Easy food in the jungle: evaluating presence and relationships of Amazon River dolphin (*Inia geoffrensis*) at a provisioning site in the Amazon, Brazil

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Abstract

Provisioning food to wildlife is a strategy used to habituate animals to human proximity during tourism activities, but it can contribute to changes in individual behavior and social structure and impacts on the nutritional health status. This article evaluates the presence and relationships of Amazon River dolphins (*Inia geoffrensis*) in feeding sessions at a floating house in Anavilhanas National Park, Brazil. The Amazon River dolphins most frequently observed during the study period also presented higher constancy in the feeding sessions. Food provisioning had a variable impact on Amazon River dolphins, making it possible to identify regular, occasional, and rare visitors. The most frequently observed Amazon River dolphins showed strong connectivity, with some individuals playing an important role in the network, acting as a bridge, connecting the set of nodes. These results provide important information about the level of conditioning and social relationships of Amazon River dolphins, which can assist in the development of strategies aimed at reducing the negative population health consequences of supplying food.

Introduction

Offering food to wild animals in their natural environment is a strategy widely used by tourist guides and visitors to promote a closer physical approximation to the provisioned animals. However, providing food to wild animals can have several consequences, including changes in population density, group composition, environment use, individual behavior, and impacts on reproduction and parental care (Orams, 2002; Mann and Kemps, 2003; Sabino and Andrade, 2003; Saito *et al*., 2010; Alves *et al*., 2013*a*; Christiansen *et al*., 2016; Tortato and Izzo, 2017).

Recognizing these deleterious consequences of wildlife food provisioning, many countries have prohibited it and imposed substantial fines; however, illegal food provisioning of wild animals still occurs and is a major concern for management and conservation agencies (Samuels *et al*., 2000; Finn *et al*., 2008; Christiansen *et al*., 2016). In Brazil, there is no specific legislation regarding the artificial feeding of wild animals and the activity is used to attract various animals, including fish (Sabino and Andrade, 2003), monkeys (Saito *et al*., 2010), coatis (Gazeta do Povo, 2012), alligators, giant otters, jaguars (Tortato and Izzo, 2017), and river dolphins (Alves *et al*., 2011; Rodrigues *et al*.,

2019; Vidal *et al.*, 2019). Supplying food to wild fauna is banned by the internal regulations of protected areas such as Serra dos Órgãos National Park, in Rio de Janeiro, and Iguaçu National Park, in Paraná (Vidal, 2011; Alves *et al.*, 2013*b*).

The Amazon River dolphin or boto (*Inia geoffrensis* de Blainville, 1817) is classified as "Endangered" on the IUCN Red List of Threatened Species (da Silva *et al.*, 2018). This is due to anthropogenic stressors and factors such as accidental capture in fishing nets or slaughter as a retaliation for conflicts with fishermen (Alves *et al.*, 2012; Iriarte and Marmontel, 2013*a*), which includes using their carcasses as bait (Iriarte and Marmontel, 2013*b*; Brum *et al.*, 2015), the loss and degradation of their habitats (Hollatz *et al.*, 2011; Gomez-Salazar *et al.*, 2012), the increase in disorderly tourist activities that negatively impact these animals (Alves *et al.*, 2011; Romagnoli *et al.*, 2011; Vidal *et al.*, 2017*a, b*; 2019), and the aquatic pollution by persistent organic pollutants, mercury and other metals, hydrocarbon and oil spills, and plastic debris as additional stressors affecting the individual/population health and critical habitats of botos in the Amazon (Rosas and Lehti, 1996; Torres *et al.*, 2009; Mosquera-Guerra *et al.*, 2019; Barbosa *et al.*, 2021).

The Flutuante dos Botos, a private floating house located in Anavilhanas National Park, a protected area in the municipality of Novo Airão, Amazonas state, developed interactive tourism activities with the Amazon River dolphin (Vidal *et al.*, 2018). These interactions, which started in 1998 as play between the local children and a few Amazon River dolphins, have moved on to an activity of supplying fish for the cetaceans. This eventually attracted more Amazon River dolphins and called the attention of national and foreign visitors, gaining popularity and becoming the main tourist attraction of the protected area and the city (Alves *et al.*, 2009; Romagnoli, 2009). Tourists were allowed to feed and get into the water with the dolphins. The initiative grew over time, without any monitoring or standardization of procedures by the state (Secretary of State for the Environment - SEMA) and federal (Chico Mendes Institute for Biodiversity Conservation - ICMBio and Brazilian Institute for the Environment and Renewable Natural Resources - IBAMA) environmental agencies in charge of wildlife or protected areas - for over 10 years. For instance, there was no control over the quantity and quality of fish offered to the Amazon River dolphins, or the number of tourists and the types of interactions permitted. Consequently, there were situations of tourists swimming with the dolphins and trying to hold them forcefully; offering food that was not part of the animals' natural diet; and tourists accidentally being bitten by the dolphins (Romagnoli, 2009; Alves *et al.*, 2011; Vidal *et al.*, 2013).

In 2010, a multidisciplinary working group, under the leadership of ICMBio, designed a pilot program to manage the logistics of this tourism program (Vidal *et al.*, 2017*a*). As an offshoot of this process, ICMBio issued Ordinance Nbr. 47/2012, whereby Amazon River dolphins' feeding by tourists was forbidden in the protected area, and only allowed to the establishment's employees, at defined times and maximum volumes per day. This measure significantly reduced problems of visitors being accidentally bitten. Currently visitors can only observe the food provisioning, touch the Amazon River dolphins, and take pictures.

The fact that Amazon River dolphins are still offered food can potentially affect natural dietary patterns (such as the time dedicated to foraging and the number and diversity of prey), and the presence of Amazon River dolphins in the enterprise and their conditioning to human presence. In the long term, it is essential to monitor the dolphins that are fed on site to guarantee their well-being and the tourist attraction's contribution to the local economy.

Based on the context above, this study aimed to examine the presence and relationships of known Amazon River dolphin individuals that regularly visited the food provisioning area in Anavilhanas National Park.

Materials and method

Study area

The study was carried out at the Flutuante dos Botos, a private floating house located in the south-central region of the Anavilhanas National Park – ANP (Fig. 1), Amazonas state, Brazil. ANP is located in Novo Airão, a small town 183 km by land from Manaus and represents one of the main destinations for local inhabitants and tourists alike (Alves *et al.*, 2013*a*; Vidal *et al.*, 2017*a*). ANP has approximately 350,000 hectares of area, and about 400 islands, making it the second largest river archipelago in the world (ICMBio, 2017). This protected area also includes forest formations of *terra-firme* (upland areas) and *igapó* (lowland areas seasonally flooded), in addition to several streams, lakes, and secondary channels (ICMBio, 2011). This aquatic environment is formed by black waters of the Negro River that are poor in nutrients, with high concentrations of organic compounds leading to an acidic pH (Sioli, 1984; Goulding *et al.*, 2003).

Data collection and analysis

To evaluate the presence of individuals of the Amazon River dolphin at the Flutuante dos Botos only, we recorded each individual present daily at the eight feeding sessions (09:00 h, 10:00 h, 11:00 h, 12:00 h, 14:00 h, 15:00 h, 16:00 h, 17:00 h), except for the few days the enterprise was closed, or due to inclement weather conditions (*e.g.* storms). Data on dolphin presence over 701 days from August 2013 to September 2015 were recorded on spreadsheets, yielding 5,608 feeding sessions
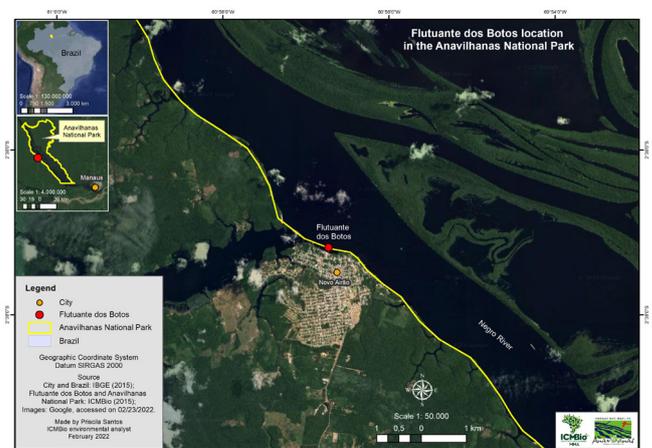

Figure 1. Map of Lower Negro River highlighting the location of the Flutuante dos Botos, Anavilhanas National Park, Amazonas, Brazil.

monitored throughout the hydrological cycle's different phases (low water = 173, rising = 172, high water = 183, falling water = 173). We recorded which dolphins were present in each feeding session with the aid of the employees of Flutuante dos Botos, who were able to visually recognize each individual by their scars, pigmentation patterns, and behaviors, and identify them by names (Vidal *et al.*, 2017*a*; Gravena *et al.*, 2019). During the data collection period of this research, up to 15 recognizable dolphins attended the Flutuante dos Botos, which were known by the names: Alexandre, Bob, Cauã, Chico, Curumim, Dani, Doidinha, Eide, Fefa, Josafá, Lawrence, Marimoni, Pimentinha, Rafinha, and Reginaldo. Despite the names received, no differences were identified by sex and age between individuals.

A network analysis (NA) was used to investigate the social dynamics of individual dolphins influencing one another in a social network setting and the influence of such associations in the community. In general, networks feature nodes (in this case, specimens), and edges (connections among nodes) (Hevey, 2018). The key advantage of the NA approach is that it visually explores the multivariate dependencies of the data that otherwise remain uncovered (Costantini *et al.*, 2015). Typically, the most informative visualization approach of NA is the one that allows attributing edges to partial correlation coefficients, meaning that a connection between nodes X and Y is the connection after controlling for all other edges in the network. Here, we estimated a Gaussian Graphical Model that estimates pairwise association parameters between all nodes (specimens). As we have 15 individual nodes, 105 pairwise association parameters were estimated. The estimation of large numbers of parameters usually results in a considerable number of false-positive connections. To control this issue, we used least absolute shrinkage and selection operator procedure (LASSO), which employs a regularization approach that conservatively recognizes only the relevant edges, and accurately discovers the underlying network structure (Hevey, 2018).

According to Hevey (2018) nodes cluster within the networking space when they are correlated more strongly. Conversely, the more peripherally a node is positioned, the less correlated it is to other nodes. For this purpose, three common graph-theoretical centrality measures were estimated: 1) strength, 2) closeness, and 3) betweenness. Node strength sums all edges of a given specimen with all other individuals, assessing how powerfully a node is directly connected with the network. Closeness centrality provides a quantity of how intensely a node is indirectly connected with the network by taking the inverse of all shortest path lengths between a node and all other nodes. Betweenness centrality relies on the concept of the shortest path length connecting any two specimens, and an individual with a high betweenness centrality can be central in connecting others (Hevey, 2018).

The analyses were performed in the *R* programming language, using the *Qgraph* package (R Development Core Team, 2012). Collecting permits were provided by SISBIO/ICMBio No. 37309-1 and 45110-1.

Results

At the food provisioning station, the average number of Amazon River dolphins in the feeding sessions ranged from 3.6 (feeding session at 09:00 h) to 1.4 individual (feeding session at 17:00 h), showing a decreasing trend towards sunset hours, but the average number of individuals significantly increased (3.2 individuals) during the 15:00 h feeding session.

Curumim, the oldest dolphin that frequents the Flutuante dos Botos, was the most regularly present specimen in the feeding sessions (1,946 sessions), while Cauã, a juvenile, was the least frequent (81 sessions). The average number of days attended by all individuals was 279.4 and the average number of feeding sessions was 968.5. This resulted in an average of 3.46 feeding sessions per day for the entire population that attended the Flutuante dos Botos. Regarding individual presences, Amazon River dolphins with a higher frequency in the number of days also showed a higher frequency during feeding sessions (Fig. 2), with a strong correlation level (R^2 = 0.973; p = 0.00001).

Comparative analyses of the individuals' presence allowed us to identify three groups of Amazon River dolphins at the site (Fig. 3). A group of regular visitors, formed by the oldest individuals Curumim, Dani, Eide, Reginaldo, and Josafá, was present for 61% or more of the days monitored; a group of occasional visitors, formed by individuals Fefa, Alexandre, Chico, and Doidinha, was present for 31-60% of the days monitored; and a group of rare visitors, formed by individuals Marimoni, Bob, Pimentinha, Lawrence, Rafinha, and Cauã, was present for 30% of the days monitored or less.

The network analysis (Fig. 4) indicated strong connectivity of the nodes that connect the most regular Amazon River dolphins (Curumim, Dani, Eide, Reginaldo, Josafá, and Fefa). Moreover, strong connectivity was also noted between Lawrence-Pimentinha and Marimoni-Bob, although they are among the individuals less regular at the site. Alternatively, some dolphins have an agonistic relationship of presence at the site. This is the case with Reginaldo-Rafinha and, to a lesser extent, Alexandre-Bob, Dani-Cauã, and Chico-Lawrence-Pimentinha.

The assessment of centrality indices (Fig. 5) revealed that Alexandre and Eide have the highest values, indicating that they
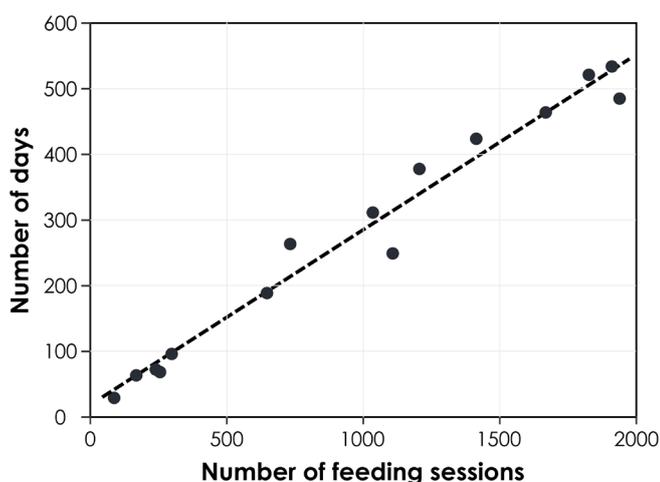

Figure 2. Relationship between number of days and number of feeding sessions attended by recognizable individuals of Amazon River dolphins (*Inia geoffrensis*) at the Flutuante dos Botos, Anavilhanas National Park, Amazonas, Brazil.

have strong connections with nearby nodes, play an important role in the network, and act mainly as a bridge, connecting the set of nodes. At the other extreme, Cauã and Bob are the individuals with the lowest values and, consequently, lowest influence in
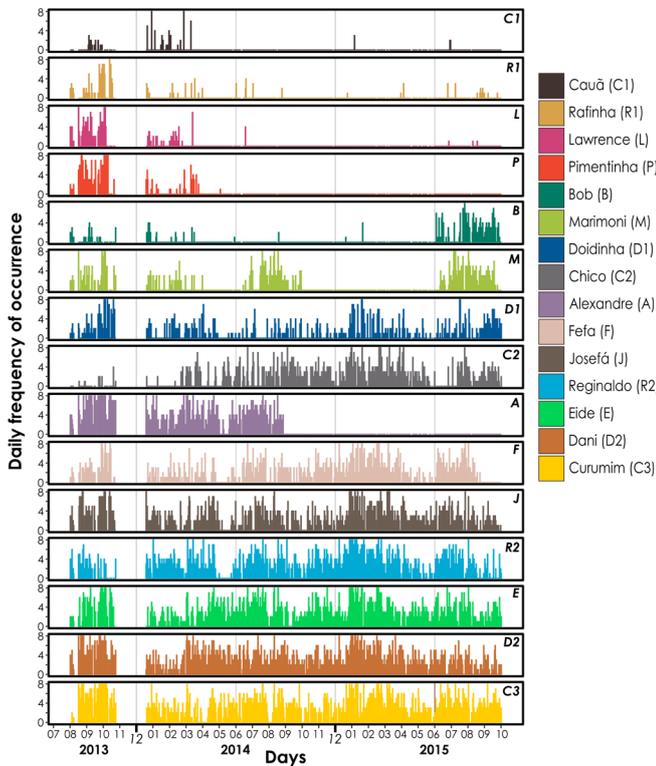

Figure 3. Frequency of Amazon River dolphins (*Inia geoffrensis*) in feeding sessions at the Flutuante dos Botos, Anavilhanas National Park, Amazonas, Brazil.
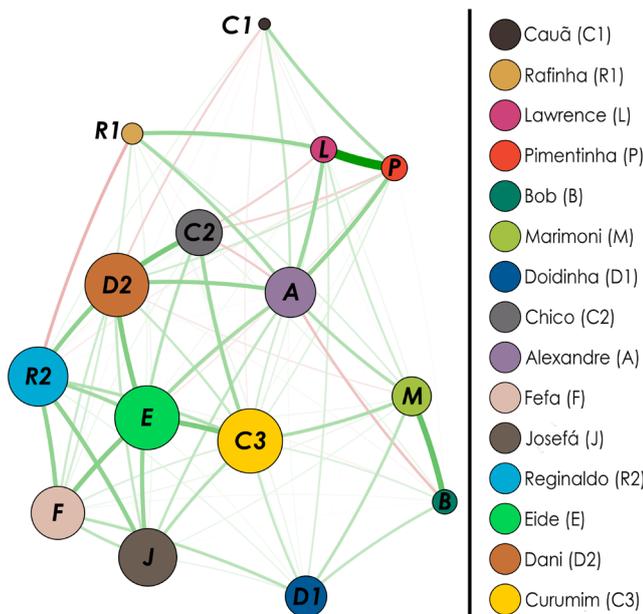

Figure 4. Network analysis of Amazon River dolphins (*Inia geoffrensis*) that attend the feeding sessions at the Flutuante dos Botos, Anavilhanas National Park, Amazonas, Brazil. Green lines represent positive associations, red lines are negative associations, and the thickness of the lines indicate the strength of the association; the bubble size indicates the frequency at the sampling site.
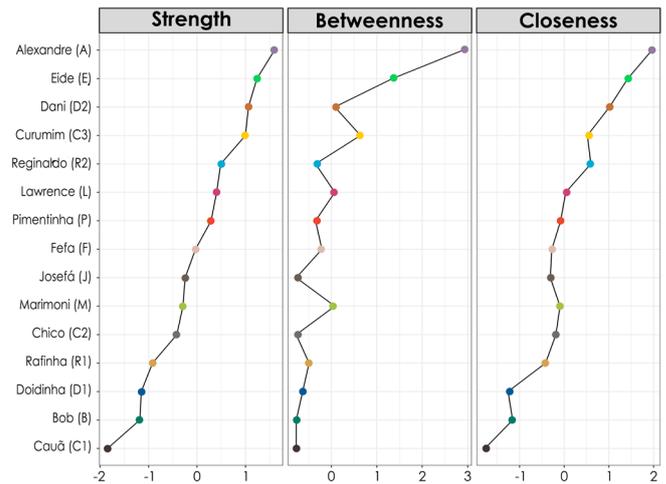

Figure 5. Estimated centrality coefficients for the Amazon River dolphins (*Inia geoffrensis*) that attend the Flutuante dos Botos, Anavilhanas National Park, Amazonas, Brazil, representing the network analysis results.

the social network.

Discussion

Our results demonstrate a strong correlation between the number of days and the number of feeding sessions attended by the known Amazon River dolphins (Fig. 2). That is, although individuals do not go to the enterprise every day (Fig. 3), when they do, they attend as many feeding sessions as possible, in a behavior that may represent the maximization of daily food gain, even in an environment of high competition and agonistic interactions for the resource.

In general, Amazon River dolphins are solitary animals, rarely seen in cohesive groups of more than three individuals, although larger aggregations occur in feeding areas or when they are involved in courtship and mating (Best and da Silva, 1993; Martin and da Silva, 2006). The environment around the Flutuante dos Botos, clearly of anthropic origin, represents a feeding area for Amazon River dolphins, gathering several known individuals who dispute the food that is offered. Curiously, in underwater observations of the Amazon River dolphins' genital opening, Barezani (2005) evidenced that all recognized individuals that visit the enterprise in Novo Airão were males. The evidence of an exclusively male presence among the conditioned Amazon River dolphins led Alves *et al.* (2013*a*) to evaluate their social strategies to respond to aggression, including bites, shoving, and short chasing during provisioning sessions. Further analyses on individuals at this location, using molecular markers, corroborated Barezani's (2005) conclusion that in fact they were all males (Gravena *et al.*, 2019). In this sense, the location of the Flutuante dos Botos, anchored on the banks of the main channel of the Negro River, may be favoring the exclusive approach of males, as they usually prefer the riverbeds and more open places, while females and calves prefer bays and flooded forests, which are more protected habitats (Martin and da Silva, 2004; 2006). Thus, despite the apparently high costs of this typical competition involving only male individuals, it seems that the food easily

obtained at the Flutuante dos Botos is extremely attractive and worth the efforts (Alves *et al*., 2013*a*).

Considering the presence bands identified (regular, occasional, and rare), we can indicate that Amazon River dolphins that search for food at the Flutuante dos Botos show different degrees of change in their natural behavior of foraging, that is, the active search for prey in nature. Furthermore, considering that the maximum amount of fish offered per day for each dolphin at the enterprise is 2 kg (Vidal *et al*., 2017*a*), a value that does not satisfy their daily food requirement - estimated at 2.2 to 4.0% of their body weight (Best and da Silva, 1993) - equivalent to 4.5 kg/day for a 180-kg dolphin; and that the daily average of feeding sessions attended by dolphins was 3.46 (out of a total of eight daily sessions), we can conclude that they continue to capture much of their food in nature, to support their daily food requirement.

In our study, the network analysis indicated a strong connectivity of the nodes that link the most regularly present Amazon River dolphins (Curumim, Dani, Eide, Reginaldo, Josafá, and Fefa) and among some of the less regularly present Amazon River dolphins (Lawrence-Pimentinha, Marimoni-Bob) (Fig. 4). On the other hand, some dolphins presented an agonistic relationship, which seems to indicate that the presence of a certain individual in the feeding session inhibits the presence of another. In this context, the lack of overlapping visits between Reginaldo and Rafinha is evident. Intraspecific segregation behaviors have already been identified in other dolphin species (Orams *et al*., 1996; Browning *et al*., 2014; Giménez *et al*., 2017) and the sex of individuals is one of the main characteristics to explain agonistic behaviors.

Gravena *et al*. (2019) revealed that Rafinha and Ricardo, both from Novo Airão, were brothers according to the pattern of allele sharing. Unfortunately, Ricardo was last observed in December 2012, and was found dead in May 2013. Rafinha is considered a rare visitor to the Flutuante dos Botos, which may be related to a weaker position in the aggregation, probably after losing his brother. Considering that we do not know the kinship level of most Amazon River dolphins visiting the enterprise, we can only guess that social ties might be stronger between individuals with similar frequencies and between individuals with probable kinship. On the other hand, social ties should be weaker in unrelated Amazon River dolphins, leading to a more intense agonistic behavior among them. Obviously, this must be assessed using a combination of molecular analysis and long-term monitoring of individuals.

Alexandre and Eide showed the highest centrality index values, indicating that they have strong connections with the nearby nodes, play an important role in the network, and act mainly as a bridge, connecting the set of nodes. The individuals with less influence on the social network, Cauã and Bob, are also those who show less presence in feeding sessions. These results suggest a certain degree of individual inequality in terms of social role within the Amazon River dolphin community, as reported by Lusseau (2003). Although our analyses do not allow us to accurately identify the phenomena involved in these characteristics of influence and individual leadership in the community, a complex social cohesion is suggested, which can be stimulated by the supply of food, as the availability of prey can affect the interaction dynamics between individuals (Lusseau *et al*., 2006). This composition in the individual interaction dynamics

has implications for the conservation of communities due to a possible imbalance in the social structure. However, Lusseau (2003) noted a behavior of social resilience when removing key individuals in a community of bottlenose dolphins. This resulted in a social restructuring to compensate for individual losses.

At the Flutuante dos Botos, a higher average number of individuals seeking the fish offered in the enterprise occurred between 09:00 h and 15:00 h, coinciding with the times when non-conditioned Amazon River dolphins intensify their search for prey in the wild. Amazon River dolphins search for food both in the daytime and at night, but the foraging activity is more intense between 06:00 h and 09:00 h and between 15:00 h and 16:00 h (Best and da Silva, 1989). This shows that, although conditioned to the offered food, the individuals that attend the enterprise still eat at the species' characteristic times.

The supply of food at the Flutuante dos Botos affects differently the individuals who attend this place, allowing the recognition of three groups of attendees (regular, occasional, and rare). This information can be used in management strategies, such as decreasing the amount of food offered to the most regular individuals at the enterprise to encourage them to increase their levels of active search for prey in nature.

Despite the conditioning of these animals to the food supply, dolphins that visit the Flutuante dos Botos continue to eat at the species' characteristic times and capture a good part of their food in nature, to support their daily food requirement. Hence, the little influence of the Negro River level on the presence of dolphins in that site may indicate a distancing from the natural seasonal movement related to the foraging of *I. geoffrensis.*

The individuals monitored at the Flutuante dos Botos form unlikely associations for specimens of *I. geoffrensis*, which tend to be solitary. The analysis of associations indicated a strong connectivity between the dolphins that visit more often (Fig. 4), and the evaluation of the centrality indices revealed that some individuals play an important role in the network and act as a bridge (Fig. 5), connecting the set of nodes. Probably, the strongest associations are among males with some degree of kinship and among other males who take advantage of the food supply there, even though the level of competition is high.

The fact that Amazon River dolphins are still offered food can potentially affect natural dietary patterns (such as the time dedicated to foraging and the number and diversity of prey), increase the hierarchies and aggressions among dolphins, alter maternal and calf behavior, and the presence of Amazon River dolphins at the enterprise and their conditioning to human presence.

The results provide important information on the level of conditioning and social relationships of Amazon River dolphins attending the provisioning site, which can help to develop strategies aimed at reducing the negative consequences of the food supply to this group of cetaceans, which is considered the main attraction of the Anavilhanas National Park.

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