Figure 2, Figure 3). The mean abundance of zooplankton across all sites was significantly higher in March (21±11.3 ind L^{-1}) compared to July (2±1.4 ind L^{-1}): Mann-Whitney U test=0.002, $p<0.011$). Similarly, the mean abundance of phytoplankton across all sites was significantly higher in March (251±333 ind L^{-1}) than in July (29±10.9 ind L^{-1}): Mann-Whitney U test = 0.001, $p<0.008$). Zooplankton diversity was also higher in March with 22 genera (from 10 classes) of zooplankton identified, compared to 14 genera (from 7 classes) in July (Table 2). Similarly, phytoplankton diversity was higher with 42 genera (from 4 classes) identified in March, compared to 30 genera (from 3 classes) identified in July (Table 2).

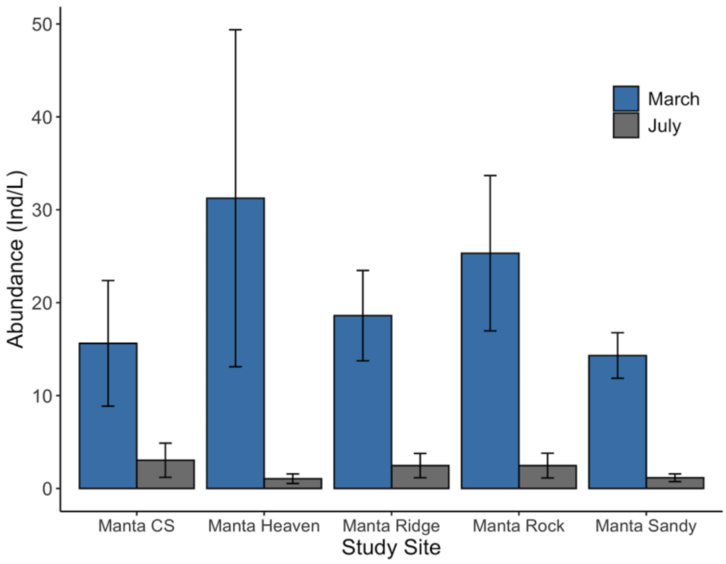


Figure 2. Mean abundance of zooplankton at the five study sites in March and July. Error bars represent standard deviation.

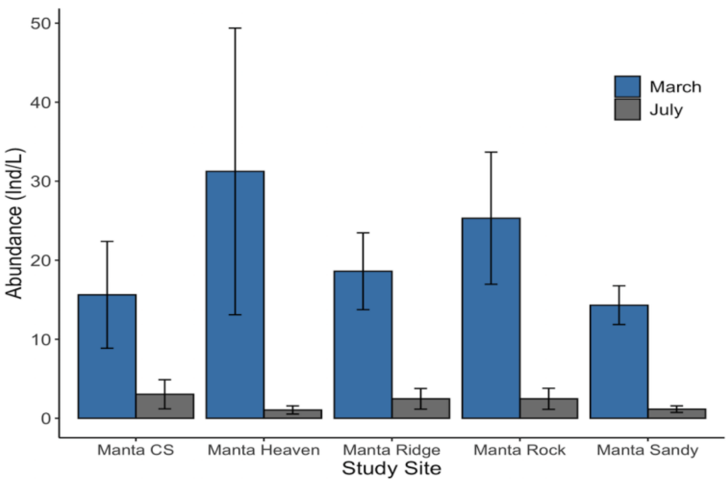


Figure 3. Mean abundance of phytoplankton at the five study sites in March and July. Error bars represent standard deviation.

Mean plankton abundance was the highest in March, at Manta Heaven (zooplankton: 31±18.1 ind L^{-1}, phytoplankton: 649±584.8 ind L^{-1}), and the lowest in July, at Manta Sandy (zooplankton: 1±0.4 ind L^{-1}, phytoplankton: 18±7.2 ind L^{-1}), as shown in Figure 2.

Table 1
Community structure of zooplankton and phytoplankton combined over all study sites in March and July 2017

Phylum	Class	Subclass	Order	Genera	March	July
			Zooplankton			
Annelida	Polychaeta				x	
					x	
Arthropoda	Malacostraca	Copepoda	Decapoda	Thenus	x	x
					x	x
					x	
Chaetognatha	Sagittoidea			Sagitta	x	x
Chordata	Osteichthyes (Fish egg)				x	x
	Appendicularia			Oikopleura	x	x
Ciliophora	Oligotrichea			Dictyocysta		x
				Epiplocylis	x	
				Eutintinnus	x	x
				Favella	x	x
				Helicostomella	x	
				Parafavella	x	x
				Parundella	x	
				Protorhabdonella	x	
				Rhabdonella	x	x
				Tintinnopsis	x	
				Undella	x	
				Xystonella	x	x
				Podochytrium	x	
				Lionulus		x
Cnidaria	Hydrozoa				x	x
Foraminifera	Globothalamea			Globigerina	x	
				Hastigerina	x	
Radiolaria	Acantharia			Acanthometron	x	x
Rotifera	Eurotatoria			Synchaeta	x	
			Phytoplankton			
Cyanobacteria	Cyanophyceae			Trichodesmium	x	x
Myzozoa	Bacillariophyceae			Amphora	x	
				Amphorellopsis	x	
				Asterionella	x	x
				Asteromphalus	x	
				Bacilaria	x	
				Bacteriastum	x	x
				Chaetoceros	x	x
				Climacosphenia	x	x
				Corethron	x	
				Coscinodiscus	x	x
				Cyclotella	x	x
				Diatoma	x	x
				Diploneis	x	
				Ditylum	x	x
				Donkinia	x	
				Eucampia	x	
				Fragilaria	x	
				Fragilariopsis		x
				Guinardia	x	x
				Hemiaulus	x	x
				Lauderia	x	x
				Leptocylindrus	x	x
				Licmophora	x	
				Meuniera	x	x
				Navicula	x	x
				Nitzschia	x	x

Zooplankton						
Phylum	*Class*	*Subclass*	*Order*	*Genera*	*March*	*July*
				Odontella	x	x
				Phaeodactylum	x	
				Planktoniella	x	x
				Pleurosigma	x	x
				Pseudo-nitzschia	x	x
				Rhabdonema	x	
				Rhizosolenia	x	x
				Thalassionema	x	x
				Thalassiosira	x	x
Myzozoa	Dinophyceae			Ceratium	x	x
				Gonyodoma	x	x
				Ornithocercus	x	x
				Peridinium	x	x
				Podolampas	x	x
				Pyrocystis	x	x
Ochrophyta	Chrysophyceae			Dictyocha	x	

Diversity index. In March, the mean zooplankton diversity index was 1.67 (±0.60), compared to a mean zooplankton diversity of 0.63 (±0.42) in July (Table 2). Phytoplankton diversity showed minimal variation between sites and was high in both March and July. The mean phytoplankton diversity index was 2.84 (±0.34) in March and 2.32 (±0.26) in July (Table 2).

Table 2
Plankton diversity indices (H'; mean±SD) at each site during March and July 2017

Study site	*Zooplankton*		*Phytoplankton*	
	March	*July*	*March*	*July*
Manta ridge	1.77±0.17	0.86±0.45	2.95±0.15	2.52±0.20
Manta rock	2.17±0.19	0.80±0.33	3.10±0.11	2.52±0.12
Manta heaven	2.03±0.37	0.37±0.55	2.86±0.38	2.23±0.22
Manta sandy	1.38±0.68	0.43±0.32	2.62±0.38	2.16±0.19
Manta cleaning station	1.02±0.55	0.68±0.19	2.66±0.38	2.18±0.28
Overall	1.67±0.60	0.63±0.42	2.84±0.34	2.32±0.26

The mean zooplankton evenness index was 0.70 (±0.17) in March and 0.66 (±0.38) in July, while for phytoplankton the mean evenness index was 0.81 (±0.06) in March and 0.87 (±0.05) in July (Table 3).

Table 3
Plankton evenness indices (mean±SD) at each site during March and July 2017

Site	*Zooplankton*		*Phytoplankton*	
	March	*July*	*March*	*July*
Manta ridge	0.80±0.12	0.85±0.17	0.84±0.02	0.85±0.05
Manta rock	0.77±0.13	0.74±0.29	0.81±0.02	0.88±0.04
Manta heaven	0.79±0.08	0.33±0.50	0.74±0.10	0.87±0.05
Manta sandy	0.61±0.19	0.61±0.46	0.84±0.02	0.88±0.05
Manta cleaning station	0.51±0.12	0.76±0.18	0.83±0.02	0.85±0.06
Overall	0.70±0.17	0.66±0.38	0.81±0.06	0.87±0.05

The mean dominance index for zooplankton in March was 0.34 (±0.21), while the mean zooplankton dominance index in July was 0.62 (±0.23). For phytoplankton, the mean dominance index was 0.09 (±0.03) in March and 0.13 (±0.04) in July (Table 4).

Table 4

Plankton dominance indices (mean±SD) at each station during March and July 2017

Station	*Zooplankton*		*Phytoplankton*	
	March	*July*	*March*	*July*
Manta ridge	0.25±0.08	0.50±0.20	0.07±0.01	0.11±0.03
Manta rock	0.19±0.08	0.54±0.18	0.06±0.01	0.10±0.02
Manta heaven	0.20±0.09	0.78±0.34	0.10±0.05	0.14±0.04
Manta sandy	0.46±0.25	0.71±0.22	0.10±0.03	0.15±0.03
Manta cleaning station	0.58±0.19	0.59±0.10	0.09±0.03	0.15±0.06
Overall	0.34±0.21	0.62±0.23	0.09±0.03	0.13±0.04

Water quality parameters. Water temperatures recorded at the study sites ranged from 29 to 32^{o}C in March and from 28 to 30.5^{o}C in July (mean values shown in Table 5).

Table 5

Water temperature (^{o}C, mean±SD) at study sites

Sampling period	*Manta ridge*	*Manta rock*	*Manta heaven*	*Manta sandy*	*Manta cleaning station*
March	29.8±0.8	30.0±1.0	31.2±1.0	31.0±0.9	30.8±0.8
July	29.0±0.5	28.5±0.8	30.2±0.3	28.3±0.6	28.8±0.3

Current velocity in March ranged from 0.103 to 0.204 m sec^{-1} (mean values shown in Table 6). While the current velocity in July ranged from 0.105-0.209 m sec^{-1}. Surface current velocity in both months is in the range of 0.1-0.25 m sec^{-1}. We found no significant difference in current velocity between March and July (Mann Whitney U test=0.3, p>0.05).

Table 6

Current velocity (m s^{-1}, mean±SD) at study sites

Sampling Period	*Manta ridge*	*Manta rock*	*Manta heaven*	*Manta sandy*	*Manta cleaning station*
March	0.163±0.008	0.129±0.024	0.207±0.009	0.130±0.011	0.115±0.008
July	0.167±0.017	0.135±0.004	0.183±0.014	0.125±0.004	0.118±0.012

The intensity of light found in March ranged from 72.0 to 93.6 lux. While the light intensity recorded in July ranged from 68.8 to 89.5 lux (mean values shown in Table 7).

Table 7

Intensity of light (lux, mean±SD) at study sites

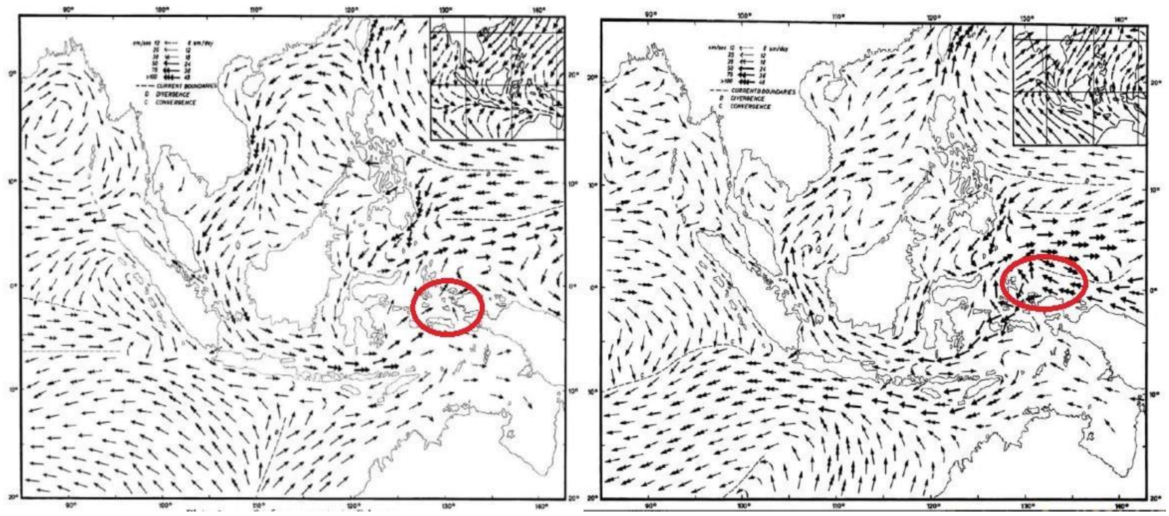
Sampling period	*Manta ridge*	*Manta rock*	*Manta heaven*	*Manta sandy*	*Manta cleaning station*
March	86.5±0.6	81.2±8.0	85.78±11.9	88.6±4.6	85.9±8.5
July	78.8±4.7	80.7±5.5	83.2±10.1	76.2±11.3	81.9±5.6

In addition, microplastics were present in plankton tows in both March and July.

Discussion. The increased abundance of plankton at Manta Heaven in March may be due to the high current velocity at this site. Nontji (2002) suggested that current flow assists the movement of plankton from one place to another and supplies nutrients to phytoplankton and prey to zooplankton.

A higher number of phytoplankton genera was found in both March and July (Table 1), and copepods were the most abundant zooplankton taxon with high numbers of copepods found at all study sites. Similarly, calanoid and cyclopoid copepods were the dominant taxonomic groups reported at a *M. alfredi* feeding site in Eastern Australia, where similar daytime feeding behavior is often observed in inshore waters (Armstrong et al 2016; Jaine et al 2012). Further investigation using stable isotope signatures and fatty acid analysis concluded that *M. alfredi* feed on both epipelagic and demersal zooplankton in this region (Couturier et al 2013).

A significant difference in plankton abundance was found in March and July. This difference may be caused by temporal variations in current patterns during these months. In March, the prevailing currents originate from Southern Papua and the islands of Maluku and carry a mass of nutrient-rich water which is utilized by plankton to reproduce, resulting in dense blooms and high productivity (Prihatiningsih 2014), while in July, the currents flow into the Dampier Strait from the Pacific Ocean and Northern Papua (Figure 4). This is consistent with Sartina (2017) who state that nutrients are generally more abundant in areas near the islands than in the open ocean.



(a) (b)

Figure 4. Circulation patterns of currents in Indonesian waters (red circle shows location of Raja Ampat) (a) March (b) July (Wyrtki 1961).

The higher abundance of plankton in March could likely be due to the intense upwelling of cold water that occurs during the southeast monsoon, when strong winds blow from the south (Mangubhai et al 2012). The higher abundance in March is likely to be related to the higher frequency of reef *M. alfredi* sightings during these months. BPSPL (2014) found that *M. alfredi* prefer waters which are abundant in plankton. *M. alfredi* usually feed in the flowing waters by opening their mouth and swimming into the current, which is a more energy efficient feeding technique compared to continuously swimming to filter plankton.

Nutrient availability in the water column is related to the reproductive rate of phytoplankton. Lancelot & Muylaert (2011) suggested that the phytoplankton abundance and growth rate peaks are determined by the availability of nitrogen (N) and phosphorus (P) or silica (Si). Waters near to islands or estuaries are generally rich in these nutrients due to run-off from the mainland and to the process of remineralization.

Zooplankton diversity was higher in March than in July, at all sites. In March, the mean zooplankton diversity index, of 1.67 (±0.60), was higher compared to a mean zooplankton diversity of 0.63 in July (Table 2). In accordance with Susanti (2010), a H' value between 1.6 and 2.9 indicates high diversity and a H value of <1 indicates low diversity. The higher mean diversity index of zooplankton in March, compared with July, could be caused by warmer water temperatures in March. Hasanah et al (2014) stated that warmer water temperatures have higher index values of diversity than waters with lower temperatures. This may be a result of phytoplankton requiring sunlight for photosynthesis and zooplankton requiring warm temperatures to grow.

The evenness values both zooplankton and phytoplankton in March and July were >0.5, indicating the distribution of zooplankton and phytoplankton taxa is relatively uniform (Adinugroho & Subiyanto 2014). Copepods were the dominant zooplankton taxon observed in samples collected in both sampling periods. In July, copepods were the only zooplankton taxon found at all study sites, whereas in March more than one species of zooplankton were present at each study site. Copepods are typically the most common type of herbivorous zooplankton found in marine waters (Nybakken 1992). The absence of a dominant type of phytoplankton suggests that the waters are not polluted, allowing a diverse range of phytoplankton species to live in these waters (Odum 1993).

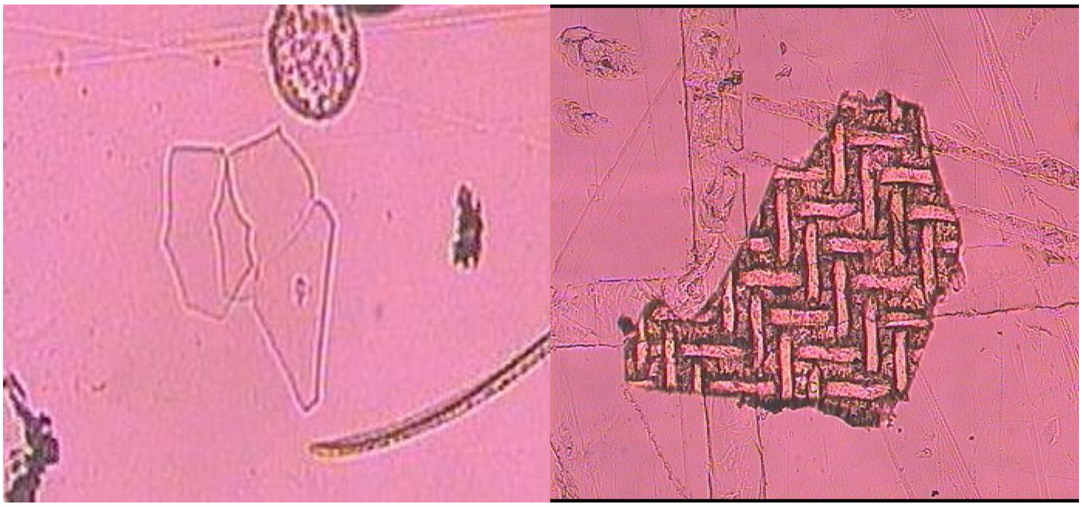
The mean dominance index for zooplankton in March was 0.34 (±0.21; Table 4), indicating no particular taxon dominated the sample. In July, the mean zooplankton dominance index was 0.62 (±0.23), indicating that one group dominated zooplankton communities in July (Table 4). For phytoplankton, the mean dominance index was 0.09 (±0.03) in March and 0.13 (±0.04) in July (Table 4), which indicates that there was no dominant genus in either sampling period.

Water temperature is an important physical factor affecting plankton growth. Its recorded values were in the range of 28 to 32^{o}C, which are optimal, according to Handayani (2009). Water temperatures were higher in March than in July, at all sites. This finding was in line with a well-known phenomenon across Indonesia: sea surface temperatures (SSTs) are lower during the southeastern monsoon (Wyrtki 1961; Mangubhai et al 2012). The mean SSTs recorded in the study area ranged between 19.3 and 36.0^{o}C, matching the results reported by Mangubhai et al (2012). According to Ulath (2012), high temperatures in March may be caused by weak winds blowing in that month. Weak winds can cause the transfer of heat from water bodies into the air to be reduced, so the water temperature becomes warmer. Moreover, coastal upwelling in the northern coastal water of Papua occurs in response to the westerly winds during December to March, which may affect the sea temperature and phytoplankton blooming (Waas et al 2012).

Currents are one of the parameters that can affect plankton abundance and distribution in the marine environment, by transporting plankton both horizontally and vertically throughout the water column. Surface current velocity in both months was in the range of 0.1-0.25 m sec^{-1}, which means the waters were slow-moving, due to tidal conditions during the sampling time (Alldredge & Hamner 1980). The currents in Raja Ampat are relatively strong, but plankton is adapted to their velocity (Sartina 2017). There was no significant difference in current velocity between March and July, probably due to the tidal sea water influence. As observed by Boli (2014), the waters of the Dampier Strait have a current velocity of less than 1m s^{-1} and is dominated by tidal influences.

The intensity of light affects the process of photosynthesis in waters, stimulating plankton abundance as well as aquatic productivity. Tasak et al (2015) reported that the abundance of phytoplankton such as Dinoflagellata ranged from 9 to 1.105 cells L^{-1} for a light intensity range of 50-3,000 lux, being higher from 10:00 to 12:00 and from 14:00 to 16:00.

Microplastics were found at four sites (excluding Manta Cleaning Station), in every tow, in March and at all sampling sites in July (Figure 5). The conclusions we can draw regarding the abundance of microplastics in the Dampier Strait are limited as sampling was only conducted during two months of the year at five study sites. However, there is rising concern regarding the ingestion of microplastics by marine filter feeders including *M. alfredi* (Germanov et al 2018). Germanov et al (2019) suggested that microplastics ingested by *M. alfredi* while feeding at sites in Nusa Penida and Komodo National Park may remain inside the digestive tract and associated toxins may be absorbed into muscle tissues.



a. March b. July

Figure 5. Examples of microplastics found in plankton samples in a. March and b. July (Size 0.003-0.005 mm).

Conclusions. Mean plankton abundance and diversity were significantly higher at all sites in March compared to July, which corresponds with higher sightings of *M. alfredi* during this month. Copepods were the dominant zooplankton taxa during both sampling periods. Evidence of microplastic pollution was found at four sites during both sampling periods. Due to the potential for detrimental effects of plastic ingestion on the health of marine filter feeders, we suggest strategies to improve waste management systems to be considered in the Raja Ampat region. More in-depth research is required regarding plankton abundance and distribution, and nutrients in the Dampier Strait to further investigate the relationship between plankton availability and *M. alfredi* sightings. We suggest a wider temporal and spatial range of sampling to be included in future studies.

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