PROGRESS REPORT II

IMPACTS, ALTERNATIVE SOLUTIONS AND AWARENESS OF MOBULA FISHERIES IN INDONESIA

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1. Background

Indonesia is home to the fifth most productive fishery in the World; with a total marine capture production of 5.4 million tones recorded in 2010 (FAO, 2013). The recent modernization of fishing techniques in the country has led to the overfishing of many elasmobranch species in the Java Sea (Blaber et al., 2009). In particular, great concern is raised concerning the vulnerability of mobulid rays to overfishing in Indonesia, due to the increasing demand for mobulid gill rakers in the Chinese medicine market. The recent creation of a large manta sanctuary in Indonesian waters could shift demand to mobula species, which similarly to the genus manta, possess low fecundity, slow growth, and late maturation (Couturier et al., 2012; Cuevas-Zimbron et al., 2013; Dulvy et al., 2014). The two most abundant mobula species in Guangzhou markets were also the two most commonly caught species in Indonesia, representing ~ 50% (*M. japanica*) and 24% (*M. tarapacana*) of the total mobula by-catch (White et al. 2006; Ward-Paige et al., 2013). Specifically, work towards habitat conservation, mitigating obstacles to the migration, and controlling fisheries of mobulas is necessary, and requires basic biological and ecological information for mobula species and from the extent of their range. For example, determining the overlap of fisheries with mobula feeding grounds will constitute essential information to understand which proportion of the population is under a particular threat and how, when and where management is needed. Mobulas are often confused with mantas and disregarded for alternative activities to fishing (i.e. ecotourism) due to their epipelagic behaviour, although predictable aggregations in some places of the World (e.g. in the Azores) are proving otherwise.

2. Objectives

- Use fishing market surveys and citizen science to conduct a preliminary assessment on mobula ray density and species-specific abundance in main fishing and diving grounds.
- Determine species-specific foraging habits of mobulas landed in Indonesia.
- Develop an educational program to raise the awareness of stakeholders about the importance of conserving mobulas for long-term sustainability and identify alternative solutions to reduce mobula target and by-catch.

3. Materials and Methods

3.1. Study area

The study took place in key mobula landing areas in Indonesia: Tanjung Luar, Lombok (West Nusa Tenggara), Lamakera (East Nusa Tenggara), and Muncar (East Java) (**fig. 1**). Tanjung Luar is located on the Eastern coast of Lombok, and has been the object of previous elasmobranch landing surveys especially focusing on shark catch in the pelagic longline fishery. Lamakera is home to a traditional mobulid hunting fleet that uses mainly harpoons (Dewar, 2002). Muncar is home to a large traditional purse seine fleet that targets *Lemuru*, although gillnets are also present.

Fig. 1: Study locations are represented by green circle markers: East Java regency (Muncar), in West Nusa Tenggara regency (Tanjung Luar), and East Nusa Tenggara regency (Lamakera). Scale bar equals 200 km.

3.2. Study species

Our study was focused on the genus *Mobula*, of which five species are currently reported in Indonesian waters: the Spinetail devilray (*Mobula japanica*), the Bentfin devilray (*Mobula thurstoni*), the Chilean devilray (*Mobula tarapacana*), the Shortfin devilray (*Mobula kuhlii*), and the Pygmy devilray (*Mobula eregoodootenkee*) (IUCN Red List).

Mobula japanica (Müller & Henle, 1841), the Spinetail devilray: listed as 'Near Threatened' by the IUCN Red List for Threatened Species (IUCN Shark Specialist Group), and 'Vulnerable' in South- East Asia, with unknown population trends (White et al., 2006). This mobula is probably circumglobal but its biogeography needs to be examined. Of particular concern is its resemblance to *Mobula mobular* (Compagno & last, 1999). *Mobula japanica* is a common by-catch of the inshore tuna gillnet fishery in Indonesia (White et al., 2006).

Mobula thurstoni (Lloyd, 1908), the Bentfin devilray: listed as 'Near Threatened', with unknown population trends (Clark et al., 2006). *Mobula thurstoni* is circumglobal in all temperate and tropical seas, and is usually present in pelagic shallow and neritic waters, which makes it a common take in the inshore gillnet fishery of Indonesia (Clark et al., 2006).

Mobula tarapacana (Philippi, 1893), the Chilean devilray**:** listed as 'Data Deficient' by the IUCN red list for threatened species, with an unknown population trend, and represents one of the least known mobulid species (Clark et al., 2006). Although this species represents one of the least known mobulas, its ecology appears drastically different from congenerics (Thorrold et al., 2014), resulting in contrasting biological adaptations (Alexander, 1995).

Two other species that are known to occur in Indonesia but which were not encountered during our surveys are listed hereafter:

Mobula kuhlii (Müller & Henle, 1841), the Shortfin devilray: listed as 'Data Deficient' by the IUCN red list for threatened species, although its population trend is decreasing (Bizzarro et al., 2009). It occurs in coastal waters of the Indian Ocean and western Central Pacific, although its range is not well defined (White et al., 2006). It is taken in surface gillnet, purse seine, longline and directed harpoon fisheries in Indonesia, and represents only 2% of all rays caught (Bizzarro et al., 2009).

Mobula eregoodootenkee (Bleeker, 1859), the Pygmy devilray: is listed as 'Near Threatened', with unknown population trends (Pierce & Bennett, 2003). It is native to the Indo-west Pacific and northern Indian Ocean, and is likely taken as by-catch in fisheries within its range although it is rarely encountered at landing sites. Crucial biological and ecological data is lacking for this species.

3.3. Data collection

3.3.1. Fishing market surveys

Information on mobula species-specific landings was collected through fishing market surveys, in Tanjung Luar, Lamakera, and Muncar from August to November 2015. Markets were visited during peak attendance hours, before and during the shark and ray auction in Tanjung Luar which starts at ~ 8AM, during the morning in Muncar (peak landing activity), and at variable times in Lamakera (although usually from 4AM to 6AM), depending on when the boats return from the fishing trip (can vary depending on weather condition, etc.). Mobula species were identified using ID-guides of the Manta Trust and KKP to record species-specific abundance. When possible were also recorded disc width (mm), disc length (mm), total length (mm), weight (kg), sex, maturity stage (for females: only confirmed when pregnant individuals were observed, for males: juvenile or adult based on clasper length). We also recorded the time and location of disembarqument, the type of fishing gear used, and whether the mobulas contituted by-catch or whether they were directly targeted. In the latter case other target or bycatch species landed were recorded, when possible.

3.3.2. Stomach contents

A total of twelve stomachs were collected from August to November 2015 (one from *Mobula tarapacana*, four *Mobula thurstoni* and seven *Mobula japanica*), out of which seven contained material in the stomach. The remaining mobula rays only had material in the digestive track, which rendered difficult the visual identification of digested prey items. In a few instances, the stomachs were full upon arrival but were sold at the fishing market for human consumption, limiting the number of samples that could be collected. Stomachs were extracted from the mobula and placed directly into a plastic zip lock bag, which was weighed, whole and placed on ice for a maximum of 3 hours. The stomachs were later thawed and the contents poured into a plastic container. The empty stomach was weighed again to record stomach content weight. The contents were stirred with a spatula to homogenize and a 50 mL subsample was fixed in 8% paraformaldehyde in 0.1 M phosphate buffer for the samples collected in Muncar, or in 70% ethanol for samples collected in Tanjung Luar and Lamakera. Samples were brought to the National Institute of Sciences (LIPI) in Jakarta for further analyses.

3.3.3. Interviews with fishermen

A total of 25 interviews were carried out with shark and ray fishermen in Tanjung Luar and Gilli Manuk (Lombok) during the month of October 2015. Interviews were conducted in small groups during the resting days of fishermen over a two-week period. Only a limited numbers of respondents could participate in the interviews due to remaining fishing fleet being at sea during the duration of the study. A total of 47 questions focused on three main components (1) respondent background, (2) spatio-temporal trends in mobula aggregation patterns, and (3) socio-economic trends in mobula ray fisheries. The interviews were preceded by a mobula ray identification discussion and identification guides were kept available at all times to ascertain that respondents could answer species-specific questions.

3.4. Data analysis

3.4.1. Landings

In order to standardize our landings data, mobula landings were expressed in number of individuals per week. Differences in the proportion of species between sites were assessed using Z- tests. Differences in the proportion of males and females in each species were assessed in a binomial test, with 0.5 as the expected proportion for equal occurrence of males and females.

3.4.2. Preliminary stomach content analysis

Stomach contents were analyzed as per Rohner et al. (2013). The 50 mL stomach content subsamples was stained with Rose Bengal overnight and 2mL subsamples were placed into a petri dish under an imaging microscope, until all or up to a hundred prey items were counted. In cases where parts of individual prey items were encountered, the prey item was counted and identified from the part, when possible. Quantitative importance of each prey category was counted as proportion of the total prey count ($\%N_O$), and the frequency of occurrence was calculated as the percentage of all stomachs containing each category ($\%F_O$). Up to fifty individual prey items per prey category were photographed using the imaging microscope with a Nikon camera and measured a posteriori using ImageJ. Total length (TL) of each individual was measured in millimeters to create a size spectrum. We used the same method as Rohner et al. (2013), to infer mass (mass = TL^3. density) with a density equal to that of seawater, approximately 1 $g.cm^{-3}$, and further calculated the mass of the prey category as a percentage of total mass ($\%M_O$). The percent of relative importance (%IRI = (%N + %M) %F) was used to describe stomach contents (Pinkas et al., 1971; Cortes, 1997).

3.4.3. Fishermen interviews

Responses to multiple-choice questions were described in terms of percentage respondents choosing a specific answer, while open-ended quantitative questions were analyzed using descriptive statistics (mean, standard deviation of the mean), and barplots using the statistical software R.

Fishermen's income per month was calculated by (a) dividing average fishing trip income (IDR) by the fishing trip duration (days), and (b) multiplying the result by 30 days. Similarly, the estimated percentage salary derived from mobula rays was estimated by (a) dividing the average percentage salary derived from mobulas in one fishing trip (%) by the duration of a fishing trip (days), and (b) multiplying the result by 30 (assuming 30 days worked per month), and 25 (assuming 25 worked days per month).

4. Results and discussion

4.1. Abundance patterns of mobulas at fishing markets

4.1.1. Fishery type and species composition

In total, 84 mobula individuals were recorded over 60 sampling days. Only one specimen of each *Mobula japanica*, *Mobula thurstoni*, and *Mobula tarapacana* were recorded in Tanjung Luar (West Nusa Tenggara) in August, at a frequency of one individual per week. These individuals were landed as bycatch in the pelagic fishery targeting sharks. Seven individuals were recorded in Lamakera (East Nusa Tenggara), which were direct targets of local fishermen using harpoon in September. We recorded 75 mobula rays landed as bycatch in the gillnet fishery targeting marlin and tuna in Muncar (East Java), over a period of 26 days in October and November 2015.

Mobula abundance at the fishing markets was much higher in Muncar overall (24.7 inds.week^{-1}) than in Tanjung Luar and Lamakera (1 and 5.25 inds.week^{-}1, respectively), especially due to the large abundance of *Mobula japanica* at that location (18.9 inds.week^{-1}) (**fig. 2**). The least mobulas were encountered at the market of Tanjung Luar, likely due to the fact that fishermen appear to land mobulids in other locations that the fishing market/ auction since the recent implementation of the manta ray fishing ban in the country. The least encountered species was *Mobula tarapacana* is both Muncar and Tanjung Luar, although second most abundant species in Lamakera, after *Mobula thurstoni* (**fig. 2**). The proportion of *Mobula japanica* was significantly different between Muncar and Tanjung Luar (Z-test, $p < 0.05$) and between Muncar and Lamakera ($p < 0.05$), but not between Tanjung Luar and Lamakera.

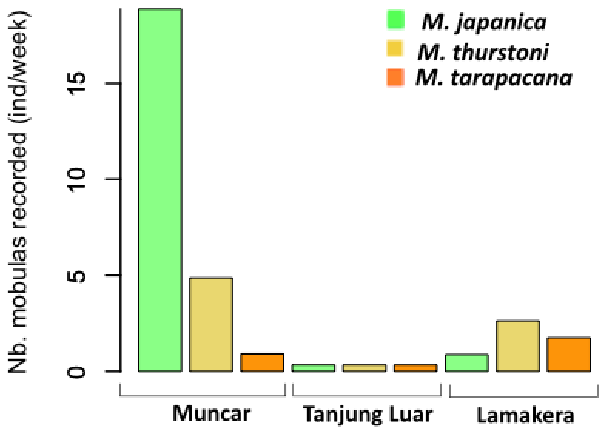

Fig. 2: Mobula abundance at fishing markets per week, at the three study locations. *Mobula japonica* landings are represented in green, *Mobula thurstoni* in yellow and *Mobula tarapacana* in orange.

4.1.2.Sex, size composition, and maturity stage

Taking into account only the specimens for which sex could be identified, the sex ratio of *Mobula japonica* was significantly different from equal proportions (N = 42, p = 0.28), with females representing 59.5% of the sample and males representing 40.5%. The sex ratio of *Mobula thurstoni* was also significantly different from equal proportions (N = 14, p = 0.42), with females representing 64.3% of the sample and males representing 35.7%. All *Mobula tarapacana* specimens were females.

Mean *Mobula japonica* disc width ranged from 72 cm (fetus) to 275 cm for females, (mean =195.4 ± 43.8 cm), and from 114 cm (late stage fetus) to 238 cm for males (mean = 196.4 ± 34.1 cm) (**fig. 3**). The disc width of the late stage fetus was larger than the birth size of 70 to 85 cm disc width reported for the species (Notarbartolo-di-Sciara, 1988; Compagno and Last, 1999). *Mobula japonica* females mean total weight was 66.5± 27.6 kg, ranging from 31 kg (juvenile of 152.5 cm disc width, no weight available for the fetus in the sample) to 103 kg (229 cm disc width, no total weight available for largest female). In *Mobula japonica* males, mean total weight was 58.0 ± 30.9 kg and ranged from 10 kg (fetus, no disc width data) to 95 kg (225 cm disc width). *Mobula thurstoni* disc width ranged from 33.8 cm (early stage fetus, **fig. 4**) to 189 cm for females (mean = 150.7 ± 54.2 cm), which extends the upper size limit of 180 cm reported by Notarbartolo-di-Sciara (1987) (**fig. 3**). Male *Mobula thurstoni* size ranged from 33.9 cm disc width (early stage fetus) to 172 cm disc width (mean = 98.5 ± 56.7 cm) (**fig. 3**). *Mobula tarapacana* for which morphometric data were available were all females, which ranged in size from 194 cm disc width to 297 cm disc width (mean = 260.7 ± 57.8). Weight was available only for the largest individual, which weighed 260 kg (**fig. 3**).

In Muncar, the female maturity stage varied as a function of species, with juvenile and mature (non-pregnant) females representing most of the *Mobula japanica* sample, while pregnant females were the most abundant category of females in *Mobula thurstoni* (**fig. 3**). Although no *Mobula tarapacana* fetuses or pregnant females were found, at least one of the specimens present was likely a juvenile due to their relatively small disc width (194 cm), which was much smaller to the estimated size at maturity of 270-280 cm disc width (Notarbartolo-di-Sciara, 1988).

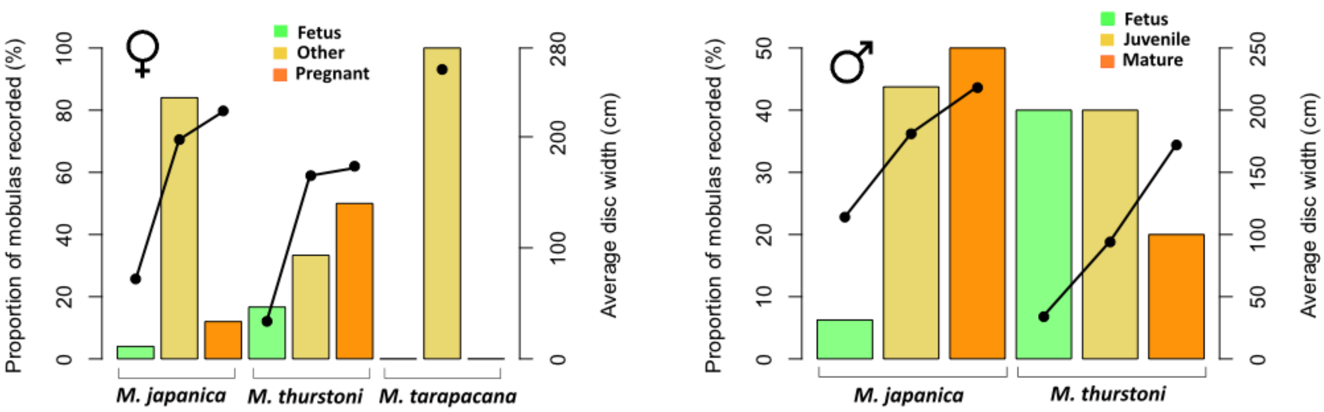

Fig. 3: Barplots representing the proportion (%) of fetuses, pregnant, and other maturity stage (juvenile or mature) females (left panel), and the proportion (%) of fetuses, juveniles, and mature males (right panel) recorded in Muncar. Points represent the average disc width (cm) for each maturity category.

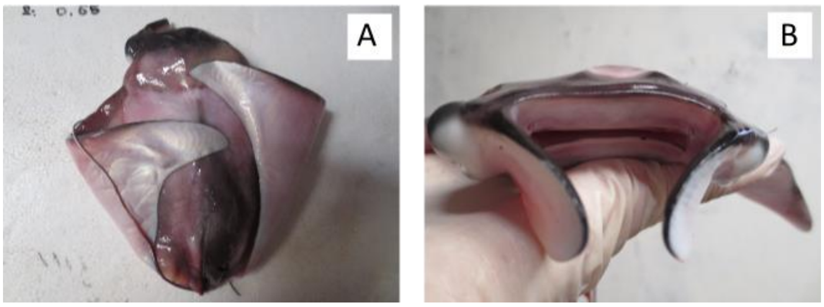

Fig. 4: *Mobula thurstoni* embryos in early stages of development, as confirmed by their small size (33.8 cm disc width), (A): dorsal view of an embryo in fetal position with fins wrapped around body,
(B) front view of embryo, cephalic fins unfolded.

4.2. Preliminary results of stomach content analysis

Mobula tarapacana

The only stomach available for a *Mobula tarapacana* was collected in Lamakera at the end of the month of August. No disc width data was available and the sex could not be identified. The stomach contained euphausiids (92.73% by count; 91.99 %IRI), fish otoliths (4.55% by count; 4.97 %IRI), copepods (1.82% by count; 1.74 %IRI), and crustacean larvae (0.91 % by count; 1.3 %IRI) (**fig. 5A**). The only available dietary information for the species comes from a stomach content analysis of 2 specimens from Mexico, by Notarbartolo-di-Sciara (1988). In that landmark study, one of the stomachs was empty upon collection, and only remains of copepods, amphipods, one brachyuran, one euphausiid, two decapods, megalopae and stomatopod larvae, and one fish egg. However, the second stomach was full and contained remains of small fishes, raising the question as to whether *Mobula tarapacana* is a specialized ichtyophagous ray or a generalist feeder (Notarbartolo-di-Sciara, 1988). Although our sample size is equal to one, and hence any conclusions brought forward herein should be tested with more data, it appears that the specimen collected in Lamakera had fed on a generalist/ opportunistic diet prior to collection.

Mobula japanica

Three *Mobula japanica* stomachs were collected, the first and second belonged to females landed in Muncar during the month of October (DW = 222 cm and 228 cm), and the third belonged to an individual of unidentified sex (DW unknown) landed in Lamakera towards the end of August. The first stomach contained only euphausiids (100% by count and IRI), while the second collected on the same day contained a large amount of eggs and euphausiids. The third stomach sampled in Lamakera contained remains of what appear to be euphausiids (prey items could not be identified further due to degradation), and other unidentified items. These data suggest that the mobulas landed in Muncar had fed on a dense patch of euphausiids, since a single morphotype (and hence species) were found. Previous studies of the feeding habits of *M. japanica* in the Gulf of California, found that stomach contents (n = 19 stomachs) were dominated, similarly to our study, by euphausiids (*Nyctiphanes simplex*- 99.62 %IRI) (Notarbartolo-di-Sciara, 1988). A stable isotope study by Sampson et al. (2010) confirmed the findings of Notarbartolo-di-Sciara.

Mobula thurstoni

The three stomach of *Mobula thurstoni* belonged to a juvenile male landed in Tanjung Luar in August, one juvenile male (DW = 91 cm) landed in Muncar in October, and one mature (pregnant) female (DW = 172 cm) also landed in Muncar in October. The stomach collected in Tanjung Luar was virtually empty upon collection and only contained remains of crustacean eyes, while the juvenile male collected in Muncar contained unidentifiable fibrous material. The pregnant female collected in Muncar contained only euphausiids (100% by count and IRI), suggesting that the animal had fed on a zooplankton patch composed of the same euphausiid species as that fed upon by the *M. japanica* individuals landed in Muncar. Although no information on the dietary habits of *M. thurstoni* are available for the region, a previous study by Notarbartolo-di-Sciara (1988) found that in the Gulf of California, the species (n = 57 stomachs) feeds primarily on euphausiids (*Nyctiphanes simplex* sp.- 97.90 %IRI), a trend that was later confirmed by Sampson et al. (2010).

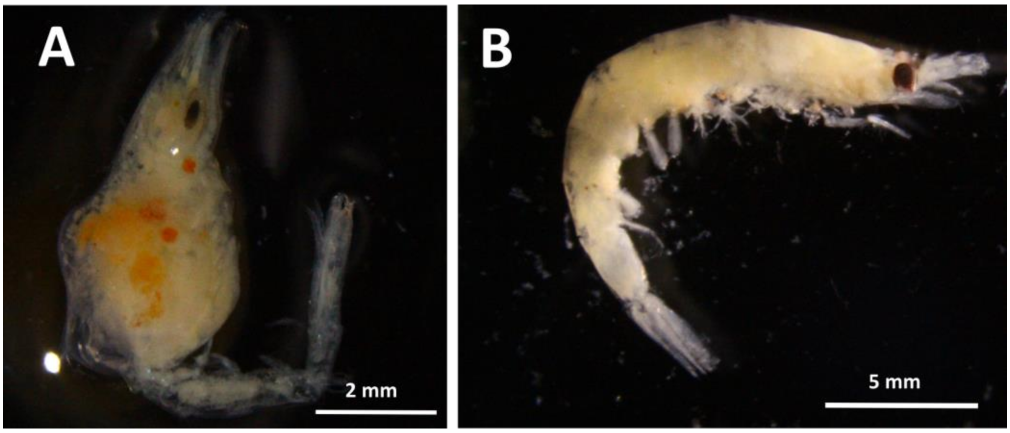

Fig. 5: Stomach contents of mobula rays. **Left panel (A)**: Crustacean larvae recovered from the stomach of a *Mobula tarapacana* landed in Lamakera in August (scale bar is 2 mm). **Right panel (B)**: Euphausiid zooplankton retrieved from a *Mobula japanica* landed in Muncar in October (scale bar is 5 mm).

4.3. Socio-economic study

4.3.1. Background of respondents and fishery characteristics

Respondent background

The age of respondents ranged from 18 to 60 years old, and was 35.16 ± 10.91 years on average. On average, the fishermen had to provide for 2.55 people in the household (range: 0 to 5), with younger respondents not having any direct dependents, because younger fishermen were less likely to be married than older ones. The length of time that respondents had been working as fishermen ranged from 4 months to over 40 years (mean career length = 18.53 ± 11.14 years long). The majority of respondents left school after the Elementary school level (56%), while 28% went until the second year of Junior high school, one person never attended school, and another person went to High school (two people did not answer the question).

Fishery characteristics

Fishermen came from two fisheries: 14 respondents belonged to the pelagic fishery characterized by larger boats (15.54 m on average) and longer fishing trips of 16 ± 2 days on average, while 11 respondents fished in coastal waters and on smaller boats (6 m on average) and went to say for one-day fishing trips. Both fisheries use mixed gears, but predominant gear types used were longline (85.7%, surface and bottom longline) and spear (64.3%) for the pelagic fishermen, while the coastal fishermen reported primarily used nest (gillnets/ trawl) (63.7%) and fishing rods (45.5%). Both groups of fishermen also reported using spears, and they reported this was one of the gears used to catch mobulas (38.46%) along with small surface trawls and gillnets (26.9%). Two fishermen reported occasionally landing mobulas on longlines.

4.3.2.Trends in behaviour and abundance

Fisheries interaction

The majority of pelagic fishermen reported that mobulas were often landed with Skipjack tunas (71.5%), while 4% of them reported that mobulas are landed alone because they catch them with the spear, and one of them reported that mobulas are occasionally caught as bycatch while landing sharks on longlines. Fishermen operating closer to the coast reported that mobulas are landed with Skipjack tunas (54.5%) or with other smaller fish. One reported never landing mobula rays. One respondent noted that mobulas could be seen in proximity of Tanjung Luar when they are out fishing for bait.

All fishermen except one (who did not answer this question) reported seeing mobulas breach, and one of them detailed that this behaviour occurred only further away from the coast and from Tanjung Luar. They reported seeing mostly smaller mobulas jump and 3 fishermen specified that they do not see *Mobula tarapacana* jump breach. The vast majority of all fishermen (96%) conceded that mobulas are easy to catch compared to other species, because they often schooling and once tangled in the net (gillnet or trawl) they cannot swim backwards and untangle themselves. They also reported that smaller mobulas are easier to catch than larger individuals, and one person reported that mobulas are easier to catch than manta rays for this reason (it is easier to tow them onto the boat).

Daily, monthly, and seasonal trends

The majority of fishermen operating in the pelagic fishery reported landing mobulas mainly during the daytime (71.4%), while 81.8% of those operating near the coast reported catching mobulas at night. Those that reported fishing during the day said mobulas tend to swim at the surface during the day and hence can be speared more easily. Of all the fishermen, those that reported catching mobulas at night said that they do not use lights to attract the mobulas, because it tends to repulse them.

After having assisted to a mobulid identification presentation and while having access to mobula species identification guides, the majority of fishermen reported that there was no particular mobula species that they landed more than another (88.4%), while one person reported fishing more *Mobula japanica* and another could not tell the difference between the species. This result seems to corroborate the relative abundances that we recorded in Tanjung Luar over our short study period, although it is likely that additional non-reported catch occurred.

Fishermen reported that mobulas migrate between fishing grounds depending on the season, but that they could be found primarily (as for pelagic sharks) near Sumbawa islands and adjacent waters, or in the Sumba strait. One fisherman reported that they migrated between the East and the West depending on the season, which explains why fishermen did not all agree on which months of the year represented the high season, probably being encountered regularly in some locations and migrating between other locations depending on the season (**fig. 6, A**). Respondents operating in the pelagic fishery reported landing average 3.34 ±

2.8 mobula rays per month during the high season, which was slightly more than the average landings reported by those operating in coastal fisheries (3 ± 2.4 mobulas per month) (**fig. 6, B**). During the low season, 80% of all the fishermen (coastal and pelagic) reported landing 0 to 1 mobula per month, while the remaining respondents reported landing 1 to 5 mobula per month (mean = 0.83 ± 0.76 mobulas per month).

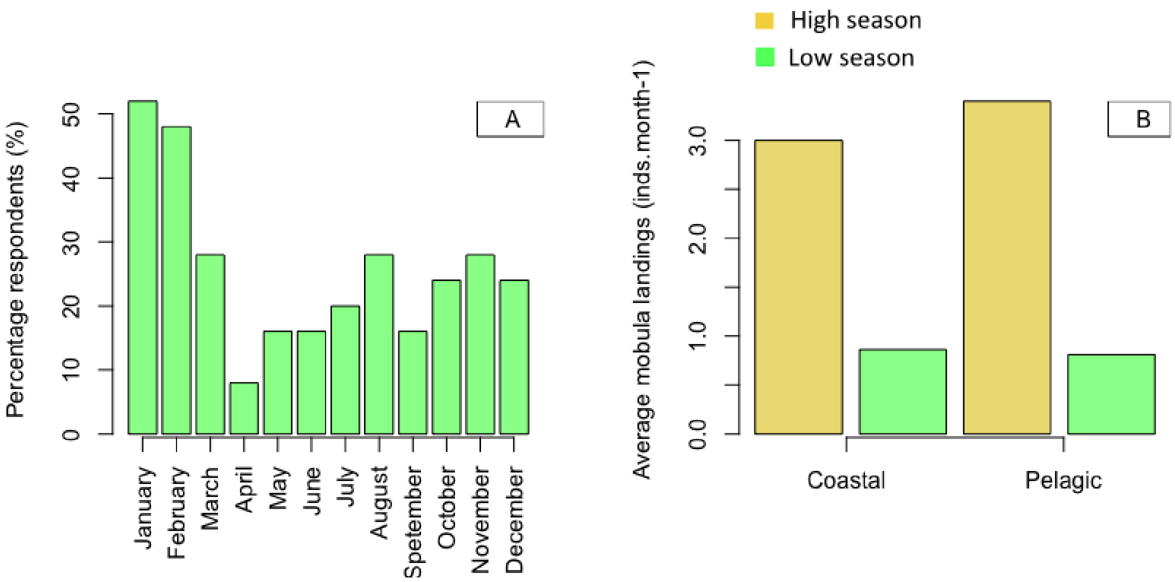

Fig. 6: Mobula landings seasonality, as perceived by fishermen in Tanjung Luar. **Left panel (A)**: barplots representing the percentage of respondents considering the given month is part of the high season for mobula landings. **Right panel (B)**: barplot representing the average mobula landings during the high (yellow), and the low (green) season.

Long-term trends

The majority of fishermen (68%) reported that they perceived a decreasing trend in mobula landings compared to landings during the year 2014, out of which two respondents believe this occurred due to the manta ray ban being put in place. Only 16% perceived an increase in mobula landings. All the fishermen agreed that this was true for all mobula species. One respondent mentioned that stingray landings had increased since 2014, to the contrary of mobula ray species. Most of the fishermen (both pelagic and coastal fisheries) reported that mobula fishing effort had overall decreased since 2014 (80%).

Out of the respondents whom had been fishing for 10 years or more (n = 21), 47.6% believed that mobula landings were decreasing in the last ten years, while 23.8% reported that mobula landings were stable or increasing 10 years ago, but were now decreasing in the past 3 years. However, 66.6% of the respondents explained that fishing effort had been increasing over the past 10 years. Just over half the respondents mentioned that their fishing grounds had not changed over the past 10 years, although 42.8% replied that fishing grounds were now further away than before.

Five respondents additionally commented that the manta fishing ban had affected mobula fisheries, in terms of price (one mentioned the price of mobula rays is increasing), and because fishermen were now afraid to land mobulas.

4.3.3. Costs and value to fishermen

The main expense during the fishing trip was fuel, which amounts to an average of 303.6 liters per trip (~19.1 liters per day of fishing) for pelagic fishermen, and 12.0 liters per day-trip for coastal fishermen. The average value of one mobula ray individual at Tanjung Luar market was significantly different between small and large specimens (Kruskal-Wallis, K=13.6, $p < 0.001$), and was 206 330.00
± 95 IDR/ US$ 15.7 (03/2016 exchange rate) for small mobulas, and 793 750.00 ± 482 IDR/ US$ 60.3 for larger individuals (**fig. 7**). None of the fishermen knew what the value of mobula cartilage was.

In the pelagic fishery, the average proportion of a fisherman's monthly salary derived from mobulas was 11.5% of the total salary considering 30 days worked in a month, and 9.6% of the total salary when considering 25 days worked in a month. In the coastal fishery, the estimated average proportion of monthly salary derived from mobulas was 6.33% assuming 30 days of work in a month, and 7.6% assuming 25 days of work in a month.

There were significant differences between the salary trends of pelagic and coastal fishermen: all pelagic fishermen reported their salary had been increasing over the past three years, due to the prices of fish going up, while landings were decreasing; while all the coastal fishermen who answered this question reported their salary had been decreasing overall due to fuel price rises and more competitors. These data corroborate the results of previous section concerning long-term fishery trends (4.3.2), and further supports the hypothesis that fishing effort has been increasing over the past three years while landings have been decreasing decreasing, causing prices to rise.

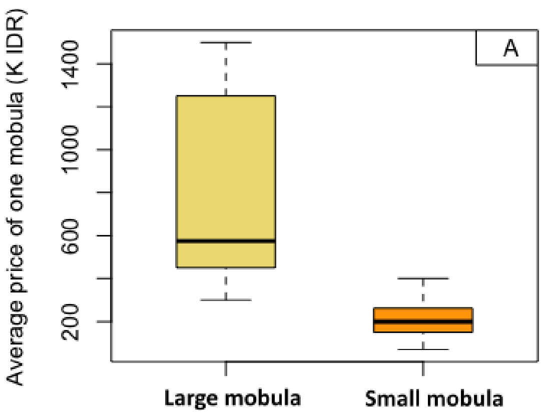

Fig. 7: Boxplot representing the average selling price for one small mobula ray (orange) versus the price for one large mobula ray individual (yellow). Horizontal bars represent the median; first, second, and third and fourth whiskers represent the minima, first quartile, third quartile and maxima, respectively.

4. Preliminary conclusions and further directions

Our study provided (1) important information on species-specific landings of mobula rays at important landing sites in Indonesia, suggesting a nursery ground occurs in proximity of the Bali strait, (2) preliminary dietary information of mobula species in Indonesia, and (3) a small-scale socio- economic study which quantifies the economic value of mobula rays for fishermen in the communities of Tanjung Luar and Gilli Manuk. Our study took place during the first phases of the implementation of the manta ray sanctuary in Indonesia, which could, in the face of ever growing demand for mobulid gills in the Chinese medicine market, raise the demand for mobula gills exported from Indonesia. The predisposition of mobula ray species to be threatened by intense fishing pressure has previously been shown in a range of studies using abundance trends and life-history theory (e.g. Ward-Paige et al., 2013; Dulvy et al., 2014; Croll et al., 2015). In this study, low fecundity was confirmed in all instances in which pregnant mobulas occurred confirmed one pup per liter. Stomach content analysis results should be interpreted with caution since a very small samples size was available, and in some cases empty. However, these represent the first dietary data available for Indonesia and suggest that mobulas feed on dense euphausiid patches close to the coast of Banyuwangi, during which they overlap with the tuna and marlin fishery in October. More sample collection is required to gain a better understanding of temporal shifts in diet and to gain a larger sample size. Interviews with fishermen revealed that fishermen in both coastal and pelagic fisheries capture mobula rays as target and bycatch, using mixed gears, and especially while targeting tuna. Fishermen recognize the seasonality of mobula occurrence in Indonesia, and encounter them either during 2 week-fishing trips in the Sumba straight and around Sumbawa Island, or in more coastal waters in proximity of Lombok during 1-day trips (especially at night). Given the perception of fishermen that mobula landings have decreased in the last three years even though fishing effort appears to be increasing, mobula prices are increasing on the local market. Given the fact that populations are likely threatened by the ever-increasing demand on the international gill market that does not directly benefit the local fishing communities as much as it does vendors further down the supply chain, conservative measures are needed, at least to mitigate the use of this resource for exportation. The proportional value of mobula rays for fishermen is limited to approximately one tenth or less of their monthly salaries.

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