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Abundance and composition of potential food items of whale shark (*Rhincodon typus* Smith, 1828) in Probolinggo waters, East Java Province

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ABSTRACT

Whale sharks (*Rhincodon typus*) appears seasonally in Probolinggo waters from January to May, where its main aggregation situated in Bentar Beach, Madura Strait. The question needs to be resolved is which factors affecting whale shark's arrival. Therefore, the research was aimed to compare the potential food items by comparing the conditions with and without whale shark represented by March and August 2017. Planktons were collected by bongo-net with 60 cm mouth opening and 350 µm mesh-size, tied to 30 m nylon rope and pulled by the boat at 2-3 knot speed for 10 min for each. Sample was preserved with 4% formaldehyde, and in laboratory, 1 mL sample was placed into Sedgwick-Rafter Counting Chamber and identified by light microscope. Abundance is calculated by taking into account the volume of filtered water, volume of screened water, and individual number of each taxon. Correlation between food items and whale shark appearance was tested by Spearman rank correlation. The results confirm that copepoda, crustacea, and fish larvae were the principal diets for whale shark. A direct effect of chlorophyll a on zooplankton hence whale shark arrival was unconfirmed.

Key words: *Whale shark, Zooplankton, Potential food items.*

Introduction

Whale shark (*Rhincodon typus*) is widely distributed in the tropic and sub-tropic seas, migrating and cruising in a very large distance (Rowat and Gore, 2007; Eckert and Stewart, 2001). Its appearance in the Indonesian seas is both seasonal (Kamal *et al*., 2016) and residential (WWF, 2014). In Probolinggo water of Madura Strait, East Java whale shark is visible seasonally during January to May (Kamal *et al*., 2016)though sometimes its period might be earlier or late both at the beginning and at the end. The arrival of this huge elasmobranch to particular coastal area is highly linked to plankton abundance coupled with environmental cues like currents and temperature (Jonahson and Harding (2007), where they feed on zooplankton and other small organisms, such as krill, corals seed, and fish eggs (Heyman *et al*., 2001), of which chlorophyll a triggers the initial plankton production in the ocean (McKinney *et al*. (2012).

Copepods are the main diet for whale shark.

Nelson and Eckert (2007) reported that up to 85% of whale shark food in Bahia Bay of Los Angeles was copepods, whereas Hancohen-Domene *et al*. (2006) had earlier identified that 3 of 12 copepods genera i.e. *Acartia*, *Udinula*, and *Corycaeus* were among dominantgenera of this small crustaceans in the Gulf of California, Mexico. Hermandez-Nava and Alvarez-Borrego (2013) delineated that the abundance of *Acartia* spp. might be the limiting factor to the presence of whale shark in El Rincon, Mexico. In the beginning of this century, several studies (Heyman *et al*., 2001; Graham, 2003) has confirmed that the movement pattern and feeding habits of whale shark has been correlated with spawning aggregation of the snapper, *Lutjanus cyanopterus* and *L. jocu*, where the shark heavily feed on fish eggs. Information on potential whale shark's food in Indonesian waters is very limited, so that the present study was aimed to explore the potential food availability in relation whale shark appearance.

Materials and Methods

Study site

The study area was situated in Bentar Beach of Probolinggo Regency. This site is considered as the highest aggregation site for whale shark during its seasonal period. The beach has been design for beach tourisms area and whale shark sight seeing. Plankton sampling was conducted at stations consisting of 5 and 6 locations representing March and August 2017, respectively (Fig. 1).

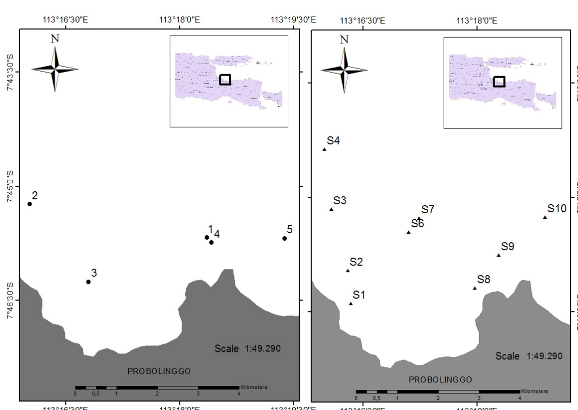

Fig. 1. Sampling sites for plankton and small organisms in Bentar Beach of Probolinggo Regency in March at 1, 2, 3, 4, 5 (left) and August 2017 at S1, S2, S3, S9, S10 (right)

Sample collection and identification

In investigating the potential food items, sampling campaign has been compared the abundance and composition of zooplankton and small organisms between the peak season (March) and the absence (August) of whale shark. Sample collection was made by bongo-net with 60 cm mouth opening and 350μm mesh size. The net was tied to the rear end of the boat and towed obliquely at 2 Knots velocity for 10 minutes each. On board, the filtered water was transferred into 500 mL container, and added by 4% formaldehyde (Brodeur *et al*., 2011; Sassa and Hirota, 2013). In laboratory, 1 mL filtered water was dropped into Sedgwick Rafter Counting (SRC) and viewed by light microscope (Olympus CH-2 at 10x magnification) from which zooplankton and others were identified down to genus level (Yamaji, 1979), and fish larvae until family (Leis and Carson-Ewart, (2000).

Data analysis

Prior to abundance estimation, the total volume of filtered water (V) by bongo-net is determined as:

V= L x t x v,

Where V is determined by Larea of the net mouth (cm), t towing duration (min.), and v boat velocity (m/min). The abundance (N) of zooplankton and other small organisms in individual/m^{3}is determined by:

$$N = n_i \times (V_r/V_o) \times (1/V_s) \times (A_r/A_o)$$

Where $n_i$is number of i_{th} individual, V_r is volume of screened water (mL), V_o is volume of water in the SRC (mL), V_s is volume of filtered water (m^3), A_o is area of field view (cm^2), and $A_r$is total area of field view (cm^2). Correlation between potential food items and whale shark appearance was tested by Spearman rank correlation (r_s) (Fowler and Cohen, 1997) as follow:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} di^2}{n^3 - n} \qquad t_h = r_s \frac{\sqrt{n-2}}{1-rs^2}$$

Where di is the different on each rank, n is number of observations between others. If $t_h \leq$´ tα, H_0 accepted (no correlation), and if $t_h \geq$ tα, H_1 accepted (correlated). The value of correlation ranges between -1 to 1, where 0=no, +1=positive, and -1=negative correlation between dependent and independent variable. Chlorophyll a concentration in the area was confirmed for two sampling period (Anggraini *et al*., 2018).

Results and Discussion

Whale shark's potential food items and abundance

All identified zooplankton and small organisms'genera were lumped into order or class but fish larvae into family. Of 14 groups organism, the copepods were in highest abundance with 1,261 and 822 ind.m^{-3} for March and August, respectively. In first sampling, the mollusks were considerably abundant dominated by veliger larvae, followed by insects and protozoans ranged between 400 – 600 ind.m^{-3}. In the second, in the following of highest copepods were decapods, echinoderms, and mysid shrimp (Fig. 1).

With respect to copepods group, a large proportion of these small crustaceans were actually composed by copepoda, calanoida, crustacean, cyclopoida, and nauplidae. Accordingly, the results are in favor to earlier statement that copepods are the main diet for whale shark (Heyman *et al*., 2001; Hacohen-Domene *et al*., 2006; Hermandez-Nava and Alvarez-Borrego, 2013). Taxonomically, the closest relative to copepods is decapods, i.e. the order of crustaceans within the class Malacostraca. It was found as the early stage of lobsters, crabs, and shrimps. Therefore, it may be concluded that crustaceans are additional important food for whale shark. It is likely since the appearance of whale shark in the study area customarily coincides with the abundance of small shrimps or krill, locally called "udang rebon" (*Acetes japonica*). Regarding fish larvae, 13 collected families were dominated by Lutjanidae and Engraulidae (March) and Engraulidae and Gerreidae (August), of which its abundance was more than three folds in March (Fig. 1). In other area, fish larvae and eggs are also one of principal food items for whale shark (Heyman *et al*., 2001; Graham, 2003).

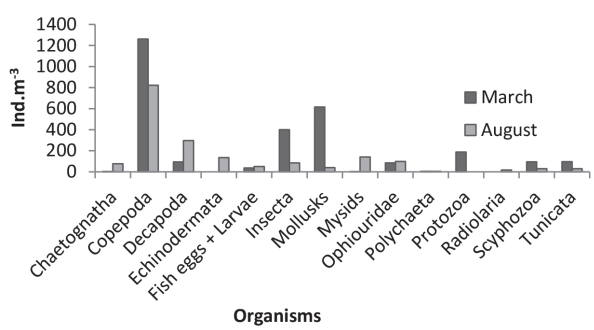

Fig. 2. Potential food items for whale shark comparing between March and August 2017 sampling

By comparing the total abundance, the results showed that sample in March was one-third higher compared to August, particularly the copepods itself was obtained 1.5 times more abundant in the first sampling campaign. It would be highly likely that copepods would be enormously plentiful in the absence of whale shark in its peak season. However, the efficacy of whale shark in reducing this particular food item remains unclear. It is presumed depending on food availability, size and mouth opening, number and behavior of whale shark. In Bentar Beach, whale sharks breach the surface and move horizontally at feeding.

Based on size data (Kamal *et al*., 2017, unpublished), whale shark length varied between 1.0 – 6.0 m. This size range falls into juvenile stage. Therefore, Probolinggo waters play an important role as nursery ground for this elasmobranch, and the protection of this habitat is mandatory.

Correlation between potential diets and whale shark appearance

A Spearman rank correlation test revealed that whale shark appearance was positively correlated with copepods and fish larvae. In prey-predator relationship, copepods and fish larvae are potential food for whale shark and copepods are fish larvae's main diet. By family basis, the occurrence of whale shark was correlated with larvae of engraulids, gobiids, and lutjanids (100%, 95.3% and 97.5%). This is in accord with others (Colman, 1997; Graham, 2003) that Engraulidae and Lutjanidae was the main food of whale shark. It does not necessarily that whale shark respects larval family for its diet but only on planktonic fish larvae.

The influence of chlorophyll a

McKinney *et al*. (2012) stated that the main trigger for plankton production is chlorophyll a, which eventually will attract the whale shark because of high abundance of plankton. In our study, it was shown that chlorophyll a concentration in March ranged between 0.6 – 1.2 mg/m^3, whereas in August was slightly higher with 1.4 – 2.4 mg/m^3. A higher concentration (>5 mg/m^3) was found both in March and August, at the closest site to land (Fig. 3). A higher concentration of chlorophyll a is influenced by land-based activities supplying higher nutrient content to sea environment (Sihombing *et al*., 2012).

The present study was not the case as McKinney

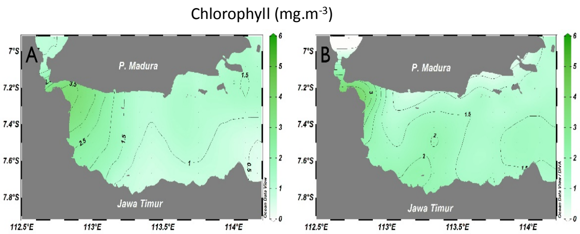

Fig. 3. Chlorophyll a concentration in Madura Strait comparing between March (left) and August (right) 2018.

et al. (2012). Though the chlorophyll concentration indicates to eutrophic conditions in both months, it has uncorrelated with whale shark appearance. Rather, our study was in accord with Sleeman *et al*. (2010) who obtained an anomaly that chlorophyll a has little to do with the appearance of whale shark. It might safe to conclude that chlorophyll a boosts on primary productivity supporting plankton growth and food web, and a direct effect on whale shark appearance need further study.

Conclusion

The potential food items for whale shark in Probolinggo waters are mainly copepods, and to some extent small crustaceans/krills, and fish larvae. It is necessary to protect its habitat in Probolinggo waters as whale shark uses this area as nursery ground. No correlation between chlorophyll and whale shark arrival, however aquatic primary productivity is important for the growth of plankton and other early life animals.

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