Riverine people's knowledge of the Vulnerable Amazonian manatee *Trichechus inunguis* in contrasting protected areas

Luciana Carvalho Crema, Vera Maria Ferreira da Silva and Maria Teresa Fernandez Piedade

Abstract Traditional knowledge gained through daily interactions with the environment can yield insights into processes at temporal or spatial scales that may be overlooked by conventional scientific research. Ninety interviews were conducted with riverine people in the vicinity of Anavilhanas National Park, Tapajós–Arapiuns Extractive Reserve and Tapajós National Forest in the Brazilian Amazon, with the aim to increase knowledge of the feeding habits of the Amazonian manatee *Trichechus inunguis* and evaluate its conservation status in contrasting protected areas. In Anavilhanas respondents identified 31 plant species consumed by the manatee, of which vines had the highest cognitive salience index value (the summed importance of each plant species), even though they are available to manatees only during the high-water season. In the Tapajós region 37 plant species were identified, with submerged species with floating leaves being the main component of the manatee's diet. Although hunting has declined it still occurs in Anavilhanas, which is susceptible to environmental crimes because of its proximity to urban centres. Manatee hunting seems to be infrequent in the Tapajós region, having little impact on the population. Given the broad knowledge within the local community about the Amazonian manatee, involvement of riverine people in manatee conservation activities is fundamental for reducing threats and increasing conservation effectiveness.

Keywords Amazonian manatee, Brazil, ethnobiology, feeding habits, interview, Rio Negro, Rio Tapajós, *Trichechus inunguis*

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Introduction

Traditional knowledge is a cumulative body of expertise, awareness and beliefs, culturally transmitted across generations, concerning the relationships of living beings among themselves and with their environment (Berkes et al., 2000). Originating from daily interactions with the environment (Fabricius & Koch, 2004), it underpins an understanding of ecosystem processes at temporal and spatial scales that would be difficult to record by conventional scientific research (Huntington, 2000). Traditional knowledge can therefore guide efforts towards the protection of habitats, supporting conservation actions at the species level (Huntington, 2000; Rajamani, 2013).

The Amazonian manatee *Trichechus inunguis* has been the most hunted aquatic mammal in Brazil since pre-colonial times (da Silva et al., 2008) and consequently has suffered significant decline. It is categorized as Vulnerable on the national list of threatened species and the IUCN Red List (MMA, 2014; Marmontel et al., 2016), and is listed in Appendix I of CITES (CITES, 2017). Despite a decrease in hunting (Marmontel et al., 2012), the consumption of manatee meat is still customary in the Amazon (ICMBio, 2011).

This aquatic mammal lives its entire life in the water, reaches up to 3 m in length and 420 kg (Amaral et al., 2010), and is herbivorous, feeding on macrophytes, roots and vegetation from floodplains (Best, 1984; Guterres-Pazin et al., 2014) with distinct physical and chemical properties, such as black and clearwater, flooded forests (*igapós*), and whitewater rivers (*várzeas*; Best, 1983; Rosas, 1994). The differences between these environments are paralleled in the variations in richness and diversity of plants the manatee feeds upon (Crema, 2017).

Studying the Amazonian manatee is challenging because of its cryptic behaviour, the turbidity of its favoured habitats (Best, 1984; Rosas, 1994) and its ability to spend long periods beneath banks of aquatic macrophytes (Junk & da Silva, 1997). However, people living in riverine communities have been able to share detailed knowledge about this species because historically they have shared and used the same environment (Calvimontes & Marmontel, 2010).

We sought to elicit traditional knowledge about *T. inunguis* (places of occurrence, reproductive season, diet, hunting, cultural importance) in federal protected areas in black and clearwater *igapós* in the Brazilian Amazon, to answer the following questions: (1) Are the diet of *T. inunguis* and

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the floristic composition of its habitat determined by the characteristics of each specific *igapó*? (2) Can traditional knowledge improve our scientific knowledge of the biology and conservation of the Amazonian manatee?

Study areas

The study was conducted in two regions: (1) Anavilhanas National Park, including residents of the municipality of Novo Airão and 14 communities of three protected areas in Amazonas State (the Environmental Protection Area on the right bank of the Rio Negro Paduari–Solimões Sector, the North Sector of Rio Negro State Park, and the Environmental Protection Area on the left bank of the Rio Negro Aturiá–Apuauzinho Sector); (2) the Tapajós region, where residents from six communities of the Tapajós–Arapiuns Extractive Reserve and three communities of the Tapajós National Forest were interviewed.

Anavilhanas (647,610 ha) is an area of integral protection in the municipality of Novo Airão, 60 km from Manaus (ICMBio, 2017). It was established as an Ecological Station in 1981 and designated a National Park in 2008. The majority of its area comprises seasonally flooded, fluvial islands, and the remainder is unflooded *terra firme* forest. The Tapajós National Forest (600,000 ha) was established in 1974 in the municipalities of Aveiro, Belterra, Rurópolis and Placas, Pará State (IBAMA, 2004). The Tapajós–Arapiuns Extractive Reserve (647,610 ha) was created in 1998 in the municipalities of Santarém and Aveiro, Pará State (ICMBio, 2014). In Tapajós National Forest and Tapajós–Arapiuns Extractive Reserve, separated by the Rio Tapajós, sustainable use of natural resources is permitted; both banks of the Rio Tapajós are largely covered by *terra firme* forest, with ria lakes and thin strips of *igapó* forest.

Methods

We selected interviewees from among the *caboclos*, the riverine people whose ancestry is a mix of Indigenous, Afro-Brazilian and European peoples (Lima-Ayres, 1992). Interviewees were selected according to three criteria: (1) experience in hunting manatees, or any direct contact with the species, (2) at least 19 years living in the area, and (3) the recommendation of community leaders. Interviews were conducted between March 2012 and October 2014, with 29 men and one woman in Anavilhanas, 34 men and four women in Tapajós–Arapiuns Extractive Reserve, and 19 men and three women in Tapajós National Forest (90 participants in total).

The interviews were semi-structured (Supplementary Material 1) and included questions about the occurrence and biology of the Amazonian manatee, focusing in particular on its feeding ecology. Part of the interview consisted of a free-listing activity (Borgatti, 1998; Albuquerque et al., 2014) in which the interviewees listed plants eaten by the manatee (Best, 1981; Colares & Colares, 2002; Franzini et al., 2013; Guterres-Pazin et al., 2014). A board with 39 photographs of plant species of the region was shown, and interviewees were asked to name the plants. Maps were created based on observations by the interviewees of manatees and signs of manatee occurrence (faeces, feeding traces, mortality).

In addition, we identified the locations of *comidias* (feeding areas), which are open areas in the aquatic vegetation resulting from the feeding of manatees (Calvimontes & Marmontel, 2010). Aquatic macrophyte vegetation was surveyed using line transects along the vegetated margins of lakes, as described by Crema (2017). In Anavilhanas 43 sites of occurrence were identified, five of them outside the protected area (Fig. 1a); 30 sites were recorded in the Tapajós region (Fig. 1b). We grouped plant species based on life-form (adapted from Junk, 1986), following the nomenclature of Forzza et al. (2016). Plant species identified from the 73 sites were deposited in the herbarium at the Federal University of Amazonas (HUAM, Manaus, Brazil).

The data from the listing of plant species by interviewees were used to calculate a cognitive salience index (Sutrop, 2001). This index (*S*) represents the summed importance of each plant, combining the frequency of citation of an item (*F*) in interviews with its mean position on all lists (mP): $S = F/(N \times mP)$, where N is the total number of the plant species named during the interviews.

Results

Interviewees were aged 32–83 years in Anavilhanas and 19–82 in the Tapajós region. None of the respondents claimed to be engaged in manatee hunting activity at the time of the interviews, but four indicated they had hunted when they were younger. Twenty per cent of the interviewees reported having seen manatees in the previous 2 years in Anavilhanas, and 56% in the Tapajós region (Table 1). The number of manatees reported killed by hunting in the previous 10 years was much higher in Anavilhanas (30% of the interviewees) than in Tapajós (5%; Table 1); the high-water season was considered to be the best time to see manatees (59% in Anavilhanas; 80% in Tapajós; Table 1).

Most interviewees (72% in Anavilhanas and 32% in Tapajós) stated that manatees move in pairs, often a female with a calf. In Tapajós 40% had seen groups of up to four individuals; in Anavilhanas larger groups had been seen (33%; Table 1). In Anavilhanas and Tapajós 68% and 95% of interviewees, respectively, stated that during the low-water season the species migrates to deeper water areas (*poços*) and to the riverbeds. In Anavilhanas 81% of interviewees indicated they had not observed manatee sexual activity, whereas in Tapajós 60% said that this occurs during the flooding season (Table 1).

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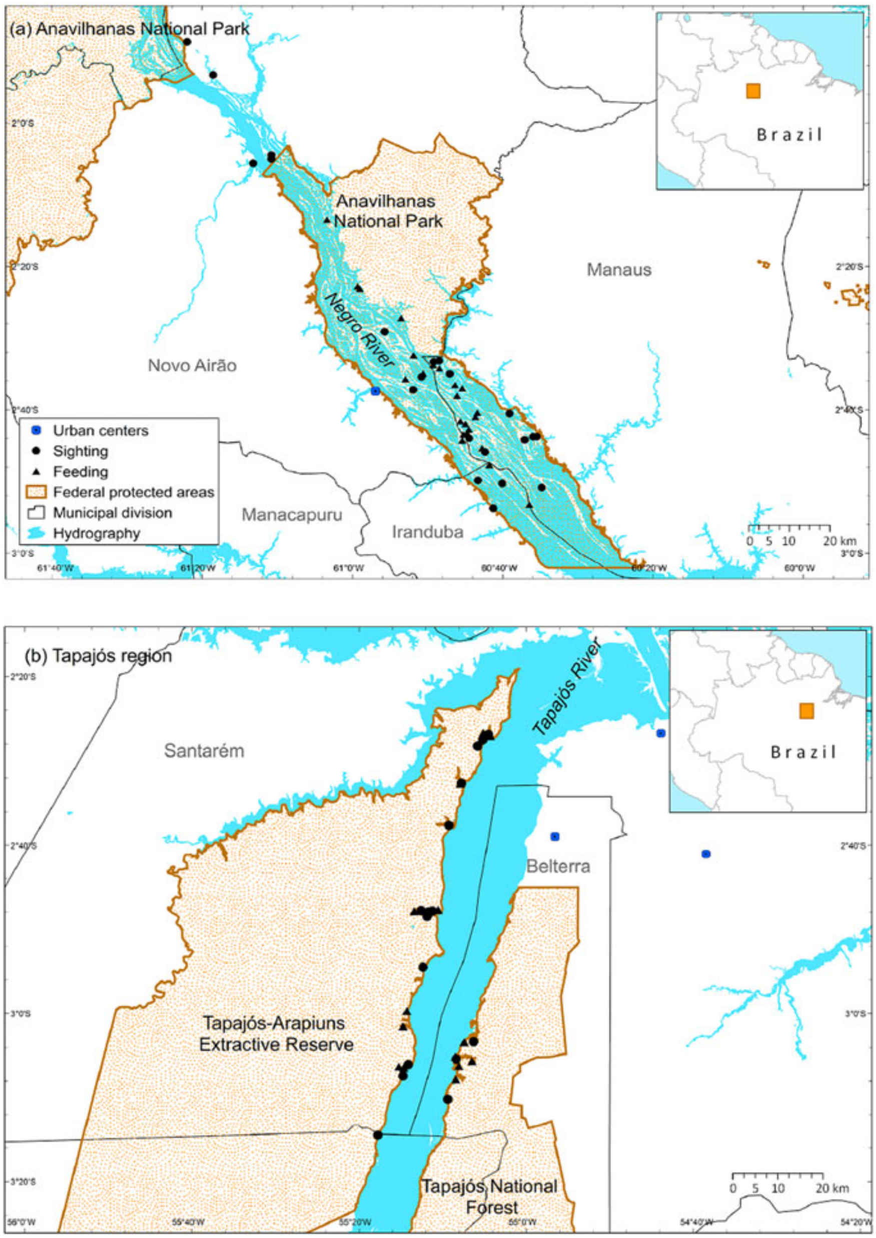

FIG. 1 Locations of sightings and evidence of feeding of the Amazonian manatee *Trichechus inunguis* in (a) Anavilhanas National Park and (b) protected areas in the Tapajós region.

Feeding habits

Interviewees indicated that 60 plant species are consumed by the Amazonian manatee, 31 in Anavilhanas and 37 in Tapajós, with 12 species common to both areas (Table 2). Seventeen of the plant species (mainly vines) cited by interviewees were not in the photographs shown, but the interviewees described the plants in detail and we were able to collect them. In Anavilhanas the plant species with the highest cognitive salience index values were the vines *Ipomoea alba, Mikania micrantha*, *Tassadia berteriana* and *Mesechites trifida*, followed by the shrub *Coccoloba pichuna* (Table 3). In Tapajós the plant species with the highest cognitive salience index values were herbaceous plants with floating leaves such as *Nymphaea* spp., and rooted submerged plants such as *Eleocharis minima* and *Eleocharis fluctuans* (Table 3). In Tapajós 70% of the respondents indicated that manatees also feed on submerged plant roots, mainly of *Nymphaea* spp.

Hunting

Hunting was reported by interviewees to be the main cause of death of the species (62% of interviewees in Anavilhanas and 52% in Tapajós), but in Tapajós 16% of interviewees also reported that manatees died from stranding and entanglement in fishing nets (Table 1). Most hunting records predate 2003 (42 and 75% in Anavilhanas and Tapajós, respectively; Table 1). In Anavilhanas 26% of respondents were aware of hunting events, compared to 2% in Tapajós. The harpoon was the most cited hunting instrument, and high-water

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TABLE 1 Principal responses to questions, provided by riverine people in Anavilhanas National Park (Fig. 1a) and protected areas in the Tapajós region (Tapajós National Forest and Tapajós–Arapiuns Extractive Reserve; Fig. 1b) in interviews (Supplementary material 1) about the Amazonian manatee *Trichechus inunguis*, with the number and percentage of interviewees who gave each response.

	No. of responses (%)		
Question	Anavilhanas National Park (n = 30)	Tapajós protected areas (n = 60)	Total (n = 90)
General			
Have you seen manatees in the wild in the last 2 years?	6 (20)	34 (56)	40 (44)
Biological			
When was the last time you heard of a manatee being hunted?	9 (30)	3 (5)	12 (13)
Is the high-water level season the best time to see the species?	18 (59)	48 (80)	66 (73)
Do manatees move in pairs?	22 (72)	19 (32)	41 (46)
Do manatees move in groups of > 10 individuals?	10 (33)	24 (40)	34 (38)
Do manatees migrate during the low-water season?	20 (68)	57 (95)	77 (86)
Do manatees breed during the flood season?	3 (9)	36 (60)	39 (43)
Feeding			
Do you know about the manatee's feeding habits?	29 (98)	57 (95)	86 (96)
Do manatees mostly consume leaves?	18 (60)	27 (45)	45 (50)
Do manatees consume whole plants?	7 (23)	17 (29)	24 (27)
Do manatees consume submerged plant roots?	0 (0)	42 (70)	42 (47)
Hunting			
Do you know if hunting is the main cause of manatee deaths?	19 (62)	31 (52)	50 (56)
Are stranding & entanglement in fishing nets a cause of manateee deaths?	1 (3)	10 (16)	11 (12)
Is there any hunting preference for male or female manatees?	29 (96)	59 (98)	88 (98)
Do you know about any hunting of manatees before 2003?	13 (42)	45 (75)	58 (64)
Do you have any information about hunting of manatees during the current year?	8 (26)	1 (2)	9 (10)
Is the harpoon a traditional hunting instrument?	30 (100)	58 (97)	88 (98)
Are manatees most hunted during the high-water season?	20 (68)	54 (90)	74 (82)
Do you know if subsistence is the main motivation for manatee hunting?	24 (80)	51 (85)	75 (83)
Have you ever consumed manatee meat?	15 (50)	43 (55)	58 (64)
Is manatee fat used in cooking?	23 (77)	55 (92)	78 (87)
Do you know any medicinal uses of manatee body parts?	0 (0)	19 (32)	19 (21)
Do you know if manatee bones are used as artefacts or tools?	2 (7)	25 (42)	27 (30)

season the hydrological phase with the highest hunting intensity (68 and 90% in Anavilhanas and Tapajós, respectively), although 23% of respondents in Anavilhanas said that hunting occurs throughout the year (Table 1). The most cited motivation for hunting was subsistence, but trade was also mentioned (22% of all interviewees). A majority of all interviewees (65%) admitted to having consumed manatee meat (Table 1), at least in their youth, and some interviewees from Anavilhanas said they knew of small markets where manatee meat was sold. Most claimed that manatee fat can be used in cooking (77 and 91% in Anavilhanas and Tapajós, respectively), and medicinal use was cited frequently in Tapajós (32%; Table 1).

Discussion

The traditional knowledge of the riverine people interviewed corroborated the findings of other researchers (Best, 1984; Arraut et al., 2010) and highlighted the influence of seasonal ecosystem changes on the distribution of Amazonian manatees:

> During high-water periods, they eat in the shallow places, at night.
>
> In the summer (low-water season) we cannot find it, there is no food, nothing. They only surface in deep areas.

Although the interviewees' level of knowledge of manatee reproduction varied, some described the reproductive behaviour of a female, with several males, as described by Pereira (1944). Several interviewees reported the birth of calves, confirming the observations of Best (1982): it occurs as waters rise, when there is greater availability of plants. In agreement with Rosas (1994), interviewees reported that manatees were usually solitary or with calves. However, they also described having seen large groups of manatees, especially in low-water seasons, in refuges. Other types of aggregations have been reported at feeding sites (Best, 1982) and during the reproductive period (Pereira, 1944; Souza, 2015).

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TABLE 2 List of plant species in the diet of the Amazonian manatee, as reported during interviews with riverine people in Anavilhanas National Park (A) and protected areas in the Tapajós region (T), complemented with reports from the literature.

Species	Vernacular name	Growth form	Locality
Apocynaceae			
Mesechites trifida (Jacq.) Müll. Arg.[1,2]	Cipó	Vine	A
Tassadia berteriana (Spreng.) W.D. Stevens[1,2]	Cipó-icica	Vine	A,T
Araceae			
Lemna minuta Kunth	Murerizinho	Free floating	A
Montrichardia arborescens (L.) Schott[3]	Aninga	Emergent	T
Montrichardia linifera (Arruda) Schott	Aninga	Emergent	T
Pistia stratiotes L.[1,2,3,4]	Aguapé flor d'água	Free floating	A,T
Cabombaceae			
Cabomba aquatica Aubl.[1,4]	Mururé-redondinho	Rooted submerged	T
Cabomba furcata Schult. & Schult.f.	Samambaia	Rooted submerged	T
Asteraceae			
Mikania micrantha Kunth	Batatarana	Vine	A
Convolvulaceae			
Ipomoea alba L.	Batatarana	Vine	A
Ipomoea sp.[2,3,4]	Batatarana	Vine	T
Curcubitaceae			
Cayaponia cruegeri (Naudin) Cogn.[1,2]	Jamarurana	Vine	A
Pteropepon deltoideus Cogn.		Vine	A
Cyperaceae			
Eleocharis confervoides (Poir.) Steud.	Amã	Rooted submerged	T
Eleocharis fluctuans (L.T. Eiten) E.H. Roalson	Capim de fundo, capinzinho	Rooted submerged	T
Eleocharis interstincta (Vahl) Roem. & Schult[1,5]	Junco	Amphibious	T
Eleocharis minima Kunth	Capim de fundo, capinzinho	Terrestrial, submerged	A,T
Eleocharis mutata (L.) Roem. & Schult.	Junquinho	Amphibious	T
Eleocharis plicarhachis (Griseb.) Svenson	Junco	Amphibious	T
Scleria gaertneri Raddi	Tiririca	Terrestrial	T
Euphorbiaceae			
Alchornea discolor Poepp.	Supiarana	Trees & shrubs	A
Fabaceae			
Aeschynomene L.[1,2]	Dormideira	Amphibious	A
Clitoria glycinoides DC.	Feijão de praia	Vine	A
Sesbania exasperate Kunth	Paricá	Trees & shrubs	T
Cymbosema roseum Benth.	Feijão graúdo	Vine	A
Vigna lasiocarpa (Mart. ex Benth.) Verdc.	Feijãoarana	Vine	A,T
Hydrocaritaceae			
Apalanthe granatensis (Bonpl.) Planch	Samambaia	Rooted submerged	T
Limnobium laevigatum (Humb. & Bonpl. ex Willd.) Heine	Mureru	Free floating submerged	A
Lentibulariaceae			
Utricularia breviscapa C. Wright ex Griseb.	Samambaia, lodo	Free floating submerged	T
Utricularia foliosa L.	Lodo, samambaia	Free floating submerged	A,T
Mayacaceae			
Mayaca fluviatilis Aubl.	Mureré do campo	Rooted submerged	T
Menyanthaceae			
Nymphoides indica (L.) Kuntze	Apé	Rooted submerged, with floating leaves	T
Nymphaeaceae			
Nymphaea potamophila Wiersema	Apézinho	Rooted submerged, with floating leaves	T
Nymphaea rudgeana G. Mey.	Apé	Rooted submerged, with floating leaves	T
Passifloraceae			
Passiflora misera Kunth	Maracujázinho	Vine	A
Passiflora pohlii Mast.	Maracujázinho	Vine	A

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Table 2 (*Cont.*)

Species	Vernacular name	Growth form	Locality
Plantaginaceae			
Bacopa reflexa (Benth.) Edwall	Samambaia d'água	Rooted submerged	T
Poaceae			
Echinochloa sp. P. Beauv	Canarana	Amphibious	A
Echinochloa polystachya (Kunth) Hitchc.[1,2,3,4]	Canarana	Amphibious	A,T
Hymenachne amplexicaulis (Rudge) Nees[1,2,3,4]	Bucho de pato	Emergent	A,T
Leersia hexandra Sw.[1,2,3]	Capim navalha	Amphibious	T
Louisiella elephantipes (Nees ex Trin.) Zuloaga	Capim	Amphibious	T
Luziola subintegra Swallen	Capim buchudo	Amphibious	T
Oryza glumaepatula Steud	Arroz, capim de arroz	Emergent	A,T
Panicum dichotomiflorum Michx.[2]	Capim	Amphibious	T
Paspalum repens P.J. Bergius[1,2,3,4]	Membeca, premembeca	Amphibious	A,T
Polygonaceae			
Polygonum acuminatum Kunth	Tabacarana, boieira	Amphibious	T
Coccoloba pichuna Huber	Maracarana	Trees & shrubs	A
Pontederiaceae			
Eichhornia azurea (Sw.) Kunth[1,3]	Mureru	Rooted submerged, with floating leaves	T
Eichhornia crassipes (Mart.) Solms[1,2,3,4,5]	Mureru	Free floating	A,T
Pontederia rotundifolia L.f.[1,2]	Mureru	Free floating	T
Pteridaceae			
Ceratopteris pteridoides (Hook.) Hieron.[2]	Mureru véu	Free floating	A
Salvinaceae			
Azolla filiculoides Lam.	Mureruzinho	Free floating	T
Salvinia auriculata Aubl.[1,3,4]	Lentilha d'água	Free floating	A,T
Salvinia sp.	Mureru	Free floating	A
Solanaceae			
Schwenckia grandiflora Benth.	Cipó	Trees & shrubs	A
Solanum subinerme Jacq.	Jurubeba	Trees & shrubs	A
Vitaceae			
Cissus erosa Rich.	Cipó	Vine	A,T
Urticaceae			
Cecropia sp. Loefl[5]	Embaúba	Emergent	T
Unknown species	Lodo/lama		A,T

[1]Franzini et al. (2013).
[2]Guterres-Pazin et al. (2014).
[3]Best (1981).
[4]Colares & Colares (2002).
[5]Best & Teixeira (1982).

Feeding habits

From the interviews and the collection of plants both in Anavilhanas and the Tapajós region (Crema, 2017), 60 food species were recorded, of which 40 (67%) had not previously been known to be food plants (Best, 1981; Colares & Colares, 2002; Zaniolo, 2006; Franzini et al., 2013; Guterres-Pazin et al., 2014), indicating there is a significant amount of traditional knowledge yet to be gathered on the feeding ecology of wild Amazonian manatees. In contrast with findings that plants of the families Cyperaceae and Poaceae are the most important food plants for the Amazonian manatee (Best, 1981; Colares & Colares, 2002; Guterres-Pazin et al., 2014), in Anavilhanas the cognitive salience index indicated that a number of other species are important, including vines and shrubs. These become accessible to manatees during the high-water season, when shrubs are flooded and the lower leaves of vines become accessible (Crema, 2017).

In Anavilhanas there is no evidence of plant consumption by manatees during the low-water season. However, a study in central Amazonian *igapós* identified a variety of species in the faeces and stomach contents of manatees in this season (Guterres-Pazin et al., 2014). Anavilhanas does not have significant availability of food for aquatic herbivores during most of the year (Crema, 2017). In the low-water season some plant species predominate only in permanently wet places, inaccessible to the manatee. During high waters, when food is more available, manatees accumulate fat to survive the dry season (Best, 1983). Thus,

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TABLE 3 Citation frequency, mean citation position on all lists, and cognitive salience index value of each plant species reported by interviewees from the vicinity of Anavilhanas National Park, and the Tapajós National Forest and Tapajós–Arapiuns Extractive Reserve as being a component of the diet of the Amazonian manatee, ordered by descending cognitive salience index. Only those species from Table 2 that were cited in more than one interview are listed here.

Plants	Citation frequency	Mean citation position	Cognitive salience index
Anavilhanas National Park			
I. alba	12	1.75	0.34
M. micrantha			
T. berteriana	12	2.58	0.23
M. trifida			
C. pichuna	9	2.33	0.19
Cyperaceae spp.	8	2.25	0.17
O. glumaepatula	13	4.00	0.16
V. lasiocarpa	7	3.57	0.10
S. auriculata	5	2.60	0.10
E. polystachya	5	4.00	0.06
U. foliosa	4	4.50	0.04
P. repens	3	5.00	0.03
S. subinerme	2	5.00	0.03
Periphyton	2	5.00	0.02
Tapajós protected areas			
N. potamophila	43	1.88	0.38
N. rudgeana			
E. minima	31	2.01	0.24
E. fluctuans	11	1.81	0.10
O. glumaepatula	17	3.05	0.09
M. linifera	15	3.06	0.08
M. arborescens			
E. polystachya	18	3.83	0.08
U. foliosa	18	3.83	0.08
H. amplexicaulis	14	3.14	0.07
Ipomea sp.	10	9.90	0.04
E. azurea	10	4.00	0.04
E. crassipes			
E. confervoides	7	3.00	0.04
Cyperaceae ssp.	5	3.40	0.02
L. elephantipes	5	3.80	0.02
V. lasiocarpa	5	4.20	0.02
S. gaertneri	3	3.33	0.01
Cecropia spp.	2	3.50	0.01

the manatee exhibits selective or opportunistic feeding behaviour, depending on the availability of plants, which is related to the flood pulse (Colares & Colares, 2002; Guterres-Pazin et al., 2014). According to the traditional knowledge of riverine people, in the Tapajós region the manatee selects rooted plants with floating leaves and, although it feeds preferentially on leaves, it may also dig up the lake bed around *Nymphaea* spp. to consume their corms and roots. In Tapajós many lakes retain sufficient water during the low-water season to support the persistence of both submerged macrophytes and manatees (Crema, 2017).

Hunting

As already reported (Pereira, 1944; Marmontel et al., 2012), manatee hunters have specific knowledge about the species. At both study sites *comidias* are an indicator for locating manatees during the high-water season. Hunting of the Amazonian manatee is related to its variation in habitat use (Calvimontes & Marmontel, 2010; Souza, 2015). Some authors (Best, 1982; Calvimontes & Marmontel, 2010), and the interviewees in our study, reported that during low water hunting is restricted to pools where several manatees congregate and members of the community fish, increasing the potential for encounters between them (Mayaka et al., 2013).

As cited for other localities (Marmontel et al., 2012), interviewees confirmed that harpoon hunting is the primary cause of death of Amazonian manatees, followed by incidental catches in fishing nets (Aguilar, 2007; Zaniolo, 2006), particularly of vulnerable young individuals. Such impacts can substantially reduce populations (Rosas, 1994).

In 1938 peak demand for *T. inunguis* hide led to the hunting of c. 16,000 manatees (Domning, 1982; Antunes et al., 2016). Since the creation of the Fauna Protection Act in 1967 there has been no record of this type of activity. Therefore, the motivation for hunting is small-scale commercialization and an appreciation, or tradition, of manatee meat consumption (Calvimontes & Marmontel, 2010; da Silva et al., 2017).

The use of protected areas by Amazonian manatees

The locations shown in Fig. 1 indicate places of rest, refuge or foraging for the Amazonian manatee, information fundamental for defining sites for release and management of the species. Releases of rehabilitated manatees to recolonize Amazonian water bodies were carried out in 2007 in Tapajós–Arapiuns Extractive Reserve, during 2008–2009 in Rio Cuieiras (Rio Negro Basin), in 2012 in Amanã Reserve, and in 2016–2018 in Piagaçu–Purus Reserve (Diogo Souza, pers. comm.). Knowledge of places with suitable foraging resources can provide alternative locations for the release of manatees.

Although the studied areas are protected by law, in Anavilhanas 30% of the respondents reported at least one episode of manatee hunting during the 2 years preceding our research. Anavilhanas has a small human population, historically characterized by inter-ethnic conflicts, loss of cultural identity, and economic hardship that made exploitation of natural resources essential for survival (Leonardi,

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1999). The Park receives a large number of visitors, and its proximity to urban centres increases its vulnerability to anthropogenic disturbances (Tardio & da Silveira, 2015) and illegal activities (ICMBio, 2017).

The number of hunting events recorded in recent years is fewer in Tapajós, which may be attributed to fear of reporting illegal events, or a reduction in hunting practices, strengthened by traditional knowledge. The Tapajós region comprises sustainable use areas, where rational and sustainable exploitation is permitted. The creation of the Tapajós–Arapiuns Extractive Reserve was driven by a popular movement (IBAMA, 2004; ICMBio, 2014) and the inhabitants are considered to be traditional, having a history of multi-generational residence and sustainable use of natural resources (Berkes et al., 2000).

In Anavilhanas traditional knowledge highlighted the importance of vines as a component of manatee diet, despite being available only during the high-water season. As in this region there is little or no food available for aquatic herbivores during flooding (Crema, 2017), manatees may move to areas with higher food supply, such as the Rio Solimões floodplain, c. 130 km away, which is rich in aquatic plants (Piedade et al., 2010). The Amazonian manatee performs annual migrations of tens of kilometres between ecosystems (Arraut et al., 2010). Thus, conservation initiatives for *T. inunguis* in Anavilhanas need to be broadened to a larger area to ensure its protection.

Elsewhere, environmental conservation has been found to be related to education level (Fiallo & Jacobson, 1995). Through involving fishers in ecotourism and research, the Mamirauá Institute of Sustainable Development and Projeto Boto have promoted positive attitudes towards the conservation of the Amazon river dolphin *Inia geoffrensis* (Mintzer et al., 2015). We have discussed the nature of effective manatee conservation with protected area authorities, emphasizing that a suitable strategy must not only limit hunting but also increase the involvement of riverine people in management activities. Studies are also required to determine the range of the manatee, so that joint actions between all protected area stakeholders can be planned. Combining the management of these areas with the active participation of the local population is one of the greatest challenges and opportunities for conservation (Fragoso et al., 2000; Shepard et al., 2010).

The diet of the Amazonian manatee differs between *igapós* because of differences in the floristic characteristics of each. Riverine people in the vicinity of Anavilhanas and Tapajós protected areas have detailed knowledge of the biology of the Amazonian manatee and of plant species that had not been previously reported to be part of the manatee's diet. Improving social participation, including this important knowledge, is fundamental for the conservation management of the Amazonian manatee and its habitat.

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Conflicts of interest None.

Ethical standards Research was approved by the Human Research Ethics Committee of the National Institute of Amazonian Research (#501,473/2013) and followed national laws.

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