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Local Ecological Knowledge (LEK) on Fish Behavior Around Anchored FADs: the Case of Tuna Purse Seine and Ringnet Fishers from Southern Philippines

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The Fishing Industry in the Philippines plays an important role in the food and employment need of Filipino fishers. By using anchored Fish Aggregating Devices (FADs or *payao*), the Philippine tuna fisheries was transformed into a million-dollar industry. Minimal studies on exploitation rates and fish behavior around anchored FADs hampered further understanding of this fishery practice. Studies on fish behavior using Local Ecological Knowledge (LEK) are good complement where data is limited. A study using semi-structured interview ($n = 46$) and three focus group discussions ($n = 39$ participants) to record fishers' knowledge and observations on the behavior of different fish species around anchored FADs was conducted. This particularly focused on attraction, retention, and departure behavior of fishes in identified FAD sites. Based on the fishers' knowledge, tuna schools are attracted to anchored FADs at 10 km distance. In anchored FADs, tuna form schools segregated by species and size. There was no relationship between the attraction distance and the reported school size and the various waiting times for fish to aggregate below the FADs. There was no variation between the species present at day or night time although fishers have reported a distinction of species found near the surface (0–10 m) and those found at other depths (11–20 m). Juvenile yellowfin tuna (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), and frigate and bullet tunas (*Auxis* spp.) are found to stay at 25–50 m from the FAD at a depth of >20 m. Adult oceanic tunas reside in deeper waters (75 m). The fish visual census produced similar results with the semi-structured interviews and FGDs but did not observe oceanic tunas at depths of 15–20 m in the anchored FADs examined.

Keywords: FADs, fish aggregating devices, LEK, *payao*, Philippines, tuna

INTRODUCTION

Fishers are highly dependent on marine resources in terms of food and income, which led to resource over-exploitation and decline (Bell et al., 2009; Nañola et al., 2011). Some fisheries, such as tuna, have been fished down to its threshold sustainable yields, bordering toward non-sustainability (Juan-Jordá et al., 2011). Increased demand for food due to burgeoning population and the improvement of fishing efficiency has caused marine species population declines because of the advent of technological advancement in fisheries such as real-time weather monitoring, three dimensional sonars and chlorophyll *a* productivity patterns in many fishing grounds (Pauly et al., 2002; Anticamara et al., 2011; McCauley et al., 2015). Moreover, the increasing knowledge on fish behavior has aided in the increased fishing efficiency of fishers, even further increasing the exploitation rates in the fisheries (Anticamara et al., 2011). For example, the knowledge that fish tends to be attracted to floating structures in the ocean led to the development and utilization of fish aggregating devices (FADs) (Freon and Dagorn, 2000; Dempster and Taquet, 2004). The effectiveness of FADs in increasing fish catch instigated its extensive use for both artisanal and industrial fishing (Fonteneau et al., 2000; Freon and Dagorn, 2000). According to Fonteneau et al. (2000), the proliferation of FADs globally introduced uncertainties to marine fishery. For instance, the application of FADs to artisanal fishery have led to difficulties in assessing the effects of this fishing method due to a high number of artisanal fishers, making assessment logistically challenging (Teh and Sumaila, 2013). Until now, the use of anchored FADs in the commercial tuna fisheries in the Philippines have not been investigated in terms of perceptions and local ecological knowledge (LEK) of purse seine and ringnet fishers on the behavior of tuna and other pelagic fish species around anchored FADs. Fish schools often aggregate around anchored FADs and other floating objects possibly utilizing these objects as meeting points to form even larger schools (Soria et al., 2009). There are many factors that influence the schooling behavior of fishes which includes increasing its survival through predator avoidance and increasing foraging efficiency, among others (Hoare et al., 2000). The schooling behavior of fish also plays an important role on the time spent by fishes under the FADs, the mechanisms of fish aggregations under floating objects and other causes for fish departure. An understanding of the schooling behavior of tunas especially how they can replenish the harvested biomass under the FADs will be useful in predicting the catch of fishers per FAD. This study was carried out in the context of providing an overview on the tuna exploitation and fishing patterns of purse seine and ringnet fishers around anchored FADs while particularly focusing on tuna behavior.

The Philippine Tuna Fisheries

Tuna fishery in the Philippines started after World War II. From 1947 to 1950, the fisheries program was launched, in conjunction with a series of studies on oceanographic and fishing investigations in Philippine waters (Aprieto, 2011). In 1974, massive exploitation of tuna fishery for commercial purposes started, capturing skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*), and roundscads (*Decapterus* spp.) as well as other small pelagics (*Auxis* spp., *Selar crumenophthalmus, Elagatis bipinnulata, Megalaspis cordyla, Coryphaena hippurus*) (Macusi et al., 2015). The purse seine and ringnet fisheries pioneered the use of FADs to capture pelagic species and have since then been deployed in various coastal areas of the Philippines (Dickson and Natividad, 2000). The increase in FAD use has led to an increase in fisheries production (Macusi et al., 2015). In the 1980s, fishing operations were preferred to be close to the shore which ensured lower fuel costs and fresh catch (Libre et al., 2015). However, this changed in the 1990s as the distance between FAD deployment areas and the homeport increased from 100 to 500 km offshore (Macusi et al., 2015). This was due to the fact that better catches were reported in FADs located farther away from the shore (Kakuma, 2000).

As the tuna fisheries saw its growth, more fishers and ancillary industries relocated to General Santos City, in southern Philippines. Investments in private shipyards, docking stations, net, and rope factories and steel fabrications, pre-harvest and post-harvest facilities, cold storage plants, ice plants ,and canning factories soon followed—making General Santos City the "tuna export capital of the country" (Macusi et al., 2017). At present, there are six tuna processing and canning plants in General Santos City and two processing plants in Zamboanga City. These processing plants have an annual capacity of 124,000 MT of tuna with an average total annual export value of 21.6 billion pesos in the last 5 years (2010–2014) (Barut and Garvilles, 2015).

According to the Philippine Fisheries Code of 1998, a fisher in the Philippines can be classified as a commercial fisher if he owns a motorized boat with a capacity of 3.1 GT and above and fishes offshore starting at 15 km. Anchored FADs are not cited as a requirement to be a commercial fisher in the Philippines but most of the commercial fishers utilize FADs (*payao*) to significantly increase their catch (Dickson and Natividad, 2000). The use of anchored FADs in the Philippines had been widely adapted by both artisanal and commercial fishers (Dickson and Natividad, 2000; Aprieto, 2011). There are two kinds of FADs—anchored and drifting. Anchored FADs are distinguished from drifting FADs by the presence of a mooring system that anchors their floaters made of bamboo rafts, styrofoam, or steel drums to the sea bottom. A near-shore FAD to be deployed at 10–15 km would normally cost Php 30,000.00 (U$500) per unit. FADs that are anchored at depths of 2500–5000 m in Mati (Philippine Sea), Celebes and Sulu seas, however, would cost Php 120,000.00 (U$2500) per unit. FAD deployments are adjusted according to the availability of space in the fishing grounds and productivity of the area in terms of catch (Libre et al., 2015; Macusi et al., 2015).

FADs play a significant role for purse seine and ringnet fishing. A typical purse seine and ringnet fishing fleet in the Philippines is comprised of a catcher vessel, two carrier boats, and three lightboats. The master fisher mans the purse seine while aboard the catcher vessel. He oversees and manages the daily fishing operations (Dickson and Natividad, 2000). Since anchored FADs play a significant role in the fleet's fishing activities (Aprieto, 2011), the small multirole vessels (lightboats) are used together with the catcher vessel to guard the FADs and monitor the biomass of fish beneath the FADs (Macusi et al., 2015). Once a sufficient biomass of fish has settled or aggregated in the FADs, carrier vessels are sent to the site. To attract more fishes on the site, lighting of the FADs during the evening is done while nets are set at dawn. Carrier vessels with catcher vessels operating in the High Seas usually unload fish catch once a month in homeport while other carrier vessels that operate in Philippine waters may go back twice a month to gather and bring in the catch.

Local Ecological Knowledge

In the past, LEK was often dismissed as anecdotal and of lower scientific value (Johannes and Neis, 2007). LEK, however, has played an important role in conservation studies and policies. For example, Rajamani (2013) and Rajamani and Marsh (2010) utilized LEK to identify gaps in dugong (*Dugong dugon*) conservation in areas of the Sulu Sea where data are limited. Recent developments in the fisheries management recognize the significance of LEK, especially in cases where minimal empirical data are available (Silvano and Valbo-Jørgensen, 2008). Fishers spend substantial amount of time fishing at sea, thus accumulating important information on fish diversity, reproduction, ecology, and behavior through their experiences (Baird and Flaherty, 2005; Johannes and Neis, 2007; Lavides et al., 2010). LEK has been proven to be a good complement to empirical data and has proven its significance in many cases. According to Johannes et al. (2000) when LEK was ignored, underestimation of biological samples or populations would usually transpire.

Investigations on fish behavior were carried out with the aim of understanding fundamental behavior patterns (Pitcher, 1993; Cooke et al., 2004). One of the reasons why researchers study fish behavior is to understand its effect on physiological functions (Cooke et al., 2004). Fréon and Misund (1999) stated that there are very few studies on fish behavior around anchored FADs and therefore there is lack of information on this field. Gathering fishers' LEK is a good methodology to help bridge this information gap. In this case, LEK of Filipino purse seine and ringnet fishers, who spend so much time at sea acquiring detailed knowledge of their prey and of their fishing grounds necessary to be given significance. Among the ranks of FAD-based fishers, the master fishers, boat captains, master netters, and divers are the ones who are the most knowledgeable on fishing operations. These fishers are experts who can provide reliable information on fish behavior because of their constant exposure to the fishing areas during their daily fishing operations. There are four very important individuals in this area. First is the *piado* (master fisher) who oversees the fishing fleet in the fishing ground. He has both the navigational and leadership skills to lead in the boat. He crafts and executes fishing expeditions and he decides when and where to deploy the FADs. He is familiar and knowledgeable of the movement patterns of fish, current directions, and waves. He is also accustomed to the flow of the weather in the area and its impacts on the fishing grounds. Second is the *kapitan* (the boat captain) who possesses navigational skills in using compass, maps, GPS, and oceanographic knowledge. *The kapitan* is also exposed to daily fishing operations. Third is the *maestro bosero* (master diver) who gets the estimates of the biomass of fish gathered below an FAD during monitoring or before an FAD can be lighted or set. Finally, there is *maestro pokotero* (master netter) that oversees the deployment of nets during fishing operations and is in charge of keeping collection of the nets clean and organized.

Data from other sources show that the above-mentioned fishers understand the three-dimensional aspect of fish movement, schooling, and aggregation behavior around anchored FADs (Moreno et al., 2007b,a). Because of their sufficient understanding of fish behavior such as the patterns of movement as well as abundance of tuna in their specified fishing grounds, they can decide where, when and how to deploy their fishing gears and accessories which aid them in capturing fish more effectively (Moreno et al., 2007b). The deployment of a FAD is based on well-calculated decision by these fishers and not by random choice. Such decision is influenced by their anticipated risks, projected abundance of catch and foreseen operational factors or constraints (Libre et al., 2015; Macusi et al., 2015). The daily experience of fishers become a very strong information that can be very useful to field researchers as it can provide detailed knowledge on the studies of fish behavior (Johannes et al., 2000; van Densen, 2001).

Gathering data on fish behaviors from fishers is a critical and relevant move for researchers who are focused on the fishing industry. Integration of behavioral studies in conservation biology has seen positive results (Sutherland, 1998). Caro (2007) recognizes the contribution of descriptive behavioral information in addressing specific conservation challenges. With the dwindling fisheries resources (Anticamara and Go, 2016), understanding fish behavior could aid in the conservation and management of these resources.

The objectives of this study are the following: (1) to catalog fishers' knowledge and perceptions on tuna and other pelagic fish behavior around anchored FADs; (2) to identify fish species characteristics and distribution; and (3) to test whether the reported school size, large or multiple schools have any association with attraction distance, fish aggregation, length of stay of tunas below the FADs.

MATERIALS AND METHODS

Conduct of Interview

All interviews were carried out in accordance with the Wageningen Code of Conduct for Scientific Practice, approved by the Executive Board of Wageningen University and Research on September 15, 2008. All interviewee information was de-identified in the analysis. Letters of consent for interviews were sent to the local offices of the Bureau of Fisheries and Aquatic and Resources (BFAR), Philippine Fisheries Development Authority (PFDA), and the Philippines Ports Authority (PPA) before the survey was conducted. Upon approval of these agencies, interviews were then conducted in the landing sites. The interview was conducted between August 27 to October 25, 2013 in General Santos Fish Port Complex (GSFPC) and in Mati Port in Davao Oriental (**Figure 1**). The respondents in the two locations were both purse seine and ringnet fishers of various fishing companies based in General Santos City. The interviews were conducted with the fishers at the Port of Mati, at a favorable time when fishers were docked on port as a typhoon was forecasted to be passing their fishing sites. The time of the interview was most appropriate as the fishers are free of their regular duties. Respondents were fishers who were identified to possess detailed information on catch trends, schooling behavior, and movement patterns of fish around anchored FADs. A total of five master fishers, seven master divers, seven master netters, and 27 carrier boat captains from 30 purse seine boats and 16

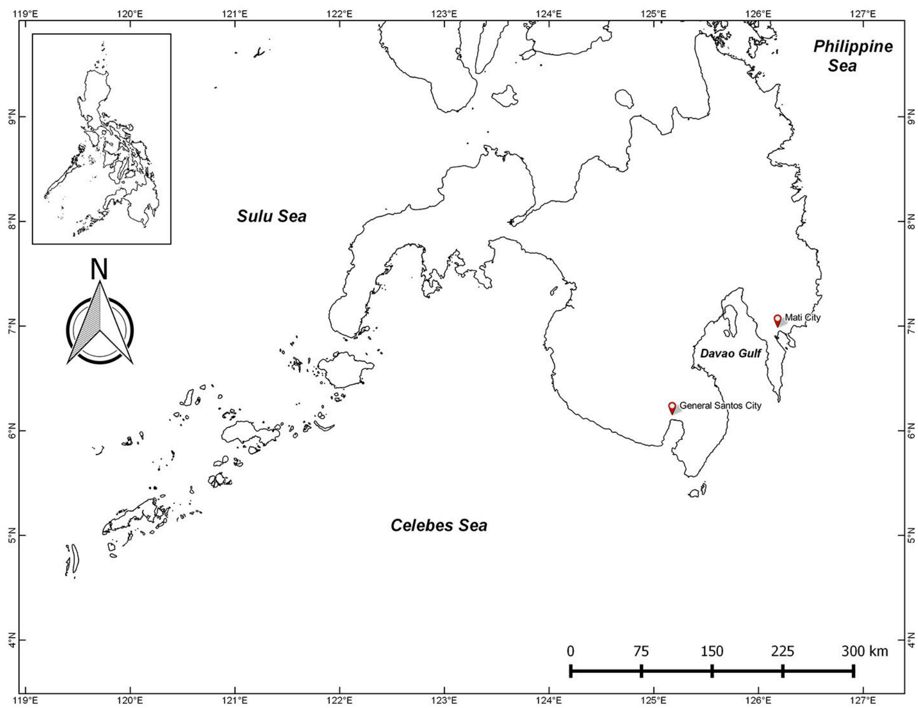

FIGURE 1 | Map of the study sites and the fishing grounds adjacent to them.

ringnet boats were interviewed individually ($n = 46$). Among the respondents, the master fishers who direct fishing operations and FAD deployment were known to have over two decades of working experience at sea.

As the only difference between a purse seine and ringnet boat, is the mechanical and manual hauling of the net during a fishing operation, the respondents are considered to be of the same set. This is particularly in terms of knowledge and exposure to FAD fishing and fish behavior in their fishing ground. Respondents of the study were all purse seine and ringnet fishers from fishing companies based in General Santos City, Philippines. The interviews lasted from 15 to 45 min and interviews were ceased after getting similar answers from the interviewees that corroborated or triangulated interview results.

Interview Design and Strategy

The interview dealt primarily with the respondent's perceptions of the behavior of fishes associated with anchored FADs, specifically on the attraction, retention, and departure behaviors. We also added questions on species distribution and community characteristics below the FAD. The interviews were done in the local *Cebuano* dialect. Questions on the general locations of FADs were asked from respondents but specific locations were withheld to keep this important information from competing fishing companies. Although interviews were done using a semi-structured format, respondents were allowed to answer freely.

The information that fishers provided during the individual interviews was verified through three focused group discussions (FGD) particularly on fish species distribution during day time and night time in the anchored FADs. The three FGDs were conducted on August 27, 2013 ($n = 20$), September 30, 2014 ($n = 11$), and October 1, 2014 ($n = 7$), and with total attendance of $n = 39$ (master fishers, boat captains, and crews). During the FGDs, fishers were shown a drawing of an FAD with fish found at various depths. They were then asked what species were found near the FAD (0–2 m) and at various depths of 0–10, 11–20, 21–50, and >50 m. The question was also repeated for fish species that are far from the FAD (25–50 m) and at various depths of 0–10, 11–20, 21–50, and >50 m.

Data Analysis

The information gathered from the fishers was quantified as percentages of total responses per question. Similar answers were grouped together under themes and these were shown through tables and figures. To examine similarities or differences with scientific research-based information on tuna behavior; answers provided by fishers were compared with the available scientific literature on tuna behavior. Secondary data on fish species characteristics related to anchored FADs also checked. Data was further analyzed using one-way ANOVA after checking normality of distribution and homogeneity of variance using Shapiro-Wilk's test and Levene's test. If the data was not normally distributed, a one-way ANOVA was still used as ANOVAS are robust to slight deviations from normality (Underwood, 1997; Quinn and Keough, 2002). We tested the association of reported school size, whether single or multiple, to attraction distance, normal wait-time for fish, wait-time for the first appearance of tuna, and wait-time for fish after a fishing event (dependent variables). The association of various tuna species to attraction distance and the various wait times were also performed using one-way ANOVA. In addition, a paired sample t-test was used to compare the presence and abundance of species during day time and during night time at depths of 0–10 and 11 to 20 m from the semi-structured interviews. All statistical tests were performed at significance level of $P < 0.05$. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 23 (Armonk, NY: IBM Corp).

Verification and Validation

Information was also gathered using dive survey of FADs to ascertain the species distribution as derived from the semi-structured interview and the FGDs. Although the location of the dive site was in Davao Gulf, the authors assumed that fish species found in the area could be similar to those mentioned by fishers in the interview whose fishing grounds are located in Sulu/Celebes Sea and the Philippine Sea—a site much farther from Davao Gulf. Fish names, comparing local names, and scientific names were confirmed using various local literature (Herre and Umali, 1948; Ganaden and Lavapie-Gonzales, 1999), verification of names from the local market, and the use of fish base published by Froese and Pauly (2017). A diver assessment survey was performed by three professional licensed divers equipped with scuba gears at depths of 0–20 m in ten randomly selected anchored FADs in Davao Gulf. The dives were performed on March 28 to 31, 2016 and lasted from 15 to 44 min on average. The divers went down together to reduce disturbance of the fishes. The visual census was done only in clear waters with a horizontal visibility of 10–20 m. All throughout the 10 dives, one diver performed the fish species identification assessment. Another diver used the video to record and document the fish species in the site. The third one was in charge of the safety of the group. The divers would enter the water scanning the various depths of 5, 10, 15, and 20 m of the FADs. All species found at these depths were recorded and counted, including fish species that are hiding inside the palm fronds. The time and GPS locations of the dives were recorded and the fish species identified during the dive and their behavioral characteristics were observed and summarized in a table.

RESULTS

Interview of Fishers

The mean age of respondents was 42 (±10 s.d.), with 16 years of fishing experience at sea (±11 s.d.) and have a total cumulative year of experience of 653 years. The mean boat length of respondents was 88 feet (±30 s.d.) and their boat have a mean weight of 83 tons (±60 s.d.) with a mean boat power of 342 HP (±146 s.d.) (see **Figure 2** for typical purse seine boats used in the Philippines). The respondents gave estimates of the deployed FADs at an average of 100 FADs (+100s.d.) per company in their respective fishing grounds. There is cumulative total of 4,600 FADs of these various FADs deployed by the different companies as seen in **Figure 3** for offshore FADs. The respondents have also mentioned an average of 40 (±17 s.d.) FADs per catcher vessel or motherboat. Majority of the respondents have also stated that they visited more than 30 FADs per motherboat, and rotated in going to the different FADs a month's time. There were times when FADs could be lost due to vandalism or could get entangled on the lines of other fishers. They can also be removed because of strong currents or wave action that causes its destruction.

FIGURE 2 | Purse seine boats docked side by side at the General Santos City Fish Port Complex preparing for deployment to the High Seas.

Majority of the respondents mentioned five main motivations in selecting their present fishing grounds: fish abundance and bigger fish size (63%), fish abundance only (24%), available area to fish (7%), fish abundance and available area (4%), and bigger fish size (2%). In addition, the respondents described their fishing grounds as either characterized by calm current (30%), or affected by moderate to intense waves (70%). Areas that have strong wave action are described to have rough waves and strong currents. These fishing areas are mostly exposed to typhoons during the rainy season.

The respondents also regularly mentioned their target species: skipjack tuna (*Katsuwonus pelamis*) (27%), roundscad (*Decapterus* spp.) (24%), juvenile yellowfin tuna (*Thunnus albacares*) (22%), bigeye scad (*Selar crumenophthalmus*) (9%), frigate/bullet tuna (*Auxis* spp.) (6%), rainbow runner (*Elagatis bipinnulata*) (5%), triggerfish (*Sufflamen fraenatum*) (2%), mackerel (*Rastrelliger* spp.) (2%), golden trevally (*Gnathanodon speciosus*) (2%) (**Figure 4A**). However, the respondents mentioned that rainbow runner (24%), golden trevally (24%), roundscad (18%), and triggerfish (9%) are the first species to aggregate or gather in the anchored FADs (**Figure 4B**). A few of the respondents also remarked that skipjack tuna (6%), bigeye scad (5%), dolphin fish (*Coryphaena hippurus*) (4%), filefish (*Aluterus monoceros*) (3%), frigate/bullet tuna (*Auxis* spp.) (3%), juvenile yellowfin tuna (3%) and torpedo scad (*Megalaspis cordyla*) (1%) are also observed to arrive first in the anchored FADs. These species were later followed by adult (big) tuna species such as bigeye tuna (*T. obesus*) (16%), skipjack tuna (*K. pelamis*) (26%), and yellowfin tuna (*T. albacares*) (30%) (**Figure 5**).

Attraction, Retention and Departure Behavior of Fish in Anchored FADs

Detailed answers from the respondents concerning the attraction behavior of fish to anchored FADs are summarized in **Table 1**. The respondents noted that tunas were attracted to FADs from 1 to 10 km. This knowledge was based on the perception that tunas transfer from one FAD to another FAD, which was estimated to be 10 km apart from each other, on average. According to the respondents, these tuna movements in between FADs are often noticed because of the flocking of seabirds and fishes leaping out of the water.

Detailed answers related to fish attraction were shown in **Table 1**. On average, the respondents have mentioned that fishers must wait for 11 days after the first deployment of the FAD before checking the biomass contents of their FADs. This waiting time could range from 2 to 30 days. After a fishing event on the FAD, fishers then have to wait for about 10 days on average before the FAD can welcome new settlers or have a new aggregated biomass. The respondents have also proposed that these smaller fishes (e.g., triggerfish and golden trevally) serve as prey in attracting other fishes.

FIGURE 3 | Materials ready for deployment offshore including steel FADs. Note the rocket like steel drum. The nose always points to the direction of the current; the fishers are standing on concrete anchors made of mixed gravel, stones, rocks, and cement.

Furthermore, the waiting time for the first schools of skipjack, yellowfin and bigeye tunas may take 22 days. Sometimes these fish species appeared as early as 5 days or as late as 2 months. Majority of the respondents have suggested that a school of tuna under a FAD is due to aggregation of multiple smaller schools of tuna (89%). Other fish species such as scads and mackerels of similar sizes also form their own schools (96%). Divers of the fishing fleets also observed that various fish species segregate based on sizes, with different size groups of the same species occupying different layers of the water.

Tunas were also observed to exhibit vertical movement behavior during early morning hours (4–8 a.m) (57%) and move away from the FAD at 8 a.m to 4 p.m during day-time (26%). Some respondents observed both behaviors (17%).

Majority of the respondents stated that the main reason for the aggregation of fish under FADs is due to the presence of food and availability of shelter (**Table 2**). The respondents claim that fish feed on algae, shells and barnacles on the ropes and the palm fronds. Other fishes prey on anchovies or smaller-sized schools of frigate/bullet or skipjack tuna or early juveniles of other fish species. The presence of krill-like organisms had also been noticed to attract other fish species toward the FAD. Meanwhile, other respondents stated that social interaction is also a reason for fish aggregation under FADs. Social interaction here is defined as the attraction of fish to other fish because of similar sizes or being conspecifics.

According to interviewed respondents, the length of stay of tunas around anchored FADs takes from less than a week to more than a month, with majority of the interviewees agreeing that tuna stays for 2 weeks (48%) around the FADs (**Table 2**).

As shown in **Table 2**, fish schools of small pelagics such as roundscads (*Decapterus* spp.), bigeye scads (*S. crumenophthalmus*), and other small tunas are mainly disturbed by a passing school of anchovies, visits of marine

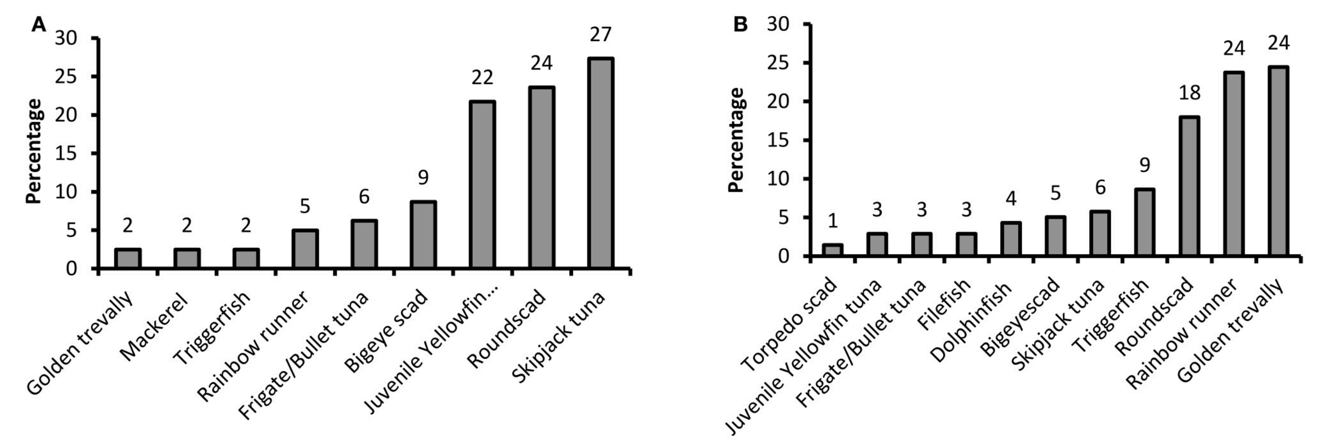

FIGURE 4 | Target fish species mentioned by fishers during interview **(A)** and proportion of occurrence of various fish species as pioneers in anchored FADs according to respondents **(B)**. Numbers are percent of the total interviewees that mentioned given information ($n = 46$).

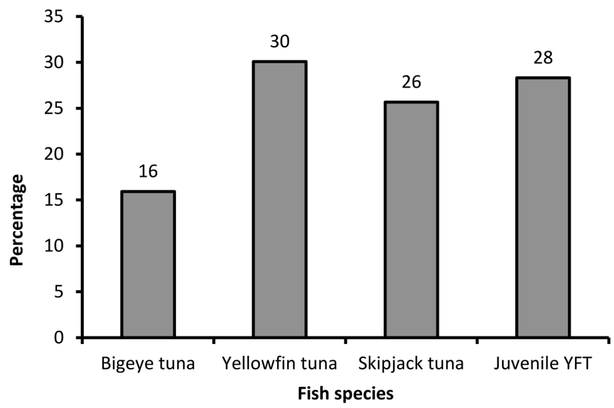

FIGURE 5 | Proportion of occurrence of various tuna species around anchored FADs according to respondents. Numbers are percent of the total interviewees that mentioned given information ($n = 46$).

TABLE 1 | Fishers' responses related to attraction behavior of fish to anchored FADs.

Attraction behavior of fish to anchored FADs		
Attraction distance to FADs	**Meters**	
Average	1000	
Min	20	
Max	9000	
Wait time for fish to aggregate below FADs	Days	
Average	11	
Min	2	
Max	28	
Wait time for fish to aggregate after a fishing event	Days	
Average	9	
Min	3	
Max	21	
Wait time for other fish species to aggregate below FADs	Days	
Average	22	
Min	5	
Max	60	
What are the source of fish school?	Response	%
Single large school	5	11
Multiple school of fish	41	89
How are fish schools organized?	Response	%
Size	2	4
Species and size	44	96
Some observed behavior of tuna fish	Response	%
Fish moves up and aggregate near the FAD (early morning)	26	57
Fish moves away from the FAD (day time)	12	26
Fish moves up and aggregate near the FAD and fish moves away from the FAD	8	17

mammals, and change of current strength and direction of the water either due to a typhoon, undersea earthquake or strong winds (63%). Another reason for this disturbance according to the fishers is the change in sea surface temperature. The presence of cetaceans is known to distract the fish schools in the anchored FAD causing them to leave temporarily. Sea current was also mentioned to affect the fish schools just as a school of anchovies and change in sea surface temperature do. This usually happens when the current direction changes unpredictably due to the meeting of two currents or because of a sudden change of wind direction. Typhoons are also known to change sea current direction because of strong winds, as well as undersea earth quakes that jolt the fishes.

Meantime, there was not a significant result on the ANOVA test on the following: reported school size, whether large or small and the attraction distance to the FAD with the various waiting times for fish to arrive or appear at the FAD (**Table 3**). Consequently, other factors might explain better the association of various school sizes to FADs and not only the attraction distance or school size of tunas, perhaps factors like productivity and sound of the anchored ropes or sea-water temperature.

Fish Species and Fish Behavior through FGD and Diver Assessment

There was little variation of species found at depths of 0–10 m ($t = -0.149$, $df = 6$, $P = 0.887$), and 11–20 m ($t = -0.044$, $df = 9$, $P = 0.966$) in the anchored FAD either during day time or night time. Results of pooled data comparing species at day time vs. night time also showed no difference ($t = -0.117$, $df = 16$, $P = 0.909$). Triggerfish and filefish that are abundant at the surface and are known to inhabit the suspended palm fronds, are also found at lower depths such as at 11 to 20 m (**Table 4**). In terms of fish schools that are abundant at surface depths (0–10 m) as well as at depths of 11–20 m, which was mentioned to occur during day and night time were golden trevally, roundscad, and rainbow runner. Tunas such as skipjack, juvenile yellowfin and frigate tunas were also discussed to appear frequently at 11–20 m and even deeper. Relevant observations by other fishers based on the FGD validate the statements that aggregations of fish under FADs are segregated based on species, sizes, and water depth. For instance, rainbow runner, roundscad, mackerel scad, and bigeye scad are observed to appear near the surface as well as at depths of 20 m. Fish species that occur near the surface are smaller in sizes. Both triggerfishes and filefishes are known to be associated with the floater or the suspended palm fronds and usually stay near the surface. Most of the bigger fish schools of skipjack, juvenile yellowfin tuna, and frigate tuna occur far from the FAD (25–50 m) and swim around. They also stay deeper at 21–50 m. Adult tunas are known to reside in deeper areas from >50 m.

Results from the fish visual census (**Table 5**) show that there are nine species recorded from the 10 FADs visited in Davao Gulf. Most of these fish species observed are like those recorded in

TABLE 2 | Fishers' responses related to retention and departure behavior of fish to anchored FADs.

Retention and departure behavior of tunas		
Reasons why tuna aggregate around FADs	Response	%
Tunas find food around FADs such as algae, shells, barnacles	3	7
Tunas find shelter or protection from other predators	8	17
Combination of food and shelter	26	57
Combination of food and social interaction	3	7
Combination of food, shelter and social interaction	6	7
How long do tunas stay around FADs	Response	%
< 1 week	1	2
1 week	5	11
2 weeks	22	48
3 weeks	1	2
1 month	13	28
> 1 month	4	9
Reasons for tuna to leave a FAD	Response	%
Distraction from passing of anchovies and from visits of marine mammals	10	22
Sudden change of currents due to winds, typhoons and seaquakes	1	2
Distraction from passing of anchovies and from visits of marine mammals and change of sea current	29	63
Distraction from passing of anchovies and from visits of marine mammals and change of sea temperature	1	2
Combination of all of the above reasons	5	11

TABLE 3 | Variables tested for its association with the reported fish school size and various tuna species using one-way ANOVA.

		School size			Tuna species		
Variables	**Source**	***df***	***MS***	***P***	***df***	***MS***	***P***
Attraction distance	Between Groups	1	828017	0.572	7	2111912	0.582
	Within Groups	44	2558600		38	2595343	
	Error	45			45		
Wait time (fish)	Between Groups	1	22	0.431	7	36	0.410
	Within Groups	44	34		38	34	
	Error	45			45		
Wait time (tuna)	Between Groups	1	31	0.696	7	126	0.743
	Within Groups	40	197		34	207	
	Error	41			41		
Wait time (fishing event)	Between Groups	1	19	0.321	7	11	0.792
	Within Groups	44	19		38	20	
	Error	45			45		

the results of the FGD interview. The main difference, however was the absence of skipjack, juvenile yellowfin tuna, frigate/bullet tuna in all the 10 dives although visibility was more than 10–20 m in all the dive sites. About 88% of the fish species recorded can be found at depths of 5, 10, and 15 m and the other remaining species 8 and 4% at depths of 20 m, and >20 m. The juveniles of sergeant fish were observed to associate near the floater of the FAD while the blue sea chub was observed to move at various depths of 10, 15, and 20 m. The schools of trevally, bigeye scad, and roundscad were observed to swim around the anchored FAD.

DISCUSSION

Most of the respondents have mentioned that demersals and small pelagics (trigger fishes, filefishes, dolphin fishes, sergeant fishes, blue sea chubs, golden trevallies, and rainbow runners), are followed by scads and mackerels which then will settle around the anchored FAD. These fishes are then followed by skipjack, frigate, bullet, and juvenile yellowfin tunas a few days or weeks after the non-tuna species have settled in the FAD (Castro et al., 2002). Tunas are known to prey on a wide range of species which

TABLE 4 | Depth distribution of fish species on anchored FADs during day time and night time based on semi-structured interviews ($n = 46$) and based on three FGDs ($n = 39$).

Semi-structured interview				Focus group discussion (FGD)			
Depth (m)	**Species**	**Day time (%)**	**Night time (%)**	**Depth (m)**	**Day time**	**Night time**	**Observations**
0–10	Golden trevally	33	25	0–10	x	x	These are the first species that colonize the FAD
	Roundscad	10	18			x	Fish are segregated by species, schools and size
	Rainbow runner	28	27		x	x	
	Common Dolphinfish	8	8			x	
	Bigeye scad	3	6		x		
	Triggerfish	5	8		x		
	Skipjack tuna	5	2				Fish usually aggregates or moves closer to the anchored FADs during the night and especially during night lighting of the anchored FADs
	Filefish		4				
	Juvenile Yellowfin tuna	8					
	Frigate/Bullet tuna		2				
11–20	Golden trevally	18	13	11 to 20			
	Roundscad	20	12		x	x	
	Rainbow runner	20	10		x	x	
	Skipjack tuna	10	22			x	
	Common Dolphinfish	6	7		x		
	Frigate/Bullet tuna	2	8			x	
	Mackerel scad				x	x	
	Triggerfish	8	4				These are usually found 25 to 50 meters from the anchored FADs and moving around during daytime
	Tripodfish	2	2				
	Bigeye scad	6	6				
	Juvenile Yellowfin tuna	8	17				
21–50	Frigate/Bullet tuna				x	x	These are species found 25 to 50 meters from the anchored FADs and moving around during daytime
	Skipjack tuna				x	x	
	Juvenile yellowfin tuna				x	x	
>50	Yellowfin, Bigeye tunas				x	x	

TABLE 5 | Presence of various fish species at different depths found in 10 anchored FADs examined in Davao Gulf, Philippines.

Species		Depths (m)				
English name	**Scientific name**	**0–5 (%)**	**10 (%)**	**15 (%)**	**20 (%)**	**>20 (%)**
Blenny	*Meiacanthus* spp.	(1) 50	(1) 50			
Blue sea chub	*Kyphosus cinerascens*	(7) 44	(8) 50	(1) 6		
Indo-Pacific sergeant	*Abudefduf vaigiensis*	(12) 86	(2) 14			
Trevally	*Carangoides ferdau*	(4) 31	(7) 54	(1) 8	(1) 8	
Filefish	*Aluterus monoceros*	(2) 18	(9) 82			
Rainbow runner	*Elagatis bipinnulata*	(2) 50	(2) 50			
Bigeye scad	*Selar crumenophthalmus*	(2) 28		(1) 14	(3) 43	(1) 14
Yellowstripe scad	*Selaroides leptolepis*			(1) 100		
Roundscad	*Decapterus spp*		(2) 40	(1) 20	(1) 20	(1) 20

Numbers are record of frequency at different depths.

includes shrimps, squids, stomatopods, other non-tuna species (e.g., lantern fish, scads, mackerels) and other smaller tunas whether juvenile yellowfin, bigeye, skipjack, and frigate and bullet tunas (Barut, 1988; Jaquemet et al., 2011). In relation to this, the association of juvenile tunas to an anchored FAD seems to indicate that they feed primarily on prey species found under the FAD because of their rapid growth, 3.8 mm per day (Mitsunaga et al., 2012). The opportunistic feeding behavior of tunas and its predisposition to social interaction (Robert et al., 2013) may have implications on its movement from one anchored FAD to another (Ménard et al., 2006).

The attraction distance of 10 km which fishers mentioned about tunas is reasonable given that the usual maximum inter-FAD distances between anchored FADs in the Philippines, is of the same distance (Libre et al., 2015; Macusi et al., 2015). In addition, tunas are attracted to floating objects and they associate with FADs for some time. The 10 km distance between FADs enable the small multirole vessels of purse seines and ringnets to navigate and check the fish biomass aggregation underneath the FADs. This attraction distance was also similar to the results of the interview of boat captains and master fishers who use drifting FADs (Moreno et al., 2007b).

Based on previous studies on the results of sonic tracking of juvenile yellowfin tunas, it was found out that tagged individual fish and fish schools associate in a network of FADs with 3 km distance from each FAD (Babaran et al., 2009a,b; Mitsunaga et al., 2012). These tagged juvenile yellowfin tuna forage in a network of anchored FADs as they start to migrate outside the locations of these fishing grounds. Moreover, a follow-up study by the same authors also showed that a tagged juvenile yellowfin tuna was caught 12 km away from the original tagging site which means that juvenile yellowfin tunas can easily move from one FAD to the other (Mitsunaga et al., 2013). In contrast, investigations of adult yellowfin tunas by Ohta and Kakuma (2005) showed that the fish stayed for a maximum of 55 days around a single FAD while Dagorn et al. (2006) reported that they stayed for a maximum of 151 days on a network of FADs.

On the attraction of various fish species to floating objects like anchored FADs, the pioneer species are usually herbivorous and piscivorous such as the Indo-Pacific sergeant fish, the filefish, golden trevally, and trevallies and juvenile tunas. While various reasons are hypothesized to explain this attraction such as sheltering, feeding, meeting point, indicative of productive areas (Freon and Dagorn, 2000; Castro et al., 2002), there is no single accepted explanation for this attraction to floating objects by these fish species. Moreover, it is thought that the biomass of fish around anchored FADs would not be enough to feed the biomass of oceanic tunas swimming around anchored FADs (Olson and Boggs, 1986). Majority of the fishers have reported that the aggregation process of various fish species takes time. This means that there was a gradual build-up of biomass around anchored FADs mainly with pioneer non-tuna species that arrived first in the FAD. These fish species were then followed by the attraction of oceanic tunas to the anchored FADs. In terms of the lack of difference between the fish species present during daytime and at night time, resident fish species seem to utilize FADs as their shelter and foraging area. But for the associated fish species which were loosely attached to the floating objects such as oceanic tunas, they are capable of swimming away to another anchored FAD when distracted.

Based on the reported tuna behavior in this study, there are three conditions involved in the attraction and retention process of oceanic tunas in a FAD fishing area: (1) Number of FADs deployed in the site—the more FADs deployed by fishers, the more choices of FADs for the school of tuna to visit (Aprieto, 1981; Macusi et al., 2015); (2) Level of productivity of FADs can have influence in the area because tunas are thought to visit productive (rich food areas), keeping those FADs located in poor food areas with less fish biomass (Jaquemet et al., 2011); (3) The size of tuna schools that visit a FAD- the size or biomass of fish school that visits a FAD will differ owing to varying level of individual productivity of FADs as well as the loosely associative behavior of tunas. Because of this difference, there is no fixed amount of catch of fishers for every FAD. However, this can be forestalled by the fishers' use of human sonars or divers as well as the use of acoustic fish finders. When fishers set a quota or baseline amount of harvestable biomass of fish per FAD monitored, more or less, their harvest would be similar to that baseline number.

As mentioned earlier, several reasons can distract tunas in the FAD, which means that FAD visits by a school of tuna may last for hours or for days, the visit or association to a FAD is therefore highly variable (Ohta and Kakuma, 2005; Mitsunaga et al., 2012). Moreover, the lack of relationship between the reported school size of tunas and attraction distance, and various waiting times for their arrival in the FADs, could be a motivation to explore other factors that might better explain the aggregation of fishes in FADs. For instance, a more direct assessment might be needed such as using acoustic techniques to relate the size of schools of fish to these waiting times. The production of sounds by anchored FADs may help orient and attract tuna toward the structure (Babaran et al., 2008), since according to Tolimieri et al. (2000), sound can serve as a navigational cue for fishes.

Concerning the results of the actual dives to examine the fish composition of anchored FADs, where there were no skipjack or yellowfin tuna observed in the vicinity of the anchored FADs, the survey was done near the shore, for instance with FADs found $<$100 km offshore as against the FADs located 500–1,000 km offshore in Mati and in Celebes sea. This was a limitation of the study. Although, before the survey was conducted in Davao Gulf, catch data, and catches were obtained from the local fishing companies with fishing areas in Davao Gulf. It was noted, however, that the local markets in Governor Generoso (a coastal municipality situated near the mouth of the Gulf) shows that juvenile skipjack, frigate, and yellowfin tunas were part of the ringnet catches. Another limitation of this study is the lack of pilot study for the dive assessment of the fish composition of anchored FADs at different times of the day before the actual conduct of the survey. There was also a lack of a chartered vessel dedicated for this purpose to study the FADs used by fishers in their fishing grounds, which could go for more than 500 km from the shore. This study can be extended in the future through an assessment program using fish visual census coupled with acoustics to understand fish schooling and association behavior in anchored FADs. This should be done since acoustics can complement and address the limitations of FVC (fish visual census; e.g., limitations on effective distance of FVC) (Taquet et al., 2007; Moreno et al., 2016). This will examine the various behavioral characteristics of small non-tuna species, and the oceanic tunas (both the juveniles and adult ones).

The implications of this study support the growing literature on overexploitation of marine resources which leads to economic losses. According to Kompas et al. (2010), overharvesting of tuna can incur an economic loss of billions of (US) dollars. This is partly due to excess in fishing effort that places enormous pressure on global marine fisheries (Anticamara et al., 2011). Excessive fishing pressure is a result of the high food needs of a burgeoning global human population (Stobutzki et al., 2006; Béné et al., 2015). Excessive fishing pressure, however, can also be a result of the failure of fishers to capitalize on available information to optimize fisheries yield on harvesting target species and lower non-target species catch, which are often discarded and also incurs economic loss (Patrick and Benaka, 2013). The complexity of the dynamics of marine fisheries is further confounded by the lack of understanding on the role of fish behavior and how it impacts marine fish population and marine fisheries in general. For example, in a model simulation conducted by Railsback and Harvey (2011) on brown trout (*Salmo trutta*) populations, it was shown that individual adaptive behavior (e.g., activity selection) has contradicted the traditional understanding on food limitation and how it regulates populations, accentuating fish behavior as a major factor to consider in formulating conservation and management strategies (Shumway, 1999). In this study, LEK has been proven to provide additional information for further understanding of the complexities of fish association to anchored FADs and how fishes behave.

The knowledge extracted from fishers, for example, in attraction behavior of fishes to FADs can help optimize FAD deployment (e.g., minimal number of FADs while achieving maximum sustainable yield by maximizing spacing between FAD deployments) and can lower operational costs for fishing fleet that will reduce fishing effort and overharvesting. Information generated by this study will be useful in designing policy formulations and management plans, especially in the regulation of FAD deployment in the country.

CONCLUSION

Various studies have shown that the high dependence on marine resources for food and livelihood can lead to excessive fishing. This was done by exploiting the fish behavior of association with floating objects and deploying FADs to increase fish production. FADs have been abundantly deployed in both near shore and offshore areas and their deployments are un-registered and unregulated. Because of the massive deployment of FADs, coupled with illegal, unreported, and unregulated (IUU) fishing, fisheries production has been steadily declining. The target species of purse seine and ringnet fisheries around anchored FADs are large pelagic (e.g., tuna) and small pelagic fish (frigate and bullet tuna, roundscads, and mackerel) while the average time of fish aggregation in FADs vary according to species and fish sizes; larger tuna (skipjack, yellowfin, and bigeye) usually aggregate last.

Moreover, fishers tend to move fishing operations in areas with more abundant and larger fishes to increase prospective revenues. To help conserve our pelagic resources, it is necessary that stricter enforcement of fisheries laws be applied. Alternative jobs for fishers and subsidies for their families for daily survival should also be an option. They also need to be educated in order for them to be less dependent on the fishing industry.

AUTHOR CONTRIBUTIONS

EM wrote, designed and conducted the survey used in the study as well as did the analysis and writing of the manuscript; NA also helped in the conduct of the field survey of the FADs as well as in writing and editing the manuscript. Both NA and RB helped in the analysis and writing of the manuscript.

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