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Behavioral responses of Irrawaddy dolphins, *Orcaella brevirostris* (Owen in Grey, 1866) to fishing boats in a globally important marine mammal area in central Philippines

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ABSTRACT

The Irrawaddy dolphins, *Orcaella brevirostris* (Owen in Grey 1866) of Guimaras Strait, Philippines, have been known to utilize a core habitat within a coastal area surrounding the Bago River estuary in Negros Occidental. The dolphins' close dependence on coastal waters often makes unavoidable direct interaction with human communities. Daily human activities in the coastal areas can pose serious threats to the dolphins, including high risk of entanglement in fishing nets, pollution, and disturbances caused by fishing boats and larger vessels. This study determined the behavior of dolphins toward different kinds of boats present in Bago-Pulupandan coastal waters. Factors identified to affect dolphin behavior towards boats include boat type (motorized or not), size, and distance from dolphins. Dolphin behavior towards boats were categorized as either positive, negative, or neutral. Results showed that the dolphins mostly exhibited neutral behavior towards boats, regardless of state and boat type. The dolphins' passive behavior around vessels may make them more vulnerable to boat strikes, especially from speeding motorized boats. Recommendations include strict regulation of boat speed and traffic within their core habitat to minimize injuries, net entanglement, and avoid mortality.

Keywords: behavioral responses, boat traffic, fishing gears, habituation, Guimaras Strait

INTRODUCTION

Behavioral studies on geographically-isolated wildlife populations are often an important consideration in localized conservation efforts. Various subpopulations of a particular species respond differently to specific environmental factors and thus require varied approaches to their management. In the Philippines, 26 species of marine mammals (Alava et al. 2012) are distributed into several fragmented subpopulations across seas, straits, estuaries, bays, and gulfs, separated by 7,641 islands. Consequently, this makes efforts to assess each species and their subpopulations a difficult task. Presently, protection of these species is covered in encompassing laws and policies based on a limited number of studies and the precautionary principle (Hoyt 2005). Marine mammals in the Philippines are protected under several laws. Among these are the Philippine Fisheries Code of 1998 (Republic Act 8550 and revised through RA 10654), the Wildlife Protection and Conservation Act of 2001 (RA 9147), and the Department of Environment and Natural Resources Administrative Order (DAO) 55 of 1991 (for dugongs), and Fisheries Administrative Order (FAO) 185-1 (for cetaceans). However, the enforcement of these laws may apply differently for geographically distinct subpopulations facing a variety of threats in their localized habitats. Moreover, the reality of wildlife law enforcement in the Philippines also largely depends on the local government agency in which the subpopulation is located (Whitty 2015).

The Irrawaddy dolphin *Orcaella brevirostris* (Owen in Grey 1866) population in the Philippines has been identified to exist in at least three geographically-isolated subpopulations: Iloilo-Guimaras Straits in the Visayas (Dolar et al. 2018; de la Paz et al. 2020), Malampaya Sound (Smith et al. 2004), and Quezon, Palawan (Dolar and Matillano unpublished data). The first two subpopulations are listed as Critically Endangered (CR) under the Red List of Threatened Species of the International Union for the Conservation of Nature (IUCN) (Smith and Beasley 2004; Minton et al. 2017; Dolar et al. 2018). Similarly, the habitats of these two subpopulations are recognized globally as Important Marine Mammal Areas (IMMAs) (MMPATF 2019).

Irrawaddy dolphins in the Philippines live in habitats that often overlap with human fishing grounds (Whitty 2015; Casipe et al. 2016; Dolar et al. 2018; de la Paz et al. 2020). Impacts of boat activity on marine mammals on coastal areas are of particular concern because of the large number of vessels operating in the area, their widespread use, and high noise production that can affect marine mammal behavior. Some marine mammal species exhibit tolerance to watercraft but apparent disturbance reactions have also been documented (Nowacek et al. 2001). Beluga *Delphinapterus leucas* (Pallas, 1776) abundance in the St. Lawrence Estuary in Canada declined after several years of increasing boat activity (Caron and Sergeant 1988); Killer whales *Orcinus orca* (Linnaeus, 1758) likewise observed in an area of increasing boat traffic off British Columbia, increased their swimming speed and adopted erratic swimming behavior (Kruse 1991). Behavioral responses in other small cetaceans include changes in dive length (Evans et al. 1992), surfacing patterns (Janik and Thompson 1996; Kreb 2004), group cohesiveness (Morimura and Mori 2019), and changes in foraging habitat selection (Allen and Read 2000).

Continuous disturbance from boat activities is likely to cause long-term population-level effects such as decreased ability to capture prey, avoidance of critical feeding or breeding areas, and changes in social activities (Morimura and Mori 2019). It is essential to understand the behavioral response of these dolphins to establish mitigation schemes against excessive exposure to disturbances. This study aimed to characterize the human activities, particularly those that utilize boats, in the Irrawaddy dolphins' habitat and investigate their behavioral response towards boats. In addition, semi-experimental observations were conducted to imitate dolphin-watching boats that intentionally move close to dolphins, to see how dolphins might react in the event that such eco-tourism program is considered by the local governments.

METHODS

Study Area

The adjacent coastal waters of Bago City and the Municipality of Pulupandan in Negros Occidental comprise a shallow, silty estuarine habitat that drains the Bago River, one of the largest river systems in Negros Island. It includes the southeastern part of Guimaras Strait, a narrow body of water that separates Negros and Guimaras Islands. A small area (approximately 12 km²) outside the mouth of Bago River has been identified as a core habitat of Irrawaddy dolphins, where they have been observed feeding around stake nets (Casipe et al. 2016; de la Paz et al. 2020). This area overlaps with the fishing grounds of at least five fishing communities that line most of the coastal area (Figure 1). On the eastern side of Pulupandan, ferryboats travel to and from San Lorenzo in Guimaras Island 3-5 times a day, and large cargo ships occasionally dock in Pulupandan port.

Data Collection

Mapping of fishing grounds. In order to characterize human activities in the habitat, information on fishing grounds, gears used, and patterns of fishing activities within the habitat were collected through focus group discussions (FGD) (Nyumba et al. 2017). Fishers from five communities (Bago: Sampinit and Punta Playa; Pulupandan: Tapong, Zone 1A, and Cavan) adjacent to the known habitat of the Irrawaddy dolphins were asked to point the location of their fishing grounds on maps of the surrounding areas. Mapping of fishing grounds was also conducted by following local fishers out at sea and recording the fishing locations using a GPS (ESSC 1998).

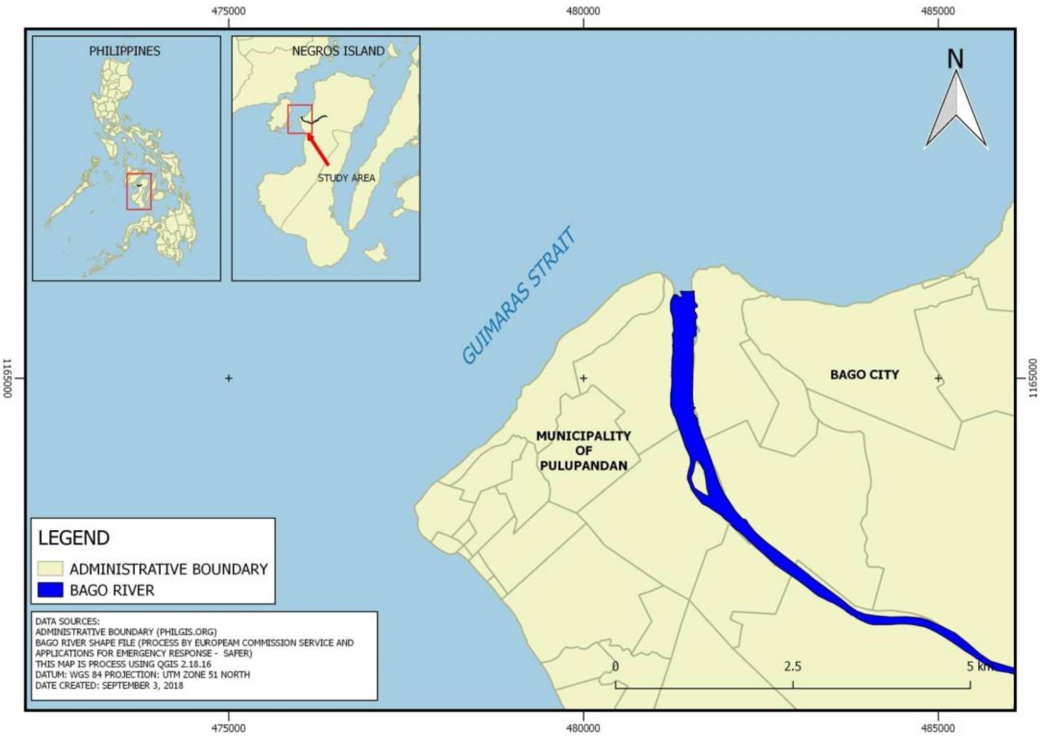

Figure 1. Map of the study site in Guimaras Strait and the coastal waters of Bago-Pulupandan relative to location in Negros Island and the Philippines (inset).

Survey method. Observations of dolphin-boat interactions were carried out by 3-4 observers during boat-based surveys from April to November 2015 and May to November 2018. These coincided with the transition period from the northeast monsoon (Amihan) to the southwest monsoon (Habagat). The research boat used was a 6 m outrigger fishing boat fitted with an outboard motor. Surveys commenced at around 0600 h and were only conducted during favorable weather conditions (Beaufort Sea State < 3) and lasted for 3-4 h, depending on the continued presence and behavior of the dolphins in the study area. The survey followed a pre-determined route 500 m parallel from the coastline from Barangay Zone 1A going north to the mouth of Bago River at an average speed of 12 kph, employing focal follow techniques (de la Paz et al. 2020). The types of boats observed in the area were listed and are described in Table 4. During the 2015 survey, the number and type of boats seen within a 200 m radius of the research boat were tallied every hour. Dolphin behavior was recorded at every 5 min interval and was categorized as either foraging, traveling, resting, or socializing (Table 1). The dominant behavior was determined based on which behavior they exhibited the longest within the 5 min observation time (Mann 1999). The locations of dolphin sightings were recorded using a handheld Global Positioning System (GPS) (Garmin GPSMap 78s) and were plotted using Quantum Geographic Information System (QGIS) 2.18.

Behavioral sampling. Behavioral responses of dolphins toward boats were observed between the nearest dolphin and the nearest boat and were classified as positive, negative, or neutral (Hashim and Jaaman 2011) (Table 2). In 2018, semi-control experiments were performed using two research boats. Observations of dolphin responses toward the second (control) boat were recorded to test their behavioral responses to a boat that would deliberately follow them, just as a research or tour boat would. These were observed from the first boat which kept a farther distance (approximately >50 m) from the control boat. The speed of the control boat did not go faster than 10 kph, but observing a 50 m distance between the control boat and the dolphins was not entirely practiced as dolphins would sometimes surface very near any boat unexpectedly.

Data Analysis

Chi-square was used to determine if a significant relationship existed between the behavioral responses of dolphins and the vessel types it encounters. The same test was used on the behavioral responses of dolphins and the boat status of vessels it encounters. When Chi-square values indicated that there was a significant relationship, Cramer's V was used to measure the strength of the association. Statistical Package for the Social Sciences (SPSS) was used for the statistical analysis.

Table 1. Ethogram of dolphin behaviors observed during the survey (Adapted from Casipe et al. 2017).

Group behavior	Description
Feeding/foraging	Frequent asynchronous dives in varying directions in one location; surfacing and respiration display no obvious pattern; dolphins often chase fish and occasional fish capture can be observed; prey is often tossed high out of the water and caught by the dolphins; flippering often observed to herd fish.
Traveling	All dolphins move in one direction, surfacing and diving synchronously; chasing fish or even social behavior extremely uncommon; movement in a faster pace usually over a larger distance while swimming when foraging; porpoising often observed; a displacement of at least 100 m from the initial location.
Resting	Low level of activity, with the dolphins apparently floating stationary and motionless at the surface, with some occasional slow forward movement, regular surfacing and diving while in one location.
Socializing and playing	Various vigorous activities including leaping out of the water, high speed movement with frequent direction changes and prolonged body contact with other dolphins; occasional splashes in aggregations of dolphins.

Table 2. Dolphin responses to oncoming vessels (adapted from Hashim and Jaaman 2011).

Response	Description
Positive	Boat-chasing behavior, actively approaching vessel
Negative	Actively moving away from boat, boat-avoiding behavior
Neutral	Dolphin continues to perform an ongoing activity or no changes in behavior observed

RESULTS

Boat Traffic and Fishing Activities

The fisheries in Bago-Pulupandan are mostly small-scale. Fishing grounds are located within respective municipal waters (<5 km from shore), or oftentimes to the neighboring waters of Guimaras Island (Figure 2). Gillnets were the most common gear used and were deployed with the use of motorized outrigger boats. Other gear types that were identified (beach seine net, lift or skimming net, cast net, bag net, and hand dredge net) were mostly operated in shallow waters in wading depths to capture fish fry and invertebrates (Table 3).

There were seven boat types operating in the study site (Table 4). The average number of boats recorded during encounters with dolphins was 14.89 boats per hour. Boat traffic was densest during the 0630-0729 h with an average of 18.38 boats, and gradually decreased as the day progressed, with the least number recorded during 0930-1029 h, with an average of just 9.89 boats (Figure 3). Small paddle boats (Type A) and motorized outrigger fishing boats that can reach a speed of up to 12-15 kph (Types B and C) were the most common in the area, with an average of 2.8 and 8.08 boats per hour respectively. An average of 1.7 passenger ferry boats (>3 gross tons) were recorded every hour. Other boat types had an average of less than one boat per hour.

Table 3. Fishing gears used in Bago and Pulupandan, as identified during the focus group discussion.

Fishing Gear Type	Local Name
Gill net a. Drift gill net b. Floating set gill net c. Drive-in gill net	Pukot Bahol; gusawan/pangusawan; kasagan; nipisan; tabagakan; tuluyan; punot Palanas Palagbong; panglantong/langtungan
Beach/drag sein net	Hila-hila; pakarus; suwayang
Cast net	Laya
Hook and line	Panglabay/ labay; panongkit
Lift net/ skimming net	Talangkaan; hudhud
Bag net	Paduyan
Crab lift net	Bintol
Hand dredge net	Karuy
Hand line	Bunit

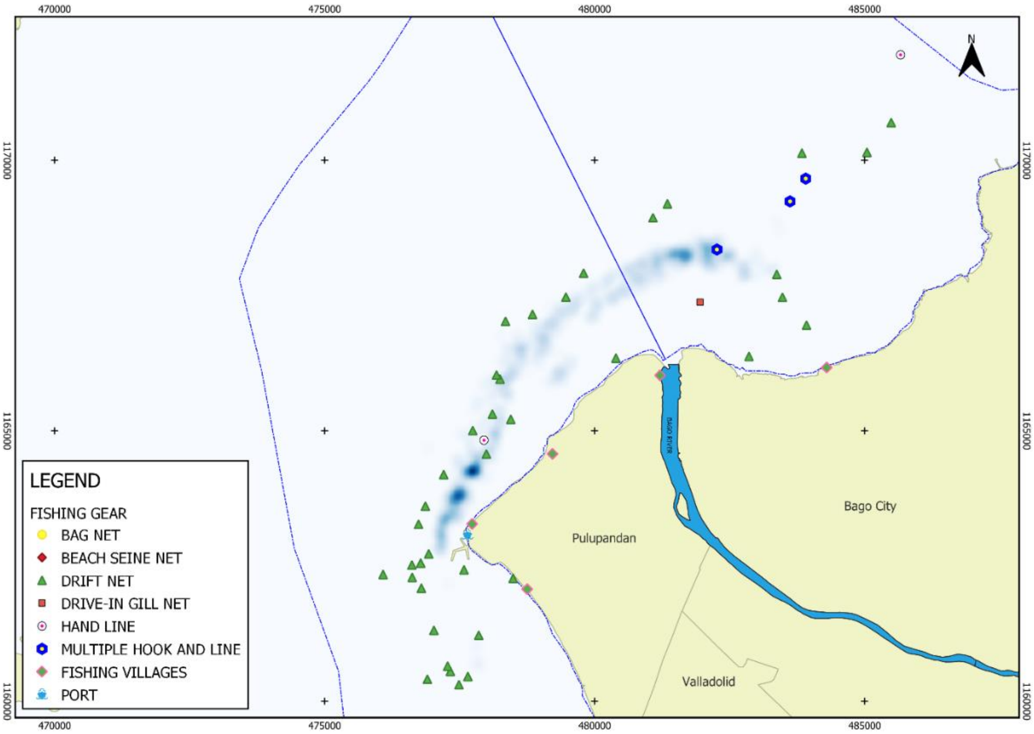

Figure 2. Map showing the distribution of fishing grounds in Bago-Pulupandan overlapping with Irrawaddy dolphin habitat (sighting density in dark blue).

Table 4. Types of vessels operating in the Bago-Pulupandan coastal waters. Some vessel's horsepower (hp) were referenced from [1]Aguilar 2006 and [2]Dinh 1999.

Type of Vessel		Description
A	Paddle / sailboat	non-motorized, semi-dugout outrigger boat; propelled by paddle or sail; 3-7 m length; 0.1-0.2 gross ton[1], usually holds 1-2 persons
B	Motorized fishing boat	5-18 m length; 0.5-2.9 gross tons; 3-16 hp[1], <3 gross tons, operated by 2-3 persons
C	Researchers' boat	motorized outrigger boat utilized by researchers to follow dolphins at a minimum distance; 5-18 m length; 0.5-2.9 gross tons; 3-16 hp[1]
D	Passenger ferry	15-30 m length; 5-20 gross tons; 80-94 hp[1]; >3 gross tons
E	Dredger	utilized for excavation operations; up to 1000 horsepower[2]
F	Tugboat	motorized boat intended for maneuvering or towing other vessels; 680-3400 horsepower
G	Cargo ship	capacity of up to 45 tons and carrying various cargo

Dolphin Response and Associated Behaviors

A total of 810 and 214 dolphin-boat interactions were recorded from the 2015 and 2018 surveys, respectively. Dolphins were usually encountered in groups ranging from 1 - 7 individuals. Foraging was the most frequently observed behavior of dolphins when sighted around the vicinity of boats, with 709 out of 812 (87.32%) recorded interactions in 2015 and 105 out of 214 (49.06%) interactions in 2018 (Figure 4). Other behaviors observed include traveling (6.28% in 2015 and 23.83% in 2018), socializing (5.05% in 2015 and 16.35% in 2018), and milling (1.35% in 2015 and 10.75% in 2018) (Figure 4). Irrawaddy dolphins mostly exhibited neutral or passive behavior toward boats, especially when foraging (80.39 % in 2015 and 65.71% in 2018) (Figure 5). However, the dolphins in 2015 were observed avoiding or swimming away from boats (47.06%) during most of the time that they were traveling but exhibited more neutral behavior (62.75%) towards the pursuing research boat in 2018. The dolphins also showed almost exclusively neutral behavior towards boats during socializing (100% in 2015 and 71.42% in 2018) and milling (100% in 2015 and 82.61% in 2018) (Figure 5).

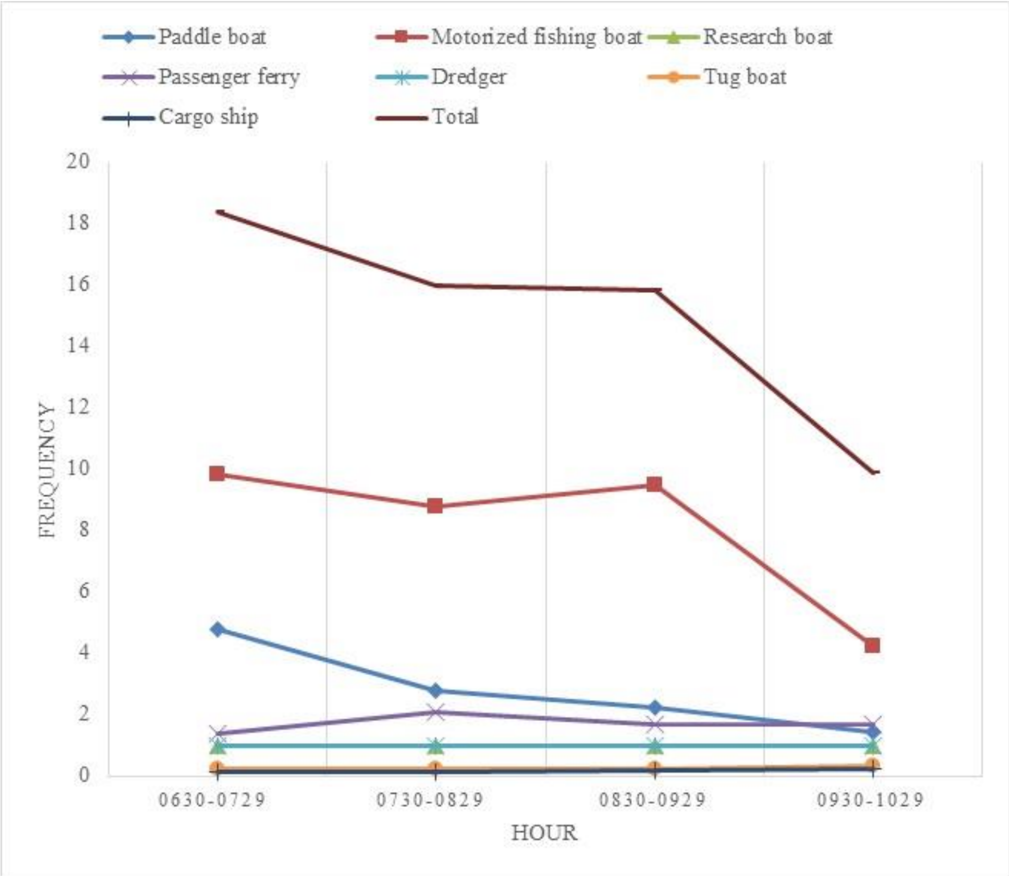

Figure 3. Mean number of boats operating per hour during the 2015 survey.

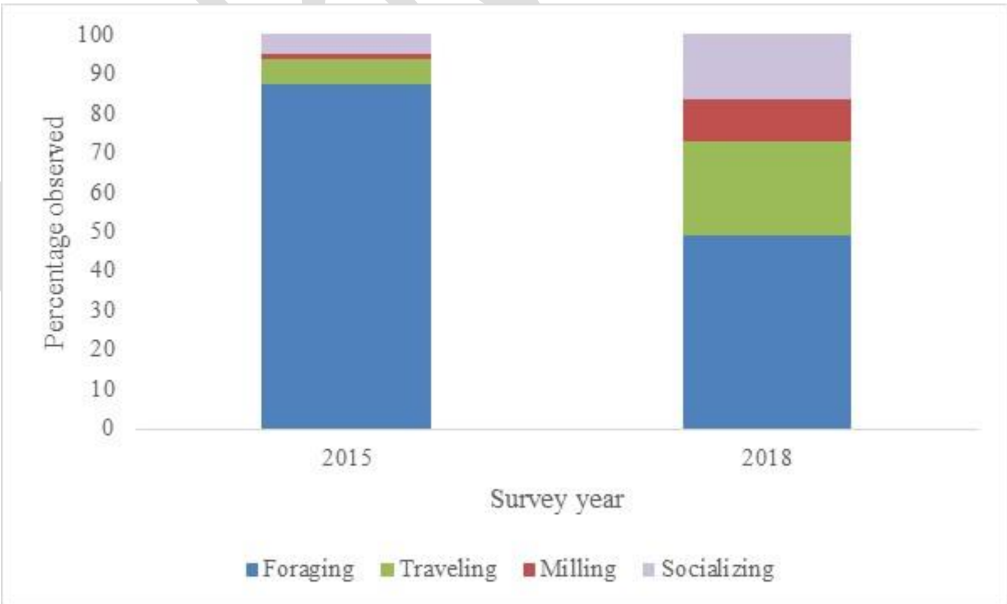

Figure 4. Percentage of observed Irrawaddy dolphin behaviors during the 2015 and 2018 boat surveys.

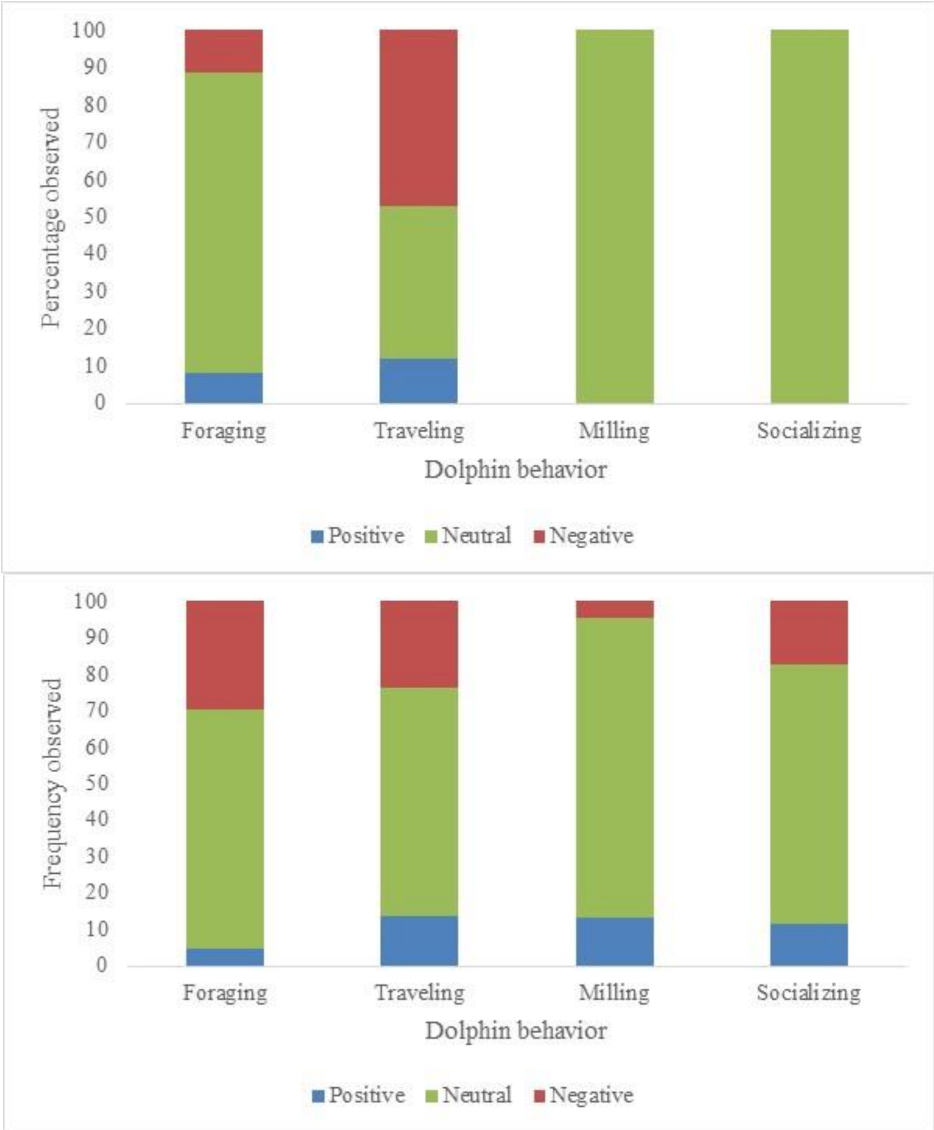

Figure 5. Percentage of Irrawaddy dolphin responses and their associated behavior during interaction with different boats in 2015 (top) and the research boat in 2018 (bottom).

Behavioral Responses toward Different Boat Types

Data analysis shows that the behavioral responses of the Irrawaddy dolphins towards different types of vessels had a significant relationship (Chi-square value = 32.866; P = 0.0001) (Table 5). Neutral behavior towards boats was the most prevalent response observed regardless of boat type nor movement state (Figure 6). As with the dredger, the dolphins mostly appeared unbothered (neutral response = 74.07%) despite its excavating activities and noise during operations. Positive response was observed in all boat types except in ferryboats, which were always moving when passing through the study area, although these observations with the ferry only occurred on three occasions. Positive response was usually observed during foraging, when dolphins congregate in large groups of 6-7 individuals.

Negative response was seldom observed with motorized boats (Type B: 8.66%; Type C: 15.04%) and dredger (3.70%). For the experimental research boat, dolphins tended to avoid (15.04%) the boat more than approach (5.76%) it, although negative behavior was only second to neutral behavior (79.20%). This, however, may be attributed to the tendency of the researcher's boat to follow the dolphins when they travel.

Table 5. Chi-Square tests on the relationship of Irrawaddy dolphin behavior toward different types of boats (7 cells (46.7%) have expected count less than five). The minimum expected count is 0.23.

	Value	**df**	***P*-value**
Pearson Chi-square	32.866[a]	8	.0001
Likelihood Ratio	33.624	8	.00005
N of valid cases	810		

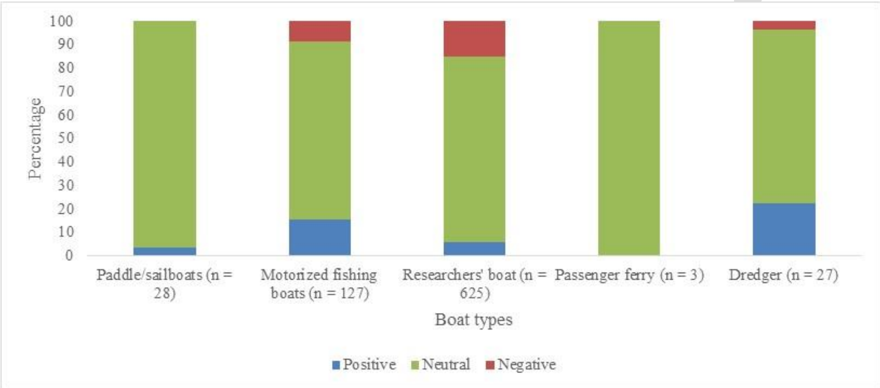

Figure 6. Percentage of Irrawaddy dolphin responses toward different types of boats in 2015.

Behavioral Responses toward Stationary vs Moving Boats

Despite the dolphins' predominantly neutral behavior towards boats, dolphins tended to avoid moving boats more than stationary boats (Figure 7). This was true, especially with motorized fishing boats (Types B and D), which usually had the noisiest engines among all the other boats. However, dolphins were more likely to swim closer to the boats when its engines were turned off. These were observed especially when fishers set their nets to catch fish. Their responses towards stationary and moving vessels demonstrated a significant relationship (Chi-square value = 31.829; $P = 0.0000001$) (Table 6). The strength of association towards both variables, however, was weak. Although stationary and moving boats had a greater strength of association with dolphin response than with different vessel types.

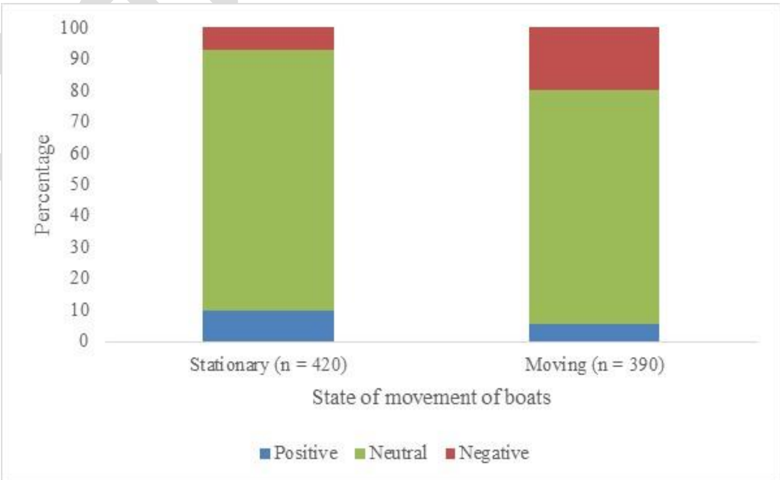

Figure 7. Irrawaddy dolphin responses toward stationary and moving boats in 2015.

Table 6. Chi-Square tests on the relationship of Irrawaddy dolphin behavior toward stationary and moving boats (0 cells (.0%) have expected count less than five. The minimum expected count is 30.33).

	Value	**df**	***P*-value**
Pearson Chi-square	31.829[a]	2	.0000001
N of valid cases	810		

DISCUSSION

Boat traffic is among the top factors that threaten Irrawaddy dolphins (Minton et al. 2017). It is a recurring factor in most Irrawaddy dolphin habitats, as their populations often overlap with fishing and navigational areas (Kreb 2004; Smith and Beasley 2004; Hashim and Jaaman 2011; Peter et al. 2016). There are at least five fishing communities adjacent to the dolphins' habitat in this study. Fishers maximize better weather conditions during the Habagat monsoon to go out and fish, and dolphins were frequently observed in this area during both seasons. Boat traffic in Bago and Pulupandan (mean = 15.02 boats per hour) was a lot busier than that in Balikpapan Bay (3.2 boats per hour); although less busy than in the Mahakam River (20.7 boats per hour), where dolphins significantly decrease their surfacing rates in the presence of boats (Kreb 2004).

Arguably, the presence of the researcher's boats may have influenced the behavior of the dolphins and affected the results of the study. However, the dolphins' apparent passive behavior towards most boats may already indicate a form of habituation, a common behavior among dolphin groups living in highly utilized navigational and fishing areas (Kreb 2004). Dolphins often benefit when foraging alongside human fishers and have been known to prioritize the availability of prey over the risks of interacting with humans (Corkeron et al. 1990). They have been known to feed on the nets set by fishers (Norris and Prescott 1961; D'Lima et al. 2013) and even be involved in cooperative fishing (Tun 2004). This may also explain why the Irrawaddy dolphins did not appear bothered by dredging activities, as such disturbance of the sediment may also attract potential prey.

The dolphins avoided moving boats more than stationary ones. They swam away from moving boats when these intercepted their path while they were traveling, suggesting that the dolphins were aware of the effects of crossing a boat's path, or that the boat's noise elicit flight response from the dolphins. Irrawaddy dolphins have been known to use acoustic cues to gauge the distance to the approaching boat and based on that knowledge, plan their dives accordingly (Hashim and Jaaman 2011). Although noise was not included in the scope of this study, motorized boats produce high-frequency noise and are likely to affect the underwater acoustic environment. One of the common fishing methods in Bago and Pulupandan is the drive-in drift net, or "palagbong". This involves fishers circling around the net on a motorized boat and striking the water surface with a paddle to drive fish toward the gillnet. Such noise-generating practice could potentially interfere with the acoustic cues of dolphins and affect their diving patterns.

Implications for Conservation

The preference of the Irrawaddy dolphins for coastal habitats puts them at risk of boat collisions and net entanglement. The dolphins forage near the local port of Pulupandan, where large vessels docked and small motorized fishing boats frequently passed. Boat strikes through impacts with hulls and lacerations from propellers have been implicated as sources of injuries on many marine mammals (Wells and Scott 1997), and the dolphins' apparent habituation with boats may increase the chances of collision.

Due to the vulnerability of the dolphins' behavior towards boats, precaution is of utmost importance. We recommend management protocols to all users in the dolphins' core habitat, zoning of fishing grounds, and the identification of boat routes around the core habitat to minimize dolphin-boat collisions as much as possible. Boaters operating within the habitat are recommended to observe a maximum speed limit and be aware of the presence of dolphins when traversing their habitat. Boats must maintain a 100-meter distance from the dolphins in accordance with the guidelines set by the Departments of Tourism, Agriculture, Interior and Local Government, and Environment and Natural Resources (Joint Memorandum Circular No. 01 Series of 2020). Boat traffic management can be done through community orientation, establishment of widespread information materials, and strict monitoring by law-enforcement agencies (e.g. Bantay Dagat, Coast Guard). Dolphin-focused tourism activities are recommended to be limited to land-based observations so as not to add further boat traffic in the habitat.

While there has been no conclusive evidence of mortalities caused by net entanglement in Bago-Pulupandan, the myriad of gillnets spread throughout their habitat can still pose potential danger to the dolphins in this area. Pacalioga et al. (2017) recorded three types of gillnets in the area, the drift gillnet, floating gillnet, and the drive-in gillnet used to catch different kinds of fish, some of which are also consumed by Irrawaddy dolphins (e.g. ponyfishes and conger eels) (Postrado et al. 2019). Gillnets are usually set 2-3 km from shore to catch pelagic fishes. There were on average 37 gillnets/day that were used by fishers in the study area. Gillnets can stretch from 1,500-2,500 m, thus can cover an extensive area inhabited by dolphins. An overlap of preferred fishes by the dolphins and those caught in nets can lead to higher risks of entanglement, a problem already implicated as one of the most common causes of mortalities in Irrawaddy dolphin populations elsewhere (Minton et al. 2017). The establishment of marine protected areas and proper zoning where gillnets can be prohibited can lessen risks of entanglement, as well as allow protection of vulnerable fish recruitment habitats.

There have never been reports of a fishery targeting dolphins in Bago and Pulupandan (Silliman University 2014). However, there has been a gradual increase in the number of fishers over the past years and fish catch data by Pacalioga et al. (2017) also indicate that fish stocks in the area are experiencing severe fishing pressure. Overfishing in these coastal areas may also affect prey availability for Irrawaddy dolphins.

This study aimed to characterize the impact of boat traffic on the behavior of Irrawaddy dolphins despite having some limitations such as the possible influence of the researcher's boats to the dolphins' responses. Other non-invasive methods to observe dolphin-boat interaction such as with the use of drones and hydrophones, or even land-based observations, may further allow us to understand this issue better. There is also a need to confirm if depredation from nets occur with Irrawaddy dolphins, as this may lead to net entanglement and even consumption of nylon net parts.

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