



Study on occurrence frequency and time, and food habit of whale shark (*Rhincodon typus*) in the National Park of Cenderawasih Bay, Papua

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Abstract. This study was aimed to inform about the presence frequency, occurrence time, and food habit of whale shark *Rhincodon typus* in east season and transitional season in the National Park of Cenderawasih Bay. It was done in June to November 2019. Data were collected from field observations, logbook of the lift net fishermen, and interviews. Based on seasons, the higher occurrence of the whale shark was recorded in the transitional season (September-November), 6.42 ± 3.23 ind, and in the east season decreased to 4.34 ± 2.66 ind. In east season, high occurrence was found in the morning (06.00-10.00), 83.08%, then declined in the day (11.00-13.00) to 1.54%. Similarly, in the transitional season, high occurrence occurred in the morning (06.00-10.00), 89.53%, and then declined in the night (19.00-05.00) to 2.33%. Regression analysis showed that the anchovy catches had only 62.39% contribution to the whale shark occurrence. As a whole, zooplankton in each observational site consisted of Crustacea (48.8%), Oligotrichea (31.7%), Polycystina (3.3%), Bivalvia (0.8%), Appendicularia (4.9%), Polychaeta (0.8%) and Gastropoda (9.8), respectively.

Key Words: lift net, anchovy, catch, zooplankton, abundance.

Introduction. Whale shark *Rhincodon typus* Smith, 1828 is the largest shark species in the world and usually does long distance journeys (Hearn et al 2016; Robinson et al 2017). It is a planktivorous fish and it is seasonally present in the oceanic zone and coastal waters worldwide, either tropical or subtropical, in relation with food availability (Rohner et al 2015, 2016). The whale sharks even show their loyalty to be in the gathering localities for several years or inter-annual periods ((Araujo et al 2017) and they are mostly dominated by young males (Araujo et al 2017; McKinney et al 2017). Some aggregations dominated by the adults have been identified in Galapagos Group of Islands (Acuña-Marrero et al 2014), St. Helena Is. (Clingham et al 2016), the offshore of Qatar (Robinson et al 2017), and Brazil (Macena & Hazin 2016). Several evidences indicate that adult whale sharks spend most of their time in the open sea (Ramírez-Macías et al 2017).

Cenderawasih Bay National Park is located between West Papua Province and Papua Province. It has been issued as one of the gathering localities for whale sharks. This species is very specific in Papua, especially in Indo-Pacific area (Stewards 2012). In the last several years, the whale sharks always occur every year without season, because there is an abundance of plankton and small fish in the waters, particularly atherinids and 4-6 cm clupeids caught in the lift net (Stewards 2012). The occurrence of whale sharks in this area makes it be a tourism destination, which has an impact to marine tourism industrial development in the area. The estimation of total economic valuation value of whale shark tourism area in Cenderawasih Bay National Park is 35.5 trillion yr⁻¹ or US\$2.6 billion (Anna & Saputra 2017).

As a result of being threatened and yearly decline of the whale shark population, the International Conservation Agencies, such as International Union for Conservation of

Nature (IUCN) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), have put the species into their conservation lists in 1997 and 2002, respectively (Fowler 2000; Norman 2000). Besides, several countries such as Honduras, Thailand, Australia, Mexico, Belize, the United States, South Africa, and the Philippines have implemented protection efforts, including the ecotourism regulations of whale sharks in several regions (Chen et al 1997; Norman 2002). In Indonesia, the Ministry of Marine Affairs and Fisheries (MMAF) through the fisheries regulation numbered 18/Kepmen-KP/2013 has issued the policy to totally protect the whale shark in several localities of the entire Indonesia waters (MMAF 2013) with Cenderawasih Bay as National Park that is one of the specific locations of whale shark occurrence in Papua waters. Local Papuan call this animal as "Gorango Bintang". Whale shark is one of very prominent species as tourism icon (Stewart 2012).

Meanwhile, monitoring and research on whale shark in this area have given information on sex and size composition revealing that this area functions as suitable habitat for young whale shark population (Himawan et al 2015). This study aims to describe the occurrence frequency, the appearance time, and the feeding habit of the whale shark in Cenderawasih Bay National Park.

Material and Method

Study site. This study was carried out in the National Park of Cenderawasih Bay located between West Papua Province and Papua Province, at the geographic position of $134^{\circ}52'15.23''$ - $135^{\circ}4'4.5''$ E and $3^{\circ}12'15.39''$ - $3^{\circ}22'11.18''$ S (Figure 1). It was done from June to October 2019.

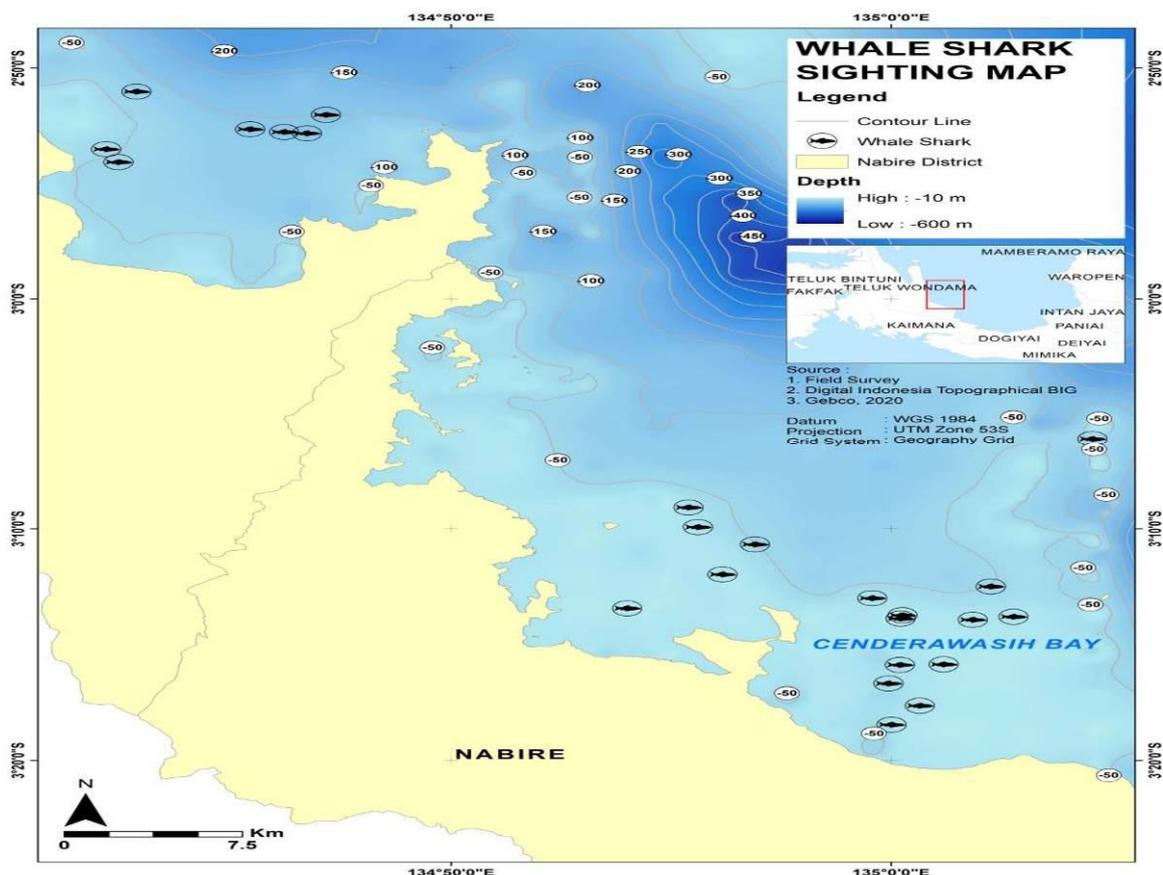


Figure 1. Study site and position of whale shark occurrence.

Data collections: whale shark occurrence, anchovy catch, and zooplankton composition. The whale shark occurrence was directly recorded from field observations in the fishermen's rafts. Other data collection was done from the logbook notes provided

by the local lift net fishermen. The data covered the number of the whale sharks, occurrence time, and geographic position of the occurrence. The positions where the whale shark appears on the surface were recorded in the logbook using Global Positioning System (GPS).

The anchovy catch data were obtained from the local fishermen's catch, and the data were tabulated on monthly basis. Direct interviews were also done to the lift net fishermen. The catch per fish box was estimated as well, and according to the fishermen, one fish box contained about 30 kg of anchovies.

Zooplankton sampling used a plankton net with an opening diameter of 25 cm, net length of 60 cm, and net mesh size of 50 μm . It was done at the place where the whale shark appeared. Samples were then preserved in lugol solution and brought to the laboratory. The samples were left for 24 h to measure the deposit volume, then diluted 10 times. One-mL of sample was taken and observed under a trinocular microscope in duplo at 400 enlargements. Identification of the zooplankton taxa followed Nontji (2008) and Johnson & Allen (2013).

Data analysis. The occurrence frequency and the appearance time data of the whale shark of all lift net rafts were tabulated and assessed on seasonal basis, and the anchovy catches were presented in histogram based on seasons. Both occurrence and appearance frequencies were presented in descriptive statistics, based on mean value and standard deviation. Besides, the catch data of the anchovy were also recorded to describe the catch distribution in time or seasonal unit.

Correlation analysis was done as well to describe the relationship between the occurrence frequency and the zooplankton abundance. The spatial distribution of the whale shark was assessed using the geographic information system approach, whereas zooplankton abundance estimation utilized Sedgewick-rafter (Rice et al 2012) at ind L^{-1} , then converted into ind m^{-3} following the formula:

$$N = \frac{T}{L} \times \frac{P}{p} \times \frac{V}{v} \times \frac{1}{w}$$

where: N = number of plankton per liter;

T = area of Sedgewick rafter;

L = view area;

P = number of plankton caught;

p = number of view areas observed;

V = water volume filtered (50 mL);

v = volume of plankton sample on the cover glass (mL);

w = volume of plankton sample filtered (50 L).

Results

Mean whale shark occurrence based on season. Mean occurrence of whale shark was the highest in the transitional season (September-November), 6.42 ± 3.23 whereas in east season (June-August), it was only 4.34 ± 2.66 (Figure 2).

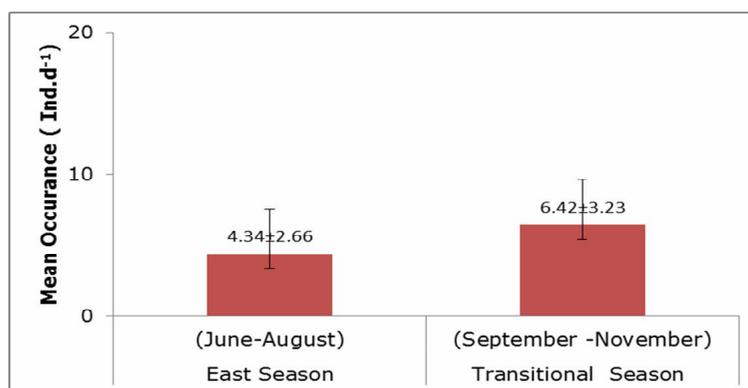


Figure 2. Whale shark occurrence with season.

Occurrence time of whale shark based on season. The whale shark occurrence time is generally in the morning (Figure 3a and 3b). In east season, the whale shark occurrence was recorded in the morning between 06:00 and 10:00 am of eastern Indonesian time, 83.08%, declined in the day (11.00-14.00), 1.54%, then rose again in the night to dawn (19:00-05.00), 15.38%. In transitional season, high occurrence was also recorded in the morning (06:00-10.00), 89.53%, declined in the day (11:00-14.00), 4.65%, afternoon (15:00-18:00), 3.49%, and night (19.00-05.00), 2.33%.

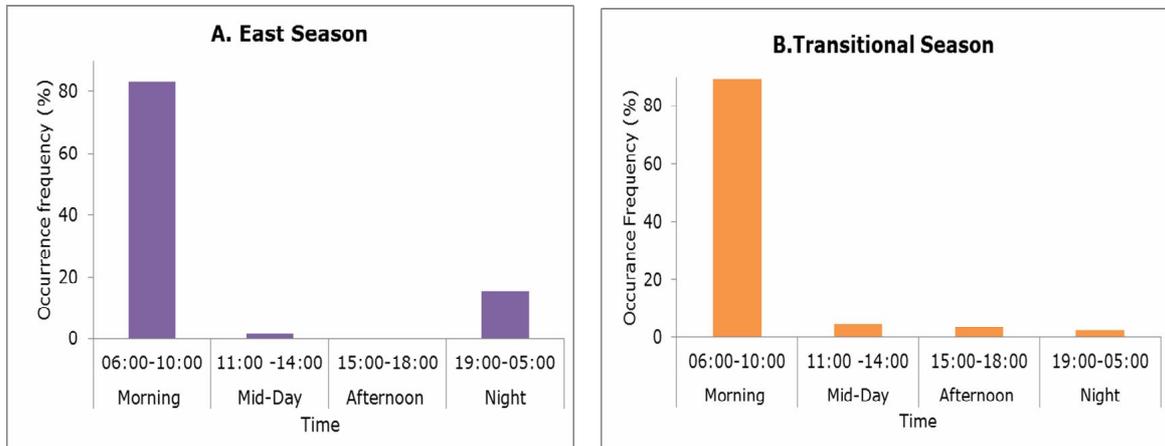


Figure 3. Whale shark occurrence time.

Season-based whale shark food habit

Relationship between whale shark occurrence and anchovy catch. The present study found that whale shark occurrence did not have strong relationship with number of anchovy catch, in which the anchovy catch did not influence the whale shark occurrence. The highest whale shark occurrence occurred in October, 121 times, and the lift net catch of anchovy was 492 kg (Figure 4).

Regression analysis shows that the whale shark and the anchovy occurrences relationship follows the equation of $Y = 0.1764 - 1.003X$. The determination coefficient (R^2) of 0.6239 indicates that 62.39% of anchovy catch could explain the occurrence frequency of the whale shark in the study site (Figure 5).

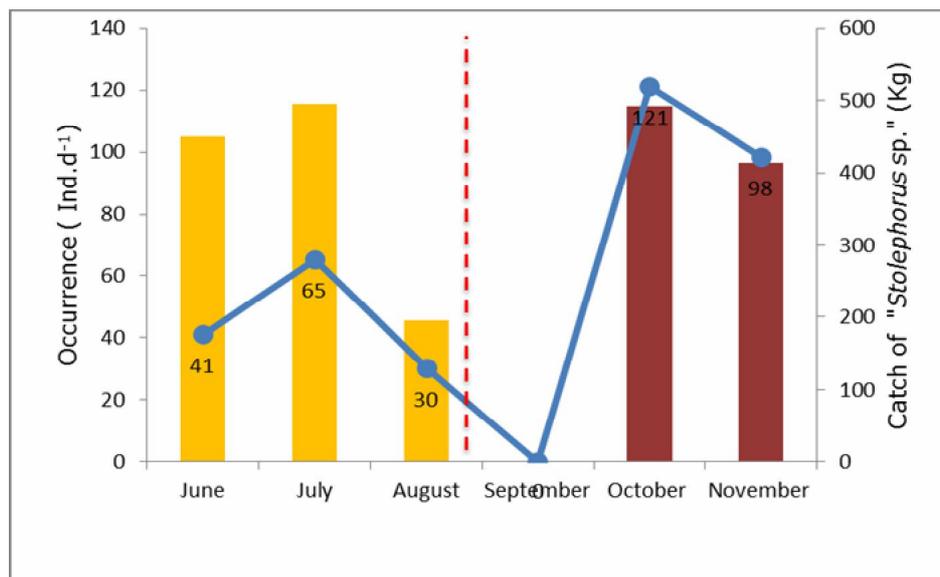


Figure 4. Relationship between whale shark occurrence and lift net-caught anchovy.

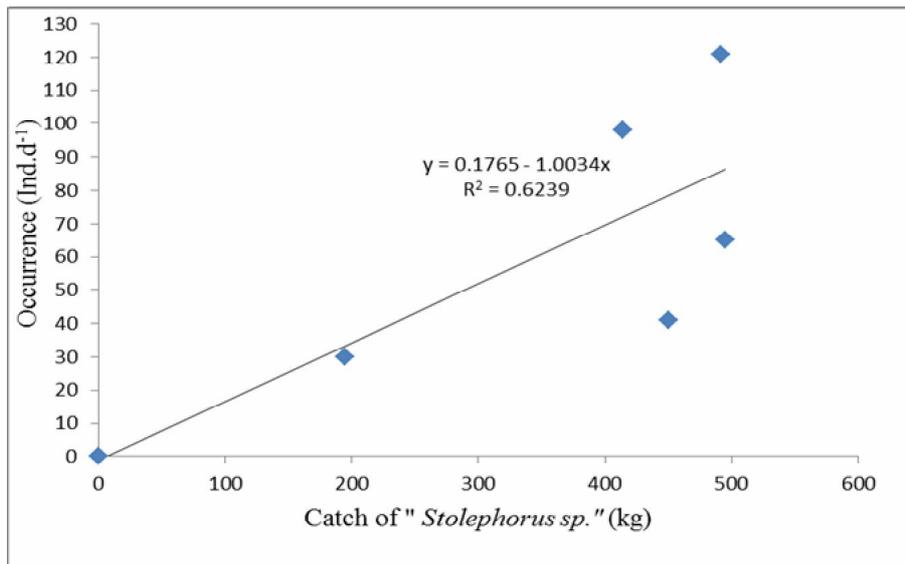


Figure 5. Relationship of whale shark occurrence and lift net-caught anchovy.

Zooplankton composition and abundance. As a whole, this study found that October has higher zooplankton abundance than July, at least during the study period. The highest individual abundance was recorded in October, 161,189 ind m⁻³, 65.8%, and the lowest was in July, 4,416 ind m⁻³, 2.7%, in station 1 (Figure 6).

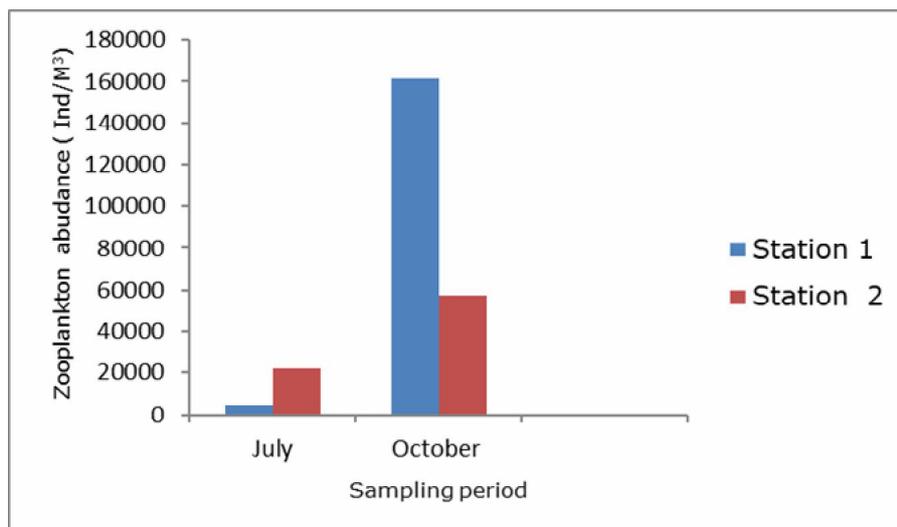


Figure 6. Zooplankton abundance during the sampling period.

Figure 7 demonstrates that zooplankton was composed of crustacean (48.8%), Oligotrichea (31.7%), Polycystina (3.3%), Bivalvia (0.8%), Appendicularia (4.9%), Polychaeta (0.8%) and Gastropoda (9.8), respectively.

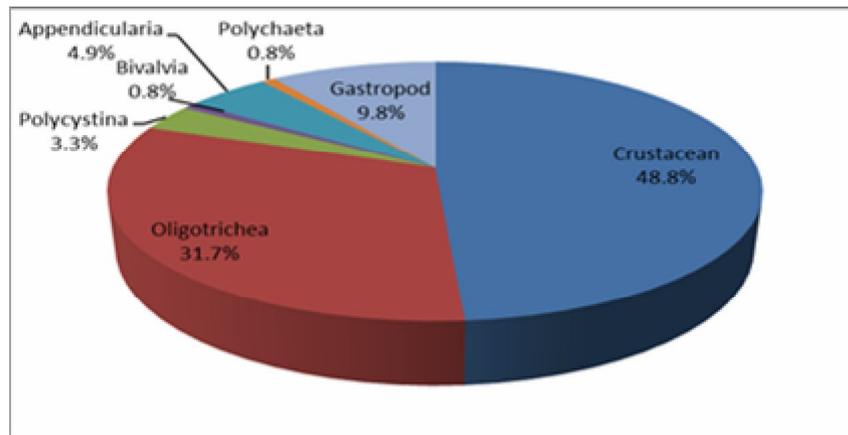


Figure 7. Zooplankton composition during the sampling period.

Discussion. The National Park of Cenderawasih Bay is a Marine Protected Area in Cenderawasih Bay waters and it is part of The Bird's Head Seascape in Eastern Indonesia (Manghubai et al 2012). This region is one of gathering localities of the whale sharks along the year without season (Stewart 2012). Present findings indicate that higher whale shark occurrence occurs in the transitional season (September-November) than that in east season (June-August) (Figure 2). It could result from that the transitional season is the period leading to the dry season, in which seawater surface temperature is very high, and the chlorophyll-*a* is highly available. High phytoplankton (chlorophyll-*a*) abundance will attract high abundance of zooplankton and small-sized herbivorous fishes that are food source of the whale shark, particularly anchovy (Rohner et al 2017).

Whale sharks mostly spend time in the open ocean, and only visit the coastal area for short periods of time (Hearn et al 2016). In the National Park of Cenderawasih Bay, whale sharks appear more in the morning than in the night in both seasons (Figure 3). This finding supports the previous report of Motta et al (2010). This occurrence is related with zooplankton migration. According to Hays et al (2016), in the night to morning, zooplankton always migrates to the water surface, while in the daytime, it moves down to deeper layers. High zooplankton abundance in the surface layer has promoted the food chain process in this area, in which zooplankton is preyed by the anchovy, then the fish is fed by bigger fish, including the whale shark as filter feeder. Therefore, besides plankton occurrence, the whale shark appearance time could be related with the anchovy catch in lift net fisheries that also attract the whale shark's attention (Himawan et al 2015).

Moreover, major catch of the lift net fishermen in Cenderawasih Bay was small pelagic fishes, such as anchovy *Stolephorus* sp. This fish species is an important food source for large pelagic fish including the whale shark. Variations in anchovy catches could result from lighting factor or food availability in the water column. The catches of the lift net are highly dependent upon the light moon (full moon) and the dark moon (new moon period). In the full moon, the moon light will uniformly disperses in the whole sea surface, and the lift net cannot gain good catch. In contrast, in the dark moon period when the moon light does not appear, the lift net light is the only lighting source. In this time, high number of fishes gather around the light, and as a result, the lift net could obtain high catch of anchovies and other small fish. The high number of anchovies in the net attracts the whale shark to come near the surface (Himawan et al 2015). According to Rumolo et al (2018), feeding behavior of the anchovy is related with the presence of zooplankton community.

Linear regression analysis on the anchovy catch against whale shark occurrence frequency found the determination coefficient (R^2) of 0.6239. It means that anchovy catch gives 62.39% contribution to the whale shark presence in the study site. This condition indicates that besides the anchovy catch, there are other factors contributing to the whale shark occurrence. However, food availability could be a crucial factor for their presence. For instance, in Tomini Bay waters, the Province of Gorontalo, Indonesia, food availability has attracted the whale shark to come (*pers. com.*, Sahami, 2019).

The highest zooplankton abundance occurred in the transitional season (October). It could result from that October occurs at the end of the transitional season and enters the dry season, in which the rainfall is very low and highly influences the zooplankton composition and abundance in the area (Marliana et al 2018). Zooplankton is mostly composed of crustaceans dominated by copepod. This finding is in agreement with Marliana et al (2018) concerning copepod occurrence in the National Park of Cenderawasih Bay. Hacohe-Domené et al (2015), based on their study in southern California Bay, also found that copepod is a major food component of the whale shark.

Conclusions. The present study in the National Park of Cenderawasih Bay found that whale sharks appeared more frequently in the morning than in the night. Their occurrence was also higher in the transitional season (September-November) than that in east season (June-August). This condition could be related with the small fish abundance, such as anchovy *Stolephorus* sp., as food source as a result of higher plankton production in the transitional season. In spite of that, anchovy catch could explain only 62.39% of the whale shark presence. This study also confirms that food availability is crucial to support the marine life, and thus, good marine environmental conditions should be maintained.

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