

# The role of *Lithodoras dorsalis* (Siluriformes: Doradidae) as seed disperser in Eastern Amazon

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Ichthyochory is an important process responsible for the high diversity of plant species in tropical flooded forests. Thus, this study aimed to investigate the role of a catfish species, *Lithodoras dorsalis*, as seed disperser in the flooded forests at the Amazon River mouth, Brazil. Analyzing the stomach contents of 371 individuals of *Lithodoras dorsalis*, the Germination Potential (GP%) and Germination Speed Index (GSI) of seeds that were removed intact were investigated. This allowed us to evaluate the germination performance of two important species of plants in Amazonia, *Euterpe oleracea* (Açaí) and *Montrichardia linifera* (Aninga), after passage through the digestive tract of this catfish species. Given that digestion by *L. dorsalis* reduced the germination viability of *M. linifera* and that seeds were often destroyed during consumption, we suggest that *L. dorsalis* may have a limited role as seed disperser of *M. linifera* and instead mostly act as seed predator. However, for the species *E. oleracea*, *L. dorsalis* was a potential disperser, since the performance of germination of these seeds was improved after digestion. In addition, the number of seeds consumed was directly proportional to the catfish's body size, reinforcing the role of doradids as potential seed dispersers in tropical forests.

**Keywords:** Catfish, *Euterpe oleracea*, Germination Performance, *Montrichardia linifera*, Seed dispersal.

A ictiocoria é um importante processo responsável pela alta diversidade de espécies vegetais nas florestas tropicais alagadas. Dessa forma, este trabalho teve como objetivo investigar o papel de *Lithodoras dorsalis* como dispersor de sementes na Foz Amazônica, Brasil. Analisando o conteúdo estomacal de 371 espécimes de *Lithodoras dorsalis*, o Potencial de Germinação (PG%) e o Índice de Velocidade de Germinação (IGS) de sementes removidas intactas foram investigados. Isto permitiu-nos avaliar o desempenho germinativo de duas importantes espécies de plantas na Amazônia, *Euterpe oleracea* (Açaí) e *Montrichardia linifera* (Aninga), após passagem pelo trato digestivo desta espécie de bagre. Dado que a digestão por *L. dorsalis* reduziu a viabilidade de germinação de *M. linifera* e que as sementes foram frequentemente destruídas durante o consumo, sugerimos que *L. dorsalis* tem um papel limitado como dispersor de sementes de *M. linifera* e, em vez disso, age como predador de sementes. No entanto, para a espécie *E. oleracea*, *L. dorsalis* foi um potencial dispersor, uma vez que o desempenho germinativo das sementes foi melhorado após a digestão. Além disso, o número de sementes consumidas foi diretamente proporcional ao tamanho corporal do bagre, reforçando o papel de doradídeos como potenciais dispersores de sementes em florestas tropicais.

**Palavras-chave:** Bagre, Desempenho de Germinação, Dispersão de sementes, *Euterpe oleracea*, *Montrichardia linifera*.

## Introduction

Seed dispersal is crucial for the maintenance of plant species, establishing patterns and limits that are critical for the population dynamics of angiosperms (Horn *et al.*, 2011; Beckman, Rogers, 2013). The dispersal process has consequences for spatial distribution, gene flow, population genetics, intra and inter specific interactions and evolution (Seidler, Plotkin, 2006; Wall, Beck, 2011; Vargas, Stevenson, 2013). Several plant species have seeds adapted for dispersal by animals (zoochory) (Fenner, 1985; Margalef, 1991; Beckman, Rogers, 2013). Generally, these plants have attractive and nutritious fruits with seeds that can survive the passage

through the digestive tract of dispersers (Fenner, 1985; Margalef, 1991).

The animal efficiency on plant dispersal depends on the amount of dispersed seeds (number of visits to the plant and number of dispersed seeds per visit) and dispersal quality (seed treatment in the animal's stomach and the site of deposition of the seed) (Herrera, Jordano, 1981; Schupp, 1993; Schupp *et al.*, 2010). Seed dispersal is a mutualism and foraging by frugivores directly influences the spatial distribution of plants in the environment (Fenner, 2000; Silvertown, Antonovics, 2001). Thus, plant seed dispersal mechanisms are probably the result of natural selection that increases the chances of spreading their seeds (Fenner, 1985; Ferreira *et al.*, 2010).

Until a few years ago, fishes had little relevance in studies about frugivory and dispersion, being this process classically linked to birds and mammals (Correa *et al.*, 2007; Correa *et al.*, 2015b). However, fishes were probably the first vertebrate dispersers, playing an important role on the dispersal of the first angiosperms, approximately 70 million years ago in South America (Correa *et al.*, 2015a). In tropical ecosystems, ichthyochory contributes to the maintenance of high diversity of plant species in flooded forests and wetlands (Gottsberger, 1978; Goulding, 1980; Horn, 1997; Pilati *et al.*, 1999; Correa *et al.*, 2007; Anderson *et al.*, 2009). Many plant species in these habitats fruit during the flood season and they are adapted to hydrochory or ichthyochory (Goulding, 1980; Correa, Winemiller, 2014; Correa *et al.*, 2015b). Thus, in such environments, understanding the relationship between the fish fauna and riparian forests can serve as a basis to understand the ecological role played by fishes (Godinho, Godinho, 2003).

There are approximately 150 species of frugivore fishes in South America, which during the flood period enter the floodplain and feed on fruits and seeds dispersing at least 566 plant species (Goulding, 1980; Junk *et al.*, 1997; Maia, Chalco, 2002; Correa *et al.*, 2015a). They represent more than 60% of all frugivorous fishes in the world (Horn *et al.*, 2011). These fishes have some adaptations that facilitate their activity as frugivores and seed dispersers, such molar like-teeth, long intestines and enzymes associated with carbohydrates digestion (Goulding, 1980; Drewe *et al.*, 2004; Correa *et al.*, 2007, 2015b). In addition to the adaptations cited above, some studies showed that ichthyochory effectiveness increases with the size of the fish, because of the high consumption of fruits, including the big ones, their extensive movement patterns and the long seed-retention time of large individuals (Galetti *et al.*, 2008; Anderson *et al.*, 2011; Correa *et al.*, 2015a).

The rock-bacu *Lithodoras dorsalis* (Valenciennes, 1840) is one of the largest thorny catfish (Siluriformes, Doradidae), reaching at least 90 cm of standard length and 12 kg in weight (Goulding, 1980). This species is exploited by commercial and local fisheries in the Amazon mouth and occurs in northern South America in the Amazon estuary and neighboring coastal areas of French Guiana (Sabaj, Ferraris, 2003). *Lithodoras dorsalis* eat fruits and seeds and possible play a role as seed disperser (Goulding, 1980; Kubitzki, Ziburski, 1994; Barbosa *et al.*, 2015). There are few studies focusing on seed dispersal by catfishes when compared to other frugivorous fish groups such as characids (*Brycon* spp.) and serrasalmids (*Colossoma macropomum*, *Mylossoma duriventre* and *Piaractus* spp.) (Horn, 1997; Galetti *et al.*, 2008; Anderson *et al.*, 2009; Anderson *et al.*, 2011; Correa *et al.*, 2015a). Few studies showed that seeds consumed by catfishes remain viable and/or had increased germination performance after passage through the digestive tract (Kubitzki, Ziburski, 1994; Stevaux *et al.*, 1994; Pilati *et al.*, 1999). The paucity

of seed dispersal studies focusing on catfishes is due to the difficulty of capturing a large number of specimens to draw solid conclusions.

Due to the importance of doradids in seed dispersal and the high consumption of fruits by rock-bacu, the aim of this study was to answer the following questions: (i) What is the frequency and the proportion of fruits relative to other food items consumed by *L. dorsalis*? As shown for Barbosa *et al.* (2015), we expect *L. dorsalis*' diet to consist mainly of fruits; (ii) What is the relationship between the size of individuals and fruit consumption? We expect that with increasing length there is an increase in the amount of consumed fruits, positively affecting the potential seed dispersal activity; (iii) Are the seeds consumed by rock-bacu destroyed during digestion? If *L. dorsalis* is a disperser, we expect that the seeds are not destroyed during digestion; (iv) What is the effect of digestion on the germination rate of intact seeds consumed by *L. dorsalis*? Considering the possibility that the species is a disperser, we expect an increase in germination performance of intact seeds.

## Material and Methods

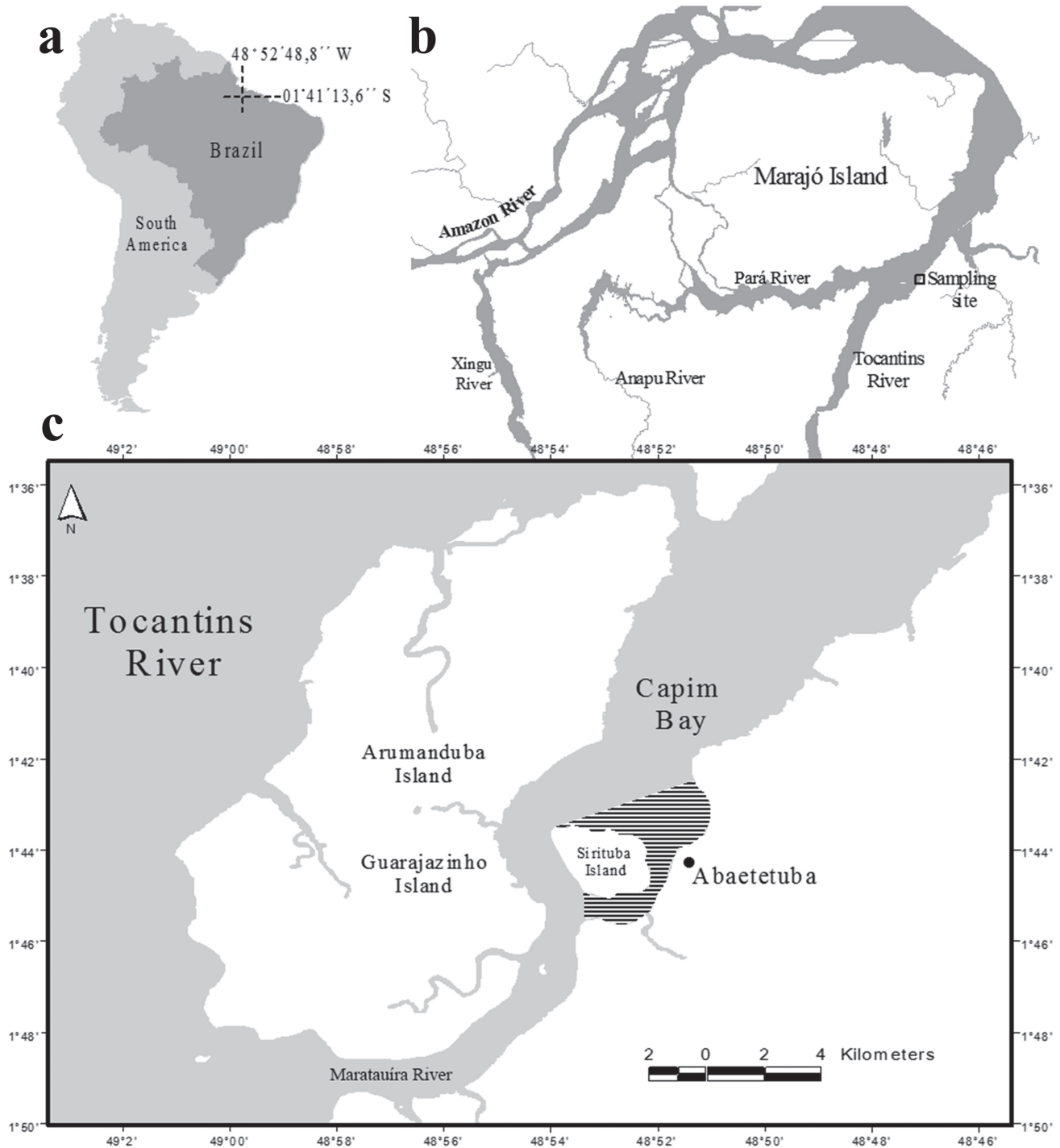
The role of *Lithodoras dorsalis* as a potential seed disperser was investigated using two abundant plant species in the Amazon estuary floodplain, listed below:

***Euterpe oleracea* (Mart.).** *Euterpe oleracea* Mart. is a palm of the Arecaceae family, which can reach up to 25 m tall. Known popularly as “açai”, it is native to the Brazilian Amazon and occurs in the states of Pará, Amazonas, Maranhão and Amapá in areas with flooded soils and floodplains (“várzea” and “igapó”) (Lorenzi *et al.*, 1996). The species has glabrous fruits (without hairs, trichomes or similar structures on the outer surface), globular and smooth surface, reaching up in average 2.14 g, 15.1 mm of diameter and 13.2 mm of length (Paula, 1975; Almeida *et al.*, 2011). The pericarp is purple and its pulp has a high calorific value (247 kcal in 100 g of dry fruit), measuring around 1 mm (Lorenzi *et al.*, 2006). Due to these characteristics, the acai berry is part of the diet of Amazon human populations (Paula, 1975; Brondizio *et al.*, 2003).

***Montrichardia linifera* (Arruda) Schott.** *Montrichardia linifera* (Arruda) Schott, popularly known as “aninga”, is an amphibious herbaceous from Araceae family, reaching 4-6 m in height. This species can occur in several types of habitat, being found onshore or in water-saturated soils (Amarante *et al.*, 2011). This macrophyte is distributed in the tropics (Mayo *et al.*, 1997) and has considerable importance in the formation of riverbanks and white water streams, forming extensive clonal populations by sprouting from underground and submerged stems (Amarante *et al.*, 2011). Seed length ranges from 33-51 mm (mean 39.53 mm) and width ranges from 23-33 mm (mean:

28.81 mm), weighing around 1.5 to 6.0 g (Amarante *et al.*, 2011). *M. linifera* serves as food for fish, reptiles and aquatic mammals, due to the high caloric value of their fruits (355.12 kcal during the rainy season and 346.4 in the dry season) (Amarante *et al.*, 2011). The aninga also has economic value for Amazon populations, since its floating stem can be used to build rafts for timber transport through rivers (Lins, Oliveira, 1994; Amarante *et al.*, 2011).

**Study area.** Fishing was conducted in the municipality of Abaetetuba, in the confluence of the Tocantins River and Pará River, in Pará State, Brazil ( $1^{\circ}41'13,6''\text{S}$ ;  $48^{\circ}52'48,8''\text{W}$ ) (Fig. 1). The region's hydrological regime is characteristic of tropical tidal rivers with a daily, rapid and broad flood (reaching up to 4m) which also causes a reversal in the direction of the current (Welcomme, 1979; Barthem, Schwassmann, 1994; Hida *et al.*, 1999).



**Fig. 1.** Location of the study area near the mouth of the Amazon River in Brazil. **a.** Location of Brazil in South America; **b.** Amazon River mouth with the sampling site; **c.** Study area (specimens were collected within the shaded area).

The region's vegetation is defined as tidal floodplain vegetation with ombrophilous, broadleaved species, merged with palm trees like buriti tree (*Mauritia flexuosa*) and açai berry tree (*E. oleracea*). The fruiting period of *E. oleracea* is from July to November (Guimarães *et al.*, 2004), while *M. flexuosa* fruits from March to August (Sampaio, Carrazza, 2012) and *M. linifera* fructifies all year round.

The local climate is classified as Af following the Köppen-Geiger classification, corresponding to the typical conditions of tropical rainforest ecosystems (Peel *et al.*, 2007). Annual precipitation is approximately 2500 mm, but during the period of our study the pluviosity was 3044 mm (mean =  $253.7 \pm 196.2$ ) (Agência Nacional de Águas (ANA), 2016). The rainy season lasts from January to May (precipitation mean =  $463.38 \pm 87.42$ ), and the dry season from June to December (precipitation mean =  $103.87 \pm 51.33$ ) (Machado, 2008; ANA, 2016). Mean temperature

is 27°C, ranging from 20°C to 35°C over the course of the year. Relative humidity is high, around 85%, varying normally between 81% and 90% (Machado, 2008).

**Data sampling.** *Lithodoras dorsalis* were sampled monthly over a full annual cycle, between July 2010 and June 2011. Specimens were collected in the main river channels and in the streams of Sirituba Island in Abaetetuba, Pará, Brazil (Fig. 1).

Weir fishing nets of approximately 10 m in length, 3 m in height and a between-knots mesh size of 3-6 cm, were used to capture specimens. Nets were set at dusk (17:00-19:00) (Fig. 2a), depending on the tide, and removed at dawn (05:00-07:00). This period was adopted to ensure the capture of individuals moving from the smaller rivers to the main channel during the low tide (Fig. 2b). Specimens were removed from the water using seine nets (5 m x 1 m) and hand- or dip-nets (Figs 2c-d).



**Fig. 2.** Sampling method applied to capture *Lithodoras dorsalis* at the Amazon River mouth, Brazil, from July 2010 to June 2011. **a.** Net set at the bottom during the dusk and with low tide to allow the fish entrance in small rivers; **b.** Net lifted during the next morning (approximately, 12 hours after setting at the bottom), blocking the exit of fishes that came during the night; **c** and **d.** Fish sample using seine nets and hand- or dip-nets.

All captured specimens were analysed in the laboratory at the Federal Institute of Pará (Instituto Federal do Pará - IFPA), where they were sacrificed with a lethal dose of anaesthetic. Then, a ventral-longitudinal incision was made from the urogenital opening to the head for the removal of the stomach, which was weighted (g) and emptied for the collection of its contents. The contents were weighed separately (g) and then sorted in a Petri dish. After the removal of the stomach, intact seeds were washed in running water and stored in paper bags containing a substrate of vermiculite ( $(\text{MgFeAl})_3(\text{AlSi})_4\text{O}_{10}(\text{OH})_2 \cdot 4\text{H}_2\text{O}$  (Oliveira *et al.*, 1996).

Only *E. oleracea* and *M. linifera* reached sufficient number of seeds for analysis of germination. We analyzed 270 intact seeds of *E. oleracea* and 60 intact seeds of *M. linifera*. The lower number of analyzed seeds for *M. linifera* is because many of them were found destroyed. Only intact seeds of *E. oleracea* were found among digestive contents.

Following evisceration, the specimens were fixed in 10% formaldehyde, conserved in 70% alcohol, and then incorporated to the ichthyological collection of the Goeldi Museum (Museu Paraense Emílio Goeldi - MCT/MPEG), under the following catalog numbers: MPEG 19134; MPEG 19202; MPEG 19203; MPEG 19610; MPEG 19611; MPEG 21668-MPEG 21681.

**Germination experiments.** *Euterpe oleracea* seeds were planted in containers containing nutrient-rich soil to a depth of 2 cm, with germinative aperture facing up (Silva *et al.*, 2007; Gama *et al.*, 2010). *M. linifera* seeds were planted in moistened vermiculite to a depth of 1 cm, also with germinative aperture facing up.

We tested the germination of *E. oleracea* under three treatments: Treatment A - seeds from the stomach of specimens of *L. dorsalis*; Treatment B - seeds from the forest with epicarp and mesocarp removed manually and; Treatment C (Control) - seeds from the forest with epicarp and mesocarp intact (Samuels, Levey, 2005). For each treatment, 90 seeds were used. To *M. linifera*, only two germination treatments were tested: Treatment A - seeds from *L. dorsalis*' stomach; Treatment C (Control) - seeds from the forest, since these seeds have no external structures (like epicarp and mesocarp) to prevent germination. For this species, 30 seeds were used in each treatment.

In all treatments, seeds were considered germinated after the appearance of the radicle. The experiment was considered to be over when no further germination occurred for seven consecutive days (Labouriau, 1983; Maia *et al.*, 2007; Ministério da Agricultura, Pecuária e Abastecimento, 2009). In our study, the experiment lasted 42 days for *E. oleracea* and 29 for *M. linifera*.

**Statistical analyses.** The Frequency of Occurrence (FOi%) was calculated for all the fruits and seeds found in *L. dorsalis*' stomachs. The aim was to define which plant species would be used in the germination test. The Frequency of Occurrence (FOi%) was calculated by the following formula (Hyslop, 1980):  $\text{FOi}\% = (N_i / N_{\text{sto}}) * 100$ , where: FOi% = frequency of occurrence of the item *i*;  $N_i$  = number of stomachs where the item *i* was present;  $N_{\text{sto}}$  = total number of stomachs analyzed.

To test the influence of the catfish's size in the intensity of consumption of fruits and seeds, a Simple Linear Regression was used relating the weight of fruits and seeds in the stomach with the body size of the specimens collected.

The Alimentary Index (AI<sub>i</sub>%) (modified from Kawakami, Vazzoler, 1980) of fruit and seeds consumed by individuals with different body sizes was calculated. The goal was to investigate if the importance of fruit and seeds changes as the catfish's body size increases. This index was calculated by  $\text{AI}_i\% = (\text{FO}_i\% * \text{W}\% / \sum \text{FO}_i\% * \text{W}\%) * 100$ , where: AI<sub>i</sub>% represents the food item *i* alimentary index, FO<sub>i</sub>% the item *i* frequency of occurrence and W% the relative weight of item *i*. Empty stomachs were not accounted for the analysis.

The Germination Potential (GP%) for *E. oleracea* and *M. linifera* was calculated to assess the effect of digestion in seeds consumed by *L. dorsalis* (viability or not). The calculation was based on the formula proposed by Labouriau, Valadares (1976):  $\text{GP}\% = (\text{GS} / \text{SA}) * 100$ , where: GS is the number of germinated seeds and SA is the total number of seeds in the sample. The comparison of germination potential between treatments was performed using the chi-square ( $\chi^2$ ) test with 5% significance. Before the test, we checked chi-square assumptions and in cases that they did not fulfill, we did a description of the Germination Potential.

The Germination Speed Index (GSI) was performed to test the effect of the passage through the digestive tract of catfishes on the seeds' germination rate. This index was determined by registering the germination frequencies at intervals of 24 hours and it was calculated by the formula adapted from Maguire (1962):  $\text{GSI} = \sum (G_i\% / N_i)$ , where: GSI is the sum of the ratio between the percentage of germinated seeds at time *i* (G<sub>i</sub>%) within given time *i* (N<sub>i</sub>).

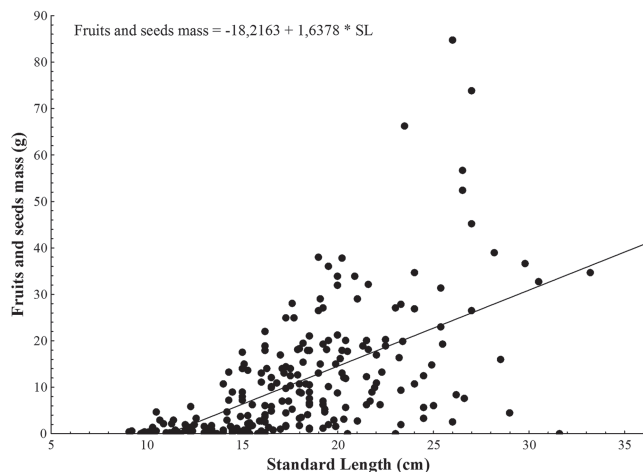
## Results

During the 12 months of the study period, 371 specimens of *L. dorsalis* were captured, of which 268 (74.93%) presented some plant species (fruits or seeds) in their stomachs. Fruits and seeds (intact and masticated) of seven different plant species were recorded and *E. oleracea*, *M. flexuosa* and *M. linifera* were the most common (Tab. 1).

**Tab. 1.** Frequency of Occurrence (FOi%) of fruits and seeds (intact and masticated) recorded in the diet of *Lithodoras dorsalis* at the Amazon River mouth, Brazil, from July 2010 to June 2011. Marked species (\*) indicate that intact seeds were sampled.

| Item  | FOi%   |
|---|--------|
| <i>Euterpe oleracea</i> Mart. *                 | 35.70% |
| <i>Mauritia flexuosa</i> Mart.                  | 30.24% |
| <i>Montrichardia linifera</i> (Arruda) Schott * | 28.88% |
| <i>Anacardium occidentale</i> L.                | 0.27%  |
| <i>Spondias mombin</i> L. *                     | 0.54%  |
| <i>Mangifera indica</i> L.                      | 0.27%  |
| <i>Zea mays</i> L.                              | 0.27%  |

Linear regression analysis showed that *L. dorsalis* have a potential role in seed dispersal. There was a positive relationship between *L. dorsalis*' body size and the total amount of fruits and seeds consumed by the specimens ( $R^2 = 0.35$ ;  $p < 0.001$ ) (Fig. 3).



**Fig. 3.** Relationship between body size (cm) and the general consumption of fruits and seeds (g) by *Lithodoras dorsalis* at the Amazon River mouth, Brazil, from July 2010 to June 2011.

*Euterpe oleracea*, pulp and seeds (mainly intact), seems to be more important in the diet of *L. dorsalis*' for individuals with intermediate size between 13.6 and 24.7 cm (Tab. 2). *M. flexuosa*, mainly pulp remains, was more important for smaller catfishes (<13.6 cm SL). *M. linifera*, pulp and seeds (mainly mastigated), was more consumed by large individuals (> 24.7 cm SL).

**Tab. 2.** Alimentary Index (AI%) of the main plant species consumed by *Lithodoras dorsalis* in each length class at the Amazon River mouth, Brazil, from July 2010 to June 2011.

| Length classes (cm)  | Alimentary Index (AI%)  |                               |                          |
|----------------------|-------------------------|-------------------------------|--------------------------|
|                      | <i>Euterpe oleracea</i> | <i>Montrichardia linifera</i> | <i>Mauritia flexuosa</i> |
| < 13.6 (n= 123)      | 1.387                   | 6.146                         | 92.467                   |
| 13.6 - 19.1 (n= 153) | 90.087                  | 2.838                         | 7.075                    |
| 19.2 - 24.7 (n= 69)  | 91.960                  | 6.127                         | 1.913                    |
| > 24.7 (n= 22)       | 32.970                  | 66.173                        | 0.857                    |

Only *Euterpe oleracea* fulfilled all assumptions of chi-square. For this species, the effect of digestion by *L. dorsalis* was similar between Treatment A (seeds from the stomach of specimens of *L. dorsalis*) and Treatment B (manual removal of epicarp and mesocarp) ( $\chi^2 = 1.966$ ;  $df = 1$ ;  $p = 0.160$ ). However, none of the seeds that had not passed through the digestive tract and which epicarp and mesocarp were still attached to the seed (treatment C) germinated (Tab. 3).

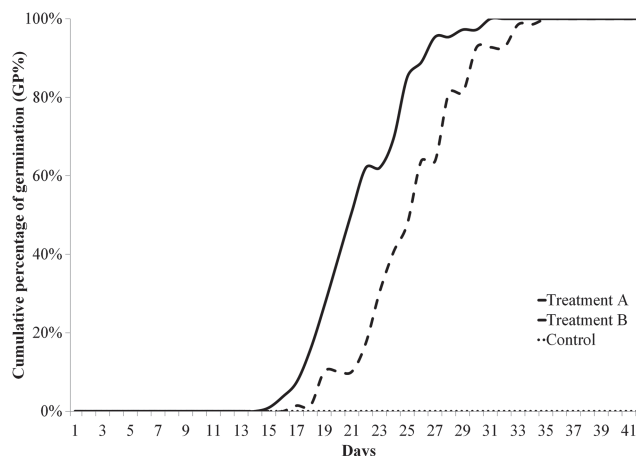
For *Montrichardia linifera*, the Germination Potential of seeds from forest plants was numerically different from that of seeds taken from the stomachs of *L. dorsalis*.

**Tab. 3.** Germination Potential (GP%) of *Euterpe oleracea*'s and *Montrichardia linifera*'s intact seeds sampled at the Amazon River mouth, Brazil, from July 2010 to June 2011. Treatment A - seeds from the stomach of specimens of *Lithodoras dorsalis*; Treatment B - seeds from the forest with epicarp and mesocarp removed manually; Treatment C (Control) - seeds from the forest with epicarp and mesocarp intact.

| Treatments | Germination Potential (GP%) |                               |
|------------|-----------------------------|-------------------------------|
|            | <i>Euterpe oleracea</i>     | <i>Montrichardia linifera</i> |
| A          | 87.5                        | 33.3                          |
| B          | 86.2                        | -                             |
| C          | 0                           | 76.7                          |

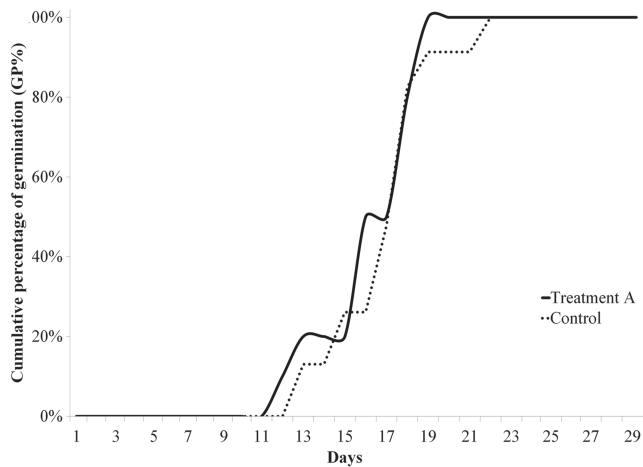
The seeds of *E. oleracea* from *L. dorsalis*' stomachs (Treatment A) germinated on the 15<sup>th</sup> day ( $\pm 0.577$ ), two days before seeds from the forest, with epicarp and mesocarp removed manually (Treatment B), which germinated on the 17<sup>th</sup> day ( $\pm 0.707$ ).

The *Euterpe oleracea*'s Germination Speed Index was higher for seeds from the stomach of *L. dorsalis*, which amounted to 50% of germination on the 21<sup>th</sup> day and 100% of germination on the 30<sup>th</sup> day. However, for Treatment B, only 10% of the seeds germinated until day 21 (Fig. 4).



**Fig. 4.** Germination Speed Index (GSI) of *Euterpe oleracea*'s intact seeds from *Lithodoras dorsalis*' stomachs (Treatment A); from the forest, with epicarp and mesocarp removed manually (Treatment B); and originating from the forest with epicarp and mesocarp intact (Treatment C) at the Amazon River mouth, Brazil, from July 2010 to June 2011.

The patterns of Germination Speed Index for *M. linifera* were similar to those of *E. oleracea*. The seeds removed from the fish's stomachs (Treatment A) germinated one day before seeds from Treatment C. Although only 33.3% of *M. linifera*'s seeds in Treatment A germinated, all of these germinated by 19<sup>th</sup> day while 78% of seeds from Treatment C germinated in 22 days (Fig. 5).



**Fig. 5.** Germination Speed Index (GSI) of *Montrichardia linifera*'s intact seeds from *Lithodoras dorsalis*' stomachs (Treatment A); and from the forest (Treatment C - Control) at the Amazon River mouth, Brazil, from July 2010 to June 2011.

## Discussion

*Lithodoras dorsalis*, as well as other species of the Doradidae family, is essentially frugivorous (Ringuet *et al.*, 1967; Stevaux *et al.*, 1994; Santos *et al.*, 2004; Santos *et al.*, 2006; Barbosa *et al.*, 2015). In the Amazon mouth, *E. oleracea*, *M. linifera* and *M. flexuosa* were the most consumed fruit species and contributed the highest proportional weight to *L. dorsalis* diet. The presence of intact seeds of three plant species in fish digestive tract can be a positive indicator that this animal is a potential disperser (Gottsberger, 1978). In general, consumption by frugivores could increase germination success via scarification (Stevaux *et al.*, 1994; Pilati *et al.*, 1999). In Neotropical regions, some studies have shown that the passage of seeds through the digestive tract of fish increased germination success between 33% and 100% (Pollux, 2011).

Besides increasing germination performance, disperser's body size, regardless of the species, can also influence the seed dispersal effectiveness (Schupp *et al.*, 2010; Wotton, Kelly, 2012; Correa *et al.*, 2015b; Li *et al.*, 2016). Individuals of different sizes can generally differ in their diets due to morphological limitations during periods of development (Abelha *et al.*, 2001; Dala Corte *et al.*, 2016). In our study, there was a dominance of young specimens (8 to 33cm) because the Amazon River mouth is known as a nursery or growth area for *L. dorsalis*, a migratory fish that reproduce in upstream areas of Amazonas River (Goulding, 1980). Despite the presence of only young specimens, the results obtained from the study of *L. dorsalis*' feeding corroborated the cited above: the bigger the individuals, the bigger the possibility of obtaining fruits and seeds (Barbosa *et al.*, 2015).

As the body size increases, specimens can expand their foraging ability, using a wider spectrum of resources (Abelha *et al.*, 2001), including larger fruits and seeds like aninga *M. linifera*. In our study, smaller fishes fed mainly on pieces of

fruits (mainly the pulp) such as buriti *M. flexuosa*. With an increased body size, catfishes started to consume other fruits such as açai *E. oleracea* and aninga *M. linifera*, and also increased the abundance and diversity of items consumed per individual, e.g. crustaceans (see Barbosa *et al.*, 2015 to access the complete diet of *L. dorsalis*). This higher fruits and seeds intake is evidence that *L. dorsalis* can be a disperser species, since one of the factors that influence the efficiency of a disperser is the number of seeds consumed per visit to the plant (Schupp, 1993; Schupp *et al.*, 2010).

Ichthyochory allows new seedlings to develop distant from the source plant, enhancing the distribution of these species throughout the floodplain (Stevaux *et al.*, 1994). A single seed can be consumed by many species of fish, increasing the probability of the plant species of reaching new areas and connect plant populations in fragmented landscapes (Goulding, 1980; Schupp, 1993; Nathan, Muller-Landau, 2000; Levey *et al.*, 2005; Piedade *et al.*, 2006; Seidler, Plotkin 2006; Schupp *et al.*, 2010). The Amazon mouth is full of islands (Goulding *et al.*, 2003; Machado, 2008) and seeds of plant species consumed by *L. dorsalis* can possibly reach several new sites that would not be attained without the aid of this potential disperser.

Even if many fishes consume a single plant species, dispersal mechanisms can cause interdependence as the result of natural selection, which selects traits that increase the survival chances of the seeds (Fenner, 1985). This may be the case of *L. dorsalis* and *E. oleracea* since, even though it feeds on several plant species, the rock-bacu led to an improvement in germination performance of seeds of açai. Due to this possible interdependence relationship, seed dispersal is an important process for dispersers and plants, where both sides are favored: the disperser, for having a high-energy food source, e.g. açai with 247 kcal in 100 g of dry fruit (Lorenzi *et al.*, 2006), and the plant, for having the opportunity to perpetuate its species and colonize new environments (Beckman, Rogers, 2013; Correa *et al.*, 2015b). The dispersion sets the initial spatial distribution of plants, determines the group of interacting species and contributes to the community structure and the maintenance of species diversity (Seidler, Plotkin, 2006; Anderson *et al.*, 2009).

*Lithodoras dorsalis* speeded germination but reduced germination success for *M. linifera*. This means that, despite the increased germination performance, a very low number of progeny plants were generated (Schupp, 1993) and thus, this catfish cannot be considered a disperser of this specific plant species. The opposite occurred for açai *E. oleracea* seeds, where the digestive process accelerated germination, resulting on a high germination percentage. The natural removal of the epicarp and the mesocarp of this plant by *L. dorsalis* may have enable the breaking of seed dormancy and its subsequent germination, generating several offsprings (around 85%) (Nascimento, Silva, 2005; Empresa Brasileira de Pesquisa Agropecuária (Embrapa), 2006; Martins *et al.*, 2009; Gama *et al.*, 2010).

In view of the potential role as a seed disperser for *L. dorsalis*, we concluded that the species has a diet composed mainly of fruits. The species is a potential disperser of açai *E. oleracea*, widening the germination performance of the seeds that passed through the animal's digestive tract, when compared to seeds taken from parent trees. Also, with an increasing in body size, the seeds consumed by the rock-bacu also increase, favoring its possible role as a disperser. Finally, there is the importance of riparian forests to fish populations and vice versa due to its interdependence relationship, where each one plays a key role: as food source and as seed disperser.

### Acknowledgments

We thank the Brazilian Higher Education Training Program (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES) for the scholarship (TAPB), the Brazilian National Research Council (Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq) for the research fellowship provided to LFAM (process no. 301343/2012-8) and the Federal Institute of Pará - Abaetetuba Campus (Instituto Federal do Pará - IFPA-Abetetuba) for the logistic support. We also thank the researches and professors M.Sc. Marta Coutinho (IFPA), Dr. José Birindeli (Museu de Zoologia da Universidade de São Paulo; MZUSP), and Dr. Alba Lins (MPEG) for helping on the identification of the stomach contents of *Lithodoras dorsalis*, Dr. Ana Cristina Mendes de Oliveira for reviewing part of the text and Mr. Ilso, Jaime and Giovani for the field assistance.

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Submitted May 10, 2016

Accepted April 03, 2017 by David Hoeninghaus