

## **DEFINITION OF PRIORITY AREAS IN ESTUARINE ISLANDS IN BELÉM (PARÁ), AMAZON ESTUARY, USING BIOLOGICAL CRITERIA**

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### **Introduction**

One of the main strategies for biodiversity conservation is the definition of priority areas based on the geographical distribution of the species and on the occurrence of key ecological process (MARGULES & PRESSEY, 2000). The need of biodiversity conservation is worldwide recognized and, as a consequence, around 3.650 terrestrial and 850 marine conservation units were established all over the world (PRASTES et al., 2000). In Brazil, there are 1.123 conservation units and 63% are in the Brazilian Atlantic Forest and the Amazon biomes (MMA, 2007).

In Brazil, the city of Belém (Pará) and its surrounding islands (Amazon estuary) is considered of main concern due to its high biological productivity. This region is an important migratory route and habitat of rare and endemic and species, and also of socio-economic, cultural and archaeological relevance. The aim of this study was to characterize the ichthyofauna of the islands surrounding Belém, as well as to identify, through biological criteria, priority areas for conservation and management of fishery resources.

### **Methods**

This study was carried out on three islands located around the city of Belém - Onças, Combu and Mosqueiro islands - and its surroundings bays, Marajo and Guajara Bays (Figure 1).

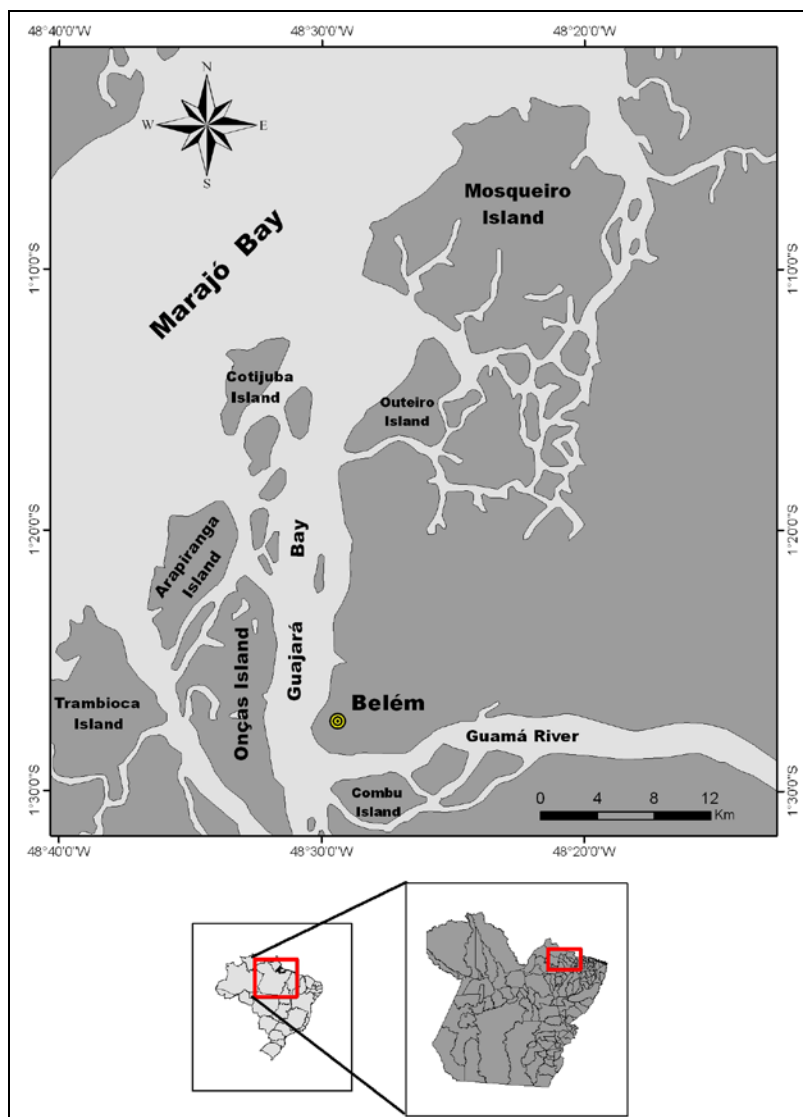


Figure 1 The study area: Combu, Onças and Mosqueiro islands; Marajo and Guajara bay

The ichthyofauna was collected between September 2008 and June 2009, in channel and creek environments. Sample stations were assessed four times during the year: (1) the period of climatic transition, dry to rainy, occurring between December and February, (2) the rainy season with a maximum river discharge, between March and May, (3) the second intermediate climatic transition, between June and August, and (4) the dry season (low rainfall), period of minimum river discharge, between September and November. Data was collected in the main channel and creeks. In the channel, it was used gill nets of stretched mesh size of 25mm, 30mm, 40mm e 50mm in Combu and Onças Islands and Guajara Bay and gill nets of 25mm, 30mm, 40mm, 50mm, 60mm and 70mm in Mosqueiro Island. Trawl net was also used when the subtract was appropriate. In the creeks, a block net (20 mm stretched mesh size) was set (except in the Island of Onças) at the mouth of the creek, closing it completely.

The priority areas were defined according to the following criteria: abundance, diversity indexes, and percentage of individuals using the area for breeding, as nursery and for feeding.

Catch per unit of effort (CPUE) was used to assess the relative abundance by area. This index was obtained by estimating the biomass abundance (weight of individuals in kilograms, w) based on the following:

$$\text{CPUE} = w / (\text{net length in m} * \text{soak time in hours})$$

Diversity indices were used to compare species composition with geography changes. Shannon's diversity index ( $H$ ), Pielou's evenness index ( $J$ ), total species present (richness  $S$ ) and Margalef index ( $D$ ) was used to explore differences. Calculations were done using PRIMER version 6.

Fishes caught were sized and weighed at the laboratory and had their gonads and stomach removed. Maturation state was determined by size and colour of the gonads, based on Vazzoler (1996): stage A, immature; stage B, maturing; stage C, mature; stage D, spent. Stomachs were examined and characterized as: 1, empty; 2, partially empty; 3, partially full; 4, full (Viana *et al.*, 2010). Individuals with mature and spent gonads (stages C and D, respectively) were considered as using the area as a breeding ground. Individuals with immature gonads (stage A) and individuals with food in their stomachs (fullness indices 2, 3 and 4) indicated that the area was used as a nursery and as a feeding ground, respectively.

## Results and discussion

It was collected 14,870 individuals classified into 10 orders, 29 families and 116 species (Table 1). The species with the largest number of individuals were *Plagioscion squamosissimus* (21.14%), *Stellifer naso* (15.92%), *Aspredo aspredo* (6.32%) e *Plagioscion surinamensis* (5.92%). A total of 15 species occurred in all sampled areas (Table 2).

Table 1: Order, family and species captured in the Island of Onças, Mosqueiro and Combu, Guajara and Marajo Bays.

Order	Family	Species
ANGUILIFORMES	Muraenidae	Not identified
BELONIFORMES	Belonidae	Strongylura timucu (Walbaum, 1792)
CHARACIFORMES	Acestrorhynchidae	Acestrorhynchus sp.
	Anastomidae	Leporinus fasciatus (Bloch, 1794)
		Leporinus friderici (Bloch, 1794)
	Characidae	Astyanax fasciatus (Cuvier, 1819)
		Astyanax sp
		Pristobrycon calmoni (Steindachner, 1908)
		Serrasalmus calmoni (Steindachner, 1908)
		Not identified
	Ctenoluciidae	Boulengerella cuvieri (Spix & Agassiz, 1829)
	Curimatidae	Curimata inornata (Vari, 1989)
	Erythrinidae	Hoplias malabaricus (Bloch, 1794)
	Hemiodontidae	Hemiodus unimaculatus (Bloch, 1794)
CLUPEIFORMES	Engraulidae	Anchoa spinifer (Valenciennes, 1848)

		<i>Anchovia surinamensis</i> (Bleeker, 1865)
		<i>Lycengraulis batesii</i> (Günther, 1868)
		Not identified
		Not identified
	<b>Pristigasteridae</b>	<i>Pellona flavipinnis</i> (Valenciennes, 1837)
<b>CYPRINODONTIFORMES</b>	<b>Anablepidae</b>	<i>Anableps anableps</i> (Linnaeus, 1758)
<b>GYMNOTIFORMES</b>	<b>Apteronotidae</b>	<i>Apteronotus albifrons</i> (Linnaeus, 1766)
		<i>Orthosternarchus tamandua</i> (Boulenger, 1898)
		<i>Sternarchella schotti</i> (Steindachner, 1868)
		<i>Sternarchella sima</i> Starks, 1913
		<i>Sternarchella terminalis</i> (Eigenmann & Allen, 1942)
		<i>Sternarchogiton</i> sp
		<i>Sternarchorhamphus muelleri</i> (Steindachner, 1881)
		<i>Sternarchorhynchus</i> cf. <i>roseni</i>
	<b>Hypopomidae</b>	<i>Steatogenys elegans</i> (Steindachner, 1880)
	<b>Rhamphichthyidae</b>	<i>Rhamphichthys rostratus</i> (Linnaeus, 1766)
	<b>Sternopygidae</b>	<i>Rhabdolichops caviceps</i> (Fernández-Yépez, 1968)
		<i>Rhabdolichops eastwardi</i> Lundberg & Mago-Leccia, 1986
		<i>Sternopygus macrurus</i> (Bloch & Schneider, 1801)
<b>MUGILIFORMES</b>	<b>Mugilidae</b>	<i>Mugil</i> sp
<b>PERCIFORMES</b>	<b>Carangidae</b>	<i>Oligoplites palometa</i> (Cuvier, 1832)
	<b>Cichlidae</b>	<i>Cichla</i> sp
		<i>Crenicichla cincta</i> Regan, 1905
		<i>Crenicichla johanna</i> Heckel, 1840
		<i>Crenicichla lugubris</i> Heckel, 1840
		<i>Crenicichla ocellata</i> (Heckel, 1840)
		<i>Crenicichla</i> sp
		<i>Geophagus proximus</i> (Castelnau, 1855)
		<i>Geophagus surinamensis</i> (Bloch, 1791)
	<b>Gobiidae</b>	<i>Gobioides broussonnetii</i> Lacepède, 1800
	<b>Sciaenidae</b>	<i>Micropogonias furnieri</i> (Desmarest, 1823)
		<i>Pachypops fourcroyi</i> (Lacepède, 1802)
		<i>Plagioscion auratus</i> (Castelnau, 1855)
		<i>Plagioscion squamosissimus</i> (Heckel, 1840)
		<i>Plagioscion surinamensis</i> (Bleeker, 1873)
		<i>Stellifer microps</i> (Bloch, 1790)
		<i>Stellifer naso</i> (Jordan, 1889)
		<i>Stellifer rastrifer</i> (Jordan, 1889)
		Not identified
		Not identified
		Not identified
		Not identified
<b>PLEURONECTIFORMES</b>	<b>Achiridae</b>	<i>Achirus achirus</i> (Linnaeus, 1758)
		<i>Apionichthys dumerili</i> (Kaup, 1858)
		<i>Synacium papillosum</i> (Linnaeus, 1758)

<b>RAJIFORMES</b>	<b>Potamotrygonidae</b>	Plesiotrygon iwamae Rosa, Castello & Thorson, 1987 Potamotrygon motoro (Müller & Henle, 1841) Potamotrygon sp5
<b>SILURIFORMES</b>	<b>Ariidae</b>	Arius phrygiatus (Valenciennes, 1840) Aspistor sp Cathorops spixii (Agassiz, 1829) Sciades couma (Valenciennes, 1840) Sciades herzbergii (Bloch, 1794)
	<b>Aspredinidae</b>	Aspredinichthys filamentosus (Valenciennes, 1840) Aspredo aspredo (Linnaeus, 1758)
	<b>Auchenipteridae</b>	Ageneiosus aff. ucayalensis Castelnau, 1855 Auchenipterus nuchalis (Spix & Agassiz, 1829) Pseudoauchenipterus nodosus (Bloch, 1794) Trachelyopterus galeatus (Linnaeus, 1766)
	<b>Callichthyidae</b>	Megalechis thoracata (Valenciennes, 1840)
	<b>Cetopcidae</b>	Cetopsis coecutiens (Lichtenstein, 1819)
	<b>Doradidae</b>	Lithodoras dorsalis (Valenciennes 1840)
	<b>Heptapteridae</b>	Rhamdia quelen (Quoy & Gaimard, 1824) Rhamdia sp
	<b>Loricariidae</b>	Acanthicus hystrix Agassiz, 1829 Ancistrus sp1 Ancistrus sp2 Ancistrus sp3 Hypostomus plecostomus (Linnaeus, 1758) Hypostomus punctatus (Valenciennes, 1840) Limatulichthys griseus (Eigenmann, 1909) Loricaria cf. cataphracta(Linnaeus, 1758) Peckoltia sp Peckoltia vermiculata (Steindachner, 1908) Pseudacanthicus histrix (Valenciennes, 1840)
	<b>Pimelodidae</b>	Brachyplatystoma filamentosum (Lichtenstein, 1819) Brachyplatystoma platynemum (Boulenger, 1898) Brachyplatystoma rousseauxi (Castelnau, 1855) Brachyplatystoma vaillanti (Valenciennes, 1840) Hypophthalmus marginatus (Valenciennes, 1840) Pimelodella gr. altipinnis (Steindachner, 1864) Pimelodella sp1 Pimelodus blochii (Valenciennes, 1840) Platystomatichthys sp Platystomatichthys sturio (Kner, 1858)
<b>TETRAODONTIFORMES</b>	<b>Tetraodontidae</b>	Colomesus asellus (Müller & Troschel, 1849)

Table 2: Common species for all sampled areas.

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**Species**

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*Astyanax fasciatus*

<i>Curimata inornata</i>
<i>Anchoa spinifer</i>
<i>Lycengraulis batesii</i>
<i>Anableps anableps</i>
<i>Pachypops fourcroy</i>
<i>Plagioscion auratus</i>
<i>Plagioscion squamosissimus</i>
<i>Ageneiosus aff. ucayalensis</i>
<i>Parauchenipterus galeatus</i>
<i>Pseudauchenipterus nodosus</i>
<i>Lithodoras dorsalis</i>
<i>Hypophthalmus marginatus</i>
<i>Brachyplatystoma vaillanti</i>
<i>Pimelodus gr. altipinnis</i>

The richness is higher in Marajo Bay (66 species) and lower in Guajara Bay (42 species). Guajará Bay supports a low biodiversity compared with other tropical estuaries (Araújo *et al.*, 1998; Baldo & Drake, 2002; Spach *et al.*, 2003; Barletta *et al.*, 2005). For all sampled areas, Margalef (D) index was found to be higher than five, indicating a high biological diversity (Margalef, 1958). The Shannon index was similar between areas and the equitability index of Pielou (J) varied from 0.5 to a 0.7 (Table 3). The high values of this index may be explained by the discrepancy in the number of individuals of a particular species, *i.e.*, few species with higher catches are reported, characteristic of estuaries (Favaro, 2004).

Table 3: Ecological indices used as biological criteria for studied areas in the Amazon estuary. Shannon's diversity index ( $H'$ ), Pielou's evenness index ( $J$ ), total species (richness  $S$ ) and Margalef index ( $D$ )

Area	Richness (S)	(Shannon $H'$ )	Margalef (D)	Pielou (J)
<b>Guajara Bay</b>	52	2.56	6.37	0.66
<b>Combu Island</b>	62	2.84	7.53	0.68
<b>Onças Island</b>	53	2.9	7.77	0.72
<b>Marajo Bay</b>	66	2.37	7.53	0.56

The main biological criteria that best discriminated the ecological importance of the islands were: relative abundance, % of the area used for nursery, breeding and feeding.

Considering the relative abundance using gill nets as a gear, mean CPUE was higher in Marajo and Guajara Bays, 614.27kg/m.h and 462kg/m.h respectively (Table 4) and *Brachyplatystoma rousseauxi*, *Pellona flavipinnis*, *Plagioscion squamosissimus* and *Litodora dorsalis* were the species which mainly contributed to this high abundance. Considering the CPUE obtained by trawl net, the higher mean relative abundance was registered in Guajara Bay (6 kg/m.h). In relation to the block net used in creeks, it was observed, for the Island of Onças, higher mean CPUE (26.75 kg/m.h) and *L. dorsalis* was the species that mainly contributed to this high biomass.

Table 4: CPUE by sampled area and gear

	<b>Area</b>			
	Guajara Bay	Marajo Bay	Onças Island	Combu Island
<b>Fishing gear</b>				
<b>Gill net</b>	461.59	614.27	29.74	100.68
<b>Trawl net</b>	5.97	2.77	-	0.79
<b>Block net</b>	1.14	2.6	26.75	4.17

Most individuals caught were found as juveniles (maturation stage A), mainly in Marajo Bay and Combu Island where more than 90% of the specimens were immature (Figure 2). However, Guajara Bay and Onças Island registered the highest percentage of breeding individual (maturity stage C and D) (Figure 3). A total of 55.5% of the individuals captured in the studied area fed but the higher percentage occurred in Guajara Bay and Island of Onças, as the reported for breeding areas. The high percentage of full stomachs in Guajara Bay (Figure 4) was reported by Viana et al (2010) during the dry season. The availability of food sources is greatest during this period in the Amazon Estuary (Barthem, 1985). This high food availability is probably related to the reduction in discharge from the Amazon River from July to December, as the suspended organic matter (previously deposited in the outermost portion of the estuary) is deposited in the innermost portion with the reduction of the hydrodynamics during the dry season. This influx of organic material provides a food supply for detritivorous species and organisms that feed on benthic material, as observed in Guajara Bay (Raiol *et al.*, 2006).

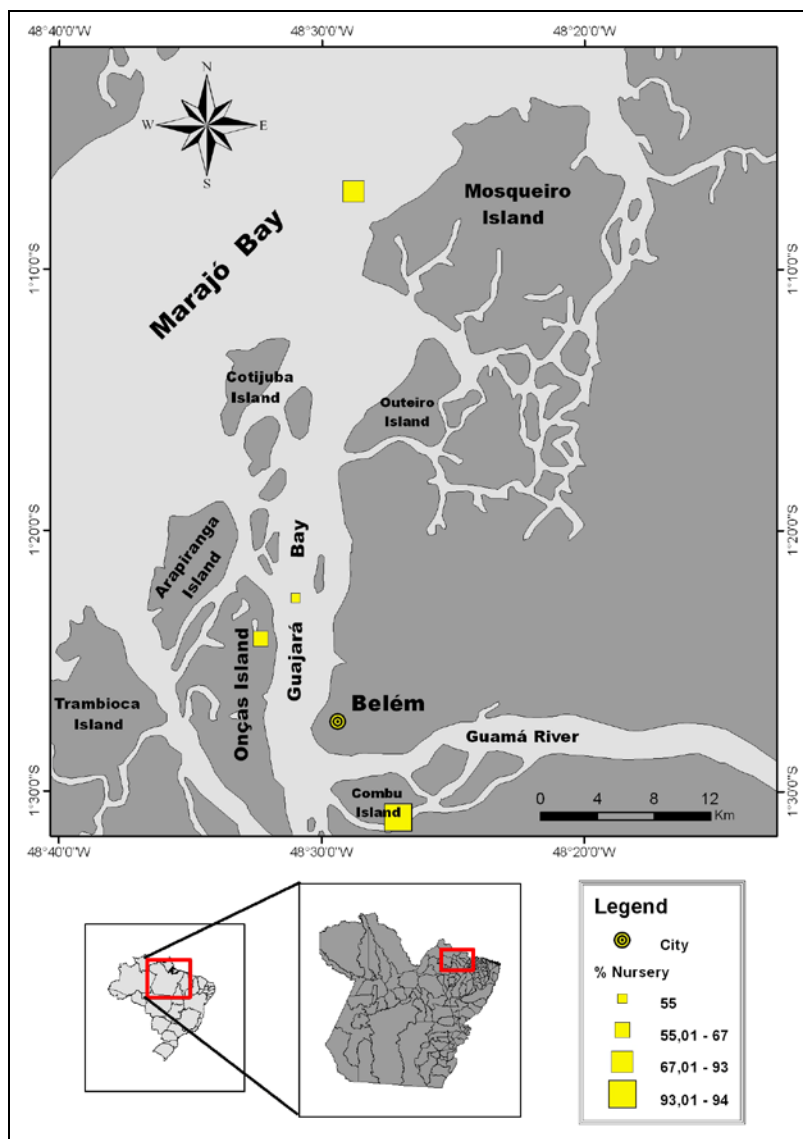


Figure 2: The importance of the studied areas as nursery ground (in percentage).

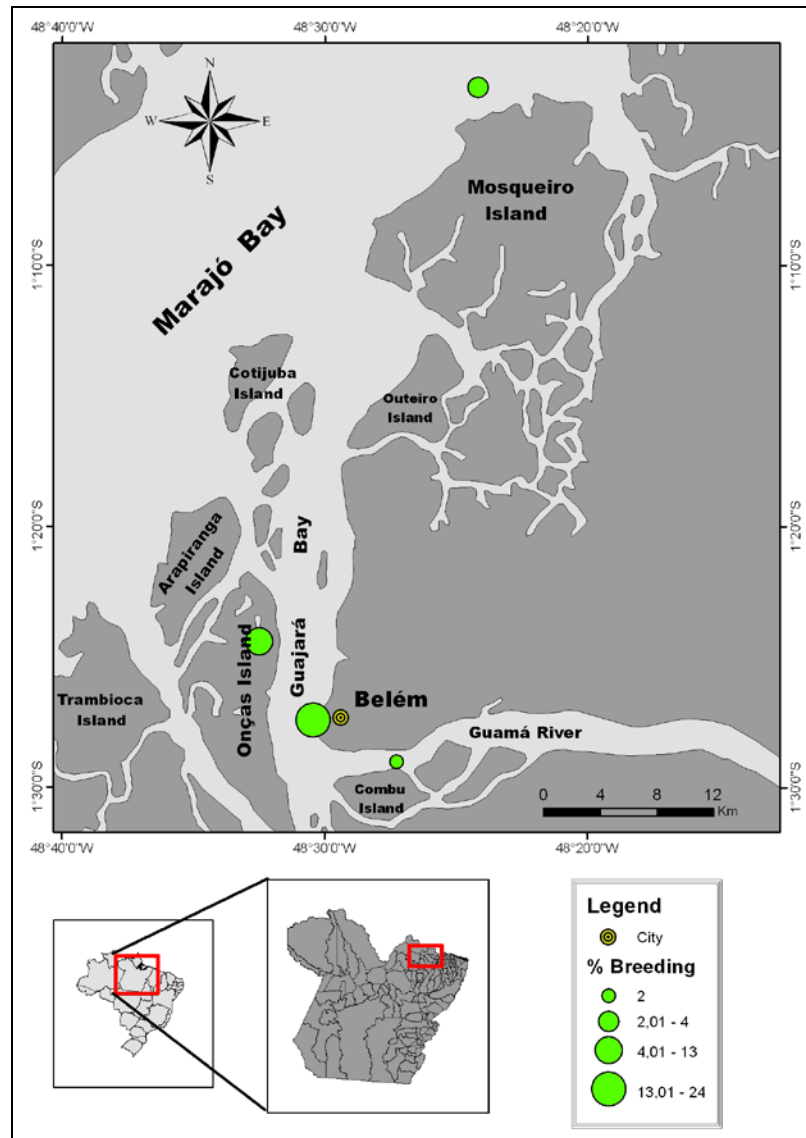


Figure 3: The importance of the studied areas as breeding ground (in percentage).

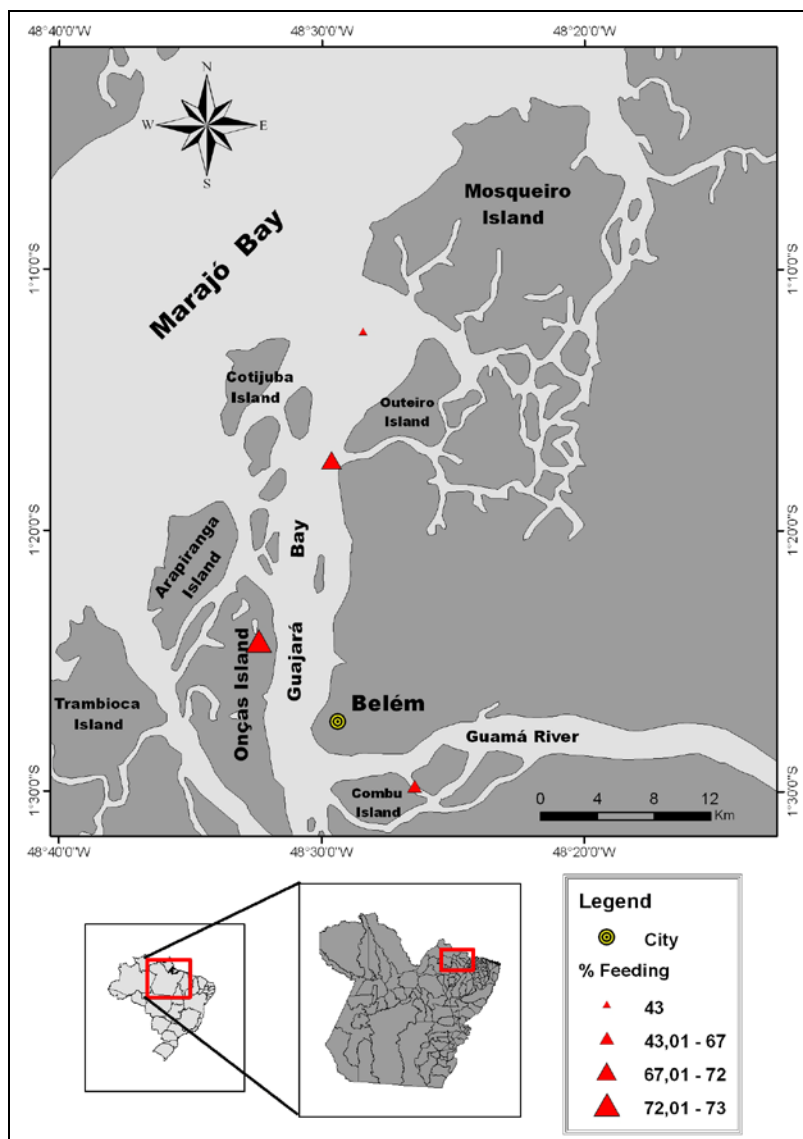


Figure 4: The importance of the studied areas as feeding ground (in percentage).

## Conclusions

The bay of Guejará and the island of Onças are considered priority areas considering the ecological importance of the ichthyofauna and food dependency in relation to fishery resources. The Marajó Bay should be considered priority area for the management of fishery resources, given the commercial relevance of the fishing activity in the area.

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