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MASTER THESIS PROJECT

Detecting anchored fish aggregating devices (FADs) and estimating use patterns from vessel tracking data in small scale tuna fisheries in Indonesia

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(SAILA/DEPARTAMENTO/DEPARTMENT)....................

PLENTZIA (UPV/EHU), SEPTEMBER 2018

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Dr ......(supervisor or presenter)......
as teaching staff of the MER Master of the University of …………………………….

CERTIFIES:

That the research work entitled “Detecting anchored fish aggregating devices (FADs) and estimating use patterns from vessel tracking data in small scale tuna fisheries in Indonesia”

has been carried out by Ahmad Catur Widyatmoko in the Commonwealth Scientific and Industrial Research Organization (CSIRO), Oceans and Atmosphere, Hobart, Tasmania under the supervision of Dr Britta Denise Hardesty and Dr Chris Wilcox from the of the the Commonwealth Scientific and Industrial Research Organization, Oceans and Atmosphere in order to achieve 30 ECTS as a part of the MER Master’s program.

On …….., September 2018

BD Hardesty

Signed: Ahmad Catur Widyatmoko   Supervisor (Britta Denise Hardesty / Chris Wilcox)

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SUMMARY

Fishing demand is increasing linearly with the growth of the global human population. To respond to this increased demand, fishers have been looking for new fishing methods and technologies aimed to maximise fish extraction from the world's oceans. The behaviour of fish, especially pelagic fish which aggregate underneath floating objects, has encouraged fishers to create artificial floating objects. These artificial objects that attract fish are called Fish Aggregative Devices (FADs) and they have helped the significant growth of world capture fisheries production by increasing fishing efficiency. However, the massive deployment of FADs in recent years has given rise to concern about the potential for negative consequences associated with FAD (over)fishing.

Fisheries authorities and regional fisheries management organizations (RFMO) have tried to manage the use of FADs in both coastal and high seas. However, due to illegal deployment and technical difficulties, FAD management is difficult. Moreover, due to the competitive nature of the fishing industry, fishing companies and individual fishers tend to avoid disclosing their FADs number and locations. This makes estimating the numbers of FADS as well as monitoring and managing FADs complex and difficult.

Regulatory changes in some parts of the world means that fishing vessels are required to have tracking devices to monitor their movements. However, in some regions, tracking of small-scale fishing vessels is voluntary. In three provinces in Indonesia, small-scale fishing vessels have opted to adopt a voluntary tracking program over the last two years. Based on their tracking data, we tried to detect the location and the use pattern of FADs and to estimate the catch rate and the number of FADs in use from the vessel movement.

A total of 48 FADs were detected as being visited by 34 fishing vessels from August 2016-January 2018. We learned that sharing FADs among vessels is common practice and that some FADs were visited multiple times in a year. We also identified that some FADs are visited over the course of more than one year, indicating that the lifetime of an individual

FAD may exceed one year. Furthermore, results from the general additive model (GAM) showed that the length of the trip was more correlated to the total catch than was the number of FADs visited by a vessel in a single trip.

Resumen

La demanda de pescado aumenta de forma lineal con el crecimiento de la población humana. Como respuesta a este aumento en la demanda de pescado, los pescadores han desarrollan un nuevo método de pesca y tecnología para maximizar la extraccion de pescado. El comportamiento de los peces, especialmente los peces pelágicos que se agregan bajo objetos flotantes, ha alentado a los pescadores a crear objetos flotantes artificiales. Los Dispositivos Agregadores de Peces (DCP) han ayudado al crecimiento significativo de la producción mundial de captura de peces al aumentar la eficiencia de la pesca. Sin embargo, la implementacion masiva de DCP en los últimos años ha generado preocupación por las consecuencias perjudiciales de la pesca asociada a DCPs.

Las autoridades pesqueras y la administración regional de pesquerías (OROP) han intentado manejar el uso de DCP tanto en la costa como en alta mar. Sin embargo, debido a la implementacion ilegal y las dificultades técnicas, el manejo de los DCP no es óptimo. Además, debido a la naturaleza competitiva de la industria pesquera, las empresas pesqueras y los pescadores tienden a evitar declarar el número de DCP y su ubicación, complicando aún más el monitoreo.

Cambios en la reglamentación obligatoria en algunas partes del mundo requieren ahora el uso obligatorio de aparatos de localizasion en barcos pesqueros para monitorear sus movimientos. Alternativamente, en algunas regiones, el seguimiento de barcos pesqueros de pequenia escala es voluntario. En tres provincias en Indonesia, barcos pesqueros de pequenia escala, han optado por adoptar un programa de seguimiento voluntario en los dos ultimos anios. Sobre la base de estos datos de seguimiento, tratamos de detectar la ubicación y el patrón de uso de los DCPs y también estimar la tasa de captura del movimiento de los barcos y el número de DCP en uso.

Se detectó un total de 48 DCP siendo visitados por 34 barcos pesqueros en este estudio desde Agosto de 2016 to Enero 2018. Tambien se encontro que compartir los DCPs entre buques es una práctica común y que algunos DCPs fueron visitados varias veces durante un año. Ademas se encontro que algunos DCPs fueron visitados sobre un periodo mayor a un anio, indicando que la esperanza de vida de un DCP puede exceder un anio . Adicionalmente, los resultado de Modelos Generales Aditivos (GAM) mostraron que la duración del viaje estuvo mas correlacionada con la capture total captura que con el número de DCP visitados por un barco en un solo viaje.

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1.0 Introduction

1.1 The State of World Fisheries

Fish are a crucial resource for current human beings, as a food resources as well as an economic engine. The fishery production in the world has reached 171 million tonnes in 2016 and the 88 percent of this production is utilized for human consumption (FAO, 2018). With a total sale value of USD 362 billion, fisheries activities generate direct employment for nearly 59.6 million people around the world (FAO, 2018).

Tuna are one of the most valuable seafood commodities. To increase tuna production, several efforts have been undertaken, including shifts in fishing gear and catching methods. Nowadays, purse seine contributes almost 70 percent of world tuna production. Another evolution of the fishing method is the use of fish aggregative devices. These fishing aids increase fishing efficiency and are now widely being deployed. Approximately 70 percent of tuna production in Western and Central Pacific is caught by using this fishing aid (Miyake et al., 2010).

Tuna are being targeted by both artisanal and industrial fisheries. The differences between artisanal fisher and industrial fishers include both their objectives and their fishing methods (Beverly et al., 2014). While artisanal fishers mostly catch fish for local consumption, the industrial sector is focused on mass production for export to meet the demands of global markets (Branch et al., 2002).

However, there are concerns about the impact of this demand on fish stocks. The natural production of fish will not keep up the growing global demand, which is increasing at approximately 3.2 percent per year (Kent, 1998; FAO, 2018). Massive fishing effort and advance catching methods have caused danger to some tuna species. For instance, based on the recent FAO State of the World Fisheries and Aquaculture report (FAO, 2011), the stock of tuna species such as blue fin has been overfished and/or is currently fully exploited in several ocean basins. In some area, tuna species are almost locally extinct, with some organizations pressing for them to be listed as endangered species (Vasquez, 2010).

1.2 Fish Aggregating Devices (FADs)

Fish aggregate around floating objects that create three-dimensional structure in the ocean. Fishers commonly take advantage of this natural behaviour, and develop human-made structures to aid in fish capture. According to the Food and Agricultural Organization of the United Nations (FAO), the definition of a fish aggregating device is any permanent, semi-permanent or temporary structure or device made from any material and used to lure fish (FAO, 2018). Other definitions define fish aggregating devices (FADs) as any man-made device, or natural floating object, whether moored or not, that is capable of aggregating fish (Itano, 2007).

The motivation for fish to aggregate under the FADs is still in discussion. Many believe that FADs are used as a meeting point for schooling, as a feeding zone or, as a sheltered place to avoid predators (Castro et al., 2002). Others suggest that fish aggregate under FADS as they provide a geographical reference or that they provide pre-settlement habitat for juveniles (Dempster et al., 2004).

1.2.2 The Types of FADs

There are generally considered to be two types of FADs, anchored and drifting. Drifting FADs are deployed in the high sea with a tracking device attached to the buoy, while anchored FADs are usually moored in coastal areas or in the open sea with the depth of no more than 2000 to 2500 m (Beverly et al., 2012.). Another difference between drifting and anchored FADs is the material of the attractor itself. Typically, anchored FADs use biodegradable material such as coconut leaves, bamboo or nipah leaves. In contrast, drifting FADs commonly use old fishing net which is more durable than leaves, as fishing net is made from plastic which does not biodegrade (Yusfiandayani, 2013; Nurani et al., 2014; Murua et al., 2014).

Furthermore, it is also important to differentiate between industrial and artisanal FADs users since their objectives is also different. Industrial fishing companies use both anchored and drifting FADs, while the artisanal fishery only use anchored. This is likely driven in part by the need for vessels to move long distances to follow drifting FADs. One important difference between these users is the type of fishing gear they use, and as a result the quantities of fish caught. Industrial vessels are typically using purse seine nets, which take all the fish in the area enclosed by the net. In contrast, artisanal fishers use handlines, troll lines, and other gears that are more selective. Another difference between industrial and artisanal users is the location of the deployment. Artisanal fishers tend to deploy their FADs in the coastal areas whereas industrial fishers usually deploy in the high seas (Beverly et al., 2012).

Since they are usually deployed by artisanal fishermen, anchored FADs are largely undocumented. These type of FADs are commonly used in the western Pacific Ocean, particularly in Indonesia and Philippine (Beverly et al., 2012). Anchored FADs are comprised of 4 different components: 1) the sinker created from multiple concrete blocks, 2) coconut or palm leaves as the main sub surface attractor, 3) plastic rope as a mainline, and 4) a buoy or surface floating object as position indicator (Itano et al., 2004; Yusfiandayani et al., 2013; WCPFC, 2016). In some regions in Indonesia, anchored FADs also have a guardian who stays in a small raft made from bamboo to prevent other fishermen from fishing the FADs (Itano et al., 2004; Beverly et al., 2012).

Although anchored FADs have a sinker and a main line to keep their position, the surface float and attractor move because the length of the main rope is usually 2 to 3 times longer than the depth of the ocean. The buoy and the surface attractor are able to sway, with a circular motion in which the radius of movement is a function of the depth of the deployment.

FADs have a finite lifetime. This finite lifetime means that deployment of new FADs will likely occur continuously. Anchored FADs have longer period of lifespan than drifting FADs, which can last up to 954 days. By comparison drifting FADs only have an average drifting period of 39.5 days (Maufroy et al., 2016; Shainee & Leira, 2011). The main three factors that influence lifetime of FADs are weather, vandalism and theft (Macfadyen et al., 2009). Moreover, for anchored FADs, regular maintenance is essential to extend the use of FADs, while in the drifting FADs, the use period is also determined by the longevity of the transmitter used to track them (Kimley & Holloway, 1996; Beverly et al., 2012).

Several efforts have been made to count the number of FADs in the ocean at a global scale (Scott and Lopez, 2014). However these efforts were mostly applied to drifting FADs and have excluded anchored FADs. This is because radio beacons or GPS trackers are usually attached to drifting FADs which make them easier to locate, compared to anchored FADs which only have a surface buoy attached as a position marker (Dempster, T., & Kingsford, M. J. 2004; Maufroy et al., 2016). Also, individual fishers and fishing companies are often reluctant to disclose FAD number and position as they want to maintain their competitive edge (Nurani et al., 2014; Maufroy et al., 2016).

It is widely believed that FAD deployment is on the rise. Currently, it is estimated there are around 73 000 anchored and 84 720 drifting FADs (Scott and Lopez, 2014). In the Atlantic Ocean, the number of drifting FADs rose from about 1175 in 2007 to roughly 8575 in 2013, a nearly seven-fold increase in only six years. In the Indian Ocean, the number of drifting FADs has similarly increased from an estimated 2250 in 2007 to 10 300 in 2013 (Maufroy et al., 2016). While there is no specific number of floating FADs reported in the Pacific Ocean, it is estimated that the number of FADS is increasing up to 25 % each year (Hall, 2011). The FAD numbers in Indonesia are largely unknown, according to Natsir (2011) the total anchored FAD is estimated up to 3858 but actual number will likely much higher.

1.2.3 The Benefits and the Drawbacks of FAD Fishing

The widespread use of fish aggregating devices or FADs started in the 1980s particularly in purse seine fishing (Ariz et al., 1992; Fonteneau et al., 2000). By using FADs, fishers can increase their catch per unit effort (CPUE), reduce fuel consumption and time spent at sea. They can also increase their at-sea safety by having a consistent, defined fishing ground (Sharp, 2011). Furthermore, in the some archipelagic areas such as the Pacific Islands, near-shore FADs are important to maintain food security for local communities (Albert et al., 2014; Bell et al., 2015).

On the other hand, the use of FADs also has drawbacks. FADs may alter the migration pattern and the habitat of tuna (Menard et al., 2000; Wang et al., 2014). FADs could act as an ecological trap for pelagic fish species (Marsac et al., 2000; Hallier, J. P., & Gaertner, D. 2008). Furthermore, the fish caught around FADs are often smaller in size and are below the length of maturity, compared to fish caught without FADs, leading to concerns about overharvest of juvenile fish (Robert et al., 2012; Nugroho et al., 2014; Nurani et al., 2014). Moreover, the deployment of FADs in the shipping line also disrupt the navigation and can result in and injury and death to crew of ships during the process of disentangling propellers and rudders (Beverly et al., 2012).

One of the main challenges or criticisms of FADS is that they do not target by species or size. They attract not only targeted catch such as tuna, but also non-targeted fish such as shark and dolphins. Hence, FAD fishing may result in more unintended by-catch compared to non-FAD fishing. This is particularly true when you compare purse seine gear used around FADs and open-sea fishing not on FADs (Gilman, 2011). The fishing efficiency of FADs is so high that without strict regulations, stock depletion may occur. Without proper management, FADs will lead to overfishing for pelagic species.

Finally, FADs are often constructed of old fishing nets and lines. This netting not only attracts fish but also other marine fauna such as sea turtles and pinnipeds who may become ensnared or trapped in the FADs. This ‘ghost fishing’ can result in unintended injury and death to threatened marine species that are ensnared by the FADs (Chanrachkij & Loog, 2003; Filmalter et al., 2013).

1.2.4 Target Catch Associated with FADs

Pelagic fishes such as tuna species are the main target catch for FAD fishing (Beverly et al., 2012). The world tuna production has shown a gradual increase from less than one ton in 1950 to more than 6.5 million tonnes in 2009 (FAO, 2009). Apart from the rise in fishing effort, the increase of purse seine fishers which use FADs in their fishing operations is the main contributor to the higher world tuna production (Miyake et al., 2010).

There are differences in the catch between the three major ocean basins, the Pacific, Atlantic and Indian Ocean. The highest tuna production come from Pacific Ocean with 64 percent of world tuna production with mostly skipjack tuna (*Katsuwonus pelamis*). However, the Pacific Ocean is also the highest when it comes to the FADs use in fishing operation, it estimates that the FADs fishing is more than 40 percent compared to non-FADs (Miyabe & Nakano, 2004; Miyake et al., 2010).

The development of the FADS have also changed the target species of commercial fisheries. For instance, catches from schools associated with dolphins are almost exclusively of yellowfin and include almost no bigeye. By comparison, FAD associated catches have been dominated by skipjack tuna (Miyake et al., 2010). Similarly, due to the use of anchored FADs, catches by small-scale, coastal fisheries rapidly increased and shifted toward FAD associated species (Beverly et al., 2012).

In general, the target catch for the anchored FADs are Big eye tuna (*Thunnus obesus*), Yellowfin tuna (*Thunnus albacares*), Albacore tuna (*Thunnus alalunga*), Skipjack tuna (*Katsuwonus pelamis*), Blue marlin (*Makaira mazara*), Black marlin (*Makaira indica*), Striped marlin (*Kajikia audax*), Sailfish (*Istiophorus platypterus*), Wahoo (*Acanthocybium solandri*), Mahi (*Coryphaena hippurus*) and Rainbow runner (*Elagatis bipinnulata*) (Beverly et al., 2012). Despite those targeted species, 32 different species were found in FADs deployed in equatorial water and 24 different species in tropical water (Taquet et al., 2007).

1.2.5 FADs in Indonesian Tuna Fisheries

Situated between the Pacific and Indian Oceans and an archipelago nation of more than 18,000 islands, Indonesia relies heavily on fishing for feeding its nearly 240 million people. Indonesia has one of the largest capture fisheries economies in the world: in 2016 it trailed only China, with 6 109 783 tonnes of fish, behind China’s 15 246 234 tonnes (FAO, 2018). The export of tuna from Indonesia is second only to shrimp (BPS, 2016).

The tuna fishing fleet in Indonesia is dominated by small scale and artisanal fishers, who account for approximately 90 percent of the total registered tuna vessels (Sunoko & Huang, 2014). These fishers move continuously during the fishing season, which runs from March to December (months) (Duggan & Kochen, 2016). Due to technology limitations for most small scale fishers, the fishing grounds in Indonesia are generally situated less than 15 nautical miles from land (Nurdin et al., 2012).

Fishers in Indonesia rely heavily on FADs to catch tuna (Wang et al., 2014). FADs there are dominated by anchored FADs which are set close to the coastal areas (Beverly et al., 2012; WCPFC, 2016). Most FADs are owned by communities, as opposed to individuals or companies. Generally, a group of fishers with from 3 to 9 vessels will pool their resources and efforts together to build FADs. This group usually has similar fishing gear and target catch (Nurdin et al., 2012; Tamarol & Wuaten, 2013). In some provinces, the fishers may own FADs, but have no fishing vessels of their own. They will offer to allow vessels to catch fish on their FADs in return for a compensation fee which has been agreed. Usually, this type of FAD has a guardian who resides on the small raft on the FAD (Napasau et al., 2015).

The fishing gears that are usually used by small scale fishers associated with FAD fishing in Indonesia are pole and line, hand line, troll line and mini purse seine (Beverly et al., 2012; WCPFC, 2016). These type of gears are targeting four main tuna species such as big eye tuna (*Thunnus obesus*), yellowfin tuna (*Thunnus albacares*), albacore (*Thunnus alalunga*) and skipjack tuna (*Katsuwonus pelamis*) (Duggan & Kochen, 2016).

Anchored FADs in Indonesia are largely undocumented (Miyake et al., 2010). The data such as the number and position of the FADs, type of fishing gears operated on the FADs, and the type of ownership which are essential for effective fisheries management and law enforcement are unavailable (WCPFC, 2016). Moreover, the Indonesian authorities still have no viable solution for detecting anchored FADs in the ocean.

Indonesia, does, however, have regulations for the deployment, use, and removal of FADs. Regulation number 26, which was issued in 2014, focuses on FAD deployment and numbers (Kelautan, 2014). According to the Indonesian federal regulation, all FADs must be deployed at least 10 nautical miles away from the nearest FAD; a single vessel is not permitted to deploy more than three FADS, all FADs must be registered with the Ministry of Fisheries; and FADS should not be placed in shipping lanes. There are also a number of clauses concerning labelling, use of radar reflectors, types of attractors, and a variety of other details about how the FADs are configured. However, this rule is hard to implement and illegal deployment abounds (Nurdin et al., 2012; Nurdin et al., 20014; WCPFC, 2016).

Fisheries management in Indonesia is very dynamic, however. At the time of this study, the government has discussed giving amnesty to FADs that are currently deployed. The amnesty will be followed by new regulations, requiring all FADs to be registered and deployed in specific zones which have been approved for FAD fishing (Satria, personal communication).

1.3 Identifying Where FADS Occur

1.3.1 VMS (Vessel Monitoring System)

The common vessel tracking that is widely in use in industrial fisheries are frequently called vessel monitoring systems (VMS) or sometimes fishing monitoring system. The VMS is generally satellite based, with fishing vessels required to pay for satellite data transmission costs. These systems can typically cover a range of scales, from local to worldwide, depending on the fishery (FAO, 1998). The systems typically give real time position of the vessel, at sampling rates ranging from a few minutes to multiple times a day, depending on the system. Some countries like Indonesia also opened their VMS data to the public in hopes that increased transparency will lead to better fisheries practice. While useful in industrial fisheries, VMS is typically not practical to be applied in small scale fishery because of its price and the fact that most of the small scale fishing vessels lack a power source (Suhendar & Kristófersson, 2013; Cutlip, 2017).

1.3.2 Spot Trace

Archival GPS systems present an alternative to traditional VMS as they record the position, but can rely on internal batteries or solar power removing the need for vessel power, and log the positions to memory greatly reducing costs. The Spot Trace is one such tracking device, which has been developed for use in an asset monitoring. This GPS based tracker is set to log its location every hour. However, it will not log a coordinate when it is stationary, in order to maximize the battery life. Powered by 2 AA size battery, the Spot Trace can last up to one month before the battery needs to be replaced. Although it is not as sophisticated as the vessel monitoring system in the big vessels, it provides a complete set of information such as movement alert, power off message, low battery and status message, which makes it ideal to be attached in small fishing vessels (SPOT LLC, 2018). Moreover, the low price of the devices and the supporting system provides a viable solution to current unmonitored small scale fishery which dominates the global tuna fishing fleet, including Indonesia (Sunoko & Huang, 2014).

1.4 The Objective and the Hypothesis of the Study

By analysing spot tracer data from small vessels in three provinces in Indonesia, my thesis set out to test whether we could use vessel tracking to identify how many FADs are in use within a region. Specifically, my objectives were to:

1. Detect the number and location of fish aggregating devices;
2. Estimate the use pattern of the fish aggregating devices;
3. Investigate whether catch rates could be estimated based on vessel movement and fish aggregating device use.

2.0 Material and Method

2.1 Data Collection:

The study covers eastern part of Indonesia from 3 different provinces, East Nusa Tenggara, West Nusa Tenggara and South of Celebes (Fig.1.). The data were collected from 2016 to 2018 by a local non-governmental organization (NGO) called Masyarakat dan Perikanan Indonesia (MDPI). The Spot Trace devices were attached to 34 different fishing vessels for one month deployments. The deployments were part of a community-based project in which fishers were asked to participate by voluntarily attaching a spot trace to their vessel: they could choose to opt in or opt out. Several vessels participated in more than one session of tracking device attachment, which allowed for a longer tracking record period. The position of each vessel was recorded every hour, while it was moving. Due to the limited number of the tracking devices available, each vessel was attached with a device at different times and devices were rotated between vessels that were 3 to 27 gross tonnes (GT). The data were collected from August 2016 to January 2018. Each vessel was given a vessel identifier code (VIC) based on the location of the fishermen’s fishing base. The following information was recorded: vessel size and engine, number of crew, and type of fishing gear. The tracking data was sent to the Masyarakat Dan Perikanan Indonesia (MDPI) server.

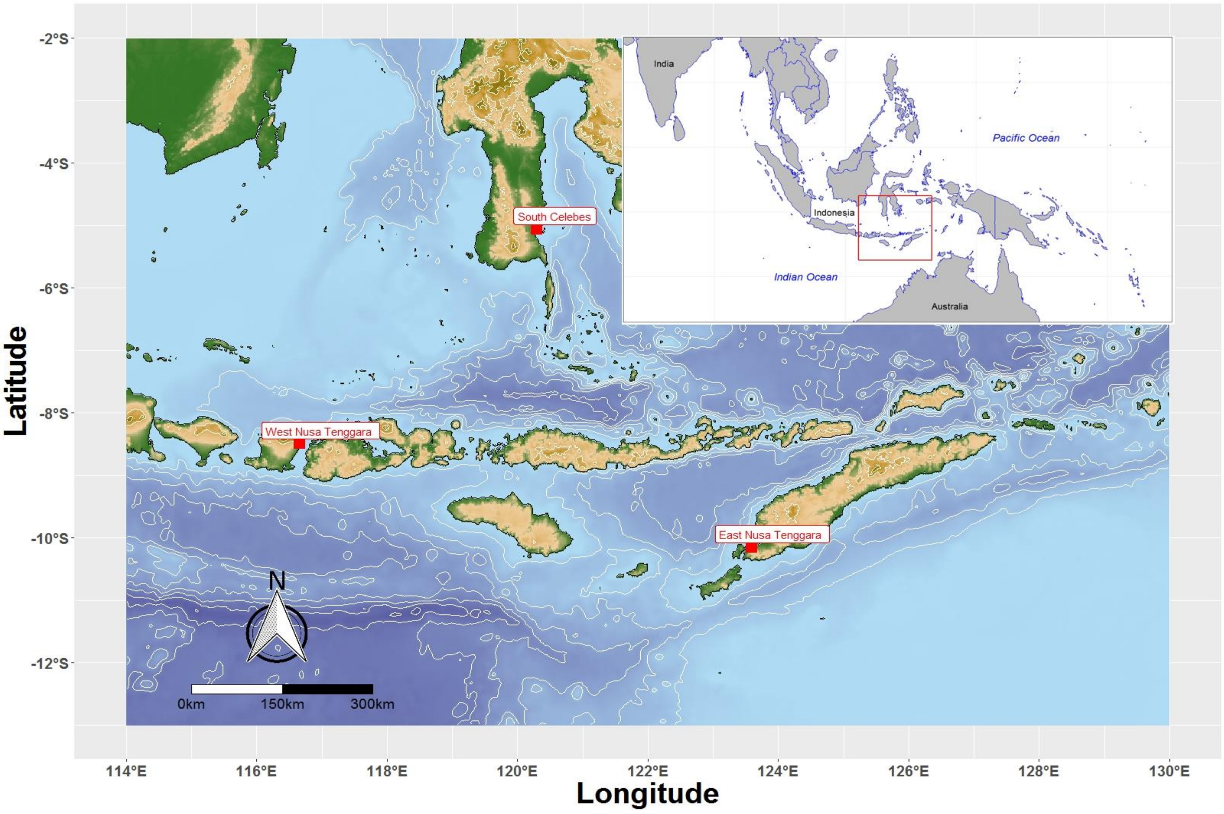

Fig. 1. The location of three different provinces in the study

To evaluate the veracity of information recorded using the spot tracer, interviews and port samplings were conducted to determine the catch composition, fuel consumption, and whether the vessels were actually fishing on FADs. The fishermen were also asked to identify their fishing grounds by showing them a map with one degree grid resolution. This was later compared to tracking device information. The port sampling also collect data about the size and weight of the catch, focusing particularly on tuna > 10 kg in weight. However, due to resource limitations, not every vessel trip was independently verified.

2.2 Data Analysis

All of the data analysis were performed in the statistical language R (R core team, 2013). Before the analysis was conducted, fishing trips from each vessel were reconstructed by using the spatial and time order from the tracking data. Each fishing trip (defined as a vessel starting at a port at an initial time and then returning to the same or to a different port at some later time) was also matched to the port sampling data. A number of descriptive variables were constructed from the trip data. This pre-processing data included the calculating the speed and bearing of the vessel, the distance of each position from land and the distance from nearest fishing port. The figures in this study were created using ggplot2 package in R, created by Wikahm (2016).

2.2.1 Cluster Analysis to Find Location of a FAD:

Density-based spatial clustering of applications with noise (DBSCAN) was implemented to the spot tracer data to determine the location of FADs on the fishing ground. Density-based spatial clustering is a method for finding aggregations of spatial positions, based on treating them as points in a network. Given epsilon, the allowable distance between two points that can be considered connected, all possible connections among a set of spatial points are drawn. Each point is then classified as one of three types, a) interior points – which have receive connections from other points and generate connections to other points, b) edge points – which only receive connections from other points, and c) outlier points – which are unconnected. Spatial clusters are then identified by drawing a boundary around each network of points using the outer-most point around the outside of the cluster.

Prior to clustering we filtered the tracking data to include positions where the vessel was greater than two kilometres from land and the vessel speed was less than one kilometre per hour. Considering the structure of anchored FADs, which have main rope longer than the depth, a FAD has a radius of movement around the anchored position. With the assumption that the length of main rope is twice of the depth location (Satria, personal communication REF), the radius of FADs movement can be obtained using the Pythagoras equation. This radius then will be used as epsilon (range of each cluster) for every position in the vessel record.

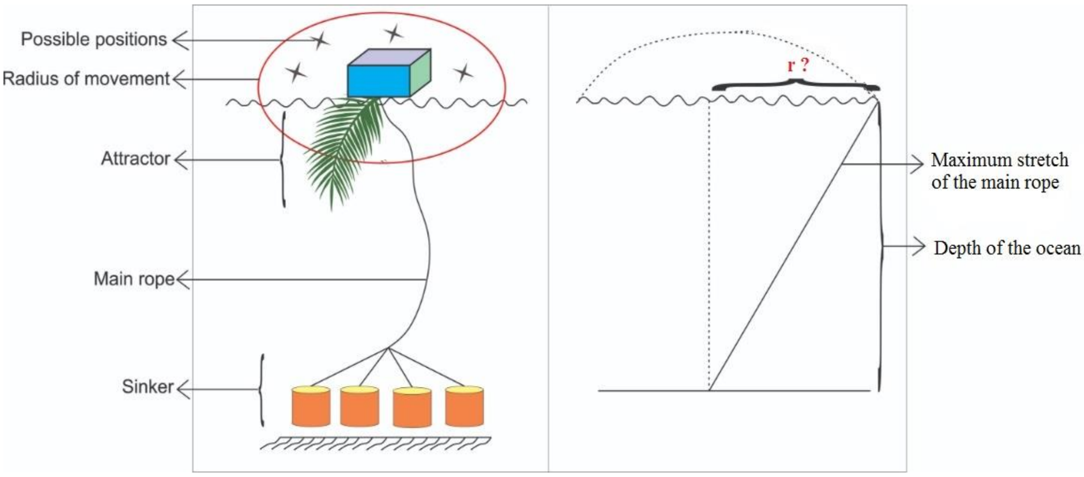

Fig. 2. The diameter calculation of the cluster analysis

The depth was determined by using bathymetry data obtained from General Bathymetric Chart of the Oceans (GEBCO, 2014 REF,). Since each position is located in a different depth, the deepest depth in the fishing ground area will be taken as a reference depth in that local area (Figure 1). Fishing grounds were divided into depth bands, to facilitate the analysis using a constant epsilon within the fishing ground. The processing of 30 arc second spatial resolution bathymetry data were done by using marmap package in R (Eric & Benoit, 2013).

The filtered vessels positions which are located with the radius movement of the FADs from each other will be clustered as suspected FADs position, based on the DBSCAN analysis. However, not all of the filtered positions are likely to be FAD fishing, clusters of stopped or slow movement could also indicate areas of bait fishing. Therefore, a suspected FADs position will be classified as a positive FADs location only if the clustered point was visited at least twice by any vessel. Later, the identified location of each FAD was validated using interview data obtained from the port sampling. The distance between each FADs was also calculated to determine whether the deployment of FADs by the fisherman were abiding by the regulations.

2.2.2 Estimating the Use Pattern of FADs

Each FAD identified using cluster analysis was then further evaluated to understand the use pattern. The use pattern of a FADs includes looking at the several parameters such as the average time a vessel spends on a FAD, the number of vessels visiting a FAD at the same time, and the number of FADs visited by each vessels. Finally, we used the visitation patterns by vessels to make a prediction of the minimum lifetime of a FADs, based on the regularity visits by vessels.

2.2.3 Catch Data Analysis

A generalized additive model (GAM) was implemented in the mgcv package to measure the success rate of the fishing trip (Wood & Wood, 2015). We assumed that if a vessel obtained enough catch it would visit fewer FADs and make a shorter trip, returning directly to the fishing base without moving to other FADs to fish. Therefore, we tested the relation between the number of FADs visited and the total catch landed from that trip. We also accounted for the length of the trip, to analyse the contribution of trip length to the total catch. The formula follows:

$$gam(\text{Total catch} \sim \text{number of FADs visited} + \text{length of the trip})$$

2.3 Field Validation

In order to validate the accuracy of the both model and the Spot Trace tracking devices, a ground check was conducted by joining in a fishing trip with fishermen. The fishermen and vessel were chosen randomly from the fleet participating in the study. After selection, a Spot Trace tracking device was attached to the vessel. The ground checking was carried out in Lombok from July 3 2018 to July 19 2018. During the fieldwork, a total of 12 days was spent on a fishing boat with a local fishermen. A dedicated GPS was also carried during the ground checking to later compare with the positions from the Spot Trace devices. Additional data including the length, the composition and the total of catch, in each FADs visited was also collected during the observed fishing trip.

3.0 Result

3.1 The Number and Location of FADs

The depth of the fishing ground varied between 1.3 and 3 km. Five different areas were identified using the tracking locations of vessels to create fishing areas with relatively similar depths, and thus a constant epsilon for the area.

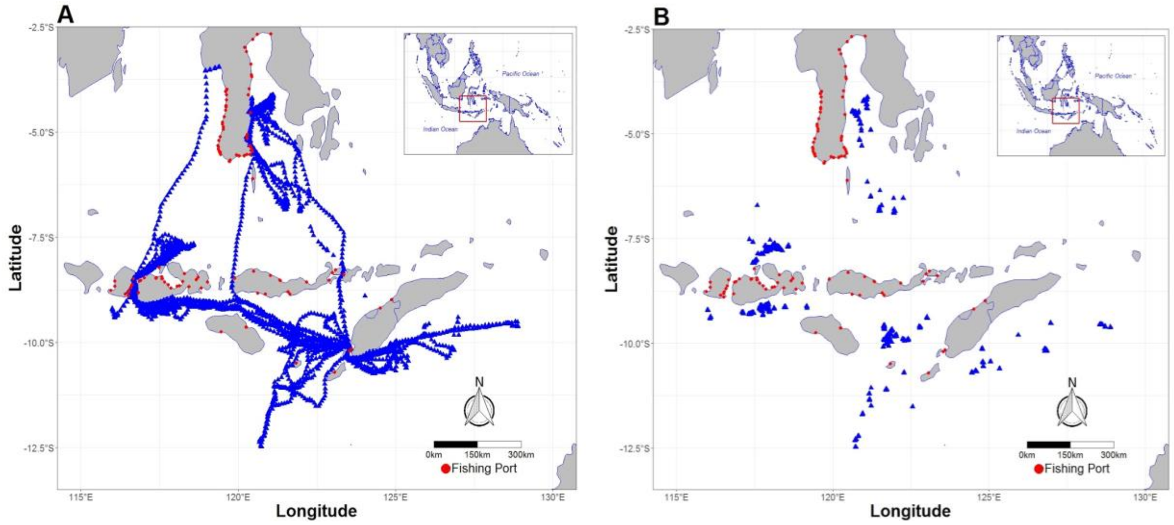

FIG.3. (A) Plot of all tracking data collected during the study, (B) Suspected FADs Position

As it is expected, the location of the fishing positions or the suspected FADs position can be seen in the aggregated areas of positions meeting our filtering requirements (Fig. 3B). The DBSCAN algorithm identified 136 aggregations of positions, which represent 136 potential FAD positions (Fig 3B). The FAD positions were also concentrated into clusters, and appear to correspond with frequent routes taken by the vessels (Fig. 3A). The tracking records also show that the fishers in these three provinces were moving from one to other different province (Fig. 3A).

On the other hand, not all of the 136 clustered point in the (Fig.3) were classified as FADs. We treated the spatially clusters positions as potential but not confirmed FADs, unless they were visited on more than one occasion by a vessel. Based on this criteria, a total of 48 confirmed FADs were identified (Fig. 4). These positive FADs were given FADs ID based on the depth of its deployment and the province where the FADs are located (Fig 4).

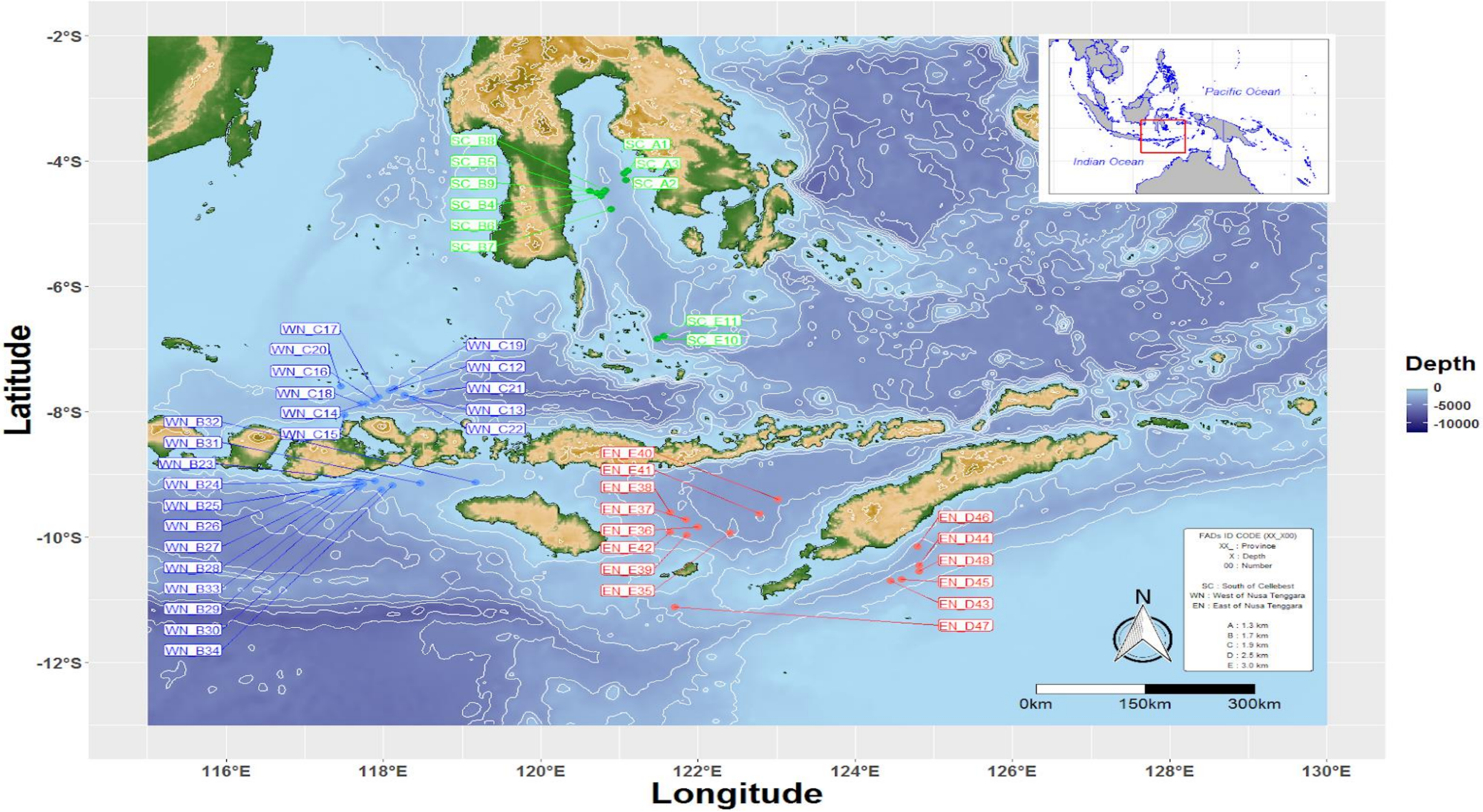

Fig.4. Positive FADs Location

Based on the positive FADs detected, not all of the vessel were detected using FADs fishing. We found FADs in 30 out of 34 vessels attached to the Spot Trace Tracker. The four non FADs vessels detected comes from each province with 2 from West Nusa Tenggara, and one each from East Nusa Tenggara and South of Celebes. The comparison between number of tracker and FADs found is that South of Celebes with seven trackers and 11 FADs, West of Nusa Tenggara with 14 trackers and 23 FADs and East of Nusa Tenggara with nine trackers and 14 FADs. However, there are two different vessels from west of Nusa Tenggara province which fish on the FADs situated in East of Nusa Tenggara.

Comparing the distance among the FADs, detected FADs in the South of Celebes province are more concentrated (less than 10 nautical mile) than the two other provinces. However, when we look at the FADs distance from the coastline, FADs in the West of Nusa Tenggara province are the closest with less than 15 nautical mile. In general, the FADs deployment tend to be situated in the coastal region rather than high seas.

3.2 The Use Pattern of FADs

During the period of study, a vessel can visit up to seven different FADs (Fig. 5), and 15 of the vessels participant visited at least 3 different FADs (Fig. 5). Sharing of FAD between vessels can be seen in all of three different provinces, where a FAD can be visited by a maximum of 5 different vessels (Fig. 5). Moreover, it was common to find 2 different vessels fishing at a FAD at the same time. In some cases a vessel would arrive at a FAD just a few hours after previous vessels left (unpublished data). One vessel from West Nusa Tenggara was also found fishing on FADs located in the east Nusa Tenggara; however, this cross province fishing did not happen with the fishers from South of Celebes.

In average, the vessels can spend up to 15 days fishing in a FAD, while the quickest residence in a FAD in several hours (Fig. 5).

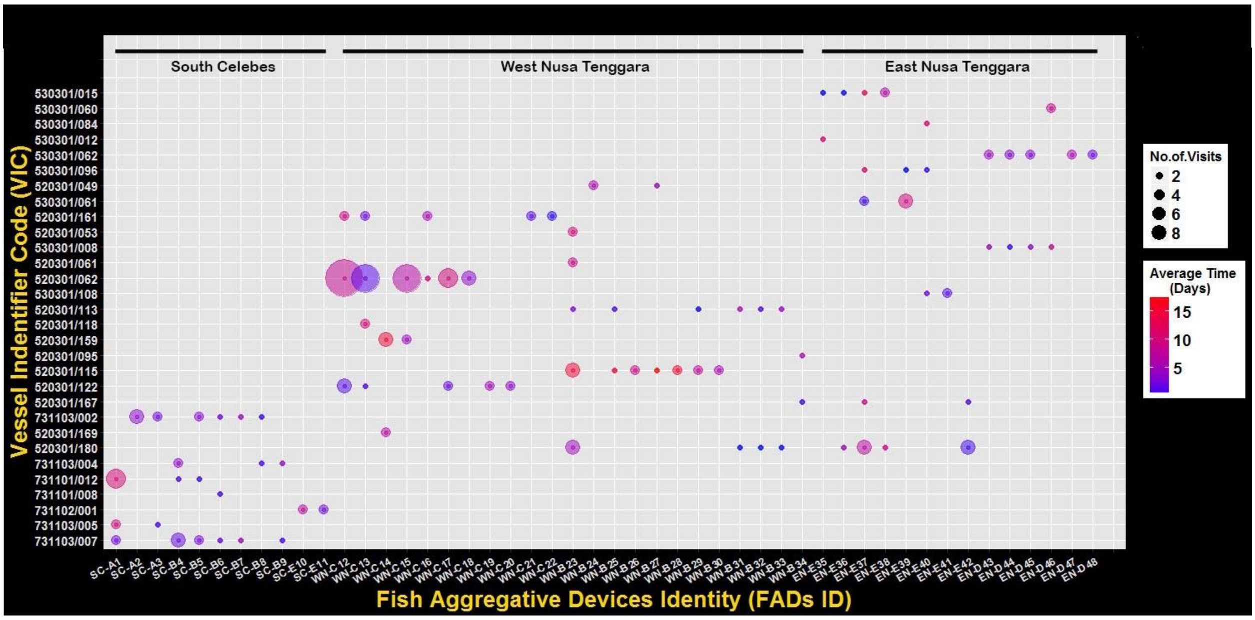

FIG.5. Number of Fish Aggregating Devices (FADs) visits and average time in days visited by fishing vessels

The cumulative ping location of the tracker record Fig. 6 shows that the FADs can last up to more than one year. This record, documented the first time of FADs being visited until the last date of the tracker being detach from the vessels.

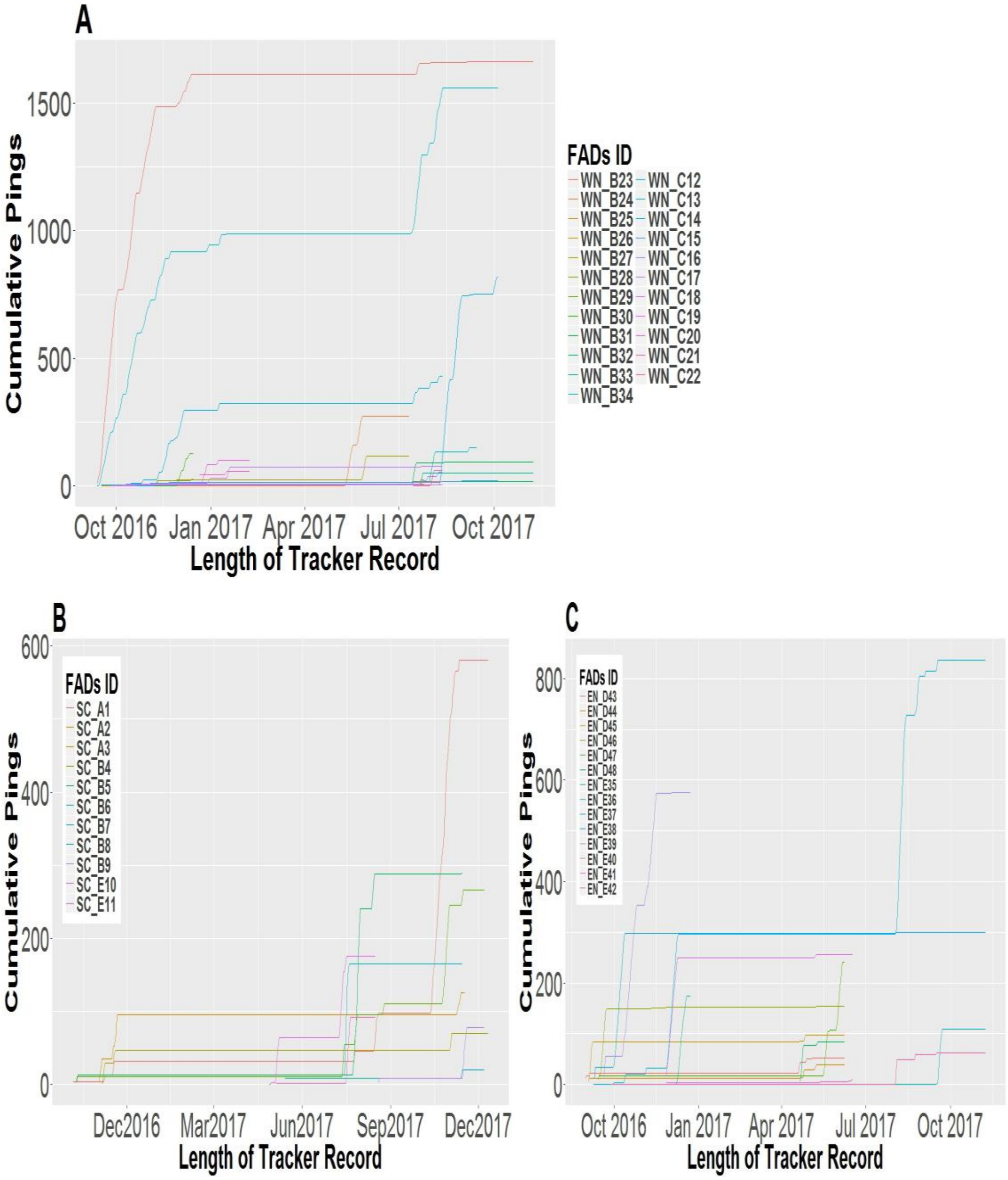

Fig.6. The length of tracker record for each FADs detected in (A) West Nusa Tenggara, (B) South Celebes, (C) East Nusa Tenggara.

Based on the Fig.6, it can be seen that the FADs in these three difference provinces have different peak seasons visit. The fishers in the have two high fishing time in around October and January for West Nusa Tenggara, while the East Nusa Tenggara is October and August. On the other hand, the peak FADs visit for the fisher in the South Celebes only occur around August.

3.3 Modelling Catch on a Fishing Trip

Based on the port sampling data for the 19 fishing trips we were able to match to the Spot Trace data the average catch was 984.2 kg, with a range from 137kg to 4440 kg. We found that catch landed from a fishing trip was significantly related to the length of the trip and the number of FADs visited (Table 1). Fish catch increased with the length of time a vessel spent at sea, but decreased with the number of FADs visited. A basic model with two terms was able to explain 32.6 percent of the deviance in the data, and was significantly better than a null model based on a comparison of AIC values (Null AIC: 318.13, Two term model AIC: 314.62). Comparing the effect size of the model terms at the median value for each covariate, the number of FADs visited is roughly ¼ as important in determine the catch as the trip length is (Table 1).

Table. 1. The Result of the General Additive Model (GAM)

Term	Coefficient Estimate	Standard of Error	P Value	Median of Covariate	Coefficient*Median
Intercept	170	580	0.78	NA	NA
No FADs Visited	-230	120	0.072	2	-460
Length of Trip (days)	120	50	0.025	11.57	1388.4

3.4 A Case of Study

The fishing ground used by the vessel during the case study is located in approximately 216 km distance from the fishing base at Labuhan Lombok (Fig 7). Fishermen stopped for one night to sleep at an island along their transit route to the fishing ground (Fig. 7B). Three different FADs were visited during the fishing trip and in term of FADs ownership, the fishermen only own the first FADs while the second and the third FADs belong to other fishermen outside of their group.

The gear that are used by the fishermen was a hand line with multiple hooks (up to 15 hooks) to catch small tuna and single hook to target bigger tuna. After the vessel arrived at the fishing ground, the fishermen attached a rope to the FAD and used it as a mooring point. The main fishing activities took place in the range of 50-300 m from the FAD, and were done by deploying a canoe or small boat.

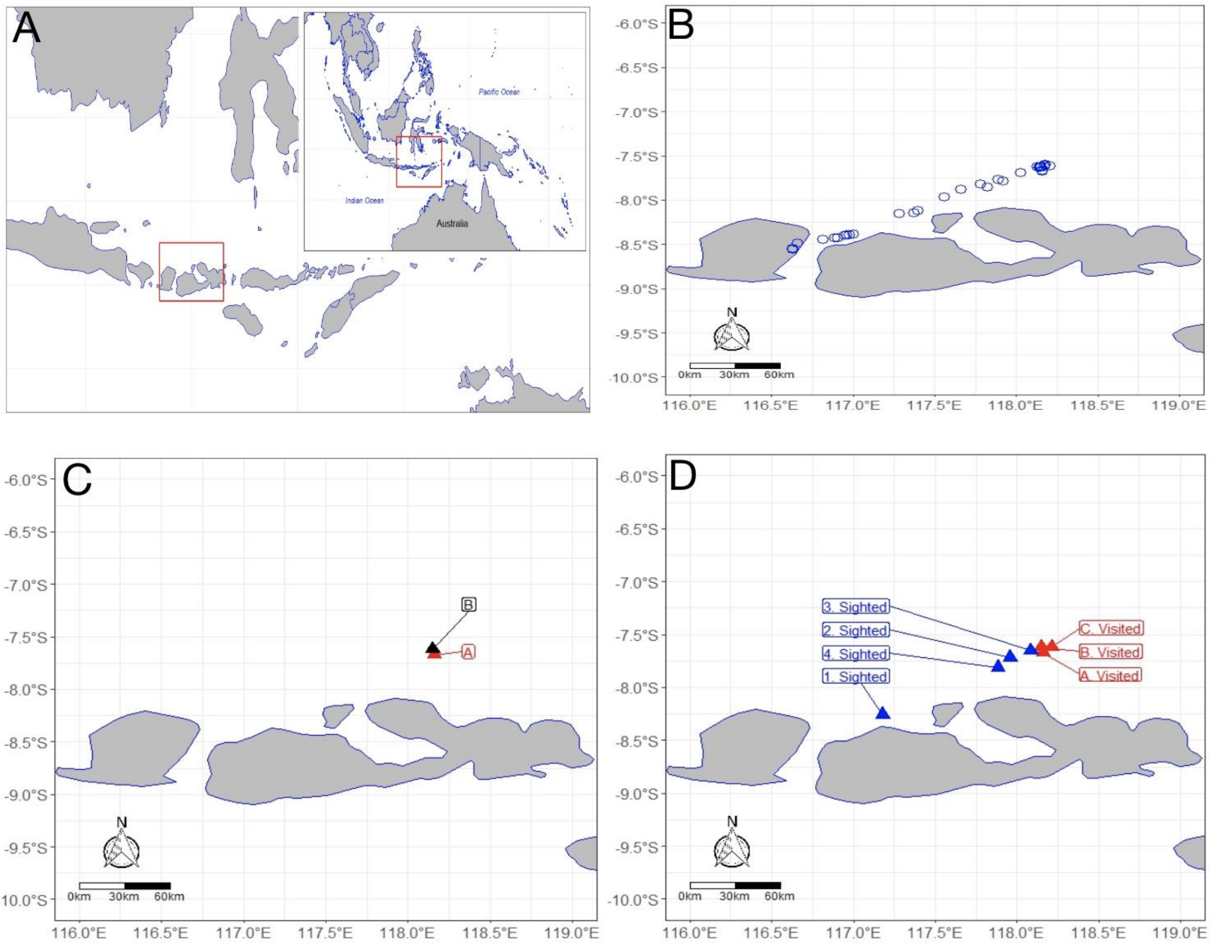

Fig. 7. (A) The location of the case study. (B) The full record from tracker device. (C) FADs detected by using the similar approach. (D) The position of actual FADs visited and spotted during the fishing trip.

3.4.1 Use Pattern and Catch Data from the Case Study

A total of 10 days were spent on the FADs. The fishing vessel spent one day at the first FAD (Fig. 7D, FAD A. Visited), before moving to the second FAD (Fig. 7D, FAD B. Visited). The vessel remained only a short time at the first FAD because the subsurface FAD attractor was missing, so few fish were found. The vessel then moved to the second FAD where it spent eight days. Based on feedback from the crew, there was good fishing at the second FAD. Most of the fish caught on this trip were caught at the second FAD visited (see Table 2, FAD B Visited). We then moved to the third FAD (Fig. 7D, FAD C Visited) where we spent only one day, as it was occupied by another fishing boat.

Based on informal discussions with the vessel operator and crew, FADs are often owned by a community, sharing of FADs between vessels is a common practice. A FAD can be owned by 4 or 5 different vessels and it is also possible for them to fish in a FADs in the same time (Nurani at al., 2014). Sharing is more likely when vessels are using the same fishing method, particularly hand line. Unlike the surrounding nets or purse seine which catch all of fish under the FADs, the hand line gear also makes it possible for the FADs visited consecutively by different vessels. The sharing of FADs also occurs across the community, particularly occurs when the FAD in empty from vessels. There is some hierarchy of access however, as vessels that are using a FAD owned by another operator will depart if that operator arrives at the FAD.

Table 2. The number of Yellowfin tuna (*Thunnus albacares*) caught and the time spent in each FADs

FADs	**Duration of Stay (Days)**	**Number of Yellowfin tuna >50 cm Caught**
First	1	0
Second	8	26
Third	1	6

The main target catch is Yellowfin tuna (*Thunnus albacares*), Skipjack tuna (*Katsuwonus pelamis*). However, they also got other fish such as Mahi mahi (*Coryphaena hippurus*), Flying fish (*Cheilopogon antoncichi*) and Squid (*Teuthida*).

4.0 Discussion

4.1 Detection of FADs

Fish aggregating devices significantly contribute to global fisheries production. The advantages of FADs provide for fishing has influenced fishing methods for both artisanal fishers and fishing companies. While the use of FADs is becoming popular, the increase in fishing efficiency has led to rising concern of the impact of their use on tuna stocks and consequently, increasingly strict regulation by the fishing authorities. However, the lack of availability data about FADs deployment has become main challenge for management.

The popularities of FADs fishing among small scale tuna vessels in Indonesia can be seen in the number of FADs found in all three different provinces we studied. Nearly all of the vessels we analysed used FADs across all three provinces, and typically every vessel used more than one FAD, even within a single trip. However, the number of FADs in use by vessels is still within the current regulations, which allow a vessel to have up to three FADs concurrently deployed. Based on our analysis, the highest the number of FADs per vessel occurs in East Nusa Tenggara province, with 1.6 FADs per vessel.

The use of spatial clustering of slow positions outside the coastal margin using DBSCAN appeared to be an effective method for identifying FADs. We were able to detect both potential and confirmed FADs using a relatively simple rule-based filtering of position data, with subsequent spatial clustering using the deployment depth of the FAD. In contrast to many applications of DBSCAN, in the context of detecting FADs we have a natural underlying process that should lead to a spatial cluster, and a clear mechanistic basis for estimating epsilon, the key parameter needed for the analysis.

However, the number of actual FADs will likely much higher than presented in this study. This is in part due to our requirement for a potential FAD to have visited at least two times before we considered it a confirmed FAD. This criteria significantly reduces the number of FADs detected from 136 to only 48 FADs. However, this requirement is needed since we are unable to distinguish the difference between FADs fishing and other non-FAD fishing behaviours, such as bait fishing. Furthermore, given that the length of trip for a vessel is 10 to 15 days, the one month period for a single session of tracker attachment will only give two fishing trips record. If we assume the fishing ground for previous and the next trip is different or if there is any rotational pattern among FAD visitation by vessels, the FADs will not be visited twice by that vessel within the deployment period. The 34 vessels which had a tracking device attached for this study also represent only a small amount of the total fishing vessel Indonesia which account for 768 123 registered vessels (BPS, 2017). Even for ports in the study area the Spot Trace deployments are only covering a modest fraction of the fleet, suggesting that many FADs may exist which were not used by the portion of the fleet included in the study.

Another under estimation of actual FAD numbers come from the distance among the FADs deployed. During the ground checking, only two out of three visited FADs were detected by DBSCAN. This occurs because the radius of movement between two of the FADs (Fig. 8D, FADs B and C) is overlapping. Therefore, when DBSCAN evaluates the distance among points, locations at these two FADs will be clustered as a single FAD. Moreover, since fishermen in the visited site never deployed the FADs using a regular grid, this result of multiple FADs within a DBSCAN cluster could indicate that the FAD locations we detected in fact represent a much larger number of FADs that are deployed closely together in groups.

There are several strategies that could be explored to address this issue, taking advantage of the spatial and temporal structure in the position data. For instance, two adjoining FADs that are deployed close together should jointly inscribe a set of positions that are longer than they are wide. In one axis they will be able to take positions that are 4 times the radius of a single FAD, while in the other axis they will only be able to take positions that are 2 times the radius of a single FAD. Similarly, segregating the trips into time should yield a median location during one period of mooring at a FAD that is spatially separated from the median position at a very nearby FAD on another trip.

4.2 The Use pattern of FADs

Based on the vessels record, a few FADs are visited for more than one year. Because the record is from a vessel perspective, when the tracker is detached, the record will stop although the FADs may still exist. Due to this reason, the complete lifespan of FADs cannot be measured and our estimates should be treated as a minimum lifespan. However, the observed usage patterns gives an idea about the cycle of FADs, and can be useful for anticipating the rough timeline for the future deployments.

According to the fishermen, the FADs lifetime depends strongly on the current during the west monsoon, which usually occurs from January to March. If the current is high, the fishermen loose more FADs and will need to deploy new FADs after the monsoon ends. The FADs design used in Indonesia generally requires little maintenance. Nevertheless, the attractor needs to be replaced periodically since it is made from biodegradable materials. However, based on the field trip during the case study it is unlikely that one could detect this activity, in the context of normal fishing events.

The FADs sharing practice identified in our analysis and fieldwork revealed a management option to reduce the number of FADs deployment in the sea. The use of FADs can be maximised by extending the user to other fishers outside of the owner community considering this practice has been occurred when the actual owners of FADs do not fishing. Moreover, it may also reduce the chance for the fisher hiding the location of FADs deployment.

A vessel can spend a few days or entire fishing trip to stay at a single FADs. The several days documented of fishermen fishing on single FAD suggests that FADs only help the fisher to reduce the time searching for fishing grounds, but do not significantly increase the actual time of the fishing effort. We found that fishermen do not change the method from FAD fishing to non-FAD fishing during a trip, based on both the Spot Trace data and our field survey. Instead, they will search other nearby FADs, even though they belong to other fishermen.

Indonesia has a clear set of regulations governing FADs. According to the regulation FAD deployment must be at least 10 nautical miles from each other. Every FAD must be registered and reported to the ministry of fisheries. FADs must have clear markings to identify ownership, along with features to assist navigation such as radar reflectors. Deployments are only allowed in specific areas, and are prohibited in shipping lanes. However, these regulations have proven hard to implement. Based on our fieldwork, none of the FADs we encountered were registered. Coordination among fishermen during FAD deployment is another challenge to apply 10 nautical mile rules. When the fishermen decided to deploy the FADs, they only coordinate with the fishermen in their group and do not communicate with the others outside them. The FADs location is also not as a secret as it is expected before because when the fishermen fishing in other FADs, they know who is the owner of the FADs.

4.3 Catch Data

The catch data obtained from the port sampling allowed us to identify the factors that influence the total fish caught. The length of the trip is the main factor that significantly affect the number of catch for the fishing vessel. We suggest that this is due to fishing effort increasing as the length of a trip increases. On the other hand, it seems that the number of FADs visited has a negative influence on the number of fish caught.

This pattern might be expected, if fishers are considered as central place foragers in the context of optimal foraging theory (Mangel and Clark, 1986). The vessels leave and return to the same port. Presumably while at sea they attempt to either maximize their catch or at least satisfy a minimum requirement to meet their fixed costs. In either event one would expect fishers to extend their trip length if catch rates are low to try to meet their objective. In this context, if they visit a FAD and have a low catch rate, one would expect them to move on to another FAD. Thus together, the number of FADs visited and the length of the trip provide a reliable predictor of the quality of a fishing trip. This information is very useful, as it suggests that the Spot Tracking data, or in fact any other vessel tracking information, can be used as a proxy for port sampling or fisheries logbooks. Thus remote monitoring of the vessels can be used to get some measure of stock status, via catch rates, or as a check against port sampling or logbooks to check their veracity.

The catch composition from the MDPI port sampling, the catch is dominated by Yellowfin tuna (*Thunnus albacares*) and Skipjack tuna (*Katsuwonus pelamis*). However, Yellowfin tuna (*Thunnus albacares*) is the main target for the vessels involved in this study. In order to know whether or not catches at FADs are dominated by juvenile, we evaluated the size of the fish from the field program. The length of maturity of this species could be vary depends on the latitude of the fish being caught. This ranges from 98.1 cm from one study in the Western

Pacific (Itano, 2000) to 101 cm and 110 cm for the females and males, respectively (Zhu et al., 2007). On the other hand, the Skipjack Tuna (*Katsuwonus pelamis*) in the Western and Central Pacific reach length of maturity at the fork length (FL) of 30-40 cm (Ashida et al., 2010). Based on Itano (2000), the comparison between the mature and immature Yellowfin (*Thunnus albacares*) the catch during the field sampling was 17 adult yellowfin and 216 juvenile yellowfin. It means for a single mature Yellowfin tuna (*Thunnus albacares*), they will also catch 12 immature Yellowfin tuna (*Thunnus albacares*) and 7 immature Skipjack tuna (*Katsuwonus pelamis*).

Interestingly, catch composition appears to be tied to the vessel and trip economics. Based on discussion with the skipper and crew during the fieldwork, the fishermen target small fish, and both yellowfin and skipjack, early in a trip. These smaller fish have higher catch rates, and thus provide a low risk way to ensure that the trip cost is covered. Subsequently the fishermen target larger yellowfin, which are rarer to catch but which bring a much higher price. Thus the size distribution of fish landed is also a function of decision-making by the fishermen, and may represent a biased sample of the fish population around the FADs. Given this strategy, one would expect small fish to be overrepresented in any port sampling, while large fish would be underrepresented.

Despite the issues raised here with multiple FADS, our method provides a rapid and effective tool for at least identifying the minimum number of FADS, being able to map their locations, evaluate their compliance with existing regulations, and potentially detect the deployment of new FADs.

5.0 Conclusion

The aim of this study was to identify the number and locations of fish aggregative devices (FADs) by using vessel tracking data. We explored several aspects of FAD use from both the perspective of the vessel and that of the FAD. We attempted to 1) identify FAD locations and estimate numbers of FADs, 2) investigate use patterns and identify sharing across vessels and minimum FAD lifetimes, and 3) relate FAD use patterns to total catch on a trip. These analyses were backed up by a field program in which we accompanied a vessel on a fishing trip to gather background information on fishing practices, and to evaluate the FAD identification protocol we developed.

We found that voluntary vessel tracking data using GPS logging technologies, such as the Spot Trace device, can provide a high quality dataset that provides significant insight into fishing operations and stock status. We were able to identify FAD use based on the vessel movement patterns, including estimating the number and location of FADs. While we found there may be some underestimation in cases where FADs are placed close together, there were no false positives observed, and thus vessel tracks provide a reliable way to estimate the number and location of FADs. We detected several issues with FAD use from a regulatory perspective, in particular the use of multiple FADs, although this did not generally exceed the three FAD limit established by the regulatory body. Furthermore, we did detect that FADS were placed more closely together than the regulations allow.

We also found that we could extract useful information on the catch on a trip from a simple analysis of FAD use patterns and trip length. This is likely tied to the underlying economics of the fishery, in which the use of large numbers of FADs is an indicator of low catch rates. Overall, this relationship suggests that an estimator for catch which is built from FAD visitation and trip length could provide a useful proxy for both stock status and a quality check on logbook or port sampling data. Finally, economics play a strong role in catch composition and are affected by relationships among FAD owners and communities. Fishermen appear to adjust their fishing strategy in a trip to minimize financial risk, which implies that port sampling will likely be a biased measure of catch rates. Clearly there are also complex social relationships that affect FAD use and sharing, which may well also translate into bias in port sampling, FAD use patterns, and other metrics that are important for fisheries management.

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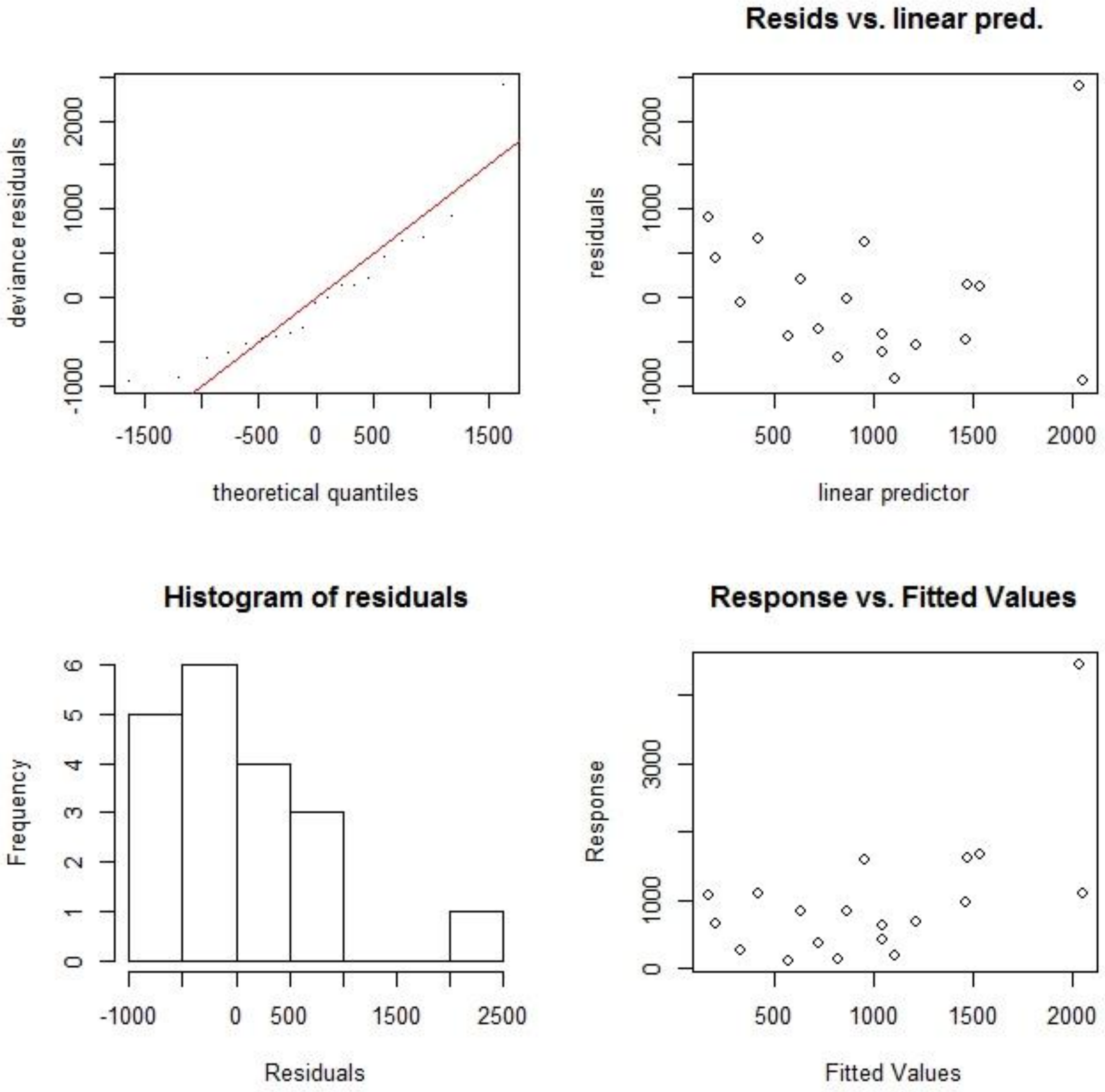
Appendix:

Appendix I

General Additive Model (GAM) output:



Appendix II

Catch composition during the ground checking:

MDPI FORM SAMPLING TUNA at the PORT HL VERSION

Version : January 2017

Section 5 : Notes Per Category of the Main Catch (Including all of Tuna Species < 10kg)

No.	Code	Description	Total Weight (Kg.)
1	TN	Dominant Baby Tuna Good Quality > 1 kg	
2	TR	Dominant Skipjack Tuna Good Quality > 1 kg	
3	TRK	Dominant Skipjack Tuna Good Quality < 1 kg	66
4	TR BS	Dominant Skipjack Tuna Rejected Quality > 1 kg	
5	TRK BS	Dominant Skipjack Tuna Rejected Quality < 1 kg	
6	BSS	Mixed Skipjack Tuna and Baby Tuna Very Bad Quality	
7			

Section 6 : Random Sampling for all tuna catch (All of tuna species < 10kg)

Total Weight (kg)	Species	Length (Cm)
46	YFT	33
	YFT	34
	YFT	32
	YFT	33
	YFT	34
	YFT	32
	YFT	31
	SKJ	35
	SKJ	33

	SKJ	**33**
	SKJ	**33**
	SKJ	**34**
	SKJ	**33**
	SKJ	**31**
	SKJ	**33**
	YFT	**33**
	YFT	**31**
	YFT	**29**
	YFT	**30**
	YFT	**29**
	YFT	**34**
	YFT	**30**
	YFT	**34**
	YFT	**32**
	YFT	**31**
	YFT	**34**
	YFT	**34**
	YFT	**33**
	YFT	**33**
	YFT	**34**
	YFT	**34**
	YFT	**33**
	YFT	**35**
	YFT	**32**
	YFT	**30**
	YFT	**30**
	YFT	**33**
	YFT	**33**
	YFT	**33**
	YFT	**30**
	YFT	**35**
	YFT	**33**
	YFT	**34**

	SKJ	**36**
	SKJ	**34**
	SKJ	**36**
	SKJ	**33**
	SKJ	**35**
	SKJ	**35**
	SKJ	**34**
	SKJ	**32**
	SKJ	**32**
	SKJ	**33**
	SKJ	**35**
	SKJ	**33**
	SKJ	**35**
	SKJ	**35**
	SKJ	**33**
	YFT	**34**
	YFT	**31**
	YFT	**33**
	YFT	**32**
	YFT	**35**
	YFT	**32**
	YFT	**35**
	YFT	**35**
	YFT	**29**
	YFT	**32**
	YFT	**34**
	YFT	**34**
	YFT	**32**
	YFT	**34**
	YFT	**30**
	YFT	**33**
	YFT	**31**
	YFT	**29**
	YFT	**30**

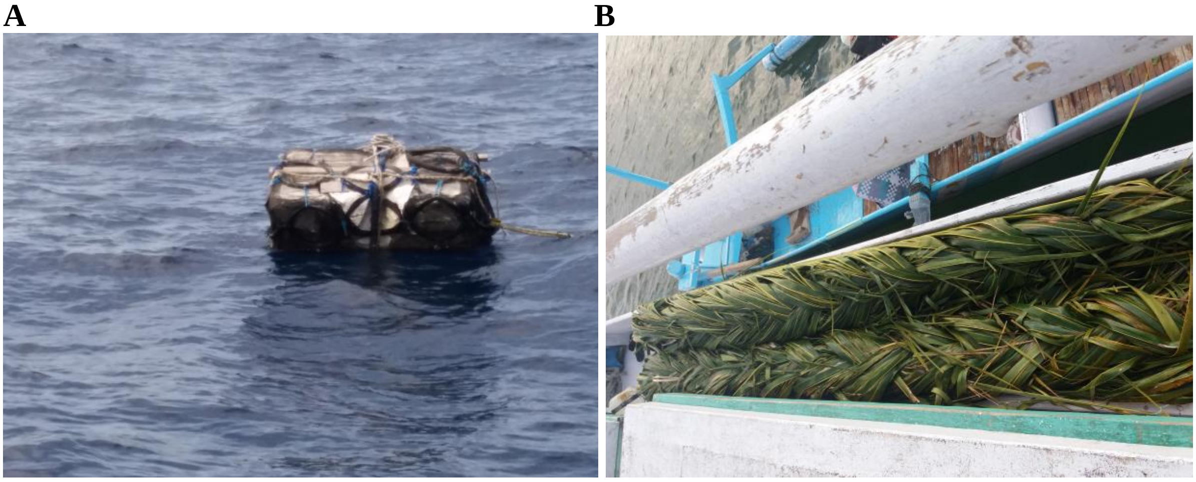
	SKJ	**33**
	SKJ	**32**
	SKJ	**34**
	SKJ	**38**
	SKJ	**34**
	SKJ	**32**
	SKJ	**35**
YFT= Yellowfin Tuna		
SKJ= Skipjack Tuna		

MDPI FORM SAMPLING TUNA AT PELABUHAN HL VERSION								
Version : January 2017								
Section 7 : Ringkasan Per Categori (Tuna >10kg)								
No	Code	Description		Total Weight (Kg)				
1	H	Export Quality		302				
2	M	Local Quality		273				
3	K	Rejected > 20 kg						
4								
5								
6								
7								
8								
9								
10								
Section 8 : Tuna > 10kg								
No		Species	Code	Full Weight		Including the weight of :		
				Weight (Kg)	Length (Cm)	Gill	Belly content	Meat in the Belly Part
1		YFT	M	18	101	No	No	Yes
2		YFT	H	22	110	No	No	Yes
3		YFT	H	24	112	No	No	Yes

4		YFT	H	24	110	No	No	Yes
5		YFT	M	17	102	No	No	Yes
6		YFT	M	17	101	No	No	Yes
7		YFT	H	21	105	No	No	Yes
8		YFT	H	40	128	No	No	Yes
9		YFT	H	23	112	No	No	Yes
10		YFT	H	23	109	No	No	Yes
11		YFT	H	20	104	No	No	Yes
12		YFT	H	26	112	No	No	Yes
13		YFT	H	24	110	No	No	Yes
14		YFT	M	19	106	No	No	Yes
15		YFT	M	19	103	No	No	Yes
16		YFT	H	33	119	No	No	Yes
17		YFT	H	22	109	No	No	Yes
18		YFT	M	16	96	No	No	Yes
19		YFT	M	11	88	No	No	Yes
20		YFT	M	12	89	No	No	Yes
21		YFT	M	10	85	No	No	Yes
22		YFT	M	10	86	No	No	Yes
23		YFT	M	10	83	No	No	Yes
24		YFT	M	10	83	No	No	Yes
25		YFT	M	10	84	No	No	Yes
26		YFT	M	10	83	No	No	Yes
27		YFT	M	15	94	No	No	Yes
28		YFT	M	10	86	No	No	Yes
29		YFT	M	10	84	No	No	Yes
30		YFT	M	10	85	No	No	Yes
31		YFT	M	16	94	No	No	Yes
32		YFT	M	10	85	No	No	Yes
33		YFT	M	13	92	No	No	Yes
YFT= Yellowfin Tuna								

Appendix III

Documentations:



A.The styrofoam as a position marker of FADs, **B**. The coconut leaf tree that are prepared to replace the attractor of FADs

A. The mixed catch of small Yellowfin Tuna (*Thunnus albacares*) and Skipjack Tuna (*Katsunwonus pelamis*), **B.** On board length measurement of Yellowfin Tuna (*Thunnus albacares*)

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Format : Oral presentation

Title : Detecting FADs and Estimating Use Patterns From Vessel Tracking Data In Small Scale Fisheries in Indonesia.

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