Interaction Analysis in Hunting Behavior of Finless Porpoises

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***Abstract*—Finless porpoises (*Neophocaena asiaeorintalis*) usually live in a relatively small group. Aggregated porpoises prey on fish simultaneously and they do not show explicit allotted roles like other dolphins. However, whether each individual hunt fish independently from others is not clear. In this study, we tried to find dependency in porpoises' hunting using movies of their feeding taken by a drone.**

I. Introduction

Human is a social species but not only the social species. Chimpanzees, for example, share their food in hunting [1] and elephants know when they need a helping trunk in a cooperative task [2]. One of the advantages of sociality or cooperative hunting is its high efficiency [3]. Cooperative hunting is observed in birds [4] and mammals [5], including whales such as spinner dolphins (*Stenella longirostris*) [6], bottlenose dolphins (*Tursiops truncates*) [7], [8], killer whales (*Orcinus orca*) [9] and humpback whales (*Megaptera novaeangliae*) [10].

In cooperative hunting, communication with each other is inevitable. In case of whales, they use sound/ultrasound signals called whistles since they live under water. Analyzing the whistles revealed that bottlenose dolphins include a context into their whistles [11], that they identify each other [12], that they have joint attentions [13], and that they make an alliance in their social network [14]. During a cooperative hunting, in addition, they show the complex behavior that some play as barriers and others as drivers [8].

Although finless porpoises (*Neophocaena asiaeorintalis sunameri*) also belong to toothed whales, they were thought not to make an explicit group [15] but just to stay at the same place during hunting [16]. Recently, however, they were found to show social responses to boat traffic risk [17]. Thus, we hypothesize that they may show social responses during hunting.

To test this hypothesis, we tracked finless porpoises during hunting from the air and see whether their traces are independent or not.

II. Materials and Preprocessing

The videos used in this study were recorded in the previous paper [17]. Note the clipped parts are different from those in the previous paper since the previous paper analyzed responses to boat traffic while this paper targets hunting.

A. Study site

Neophocaena asiaeorientalis sunameri is distributed throughout the shallow (usually < 50 m deep) coastal waters of Japan [15]. Fieldwork was conducted in an area of 1.2 km^2 off the Japanese coast in the marine waters of the Misumi West Port (Fig 1; 32°37' 7.4" N, 130° 27' 13.5" E) between March 2017 and May 2018. During the study, we regularly launched a drone to conduct observational studies on finless porpoises in the bay. Our year-round observations showed single and aggregated finless porpoises, sometimes exceeding more than 60 individuals, engaging in a variety of behavioral repertoires including solitary and group feeding, travelling, copulation, and mother-calf interactions. We conducted the observations without identifying each individual. Water visibility during the study period was usually less than 2 m, but varied daily depending on the weather and tide conditions.

B. Drone observations

Surface behavior of finless porpoises was recorded using drones (DJI Co. Ltd, Mavic Pro). The aircrafts were manually controled with the Litchi application (ver. 4.6.1-g) for Android OS (VC Technology Ltd). We collected video footage that totalled 15 min for a single flight. The flight was conducted from 5 PM until sunset for a maximum of 3 h per day. The flight height of the drone varied from 40 to 149 m above sea level (asl) and was adjusted to provide the most preferable recording conditions for targeting individuals. Thus, the presence and noise of the aircraft had to have limited impact on the animal's surface behavior, while its distance potentially influenced its ability to determine the animal's social interactions in detail. The pitch angle value of the camera embedded in the drone was kept at -90 degrees during the flight, but the pitch angle varied if necessary to record a whole episode continuously. The observation was repeated daily, but was cancelled if the weather conditions were unsuitable. The recorded videos were 3840 × 2160px and 29.97 fps, which were down samples to every 5 frames for the analysis below. Although we targeted finless porpoises and fish flock, some flying/floating birds were also included in the videos (Fig. 1).

C. Hunting behavior

In continuous behavior of finless porpoises, it is difficult to determine the starting point of hunting. However, they

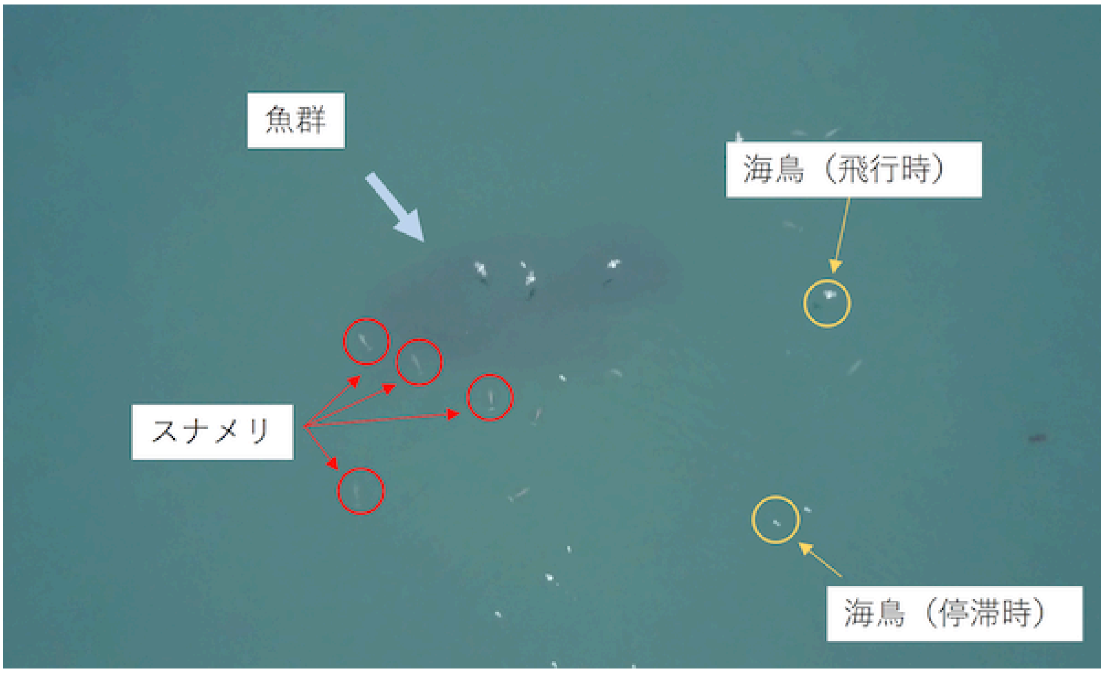

Fig. 1. A snapshot of a movie.

sometimes show a sudden acceleration to a fish flock after a slow approach, which is easy to clip "hunting behavior" from the videos. Thus, we define this behavior as a hunting and we got 33 huntings from the collected videos. We call a slow approach and a sudden acceleration approaching and chasing, respectively, and the time of the behavior switching was set to the origin of time, $t = 0$.

D. Image processing

Each porpoise was localized using a tracking software (Tracker v.5.0.5 [18]) and the middle point of the both pectoral fines was extracted. The trajectory of a porpoise was normalized using the body length of the porpoise.

The form of a fish flock was determined as the boundary of the color change manually.

E. Classification of solitary and cooperative hunting

There is no baseline for a cooperative hunting in finless porpoises because the sociality is mostly unknown owing to a limitation in previous observation opportunity. We defined a solitary hunting as the cases when one of the conditions below was satisfied.

1) No other finless porposes exist in the flame at $t = 0$.
2) No other finless porposes exist near the considered one.
3) Other finless porposes approach from different directions.
4) Other finless porposes do not face the fish flock at $t = 0$.

As the result, the 33 huntings were divided into 18 solitary huntings and 15 cooperative huntings. In the following, solitary and cooperative huntings are often referred to as single and multiple, respectively.

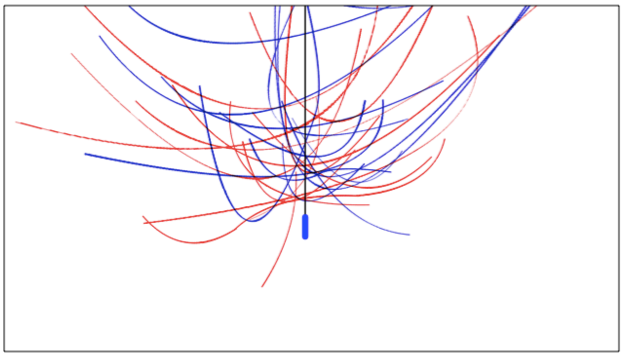

Fig. 2. Fish flocks with respect to a porpoise. (red, solitary; blue, cooperative)

III. Relationship between Chasing and Fish Flock

A. Form of fish flock

We hypothized that a finless porpoise take a chasing when a fish flock has a fixed form and the form depends on whether hunting is solitary or cooperative. To see whether this is correct, we applied the reverse correlation to the fish flocks at time $t = 0$. More concretely, we scaled and plotted the fish flocks so that the positions of the head and the tail are aligned.

As the result, we could not find the difference between the solitary and cooperative huntings. On the contrary, finless porpoises did not start chasing in a fixed form at all (Fig. 2).

B. Distance from fish flock

We made a simpler hypothesis than the form that there is a difference in the distance from the targeted fish flock between the both cases, solitary hunting and cooperative hunting. To

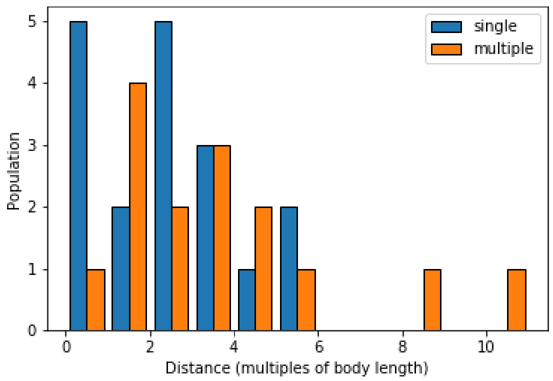

Fig. 3. Distribution of the distances from finless porpoises to the closest points.

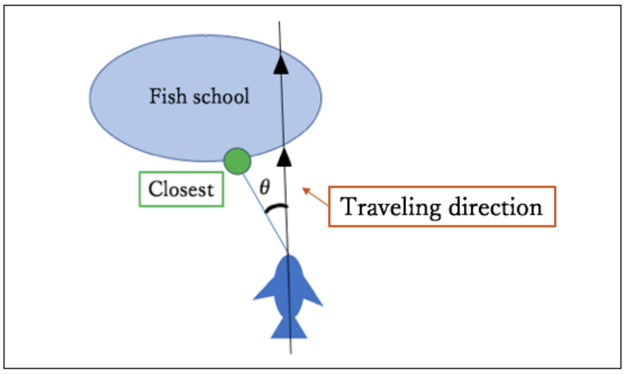

Fig. 4. Definition of the attacking angle.

see whether this is correct, we derived the distribution of the normalized distances with the body lengths from finless porpoises to the closest points in the fish flock at time $t = 0$.

As the result, we could not find a statistically significant difference between the both cases (Kolmogorov-Smirnov test, $p = 0.30$; Mann-Whitney U-test, $p = 0.14$). Note both distributions have rich tails (Fig. 3).

C. Angle to fish flock

In Fig. 2, finless porpoises seem to attack not in the perpendicular direction but in a slant direction. Thus, we hypothesized that the distribution of the angles are different in the both cases since a finless porpoise has no restriction in a solitary hunting while it must avoid others in a cooperative hunting. To see whether this is correct, we defined the attacking angle as the angle between the traveling direction and the line to the closest point in the fish flock at time $t = 0$ (Fig. 4) and derived the distribution of the angles.

As the result, we could not find a statistically significant difference between the both cases (t-test, $p = 0.05$; Kolmogorov-Smirnov test, $p = 0.17$; Mann-Whitney U-test, $p = 0.05$). Note both distributions were bimodal and the direction of the perpendicular were rarely taken (Fig. 5).

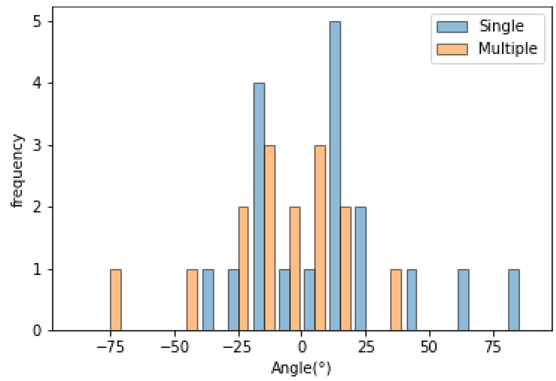

Fig. 5. Distribution of the attacking angle.

D. Laterality of the attacking angle

In the previous subsection, we found that the distribution of the attacking angles is bimodal and that the modes seem to have different sizes. Thus, we hypothesized that finless porpoises have a laterality in the attacking angle and that the laterality depends on whether the hunting is solitary or cooperative.

As the result, 61% of the angles take a positive value (right) in solitary huntings while 40% of the angles do in cooperative huntings (Table I). However, the difference was not statistically significant (χ^2-test, $p = 0.74$; binomial test for solitary hunting, $p = 0.24$; binomial test for cooperative hunting $p = 0.30$).

TABLE I
LATERALITY OF THE ATTACKING ANGLE.

	Left	Right	Sum
Solitary	7	11	18
Cooperative	9	6	15
Sum	16	17	33

The counts in Table I include both of the two individuals in one cooperative hunting. This means that the counts do not take into account their interaction. Thus, we tested whether the two get closer/further or independent, which implies their interaction.

As the result, 53% of pairs got closer and the interaction was not statistically significant (Table II). Note we exclude samples where an individual had neighbors in both sides.

TABLE II
DEPENDENCY ON THE NEAREST INDIVIDUAL.

	Closer	Opposite	Sum
Multiple	7	6	13

IV. DISCUSSION

We tried to find any differences between solitary and cooperative huntings, from the following four viewpoints, the form, the distance and the angle of the fish flock, and the laterality of the attacking angle. As the results, we could not find any difference between them and no hypotheses were supported by statistical tests.

In our analysis, the attacking angles are not unimodal but bimodal (Fig. 5). In addition, although the laterality is not statistically significant, solitary huntings may have a laterality if we collect more data, since many whales are reported to have a laterality. For example, Clymene dolphins (*Stenella clymene*), another species of whales, in the Gulf of Mexico mainly swim anticlockwise during their huntings [19]. The laterality in whales appears not necessarily during their huntings [20]. Bottlenose dolphins have a bias of anticlockwise in swimming in both America and Russia [21]. Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in Monterey Bay, California, show an anticlockwise bias even in sleeping [22]. Another report that Bottlenose dolphins in South Africa have a bias of clockwise [23] implies that the laterality is induced by the earth rotation and/or the geomagnetism.

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