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Using the case of illegal manta ray trade in Indonesia to evaluate the impact of wildlife trade policy

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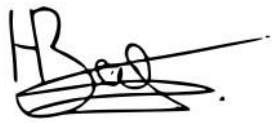
I declare this thesis "Using the case of illegal manta ray trade in Indonesia to evaluate the impact of wildlife trade policy" is entirely my own work, and that where material could be construed as the work of others, it is fully cited and references and/or with appropriate acknowledgment given.

Signature



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List of Acronyms and Abbreviations

AIC	Akaike Information Criteria
CITES	Convention on International Trade in Engendered Species of Wild Flora and Fauna
GLHT	General Linear Hypothesis Test
GLM	General Linear Model
MMAF	Ministry of Marine Affairs and Fisheries
NGO	Non-Governmental Organisation
US	United States
WCS	Wildlife Conservation Society
WCU	Wildlife Crimes Unit

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Statement of Own Work

The Wildlife Conservation Society Indonesia provided me with raw landings data from Tanjung Luar for 2013-2016, law enforcement records, intelligence records, and project records with data from market surveys collected by various staff members and consultants. Misool Baseftin provided me with landings data from Lamakera for 2015-2016. Popi Puspitasari and Devina Sandriati collected and translated primary data for all semi-structured interviews and interview-administered questionnaires with Indonesian stakeholders. All other secondary data sources drawn from for this study have been cited appropriately. All other work, including research design, collection of primary data from English-speaking stakeholders, and analysis and interpretation of data is my own, unless explicitly stated otherwise in the text.

Simon Pooley, Tom Clements and E.J. Milner-Gulland provided comments on early drafts.

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Abstract

Human overexploitation represents one of the greatest threats to wildlife; with the severest impacts felt by slow growing, economically valuable species. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) aims to ensure that commercial trade does not threaten wild species, but since implementation takes place in complex socio-ecological systems, it is often unclear how effectively CITES decisions translate into practice. Manta rays (*Manta* spp.) were listed on Appendix II of CITES in 2013, and declared a protected species in Indonesia in 2014. This study focuses on the specific case of manta rays in Indonesia to evaluate the impact of wildlife trade policy. I used a mixed-methods approach to develop the first framework for monitoring illegal manta ray catch and trade in a source country and assess the impact of the regulation in two case study sites. The results suggest that the regulation is having an impact, but the nature and magnitude of the impact remain unclear. The study highlights the challenges associated with implementing, monitoring and evaluating wildlife trade regulations in dynamic, complex, real-word situations. In the future, monitoring and evaluation of wildlife trade policy could benefit from more strategic and integrated data collection systems, coupled with methodological innovations in the way we use monitoring data: integrating qualitative and quantitative methods and acknowledging complexity are crucial for strengthening causal inference and attribution of impacts.

Key words: complex systems, compliance, impact evaluation, law enforcement, marine megafauna, trade chains, wildlife crime

Introduction

International wildlife trade represents a major threat to biodiversity (Broad et al. 2003), and is of increasing concern to policy-makers due to bourgeoning illicit markets (Rosen & Smith 2010; Haken 2011). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) aims to reduce this threat by regulating international trade of species. However, in order to be effective, CITES must be actioned through domestic controls, which are implemented in complex socio-ecological systems. Success or failure is often dictated by context-specific factors (Berkes 2007; Underwood et al. 2013) and unintended consequences for humans and wildlife are well documented (Challender et al. 2015). As such, although CITES is regarded as one of the world's most important multilateral environmental agreements (Huxley 2000), implementation is challenging and its effectiveness remains empirically questionable (Challender et al. 2015). There is a need for methodological innovations that enable robust causal analysis within the inherent complexity of wildlife trade.

Over the past 20 years manta rays (*Manta* spp.) and their sister genus devil rays (*Mobula* spp.) (collectively mobulids) have been increasingly targeted to meet emerging demand for their prebranchial appendages, commonly referred to as gill plates, in traditional Chinese medicine markets (White et al. 2006). Like other marine megafauna manta rays are vulnerable to trade-driven extinction (McClenachan et al. 2016), and with growing international concern regarding their overexploitation both species (*Manta birostris* and *Manta alfredi*) were added to Appendix II of CITES in March 2013.

Small-scale elasmobranch fisheries have operated in Indonesia for centuries, providing a source of sustenance and barter goods for coastal communities (Christensen & Tull 2014) but the expansion and modernisation of artisanal fishing fleets coupled with the emergence of a commercialised industry has lead to dramatic intensification of targeted mobulid exploitation (Lewis et al. 2015). Indonesia is now one of the world's top mobulid fisheries (FAO 2014) and a major supplier of gill plates to consumer markets (O'Malley et al. 2016). However, with large declines in catch over the past fifteen years and anecdotal reports of extirpations there is considerable evidence that Indonesia's mobulid fishery is

47 overexploited (Lewis et al. 2015), with potentially detrimental consequences for Indonesia's growing
48 tourism industry (O'Malley et al. 2013).

49 In response to these concerns and the CITES listing, the Indonesian Ministry of Marine Affairs
50 and Fisheries (MMAF) issued a Ministerial Decree in February 2014 to prohibit exploitation of manta
51 rays throughout the country's entire exclusive economic zone (MMAF No.4/KEPMEN-KP/2014): a
52 huge step forward for elasmobranch conservation, but a significant challenge for implementation and
53 monitoring, particularly in a country as vast, disparate and relatively under-resourced as Indonesia.
54 With developing countries at highest risk from illegal fishing (Agnew et al. 2009), and the severest
55 impacts felt by large, economically valuable species traded for non-perishable parts (McClenachan et al.
56 2016) the effectiveness of Indonesia's manta ray regulation warrants attention. This case also provides
57 an opportunity to assess the impacts of a CITES decision and corresponding national regulation, and
58 learn lessons for future implementation and impact evaluation of wildlife policy.

59 In partnership with several international Non-Governmental Organisations (NGOs), the
60 Indonesian government has been building capacity to implement the manta regulation. The Wildlife
61 Crimes Unit (WCU), a partnership between government agencies, civil society groups and media
62 organisations, facilitated by the Wildlife Conservation Society (WCS), has been leading enforcement
63 efforts. These efforts have been met with some proximate success, including the arrest and prosecution
64 of 10 manta ray traders since August 2013 (D. Adhisto personal communication 2016). However
65 international demand for manta products continues (O'Malley et al. 2016) and there are anecdotal
66 reports of continued exploitation in several locations (S. Lewis personal communication 2016),
67 suggesting the persistence of a now illegal industry. To evaluate the impacts of the regulation an
68 assessment of changes in manta trade and a comprehensive causal analysis are required, however this
69 presents several practical and technical challenges including bias, complexity, scope, scale and data
70 paucity.

71 Recognising these needs and challenges, this study presents:

72 a) the first framework for monitoring illegal manta ray catch and trade in a source country;

b) a preliminary analysis of the impact of Indonesia's manta ray regulation on fishing effort and onward trade in two case study sites;

c) recommendations for further monitoring and implementation of the regulation, and for evaluating the impacts of wildlife trade regulations in the future.

Methods

The manta ray trade chain is complex, dynamic and heterogeneous. The system is spatially and temporally diffuse, with many drivers and feedbacks operating at multiple scales (Fig.1). The illicit nature of the trade means there will be uncontrollable bias in monitoring data, which can be context-dependent (Gavin et al. 2010). Further, baseline data is sparse and methodologically inconsistent.

These challenges necessitated an exploratory mixed-methods approach with flexible and opportunistic data collection at multiple levels of the trade chain; the use of qualitative and quantitative techniques; triangulation of multiple datasets; and critical evaluation of different types of evidence to strengthen causal inference.

Framework development

I developed a monitoring framework through an iterative process of targeted literature review and consultation with non-sensitive stakeholders (I defined 'non-sensitive stakeholders' as those not directly engaged in manta ray trade e.g. NGOs, researchers, government). I identified stakeholders by referral, and collected data using unstructured and semi-structured interviews. A total of 26 non-sensitive stakeholders were interviewed throughout the study (Supporting Information). Through this process I developed an understanding of the system and context; and identified key themes, locations, people, methods and datasets. I consolidated potential methods and datasets into a draft monitoring framework, which I circulated for expert-opinion-led review via an online survey (Supporting Information).

Figure 2 presents a conceptual diagram of the manta ray trade chain with identified points of monitoring opportunity, which can be cross-referenced to Table 1 for a summary of the monitoring

framework used for this study. An evaluation of all methods and datasets that were considered is available in Supporting Information.

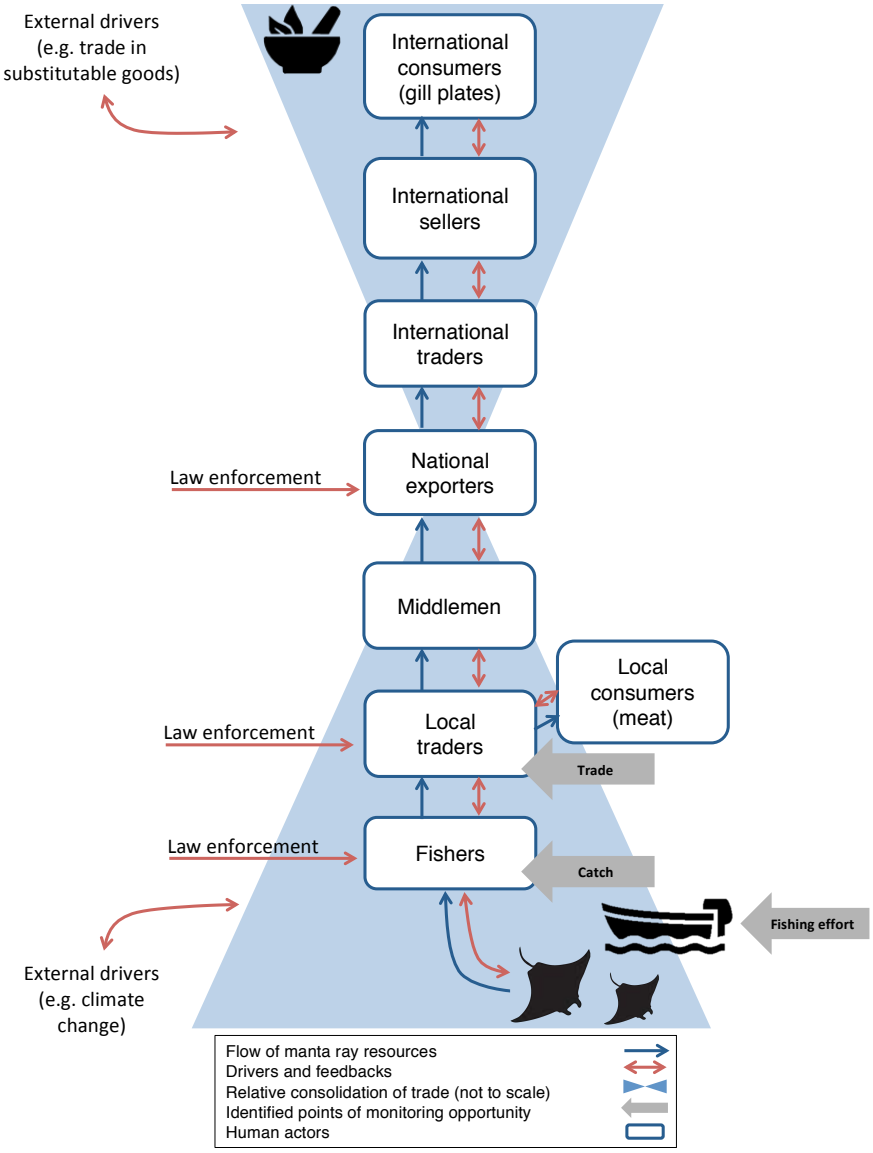


Figure 1. A conceptual diagram of the manta ray trade chain with identified points of monitoring opportunity. The diagram is highly simplified: in reality, there are many actors at each level; and multiple, overlapping routes for the flow of resources, drivers and feedbacks. The monitoring points are not exhaustive, but represent those for which data was readily available or methods were feasible to implement at the time of the study.

Table 1. An operational framework for monitoring manta ray trade in Indonesia.

Method of monitoring illegal activity*	Dataset	Level of trade chain		
		Fishing effort	Catch	Trade
Direct questioning using interview-administered questionnaires	Community member questionnaires	✓	✓	✓
Covert direct observation using informers	Intelligence data			✓
Overt direct observation using official enumerators	Landings data		✓	
Indirect observation using market surveys	Price data			✓
Law enforcement records from law enforcement actions	Case summaries			✓

*Categorised based on a modified version of the methods identified in Gavin et al. (2010)

The table shows which datasets and methods are readily available for monitoring the manta ray trade chain and the level of the trade chain they can provide data on, multiple datasets were triangulated where possible. The methods and datasets listed here are not exhaustive, but represent those most appropriate and useful for this study. Qualitative data on contextual factors was also collected to provide commentary on the reliability of each dataset (see text for details).

Case studies

I used the monitoring framework to conduct a preliminary impact evaluation of the regulation in two case study sites: Tanjung Luar (Lombok, West Nusa Tenggara) and Lamakera (Solor, East Nusa Tenggara) (Fig.2). A case study approach was necessary because a) local context was critical to understanding responses to the regulation and the reliability of different datasets; b) a combination of data collection methods was required, with triangulation of different datasets (Yin 2013); and, c) a national overview was unfeasible at the time of the study. The two sites were chosen due to their historic scale and importance as commercial mobulid fisheries (Lewis et al. 2015), availability of historic data, the presence of an enforcement effort, and their polarity as case types in terms of physical and social context (Supporting Information).

Sites

Tanjung Luar

Located on the East coast of Lombok, West Nusa Tenggara, Tanjung Luar is one of Indonesia's most productive elasmobranch fishing ports and previously recognised as a major targeted mobulid fishery (Lewis et al. 2015). Tanjung Luar's heavily trafficked fishing grounds are situated between two of

Indonesia's most important marine protected areas, representing a threat to manta rays migrating between these regional sanctuaries (Germanov & Marshall 2014).

Lamakera

Lamakera is the collective name given to two adjacent fishing villages (Moton Wutun and Wotobuku) in East Solor, East Nusa Tenggara. The Alor Strait surrounding Lamakera is an important site for marine megafauna (Kahn 2003), and Lamakera has attracted international attention for its controversial fishing practices in these waters (Heinrichs 2014). With peak annual landings of up to 2,400 individuals in the early 2000's, Lamakera is considered the world's top manta hunting location (Dewar 2002; Heinrichs 2014).

Figure 2. Map of Indonesia with case study sites highlighted, along with known manta ray aggregation sites (Germanov & Marshall 2014) and major gill plate trading hubs (D. Adhisto personal communication 2016).

143 **Data collection and analysis**

144 I gathered primary and secondary data (Table 1; Supporting Information) for both sites. Field data
145 collection was conducted during June-August 2016 and experienced Indonesian research assistants
146 collected and translated data from all Indonesian research participants. The ethics committee of
147 Conservation Science, Faculty of Natural Sciences, Imperial College London, approved this research.

148 ***Fishing effort***

149 I used direct questioning via interview-administered questionnaires to gather data on fishing effort from
150 community members. Due to the exploratory nature of the research and hidden characteristics of the
151 trade it was not possible to make a priori sampling decisions: opportunistic and respondent-driven
152 sampling were used (Cohen & Crabtree 2006). I used descriptive statistics and thematic analyses to
153 identify trends.

154 ***Catch***

155 I used current and historic landings data to assess catch trends. I conducted a multi-step events-based
156 analysis to determine a) if there had been a significant decline in manta ray landing occurrences over
157 time, and b) whether this decline could be plausibly attributed to the regulation, given contextual
158 factors such as timing, onset of enforcement and external influences. I fitted generalised linear models
159 (GLM) with binomial errors, considered all meaningful models (Supporting information), and used
160 minimum AIC to determine the best-fit (Burnham & Anderson 2003). Since devil rays are exploited for
161 the same market as manta ray but are not a protected species, I used devil ray landings as an indicator of
162 external factors such as seasonality and market fluctuations, however they were not considered a
163 control, as the trade chains are not independent. For GLMs with multiple variable contrasts I applied a
164 post hoc generalised linear hypothesis test (GLHT) to compare factor levels. I used only raw daily
165 landings data for this analysis, which was available for March 2013-June 2016 for Tanjung Luar and
166 May 2015-July 2016 for Lamakera. I used RStudio Version 0.99.489 for statistical analysis.

167 To provide a descriptive overview of trends in total landings over time, I extrapolated estimated
168 total annual landings for both sites using a modified version of the methods in White et al (2006)

(Supporting Information). This was necessary for comparison with historic data from Lamakera (2002-2014; Lewis et al 2015), which could not be included in the statistical analysis due to different sampling methods.

Fishers were also asked to estimate mobulid landings during semi-structured interviews.

Trade

As with fishing effort I collected data on manta trading using interview-administered questionnaires. This data was triangulated with intelligence and law enforcement data on known and suspected trading activity.

I combined current and historic price data for manta and devil ray gill plates from across Indonesia and major international markets, corrected for inflation, and converted all prices to US dollars using exchange rates from Oanda.com. I categorised prices according to site, genus and level in the supply chain, and observed trends across levels and sites. I did not conduct statistical analysis on this data, as data collection methods have been inconsistent.

Context

Throughout the study period, during interviews, questionnaires and through naturalistic observation (Cohen and Crabtree 2006), I gathered qualitative data on contextual factors pertaining to each dataset, such a data collection processes and source credibility. This provided commentary on the accuracy, reliability and relative inferential weight of each dataset.

Impact evaluation

Drawing on techniques from process tracing (Bennett 2010; Woodhouse et al. 2016) I triangulated the datasets for each level of the trade chain to identify trends, and combined this with qualitative, contextual data to evaluate the inferential weight of each dataset and plausible alternative explanations for the observed trends. Through a process of causal inference, this enabled an assessment of a) whether there had been any real changes in the trade chain since the regulation, and b) whether these changes could be plausibly attributed to the regulation.

Results

Fishing effort

All interviewed fishers from Tanjung Luar reported that they used to catch manta ray but no longer do. Three fishers stated they changed behaviour because of the regulation, but two reported they switched target species prior to the regulation. Perceived risk of enforcement was "moderate" to "very likely". Three fishers stated they did not know how many other fishers targeted manta, while two reported "none since the regulation". One fisher commented that he knows of four fishers using spears, which, according to interviews with non-sensitive stakeholders, suggests those fishers target manta. Several non-sensitive stakeholders reported anecdotes of opportunistic, clandestine catches. Overall perceived community compliance was high for every interviewee. Support for and attitudes towards the regulation were predominantly low/negative (Table 2).

In Lamakera, two out of three interviewed fishers reported that they used to catch manta ray but no longer do, and stated that the change was due to the regulation. One fisher reported that he still catches manta. Perceived risk of enforcement was "moderate" to "likely", with two fishers commenting that it is "hard" for the marine police to "patrol all areas [of the sea]". For peer-reported behaviour, the number of known manta fishers ranged from no one to 400, and the number of boats targeting manta ranged from zero to 30. Overall perceived compliance ranged from "few people comply" to "lots of people comply". Support for and attitudes towards the regulation were mixed (Table 2).

Table 2. Responses to selected compliance-related and attitudes-related questions from interview-administered questionnaires with community members in Tanjung Luar and Lamakera.

Question	Responses			
	Tanjung Luar		Lamakera	
Self-reporting of illegal fishing[a]	Yes	No	Yes	No
"Nowadays, do you ever catch manta ray?"	0	5	1	2
"Did you catch manta ray in the past?"	5	0	3	0
Changed because of the regulation	3	2	1	2
Self-reporting of illegal trading[b]	Yes	No	Yes	No
"Nowadays, do you ever trade manta ray?"	0	4	0	1
"Did you trade manta ray in the past?"	4	0	1	0
Changed because of the regulation	4	0	0	1
Peer-reporting of illegal fishing and trading[c]				
"[Of the fishers you know], how many have caught manta ray in the past two years?"	Don't know/none		0-400	
"[Of the number of boats in your village], how many target manta ray?"	-		0-30	
"[Of the traders you know], how many have traded manta ray in the past two years?"	0		2	
Support for the regulation[c]				
To what degree do you support the regulation on manta ray fishing?"[d]				
"How many people in your community do you think are in support of the regulation?"[e]				
"To what degree do you think the regulation is fair?"[f]				
Reasons given for negative responses	Reduced income without provisions for an alternative		Reduced income and affected culture	

[a] Fishers only (Tanjung Luar n=5, Lamakera n = 3);
[b] Traders only (Tanjung Luar n=4, Lamakera n=1);
[c] Fishers and traders (Tanjung Luar n=9, Lamaera n=4);
[d] strongly support, support, neutral, against, strongly against;
[e] most people, lots of people, around half of the population, few people, very few people;
[f] very fair, fair, neutral, unfair, very unfair

Catch

In Tanjung Luar, the probability of recorded manta landing occurrences declined from March 2013-June 2016, with an apparent negative step-change around the time the regulation was introduced, which was not observed for devil ray (Supporting Information). The best-fit generalised linear model (GLM) of landing occurrences (both genera) indicated a highly significant negative difference ($p<0.001$) between pre- and post- regulation landing occurrences, with a significant interaction between genus and regulation (Table 3). Pairwise comparisons showed that difference between pre- and post-regulation landing occurrences is highly significant for manta rays ($p<0.001$), but not significant for devil rays, and estimated total annual catch for 2013-2016 declined over time for manta ray, but not devil ray (Fig.3).

In Lamakera, the probability of manta ray landing occurrences did not decline significantly between May 2015-July 2016 (Supporting Information). Estimated total annual catch declined from 2002-2016, and 2016 is the first year on record with proportionately more devil ray landed than manta ray (Fig 3). No fishers provided estimates of mobulid landings.

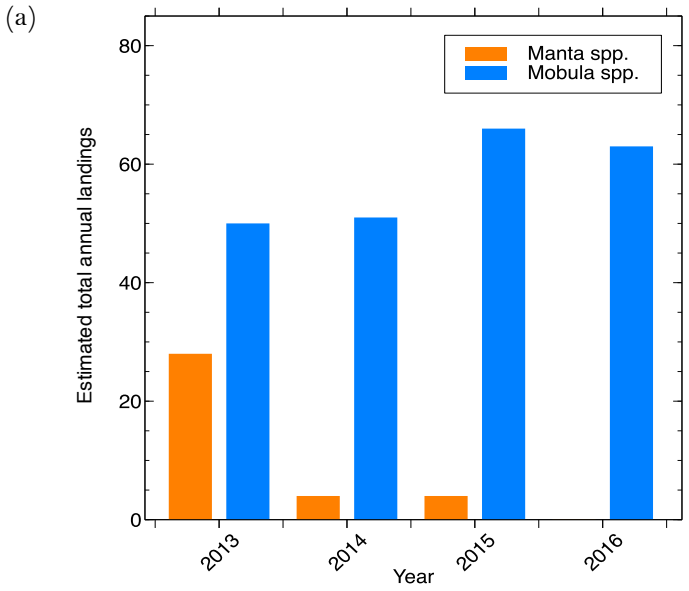
Table 3. Coefficients of generalised linear model with binomial errors for landing occurrences in Tanjung Luar.

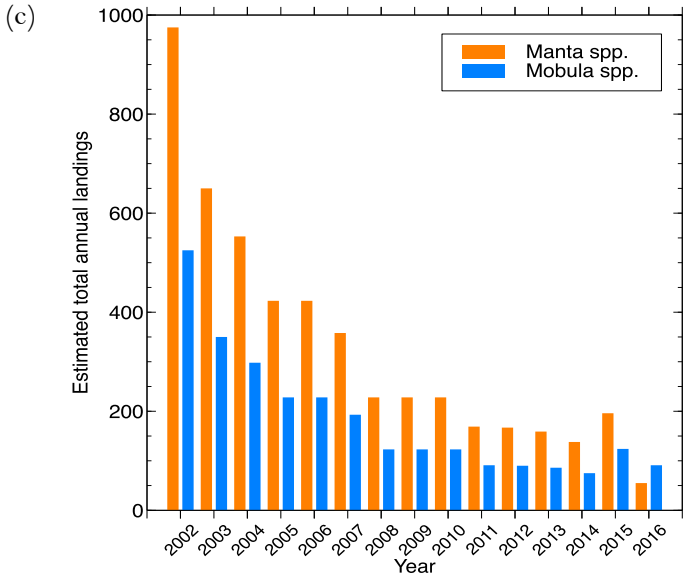
Coefficients	Estimate[b]	Std. Error	z value	Pr(>|z|)	Significance[a]
(Intercept)	-2.9004	0.3097	-9.366	<2e-16	***
GenusDevil	0.7497	0.383	1.958	0.050263	.
RegulationPost	-1.7782	0.4712	-3.774	0.000161	***
GenusDevil:RegulationPost	1.2536	0.5403	2.32	0.02033	*

[a] Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

[b] Reference level is RegulationPre (i.e. pre February 2014) GenusManta

Model built with daily landing occurrences as a binary response variable (genus landed: Y/N) and regulation (pre- and post-) and genus (manta and devil) as categorical predictor variables





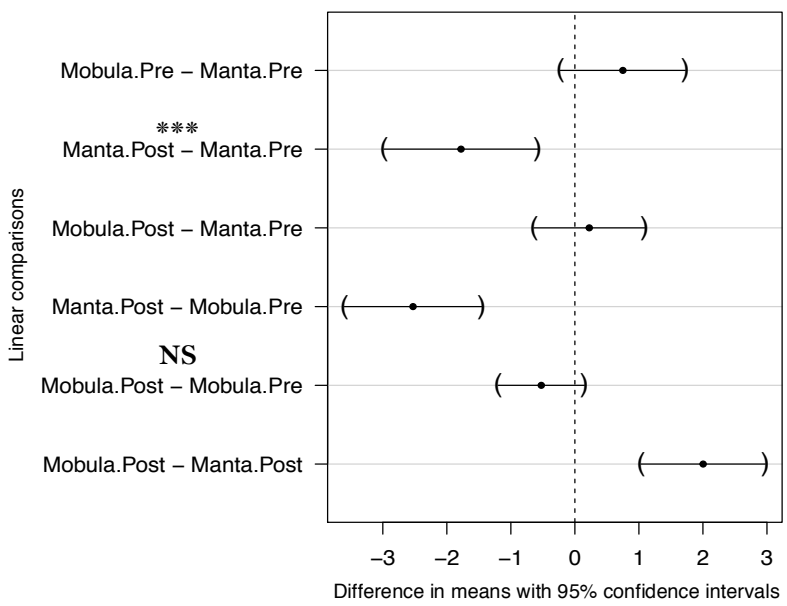


*Figure 3. Results of landings data analysis for Tanjung Luar and Lamakera: (a) estimated annual mobulid landings for Tanjung Luar 2013-16; (b) plot of pairwise comparisons from general linear hypothesis test of pre-post regulation mobulid landing occurances model in Tanjung Luar. Pre-post mobula pairwise comparison was not significant (NS), pre-post manta pairwise comparison was highly significant ($p<0.001$: ***); (c) estimated annual mobulid landings for Lamakera 2002-16 (N.B. data prior to 2015 based on community records/village elder personal commmunication (Lewis et al. 2015)).*

Trade

Prior to the regulation at least 200 individuals were engaged in the elasmobranch trade chain in Tanjung Luar, although the number specifically engaged in manta ray trading is unclear (Mutaqin & Dharma 2014). Intelligence data indicates two major traders continued trading manta products post-regulation, both of whom were arrested and prosecuted in 2015. No further traders have been identified, although secondary and tertiary connections could still exist with other traders operating in West Nusa Tenggera.

In Lamakera, the number of manta product traders prior to the regulation is unknown, but three major traders continued trading manta products post-regulation. Of these, two specialised in gill plates, while another specialised in processing and meat trading. In July 2015 one gill plate trader was arrested and prosecuted, while the two other traders remain operational. Manta meat is still easily sold in local markets but trading routes for gill plates are unclear as enforcement has disrupted known connections between Lamakera and major export hubs.

Interviews with fishers and traders in Tanjung Luar and Lamakera were consistent with intelligence information (Table 2). All interviewed traders reported that they no longer trade manta; all interviewees in Tanjung Luar reported that no one they know trades manta products; and all interviewees in Lamakera reported two known traders. Perceived risk of enforcement for all interviewed traders was that it was "very likely", with comments that they are the "targets" for enforcement and that it is "difficult to cheat".

Local average manta gill plate prices declined in both sites between 2014 and 2015, while prices for devil ray gill plates showed little variation (Supporting Information). These local trends contrast national and international trends: national prices rose significantly in 2015, and fell again in 2016 by over 50%; average retail prices in international consumer markets remained relatively stable, but with some variability within individual countries (O'Malley et al. 2016).

A summary of all observed trends is presented in Table 4, alongside commentary on contextual considerations, judgements of each dataset's inferential weight, and plausible alternative explanations for observed trends.

Table 4. A summary of the observed trends for each dataset, with subjective judgement of inferential weight based on contextual considerations, and possible alternative explanations.

Level in trade chain	Dataset	Case study results						Alternative explanations for observed trends
		Tanjung Luar			Lamakera			
		Observed trend	Contextual considerations	Inferential weight	Observed trend	Contextual considerations	Inferential weight	
Fishing effort	Community member questionnaires	Manta fishing effort has declined since the regulation, but whether this is due to the regulation is equivocal	Sample size is small (n=5); the topic is sensitive non-response and social bias likely to be high	Low	Manta fishing effort has declined since the regulation, but whether this is due to the regulation is equivocal	Sample size is small (n=1); the topic is sensitive non-response and social likely to be high; interviewees were not consistent in their responses	Low	1. Interviewees are giving dishonest answers 2. Manta fishing effort is declining due to external influences (e.g. reduced profitability as target species)
Catch	Landings data	Manta landing occurrences significantly lower post-regulation but devil landings are not, estimated total annual catch has declined	Possible to conceal landings from enumerators so data may not be accurate	Moderate	Manta landings occurrence did not significantly decline between May 2015-July 2016, estimated total annual catch for manta has declined relative to devil	Difficult to conceal landings, but data collection methods have not been consistent over time	Moderate	1. Landings have become clandestine 2. Landings are declining due to external trade fluctuations (e.g. reduced demand) 3. Landings declining due to mantra ray population declines/natural stochasticity
Trade	Community member questionnaires	Manta trading has stopped because of the regulation	Small sample size (n=4) and the topic is sensitive, but all interviewee answers were consistent	Moderate	Manta trading has reduced since the regulation but continues, whether the reduction is due to the regulation is equivocal	Small sample size (n=3) and the topic is sensitive, but all interviewee answers were consistent	Moderate	1. Interviewees are giving dishonest answers 2. Manta trading declining due to external influences (e.g. reduced demand in consumer countries) 3. Intelligence information is incomplete and other unknown traders are operating 4. Higher level traders shifted to source from less risky locations
	Intelligence data	No suspected traders are operating in the area	Information from credible sources but could be knowledge gaps	Moderate	Two known traders are still operating in the area	Information is from trusted sources but could be knowledge gaps	Moderate	
	Law enforcement data	Two active traders have been arrested and prosecuted	Credible, verifiable source	High	One active trader has been arrested and prosecuted	Credible, verifiable source	High	
	Price data	Price has declined since the regulation	Indirect measure with multiple potential interpretations; inconsistent data collection over time	Low	Price has declined since the regulation	Low – indirect measure which could have multiple interpretations, with inconsistent data collection over time	Low	

Discussion

Using the specific case of manta ray in Indonesia, this study has developed and tested a mixed-methods approach for evaluating the impact of wildlife trade regulation on species exploitation and trade in a source country. The findings have implications for the effectiveness of the manta ray regulation and its monitoring and implementation in Indonesia, and can provide general lessons for future impact evaluation of wildlife trade policy and CITES decisions.

Impact evaluation

Results from the case studies indicate that the regulation is having some impact, although the nature and magnitude of this impact remain unclear.

In Tanjung Luar, interviewees reported reduced manta fishing and trading because of the regulation. These reports are substantiated by an observed step-change in manta ray landing occurrences around the time the regulation was introduced, and by intelligence data suggesting that manta trading at the site has ceased. However, this does not negate the possibility that trade has gone underground. Risk of enforcement is relatively low for fishers in Tanjung Luar, and the scale of Tanjung Luar port means fishers can easily conceal catch and circumvent official channels by using mobile phones to arrange clandestine hand-offs. Further, given that manta ray is a genuine by-catch species, with local demand for mobulid meat, it is unrealistic that catch declined to zero in 2016, as landings data suggests. It is also not possible to directly attribute observed trends to the regulation. External drivers, such as declining profitability due to reduced consumer demand in China (O'Malley et al. 2016), could be playing a role. This seems plausible, as several stakeholders reported that they had stopped manta fishing or trading prior to the regulation, however similar patterns were not observed for devil rays, indicated that a profitable mobulid market still operates.

Given that over 230 manta rays were landed in Lamakera between March 2015 and July 2016, and that two known traders of meat and gill plates continue to operate, the regulation appears to have

been less successfully implemented at this site. However the observed differences between Tanjung Luar and Lamakera could be an artefact of insufficient pre-regulation data for Lamakera and more open noncompliance with the regulation, particularly as concealing illegal catch is more challenging in the small and relatively self-contained site. Lamakera also began with a higher baseline catch when the regulation was introduced and enforcement efforts began approximately one year later, so a time lag in response to the regulation is likely. Landings so far for 2016 indicate an unprecedented decline in manta ray catch relative to devil ray, which could be the beginning of the regulation, and associated enforcement measures, taking effect. However the data are insufficient to statistically support this: it could also be down to seasonal or climatic (e.g. El Niño) fluctuations, and a general decline in catch over time. It is too early to tell.

It should also be acknowledged that the trade chain does not operate in isolation in these two sites: effort may have been displaced to other locations in Indonesia that are beyond the scope of this study. Data from O'Malley et al. (2016) indicates that at least 600 manta rays may have been supplied from Indonesia to meet sales, stock and source figures in Hong Kong and Guangzhou in 2015. If this figure is correct there is a considerable gap between official combined catch figures from Indonesia's two largest mobulid fisheries (~200 in 2015) and the estimated amount of manta ray products exported to consumer markets. However this is difficult to validate, since the non-perishable nature of gill plates limits the feasibility of tracking source populations in space and time (e.g. Anderson et al. 2011).

Research needs

The primary practical and technical limitations of this study include: data limitations, biases and system complexity. I discuss each of these in turn, with suggests for future improvement.

Data limitations

Inconsistent data collection means that different datasets cannot be reliably compared across time and space. For landings data, these inconsistencies reduced the effective datasets to relatively small samples, which were zero-inflated, creating limitations for statistical modelling. A structured, long-term data

collection program, linked to a centralised database that integrates data across space and time, could improve consistency and pooling of data. In the past, robust analyses of wildlife trade data have often been based on global, longitudinal datasets such as the CITES Elephant Trade Information System (ETIS) and Monitoring the Illegal Killing of Elephants (MIKE) databases (Underwood et al. 2013). Other statistical methods adapted for zero-inflated data (Zuur et al. 2009) could also help to improve future analyses.

Bias

All of the datasets used in this analysis were vulnerable to bias. Collecting and triangulating multiple datasets can help to highlight and correct for bias (Gavin et al. 2010), and a future monitoring program for manta ray trade would benefit from gathering at least three independent datasets, such as landings, seizures, and local meat sales, to compare patterns within and between data.

Modelling can support dataset comparisons by correcting for biases and uncertainties (Gavin et al. 2010), but appropriate metadata is required (e.g. Underwood et al. 2013). Systems for recording intelligence collection and law enforcement effort could help to make these datasets more suitable for assessing manta trade patterns.

Innovative techniques to reduce bias in social research methods, such as sensitive questioning techniques (Nuno & St John 2015), also have potential, although their utility is limited in the specific context of Indonesia's manta ray trade, as low prevalence and actor inter-dependency would affect statistical analysis. Alternatively, technology could play a role in facilitating participatory monitoring of illegal catch (Vitos et al. 2013) and reducing bias (Langhaug et al. 2010) through a system of anonymous, smartphone-based logbooks.

System complexity

To develop an operational monitoring framework it was necessary to create a simplified conceptual model of the trade chain, but many confounding factors beyond the scope of the study could not be controlled for. Experimental or quasi-experimental design studies can help to eliminate confounding factors (Ferraro, 2009), but this approach is not suited to all systems, often due to a lack of appropriate

controls, which is a challenge in the case of manta trade. Nonetheless, the broader impact evaluation literature offers a range of methods for casual inference, suitable to almost any aim, budget and dataset (Margoluis et al. 2009; Woodhouse et al. 2016), which can be drawn from for future work.

Place-based factors also create limitations for applying general frameworks (Berkes 2007; Lejano & Ingram 2007). Understanding place is particularly relevant for contextualising the different results for Tanjung Luar and Lamakera, as there are a number of possible place-specific explanations, including: different data biases, different site-based enforcement effort, and different social responses to the regulation. Reconciling localised nuances with general monitoring frameworks can be problematic, but one solution is to combine etic and emic approaches, applying externally valid methods that enable extrapolation and cross-case comparison alongside internally valid methods that are tailored to local conditions. Place-based thinking could also better identify relevant spatial and temporal scales in which the trade chain operates to direct future research (Williams et al. 2013).

Despite these limitations, we should not let the perfect be the enemy of the good: this study is a first step towards creating a robust monitoring and evaluation framework, and it is hoped the findings will motivate discussion and further research at the necessary spatial and temporal scales.

Recommendations

Social considerations

"Regulation will not always, and not alone, effectively address conservation problems" (Cooney 2003)

To date, Indonesia's manta ray regulation has primarily been implemented by means of enforcement. There are a number of issues with this approach, which may explain the questionable effectiveness of the regulation: enforcement can drive trade underground; undermine positive incentives for conservation; fail to address drivers of conservation problems; and be socially costly, which in turn can undermine legitimacy (Challender et al. 2015; Arias 2015). Previous case studies also suggest that enforcement is

particularly ineffective for large species that yield high value products, which are in high demand in Asian markets and easy to smuggle (tSas-Rolfes 2000). Therefore, enforcement alone is unlikely to successfully curb manta ray exploitation.

Lessons from drug policy indicate that although enforcement is often necessary to control illicit trade, it can lead to paradoxical outcomes, which depend on the specific mix of regulatory instruments and market environment (Poret 2002). Other cases from marine protected areas indicate that social factors can ultimately determine the long-term biological success of regulations (Christie 2004). These examples highlight the context-dependency of compliance management and, therefore, the need to better understand socioeconomic nuances (Arias 2015). Further, since conservation should "do no harm", and enforcement can have disproportionately negative impacts on the poor (Arias 2015), there is a moral and practical impetus for paying more attention to the socioeconomic dimensions of the manta trade.

It is also widely recognised that the same general solution will not work for all circumstances (e.g. Lejano & Ingram 2007) and since the regulation has had different impacts in Tanjung Luar and Lamakera, it is important to understand what has shaped responses in each site. Manta ray hunting has cultural value in Lamakera, and enforcing the regulation could create a conservation conflict. Further, there is a sizable local market for manta ray meat in and around Lamakera, which warrants further attention, as it may be naïve to assume that disrupting trade routes to international markets will necessarily remove incentives for local exploitation. Understanding these nuances will be crucial for designing appropriate local interventions that foster compliance (St John et al. 2010) and prevent negative consequences for people and wildlife (Lejano & Ingram 2007). Approaches from social sciences such as scenarios, experimental games, choice experiments and participatory impact evaluation could build trust with communities, highlight unintended socioeconomic consequences of the regulation, indirectly reveal new information on the manta ray trade chain, and identify opportunities to improve implementation.

Broader horizons

This study covers a small part of the manta ray trade chain, but manta rays are caught and traded across the globe, with diffuse supply-chains make them vulnerable to sequential depletion by roving bandits (Berkes et al. 2006). Therefore long-term manta conservation depends on a concerted international effort. Improving traceability (e.g. Hinsley et al. 2016) and understating broader trade characteristics, such as other sources, stockpiles and time lags, are necessary for characterising the trade on a global scale. Further, since demand-reduction has, in many cases, been the most effective approach for controlling wildlife trade (Challender et al. 2015), and may have already yielded promising results in China's gill plate market (O'Malley et al. 2016), efforts in consumer countries will be crucial.

The future of wildlife policy impact evaluation

More broadly, this study provides important lessons for evaluating the impacts of future wildlife trade regulations and CITES decisions. Making reasonable inferences about the impacts of wildlife trade regulations requires mixed-methods, multiple datasets, and acknowledgement of bias and complexity. These types of evaluations can benefit from: 1) integrated monitoring programmes, which collect data from multiple levels of a trade chain, and are ideally in place before regulations come in to force, and 2) methodological innovations in the way we use trade monitoring data, which cross epistemological divides. Crucially, a combination of qualitative and quantitative methods is required to not only observe trends but to understand the systems and context that create those trends. Such approaches can strengthen causal inference and attribution, and ultimately shape more informed and appropriate interventions into the complex human-nature relation.

Acknowledgments

This study was supported by Imperial College London and the Wildlife Conservation Society, with financial support from the Darwin Initiative and Vulcan. I thank Tom Clements, Simon Pooley and E.J. Milner-Gulland for their indispensable advice; and the many experts, practitioners and stakeholders who offered their time and knowledge to this process.

Supporting information

Further details on semi-structured interviews (S1-2); monitoring framework development (S3-5); background on case study sites (S6); secondary data sources (S7); community questionnaire methods (S8); catch data analysis and model outputs (S9); and price data analysis (S10); are available in appendices.

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S1 Semi-structured interview template

Semi-structured interview:
Non-sensitive stakeholders

Section 1: Participant information

You are being invited to take part in a research study by the Wildlife Conservation Society. Before you decide to participate it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please feel free to discuss it with others and ask any questions you wish. Let us know if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you in advance for reading this.

Aim
The overall aim of this study is to investigate the impacts of the national ban on fishing and trade of Manta Ray in Indonesia**,** as part of the Wildlife Conservation Society's conservation and research efforts.

If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form (Section 2), although you will still be free to withdraw at any time and without giving a reason.

What will happen if I decide to take part?
This interview will take approximately one hour, but it may be longer or shorter depending on the length of answers and discussion. I have a number of topics I would like to cover during this time, and you will have the freedom to express your views in your own terms.

This entire research project is being conducted during May-September 2016. This interview is a one off, although you may be contacted after this interview for some follow-up questions if you are willing.

What are the possible benefits of taking part?
We cannot promise the study will help you directly, but the information we get might help improve the monitoring, management and protection of manta ray in Indonesia.

What if something goes wrong?
If you have any issues or complaints regarding this study and/or your treatment as a subject, please contact the lead researcher immediately on hollie.louise.booth@gmail.com to discuss your concerns.

Will my taking part in this study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential. Any information about you which leaves the research facility or team will have your name, address and any other personal details relating to your identity removed so that you cannot be recognised from it.

What will happen to the results of the research study?
The results of this research study will be compiled into a scientific report for the Wildlife Conservation

Society and may be published in one or more scientific journals. A copy of the published results will be available online, and you can contact the lead researcher (hollie.louise.booth@gmail.com) for any questions, documents or further information

You will not be personally identified in any report or publication.

Who is organising and funding the research?
The Wildlife Conservation Society with financial support from the Darwin Initiative and Vulcan.

Who has reviewed the study?
This study has undergone external ethical review.

Contact for Further Information
For any further questions please contact the lead researcher, Hollie Booth, on hollie.louise.booth@gmail.com

Thank you for taking part!

Section 2: Informed consent

I confirm that I have read and understood the above section entitled 'participant information', and have had the opportunity to ask any questions I wish regarding the research and have had these answered satisfactorily.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. Should I choose to withdraw, any data that has been collected will be deleted.

I understand that the information I give may be used in future reports, articles or presentations by the lead researcher, but that my identity will be protected and my name will not be shared with anyone beyond the lead researcher.

I agree to participate in this research being conducted by the Wildlife Conservation Society.

Name of participant:
Signature:
Date:
Signature of person taking consent:
Signature of lead researcher:

Section 3: Personal information

Name:	**Nationality:**
Organisation:	**Position:**
Number of years working on conservation issues in Indonesia:	
Number of years working on manta ray issues in Indonesia:	
Working location (i.e. area/location they focus on during their work):	
On a scale of 1-5 (1 being novice, 5 being expert) how would you rate your level of knowledge and expertise regarding manta ray issues in Indonesia:	

1	2	3	4	5

Section 3: Personal information

4.1 Key locations

4.1.1 Can you indicate any key locations in Indonesia for manta ray hunting and trade? Please use this map for assistance if necessary.

- Situation now
- Historic - are things different now to how they were in the past, and if so why?
- Known habitat, fishing grounds, landing sites, trading centres
- Evidence that the knowledge is based on and estimate of certainty (e.g. known site or suspected)
- How likely is it that there are other locations we are currently not aware of?

4.2 The system

4.2.1 Can you explain in more detail your understanding of how the system/supply chain works (i.e. how the gill plates get from the sea to the consumer)?

- Situation now
- Are things different now to how they were in the past, and if so why?
- National scale and local level
- Both gill plates and manta meat
- Who is benefiting and who is losing?

4.3 Key events

4.3.1 Can you think of any key events (either national or local) that have happened in recent years that may have influenced manta hunting and trade?

- How has [whatever it is if not the ban] affected the trade?
- How has the ban affected trade?
- Future perspectives

4.4 The ban: pros and cons

4.4.1 Now more specifically on the 2014 ban on fishing and trade - what impacts do you think the ban has had on:

- **Fishers**
- **Traders**
- **You**
- **The community/village more broadly (if applicable)**

4.4.2 Overall, I think the ban is:

Very positive	Positive	Neutral/no opinion	Negative	Very Negative

Please explain your answer:

4.5 Influencing factors

4.5.1 What do you think are the major factors that influence attitudes towards the ban for the following:

- **Fishers**
- **Traders**

4.5.2 What factors are likely to influence decisions to stop manta hunting vs. continue illegally?

- **Fishers**
- **Traders**

4.5.3 Overall, how do you think people feel about the ban?

Fishers	Happy ☺	Neutral	Sad ☹
	Peaceful ☺	Neutral	Angry ☹
	Relaxed ☺	Neutral	Worried ☹
Traders	Happy ☺	Neutral	Sad ☹
	Peaceful ☺	Neutral	Angry ☹
	Relaxed ☺	Neutral	Worried ☹
You Punishment is not high enough	Happy ☺	Neutral	Sad ☹
	Peaceful ☺	Neutral	Angry ☹
	Relaxed ☺	Neutral	Worried ☹

4.7 Communication and community engagement

4.7.1 What is your opinion on the communication of the ban to relevant communities and individuals in Indonesia:

Very good	Good	Neutral/no opinion	Poor	Very poor

Please explain your answer:

4.7.2 What kind of communication has taken place between regulatory institutions and relevant communities and individuals?

4.7.3 What is your opinion on the level of community engagement during the decision-making process?

4.7.4 Should it have been communicated better and would it have helped?

4.8 Monitoring and enforcement capacity

4.8.1 Can you describe to me your understanding of the current national capacity to monitor manta ray hunting and trade:

- Government and NGOs
- Where, how, who, how many
- Strengths and weaknesses
- Quality/accuracy of the data
- Any suggestions for improvement

4.8.2 What is your opinion on the current levels of monitoring of manta ray catch and trade

Very good	Good	Neutral/no opinion	Poor	Very Poor

Please explain your answer:

4.8.3 Can you describe to me your understanding of the current national capacity to enforce the ban on manta ray hunting and trade:

- Government and NGOs
- Where, how, who, how many
- Strengths and weaknesses
- Quality/accuracy of the data
- Any suggestions for improvement

4.8.4 What is your opinion on the level of enforcement of the ban

Very good	Good	Neutral/no opinion	Poor	Very Poor

Please explain your answer:

4.8.4 What do you think could be some of the major challenges and limitations for trying to collect data on manta ray catch and trade? Why do you think these challenges and limitations occur?

4.9 Other

4.9.1 Can you recommend anyone else who we should contact to discuss this research?

4.9.2 Do you have anything else you'd like to add on this topic that has not already been covered in the scope of these questions?

4.10.3 Are you happy to be contacted after this interview by a member of the research team, if we require any further information or clarifications?

S2 Non-sensitive stakeholder interviewee list

Name	Organisation and position	Date	Interview method(s)	Language	Interviewer
1. Sarah Lewis	The Manta Trust, Indonesian Manta Project	17/06/2016	Unstructured interview and semi-structured interview in person	English	Hollie Booth
2. Iqbal Herwata	Reef Check Foundation Indonesia, Project Coordinator and GIS specialist	17/05/2016	Unstructured interview and semi-structured interview in person	English	Hollie Booth
3. Matt Fox	Conservation International, Marine Program Advisor	07/06/2016	Unstructured interview and semi-structured interview in person	English	Hollie Booth
4. Andy Harvey	Manta Watch, Director	14/06/2016	Unstructured interview and semi-structured interview in person	English	Hollie Booth
5. Vanessa Jateih	Murdoch University/Coral Reef Research Foundation, Fisheries Scientist	20/07/2016	Semi-structured interview by Skype	English	Hollie Booth
6. Abraham Sianipar	Conservation International, Elasmobranch conservation coordinator	14/06/2016	Unstructured interview and semi-structured interview in person	English	Hollie Booth
7. Peni Lestari	Wildlife Conservation Society Indonesia, Socio-economic specialist	17/06/2016	Unstructured interview and semi-structured interview in person	English	Hollie Booth
8. Dwi Adhisto	Wildlife Conservation Society Indonesia, Wildlife Trade Program Manager	29/06/2016	Unstructured interview and semi-structured interview in person	English	Hollie Booth
9. Fahmi	Indonesian Institute of Sciences (LIPI), Senior Researcher	20/07/2016	Semi-structured interview in person	Bahasa Indonesia	Devina Sandriati
10. Dharmadi	Ministry of Maritime Affairs and Fisheries (KKP), Dpt. Research and Development, Senior Researcher	18/07/2016	Semi-structured interview in person	Bahasa Indonesia	Devina Sandriati
11. Dwi Ariyoga Gautama	World Wildlife Fund for Nature (WWF) Indonesia, Fisheries Officer	21/06/2016	Semi-structured interview in person	Bahasa Indonesia	Devina Sandriati
12. Suraji	Ministry of Maritime Affairs and Fisheries (KKP), Dpt. Area and Fish Species Conservation	24/06/2016	Semi-structured interview in person	Bahasa Indonesia	Devina Sandriati
13. Mary O'Malley	WildAid, Secretary	21/05/2016	Unstructured interview only by Skype	English	Hollie Booth
14. Andy Miners	Misool Baseftin, Director	08/05/2016	Unstructured interview only in person	English	Hollie Booth
15. Elitza Germanov	Marine Megafauna Foundation, Researcher	25/05/2016	Unstructured interview only by telephone	English	Hollie Booth
16. Dewi Sari	The Manta Trust, Lamakera intern	17/05/2016	Unstructured interview only in person	English	Hollie Booth
17. Evi	The Manta Trust, Lamakera community liason	17/05/2016	Unstructured interview only in person	English	Hollie Booth
18. Iim Naimah	Ministry of Maritime Affairs and Fisheries (KKP), Dpt. Area and Fish Species Conservation, Head of Sub-Directorate of Area and Fish Species Conservation Monitoring	04/08/2016	Semi-structured interview in person	Bahasa Indonesia	Devina Sandriati
19. Apolinardus Yosef Lia Demor	DKP Larantuka, Head of Monitoring and small islands	04/08/2016	Semi-structured interview in person	Bahasa Indonesia	Popi Puspitasari
20. Frans	Marine Police, East Flores, Captain	04/08/2016	Semi-structured interview in person	Bahasa Indonesia	Popi Puspitasari
21. Huda	Wildlife Crime Unit, Team Leader of East Nusa Tenggara	29/07/2016	Semi-structured interview in person	Bahasa Indonesia	Popi Puspitasari

		patrol area				
22.	Najamudin Sayuti	Wildlife Conservation Society Indonesia, Consultant	06/06/2016	Semi-structured interview in person	Bahasa Indonesia	Popi Puspitasari
23.	Lalu Hamdi	DKP Mataram, Head of capture fisheries department	17/06/2016	Semi-structured interview in person	Bahasa Indonesia	Popi Puspitasari
24.	Lalu Adrajatun	Special Police (BPSPL), Coordinator Mataram area	16/06/2016	Semi-structured interview in person	Bahasa Indonesia	Popi Puspitasari
25.	Sabid	Ministry of Maritime Affairs and Fisheries (KKP), Field Processing and Marketing of Fishery (P2HP)	04/08/2016	Semi-structured interview in person	Bahasa Indonesia	Popi Puspitasari
26.	Jonathan Hunter	Wildlife Conservation Society, law enforcement consultant	16/08/2016	Unstructured interview only by Skype	English	Hollie Booth

S3 Online survey for expert review of monitoring framework

Introduction

Participant information

You are being invited to take part in a research study by the Wildlife Conservation Society. Before you decide to participate it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully, and feel free to discuss with others and ask any questions you wish. Let us know if there is anything that is not clear or if you would like more information.

Thank you in advance for reading this.

Aim
This survey is part of a wider study to investigate the impacts of the national ban on catch and trade of Manta Ray in Indonesia.

In order to conduct this study, we need to understand the different types of data and methods available for monitoring levels of illegal catch and trade, and their pros and cons. The survey therefore aims to present different types of data and methods that could plausibly be used to measure and monitor manta ray take and trade, and evaluate them in terms of their feasibility, cost-effectiveness and accuracy.

What will happen if I decide to take part?
This survey will take approximately 20 minutes, but it may be longer or shorter depending on how much you elaborate on your answers. You will be asked to consider multiple indicators and data sources, review them in terms of feasibility, cost-effectiveness and accuracy, and then asked to explain your answers in more detail, during which you will have the freedom to express your views in your own terms.

What are the possible benefits of taking part?
The information provided will be used to help to improve the monitoring, management and protection of manta rays in Indonesia.

What if something goes wrong?
If you have any issues or complaints regarding this study and/or your treatment as a subject, please contact Peni Lestari (plestari@wcs.org) immediately or contact WCS Indonesia Program on +62 251 8342135/+62 251 8306029 to discuss your concerns.

Will my taking part in this study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential. Any information about you which leaves the research facility or team will have your name and any other personal details relating to your identity removed so that you cannot be recognised from it.

What will happen to the results of the research study?
The results of this research study will be compiled into a scientific report for the Wildlife Conservation Society and may be published in one or more scientific journals. A copy of the published results will be available online, and you can contact Peni Lestari (plestari@wcs.org) as the person in charge for any questions, documents or further information. You will not be personally identified in any report or publication.

Who is organising and funding the research?
The Wildlife Conservation Society with financial support from the Darwin Initiative.

Deadline for responses
We would appreciate responses by 31sth July 2016.

Contact for Further Information
For any further questions please contact Peni Lestari (plestari@wcs.org) or WCS Indonesia Program on +62 251 8342135/+62 251 8306029.

Thank you for taking part!

I confirm that I have read and understood the above information, and have had the opportunity to ask any questions I wish regarding the research and have had these answered satisfactorily.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. Should I choose to withdraw, any data that has been collected will be deleted.

I understand that the information I give may be used in future reports, articles or presentations by the lead researcher, but that my identity will be protected and my name will not be shared with anyone beyond the lead researcher.

By choosing the 'I agree' option below, you hereby agree to participate in this research being conducted by the Wildlife Conservation Society.

◯ I agree

Respondent Information

Name

Organisation

Nationality

Area(s) of expertise (please tick all that apply)

- [ ] Manta ray ecology
- [ ] Marine conservation
- [ ] Illegal wildlife trade
- [ ] Other (please specify)

On a scale of 1-5, 1 being a novice and 5 being an expert, please provide a self-assessed rating of you level of knowledge and expertise regarding the topic of this survey

- ( ) 1 - Novice / very poor knowledge
- ( ) 2 - Somewhat of a novice / poor knowledge
- ( ) 3 - Neither novice nor expert / some knowledge
- ( ) 4 - Somewhat of an expert /good knowledge
- ( ) 5 - Expert / very good knowledge

Indicator review

In the sections that follow you will be presented with a number of different indicators of manta ray catch and trade, along with a number of potential data sources and methods corresponding to each indicator. The sections are divided as follows:

- **Indicator 1: Population trends**
- **Indicator 2: Estimated illegal catch**
- **Indicator 3: Estimated illegal fishing effort**
- **Indicator 4: Estimated illegal trade**
- **Indicator 5: Estimated consumption**

Please rate each data source and method based on your subjective perception of theirfeasibility, cost effectiveness and accuracy, and explain your answers.

For the purposes of this survey, we define the terms as follow:

Feasibility: the degree of being easily or conveniently done. In this context, the degree to which a particular method or type of data can be easily or conveniently implemented/collected.
Cost-effectiveness: the degree of being good value for money in terms of the amount of the outcome produced and the time, effort and money spent to achieve the outcome. In this context, the degree to which a particular method or type of data can be economically implemented/collected.
Accuracy: the degree of being both true and consistent. In this context, the degree to which a particular method or type of data can provide a true and consistent measure for illegal manta ray take and trade.

Indicator 1: Population Trends

This page covers data sources and methods for monitoring manta population trends.

Indicator 1: Manta ray population trends

Date source: Sightings data

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost-effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Indicator 1: Manta ray population trends

Date source: Capture-recapture (sightings and re-sightings)

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost-effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Indicator 1: Population Trends

Please rank **all of the data sources for manta population trends** in terms of their overall importance for monitoring manta ray populations

- [ ] Sightings
- [ ] Capture-recapture
- [ ] Other (please specify below)

Please add any other comments or suggestions for data sources and methods relevent to this indicator

Indicator 2: Estimated illegal catch

This page covers data sources and methods for monitoring manta ray catch.

Estimated manta ray catch

Data source: Landings data from direct questioning with fisher communities

	Very good	Good	Neutral/no opinon	Poor	Very poor
Feasibility	○	○	○	○	○
Cost-effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated manta ray catch

Date source: Landings data from official enumerators

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated manta ray catch

Date source: Landings data from covert observers and informers (i.e. wildlife crime intelligence information)

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated manta ray catch

Date source: Landings data from citizen science anonymous hotline

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated manta ray catch

Date source: Estimated catch from sensitive questioning techniques***

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

*** **Sensitive questioning techniques**, also known as 'indirect questioning techniques' have been developed in disciplines including political and health sciences to ensure respondent anonymity, increase willingness to answer honestly, and make it impossible to directly link incriminating data to an individual. Despite some recent applications, most of these techniques have not been applied within a conservation and natural resource management context. This suggests potential to ask about illegal or otherwise sensitive topics using novel survey techniques, but also requires caution in terms of how effective they can be in a conservation context. In particular, many of the techniques rely on statistical methods to estimate the overall prevalence of a sensitive behaviour within a population, thus necessitating large sample sizes, independent individual behaviour, and/or considerable levels of prevalence in order to identify significant results. For more information, see A. Nuno, F.A.V. ST. John / Biological Conservation 189 (2015) 5–15 or contact the survey administrator via Skype, phone or email.

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Indicator 2: Estimated illegal catch

Please rank **all of the data sources for estimated illegal manta ray catch**in terms of their overall importance for monitoring illegal manta ray catch

- [ ] Landings data from direct questioning with fisher communities
- [ ] Landings data from official enumerators
- [ ] Landings data from covert observers and informers (intelligence)
- [ ] Landings data from citizen science anonymous hotline
- [ ] Estimated catch from sensitive questioning techniques
- [ ] Other (please specify below)

Please add any other comments or suggestions for data sources and methods relevent to this indicator

Indicator 3: Estimated illegal fishing effort

This page covers data sources and methods for monitoring illegal fishing effort.

Estimated illegal fishing effort

Data source: Number of suspected fishing boats/fishers based on covert observers and informers (i.e. wildlife crime intelligence information)

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal fishing effort

Data source: Number of suspected fishing boats and/or fishers from direct questioning with fisher communities

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal fishing effort

Data source: Number of known illegal fishing incidents from marine patrol reports

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility

Cost-effectiveness

Accuracy

Estimated illegal fishing effort

Date source: Estimated prevalence of manta fishing using sensitive questioning techniques

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility

Cost-effectiveness

Accuracy

Indicator 3: Estimated illegal fishing effort

Please rank **all of the data sources for estimated illegal fishing effort** in terms of their overall importance for monitoring illegal manta ray catch

- [ ] Number of suspected fishing boats and/or fishers based on covert observers and informers (intelligence)
- [ ] Number of fishing boats and/or fishers from direct questioning with fisher communities
- [ ] Number of known illegal fishing incidents from marine patrols
- [ ] Estimated prevalence of manta fishing using sensitive questioning techniques
- [ ] Other (please specify below)

Please add any other comments or suggestions for data sources and methods relevent to this indicator

Indicator 4: Estimated illegal trade

This page covers data sources and methods for monitoring illegal trade.

Estimated illegal trade

Date source: Quantity of manta products in trade based on covert observers and informers (i.e. wildlife crime intelligence information)

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal trade

Date source: Number of suspected traders based on covert observers and informers (i.e. wildlife crime intelligence information)

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal trade

Date source: Quantity of manta products confiscated during enforcement actions

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal trade

Date source: Quantity of manta products in trade based on direct questioning with local traders in fisher communities

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal trade

Date source: Quantity of manta products in trade based on local market surveys in fisher communities

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal trade

Date source: Quantity of gill plates supplied from Indonesia on sale in major international consumer markets (E.g. China and Hong Kong), based on market surveys

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal trade

Date source: local trading prices for manta products, based on direct questioning with local fishers and traders

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal trade

Date source: national trading prices for gill plates at middleman and large trader level, based on covert observers and informers (i.e. wildlife crime intelligence information)

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated illegal trade

Date source: international trading price for manta products in major consumer markets (E.g. China and Hong Kong), based on market surveys

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Indicator 4: Estimated illegal trade

Please rank **all of the data sources for estimated illegal trade** in terms of their overall importance for monitoring illegal trade

- [ ] Quantity of manta products in trade based on covert observers and informers (intelligence)
- [ ] Number of suspected traders based on covert observers and informers (intelligence)
- [ ] Quantity of manta products confiscated during law enforcement actions
- [ ] Quantity of manta products in trade based on direct questioning with fisher communities
- [ ] Quantity of manta products in trade based on local market surveys in fishing communities
- [ ] Quantities of gill plates supplied from Indonesia on sale in consumer markets, based on market surveys
- [ ] Local trading prices for manta products, based on direct questioning in fisher communities
- [ ] National trading prices for manta products, based on covert observers and informers (intelligence)
- [ ] International trading price for manta products, based on market surveys in consumer countries
- [ ] Other (please specify below)

Please add any other comments or suggestions for data sources and methods relevent to this indicator

Indicator 5: Estimated consumption

This page covers data sources and methods for monitoring consumption of manta ray products.

Estimated consumption

Date source: Prevalence of local manta meat consumption through direct questioning with fisher communities

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated consumption

Date source: Prevalence of local manta meat consumption using sensitive questioning techniques in fisher communities

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Estimated consumption

Date source: International consumption of manta products from consumer surveys in consumer countries

	Very good	Good	Neutral/no opinion	Poor	Very poor
Feasibility	○	○	○	○	○
Cost effectiveness	○	○	○	○	○
Accuracy	○	○	○	○	○

Please explain your answers

Feasibility	
Cost-effectiveness	
Accuracy	

Indicator 5: Estimated consumption

Please rank **all of the data sources for estimated consumption** in terms of their overall importance for monitoring consumption of manta ray products.

- [ ] Prevalence of local manta meat consumption based on direct questioning with fisher communities
- [ ] Estimated prevalence of local manta meat consumption using sensitive questioning techniques
- [ ] International consumption of manta products based on consumer surveys in consumer countries
- [ ] Other (please specify below)

Please add any other comments or suggestions for data sources and methods relevent to this indicator

Overall indicator ranking

Almost there! Final question...

Please rank the five overarching indicators on their overall importance for monitoring manta ray hunting and trade

- [ ] Manta ray population estimates
- [ ] Estimated illegal catch
- [ ] Estimated illegal fishing effort
- [ ] Estimated illegal trade
- [ ] Estimated consumption
- [ ] Other (please specify below)

Please use this space to provide any additional comments/information on anything that has not already been covered in the scope of this survey

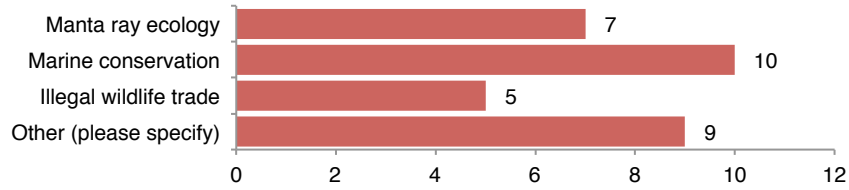
Survey complete

Thank you for taking part! Your contributions will help WCS to design improved monitoring protocols for manta ray catch and trade.

S4 Summary statistics of online survey respondents

Q. Area(s) of expertise (please tick all that apply)

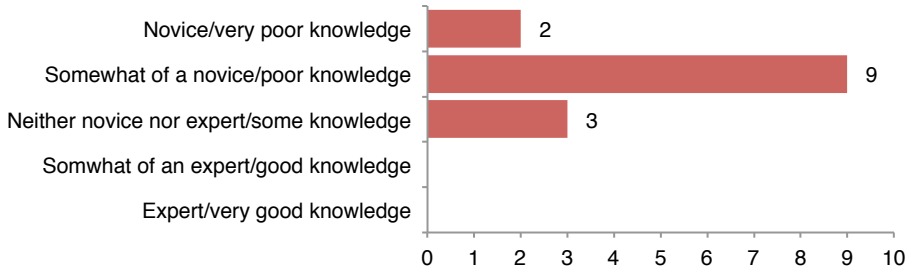
Total responses: 13



Other included: elasmobranchs; shark and ray biology; Indonesian elasmobranch conservation; fisheries management; seafood trade; fisheries science and governance; shark fisheries in eastern Indonesia; online trade; microplastics

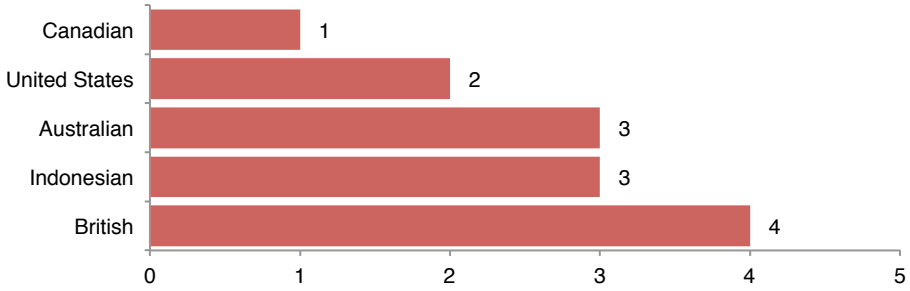
Q. On a scale of 1-5, 1 being a novice and 5 being an expert, please provide a self-assessed rating of you level of knowledge and expertise regarding the topic of this survey

Total responses: 13



Q. Nationality

Total responses: 13



S5 Summary of monitoring framework review

Indicator		Type of data – method	Pros	Cons	Data characteristics			Trialled in this study?
					Feasible	Cost effective	Accurate	
1	**Manta ray population trends**	Population estimates - sightings data	Data collection can be very low cost high volume Good for site-level monitoring	Patchy sampling Difficultly drawing conclusions for wider population Difficultly verifying data Population estimates not yet available	✓	✓	✓	No
		Population estimates - mark-recapture	Data collection and site-level benefits as above Relatively easy to do with simple technology Data verifiable as requires photos	Sampling and wider population challenges as above Models must be able to differentiate resident and transient populations if they are to be effective Population estimates not yet available	✓	✓	✓	No
2	**Estimated illegal fishing effort**	Number of suspected fishing boats/fishers - covert observation	Not technically complex to collect Low vulnerability to dishonesty/high reliability of data	Sampling not systematic Resource intensive to scale up for national coverage Risky for observers and difficult to recruit reliably Difficult to establish relationship with total take	~	~	✓	No
		Estimated prevalence of manta fishing - sensitive questioning techniques	Can encourage honest responses Maintains anonymity of respondents	Resource challenges as above Problematic to apply probabilistic analysis in this context Requires large sample size and community buy-in	✓	~	✓	No
		Number of suspected fishing boats and/or fishers - direct questioning with fishers	In principle, relatively easy to implement at the site-level	Resource challenges as above Context dependent bias – depends on openness of behaviour and relationship between fishers and data collector Difficult to establish relationship with total take	✓	✓	~	Yes
		Number of illegal fishing incidents from marine patrol reports – LE monitoring	Relatively easy to get data where there is already an enforcement effort	Sampling unsystematic/opportunistic/biased Context dependent bias – depends on capacity and integrity of LE officers Patrol costs can be high	~	~	~	No
3	**Illegal manta ray catch**	Landings data - covert observation	Low vulnerability to dishonesty/high reliability of data	Sampling unsystematic/opportunistic/biased Inaccurate numbers if high volumes of illegal catch Resource intensive to scale up for national coverage Risky for observers and difficult to recruit reliably	~	~	✓	No
		Landings data - official enumerators	Relatively easy to implement at the site-level	Accuracy context dependent – depends on openness of illegal landings and integrity and capacity of enumerators Resource intensive to scale up for national coverage	✓	~	~	Yes
		Landings data - direct questioning with fishers	Implementation benefits as above	Resource challenges as above Context dependent bias – depends on openness of illegal landings and relationship between fishers and data collector	✓	✓	~	Yes
		Estimated take - sensitive questioning techniques	Can encourage honest responses Maintains anonymity of respondents	Resource challenges as above Problematic to apply probabilistic analysis in this context Requires large sample size and community buy-in	~	~	~	No
		Landings data - citizen science anonymous hotline	Reduces peer pressure biases Maintains anonymity of respondents Could be low cost high volume once established	Patchy sampling Difficulty verifying data Could be costly to establish and sufficiently promote	~	~	~	No
4	**Estimated illegal trade**	Quantity of manta products in trade - covert observation	Low vulnerability to dishonesty/high reliability of data More cost effective than covert observation of fishers/landings as trade more consolidated	Sampling not standardised Accuracy depends on ability to scale up Risky for observers and difficult to recruit reliably	~	✓	✓	No
		Number of suspected traders – covert observation	Reliability and cost effective benefits as above	Sampling, accuracy and risk challenges as above Difficult to establish relationship with total take	✓	✓	✓	Yes
		Quantity of manta products confiscated during law enforcement (LE) actions – LE monitoring	Relatively easy to get data where there is already an enforcement effort Data verifiable as based on physical evidence	Sampling unsystematic/opportunistic/biased Difficult to standardise effort across LE actions Need lots of detailed metadata to extrapolate to total take	✓	~	~	No

		Quantity of manta products in trade in fisher communities - market surveys	More objective as relies on direct observation and not on individuals concerned to share sensitive information	Access and accuracy depends on openness of trade Species identification issues	✓	~	~	No
		Quantity of manta products from Indonesia on sale in international consumer markets - market surveys	Can provide an indication of overall volumes leaving Indonesia More cost effective than monitoring take as trade more consolidated	Difficult to get reliable information on supply country Accuracy depends on openness of trade Resource intensive to get good international coverage	~	~	~	Yes
		Quantity of manta products in trade - direct questioning with local traders	Relatively easy to implement at the site-level More cost effective than direct questioning of fishers as trade more consolidated	Context dependent bias – depends on openness of trade and relationship between traders and data collector Resource intensive to scale up for national coverage	~	~	~	Yes
		Local trading prices for manta products - direct questioning with local fishers and traders	Easier to get accurate information on prices than quantity as doesn't necessarily require sharing of sensitive information Doesn't require a huge survey sample	Difficult to establish clear relationship between prices and overall take given other drivers in system Access and accuracy depends on openness of trade	✓	✓	✓	Yes
		National trading prices for manta products - covert observation	High reliability of information as intelligence operations often involve actual or planned transactions Easier to obtain than local prices as national trade more consolidated within a small number of trading centres	Sampling unsystematic/opportunistic/biased Difficult to establish clear relationship between prices and overall take given other drivers in system Risky for observers and difficult to recruit	~	✓	✓	Yes
		International trading prices of manta products in consumer markets - market surveys	Easier to get accurate information on prices than quantity as doesn't necessarily require sharing of sensitive information	Difficult to establish clear relationship between prices and overall take given other drivers in system Access and accuracy depends on openness of trade	✓	~	~	Yes
5	**Estimated consumption**	Prevalence of local manta meat consumption - direct questioning with fishers	In principle, relatively easy to implement at the site-level Respondents more likely to give honest responses as consumption less sensitive	Difficult to establish relationship with total take Cannot visually distinguish meat of different mobulids Resource intensive to scale up for national coverage Results likely to present cultural bias	✓	~	✓	No
		Prevalence of local manta meat consumption - sensitive questioning techniques	Can encourage honest responses Maintains anonymity of respondents	Challenges as above Requires large sample size and community buy-in	✓	~	✓	No
		International consumption of manta products– consumer surveys	Easy to get honest responses where consumption is not regulated or sensitive	Could be difficult to implement on a broad enough geographic scope and scale	✓	~	~	No

Key:
✓ = Overall average rating of 'good' ~ = Overall average rating of 'average' ✗= Overall average rating of 'poor' based on ratings from online expert review.

Table shows the pros, cons and key characteristics of different types of data and methods that could feasibly be used for monitoring illegal manta ray take and trade in Indonesia. During the review experts were asked to rate the characteristics of data sources and methods using likert-type statements with options including: very good (+2), good (+1), neutral/no opinion (0), poor (-1), very poor (-2). Due the variability in responses I then classified the average scores of each data into more coarse categories good (>1.67), average (1.67<-1.67) or poor (<-1.67)

S6 Case study sites background

Tanjung Luar

Fishing behaviour

Tanjung Luar is a large, busy port that serves as a landing site for at least 1000 fishing boats. The majority of boats are owned and operated by fishers and vessel owners from Tanjung Luar or the nearby island of Gili Maringkik, but fishers from Sulawesi, Sumbawa, East Java and smaller villages in East Lombok also come to land and trade catch in Tanjung Luar. With at least 500 fisher households, a number of different fishing strategies have developed, with a range of gears, vessel types and target species including sharks, rays, snapper, grouper, tuna and squid, as well as smaller pelagic fish.

Vessels specifically targeting elasmobranchs can be divided into two categories according to engine power and fishing behaviour: large boats (15m in length) with 60HP inboard engines carry out long fishing trips of 14-17 days, reaching as far as Timor, Sumbawa and eastern Flores, while smaller (8m) boats with <23 HP inboard engines remain in coastal waters carrying out shorter trips of 1-3 days in duration. Both vessel types use longline gears, and at least 20 of each boat type are known to operate from Tanjung Luar (Efin and Made 2014a; Table 6.1, Fig. 6.1).

Historically, elasmobranch fishers operating in the larger fishing boats (60HP) have been known to specifically targeting manta, with smaller boats (23HP) usually catching smaller sharks and rays up to 1.5m (Efin and Made 2014a). However other fishers have been known to catch manta as opportunistic and accidental by-catch.

Table 6.1. Details of elasmobranch fishing boats operating from Tanjung Luar, taken from Efin and Made (2014a)

Engine power (HP)	Engine type	Boat material	Boat size (m)	Boat crew (people)	Fishing gears	Number of boats (unit)	Fishing ground	Distance to fishing grounds (km)	Fishing trip duration (days)	Fuel consumption (litre/trip)
60	Inboard	Wooden	15	4	Drift/bottom longlines	22	Sumba Island, south of Sumbawa, West Sumba and South Sumba, Savu Sea and Flores Sea	300 – 500	14 -17	300 – 500
< 23	Outboard	Wooden	8	2-3	Bottom longlines	22	Awang Bay, South of Kuta Lombok, Alas Strait, Panjang Island in Sumbawa	20 – 60	2- 3	50 – 100

Figure 6.1. Fishing grounds for elasmobranch fisherman in Tanjung Luar, taken from Efin and Made (2014a)

Local trading and consumption

Prior to the regulation there were several stages in the manta ray supply chain even at the local level, with people employed in fishing, collecting, processing and local trading (Fig 6.2).

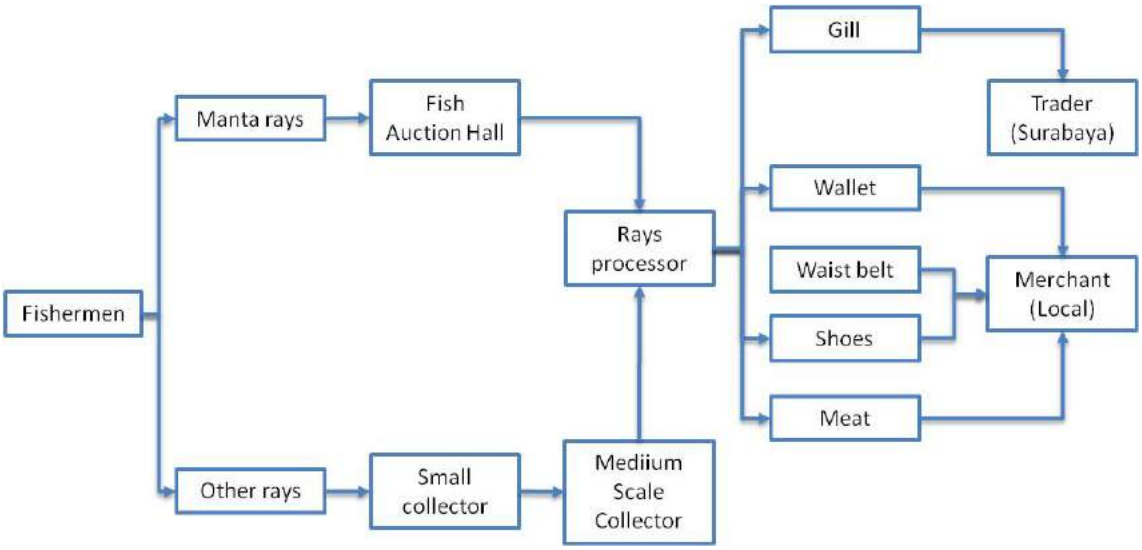


Fig 6.2. Local ray supply chain in Tanjung Luar, pre-regulation. Taken from Efin and Made (2014a)

Mobulid skin and meat has local value, with wallets, belts and shoes produced from the skin, and fish satay referred to locally as 'kluyu' produced from the meat. All mobulid meat is processed in the same way, and sold and consumed under the same name, making it visually indistinguishable at the market and consumer level: "Meat can easily be disguised as mobula. After process it further and make a satay or other food format you wouldn't recognise it's manta meat" (P. Lestari, personal communication, 2016).

Culture and traditions relating to manta ray

There does not appear to be a strong tradition of fishing, trading and consuming manta ray. Interestingly, one village leader interviewed stated that manta fishing is "unimportant" for people in Tanjung Luar because only a "small number of manta fishers are originally from Tanjung Luar". Despite this, manta ray consumption may have been incorporated into local culture and traditions to some degree, as an easily accessible source of meat during large celebrations: "a tradition after people

die, on the 9th day they hold a big celebration and it is easier to get manta than to buy cow or buffalo" (P. Lestari, personal communication, 2016).

Regulation implementation

Since 2013, WCS has conducted daily monitoring of elasmobranch catch in Tanjung Luar. A total of four enumerators (three from WCS, one from MMAF) are currently employed, primarily based in the shark auction hall, where elasmobranch landings are measured and sold. Since Tanjung Luar is a large, busy port without a structured system for monitoring all boats from the point of docking, it is very easy for fishers to circumvent the auction hall. Fishers may already dissect mantas out at sea and hide the parts within or beneath ice and other legal take: "when you already cut it I'm not sure how the government or law enforcement officer can check" (P. Lestari, personal communication, 2016). This risk was confirmed by a local government monitoring officer in Tanjung Luar who commented "mobula also need to banned in order to make monitoring easier, especially if [manta] already cut". In addition, with good transport and telecommunications, it is possible to arrange clandestine sales: "They can land everywhere. Now with mobile phone access if someone got something very valuable they can contact the direct buyer and the buyer will come and park outside the auction place and the fisher will directly take it to the car without anyone knowing about it." (P. Lestari, personal communication, 2016).

A small team of covert wildlife crime informers operates at several landing sites and markets in east Lombok, while fishers reported awareness of overt policing efforts in the form of marine patrols, but the frequency and location of the patrols is unclear. Those conducting monitoring lack a remit to enforce the law, and any law enforcement operations must be planned and coordinated with appropriate regulatory authorities.

Since the regulation came in to force in February 2014, a total of three fish traders from Tanjung Luar have been arrested for illegally trading manta ray products. Of these, two have been prosecuted and received fines and prison sentences; the other case is pending. These arrests are common knowledge among the fishers interviewed for this study, and were reported as the most significant factor in influencing decisions of both fishers and traders to refrain from conducting illegal activities

related to manta, although no fishers have been arrested to date. Despite a number of socialization events conducted by WCS and MMAF since the introduction of the regulation, including a large event in Tanjung Luar in September 2014 which used a traditional puppet show as a means of communicating the regulation to more than 1,000 fishers, communication was generally felt to be insufficient and poorly timed, with a lack of engagement at the local user level. Nonetheless, all interviewed individuals fully understood the regulation and its implications, although many did not understand why or see any value in the regulation. "They know [catching manta] is illegal and they want to abide by the law, but they don't agree with the regulation" (P. Lestari, personal communication 2016)

To date it appears that no tangible compensation or alternative livelihoods intervention has been introduced to replace income foregone as a result of the regulation, which was a grievance for several interviewed individuals. The majority of interviewed fishers and traders reported income declines with general feelings of increasing livelihood insecurity due to increasing government restrictions, increasing operational costs, changing supply chains, lower fish stocks and increasingly unpredictable weather.

Summary of key interview stats

Understanding and compliance

All respondents (n=9) reported that they no longer fish or trade manta, but used to in the past (Figure 6.3). Half of respondents reported that they also no longer fish or trade mobula either. Two of these were traders who "feel safer" not trading mobula because of the regulation All respondents were fully aware of the regulation and could explain what it was and its implications. Two respondents, although they are no longer fishing manta, did not change because of the regulation – they had changed their target species/fishing gear prior to the regulation anyway – suggests that manta fishing was already becoming difficult/unprofitable prior to the regulation and that other equally lucrative options are available and could be relatively easy to switch.

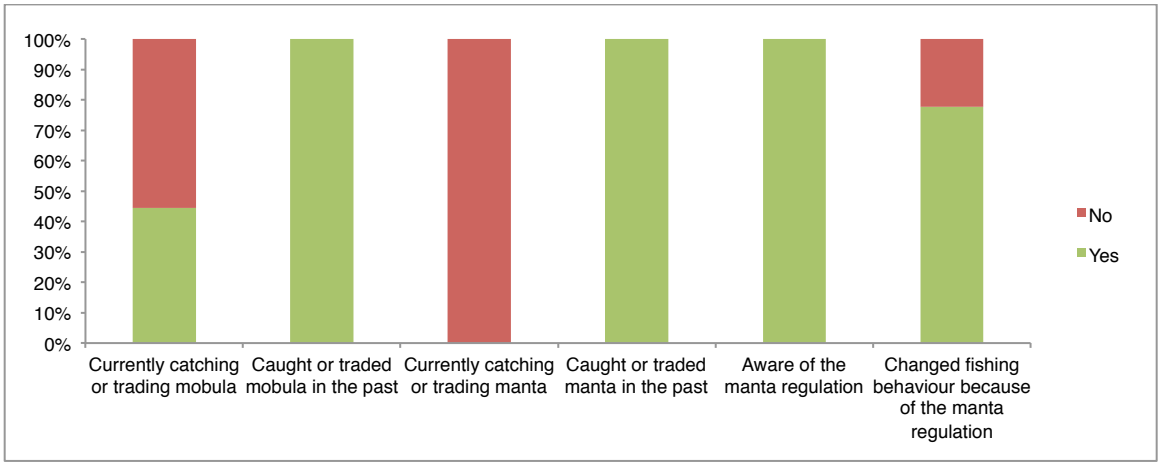


Figure 6.3: summary of responses to key understanding and compliance questions

Attitudes and opinions towards the regulation

70% of respondents are openly against the regulation, and 60% consider it 'unfair' (Fig 6.4)

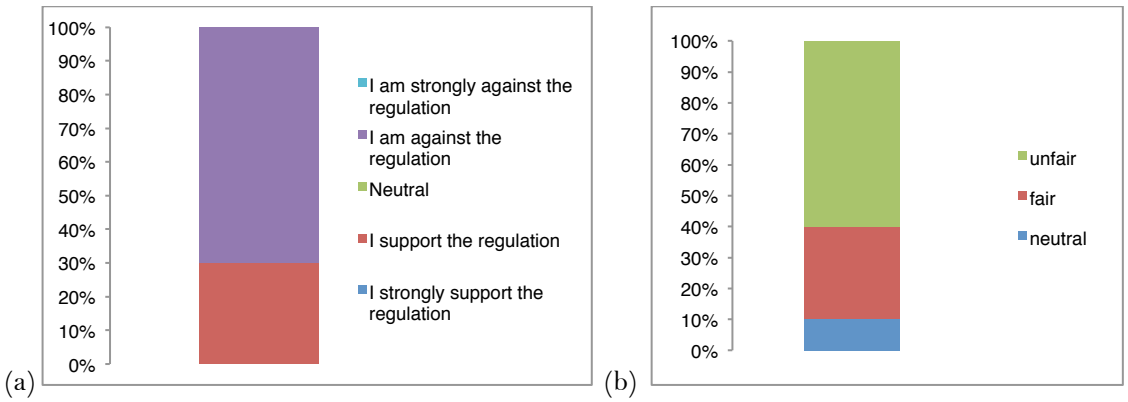


Figure 6.4: Summary of responses to key attitudes and opinions questions (a) level of support (b) perceived fairness

Responses to likert-type statements on level of support (responses rated from -2 to +2 across 5 options ranging from very negative to neutral to very positive) for the regulation were negative on average, in terms of levels of personal support, community support and perceived fairness (Fig 6.5).

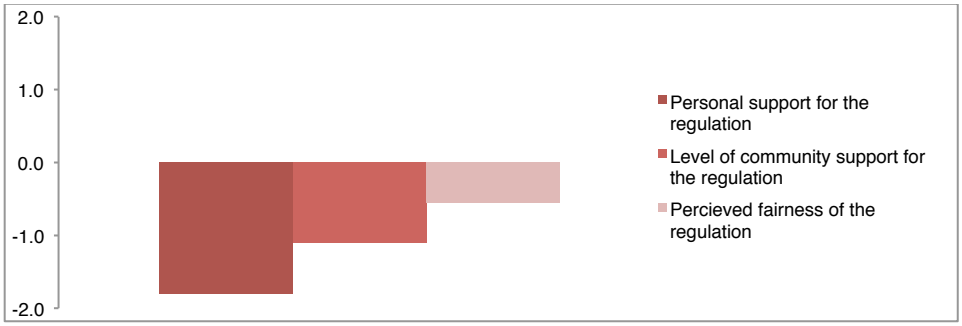


Fig 6.5. Average level of support for the regulation based on interviewee likert-type statements

Relationships and process

Relationship and communication with the government is negative on average based on responses to likert-type statements on level of support (responses rated from -2 to +2 across 5 options ranging from very negative to neutral to very positive) (Fig. 6.6)

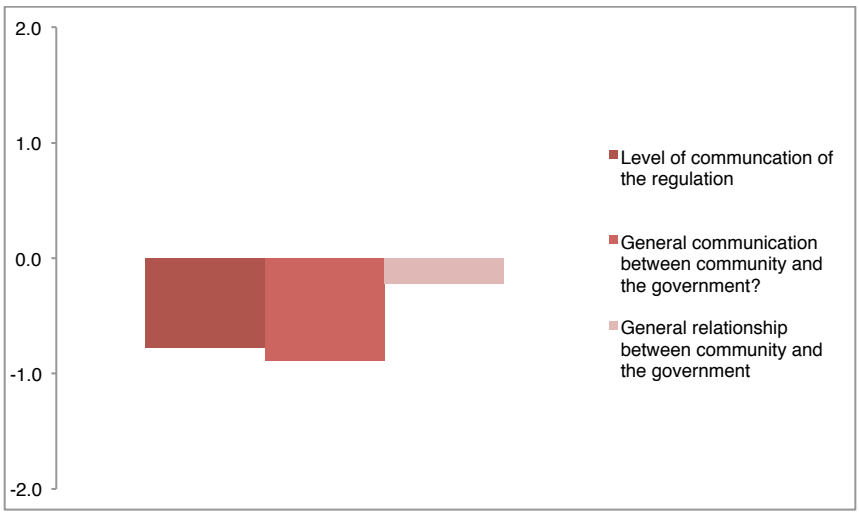


Figure 6.6: Average perceived relationship and communication with the government based on interviewee likert-type statements

Lamakera

Fishing behaviour

Lamakera is the collective name given to two adjacent but administratively distinct fishing villages in East Solor: Moton Wutun and Wotobuku. Although closely connected, both spatially and socially, the two villages have adopted slightly different fishing strategies. *Manta* spp. are the primary target species for most fishers in Moton Wutun, which they catch using specifically designed boats and harpoons. *Mobula* spp. are also targeted using this method. Conversely, fishers from Watobuku diversify their fishing behaviour: many fishers own and use several fishing gears and target several species, including snapper, grouper, tuna and sharks, but mobulids are still targeted at times, and caught as opportunistic and accidental by-catch. Lamakera's total population is approximately 2,500, with 35-40 manta-hunting boats in operation, each carrying 5-10 crewmembers. A well-established hierarchy exists on board the boats, with one 'spearing captain' who is in charge of the harpoon. These are experienced fishers from a

lineage of spearing captains, who are nominated each year by the boat owners but often remain the captain for many years. In most cases, the spearing captain harpoons the first manta of a trip, and then passes on the spear on to other crewmembers that want to practice. There is considerable prestige associated with being a spearing captain, and feelings of self-identity, personal pride and loyalty to ancestors are seemingly associated with manta hunting.

According to community interviews, mobulid hunting takes place seasonally, from late March to October, peaking in early July. This is due to climatic factors, with regular rainfall from January to March preventing adequate drying of manta products (Lewis et al 2015). During this season, major hunting events take place for 2-4 days per month when manta aggregate on the surface. Once a manta aggregation is observed, fishers will report back to the rest of the village, and manta will be intensively targeted. The timing of these events is reportedly linked to the lunar phase and oceanic upwellings/plankton concentration, and may therefore be spatially and temporally predictable (I. Herwata personal communication 2016). Mantas are targeted opportunistically for the remainder of the month. Fishing mostly takes place in one-day trips, with the boats remaining in nearby coastal waters and fishing grounds shifting according to mobulid movements (Fig 6.7).

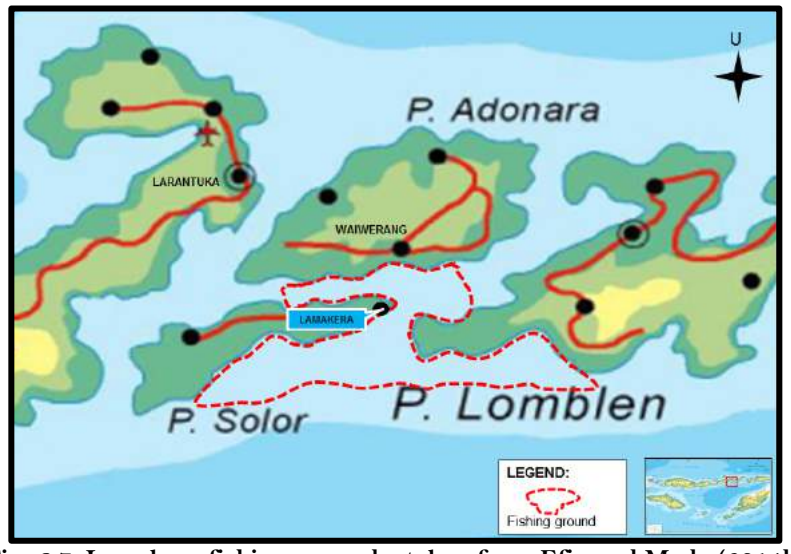


Fig. 6.7: Lamakera fishing grounds, taken from Efin and Made (2014b)

Local trade and consumption

Manta catches are shared amongst the crew, the owner of the boat, and the owner of the engine, with specific parts allocated to specific people as per the following system:

- The meat from the abdomen is divided between the boat and engine owners
- The head is given to the crew member who first spotted the animal
- The wings are divided between the remainder of the crew
- The gills are sold, and the proceeds divided equally between the crew, and the boat and engine owners

The meat is either retained by the fishermen for personal consumption or sold to local fish merchants (usually women, known locally as *papalele*). The meat is prepared for consumption by cutting it into strips, connecting the ends, and drying it in the sun. The product is known as *ikan gelang* ("fish bracelet"). *Ikan gelang* is sold on for local consumption in Lamakera, and in other nearby markets in Solor, Larantuka, Adonara and Lembata. Meat from all mobulids is prepared in exactly the same way, and is indistinguishable by species or genus without genetic testing. Lamakeran's reportedly have a strong preference for mobulid meat and reportedly enjoy the taste (D. Sari, personal communication 2016). Gill plates are sold on to specific traders who then sell the products on to buyers in Surabaya and Jakarta, where it is exported internationally. See Fig. 6.8 for supply chain schematic (Efin and Made 2014b). Manta ray fishing may also play an important safety net function, with two fishers reporting that they get 80% of their income during manta high season and then "save the money for bad season".

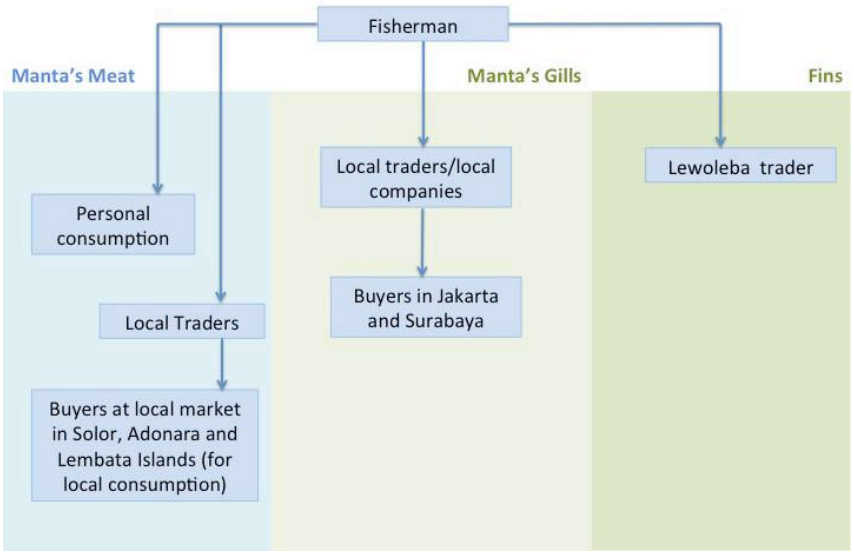


Fig 6.8: Local shark and manta ray supply chain in Lamakera, pre-regulation. Taken from Efin and Made (2014b)

Culture and traditions relating to manta ray

Opinion is divided as to the historic legacy of manta hunting in Lamakera: Lamakerans describe manta hunting as part of their cultural heritage while some interviewed NGOs and researchers claim that targeted manta hunting is not a cultural tradition, and only arose in the 1990's due to international demand for gill plates and thus increased value. According to Barnes' ethnographic study in 1996 (Barnes 1996), Lamakerans historically targeted baleen whales, although did have an established preference to hunt manta ray during August, and the number of traditions and taboos associated with manta hunting (D. Sari personal communication 2016) suggests a considerable historic legacy. Either way, it is clear that any historic hunting was non-commercialised and significantly less intensive in terms of both effort and catch. According to Dewar (2002) government subsidies in the late 90's/early 00's enabled Lamakera's fishermen to "make the same number of trips in one month (~12) that used to take the entire 6-month season." Regardless, the present reality is one in which manta hunting holds considerable intrinsic value for the people of Lamakera, particularly those in Moton Wutun. Every community member interviewee from Lamakera reported that manta ray fishing is important for their community in terms of both livelihoods and culture. E.g. "It is our culture so we must keep the tradition, and it also our main income"; "my ancestor start it in the past so I have to keep the culture [and] manta

give me high amount of money" Acknowledging this is important for understanding behavioural responses to the ban.

Regulation implementation

Through a collaborative project between Misool Baseftin, Manta Trust and Reef Check, there has been an NGO presence in Lamakera since 2013. Through this project, an enumerator has been collecting daily landings data since May 2015. Since Lamakera is relatively small and self-contained, and there have been limited efforts to hide illegal catch, this data is thought to be relatively accurate.

The Wildlife Crimes Unit (WCU) have been conducting covert monitoring of trade since 2015, leading to the arrest and prosecution of one major local gill plate trader in July 2015, who received a fine and prison sentence. Another known major gill plate trader is still active after a failed operation in early 2016, as is a well-known *papalele*.

Enforcement efforts intensified in February 2016 with the launch of overt joint marine patrols by the Wildlife Crime Unite (WCU)/Marine Police/Ministry of Marine Affairs and Fisheries (MMAF) to deter illegal hunting at the source. Due to limited resources and manpower patrols are not conducted regularly, but take place a few days per month, and are intelligence-led where possible. A terrestrial-based informer will report to the marine police and WCU when a manta hunt appears to be taking place, and this will trigger a patrol. However the perception of interviewed community members is that the patrols are regular/frequent, with some reporting that they take place "almost everyday". Anecdotally, the patrols seem to be playing both a reactive role (i.e. catching illegal fishermen after the fact) and a preventative role (i.e. chasing would-be manta illegal fishermen away before the fact and/or deterring manta hunters from going out to sea at all due to fear of enforcement), with several interviewed community members reporting feelings of "discomfort" regarding going out fishing. This strategy works relatively well in Lamakera because fishing remains within coastal waters, occurs in periods of intense targeting, and hunting boats are easily identifiable and can therefore be observed from the shore.

The response of the Lamakeran community to the regulation has been dynamic and heterogeneous, seemingly influenced by a complex interaction of history, culture, politics, household

economics, power and peer pressure. Several socialization events have taken place to communicate the regulation, jointly organised by MMAF and a number of international NGOs: one in April 2014, one in September 2015 and another in April 2016. These socialisations have yielded mixed reactions, although the most recent one was met with resistance and conflict.

In 2014, following the first socialisation, the community expressed a willingness to collaborate with NGOs and find alternatives to manta hunting. As such a livelihoods program was developed by Misool Baseftin/Manta Trust/Reef Check, which began with mutual agreement in 2015 and combined marine research and sustainable livelihoods, with the aim of providing alternatives to targeted mobulid hunting. The livelihoods program consisted of four major components: fishermen groups, textiles, fish processing and research. For the fishermen groups, fish aggregation devices have been built offshore attracting grouper and other valuable species, and fishers are required to sign official government agreements pledging not to conduct illegal activities (including manta hunting, dynamite fishing etc.) in order to gain access. For textiles, women are being supported to regain traditional skills in fabric weaving, and the fabrics are then tailored into products such as bags and wallets, which are sold to tourists in Raja Ampat via Misool Baseftin. Fish processing aims to add value to the supply chain by providing people with the skills and materials to make traditional shredded fish products which can be sold in Larantuka. For the research component, fishermen are paid for the use of their boat and a crew for the day in order to conduct species monitoring in the local area. These efforts were met with some initial success and acceptance, but were later stalled due to conflict over the regulation, which began following the arrest of the first trader in July 2015 and was still not fully resolved at the time of writing.

Located in one of the poorest parts of one of Indonesia's poorest provinces, Lamakera is a community on the margins of society. Reportedly, they rarely communicate with or get benefits from the government. It seems they have little to no engagement in decision-making and received no prior consultation or preparation regarding the manta regulation until the regulation was already in place. As a result there seems to be general feelings of negativity towards the government.

Interviewed non-sensitive stakeholders who have been working in Lamakera particularly expressed the influence of social pressure and leadership on individual behavior and decisions. Generally there is a divide between people who are willing to accept the regulation and engage with alternative livelihood opportunities, and people who are not. This was backed up by the polarised responses of interviewees in Lamakera regarding attitudes, opinions and perceived fairness of the regulation. There is also considerable evidence of conflict, with several interviewees reporting some feeling of "conflict" or "dilemma".

A small number of individuals have been strongly adverse to the ban, continuing to directly oppose it and catch manta openly since 2014, with around three major provocateurs creating the majority of the conflict. Another group of individuals (reportedly ~10% of the community) are actively in support of the intervention, while many others (~40-50% of the community) are somewhere in the middle – not openly against but not willing to engage, although several individuals have reportedly come forward to the NGO to say they would like to engage but feel like they can't because of social pressure. A mistrust of NGOs has also developed, with one interviewee reporting "we heard this regulation is supported by NGOs because they want develop tourism" and the Watobuku villager leader also stating "I strongly support the regulation but the community see the regulation as effort from NGO to develop tourism in Lamakera and that is not good for community because it will change culture. Western culture will break Lamakera's culture."

In the case of Lamakera, escalating enforcement of the regulation has played a dual role: on the one hand, it has created a deterrent against manta hunting had trade, but it has also negatively impacted the relationship between the NGO project and the community, by causing a break down of trust and increasing local conflict over the regulation.

Summary of key interview stats

It is worth noting that this was a very small (n=4) sample, and likely skewed towards people who are more in support of/less impacted by the regulation, as those were the stakeholders willing to be interviewed.

Understanding and compliance

All respondents (n=4) fully understood the regulation, and caught or traded manta and mobula in the past. One fisher reported that he still catches manta, but all others interviews said they no longer catch or trade manta. Of these, only one reported that it was because of the regulation. One fisher reported he had already changed to bomb fishing prior to the manta ray regulation, and another trade reported he had already left the manta trading business because the "competition was not healthy" (Figure 6.9).

Figure 6.9: summary of responses to key understanding and compliance questions

Attitudes and opinions towards the regulation

Two respondents were openly against the regulation, while two were in support. Two respondents also felt the regulation was unfair, while one reported fair and another did not respond.

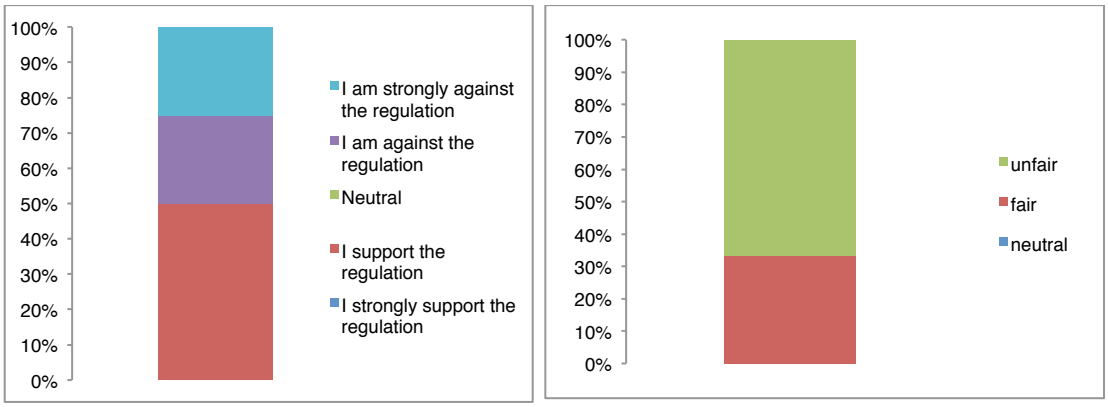


Figure 6.10: Summary of responses to key attitudes and opinions questions (a) level of support (b) perceived fairness

Responses to likert-type statements on level of support (responses rated from -2 to +2 across 5 options ranging from very negative to neutral to very positive) for the regulation were split, averaging out close to zero, in terms of levels of personal support, community support and perceived fairness (Fig 6.11).

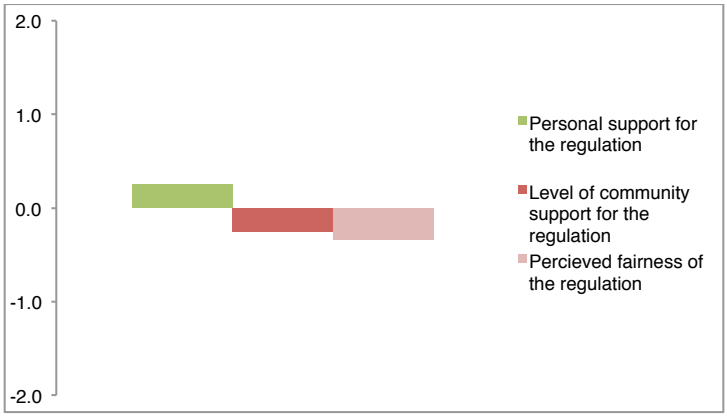


Fig 6.11. Average level of support for the regulation based on interviewee likert-type statements

Relationships and process

Relationship and communication with the government based on average responses to likert-type statements on quality of relationship/communication (responses rated from -2 to +2 across 5 options ranging from very negative to neutral to very positive) were neutral to slightly positive on average (Fig. 6.12). This is slightly counter to other qualitative reports suggesting a negative relationship with the government, and may be due to the biased sample and/or that people are often reluctant to openly criticise the government.

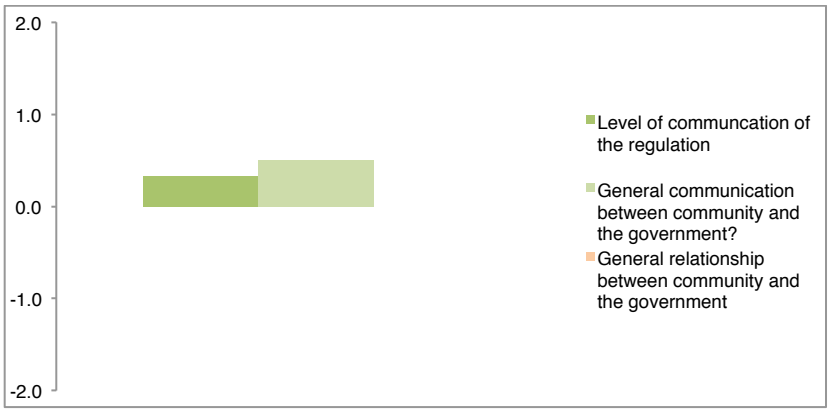


Fig 6.12. Average perceived relationship and communication with the government based on interviewee likert-type statements

S7 Description of secondary data sources

Intelligence data

Secondary data gathered from unpublished records

Collected by the Wildlife Crime Unit and collated and analysed by the Wildlife Conservation Society Indonesia using IBM i2 software.

Time frame of data collection: February 2014-present

Custodian of unpublished records: Wildlife Conservation Society Indonesia

Data is confidential

Landings data

Secondary data gathered from published literature and unpublished records (Table 7.1 and 7.2).

For Tanjung Luar the data used in this study was from unpublished records collected by Reef Check Indonesia (March 2013-October 2013) and the Wildlife Conservation Society Indonesia (November 2013-June 2016). Other published data sources were available (Table 1), but were not used in this study due to small sampling effort and lack of metadata (i.e. was not possible to disaggregate landings by day)

Custodians of unpublished records: Reef Check Indonesia and Wildlife Conservation Society Indonesia, respectively

Data not freely available.

For Lamakera the data used in this study was from Dewar (2002); Lewis et al. (2015); and collected by Misool Baseftin from May 2015-present. Only data from May 2015-present was used in statistical analysis as previous data was based on annual estimates from village landings records/villager elder personal communication rather than observed landings (Lewis et al. 2015)

Custodians of unpublished records: Misool Baseftin

Data not freely available:

Table 7.1: All identified sources of mobulid landings data for Tanjung Luar

Source	Method	Year(s)	Month(s)	No. survey days	% year sampled	Used in this study
White et al 2006	Observed landings	2001-2005*	Jan, March, April, May, Jun, Jul, Aug, Sept, Oct, Nov, Dec	59	0.036	✗
RCI/Lewis et al 2015	Observed landings	2007	June	2	0.005	✗
RCI/Lewis et al 2015	Observed landings	2009	December	5	0.014	✗
RCI/Lewis et al 2015	Observed landings	2010	Jan, April, July	12	0.033	✗
RCI/Lewis et al 2015	Observed landings	2011	August	3	0.008	✗
RCI/Lewis et al 2015	Observed landings	2012	May, June	13	0.036	✗
RCI/WCS	Observed landings	2013	March, April, May, June, Oct, Nov, Dec	152	0.416	✓
Unpublished WCS records	Observed landings	2014	Jan-Dec	359	100	✓
Unpublished WCS records	Observed landings	2015	Jan-Dec	359	100	✓
Unpublished WCS records	Observed landings	2016	Jan-June	182	100	✓

*White et al 2006 is not disaggregated by year so only possible to get data for entire survey period, which was April 2001-October 2005, with a total of 1,643 days

Table 7.2: All identified sources of mobulid landings data for Tanjung Luar

Source	Method	Year(s)	Month(s)	No. survey days	% year sampled	Used in this study
Dewar 2002	Interviews with fishermen	2002	N/A – obtained estimate of total annual landings	N/A	N/A	✓
Lewis et al 2015	Community landings records/interviews with village elder	2003-14	N/A – obtained estimate of total annual landings	N/A	N/A	✓
Unpublished Misool Baseftin project records	Observed landings	2015	May-Dec	229	62	✓
Unpublished Misool Baseftin project records	Observed landings	2016	Jan-July	182	50	✓

Price data

Secondary data gathered from various sources of published literature and unpublished records (Table 7.3)

Table 7.3: All identified sources of mobulid price data

Source	Location	Year(s)	Method	Systematic sampling?	Type of data	Acknowledgment of variation or uncertainty?
Dewar 2002	Lamakera	2002	Interviews with fishers	✗	Price per individual	No – single values given
White et al. 2006	Tanjung Luar	2005	Interviews with fishers and traders	✗	Price per individual, price per kg gill plates, price per kg meat	Yes – range of values given for different quality gill plates
Lewis et al. 2015	Lamakera	2005, 2010,	Market	✗	Price per individual,	Yes – range of

		2011, 2014, 2015	observations and community interviews		price per kg gill plates, price per kg meat	values given
Unpublished WCS Project Records	Tanjung Luar and Rumbuk	2014	Market observations	✗	Price per kg manta meat, price per kg gill plates	No – single value given
Efin and Made 2014a	Tanjung Luar	2015	Market observations	✗	Price per kg gill plates	No – single values given
Efin and Made 2014b	Lamakera	2015	Unstructured interview with trader	✗	Price per individual, price per kg gill plates, price per kg meat	No – single values given
Unpublished WCU Intelligence and Operations reports	Tanjung Luar, Lamakera, Surabaya, Indramayu, Pangambengan	2014, 2015, 2016	Covert observations and/or false transactions as part of law enforcement operations	✗	Price per individual, price per kg gill plates	No – single value given
Primary data collection during this study	Lamakera, Cemara, Labuhan Haji	2015, 2016	Interview-administered questionnaires with fishers and traders	✗	Price per individual, price per kg gill plates, price per kg meat	Yes – ranges of values given (in some circumstances)
Unpublished WCS Records	Guangzhou	2016	Market surveys	✓	Price per kg gill plates	Yes – average and range given
Unpublished WCS Project	Hong Kong	2016	Market surveys	✓	Price per kg gill plates	Yes – whole dataset available
O'Malley et al. 2016	Singapore, Hong Kong, Guangzhou, Macau	2011, 2013, 2015	Market surveys	✓	Price per kg gill plates	Yes – average given but whole dataset not available

Law enforcement data

Secondary data gathered from unpublished records

Collected by the Wildlife Crime Unit and collated by the Wildlife Conservation Society

Time frame of data collection: February 2014-present

Custodian of unpublished records: Wildlife Conservation Society Indonesia

Some data is confidential; some data is publicly available in Bahasa Indonesia in Indonesian legal proceedings documents.

S8 Interview-administered questionnaires

Interview-administered questionnaires enabled direct questioning of the target population while providing room for personalisation and adaptation (Cohen and Crabtree 2006). This was considered particularly important for understanding context, gathering indirect information on the perceived openness and honesty of respondents, and adapting the approach according to levels of sensitivity. The questionnaires were developed based on a template from previous fisheries data collection by WCS in Tanjung Luar, which was adapted to suit the specific needs of this research, piloted in two locations in East Lombok (Cemara and Labuhan Haji), and reduced and refined before being implemented in Tanjung Luar and Lamakera. Three separate questionnaire templates were designed for villager leaders, fishers and traders. The questionnaires were designed to provide some redundancy, with multiple ways of asking the same question in order to provide several avenues for gathering sensitive information. The main themes of the questionnaire included demographics, fishing/trading characteristics, communication and understanding of the regulation, compliance to the regulation, attitudes and opinions towards the regulation, and relationships and process.

This data collection was also supplemented with naturalistic observation of fishing communities at landing sites, markets, homesteads and informal social settings. By living with fisher families in target villages during data collection, research assistants were able to indirectly assimilate ethnographic information and observe behaviour in more natural settings. This data was gathered in the form of field notes and provided a richer understanding of local context, and additional information for evaluating the fidelity of the quantitative and self-reported data (Cohen and Crabtree 2006).

FISHER AND VESSEL OWNER

Questionnaire Number		Interviewee serial number:	
Date		Sub-District	

A. DEMOGRAPHIC INFORMATION

A01 Is fishing your primary profession? ☐1. Yes ☐2. No

A02 If no, what is your primary profession?

A03 What your monthly HH income?

A04 How much of your HH income is from fishing? (IDR and %) IDR %

A05 Is your monthly income stable all year around, or does is vary seasonally? ☐ Stable ☐ Seasonal

A06 If seasonal: Income in good season / Income in bad season

A07 How would you describe your monthly income compared to three years ago? ☐Better ☐Similar ☐Worse

A08 If better or worse, please explain why:

B. FISHERIES INFORMATION

B01 Main target species
1. _____
2. _____
3. _____

B02 How would you describe your total fish catch now compared to last year? ☐Better ☐Similar ☐Worse

B03 How would you describe your total fish catch now compared to three years ago? ☐Better ☐Similar ☐Worse

B04 If better/worse please explain why

B05 How would you describe your fishing effort now compared to last year? ☐Higher ☐Similar ☐Lower

B06 How would you describe your fishing effort now compared to three years ago? ☐Higher ☐Similar ☐Lower

B07 If higher/lower please explain why

B08	Do you ever catch mobula rays?	☐ Yes ☐ No	B09	If no, did you ever catch mobula rays in the past?	☐ Yes ☐ No

B10 If yes to B09, why did you change?

B11	Do you ever catch manta rays?	☐ Yes ☐ No	B12	If no, did you ever catch manta rays in the past?	☐ Yes ☐ No

B13 If yes to B11, why did you change? Now go to B35

B14	How would you describe your manta ray fishing behavior?	☐ Targeted ☐ Opportunistic ☐ By-catch ☐ Other (specify)……
B15	Have you always caught manta rays?	☐ Yes ☐ No
B16	If no, since when?	
B17	Approximately how often do you catch manta rays?	☐ At least once a day ☐ At least once a week ☐ At least once a month ☐ At least once a year ☐ Other (specify)…….
B18	Why do you choose to catch manta rays? (tick all that apply)	☐ Huge demand ☐ High price ☐ Easy to catch ☐ It's part of my cultural heritage ☐ It's the only skill I have ☐ Other (specify)……
B19	Please explain in more detail	

B20 How important are manta rays for your livelihood?

☐ Very important
☐ Important
☐ Neutral
☐ Unimportant
☐ Very unimportant

B21 Please explain in more detail – what are they important/unimportant?

B22 Approximately what proportion of your income comes from manta ray? (%)

B23 Is this stable or does is change throughout the year? Please explain

☐ Stable ☐ Changes

B24 How would you describe your manta ray catch now compared to last year?

☐ Better
☐ Similar
☐ Worse

B25 How would you describe your manta ray catch now compared to three years ago?

☐ Better
☐ Similar
☐ Worse

If better/worse please explain why

B26 How would you describe your manta ray fishing effort now compared to last year?

☐ Higher
☐ Similar
☐ Lower

B27 How would you describe your manta ray fishing effort now compared to three years ago?

☐ Higher
☐ Similar
☐ Lower

If higher/lower please explain why your effort has changed

B28 What kinds of rays do/did you catch, when do/did you catch them, and roughly how many per month?

Ray Family (name)	Month												Average effort (days per month)	Average catch (individuals/trip)	Targeted/ opportunistic/by-catch/ other	Gear used
	J	F	M	A	M	J	J	A	S	O	N	D				
Mobula spp.																
Manta spp.																
Other_____																

B29 Do you, or anyone else, keep any informal records of manta or mobula ray landings (e.g. community landings records)?

[If yes, ask if you can see them and record landings data per genus per month and/or year – use a separate sheet if necessary]
[If no, can you provide any estimates of annual landings over the past 5-10 years? What are these estimates based on?]

2007 -
2008 -
2009 -
2010 -
2011 -
2012 -
2013 -
2014 -
2015 -
2016 -

B30 How/where/to whom do you sell your ray catch? If different for different species please explain. If more than one person, please mention percentage per person

B31 Please list the current trading prices (i.e. the price that you sell for to the trader) of different ray species and their parts.

Ray species	Whole animal	Gills (IDR/kg)	Meat (IDR/kg)	Skin (IDR/kg)	Cartilage (IDR/kg)	Other (IDR/kg)
Mobula spp.						
Manta spp.						

B32 Please list the approximate amount of each product (in kg) that you get from an individual ray

Ray species	Gills (kg)	Meat (kg)	Skin (kg)	Cartilage (kg)	Other (kg)
Mobula spp.					
Manta spp.					

B33 How is the relationship between you and the ray traders?

☐ Very good
☐ Good
☐ Neutral/don't know
☐ Poor
☐ Very poor

Please explain your answer

B34 How is the relationship between you and the boat owner/investor

☐ Very good
☐ Good

Please explain your answer

☐ Neutral/don't know

☐ Poor

☐ Very poor

B35 Has the price for manta ray significantly changed over the past 3 years? ☐ Yes ☐ No

If yes, why?

B36 In total, approximately how many boats in the village are equipped to catch manta?

B37 Of those, how many boats do you know of that regularly go on manta hunting trips?

B38 In total, approximately how many people do you know who are fishers?

B39 Of those, how many do you know who have caught manta ray in the past 2 years?

B40 In total, approximately how many people do you know who are traders?

B41 Of those, how many do you know who have traded manta products in the past 2 years?

B42 Do you always land your catch in the main landing site in the village? ☐ Yes ☐ No

If no, please describe where else you land you catch and why

B43 Over the past three years, have there been any major events that have influenced fishing and fish trade in the village? If yes, please explain events and their impacts

C. KNOWLEDGE AND PERCEPTION OF FISHERIES MANAGEMENT

C01 Are you aware of any fishing laws or regulations (customary or government) that are in place in your ☐ Yes ☐ No

village, or species what are forbidden to catch?

C02	If Yes, please list	1. 2. 3. 4. …
C03	Are you aware of any regulation on manta ray catch and trade?	☐ Yes ☐ No
C04	If Yes, please explain your understanding of the regulation	
C05	If Yes, from where did you get this information?	☐Ministry of Marine Affairs ☐Local government ☐Friends/family ☐Village elder ☐NGO ☐Other (please specify)
C06	How was this information communicated (e.g. please describe any socialization events and when these took place)	
C07	To what degree do you support the regulation on manta ray fishing?	☐ I strongly support the regulation ☐ I support the regulation a little ☐ Neutral/don't know ☐ I am against the regulation ☐ I am strongly against the regulation
C08	Please explain your answer - why do you support/oppose the regulation?	
C09	How many people in your village do you think are in support of the regulation?	☐ Most people (80-100%) ☐ Lots of people (60-80%) ☐ Around half of the population (40-60%) ☐ Few people (20-40%) ☐ Very few people (0-20%)
C10	What is your opinion on the level of communication on the manta ray regulation to you community	☐ Very good communication ☐ Good communication ☐ Neutral/don't know

☐ Poor communication

☐ Very poor communication

C11 Please explain your answer – why do you think the communication has been good/poor?

☐ Very fair

☐ Fair

C12 Do you think the regulation is fair? ☐ Neutral/don't know

☐ Unfair

☐ Very unfair

C13 Please explain your answer – why do you think it is fair/unfair?

C14 What impacts has this regulation had on you? What about other fishers?

C15 Are you aware of any monitoring and enforcement of the regulation in your village? ☐Yes ☐ No

C16 If yes, who is doing the monitoring and enforcement?

C17 What types of monitoring and enforcement are taking place?

C18 How do you feel about the monitoring and enforcement?

C19 Are there any punishments for breaking this regulation? ☐ Yes ☐ No ☐ I don't know

C20 If yes, please describe

C21 Within the last year, how many times do you think the regulation has been broken?

C22 Within the last year, how many of the offenders have received a fine/penalty? What did they receive a penalty for?

C23 Overall, what do you think the level of compliance with this regulation is?

- ☐ Most people comply (80-100%)
- ☐ Lots of people comply (60-80%)
- ☐ Around half of the population complied (40-60%)
- ☐ Few people comply (20-40%)
- ☐ Very few people comply (0-20%)

C24 If you chose to break the regulation, how likely do you think it is that you will be penalised?

- ☐ Very likely (81-100%)
- ☐ Likely (61-80%)
- ☐ Moderate (41-60%)
- ☐ Unlikely (21-40%)
- ☐ Very unlikely (0-20%)

C25 Please explain your answer – why do you think is it likely/unlikely?

C26 What factors would influence your decision to abide by or break the regulation?

C27 Overall, how do you feel about the regulation?

D. RELATIONSHIP WITH GOVERNMENT

D1 How is the relationship between your community and the government? ☐ Very good ☐Good ☐Ok ☐Poor ☐Very poor

D2 How is the communication/consultation between your community and the government? ☐Very good ☐Good ☐Ok ☐Poor ☐Very poor

D3 Do you feel that your community is involved in government decisions-making? ☐Yes ☐No ☐Don't know

D4 Please explain your answers

E. OTHER

E1 Would you like to make any further comments on this topic, that have not already been discussed in the duration of this questionnaire?

E2 Can you recommend any other key informants with whom we can discuss this topic? In particular, senior fishermen, traders, processors?

[Names not recorded here to maintain anonymity]

TRADER

Questionnaire No		Interviewee serial number	
Date		Sub-district and village	

A. DEMOGRAPHIC INFORMATION

A01 Is fish trading your primary profession? ☐ Yes ☐ No

A02 If no, what is your primary profession?

A03 What is your HH monthly income? (IDR) IDR

A04 How much of your HH income is from fish trading? (IDR and %) IDR %

A05 Is your monthly income stable all year around, or does is vary seasonally? ☐ Stable ☐ Seasonal

A06 If seasonal: Income in good season / Income in bad season

A07 How would you describe your monthly income compared to three years ago? ☐ Better ☐ Similar ☐ Worse

A08 If better or worse, please explain why:

B. FISHERIES INFORMATION

B01 Top 3 fish commodity and price

No	Fish family (or name)	Average trade volume per month (kg)	Price (IDR/kg)
1.			
2.			
3.			

B02 Please list all other species you trade

B03 Overall, how would you describe fish trading business over the past 12 months? ☐Very good ☐Good ☐Enough ☐Poor ☐Very poor

B04 Overall, how would you describe your trading compared to last year? ☐Better ☐Similar ☐Worse

B05 Overall, how would you describe your trading now compared to three years ago? ☐Better ☐Similar ☐Worse

B06 If there have been any changes in fishing and trading in the past year or three years, please explain why

B07 Do you ever trade mobula rays? ☐Yes ☐No

B08 Did you ever trade mobula rays in the past? ☐Yes ☐No

B09 If yes to B08, why did you change?

B10 Do you ever trade manta rays? ☐Yes ☐No

B11 Did you ever trade manta rays in the past? ☐Yes ☐No

B12 If yes to B11, why did you change? (Now go to B26)

B13 If yes, how often?

☐Every day
☐At least once a week
☐At least once a month
☐At least once every six months
☐At least once a year

B14 Have you always traded manta rays? ☐Yes ☐No If no, since when:

B15 If yes, why do you choose to trade manta rays?

☐Huge demand
☐High profit
☐Easy to source
☐Easy to sell
☐Other…….

Please explain in more detail:

TRADER

B16 How much of your HH income is from manta trading? IDR %

B17 How would you describe your ray trading now compared to last year? ☐Better ☐Similar ☐Worse

B18 How would you describe your ray trading now compared to three years ago? ☐Better ☐Similar ☐Worse

If better/worse please explain why

B19 Do you, or anyone else, keep any informal records of manta or mobula trading volumes (e.g. business ledgers)?
[If yes, ask if you can see them and record trading data per genus per month and/or year – use a separate sheet if necessary]
[If no, can you provide any estimates of total trading volumes over the past 5-10 years? What are these estimates based on?]

2007 -
2008 -
2009 -
2010 -
2011 -
2012 -
2013 -
2014 -
2015 -
2016 -

B20 In what condition do you purchase the rays? ☐ Whole ☐ Parts

If parts, please describe

B21 In what condition do you sell the rays? ☐ Whole ☐ Parts

B22 If parts, which parts do you sell? ☐ Bone ☐ Meat ☐ Skin ☐ Gills ☐ Other (please specify) _____

B23 Please list the current trading prices of different ray species and their parts.

TRADER

Price that you buy from fishers

Ray species	Whole animal	Gills (IDR/kg)	Meat (IDR/kg)	Skin (IDR/kg)	Cartilage (IDR/kg)	Other (IDR/kg)
Mobula spp.						
Manta spp.						

Price that you sell to other traders/consumers

Ray species	Whole animal	Gills (IDR/kg)	Meat (IDR/kg)	Skin (IDR/kg)	Cartilage (IDR/kg)	Other (IDR/kg)
Mobula spp.						
Manta spp.						

B24 Where/how/to whom do you sell the rays? If different for different products, please explain

B25 Is there anyone else along the supply chain in between you and the fishers and you and the consumers of the final product? If yes, please describe the other actors in the supply chain and how the supply chain works

B26 Approximately how many manta ray hunting boats do you know of that are currently active in your village?

B27 In total, approximately how many people do you know who are fishers?

B28 Of those, how many do you know who have caught manta ray in the past 2 years?

B29 In total, approximately how many people do you know who are traders?

B30 Of those, how many do you know who have traded manta products in the past 2 years?

C. KNOWLEDGE AND PERCEPTION OF FISHERIES MANAGEMENT

C01 Are you aware of species which are forbidden to catch and/or trade? ☐ Yes ☐ No

C02 If yes, please list the name(s)

1.
2.
3.
…

TRADER

C03 Are you aware of any regulation on manta ray catch and trade? ☐ Yes ☐ No

C04 If Yes, please explain your understanding of the regulation

C05 From where did you get this information?
☐Ministry of Marine Affairs ☐Local government ☐Friends/family
☐Village elder ☐NGO ☐Other (please specify)……

C06 How was this information communicated (e.g. please describe any socialization events and when these took place)

C07 To what degree do you support the regulation on manta ray fishing?
☐I strongly support the regulation
☐I support the regulation
☐Neutral/don't know
☐I am against the regulation
☐I am strongly against the regulation

C08 Please explain your answer - why do you support/oppose the regulation?

C09 How many people in your village do you think are in support of the regulation?
☐ Most people (80-100%)
☐ Lots of people (60-80%)
☐ Around half of the population (40-60%)
☐ Few people (20-40%)
☐ Very few people (0-20%)

C10 What is your opinion on the level of communication on the manta ray regulation to you community
☐ Very good communication
☐ Good communication
☐ Neutral/don't know
☐ Poor communication

☐ Very poor communication

C11	Please explain your answer – why was the communication good/poor?	

C12	Do you think the regulation is fair?	☐ Very fair ☐ Fair ☐ Neutral/don't know ☐ Unfair ☐ Very unfair
C13	Please explain your answer – why do you think it is fair/unfair?	

C14 What impacts has this regulation had on you? What about other traders?

C15	Are you aware of any monitoring and enforcement of the regulation in your village?	☐ Yes ☐ No
C16	If yes, who is doing the monitoring and enforcement?	
C17	What types of monitoring and enforcement are taking place?	
C18	How do you feel about the monitoring and enforcement?	
C19	Are there any punishments for breaking this regulation?	☐ Yes ☐ No ☐ I don't know

C20 If yes, please describe

C21 Within the last year, how many times do you think the regulation has been violated?

C22 Within the last year, approximately how many of the offenders received a fine/penalty? What did they receive a penalty for?

C23 Overall, what do you think the level of compliance with this regulation is?

☐ Most people comply (80-100%)

☐ Lots of people comply (60-80%)

☐ Around half of the population complied (40-60%)

☐ Few people comply (20-40%)

☐ Very few people comply (0-20%)

C24 If you chose to break the regulation, how likely do you think it is that you will be penalised?

☐ Very likely (81-100%)

☐ Likely (61-80%)

☐ Moderate (41-60%)

☐ Unlikely (21-40%)

☐ Very unlikely (0-20%)

C25 Please explain your answer – why do you think it is likely/unlikely?

C26 What factors would influence your decision to abide by or break the regulation?

C27 Overall, how do you feel about the regulation?

TRADER

D. RELATIONSHIP WITH GOVERNMENT

D1	How is the relationship between your community and the government?	☐Very good ☐Good ☐Ok ☐Poor ☐Very poor
D2	How is the communication/consultation between your community and the government?	☐Very good ☐Good ☐Ok ☐Poor ☐Very poor
D3	Do you feel that yourself and your community are involved in government decisions-making?	☐Yes ☐No ☐Don't know
D4	Please explain your answers	

E. OTHER

E1 Would you like to make any further comments on this topic, that have not already been discussed in the duration of this questionnaire?

E2 Can you please recommend any other key informants with whom we can discuss this topic? In particular, senior fishermen, traders, processors.

[Names not recorded here to maintain anonymity]

GOVERNMENT OFFICIAL/VILLAGE LEADER

Questionnaire No:		Interviewee serial number:	
Date:		Village and sub-district:	

A. VILLAGE INFORMATION

A01	Population		A02	#Household	
A03	Fisher household (# and %)		A04	Vessel (# and % based on HP)	

B. FISHERIES INFORMATION

Please describe the fisheries activity in your village:

B01 How many fishers are in the village?

Full time:
Part time:

B02 What types of fishing vessels do they use?

☐1. Vessel type:_____Approx. % of fishers using:_____
☐2. Vessel type:_____Approx. % of fishers using:_____
☐3. Vessel type:_____Approx. % of fishers using:_____

B03 Main fishing gear used? (3 main ones and then ask any if there are any others)

☐1. _____
☐2. _____
☐3. _____
☐List others _____

B04 Main fish catch?

☐1. _____	☐4. _____
☐2. _____	☐5. _____
☐3. _____	☐6. _____

B05 Are you aware of any mobula rays being landed in your village? ☐ Yes ☐ No

B06 Are you aware of any manta rays being landed in your village? ☐ Yes ☐ No

B07 If yes, how often are mobula rays landed in your village?

☐ At least once a day
☐ At least once a week
☐ At least once a month
☐ At least once a year
☐ Other (specify)……..

B08 And how often are manta rays landed in your village?

☐ At least once a day
☐ At least once a week
☐ At least once a month
☐ At least once a year
☐ Other (specify)……..

B09 How important is manta ray fishing for your community?

☐ Very important ☐ Important ☐ Neutral ☐ Unimportant ☐ Very unimportant

Please explain your answer – why important/unimportant?

B10	How/where do ray fishers they sell their catch?	
B11	How many traders are in the village?	
B12	Where do the traders sell their catch?	
B13	How many manta ray fishing boats are you aware of that are currently in operation in your village?	

B14	In total, approximately how many people do you know who are fishers?		B15	Of those, how many do you know who have caught manta ray in the past 2 years?	
B16	In total, approximately how many people do you know who are traders?		B17	Of those, how many do you know who have traded manta products in the past 2 years?	

B18 Do all fishers from Lamakera land their catch in the same place in the village? [as opposed to landing catch in another location outside of the village for example] ☐ Yes ☐ No

If no, please describe where else they land their catch and why

B19 Do you, or anyone else, keep any informal records of manta or mobula ray landings (e.g. community landings records)? [If yes, ask if you can see them and record landings data per genus per month and/or year – use a separate sheet if necessary] [If no, can you provide any estimates of annual landings over the past 5-10 years? What are these estimates based on?]

2007 -
2008 -
2009 -
2010 -
2011 -
2012 -
2013 -
2014 -
2015 -
2016 -

B20 Does catch vary throughout the year? If yes, please describe the annual patterns. In which months do most landings take place? Generally what % of total annual landings occurs per month?

B21 Over the past three years, have there been any major events that have influenced fishing and trade of fish products in the village? If yes, please explain the events, when they happened, and their impacts

C. KNOWLEDGE AND PERCEPTION OF FISHERIES MANAGEMENT

C01	In your village, are there any fishing laws or regulations (government or traditional), or species that are forbidden to catch?	☐ Yes ☐ No ☐ I don't know	If No, go directly to C05
C02	If Yes, please list	1. 2. 3. …	
C03	Are you aware of any regulation on manta ray catch and trade?	☐ Yes ☐ No	If No, go to C37
C04	If Yes, please explain your understanding of the regulation		
C05	If Yes, from where did you get this information?	☐ Ministry of Marine Affairs ☐ Local government ☐ Friends/family ☐ NGO ☐ Other (please specify)	
C06	Do you think the fishers in this village are aware of this regulation?	☐ Yes ☐ No	If No, go to C14
C07	If Yes, from where did the village this information?	☐ Ministry of Marine Affairs ☐ Local government ☐ Friends/family ☐ Village elder ☐ NGO ☐ Other (please specify)	
C08	How was this information communicated (e.g. please describe any socialization events and when these took place)		
C09	To what degree do you support the regulation on manta ray fishing?	☐ I strongly support the regulation ☐ I support the regulation	

☐ Neutral/don't know

☐ I am against the regulation

☐ I am strongly against the regulation

C10 Please explain your answer – why do you support/oppose the regulation?

C11 How many people in your village do you think are in support of the regulation?

☐ Most people (80-100%)

☐ Lots of people (60-80%)

☐ Around half of the population (40-60%)

☐ Few people (20-40%)

☐ Very few people (0-20%)

C12 What is your opinion on the level of communication on the manta ray regulation to you community

☐ Very good communication

☐ Good communication

☐ Neutral/don't know

☐ Poor communication

☐ Very poor communication

C13 Please explain your answer – why do you think the communication is good/poor?

C14 Do you think the regulation is fair?

☐ Very fair ☐ Fair

☐ Neutral/don't know

☐ Unfair ☐ Very unfair

C15 Please explain your answer – why do you think the regulation is fair/unfair?

C16 What impacts do you think this regulation has had on people in your community?

Fishers

	Traders **You** **Other (please specify)**	
C17	Are you aware of any monitoring and enforcement of fisheries regulations in your village?	☐ Yes ☐ No
C18	If yes, who is doing the monitoring and enforcement?	
C19	If yes, what types of monitoring and enforcement are taking place?	
C20	How do you feel about the monitoring and enforcement?	
C21	Are there any punishments for breaking this regulation?	☐ Yes ☐ No ☐ I don't know
C22	If yes, please describe	
C23	Within the last year, how many times do you think the manta regulation has been violated?	
C24	Within the last year, how many of the offenders have received a fine/penalty? And what did they	

receive a penalty for?

C25	Overall, what do you think the level of compliance with this regulation is?	☐ Most people comply (80-100%) ☐ Lots of people comply (60-80%) ☐ Around half the population complies (40-60%) ☐ Few people comply (20-40%) ☐ Very few people comply (0-20%)

C26 I want to ask you about the risks of breaking the regulation for different people. Consider each of these groups of people in turn – in your opinion, how likely is it that they will be penalised for breaking the regulation?

For fishers: ☐1. Very likely (81-100%) ☐2. Likely (61-80%) ☐3. Moderate (41-60%) ☐2. Unlikely (21-40%) ☐2. Very unlikely (0-20%)	Please explain your answer – why do you think it is likely/unlikely?
For traders: ☐1. Very likely (81-100%) ☐2. Likely (61-80%) ☐3. Moderate (41-60%) ☐2. Unlikely (21-40%) ☐2. Very unlikely (0-20%)	Please explain your answer – why do you think it is likely/unlikely?

C27 What factors do you think influence people's decisions to comply with the regulation vs. continue to fish/trade illegally?

C28 Overall, how do you feel about the regulation?

C29 How do you think other people in your village, such as fishers or traders, feel about the regulation?

D. RELATIONSHIP WITH GOVERNMENT AND COMMUNITY

D1 Overall, how is the relationship between your community and the government? ☐Very good ☐Good ☐ Ok ☐ Poor ☐ Very poor

D2 How is the communication/consultation between your community and the government? ☐Very good ☐Good ☐ Ok ☐ Poor ☐ Very poor

D3 Do you feel that your community is involved in government decision-making? ☐ Yes ☐ No ☐ Don't know

D4 Please explain your answers – why do you feel this way about your relationship with the government?

D5 How is the relationship between you and your community? ☐Very good ☐Good ☐Ok ☐Poor ☐Very poor

D6 Please explain your answer – why is the relationship good/poor?

D7 To what degree does the community obey your decisions and authority? ☐Always obey ☐Usually obey ☐Sometimes obey ☐Rarely obey ☐Never obey

D8 Please explain your answer – why do you think they obey/disobey?

E. OTHER

E1 Would you like to make any further comments on this topic, that have not already been discussed in the duration of this questionnaire?

GOVERNMENT OFFICIAL/VILLAGE LEADER

E2 Can you recommend any other key informants with whom we can discuss this topic? In particular, senior fishermen, traders, processors?

[Names not recorded here to maintain anonymity]

S9 Catch data analysis and model outputs

Overview of data structure

Manta ray landing occurrences are a relatively rare event, meaning that data is zero-inflated. Further, when a landing event does take place, the count of landings on a given day is relatively low, particularly for Tanjung Luar (See Figure 9.1).

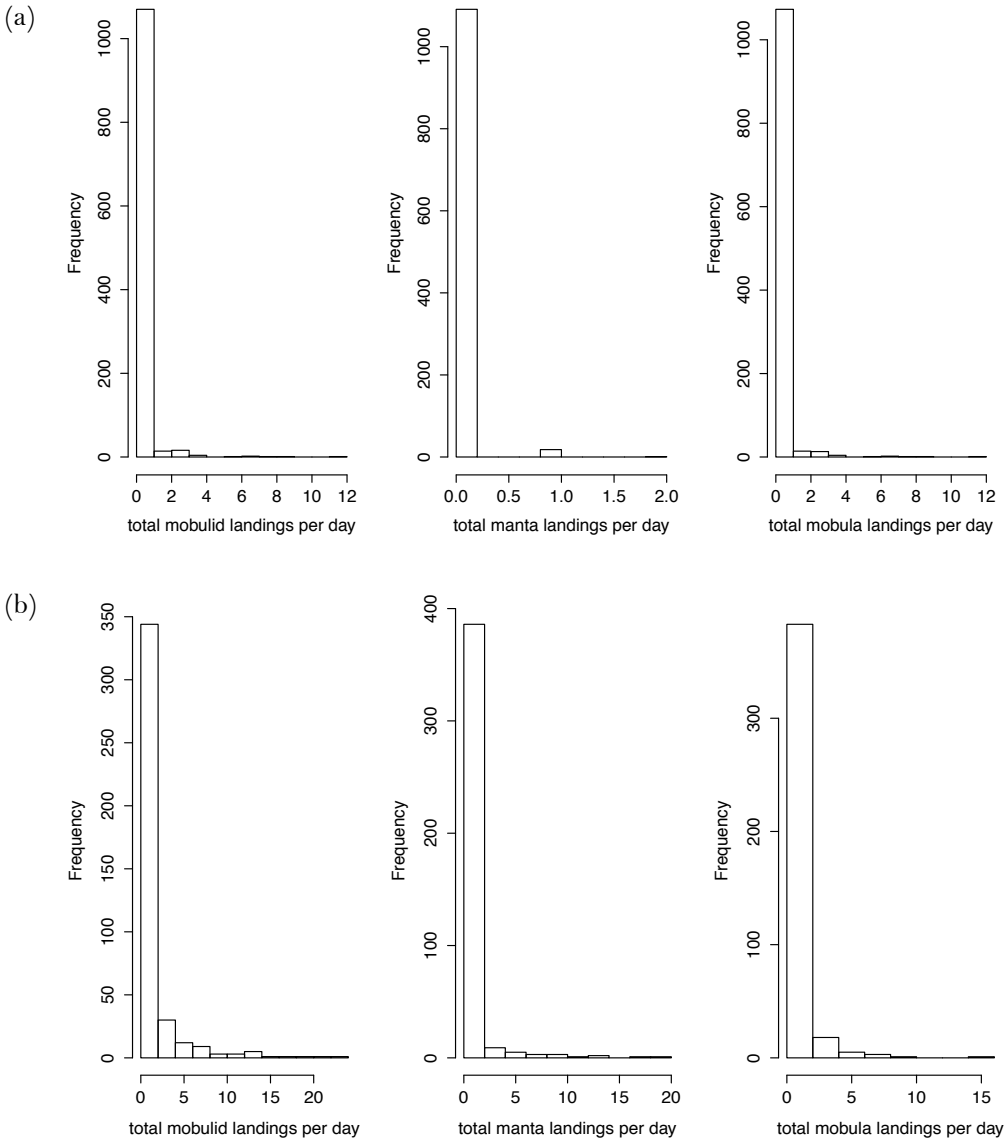


Figure 9.1: Histograms of daily counts of mobulid landings in (a) Tanjung Luar (March 2013-June 2016) and (b) Lamakera (May 2015-July 2016)

For ease of statistical analysis, I converted all landings data into binary (Y/N) data, so that it fitted the assumptions of a binomial error structure. I intended to aggregate data by month to reduce the number of zeros, however this was not possible as there had been different survey efforts in different months throughout the sampling periods. Therefore I analysed the data based on daily, binary landing occurrences. There are a number of potential issues with this for zero-inflated data, and future analyses could benefit from using specialised techniques for dealing with this kind of data, such as Zero-Inflated Poisson Regression (e.g. Zuur 2009)

Analysis of landing occurrences

Tanjung Luar

Manta landing occurrences modelled against time

I fitted a Generalised Linear Model (GLM) of manta landing occurrences (Y/N) to month, with February 2014 (the month the regulation was introduced) as the reference level, to assess whether there were any significant and persistent differences in the probability of landing occurrences post-regulation (Table 9.1). I used months as categorical variables so as not to assume a linear trend.

Table 9.1: Output of generalised linear model with binomial errors for manta landing occurrences in Tanjung Luar fitted to month as a cateogirical variable Call: glm(formula= NumberBIN~Month, family = binomial, data = TLmanta), reference level = February 2014

Deviance Residuals:

	Min	1Q	Median	3Q	Max
	-0.45904	-0.25609	-0.00003	-0.00003	2.62068

Coefficients:

	Regulation	Estimate	Std. error	z value	Pr(>|z|)
(Intercept)	-	-2.16E+01	5.52E+03	-0.004	0.997
March 2013	Pre	1.94E+01	5.52E+03	0.004	0.997
April 2013	Pre	1.82E+01	5.52E+03	0.003	0.997
May 2013	Pre	1.82E+01	5.52E+03	0.003	0.997
June 2013	Pre	1.90E+01	5.52E+03	0.003	0.997
October 2013	Pre	4.31E+01	2.98E+04	0.001	0.999
November 2013	Pre	1.89E+01	5.52E+03	0.003	0.997
December 2013	Pre	1.82E+01	5.52E+03	0.003	0.997
January 2014	Pre	-3.29E-06	7.62E+03	0	1
March 2014	Post	1.82E+01	5.52E+03	0.003	0.997
April 2014	Post	-3.29E-06	7.68E+03	0	1
May 2014	Post	-3.29E-06	7.62E+03	0	1
June 2014	Post	-3.29E-06	7.68E+03	0	1
July 2014	Post	-3.29E-06	7.68E+03	0	1
August 2014	Post	-3.29E-06	7.62E+03	0	1

September 2014	Post	-3.29E-06	7.68E+03	0	1
October 2014	Post	-3.29E-06	7.96E+03	0	1
November 2014	Post	1.89E+01	5.52E+03	0.003	0.997
December 2014	Post	1.82E+01	5.52E+03	0.003	0.997
January 2015	Post	1.82E+01	5.52E+03	0.003	0.997
February 2015	Post	-3.29E-06	7.81E+03	0	1
March 2015	Post	-3.29E-06	7.62E+03	0	1
April 2015	Post	-3.29E-06	7.68E+03	0	1
May 2015	Post	-3.29E-06	7.62E+03	0	1
June 2015	Post	1.89E+01	5.52E+03	0.003	0.997
July 2015	Post	1.82E+01	5.52E+03	0.003	0.997
August 2015	Post	-3.29E-06	7.62E+03	0	1
September 2015	Post	-3.29E-06	7.75E+03	0	1
October 2015	Post	-3.29E-06	7.89E+03	0	1
November 2015	Post	-3.29E-06	7.68E+03	0	1
December 2015	Post	-3.29E-06	7.62E+03	0	1
January 2016	Post	-3.29E-06	7.62E+03	0	1
February 2016	Post	-3.29E-06	7.75E+03	0	1
March 2016	Post	-3.29E-06	7.62E+03	0	1
April 2016	Post	-3.29E-06	7.68E+03	0	1
May 2016	Post	-3.29E-06	7.62E+03	0	1
June 2016	Post	-3.29E-06	7.68E+03	0	1

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 191.19 on 1079 degrees of freedom
Residual deviance: 213.73 on 1043 degrees of freedom
AIC: 213.73
Fisher Scoring iterations: 20

All coefficients were uncertain/insignificant, which is likely due to the limited numbers of landings/zero-inflated data, however the concentration of negative coefficients around post-regulation months suggests a possible trend.

I fitted a second GLM of manta landing occurrences to year, again with year as a categorical variable so as not to assume a linear trend, and with 2013 as the reference level (Table 9.2). 2014 and 2015 had significant negative coefficients relative to 2013. 2016 had an insignificant negative coefficient. This implies a significant decline in manta ray landing occurrences in the years post-regulation.

Table 9.2: Output of generalised linear model with binomial errors for manta landing occurrences in Tanjung Luar fitted to year Call: glm(formula= NumberBIN~Year, family = binomial, data = TLmanta)

Deviance Residuals:

	Min	1Q	Median	3Q	Max
	-0.3551	-0.1497	-0.1497	-0.1497	2.999

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.732	0.3112	-8.78	<2e-16	***
Year2014	-1.7538	0.5913	-2.966	0.00302	**
Year2015	-1.7538	0.5913	-2.966	0.00302	**
Year2016	-17.8341	1314.2625	-0.014	0.98917	

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 191.19 on 1079 degrees of freedom
Residual deviance: 170.67 on 1076 degrees of freedom
AIC: 178.67
Fisher Scoring iterations: 19

Manta landing step-change

So as not to assume if/when a significant event occurred, I fitted landing occurrences to pre-post models for every month during the time series. I compared AICs of the models with a null model, and with each other (Table 9.2), to identify which was the best fit (Burnham and Anderson 2003) and therefore if/when in the timeline a step-change in landing occurrences may have taken place.

Table 9.3: AIC values of generalised linear models with binomial errors for manta landing occurrences in Tanjung Luar fitted to pre-post for every month in the time series

Model	Corresponding month and year	AIC manta
NumberBIN~1 (no step change)	-	193.19
NumberBIN~Regcontrol (step change at month2)	Apr-13	189.15
NumberBIN~Regcontrol (step change at month3)	May-13	189.65
NumberBIN~Regcontrol (step change at month4)	Jun-13	189.66
NumberBIN~Regcontrol (step change at month8)	Oct-13	186.29
NumberBIN~Regcontrol (step change at month9)	Nov-13	182.98
NumberBIN~Regcontrol (step change at month10)	Dec-13	178.87
NumberBIN~Regcontrol (step change at month11)	Jan-14	178.3
NumberBIN~Regcontrol (step change at month12)	Feb-14	181.34
NumberBIN~Regcontrol (step change at month13)	Mar-14	183.62
NumberBIN~Regcontrol (step change at month14)	Apr-14	183.62
NumberBIN~Regcontrol (step change at month15)	May-14	182.64
NumberBIN~Regcontrol (step change at month16)	Jun-14	184.69
NumberBIN~Regcontrol (step change at month17)	Jul-14	186.53
NumberBIN~Regcontrol (step change at month18)	Aug-14	188.07
NumberBIN~Regcontrol (step change at month19)	Sep-14	189.42
NumberBIN~Regcontrol (step change at month20)	Oct-14	190.63
NumberBIN~Regcontrol (step change at month21)	Nov-14	191.64
NumberBIN~Regcontrol (step change at month22)	Dec-14	192.41
NumberBIN~Regcontrol (step change at month23)	Jan-15	189.52
NumberBIN~Regcontrol (step change at month24)	Feb-15	188.26
NumberBIN~Regcontrol (step change at month25)	Mar-15	186.68
NumberBIN~Regcontrol (step change at month26)	Apr-15	187.9
NumberBIN~Regcontrol (step change at month27)	May-15	189.14
NumberBIN~Regcontrol (step change at month28)	Jun-15	190.23
NumberBIN~Regcontrol (step change at month29)	Jul-15	191.26
NumberBIN~Regcontrol (step change at month30)	Aug-15	186.12
NumberBIN~Regcontrol (step change at month31)	Sep-15	181.19
NumberBIN~Regcontrol (step change at month32)	Oct-15	182.75
NumberBIN~Regcontrol (step change at month33)	Nov-15	184.15
NumberBIN~Regcontrol (step change at month34)	Dec-15	185.41
NumberBIN~Regcontrol (step change at month35)	Jan-16	186.76
NumberBIN~Regcontrol (step change at month36)	Feb-16	188.11
NumberBIN~Regcontrol (step change at month37)	Mar-16	189.42
NumberBIN~Regcontrol (step change at month38)	Apr-16	190.6
NumberBIN~Regcontrol (step change at month39)	May-16	191.82

There is a cluster of low AIC models around the time the regulation was introduced, which differ substantially from the null model (Δ AIC>9), suggesting a step-change in landing occurrences may have taken place at this time. There could be a number of real-world reasons for this cluster, such as publicity and awareness raising before the regulation was introduced, resulting in an early reduction of catch, or

time-lags in adapting to the regulation and onset of enforcement and implementation. As a rule of thumb, a Δ AIC<3 indicates there is very little difference between models (Burnham and Anderson 2002). For simplicity, because it was the month the regulation was introduced, and because it sits in the middle of the low AIC cluster, February was chosen as the month for further analysis. Low AIC values were also noted around September/October 2015.

Devil ray landings

The same process was repeated for devil ray landings to assess whether similar patterns could be observed, and therefore a changed more likely explained by external factors such as seasonality, a general decline in the mobulid market or climatic factors relating to El Niño (Table 9.4,9.5,9.6).

Table 9.4: Output of generalised linear model with binomial errors for mobula landing occurrences in Tanjung Luar fitted to month Call: glm(formula= NumberBIN~Month, family = binomial, data = TLmobula)

Deviance Residuals:

Min	1Q	Median	3Q	Max
-0.66805	-0.45904	-0.37146	-0.00008	2.60814

Coefficients:

	Regulation	Estimate	Std. error	z value	Pr(>|z|)	
(Intercept)	-	-2.57E+00	7.34E-01	-3.495	0.000473	***
March 2013	Pre	6.93E-01	9.09E-01	0.762	0.445916	
April 2013	Pre	4.06E-01	9.54E-01	0.425	0.670849	
May 2013	Pre	3.31E-01	9.53E-01	0.348	0.727966	
June 2013	Pre	9.96E-01	8.83E-01	1.128	0.259306	
October 2013	Pre	-1.70E+01	1.08E+04	-0.002	0.998739	
November 2013	Pre	-7.41E-02	1.04E+00	-0.072	0.942997	
December 2013	Pre	3.68E-01	9.53E-01	0.386	0.699698	
January 2014	Pre	-1.09E-01	1.04E+00	-0.105	0.916041	
March 2014	Post	6.55E-01	9.09E-01	0.721	0.470687	
April 2014	Post	3.68E-01	9.53E-01	0.386	0.699698	
May 2014	Post	-1.09E-01	1.04E+00	-0.105	0.916041	
June 2014	Post	-7.41E-02	1.04E+00	-0.072	0.942997	
July 2014	Post	-8.02E-01	1.25E+00	-0.64	0.52234	
August 2014	Post	-1.70E+01	1.93E+03	-0.009	0.992977	
September 2014	Post	-1.70E+01	1.96E+03	-0.009	0.993091	
October 2014	Post	-1.70E+01	2.11E+03	-0.008	0.993568	
November 2014	Post	-7.41E-02	1.04E+00	-0.072	0.942997	
December 2014	Post	-1.70E+01	1.93E+03	-0.009	0.992977	
January 2015	Post	-1.70E+01	1.93E+03	-0.009	0.992977	
February 2015	Post	-1.70E+01	2.03E+03	-0.008	0.993325	
March 2015	Post	-1.70E+01	1.93E+03	-0.009	0.992977	
April 2015	Post	-1.70E+01	1.96E+03	-0.009	0.993091	
May 2015	Post	6.55E-01	9.09E-01	0.721	0.470687	
June 2015	Post	-8.02E-01	1.25E+00	-0.64	0.52234	
July 2015	Post	-8.02E-01	1.25E+00	-0.64	0.52234	
August 2015	Post	6.55E-01	9.09E-01	0.721	0.470687	
September 2015	Post	4.06E-01	9.54E-01	0.425	0.670849	
October 2015	Post	8.16E-01	9.12E-01	0.894	0.371131	
November 2015	Post	1.18E+00	8.64E-01	1.364	0.172596	
December 2015	Post	3.31E-01	9.53E-01	0.348	0.727966	
January 2016	Post	3.31E-01	9.53E-01	0.348	0.727966	
February 2016	Post	-3.77E-02	1.04E+00	-0.036	0.97097	

March 2016	Post	3.31E-01	9.53E-01	0.348	0.727966
April 2016	Post	-8.02E-01	1.25E+00	-0.64	0.52234
May 2016	Post	3.31E-01	9.53E-01	0.348	0.727966
June 2016	Post	-7.41E-02	1.04E+00	-0.072	0.942997

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 560.2 on 1079 degrees of freedom
Residual deviance: 503.06 on 1043 degrees of freedom
AIC: 577.06
Fisher Scoring iterations: 18

Table 9.5: Output of generalised linear model with binomial errors for mobula landing occurrences in Tanjung Luar fitted to year Call: glm(formula= NumberBIN~Year, family = binomial, data = TLmobula)

Deviance Residuals:

Min	1Q	Median	3Q	Max
-0.3551	-0.1497	-0.1497	-0.1497	2.999

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.0794	0.2372	-8.768	<2e-16	***
Year2014	-0.8621	0.3387	-2.545	0.0109	*
Year2015	-0.4706	0.3126	-1.505	0.1322	
Year2016	-0.4055	0.3656	-1.109	0.2674	

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 560.2 on 1079 degrees of freedom
Residual deviance: 553.7 on 1076 degrees of freedom
AIC: 561.7
Fisher Scoring iterations: 5

Table 9.6: AIC values of generalised linear models with binomial errors for mobula landing occurrences in Tanjung Luar fitted to pre-post for every month in the time series

Model	Corresponding month and year	AIC mobula
NumberBIN~1 (no step change)	-	562.2
NumberBIN~Regcontrol (step change at month2)	Apr-13	560.3
NumberBIN~Regcontrol (step change at month3)	May-13	562.79
NumberBIN~Regcontrol (step change at month4)	Jun-13	562.47
NumberBIN~Regcontrol (step change at month8)	Oct-13	562.24
NumberBIN~Regcontrol (step change at month9)	Nov-13	559.26
NumberBIN~Regcontrol (step change at month10)	Dec-13	559.4
NumberBIN~Regcontrol (step change at month11)	Jan-14	559.83
NumberBIN~Regcontrol (step change at month12)	Feb-14	560.51
NumberBIN~Regcontrol (step change at month13)	Mar-14	560.81
NumberBIN~Regcontrol (step change at month14)	Apr-14	560.81
NumberBIN~Regcontrol (step change at month15)	May-14	559.25
NumberBIN~Regcontrol (step change at month16)	Jun-14	558.58
NumberBIN~Regcontrol (step change at month17)	Jul-14	559.09
NumberBIN~Regcontrol (step change at month18)	Aug-14	559.45
NumberBIN~Regcontrol (step change at month19)	Sep-14	560.69
NumberBIN~Regcontrol (step change at month20)	Oct-14	562.45
NumberBIN~Regcontrol (step change at month21)	Nov-14	563.56
NumberBIN~Regcontrol (step change at month22)	Dec-14	564.07
NumberBIN~Regcontrol (step change at month23)	Jan-15	564.1
NumberBIN~Regcontrol (step change at month24)	Feb-15	564.15
NumberBIN~Regcontrol (step change at month25)	Mar-15	563.64
NumberBIN~Regcontrol (step change at month26)	Apr-15	562.7
NumberBIN~Regcontrol (step change at month27)	May-15	561.1
NumberBIN~Regcontrol (step change at month28)	Jun-15	558.98
NumberBIN~Regcontrol (step change at month29)	Jul-15	560.63
NumberBIN~Regcontrol (step change at month30)	Aug-15	559.37
NumberBIN~Regcontrol (step change at month31)	Sep-15	557.84
NumberBIN~Regcontrol (step change at month32)	Oct-15	559.61

NumberBIN~Regcontrol (step change at month33)	Nov-15	560.32
NumberBIN~Regcontrol (step change at month34)	Dec-15	561.98
NumberBIN~Regcontrol (step change at month35)	Jan-16	563.97
NumberBIN~Regcontrol (step change at month36)	Feb-16	564.12
NumberBIN~Regcontrol (step change at month37)	Mar-16	564.19
NumberBIN~Regcontrol (step change at month38)	Apr-16	564.19
NumberBIN~Regcontrol (step change at month39)	May-16	564.13

There has been no clear, persistent decline in landing occurrences over time for mobula rays, with no low AIC values were noted around the time of the regulation, and most step-change models not differing substantially from the null model (Δ AIC<3). The lowest AIC values were noted around September and October 2015.

Interpretation of best-fit models

For manta ray, the February 2014 pre-post- GLM indicated a significantly lower probability of landing occurrences post-February 2014 (Table 9.7), while the September 2015 pre-post GLM gave an insignificant negative co-efficient for post-September 2015 (Table 9.8).

Table 9.7: Output of generalised linear model with binomial errors for manta landing occurrences in Tanjung Luar fitted to pre-post regulation (February 2014) Call: glm(formula= NumberBIN~Regulation, family = binomial, data = TLmanta)

Deviance Residuals:

	Min	1Q	Median	3Q	Max
	-0.3272	-0.136	-0.136	-0.136	3.062

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.9004	0.3097	-9.366	<2e-16	***
Post Regulation (Feb 2014)	-1.7782	0.4712	-3.774	0.000161	***

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 191.19 on 1079 degrees of freedom
Residual deviance: 177.34 on 1078 degrees of freedom
AIC: 181.34
Fisher Scoring iterations: 2

Table 9.8: Output of generalised linear model with binomial errors for manta landing occurrences in Tanjung Luar fitted to pre-post regulation Sept 2015 Call: glm(formula= NumberBIN~Regulation, family = binomial, data = TLmanta)

Deviance Residuals:

	Min	1Q	Median	3Q	Max
	-0.22654	-0.22654	-0.22654	-0.00005	2.71132

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.65	0.2324	-15.707	<2e-16	***
Post Sept 2015	-16.9161	976.0248	-0.017	0.986	

Dispersion parameter for binomial family taken to be 1)
Null deviance: 191.19 on 1079 degrees of freedom
Residual deviance: 177.19 on 1078 degrees of freedom
AIC: 181.19
Fisher Scoring iterations: 19

For mobula ray, the September 2015 pre-post GLM gave a significant positive coefficient (Table 9.9), confirming that no step-change decline has occurred for mobula ray landing occurrences.

Table 9.9: Output of generalised linear model with binomial errors for mobula landing occurrences in Tanjung Luar fitted to pre-post Sept 2015 Call: glm(formula= NumberBIN~Regulation, family = binomial, data = TLmobula)

Deviance Residuals:

	Min	1Q	Median	3Q	Max
	-0.4663	-0.4663	-0.3477	-0.3477	2.3815

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.7754	0.1554	-17.862	<2e-16	***
Post Sept 2015	0.6114	0.2386	2.562	0.0104	*

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 560.2 on 1079 degrees of freedom
Residual deviance: 553.84 on 1078 degrees of freedom
AIC: 557.84
Fisher Scoring iterations: 5

Overall, manta ray landing occurrences appear to have significantly declined post-February 2014, while mobula ray landings have not. Given that no other major events or fluctuations that I am aware of have taken place, it is plausible to attribute at least some of this change to the regulation.

Both genus models

In order to test interactions between genera and regulation, I combined the manta and mobula ray datasets, ran all meaningful models, and compared AIC's with a null model, and between each model (Table 9.10)

Table 9.10: AIC values of all meaningful generalised linear models with binomial errors fitted for all mobulid (both genera) landing occurrences in Tanjung Luar

Models	AIC
NumberBIN~1	793.59
NumberBIN~month	802.07
NumberBIN~year	783.89
NumberBIN~year+month	802.07
NumberBIN~year*month	802.07
NumberBIN~monthnumber	778.26
NumberBIN~Genus	755.39
NumberBIN~Regulation	783.77
NumberBIN~month*Genus	790.79
NumberBIN~month+Genus	763.76
NumberBIN~year*Genus	740.37
NumberBIN~year+Genus	751.71
NumberBIN~monthnumber*Genus	744.6
NumberBIN~monthnumber+Genus	752.86
NumberBIN ~ Regulation*Genus	741.85
NumberBIN ~ Regulation+Genus	745.33

Year*Genus and regulation*Genus are the best-fit models, indicating that there has been a significant change over time in mobulid landings, but there is variation between mobulid genera, and that pre-post regulation also explains this variation well, although it was not possible to compare between year and regulation, as they are very highly covaried.

The GLM for regulation*species suggests a highly significant negative probability of landing occurrences post-regulation, but a significant positive coefficient for the mobula:post-regulation interactions (Table 9.11). A family-wise general linear hypothesis test (GLHT) of this model indicates there is a highly significant difference between manta landings pre- and post-regulation, with the probability of manta landings declining post-regulation. For mobula, there is a negative coefficient, suggesting a decline, but it is not significant (Table 9.12).

Table 9.11: Output of generalised linear model with binomial errors for all mobulid landing occurrences in Tanjung Luar fitted to pre-post regulation (Feb 2014) Call: glm(formula= NumberBIN~Regulation*Genus, family = binomial, data = TLmobulids)

Deviance Residuals:

	Min	1Q	Median	3Q	Max
	-0.4693	-0.365	-0.3272	-0.136	3.062

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.9004	0.3097	-9.366	<2e-16	***
GenusMobula	0.7497	0.383	1.958	0.050263	.
RegulationPost	-1.7782	0.4712	-3.774	0.000161	***
GenusMobula:RegulationPost	1.2536	0.5403	2.32	0.02033	*

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 791.59 on 2159 degrees of freedom
Residual deviance: 733.85 on 2158 degrees of freedom
AIC: 741.85
Fisher Scoring iterations: 7

Table 9.12. output of family-wise general linear hypothesis test for mobulid landing occurrences generaised linear model. (Multiple Comparions of Means: Tukey Contrasts Fit: glm(formula=NumberBIN~Species*Regulation, family=binomial, data=TLdatabase))

Linear Hypotheses:

	Estimate	Std. Error	z value	Pr(>|z|)	
Mobula.Pre-Manta.Pre==0	0.7497	0.383	1.958	0.196	
Manta.Post-Manta.Pre==0	-1.7782	0.4712	-3.774	<0.001	***
Mobula.Post-Manta.Pre==0	0.225	0.3391	0.664	0.907	
Manta.Post-Mobula.Pre==0	-2.5279	0.4206	-6.01	<0.001	***
Mobula.Post-Mobula.Pre==0	-0.5247	0.2643	-1.985	0.185	
Mobula.Post-Manta.Post==0	2.0033	0.3811	5.256	<0.001	***

(Adjusted p values reported -- single-step method)

Lamakera

Manta landing occurrences modelled against time

As with Tanjung Luar I fitted a Generalised Linear Model (GLM) of manta landing occurrences (Y/N) to month (Table 9.13) and year (Table 9.14) and mobula landing occurrences (Y/N) to month (Table 9.15) and year (Table 9.16) with both month and year as a categorical variable, to assess whether there were any significant and persistent changes in the probability of landing occurrences over time. However as no pre-regulation data was available I used June 2015 as the reference level, as this was the month that enforcement actions began in Lamakera, with the first trader arrested.

Table 9.13: Output of generalised linear model with binomial errors for manta landing occurrences in Lamakera to month as a categorical variable

Call: glm(formula= NumberBIN~Month, family = binomial, data = LAMmanta), reference level = June 2015

Deviance Residuals:

	Min	1Q	Median	3Q	Max	
	-2.03933	-0.72898	-0.37146	-0.00013	2.62068	

Coefficients:

	Law enforcement	Estimate	Std. error	z value	Pr(>|z|)	
(Intercept)	-	-1.19E+00	4.32E-01	-2.756	0.00585	**
May 2015	Pre	1.78E-01	7.26E-01	0.245	0.80637	
July 2015	Post	-1.04E+00	7.45E-01	-1.401	0.16124	
August 2015	Post	4.48E-01	5.78E-01	0.775	0.43856	
September 2015	Post	-1.45E+00	8.50E-01	-1.706	0.08805	.
October 2015	Post	-7.20E-01	6.88E-01	-1.046	0.29537	
November 2015	Post	9.56E-15	6.11E-01	0	1	
December 2015	Post	-1.74E+01	1.17E+03	-0.015	0.98817	
January 2016	Post	-2.21E+00	1.10E+00	-2.003	0.04522	*
February 2016	Post	-1.74E+01	1.21E+03	-0.014	0.98855	
March 2016	Post	-1.74E+01	1.17E+03	-0.015	0.98817	
April 2016	Post	-1.45E+00	8.50E-01	-1.706	0.08805	.
May 2016	Post	1.78E-01	5.97E-01	0.298	0.76573	
June 2016	Post	1.48E-01	6.42E-01	0.231	0.81745	
July 2016	Post	3.14E+00	1.15E+00	2.72	0.00654	**

Table 9.14: Output of generalised linear model with binomial errors for manta landing occurrences in Lamakera fitted to year

Call: glm(formula= NumberBIN~Year, family = binomial, data = LAMmanta), reference level = 2015

Deviance Residuals:

	Min	1Q	Median	3Q	Max
	-0.5937	-0.5937	-0.5318	-0.5318	2.0129

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.6466	0.1795	-9.171	<2e-16	***
Year2016	-0.238	0.2833	-0.84	0.401	

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 345.20 on 410 degrees of freedom
Residual deviance: 344.49 on 409 degrees of freedom
AIC: 348.49
Fisher Scoring iterations: 4

Table 9.15: Output of generalised linear model with binomial errors for mobula landing occurrences in Lamakera to month as a categorical variable
Call: glm(formula= NumberBIN~Month, family = binomial, data = LAMmobula), reference level = June 2015

Deviance Residuals:

Min	1Q	Median	3Q	Max
-2.03933	-0.72898	-0.37146	-0.00013	2.62068

Coefficients:

	Law enforcement	Estimate	Std. error	z value	Pr(>|z|)	
(Intercept)	-	-0.4055	0.3727	-1.088	0.27661	
May 2015	Pre	1.0986	0.6625	1.658	0.09725	.
July 2015	Post	-1.0217	0.5878	-1.738	0.08222	.
August 2015	Post	-1.5041	0.6526	-2.305	0.02119	*
September 2015	Post	-2.2336	0.8213	-2.719	0.00654	**
October 2015	Post	-1.5041	0.6526	-2.305	0.02119	*
November 2015	Post	-0.9808	0.5893	-1.665	0.09601	.
December 2015	Post	-19.1606	1931.4778	-0.01	0.99208	
January 2016	Post	-19.1606	1931.4778	-0.01	0.99208	
February 2016	Post	-19.1606	1996.9701	-0.01	0.99234	
March 2016	Post	-19.1606	1931.4778	-0.01	0.99208	
April 2016	Post	-1.4663	0.6537	-2.243	0.02489	*
May 2016	Post	0.1372	0.5241	0.262	0.79347	
June 2016	Post	0.3185	0.5596	0.569	0.56929	
July 2016	Post	-0.1054	0.8199	-0.129	0.89775	

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 390.56 on 410 degrees of freedom
Residual deviance: 289.38 on 396 degrees of freedom
AIC: 319.38
Fisher Scoring iterations: 18

Table 9.16: Output of generalised linear model with binomial errors for mobula landing occurrences in Lamakera fitted to year
Call: glm(formula= NumberBIN~Year, family = binomial, data = LAMmobula), reference level = 2015

Deviance Residuals:

Min	1Q	Median	3Q	Max
-0.6532	-0.6532	-0.6111	0.6111	1.8815

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.4362	0.1677	-8.562	<2e-16	***
Post Sept 2015	-0.1471	0.2589	-0.568	0.57	

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 390.56 on 410 degrees of freedom
Residual deviance: 390.24 on 409 degrees of freedom
AIC: 394.24
Number of Fisher Scoring iterations: 4

There is no indication of significant persistent declines over time for either manta or mobula ray landings.

Step-change models

As with Tanjung Luar I fitted landing occurrences to pre-post models for both manta and mobula for every month during the time series to look for further evidence of a step-change. I compared AICs of the

models with a null model, and with each other (Table 9.17), to identify if/when in the timeline a step-change in landing occurrences may have taken place.

Table 9.17: AIC values of generalised linear models with binomial errors for mobula and manta landing occurrences in Lamakera fitted to pre-post for every month in the time series

Model	Corresponding month and year	AIC Manta	AIC Mobula
NumberBIN~1	-	347.2	392.56
NumberBIN~Regcontrol (step change at month2)	June 2015	347.74	376.7
NumberBIN~Regcontrol (step change at month3)	July 2015	345.95	369.11
NumberBIN~Regcontrol (step change at month4)	August 2015	348.3	375.72
NumberBIN~Regcontrol (step change at month5)	September 2015	343.07	382.37
NumberBIN~Regcontrol (step change at month6)	October 2015	346.51	388.83
NumberBIN~Regcontrol (step change at month7)	November 2015	347.19	390.97
NumberBIN~Regcontrol (step change at month8)	December 2015	344.72	390.51
NumberBIN~Regcontrol (step change at month9)	January 2016	348.49	394.24
NumberBIN~Regcontrol (step change at month10)	February 2016	349.18	393.74
NumberBIN~Regcontrol (step change at month11)	March 2016	347.08	388.87
NumberBIN~Regcontrol (step change at month12)	April 2016	340.12	377
NumberBIN~Regcontrol (step change at month13)	May 2016	331.31	367.58
NumberBIN~Regcontrol (step change at month14)	June 2016	334.45	381.5

A step-change in May 2016 was identified as the best-fit model for both genera.

Interpretation of best-fit models

For both manta and mobula ray, the May 2016 pre-post- GLM indicated a significantly higher probability of landing occurrences post-May 2016 (Table 9.18; 9.19).

Table 9.18: Output of generalised linear model with binomial errors for manta landing occurrences in Lamakera fitted to pre-post May 2016

Call: glm(formula= NumberBIN~May 2016, family = binomial, data = LAMmanta), reference level = Pre

Deviance Residuals:

Min	1Q	Median	3Q	Max
-0.9187	-0.4927	-0.4927	-0.4927	2.0828

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	2.0477	0.168	-12.188	< 2e-16	***
Post May 2016	1.4033	0.3176	4.419	9.91E-06	***

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 345.2 on 410 degrees of freedom
Residual deviance: 327.31 on 409 degrees of freedom
AIC: 331.31
Fisher Scoring iterations: 7

Table 9.19: Output of generalised linear model with binomial errors for mobula landing occurrences in Lamakera fitted to pre-post May 2016

Call: glm(formula= NumberBIN~May 2016, family = binomial, data = LAMmobula), reference level = Pre

Deviance Residuals:

Min	1Q	Median	3Q	Max
-1.0812	-0.5432	-0.5432	-0.5432	1.9934

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.8392	0.1554	-11.837	< 2e-16	***
Post May 2016	1.6087	0.301	-5.345	9.05E-08	***

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 390.56 on 410 degrees of freedom
Residual deviance: 363.58 on 409 degrees of freedom
AIC: 367.58
Fisher Scoring iterations: 4

It can be concluded that implementation of the regulation has not had a significant impact on manta ray landings in Lamakera over the time period of the available data.

Total annual catch estimations

To estimate total annual catch (AC) I used a modified version of the methods used in White et al. (2006) and Lewis et al. (2015), based on the following simple calculation:

AC = Mean Daily Landed Catch (MDLC) x fishing days per year (FD)

Where MDLC = total observed landed catch /total number of survey days

This calculation is highly simplified and based on two major assumptions: that landed catch is uniform throughout the year and that fishing effort is uniform throughout the year, such that landings are equally likely to take place on any given day. These assumptions are flawed, particularly for Tanjung Luar where landings do not take place every day as single fishing trips can be as long as three weeks, but without more robust data on seasonal fluctuations in fishing and catch, it is not possible to conduct a more nuanced calculation: since data on daily landings and fishing behaviour, particularly pre-ban, are limited, a quantitative understanding of seasonality was not feasible in this study, but a number of simple corrections were made as follows:

In Tanjung Luar White et al (2006) previously used an FD of 365, assuming that catch is landed consistently every day, while Lewis et al (2015) modified this to assume 300 FD per year, although the

justification for this number is unclear. For this study, AC data for 2014 and 2015 were based on the total observed annual catch, since sampling for those years was 100%. For 2013 and 2016, the calculation was modified. Given that the vessels primarily targeting mobulids go out to sea for long fishing trips, sometimes three weeks at a time, fishing days and landing days cannot be considered synonymous. When monitoring from the port, there is a need to consider not only the probability of a given day being a mobulid landing day, but the probability of a given day being a landing day at all (i.e. vessels being present in the port) to take into consideration. To resolve this, I used data from 2014 and 2016 to calculate the average proportion of days in the year that are elasmobranch vessel landing days (i.e. days that elasmobranch vessels came into port), which was 0.51. I then multiplied the number of survey days by 0.51 to get an estimate of how many days were likely to be landing days, given the number of survey days. Similarly, FD was modified to an estimate of annual landing days (LD) based on the average proportion of survey days in 2015 and 2015 that were elasmobranch vessel landing days (0.51), multiplied by the number of days in the year (i.e. 365*0.51). See Table 9.19 for figures.

Table 9.19: Estimated annual catch calculations for Lamakera in 2015 and 2016

Year	Observed catch (OC)		Survey days	Est. Landing days (ELD)	MDLC (OC/ELD)		Estimated total annual landing days (LD)	Estimated Annual catch (MDLC*LD)	
	Manta	Mobula			Manta	Mobula		Manta	Mobula
2013	12	21	152	78	0.15	0.27	187	28	50
2014	4	51	365	203*	0.01	0.14	203*	4	51
2015	4	66	365	174*	0.01	0.18	174*	4	66
2016	0	32	182	93	0.00	0.18	187	0	64

*For these years landing days is observed, not estimated

In Lamakera, fishing trips tend to be daily, therefore fishing days and landing days can be considered synonymous, and aside from seasonal variations, any given fishing day can feasibly be considered a landing day. Lewis et al (2015) also assumed 300 LD for their calculations in Lamakera. For this study we used 245 as the estimated FD, since January-March are known to the off-season for mobulid fishing in Lamakera (Lewis et al 2015) and the landing records for May 2015-July 2016 show that only a single mobulid was landed (~0.3% of total annual landings) during this off-period in 2016. This time period was therefore assumed to make a relatively insignificant contribution to total annual mobulid fishing

effort. See Table 9.20 for figures. For previous years estimated annual catch was taken directly from Lewis et al. (2015) based on community landing records/village elder personal communication.

Table 9.20: Estimated annual catch calculations for Lamakera in 2015 and 2016

Year	Observed catch (OC)		Survey days (SD)	MDLC (OC/SD)		Estimated annual landing fishing days (FD)	Estimated Annual catch (MDLC*FD)	
	Manta	Mobula		Manta	Mobula		Manta	Mobula
2015	184	116	229	0.80	0.51	245	196	124
2016	41	68	182	0.23	0.37	245	55	91

S10 Price data analysis

All national price data is based on secondary data gathered from variety sources (S7). Each source collected their primary data using different people and methods (e.g. in some cases data was gathered through interviews with fishers, while in others data was gathered through market surveys); recorded their results in different formats (e.g. price per individual animal vs. price per kilogram of product); and acknowledged uncertainty and variation to varying degrees (Table 7.1). In order to make use of this data, and make it comparable from source to source year to year, it was necessary to make a number of conversions and assumptions, as follows:

For simplicity, and to enable some aggregation of data for analysis, I labelled prices 'local' or 'national' as per the following conventions:

- 'Local': Prices recorded in producer fishing communities (i.e. Lamakera and Tanjung Luar) and/or where the price is clearly denoted as the price paid for a transaction between a local actor (e.g. between fisher and processor or fisher and local trader)
- 'National': Prices recorded in known trading locations (e.g. Surabaya, Indramayu) and/or where the price is denoted as that paid for a transaction that goes beyond the fishing community (e.g. between a local trader and a 'big trader') as 'national' prices.

This is a considerable oversimplification of the supply chain, and that complex and diffuse supply chains can develop, with a number of actors and several transactions/levels of value addition from sea to consumer.

All prices were inflation adjusted and converted into USD per kg using monthly average exchange rates from Oanda.com. In many cases prices were denoted in different units, such as price per kg of gills or price per individual manta. For the purposes of the study, only prices recorded as price per kg of gills were used for comparison.

According to available data, local average manta ray gill plate prices in Tanjung Luar declined by over 50% in 2015. Comparable data for devil ray gill plate prices in Indonesia was sparse, but

indicated very little change in price between 2005 and 2015. Local trading prices for manta ray gill plates in Lamakera have gradually declined over the past six years, while prices for devil ray gill plates shown little variation between 2011 and 2015, but have remained much lower (Table 11.1; Fig. 11.1). Both of these local trends are in contrast to national and international level trading prices: national prices rose significantly in 2015, and fell again in 2016 by over 50%; average retail prices in international consumer markets remained relatively stable, gradually rising to a high of US$421 in 2016, although there has been some variability within individual consumer countries (O'Malley et al., 2016) (Fig 11.1).

Table 11.1: Average per kg gill plate prices at local, national and international levels (USD, inflation corrected)

Year	Tanjung Luar		Lamakera		National		International		Sources
	Manta	Devil	Manta	Devil	Manta	Devil	Manta	Devil	
2002	-	-	40	-	-	-	-	-	Dewar, 2002
2005	24	17	-	17	-	-	-	-	White et al., 2006; Lewis et al., 2015
2010	101	-	-	-	96	-	-	-	Lewis et al., 2015
2011	-	-	133	32	-	-	404	225	Lewis et al., 2015; O'Malley et al., 2016
2013	-	-	-	-	-	-	335	225	O'Malley et al., 2016
2014	113	-	122	-	135	-	-	-	Lewis et al, 2015; Reefcheck, WCS unpublished records
2015	51	35	86	41	262	-	377	229	Lewis et al., 2015; O'Malley et al., 2016; WCS unpublished records; fisher interviews
2016	-	-	-	-	98	-	421	312	WCS unpublished records

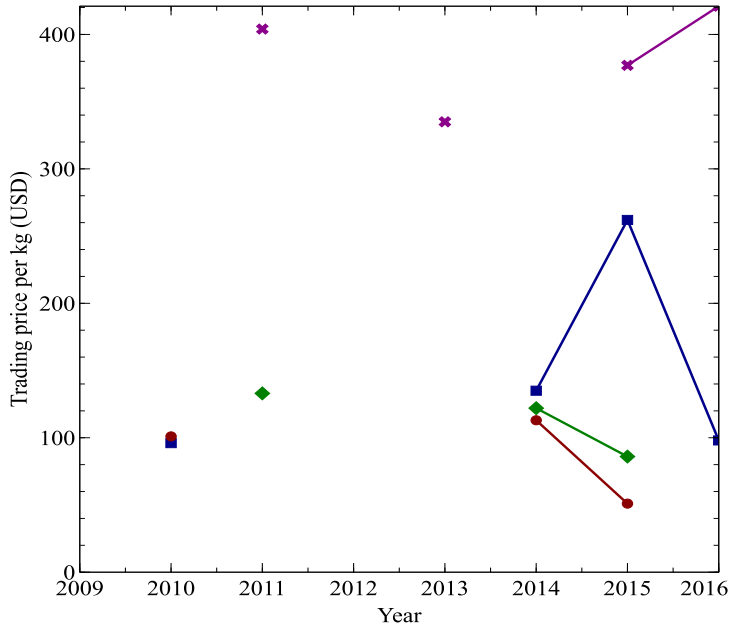


Figure 11.1 Price trends over time (2010-2016)

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