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Cover photo of this issue: A juvenile of Southern Elephant Seal *Mirounga leonina* (Mammalia, Carnivora, Phocidae). Picture taken by Renato Lopes at the Peninsula Valdez, Argentine Patagonia.

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Scientific Note

Confirmed occurrence of the longjaw snake eel, *Ophisurus serpens* (Osteichthyes: Ophichthidae) in Tunisian waters (Central Mediterranean)

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Abstract. The record of a juvenile female *Ophisurus serpens* in a Tunis Southern Lagoon confirms the occurrence of the species in Tunisian waters. This record constituted the southernmost extension range of *O. serpens* in the Mediterranean Sea, but also the first record of the species in a perimediterranean lagoon.

Key words: Description, morphometric data, meristic counts, brackish area.

Resumen. Confirmación de la ocurrencia de la anguila *Ophisurus serpens* (Osteichthyes: Ophichthidae) en aguas de Túnez (Mediterráneo Central). El registro de una hembra juvenil de *Ophisurus serpens* encontrada en una laguna al sur de Tunéz confirma la ocurrencia de la especie en aguas de la Túnez, constituyendo la extensión más al sur del rango de la especie en el Mar Mediterráneo y representando el primer registro de la especie en una laguna perimediterránea.

Palabras clave: descripción, datos morfométricos, conteo merístico, ambient estuarino

The longjaw snake eel, *Ophisurus serpens* (Linnaeus 1758) is widely distributed, reported off the eastern Atlantic coast, from the Bay of Biscay (Cappetta *et al.* 1985) to South Africa (McCosker & Castle 1986), including Madeira (Bauchot 1986). The species is also reported elsewhere, such as in western Indian Ocean (Southern Mozambique to South Africa) and western Pacific (Japan and Australasia).

Ophisurus serpens is known in western and central Mediterranean marine (Tortonese 1970; Bauchot 1986). Additionally, the species is considered as very rare in the Adriatic Sea where it lives in marine, brackish and estuarine waters between 30 and 400 m depth, on sandy and sandy-muddy bottom (Dulcic *et al*. 2005), buried with only the head exposed, looking for preys.

The longjaw snake eel was reported off the Tunisian coast by Lubet & Azzouz (1969) in the Gulf of Tunis (northern Tunisia). However, no specimen was available for confirmation according to Bradaï (2000). Additionally, the species was not reported elsewhere in Tunisian waters (Bradaï *et al.* 2004). Investigations regularly conducted in Tunis Southern Lagoon (Fig. 1 and 2) since 2003 allow the capture of one specimen of the longjaw snake eel. Description and the first main morphometric measurements made on a Tunisian specimen are presented in this note. Additionally, the distribution of *O. serpens* in both Tunisian and Mediterranean waters is commented in this paper.

The specimen was collected on 24 May

2006 by dragnet at 2.10 m of depth (Fig. 1 and 2), on sea grass beds concomitantly with ascidians, some juvenile gilthead sea breams *Sparus aurata* Linnaeus, 1758, and two invasive species, both lessepsian migrants, the mollusc *Fulvia fragilis* (Forsskål 1775) and the crab *Eucrate crenata* De Haan 1835. Measurements, counts and weights were carried out on the fresh specimen. Morphometric characteristics were determined following Dulcic et *al.* (2005): total length (TL), preanal length (LPA), predorsal length (LPD), prepectoral length (LPP), dorsal fin length (Ld), anal fin length (La), pectoral fin length (Lp), body depth (H), head length (C), eye-diameter (O), interorbital length (Io), preorbital length (PO), number of pores in *linea lateralis* and length of lower jaw are summarized in Table I. The specimen was preserved in 5% buffered formalin in the Ichthyological Collection of the Faculté des Sciences of Tunis with catalogue number FST-OPHI-serpens (Fig. 3).

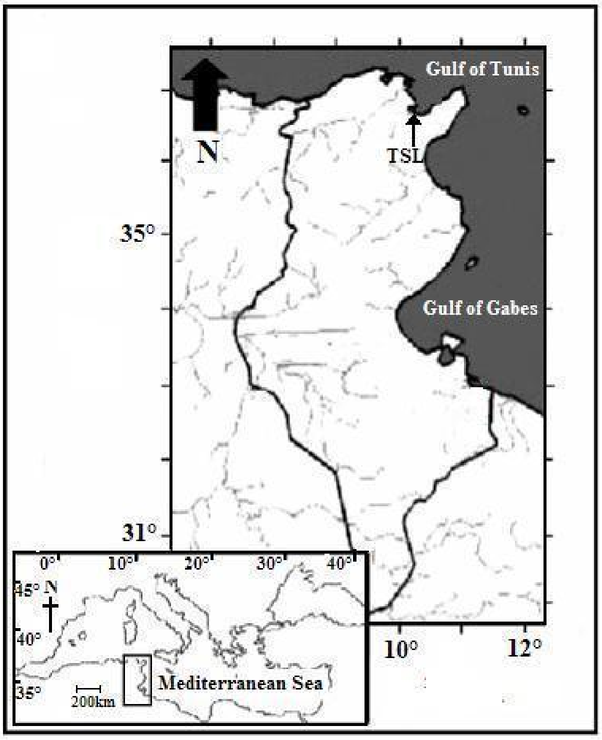

Figure 1. Map of the Tunisian coast showing the location of Tunis Southern Lagoon (TSL).

The snake eel has an extremely elongate and cylindrical body, anus in anterior half of the body, snout long and slender, jaws elongate and extending posteriorly beyond the eye. Dorsal, anal and pectoral fins well-developed. Teeth in one-two series in jaws, canines in front, teeth on one row on womer, enlarged anteriorly. Colour reddish-brown dorsally, belly yellowish, snout ochred, dorsal and anal find edged with grey, lateral pore brownish.

Description, measurements and percent in total length recorded in the Tunisian *O. serpens* are in agreement with Tortonese (1970), Böhlke (1981), Bauchot (1986), McCosker & Castle (1986), and Dulcic *et al*. (2005). Regarding the maximum size of *Ophisurus serpens*, Bauchot (1986) reported 2.40 m for the Mediterranean specimens and McCosker & Castle (1986), 2.50 m for the south African ones as maximum total length. Jardas (1996, *in* Dulcic et *al.* 2005) noted that usual length in catch is between 500 and 1500 mm with 2400 mm maximum in the Adriatic Sea, while in the same area, Dulcic *et al.* (2005) reported specimens having 2000 mm, 2100 mm and 2130 mm TL, respectively. The Tunisian longjaw snake eel, 333 mm TL, was a juvenile specimen, exhibiting inconspicuous genital duct and gonads.

The number of pores in *linea lateralis* counted in the Tunisian specimen was 149, while Dulcic *et al.* (2005) reported 202 pores in a specimen having 2130 mm TL. Jardas (1996, *in* Dulcic *et al.* 2005) noted 173 pores, but no information was provided about the size of the specimen. No sufficient data are available to state, if there is a relationship between number of pores in *linea lateralis* and total length in *O. serpens*; however, such hypothesis could not be totally excluded.

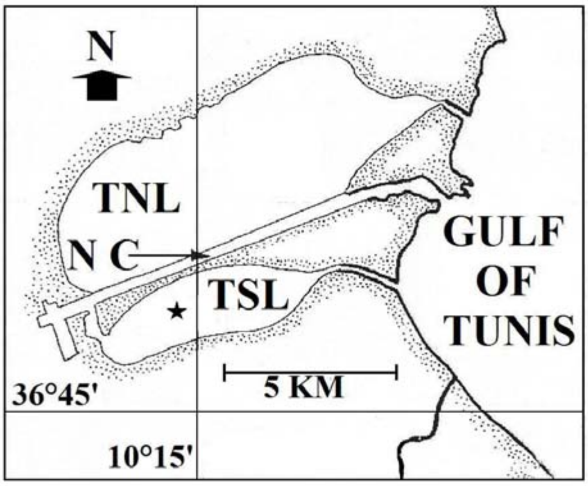

Figure 2. Map of Tunis showing the capture site of *Ophisurus serpens* (black star) in Tunis Southern Lagoon (TSL), Tunis Northern Lagoon (TNL), and navigation channel (NC).

The record of *Ophisurus serpens* in Tunis Southern Lagoon confirmed the species occurrence in Tunisian waters. Additionally, according to information recently provided by fishermen, the species was captured in the navigation channel which separates Tunis Northern Lagoon from Tunis Southern Lagoon (see Fig. 2), without mention related to number of recorded specimens. So the species *O. serpens* could be considered as very rare in Tunisian waters. Similar patterns were reported from other Mediterranean areas where *O. serpens* was considered as a rare species (Louisy 2002). For instance, recent observations carried out off the Languedocian coast (northern Mediterranean) from Michelat *et al.* (2004) to date did not record the species in the area.

Table I. Morphometric (in mm and as % TL) data and meristic counts of the specimen of *Ophisurus serpens* captured in Tunis Southern Lagoon.

Reference	FST-OPHI-serpens	
Morphometric characters (mm)	mm	%TL
Total length (TL)	333	100.0
Preanal length (LPA)	143	42.9
Predorsal length (LPD)	48	14.4
Prepectoral length (LPP)	31	9.3
Dorsal fin length (LD)	225	67.6
Anal fin length (La)	177	53.2
Pectoral fin length (Lp)	5	1.5
Body depth (H)	8	2.4
Head length (C)	42	12.6
Eye diameter (O)	2	4.8
Preorbital length (PO)	4	1.2
Interorbital length (Io)	3	0.9
Length of lower jaw	20	6
Counts		
Number of pores in *linea lateralis*	149	
Pectoral fin soft rays	13	
Weights (g)		
Total weight	11.79	
Eviscerated weight	10.36	
Liver weight	0.20	

Off Algeria, *Ophisurus serpens* was formerly reported as common by Dieuzeide *et al.* (1954), however, although investigations were regularly conducted since 1996 to date in the area, no record was reported by Hemida (2009 pers. comm.). *O. serpens* is unknown off the coast of Libya (Al Hassan & El Silini 1999, Shakman & Kinzelbach 2007), off the Mediterranean coast of Egypt (El Sayed 1994) and in the eastern Levant Basin (Golani 2005). The present record constituted the southernmost extension range of *O. serpens* not only in the Tunisian waters, but also in the Mediterranean Sea. It was also the first record of the species in a perimediterranean lagoon (*sensu* Quignard & Zaouali 1980).

Tunis Southern Lagoon was the focus of a recent environmental restoration that allowed a colonization of fish species previously unknown in the area, before restoration to date (Ben Souissi *et al*. 2004, 2005; Mejri *et al*. 2004), and 62 teleost species including *O. serpens* were recorded in the area. This shows that the environmental restoration was successful and that the area provided sufficient resources for fishes not only to inhabit these waters, but probably to develop and reproduce.

Figure 3. *Ophisurus serpens* collected in the Tunis Southern Lagoon (FST-OPHI-serpens), scale bar = 30 mm.

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References

Al Hassan, L.A.J. & El Silini, O.A. 1999. Check-list of bony fishes collected from the Mediterranean coast of Bengazi, Libya. **Revista de Biologia Marina y Oceanografía**, 34(2): 291-301.

Bauchot, M.L. 1986. Ophichthidae (including Echelidae). p. 577-586. *In*: (P.J.P. Whitehead, E. Tortonese, M.-L. Bauchot, J.-C. Hureau & J. Nielsen, Ed.), **Fishes of the North-eastern Atlantic and the Mediterranean**, 1984-1986, Unesco 1, Paris.

Ben Souissi, J., Mejri, H., Zaouali, J., El Abed, A., Guélorget, O., Capapé, C. 2004. On the occurrence of John Dory *Zeus faber* Linnaeus, 1758 (Osteichthyes: Zeidae) in a perimediterranean lagoon: the Tunis Southern Lagoon (Northern Tunisia). **Annales**, **series Historia naturalis**, 14(2): 219-224.

Ben Souissi, J., Mejri, H., Zaouali, J., El Abed, A., Ben Salem, M., Guélorget, O. & Capapé, C.

2005. Teleost species recorded in Tunis Southern Lagoon after its environmental restoration (northern Tunisia, central Mediterranean). **Annales**, **series Historia naturalis,** 15(2): 157-164.

Böhlke, J.E. 1981. Ophichthidae. *In*: W. Fischer , G. Bianchi & W. B. Scott, Ed. **FAO species identification sheets for fishery purposes**. **Central eastern Atlantic**. Fishing area 34, 47 (in part). Vol. III, Bony Fishes, Malacanthidae to Scombridae. FAO, Rome, var. pag.

Bradaï, M.N. 2000. Diversité du peuplement ichtyque et contribution à la connaissance des sparidés du golfe de Gabès (Diversity of ichthyological settlement and contribution to knowledge of sparids from the Gulf of Gabès). Thesis, University of Sfax (Tunisia), 600 p.

Bradaï, M.N., Quignard., J.P., Bouaïn, A., Jarboui, O., Ouannes-Ghorbel., A., Ben Abdallah., L., Zaouali, J. & Ben Salem, S. 2004. Ichtyofaune autochtone et exotique côtes tunisiennes: recensement et biogéographie (Autochtonous and exotic fish species of the Tunisian coasts: inventory and biogeography). **Cybium**, 28(4): 315-328.

Cappetta, H., Du Buit, M. H. & Quéro, J. C. 1985. Capture de cinq espèces de poissons en dehors de leur aire de distribution connue. **Cybium**, 9(4): 401-403.

Dieuzeide, R., Novella, M. & Roland, J. 1954. Catalgue des Poissons des côtes algériennes. **Bulletin de la Station d'Aquiculture et de Pêche de Castiglione** (n.s.), 4, 1952 [1953]: 1-384.

Dulcic, J., Matic-Skoko, S. & Kraljejic, M. 2005. New record of serpent eel *Ophisurus serpens* (Linnaeus, 1758) (Ophichthidae) in the Adriatic waters with a review of recent Adriatic records. **Annales**, **series Historia naturalis**,15(2): 181-184.

El Sayed, R.S. 1994. Check-list of Egyptian Mediterranean fishes**. Institute of Oceanography and Fisheries. Alexandria, Egypt**: ix + 77 pp.

Golani, D. 2005. Checklist of the Mediterranean Fishes of Israel. **Zootaxa**, 947: 1-90.

Louisy, P. 2002. Guide d'identification des poissons marins. Europe et Méditerranée. Paris, Les Éditions Eugen Ulmer. 430 pp.

Lubet, P. & A. Azzouz, 1969. Etude des fonds chalutables du golfe de Tunis. **Bulletin de l'Institut d'Océanographie et de Pêche de Salammbô**, 1(3): 87-111.

McCosker, J.E & Castle, P.H.J. 1986. Ophichthidae. p. 176-186. *In*: M.M. Smith & P.C. Heemstra (Ed.): **Smiths' sea fishes**. Springer-Verlag, Berlin, 1047 p.

Mejri, H., Ben Souissi, J. Zaouali, J., El Abed, A., Guélorget, O. & Capapé, C. 2004. On the recent occurrence of elasmobranch species in a perimediterranean lagoon: the Tunis Southern Lagoon (Northern Tunisia). **Annales, series Historia naturalis**, 14(2): 143-158.

Michelat, M., Daudet, L. & Faliph, J. 2004. La faune marine de la côte du Languedoc: approche qualitative et quantitative. Ph D dissertation, University of Montpellier II, 41 p.

Quignard, J.- P. & Zaouali, J. 1980. Les lagunes périméditerranéennes. Bibliographie icthyologique annotée. Première partie: les étangs français de Canet à Thau. **Bulletin de l'Office national des Pêches de Tunisie**, 4(2): 293-360.

Shakman, E. & Kinzelbach, R. 2007. Commercial fishery and fish species composition in coastal waters of Libya. **Rostocker Meereskundliche Beiträge**, 18: 65-80.

Tortonese, E. 1970. Osteichthyes (Pesci ossei). Parte prima. In: Fauna d'Italia. Calderini, Bologna, 564 pp.

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Scientific Note

New records of *Urobatis tumbesensis* (Chirichigno & McEachran, 1979) in the Tropical Eastern Pacific

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Abstract. This report confirms the presence of Tumbes round stingray *Urobatis tumbesensis* in the Colombian Pacific coast, increases the species richness of the *Urobatis* genus in the study zone, and considerably extends the known geographic distribution range of this species in the Tropical Eastern Pacific.

Key words: Batoid fishes, American rounded-rays, distribution, Colombia.

Resumen. Nuevos registros de *Urobatis tumbesensis* (Chirichigno & McEachran, 1979) en el Pacífico Oriental Tropical. Este reporte confirma la presencia de rayas redondas americanas de Tumbes *Urobatis tumbesensis* en la Costa Pacífica colombiana, incrementa la riqueza de especies del género *Urobatis* en la zona de estudio y extiende considerablemente el rango de distribución geográfica conocido de esta especie en el Pacífico Oriental Tropical.

Palabras clave: peces batoideos, rayas redondas americanas, distribución, Colombia.

The Family Urotrygonidae McEachran, Dunn & Miyake 1996, that includes the American rounded- rays, is represented in the Tropical Eastern Pacific by two genera (*Urobatis* and *Urotrygon*) and by 12 species (4 and 8, respectively) (Compagno 2005). A recent study about the elasmobranch richness in Colombia (Mejía-Falla *et al*. 2007) confirmed the presence of the two genera and five species: *Urobatis halleri* (Cooper 1863), *Urotrygon aspidura* (Jordan & Gilbert 1882), *Urotrygon chilensis* (Günther 1871), *Urotrygon munda* Gill 1863 and *Urotrygon rogersi* (Jordan & Starks 1895), on the coast of the Colombian Pacific Ocean. Such study also classified the record of *Urobatis tumbesensis* (Chirichigno & McEachran 1979) as "*in doubt*", since collected specimens or visual records had not been registered and the only records of this species were based on two bibliographic references (Estupiñán *et al*. 1990, Arboleda 2002).

The current record is based on two specimens (one male and one female) of the family Urotrygonidae captured in artisanal shrimp trawl fishery in El Tigre, Malaga Bay, Colombian Pacific coast (Fig. 1).

The male was captured on November 23rd 2006 (3º 53'42''N, 77º 19'25''W) and the female on June 21st 2007 (3º 52'20''N, 77º20'10''W). These specimens were preserved, analyzed and later donated to the Reference Ichthyological Collection of the University of Valle (CIRUV, abbreviation in Spanish), Cali, Colombia (CIRUV 006-0063 and CIRUV 007-0094, respectively). The measurements of specimens were taken following the criteria of Chirichigno & McEachran (1979) and the specific identity of specimens was validated by comparing with the description and with the proportional measurements of the holotype (Chirichigno & McEachran 1979). Both specimens presented characteristics consistent with those of the genus *Urobatis* and to the specific identification of *Urobatis tumbesensis* (Fig. 2).

These individuals have nearly rounded discs, slightly wider than long; pelvic fins with abruptly rounded tips; tail stout, bearing a serrated stinging spine, and with a rounded caudal fin; tail length near to 85% of disc length (female 85.94% and male 85.76%); tail and top of caudal fin uniformly covered with star-shaped dermal denticle bases, enlarging towards the midline of the disc; a row of thorns with star-shaped bases along midline of disc and tail; underside smooth. Dorsal surface and caudal fin covered with a bright pattern of coarse light brown and dark wriggly lines and eye-sized spots, becoming more distinct towards the margin of the disc and on the pelvic fins; creamy ventral surface with a reticulated pattern of pale spots on a dark background around the sides and rear of the disc and pelvic fins. Moreover, the proportional measurements matched those described for the holotype (Table 1). The male total weight was 273 grams and its calcified clasper was 2.9 cm long, indicating a mature state at this size (30 cm total length). The female total weight was 872 grams and its size corresponds to the maximum ever reported in the literature (at least 41 cm total length) (Robertson & Allen 2002, 2008).

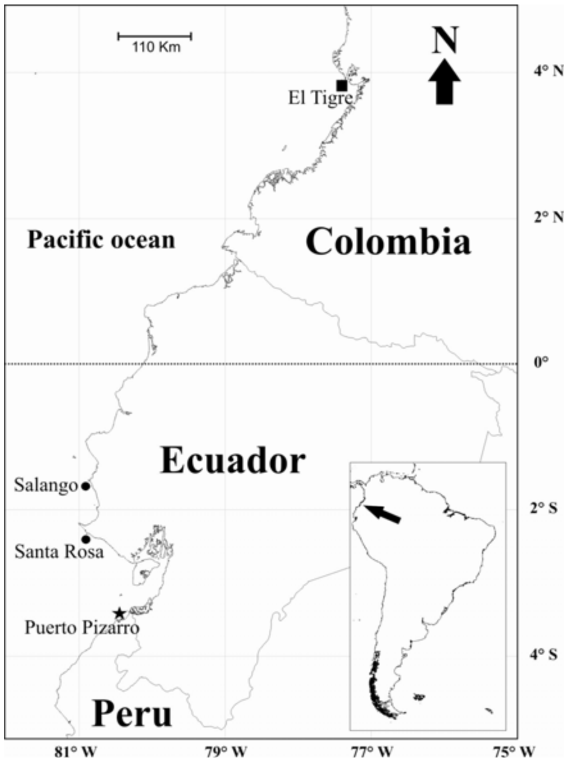

Figure 1. Distribution of *Urobatis tumbesensis* in the Tropical Pacific Ocean. (★) Holotype, (●) capture sites in Ecuador, (■) new capture site in the Colombian Pacific coast.

Urobatis tumbesensis is a little known species of round ray whose description is based on three specimens, two male specimens (40.4 and 15.7 cm total length) collected from estuarine waters at depths of 1-2 meters, and a third specimen collected in 2006 near mangroves (Chirichigno & McEachran 1979, Kyne & Valenti 2007).

The capture depth of these individuals is within the registered range for the species (< 20 m) (Jiménez & Bearez 1994, Robertson & Allen 2002, 2008), and the capture zones are coincident with their habitats, specifically muddy bottoms (Robertson & Allen 2002, 2008).

This species was originally registered in Puerto Pizarro, Tumbes, Northern Perú (Chirichigno & McEachran 1979) and later in Salango and Santa Rosa, Ecuador (Jiménez & Bearez 1994) (Fig. 1). Robertson & Allen (2002, 2008) proposed that the distribution of this species is restricted to an area between Northern Peru and Central zone of Ecuador. However, some books of marine fishes of Ecuador have not registered such species (Massay & Massay 1999, MICIP 2006). In this way, this record of *U. tumbesensis* as well as confirming the presence of this species in Colombia, it also increases its distribution in approximately 600 km from the record in Ecuador (Salango) and suggests a known distribution range in the Tropical Eastern Pacific of approximately 750 km (Fig. 1).

Since Kyne & Valenti (2007) suggested only one known locality for this species (Tumbes, Perú), *U. tumbesensis* was included in the Deficient Data category of the IUCN Red List. Thus, this paper contributes with useful information for future evaluations of threat level of this species, based on geographic distribution, which allows to calculate the extent of occurrence (B1 Criterion, UICN 2001) and/or the area of occupancy (B2 Criterion, IUCN 2001) of the species. According to the cartographic method of areas (Cartan 1978) and based on the four localities registered for the species by this study and literature, an approximate area of occupancy of 220 km^2 was estimated (using quadrants of 0.5º).

Additionally, it is possible that in Colombia (pers. obs.), Ecuador and Peru (P. Bearez, pers. comm.) this species presents a low abundance and fragmented distribution through the described range. In this case, there are other useful indicators for a new evaluation of the conservation status of *U. tumbesensis.* However, it is necessary to evaluate whether the low number of recorded individual is due to sampling problems and/or to wrong identification of the species in the area of occurrence. Moreover, *U. tumbesensis* is a very low proportion in the artisanal trawl fisheries' by-catch in Colombia (Gómez & Mejía-Falla 2008).

Finally, two out of four species of *Urobatis* of the Tropical Eastern Pacific (*Urobatis concentricus* and *U. maculatus*) are restricted to the northern zone, especially Mexico (southern Baja California, Gulf of California and southern Mexico). *Urobatis halleri* is the species with the widest distribution, while *U. tumbesensis* presents the narrowest one, and both species are reported in the Colombian Pacific coast.

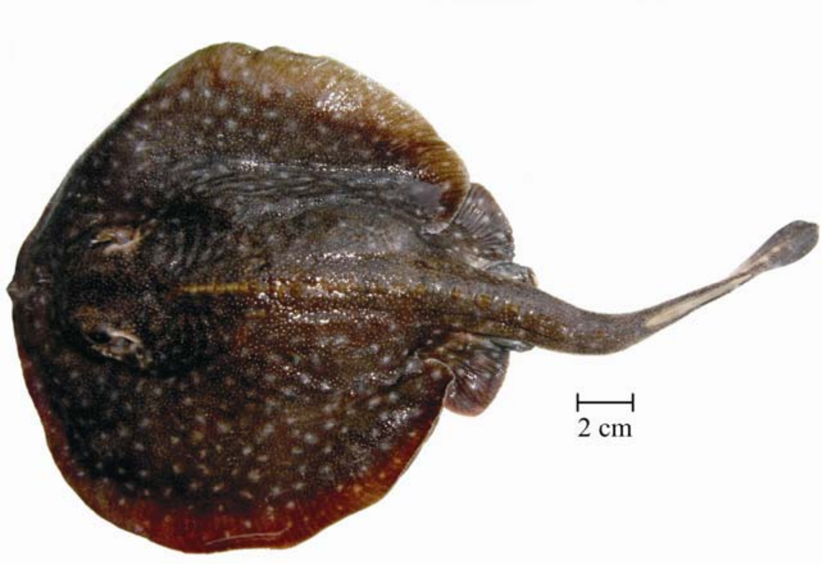

Figure 2. *Urobatis tumbesensis* male of 300 mm total length, captured in the Colombian Pacific coast.

Table I. Proportional morphometrics of holotype (Chirichigno & McEachran, 1979) and two specimens of *Urobatis tumbesensis* collected in the Colombian Pacific coast. The measurements are given as percentage of total length, except TL, which is in cm.

Morphometrics parameters	Holotype (Male)	Specimen 1 (Female)	Specimen 2 (Male)
Total length (cm)	40.4	42.0	30.0
Disc width	59.4	60.7	62.3
Preoral length	10.2	10.3	11.3
Preorbital length	12.2	13.2	14.1
Disc length	58.4	54.8	58.3
Prenasal length	9.0	8.8	8.6
Snout to maximum disc width length	27.7	28.6	30.0
Orbit diameter	4.1	3.0	2.4
Inter-orbital width	5.3	8.4	8.3
Interspiracular length	9.5	9.5	9.8
spiracle length	4.2	3.3	2.6
Mouth width	5.3	7.8	6.7
Internasal width	4.7	4.7	5,1
1st gill width	2.5	2.1	2.0
3th gill width	2.4	1.9	1.7
5th gill width	1.6	1.4	1,3
Distance between 1st gill slits	14.8	15.7	16,6
Distance between 5th gill slits	10.9	11.8	11.6
Anterior margin of pelvic fin	11.1	14.9	11,9
Snout- cloaca length	51.2	53.6	48.3
Cloaca - sting length	27.5	31.0	25.7
Cloaca - caudal origin length	40.6	40.0	41.7
Cloaca - caudal fin	49.5	47.1	50.0

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References

Arboleda. E. 2002. Estado actual del conocimiento y riqueza de peces, crustáceos, decápodos, moluscos, equinodermos y corales escleractineos del océano Pacífico colombiano. **Tesis de Biología Marina.** Universidad Jorge Tadeo Lozano, Facultad de Ciencias del Mar. Bogotá, Colombia**,** 189 p.

Cartan. M. 1978. **Inventaires et cartographies de répartition d'espéces: faune et flore**. CNRS, Paris, 127 p.

Chirichigno, N. & McEachran. J. D. 1979. *Urolophus tumbesensis*, a new stingray from the coast of Peru (Batoidea: Urolophidae). **Copeia**, 4: 709-713.

Compagno, L. J. V. 2005. Check list of living elasmobranches. Pp. 503-548. *In*: Hamlett. W. C. (Ed.). **Reproductive Biology and Phylogeny of Chondrichthyes: Sharks, batoids and chimaeras**. Science Publishers, Enfield, 515 p.

Estupiñán, F., von Prahl, H. & Rubio, E. A. 1990. Ictiofauna de la Ensenada de Utría, Pacífico colombiano. **Revista de ciencias Universidad del Valle**, 8: 65-75.

Gómez, L. S. & P. A. Mejía-Falla. 2008. Aspectos pesqueros de los batoideos capturados artesanalmente en las localidades de Juanchaco y la Bocana, Pacífico vallecaucano. *En*: Payán, L. F., Muñoz-Osorio, L. A., Ramírez-Luna, V. & Mejía-Ladino, L. M. (Eds.). **Memorias del I Encuentro colombiano sobre condrictios**. Fundación SQUALUS, Colombia, 66 p.

IUCN. 2001. **Categorías y criterios de la lista roja de la UICN: versión 3.1.** Comisión de Supervivencia de especies de UICN, Gland-Cambridge, 33 p.

Jiménez, P. & Bearez, P. 2004. **Peces marinos del Ecuador continental**. SIMBIOE/NAZCA/ IFEA, Quito, 530 p.

Kyne, P. M. & Valenti, S. V. 2007. *Urobatis tumbesensis*. **IUCN Red List Species -** World Wide Web electronic publication, accessible at http://www.iucnredlist.org. (Accessed 03/25/2008).

Massay, S. & Massay, J. 1999. Peces marinos del Ecuador. **Boletín Científico y Técnico del Instituto Nacional de Pesca**, 12(9): 1-64.

McEachran, J. D. & di Sciara, N. 1995. Peces Batiodeos. Pp.746-792. *En*: Fischer, W., Krupp, F., Schneider, W., Sommer, C., Carpenter, K. E. & Niem, V. H. (Eds.). **Guía FAO para la identificación de especies para los fines de la pesca, Pacífico Centro Oriental**. FAO, Roma, 1813 p.

McEachran, J. D., Dunn, K. A. & Miyake, T. 1996. Interrelationships of the Batoid fishes (Chondrichthyes: Batoidea). Pp. 63-83. *In*: Stiassny, M. L., Parenty, L. & Johnson, G. D. (Eds.). **Interrelationships of fishes**. Academic Press, San Diego, 496 p.

Mejía-Falla, P. A., Navia, A. F., Mejía-Ladino, L. M., Acero, A. & Rubio, E. 2007. Lista revisada y comentada de las especies de tiburones y rayas (Pisces: Elasmobranchii) registradas en aguas colombianas. **Boletín de Investigaciones marinas y costeras,** 36: 7-45.

Ministerio de Comercio Exterior, Industrialización, Pesca y Competitividad (MICIP). 2006. **Plan de Acción Nacional para conservación y manejo de tiburones de Ecuador**. Ministerio de Comercio Exterior, Industrialización, Pesca y Competitividad, Quito, 44 p.

Robertson, D. R. & Allen, G. 2002. **Peces costeros del Pacífico Oriental Tropical: Un sistema de información**. Instituto Smithsonian de investigaciones tropicales, Balboa, CD. ROM.

Robertson, D. R. & Allen, G. 2008. **Shore fishes of the Tropical Eastern Pacific -** World Wide Web electronic publication, accessible at http://www.neotropicalfishes.org/sftep (Accessed: 30/11/2008).

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Early developmental aspects and validation of daily growth increments in otoliths of *Micropogonias furnieri* (Pisces, Sciaenidae) larvae reared in laboratory

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Abstract. The rate of growth increment deposition in otoliths and the early development of *Micropogonias furnieri* larvae were studied in laboratory under salinity and temperature of 30-35 and 23-25 °C respectively. Hatching occurred between 20 to 22 h after the *in vitro* fecundation. Larvae presented closed mouth, unpigmented eyes and average standard length at hatch about 1.85 mm. Larvae started to feed around the 2nd day after hatch, when the eyes became fully pigmented. Laird-Gompertz growth model was applied and average, maximum and minimum instantaneous growth rate were estimated as 0.36, 0.78 and 0.14 $mm.d^{-1}$, respectively. First growth increment in the otoliths was observed at the 3rd day after hatch and the increment formation rate was 1.044 per day. Average percent error in increment reading was 13.75, and lower values were observed after age 5 d. Present results support the assumption of daily growth increments in otoliths of *M. furnieri* larvae.

Keywords: Daily growth increments, ear stones, whitemouth croaker, fish larvae.

Resumo. Aspectos do desenvolvimento inicial e validação da formação de anéis diários em otólitos de larvas de corvina *Micropogonias furnieri* (Teleostei, Sciaenidae) cultivadas em laboratório. O desenvolvimento inicial de larvas de corvina e a taxa de formação de anéis de crescimento em otólitos foram estudados em laboratório. A eclosão das larvas ocorreu aproximadamente 22 horas após a fecundação *in vitro*. As larvas eclodiram com boca fechada, olhos não pigmentados e comprimento padrão em torno de 1,85 mm. A boca abriu cerca de 24 horas após a eclosão e a alimentação iniciou-se quando os olhos tornaram-se pigmentados, no segundo dia após a eclosão. O modelo de crescimento de Laird-Gompertz foi aplicado e as taxas de crescimento média e instantânea máxima e mínima foram respectivamente 0,36, 0,78 and 0,14 $mm.d^{-1}$. O primeiro anel de crescimento nos otólitos surgiu em média no terceiro dia após a eclosão e a taxa de formação de anéis foi de 1,044 anel por dia. O índice de erro médio percentual na contagem de incrementos foi 13,75, com valores menores a partir do quinto dia. Os resultados encontrados permitem validar a taxa diária de formação de anéis de crescimento em larvas de *M. furnieri*.

Palavras-chave: anéis de crescimento, otólitos, corvina, larva de peixe.

Introduction

Whitemouth croaker, *Micropogonias furnieri* (Desmarest, 1823), is one of the most important fish species in the Southern Brazilian continental shelf. Together with *Cynoscion guatucupa*, supports both artisanal and industrial fisheries of the Argentinean, South Brazilian and Uruguayan coastal regions (Haimovici *et al*. 1989;

Jaureguizar *et al*. 2006). *M. furnieri* is considered an over-fished stock since the 90s (Paiva 1997, Vasconcelos & Haimovici 2006). It is an euryhaline species distributed from Gulf of Mexico, 20° N, to the Gulf of San Matias, 41° S (Chao 1978). In Southern Brazil, spawning occurs during summer (Ibagy & Sinque 1995), mainly in coastal waters of the Patos Lagoon estuary (32° 10.18'S and 52° 7.17'W). Eggs and larvae are passively transported into the estuary, where better environmental conditions favour their development (Muelbert & Weiss 1991). To analyze the effect of these estuarine conditions on larval development it is important to understand larval growth in the field. Besides, the comprehension of changes in growth and mortality of fish may improve the understanding of environmental factors that may affect fish survival and recruitment (Cushing 1988).

One of the most used techniques for studying larval growth in the environment is the analysis of daily growth increments in otoliths (Power *et al.* 2000, Nakaya *et al*. 2008). Studying the growth of fish larvae in field through otoliths requires preliminary knowledge on the rate of increment formation in the otoliths (validation), and on the existing relationship between otolith and larval growth. Validation has been approached by analysing otolith marginal increment (Moku *et al*. 2005), following larval cohorts (Morley *et al*. 2005) and by rearing larvae in laboratory, that represents one of the most used validation techniques (Campana 2001).

In this study we aimed to describe the periodicity of otolith increment formation and to evaluate the first increment deposition on sagittal otoliths of *M. furnieri.* Additionally we intended to describe some poorly known aspects of the early development of that species like size at hatch, growth rate and first feeding. The information presented here will be important to support ongoing studies approaching *M. furnieri* growth in the estuary of Patos Lagoon.

Materials and Methods

Wild broodstock of *M furnieri* were captured in the vicinity of Patos Lagoon estuary (South Brazil) during December 2002, and induced to spawn in the laboratory, with gonadotrophin injections (500 UI Kg^{-1}). Eggs were artificially fertilized, and before hatching they were transferred to small larviculture tanks (15 L). After hatching started, cultured rotifers and the algae *Tetraselmis tetrathele* were added daily to the tanks to maintain a final concentration of 20 and 2000 ind mL^{-1}, respectively. Seventeen days after hatch *Artemia franciscana* nauplii were also offered (2 – 3 ind mL^{-1}). Salinity was held between 25 and 30, and temperature between 23 and 25 °C during the whole experiment.

Initially, after hatch 7 to 10 larvae were fixed each day using an anaesthetic solution of benzocain, and placed in alcohol 98%. After 7 days of hatching larvae were fixed at intervals between one and five days up to the 29th day. Larval standard length was measured, and saggital otoliths were removed with surgical needles.

After removal, sagitta otoliths were glued on glass slides with immersion oil. All otoliths were photographed with a digital camera coupled to a light microscope (200, 400, 500 and 1000 x). Otoliths of larvae older than 10 days were mounted in epoxy glue, sanded with fine silicon carbide paper (2000, 8000 and 12000) and polished with car wax. Otoliths were measured on screen using UTHSCSA Imagetool software (University of Texas Health Science Centre at San Antonio, Texas, http://ddsdx.uthscsa.edu/dig/itdesc.html) and growth increments were counted by two independent readers on the digital images.

The rate of daily increment deposition was validated by comparing the number of increments counted in the otoliths to the known age of each larva. Otoliths from 82 larvae (from 132 examined) were successful read. The number of otolith increments was plotted against real age using each reading from the individual readers as one data point in order to consider the uncertainty between readers. Precision of counting was evaluated applying the Average Percent Error (APE) (Campana 2001):

$$APE = 100\frac{1}{R}\sum_{i=j}^{R}\frac{\left|x_{ij} - x_j\right|}{x_j} \quad (1)$$

where x_{ij} is the i^{th} age determination of the j^{th} fish, x_j is the mean age estimate of the *j* fish and *R* is the number of times that each fish was aged.

A linear regression model was used to verify increment formation rate, and the slope was compared to 1 using an *f* test (Zar 1984).

The age of formation of the first increment was determined by the frequency of occurrence of known ages with one increment and confirmed by the intercept of the linear regression between real age and growth increment number.

Growth analysis was performed using linear regression and the Laird-Gompertz growth model (Ricker 1979), fitted to the length at age data using a non-linear estimation. This model is described as:

$$S_l = L_0 e^{k(1-e^{-\alpha t})} \quad (2)$$

where S_l is standard length (mm), L_0 is the length at hatch (mm), k is a dimensionless parameter, α is the exponential decay rate and t is the time (days).

To obtain the instantaneous growth rate the first derivative of equation (2) was considered:

$$G' = \alpha.k.L_0 e^{k(1-e^{-\alpha t})-\alpha t} \quad (3)$$

where G' is the instantaneous growth rate for each day t.

Results

Larvae hatched with a large yolk sac, unpigmented eyes and closed mouth. Average initial standard length (L_0) *in vivo* was 1.85 mm (±1.17 S.D.). Mouth opened twenty-four hours after hatching, however feeding initiated only 24 hours later (2 day old larvae), when the eyes became fully pigmented. The yolk sac was totally reabsorbed by the 9th day, with larval standard length of about 3.5 mm.

Sagittal otoliths of *M. furnieri* were first observed no earlier than 24 hours after larval hatch, therefore, there was not hatching checks in otoliths of *M. furnieri*. Otoliths extracted from the youngest larvae measured 17 µm in diameter, were flat at the inner surface (Fig. 1A) and showed one single primordiun. Initial growth increments were easily observed (Fig. 1B) and the sulcus was not formed before the 19th day, when no differences between anterior and posterior edges were noticed (Fig. 1C). After 25 days, the rostrum, which defines the anterior margin of the *sagitta* (Secor *et al*. 1991) was evident, and the surface of otoliths became rugged and opaque and the first accessory primordium was observed (Fig. 1D).

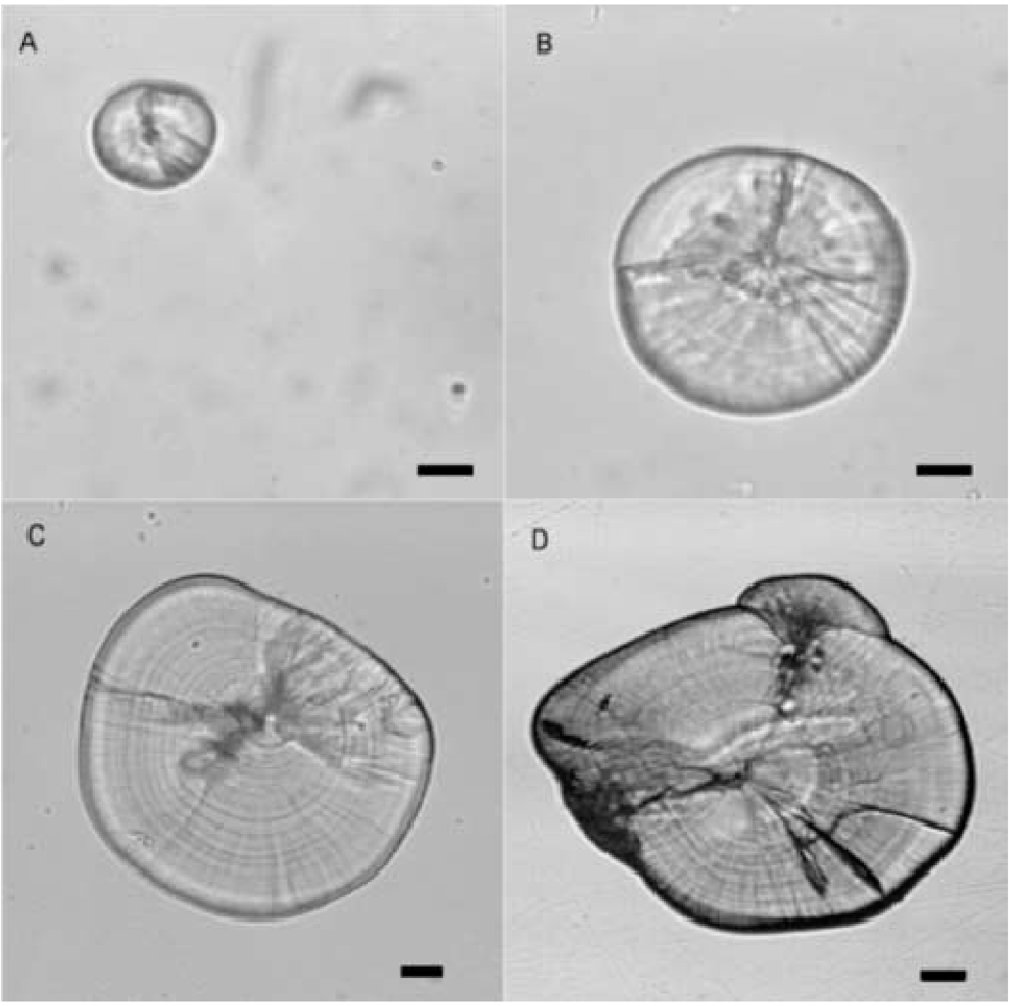

Figure 1. Saggital otolith photomicrography from *M. furnieri* larvae reared over 24 h (A), 7 days (B), 19 days (C), 25 days (D). Bar (A, B) = 6 µm; Bar (C) = 28 µm; Bar (D) = 35 µm. Note the round shape during the initial stages (A and B) and the presence of accessory nuclei (D).

On day 29 the mean standard length was 12.99 mm (±3.61 S.D.), with a minimum of 6.58 and a maximum of 17.43 mm (Table I). Two stages with reasonably different growth rates were observed (Fig. 2). Laird-Gompertz growth model parameters were estimated as α = 0.018 and k = 4.66, while L_0

was fixed at 1.85 mm (Fig.3). Instantaneous growth rate (G') showed increasing values, with minimum, average and maximum of 0.14, 0.36 and 0.78 $mm.d^{-1}$, respectively (Fig. 3).

Table I. Mean standard length (SL) of larvae of *M. furnieri* reared in laboratory from hatching to the 29th day. S.D. = Standard deviation.

Day	SL (mm)	S.D.	Range (mm)	*n*
0	1.85	0.17	1.98 – 1.50	7
0.75	2.54	0.12	2.67 – 2.34	6
1	2.58	0.05	2.64 – 5.50	8
2	2.51	0.26	2.84 – 2.00	7
3	2.57	0.07	2.87 – 2.55	9
4	2.67	0.10	2.84 – 2.70	4
5	2.69	0.12	2.97 – 2.70	5
7	2.84	0.05	3.86 – 3.33	6
12	4.82	0.50	5.35 – 4.10	7
14	4.51	0.37	5.21 – 3.86	11
16*	4.99	0.6	6.24 – 4.28	12
18*	5.40	0.6	6.29 – 4.41	13
20*	6.43	0.5	7.40 – 5.39	12
21*	6.91	0.75	7.81 – 4.80	8
25*	10.72	0.75	12.00 – 9.86	9
29*	12.99	3.61	17.43 – 6.58	8

* *Fed with Artemia salina and rotifers*

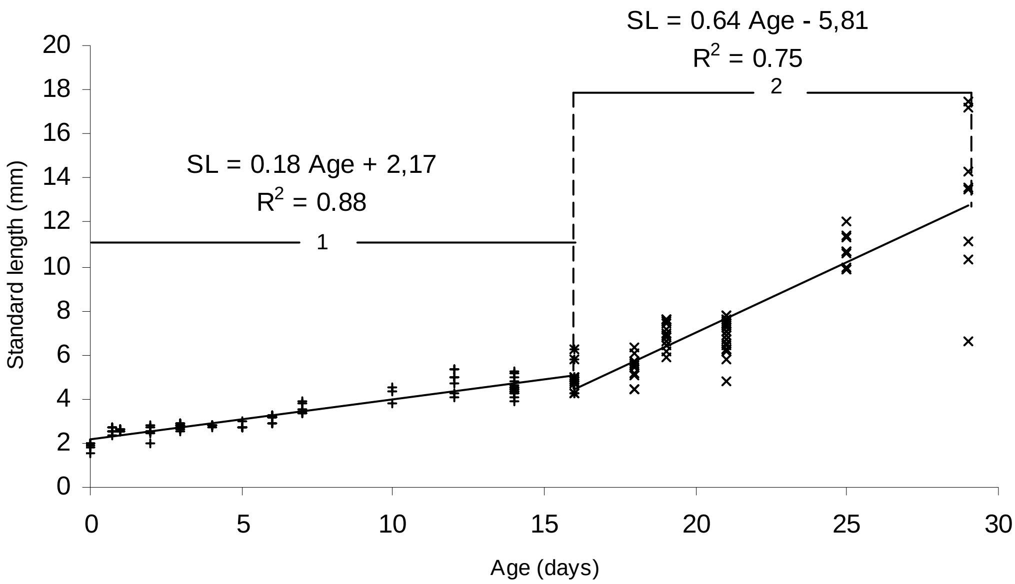

Figure 2. Age (days) and standard length (mm) for *M. furnieri* reared in laboratory. (1) Regression line for day 0 to 16; (2) for day 16 to 29.

The relationship between real age and growth increment number showed a linear pattern (Fig. 4), with slope of 1.044 (±0.008 S.E.) being significantly different from one if based on $P<0.05$, or not significantly different when considered at $P<0.1$. Analyzed otoliths showed from 0 to 29 increments that began to appear at the 1st and 2nd days, but were most often observed at the 3rd day. This result associated with the regression intercept at 1.98 days indicated that, in average, two day old larvae have otolith with zero increments and, therefore, the first increment is deposited three days after hatch.

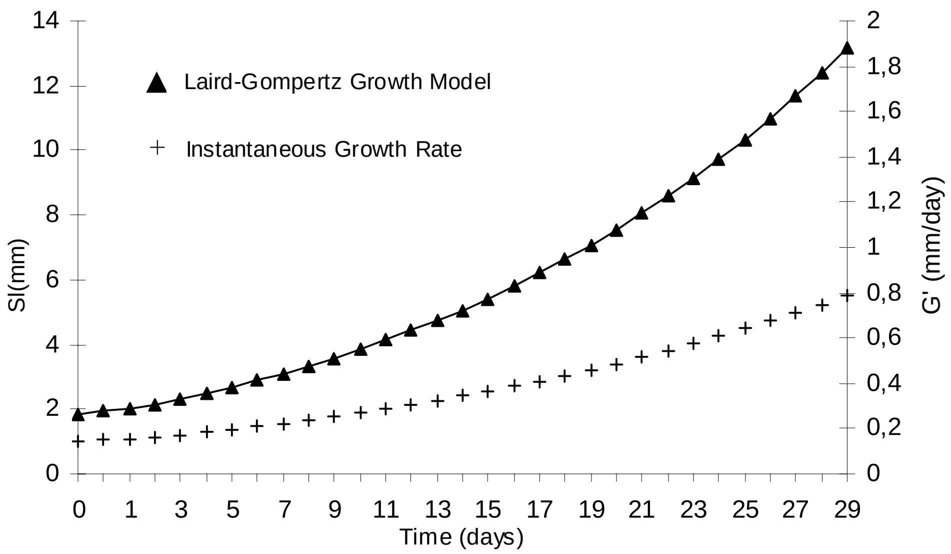

Figure 3. Laird-Gompertz growth model (▲) and instantaneous growth rate (+) for all reared *M. furnieri* larvae during the complete experiment.

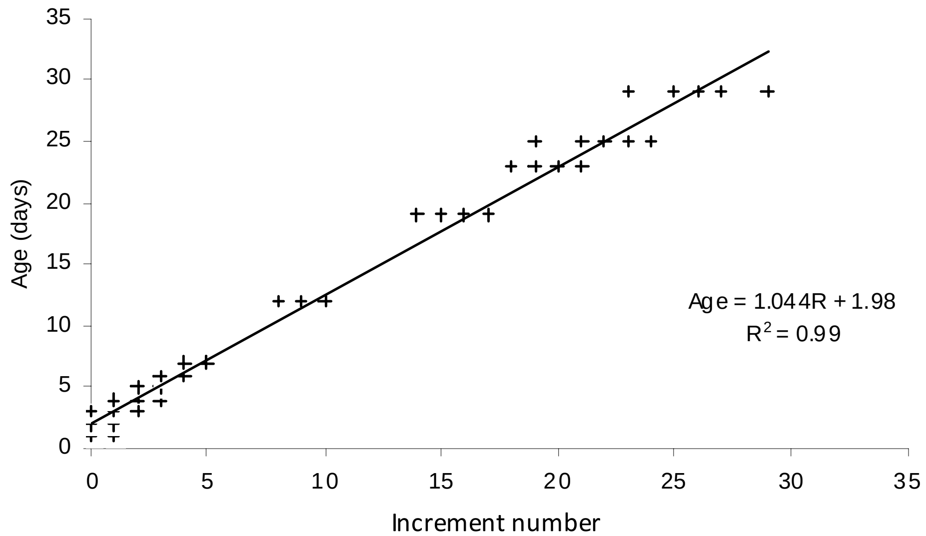

Figure 4. Linear regression between known age (days) and increment number (R) for otoliths of *M. furnieri* reared in laboratory. n = 164 (82 readings x 2 readers).

Average APE for all ages of *M. furnieri* larvae was calculated as 13.7 (Table II). The highest APE values were present at initial ages, reaching 37.0 for age 3 days. Absolute age estimates calculated from the linear model agreed better with known ages for young larvae than for older ones. The error observed for estimates at the end of the experiment (29 days) was approximately 1 day (Table II).

Discussion

Growth of *M. furnieri* larvae in captivity can be separated in two stages. Initial slow growth, when fed only with rotifera, was followed by faster growth when *A. franciscana* was added to the tanks. This growth feature is reported for fish larvae and related to the onset of external feeding (Zweifel & Lasker, 1976). Additionally, it is already known that larger prey promote better growth conditions than small prey (Hunter 1981). We suggest that the addition of A. franciscana, or its combination with rotifers, improved the quality of the diet and consequently larval growth. Accelerated growth rates have also been observed for sciaenidae larvae after 20 days of hatch as a result of settlement (Rooker et al., 1999) which could explain variability on growth rates in nature. Other experiments should be conducted with the specific objective of examining what promotes that differential growth and the effect of adding larger prey to the diet of larval white-mouth croaker.

Except for the first 7-8 days, otoliths of *M. furnieri* larvae were not easy to read. Albuquerque & Muelbert (2004) used haematoxylin to improve contrast between growth bands in *M. furnieri* larvae collected from an estuary. We did some tests with haematoxylin following these authors but the visualization of growth increments from the larvae held in laboratory did not improve. Nevertheless, approximately 62% of the examined otoliths were successfully read. Most of the otoliths in our study presented the first increment completed three days after hatch. The time of first increment deposition is a species-specific feature (Ekau & Blay 2000) that allows to improve the accuracy in age and growth evaluations when it is correctly estimated (Campana 2001). The time of first increment deposition can be influenced by environmental conditions like temperature and food availability (Radtke & Fey 1996) and can be influenced or coupled to some important life change, like hatch (Humphrey *et al.* 2005), beginning of active swimming (Laroche *et al.* 1982) and complete absorption of yolk sac (Peñaillo & Araya 1996). Since *M. furnieri* larvae started to feed around the third day after hatch, it is reasonable to suppose that the first growth increment deposition is associated to beginning of feeding, as suggested by Campana & Mosksness (1991). The variability observed on the age of first increment deposition seems to be induced by different time of first feeding. Nevertheless, for practical purposes, two days must be added to the total growth increment number on each otolith analyzed in order to estimate the real age of the larvae.

Table II. Average percent error (APE) for age determination of larval *M. furnieri* reared in laboratory from day one to 29. The estimated age was calculated using the linear model (eq. 6) and the 95% confidence intervals (CI) are presented.

Age (days)	Expected increment number	APE	Estimated age (days ± CI)	*n*
1	0	37.50	-	5
2	0	14.29	-	4
3	1	37.04	3.02 (±0.13)	7
4	2	26.67	4.07 (±0.13)	8
5	3	10.00	5.11 (±0.15)	7
6	4	8.16	6.16 (±0.15)	9
7	5	12.04	7.20 (±0.16)	8
12	10	2.79	12.42 (±0.20)	8
19	17	1.91	19.73 (±0.26)	7
23	21	2.57	23.91 (±0.29)	6
25	23	4.86	26.00 (±0.30)	7
29	27	7.23	30.18 (±0.33)	6
	Average =	13.75		

Despite the fact that the age of first increment formation is apparently species specific, our results support the assumption made by Flores-Coto *et al*. (1998) that added two days to the total growth increment number for three sciaenid species, meaning that the time of first increment deposition is assumed to be about the third day after hatch. At a previous study Nixon & Jones (1997) added five days to the number of increments in otoliths of *M. undulatus* based on the conclusions presented for a co-family species (*L. xanthurus*). Considering the results presented here, for a co-gender species, the five days assumed by those authors could promote some underestimation on the estimated growth rates, particularly for the younger fishes.

In reference to age validation, the slope of the regression should be close to one since it is expected that one growth increment is deposited each day. Our results showed a slope of 1.044 (Fig. 4) which was significantly different from 1 when at a P-level of 0.05 or not significantly different at a P-level of 0.1 (*f*-test). This result highlights an important paradox based on the acceptance of a statistical result against a biological meaning. The difference from unity found at our study (0.04) has little biological importance and can only be clearly observed at advanced ages. If larger larvae and a wider age range than that used had been examined in our samples, probably the slope would be closer to unity and this difference would have not occurred.

There is a general acceptance for daily growth increment to occur on otoliths from larvae living in favourable environmental conditions (Campana & Neilson 1985), but it was suggested that starvation could disrupt the daily formation of increments (Method & Kramer 1979). According to Siegfried & Weinstein (1989) short periods of low food availability appear not to affect increment deposition in adults or large juveniles, but may change increment formation in otoliths of larval and early juvenile fish. Additionally, Campana *et al.* (1987) and Jones & Brothers (1987) argued that rough environmental conditions could induce the formation of narrower growth increments hardly resolved at common microscopy. In our experiment temperature, salinity and food were controlled and we do not believe that the experimental environment presented any restriction. Therefore, we conclude that in otoliths of *M. furnieri* larvae, increments deposition rate is one increment per day.

There are only few available studies assessing validation of daily growth increments in otoliths of Sciaenidae larvae. Our results reinforce studies developed for other Sciaenid species, as *Cynoscion nebulosus* (McMichael & Peters 1989), *L. xanthurus* (Siegfried & Weinstein 1989) and *Bairdiella chrysoura* (Hales & Hurley 1991) and strengthen the premise that otoliths of Sciaenid fish present daily growth increments during their entire larval stage. This is the case for most species in nature, when good otolith preparation techniques are used and good environmental conditions for growth are available.

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References

Albuquerque, C. Q., Muelbert, J. H. 2004. The use of haematoxylin stain to improve contrast of growth increments in otoliths of larval whitemouth croaker. **Journal of Fish Biology**, 64: 794-798.

Campana, S. E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. **Journal of Fish Biology**, 59: 197-242.

Campana S. E. & Mosksness, E. 1991. Accuracy and precision of age and hatch date estimates from otolith microstructure examination. **ICES Journal of Marine Sciences**, 48: 303-316.

Campana, S. E. & Neilson, D. 1985. Microstructure of fish otoliths. **Canadian Journal of fisheries and Aquatic Science**, 42: 1014-1032.

Campana, S. E., Gagne, A. J. & Munro, J. 1987. Otolith microstructure of larval herring (*Clupea harengus*): Image or reality? **Canadian Journal of fisheries and Aquatic Science**, 44: 1922-1929.

Chao, L. N. 1978. A Basis for Classifying Western atlantic Sciaenidae (Teleostei: Perciformes) **NOAA Technical report Circular - 415**, 64 p.

Cushing, D. H., 1988. The study of stock and recruitment. Pp. 105-128. *In*: Gulland, J.A. (Ed.). Fish Population Dynamics, 2nd ed. John Wiley, Chichester, 422p.

Ekau, W., & Blay, J. 2000. Validation of daily increment deposition and early development in the otoliths of *Sarotherodon melanotheron*. **Journal of Fish Biology**, 57: 1539-1549.

Flores-Coto, C., Sanches-Iturbe, A.F., Zavala-Garcia, F. & S. M. Warlen. 1998. Age, growth, mortality and food habitats of larval *Stellifer lanceolatus*, *Cynoscion arenarius* and *Cynoscion nothus* (Pisces: Sciaenidae), from the Southern Gulf of Mexico. **Estuarine, Coastal and Shelf Science**, 47: 593-602.

Haimovici, M., Pereira, S.D. & P. C. Vieira. 1989. La pesca demersal en el sur de Brasil en el perıodo 1975-1985. **Frente Marıtimo** 5(Sec A): 151-163.

Hales, L. S., & Hurley, D. H. 1991. Validation of daily increment formation in the otoliths of juvenile silver perch Bairdiella chrysoura. **Estuaries**, 14: 199-206.

Humphrey, C., Klumpp, D. W. & Pearson, R. G. 2005. Early development and growth of the eastern rainbowfish. *Melanotaenia splendida splendida* (Peters) II. Otolith development, increment validation and larval growth. **Marine and Freshwater Research**, 54: 105-111.

Hunter, J. R. 1981. Feeding ecology and predation of marine fish larvae. Pp 34-77. *In*: **Marine fish larvae: Morphology, ecology, and relation to fisheries**. Lasker, R. (Ed.). Washington Sea Grant Program. Univ.

Wash. Press Seattle, Washington. 310p.

Ibagy, A. S. & Sinque, C. 1995. Distribuição de ovos e larvas de Sciaenidae (Perciformes-Teleostei) na região costeira do Rio Grande do Sul. **Arquivos de Biologia e Tecnologia**, 38: 249-270.

Jaureguizar, J. A., Ruarte, C. and Guerrero, R. 2006. Distribution of age-classes of striped weakfish (*Cynoscion guatucupa*) along an estuarine-marine gradient: Correlations with the environmental parameters. **Estuarine Coastal and Shelf Science**, 67: 82-92.

Jones, C. & Brothers, E. 1987. Validation of the otolith increment aging technique for striped bass, *Morone saxatilis*, larvae reared under suboptimal feeding conditions. **Fishery Bulletin**, 85: 171-178.

Laroche, J. L, Richardson, S. & Rosemberg, A. A. 1982. Age and growth of a pleuronectid, *Parophrys vetulus*, during the pelagic period in Oregon coastal waters. **Fishery Bulletin**, 80: 93-105.

Method, R. D. & Kramer, D. 1979. Growth of the northern anchovy, *Engraulis mordax* in the sea. **Fishery Bulletin**, 77: 413-423.

McMichael, R. H. & Peters, K. M. 1989. Early life history of spotted seatrout, *Cynoscion nebulosus* (Pisces: Sciaenidae), in Tampa Bay, Florida. **Estuaries**, 12: 98-110.

Moku, M., Hayashi, A., Mori, K. & Watanabe, Y. 2005. Validation of daily otolith increment formation in the larval myctophid fish *Diaphus* slender-type spp. **Journal of Fish Biology**, 65: 1481-1485.

Morley, S. A., Belchier, M., Dickson, J. & Mulvey, T. 2005. Daily otolith increment validation in larval mackerel icefish, *Champsocephalus gunnari*. **Fisheries Research** 75: 200-2003.

Muelbert, J. H. & Weiss, G. 1991. Abundance and distribution of fish larvae in the channel area of Patos Lagoon estuary, Brazil. **NOOA Technical Report NMFS** 95: 43-54.

Nakaya, M., Moriokaa, T., Fukunaga, K., Sekiya, S., Jinbob, T., Nagashimac H. & Ueno, Y. 2008. Validation of otolith daily increments for larval and juvenile Japanese halfbeak *Hyporhamphus sajori*. **Fisheries Research**, 93: 186-189.

Nixon, W. S. & Jones, C. M. 1997. Age and growth of larval and juvenile Atlantic croaker *Micropogonias undulatus*, from the Middle Atlantic Bight and estuarine waters of Virginia. **Fishery Bulletin** 95: 773-784.

Paiva, M. P. 1997. **Recursos pesqueiros estuarinos e marinhos do Brasil**. EUFC. Fortaleza. 287p.

Peñaillo, J. & Araya, M. 1996. Momento de formación y periodicidad de los microincrementos de crecimiento en otolitos de larvas de pejerrey (*Austromenidia regia*) mantenidas en laboratorio. **Investigaciones Marinas**, 24: 31-38.

Power, M., Attrill, M.J. & Thomas, R. M. 2000. Temporal abundance and growth of juvenile herring and sprat from the Thames estuary 1977 – 1992. **Journal of Fish Biology**, 56: 1408-1426.

Radtke, R. & Fey, D.P. 1996. Environmental effects on primary increment formation in the otoliths of newly-hatched Arctic charr. **Journal of Fish Biology**, 48: 1238-1255.

Ricker, W.E. 1979. Growth rates and models. Pp. 677-743. *In*: Hoar, W.S., Randall, D.J., Brett, J.R. (Eds.), **Fish Physiology**. Academic Press, London, 686p.

Rooker, J. R., Holt, S. A., Holt G. J., & Fuiman, L. A. 1999. Spatial and temporal variability in growth, mortality, and recruitment potential of postsettlement red drum, *Sciaenops ocellatus*, in a subtropical estuary. **Fishery Bulletin**, 97: 581-590.

Secor, D. H., Dean, J. M. & Laban, E. H. 1991. **Manual for otolith removal and preparation for microstructural examination**. Electric Power Research Institute and the Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Columbia.

Siegfried, R. C. & Weinstein, M. P. 1989. Validation of daily increment deposition in the otoliths of Spot (*Leiostomus xanthurus*). **Estuaries**, 12: 180-185.

Vasconcelos, M., Haimovici, M. 2006. Status of white croaker *Micropogonias furnieri* exploited in southern Brazil according to alternative hypotheses of stock discreetness. **Fisheries Research**, 80: 196-202.

Zar, J. H. 1984. **Biostatistical analysis**. Prentice-hall. New Jersey. 718p.

Zweifel, J.R. & Lasker, R. 1976 Prehatch and posthatch growth of fishes-a general model. **Fishery Bulletin**, 74: 609-621.

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Scientific Note

Registro da predação de girinos de rã touro (*Lithobates catesbeianus*) pelo biguá (*Phalacrocorax brasilianus*) no estuário da Laguna dos Patos, Rio Grande do Sul, Brasil

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Abstract: Record of predation of tadpoles of bullfrog (*Lithobates catesbeianus*) by biguá (*Phalacrocorax brasilianus*) in the estuary of the Patos Lagoon, Rio Grande do Sul, Brazil. We report here the predation of tadpoles of the bullfrog (*Lithobates catesbeianus*) by biguá in the estuary of the Patos Lagoon.

Keywords: exotic species, environmental impact, *Lithobates catesbeianus, Phalacrocorax brasilianus*.

Resumo: Registramos aqui a predação de girinos da rã touro (*Lithobates catesbeianus*) pelo biguá (*Phalacrocorax brasilianus*) no estuário da Laguna dos Patos.

Palavras-chave: espécie exótica, impacto ambiental, *Lithobates catesbeianus, Phalacrocorax brasilianus*.

A invasão de espécies exóticas pode afetar seriamente a biodiversidade de um determinado local, causando impactos ecológicos por competição, predação, propagação de doenças e até hibridizações, sendo considerada uma das maiores causas da perda de diversidade e extinção em escala global (Wilson 1988; Mack *et al*. 2000).

A rã touro *Lithobates castebeianus* (Shaw 1802) é um anfíbio da ordem Anura da família Ranidae, cuja distribuição original ocorre no sul do Canadá, sul e leste dos Estados Unidos até o golfo do México (Hecnar & M'Closkey 1997, Ficetola *et al*. 2007), mas no último século foi introduzida em mais de 40 países em quatro continentes em virtude da sua utilização no controle biológico, na aquacultura e ornamentação (Jennings & Hayes 1985, Lever 2003, Barraso *et al.* 2009). No Brasil a *L. catesbeianus* ocorre principalmente em áreas de Mata Atlântica, mas existem registros de sua introdução desde a região Nordeste até o Uruguai, área considerada altamente suscetível à introdução desta espécie em virtude das características climáticas e hidrológicas (Ficetola *et al.* 2007, Giovanelli *et al.* 2008, Laufer *et al.* 2008, Instituto Hórus 2009).

A introdução da rã touro é considerada uma das maiores responsáveis pelo declínio global das populações de anfíbios (Fisher & Shafer 1996, Alford & Richards 1999, Blaustein & Kiesecker 2002) e de várias outras espécies de vertebrados e invertebrados (Kats & Ferrer 2003, Wylie *et al.* 2003, Boelter 2004, Hirai 2004, Bühler & Barros 2007), entretanto, são poucos estudos que destaquem potenciais predadores desta espécie (Smith *et al.* 1999).

O biguá *Phalacrocorax brasilianus* (Gmelin 1789) é uma ave de hábitos aquáticos, sendo encontrada da Tierra del Fuego, Patagônia, Argentina até a costa do Texas, E.U.A. (Del Hoyo *et al.* 1992). Alimenta-se principalmente de peixes, entretanto, ocorrem alterações temporárias na dieta em termos de itens alimentares, abundância e tamanho de presas, revelando uma elevada plasticidade alimentar (Silva 2006, Barquete *et al.* 2008).

No dia 22 de outubro de 2008, três girinos de rã touro (Fig. 1) foram regurgitados por um exemplar de biguá em um trapiche localizado às margens do estuário do Saco do Justino, Laguna dos Patos, município de Rio Grande, Rio Grande do Sul, Brasil (32º01'40" S 52º05'40" W) (Fig. 2 e 3). Os girinos foram coletados logo após o bando, constituído apenas por biguás, abandonar o local. Os exemplares foram fotografados, fixados em formalina 10% e posteriormente transferidos para álcool 70%.

Figura 1. Regurgito do biguá (*Phalacrocorax brasilianus*) contendo três girinos de rã touro (*Lithobates catesbeianus*) encontrado no trapiche do Saco do Justino, estuário da Laguna dos Patos.

No entorno do estuário na Laguna dos Patos existem diversos cultivos de peixes, principalmente policultivo de carpas. Os peixes que povoam esses tanques são oriundos de diversos locais do Estado (principalmente da região Central e Norte), onde já há registro da introdução de rã touro nos ecossistemas naturais (Boelter 2004, Ficetola *et al.* 2007, Instituto Hórus 2009). Nesta região, muitos tanques de cultivo onde são produzidos alevinos também são habitados pela rã touro, que se reproduzem nestes locais. Muitas vezes ao comprar alevinos destas regiões, involuntariamente são capturados, juntamente com os alevinos, girinos de rã touro, que são transportados e conseqüentemente liberados junto com estes nos tanques de cultivo, sem que se realize uma triagem antes da soltura (Graeff *et al*. 2001). Além disso, o incorreto manejo realizado em ranários possivelmente esteja contribuindo para a introdução e propagação da rã touro na região.

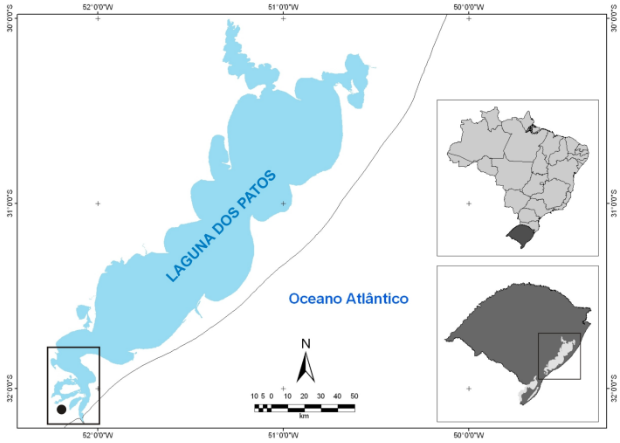

Figura 2. Localização da área do estuário do Saco do Justino, onde foi registrado o regurgito contendo os três girinos de *Lithobates catesbeianus* na Laguna dos Patos, município de Rio Grande, Rio Grande do Sul, Brasil. Autor: H. P. B. Neto. Fonte: Modificado de IBGE 2003 e Fepam 2005.

Barquete *et al.* (2008), em estudo realizado na desembocadura do estuário da Laguna dos Patos, fizeram a análise de 287 regurgitos de *P. brasilianus* e 97% deles eram constituídos por peixes, não tendo encontrado girinos entre os itens alimentares da ave. Entretanto, pela proximidade de tanques de cultivos e pequenos banhados (ambientes que por serem lênticos proporcionam ótimo local para reprodução e criação da rã touro) ao estuário do Saco do Justino, é comum encontrar biguás forrageando nesses locais. Possivelmente o biguá alimentou-se em uma área úmida adjacente ao estuário e buscou repouso junto ao bando no trapiche (Fig. 3), onde foi encontrado o regurgito.

Figura 3. Trapiche onde foi encontrado o regurgito, com bando de biguás pousados, localizado no Saco do Justino, estuário da Laguna dos Patos, município de Rio Grande.

Atualmente exemplares adultos da rã touro já são encontrados no entorno do estuário do Saco do Justino, assim como girinos (J. A. A. Xavier com. pess.), o que evidencia a introdução e a reprodução da espécie nos ecossistemas da região. O regurgito do biguá contendo os três girinos de *L. catesbeianus* representa o primeiro registro da espécie para o município de Rio Grande e o seu ponto de ocorrência mais austral no Brasil.

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Referências Bibliográficas

Alford, R. A. & Richards, S. J. 1999. Global amphibian declines: a problem in applied ecology. **Annual Review of Ecology and Systematics**, 30: 133–165.

Barquete, V., Bugoni, L. & Vooren, C. M. 2008. Diet of neotropic cormorant (*Phalacrocorax brasilianus*) in an estuarine environment. **Marine Biology**, 153: 431–443.

Barrasso, D. A., Cajade, R., Nenda, S. J., Baloriani G. & Herrera R. 2009. Introduction of the American Bullfrog *Lithobates catesbeianus* (Anura: Ranidae) in Natural and Modified Environments: An Increasing Conservation Problem in Argentina. **South American Journal of Herpetology**, 4(1):69-75.

Blaustein, A. R. & Kiesecker, J. M. 2002. Complexity in conservation: lessons from the global decline of amphibian populations. **Ecology Letters**, 5: 1–12.

Boelter, R. A. 2004. Predação de anuro nativas pela rã touro (*Rana catesbeiana*: Ranidae) no sul do Brasil. **Dissertação de mestrado**. Universidade Federal de Santa Maria, RS, Brasil, 36 p.

Bühler, D. & Barros, M. P. 2001. Registro da predação de *Lithobates catesbeianus* (Shaw 1802) (Amphibia, Anura, Ranidae) sobre *Parastacus brasiliensis* (Von Martens 1869) (Crustacea, Decapoda, Parastacidae), Rio Grande Do Sul, Brasil. **Biociências**, Porto Alegre, 15(2): 271-273.

Del Hoyo, J., Elliott, A. & Sargatal, J. 1992. **Handbook of the birds of the world**. Lynx Edicions, Barcelona, V. 6, 759 p.

Ficetola, G. F., Thuiller, W. & Miaud, C. 2007. Prediction and validation of the potential global distribution of a problematic alien invasive species the American bullfrog. **Diversity and Distributions**, 13: 476–485.

Fisher R. N. & Shaffer H.B. 1996. The decline of amphibians in California's Great Central Valley. **Conservation Biology,** 10: 1387–1397.

Graeff, A., Pruner, E. N. & Spengler, M. M. 2001. Efeito da Niclosamida no Controle de Girinos de Anuros na Propagação de Pós-Larvas de Carpa Comum (*Cyprinus carpio* Linnaeus 1758 Var. Specularis). **Revista Brasileira de Zootecnia**, 30(6): 1664-1669.

Giovanelli, J. G. R., Haddad, C. F. B. & Alexandrino, J. 2008. Predicting the potential distribution of the alien invasive American bullfrog (*Lithobates catesbeianus*) in Brazil. **Biological Invasions**, 10: 585-590.

Hecnar, S. J. & M'Closkey, R. T. 1997. Changes in the composition of a ranid frog community following bull-frog extinction. **American Midland Naturalist**, 137: 145-150.

Hirai T. 2004. Diet composition of introduced bullfrog, *Rana catesbeiana*, in the Mizorogaike Pond of Kyoto, Japan. **Ecological Research**, 19: 375-380.

Instituto Hórus (2009) Base de dados de espécies exóticas invasoras no Brasil. **http://www.institutohorus.org.br/.** Citado em 23 Junho de 2009.

Jennings, M. R. & Hayes, M. P. 1985. Pre-1900 overharvest of California red-legged frogs (*Rana aurora draytonii*): the inducement for bullfrog (*Rana catesbeiana*) introduction. **Herpetologica**, 41: 94–103.

Kats L. B. & Ferrer R. P. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. **Diversity and Distributions**. 9: 99-110.

Lever, C. 2003. **Naturalized amphibians and reptiles of the world**. Oxford University Press, New York, 280 p.

Laufer G., Canavero A., Nunes D. & Maneyro R. 2008. Bullfrog (*Lithobates catesbeianus*) invasion in Uruguay. **Biological Invasions**, 10: 1183–1189.

Mack, R. N.; Simberloff, D.; Lonsdale, W. M.; Evans, H.; Clout, M. N. & Bazzazz, F. 2000. Biotic invasions: causes, epidemiology, global consequences and control. **Issues in Ecology**, 5: 1-20.

Silva, R. R. V. 2006. Estrutura de uma comunidade de aves em Caxias do Sul, Rio Grande do Sul, Brasil. **Biociências**, Porto Alegre, 14 (1): 27-

36.
Smith, G. R., Rettig, J. E. & Mittelbach, G. G. 1999. The effects of fish on assemblages of amphibians in ponds: a field experiment. **Freshwater Biology**, 41: 829–837.
Wilson, E. O. 1988. The current state of biological diversity. Pp 3-18. In: E. O. Wilson (Ed.), **Biodiversity.** Washington, DC: National Academic Press. 538 p.
Wylie G., Casazza L. M. & Carpenter M. 2003. Diet of bullfrog in relation to predation on giant garter sanques at Colusa National Wildlife Refuge. **California Fish and Game**, 89: 139-145.

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Biologia populacional de *Serrapinnus notomelas* (Eingenmann, 1915) (Characiformes, Cheirodontinae) em um riacho de primeira ordem na bacia do rio Dourados, Alto rio Paraná

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Abstract: **Population biology of *Serrapinnus notomelas* (Characiformes Cheirodontinae) in a first order stream of the Dourados river, Upper Paraná River.** In the present study we analyzed the length/weight relationship, growth parameters, mortality, recruitment and we evaluated the influence of the seasonal variation on the individuals weight and recruitment pattern in the Chico Viégas stream, Mato Grosso do Sul. The samplings were accomplished monthly from october/2006 to september/2007, with a rectangular sieve of metallic frame (1.2 x 0.8 m) with 2 mm mesh size, in a portion of approximately 200 meters. We collected 464 individuals, varying from 12 to 34 mm of standard length. The equation that describes the length/weight relationship is: Total Weight=0.00000077*Standard Lenght$^{3.83}$. The asymptotic length estimated to *S. notomelas* was of 35.8 mm and the condition factor presented larger values in the spring and summer and the recruitment varying seasonally, with larger values in the autumn and winter. The growth rate for *S. notomelas* was elevated (k=1.05), also the natural mortality (Z=1.61), while the longevity was low (2.85 years). We observed that the species presented positive alometric growth, with seasonal influence in the recruitment, and condition factor.

Key-Words: Populational ecology, Fishes, Growth parameters, Seasonality, Recruitment, Mortality.

Resumo: No presente trabalho analisamos a relação peso/comprimento, parâmetros de crescimento, mortalidade, recrutamento e avaliamos a influência da variação sazonal sobre o peso dos indivíduos e padrão de recrutamento no córrego Chico Viegas, Mato Grosso do Sul. As amostragens foram realizadas mensalmente de outubro/2006 a setembro/2007, com uma peneira retangular de armação metálica (1,2 x 0,8 m) confeccionada com tela mosquiteiro (2 mm de abertura de malha), em um trecho de aproximadamente 200 metros. Coletamos 464 indivíduos, variando entre 12 e 34 mm de comprimento padrão. A equação que descreve a relação peso total/comprimento padrão é: Peso=0,00000077*Comprimento Padrão^{3,83}. O comprimento assintótico estimado para *S. notomelas* foi de 35,8 mm e o fator de condição apresentou maiores valores na primavera e verão e o recrutamento variando sazonalmente foi maior no outono e inverno. A taxa de crescimento para *S. notomelas* foi elevada (k=1,05), assim como a taxa de mortalidade natural (M=1,61), enquanto a longevidade foi baixa (2,85 anos). Sendo assim, observou-se que a espécie apresentou crescimento alométrico, com influência sazonal no recrutamento e fator de condição.

Palavras-Chave: Ecologia populacional, Peixes, Parâmetros de crescimento, Sazonalidade, Rrecrutamento, Mortalidade.

Introdução

A diversidade de espécies da ictiofauna neotropical, estimada em cerca de 8000 espécies (Vari & Malabarba, 1998; Lundberg *et al*. 2000), com cerca de 4500 já conhecidas (Lévêque *et al.* 2008), e com grande diversificação de grupos funcionais ainda é um dos grandes desafios da ictiologia, sendo que muitas espécies, principalmente de pequeno porte, são praticamente desconhecidas, tanto do ponto de vista taxonômico, quanto de suas características biológicas.

A ordem Characiformes é o grupo de peixes neotropicais com maior diversidade de espécies (Lévêque *et al.* 2008), formas e comportamentos, com mais de 1500 espécies descritas até o momento. Apesar da sub-família Cheirodontinae ser um dos grupos de Characidae mais bem conhecidos, em termos de filogenia e taxonomia (Malabarba, 2003; Hirano & Azevedo, 2007; Bührnheim *et al.* 2008), o número de estudos analisando aspectos da ecologia ainda é escasso.

Entre os estudos realizados sobre aspectos da biologia de espécies de Cheirodontinae destacam-se os realizados na região sul do Brasil. Gelain *et al.* (1999) analisaram a biologia reprodutiva de *Serrapinnus calliurus* no arroio Ribeiro (RS); Oliveira *et al.* (2002) analisaram o período de desova e fecundidade de *Cheirodon ibicuhiensis*, também no arroio Ribeiro (RS); Silvano *et al.* (2003) analisaram a fecundidade e período reprodutivo de *Serrapinnus piaba* no rio Ceará Mirim, (RN); Hirano & Azevedo (2007) analisaram a alimentação de *Heterocheirodon yatai* na bacia do rio Uruguai.

Diversos autores têm estudado espécies de pequeno porte na bacia do Alto Rio Paraná (Braga & Gennari-Filho 1990, Garutti & Figueiredo-Garutti 1992; Giamas *et al.* 1992; Benedito-Cecilio *et al.* 1997; Lizama & Ambrosio 1999; 2002; Piana *et al.* 2006), no entanto, poucos trabalhos foram realizados em riachos com espécies de Cheirodontinae. Ainda que, para *Serrapinnus notomelas* destacam-se alguns trabalhos, tais como os de Lizama & Ambrosio (1999, 2002) sobre a relação peso/comprimento e fator de condição na planície alagável do rio Paraná, bem como o trabalho de Piana *et al.* (2006) quantificando a importância de características bióticas e abióticas sobre a densidade populacional de *S. notomelas*, na planície de inundação do rio Paraná. Por outro lado, Súarez *et al.* (2007) quantificaram a importância das características hidrológicas sobre a ocorrência de *S. notomelas* e constataram que esta espécie tem preferência por locais com baixa velocidade da correnteza e profundidade. Lourenço *et al.* (2008) analisaram aspectos da relação peso/comprimento, mortalidade e recrutamento em riachos da porção inferior do rio Ivinhema.

Desta forma, à despeito da ampla distribuição das espécies de Cheirodontinae os estudos das características populacionais destas espécies se restringe basicamente à alimentação e sazonalidade da reprodução e na bacia do rio Paraná restringem-se basicamente à planície alagável dos grandes rios. Assim, para melhor compreensão do papel das características ambientais sobre a ecologia destas espécies, que estão entre as mais comuns nos riachos da bacia do rio Paraná-MS, ainda são necessários mais estudos. O presente trabalho tem como objetivo fornecer informações sobre a estrutura em comprimento, a relação peso total/comprimento padrão, parâmetros de crescimento, mortalidade e analisar a influência da variação sazonal da precipitação sobre o peso médio dos indivíduos e o padrão de recrutamento em um riacho de primeira ordem na bacia do rio Dourados, Alto Rio Paraná, Mato Grosso do Sul.

Material e Métodos

As coletas foram realizadas mensalmente no córrego Chico Viégas, Dourados-MS (Fig. 1) entre outubro/2006 e setembro/2007, realizadas com uma peneira retangular de armação metálica (1,2 x 0,8 m) confeccionada com tela mosquiteiro (2 mm de abertura de malha), as amostragens foram realizadas no período diurno em um trecho de aproximadamente 200 m. O trecho amostrado encontra-se na área peri-urbana da cidade de Dourados, sem vegetação ciliar e com predomínio de gramíneas em suas margens e o esforço de amostragem não foi padronizado, visando obter número suficiente de indivíduos em todos os meses, mesmo quando a densidade da espécie era baixa.

Em campo, os peixes foram fixados em formol a 10% e posteriormente foram levados ao laboratório e transferidos para álcool 70% para preservação e posterior obtenção do peso em balança analítica e do comprimento padrão, utilizando paquímetro com precisão de 1 mm.

A relação peso total/comprimento padrão para *S. notomelas* foi obtida através do ajuste de um modelo de regressão não-linear, bem como o intervalo de confiança para o coeficiente angular “b” da regressão.

O comprimento assintótico foi estimado a partir do maior individuo capturado utilizando a equação de Pauly (1983): $L\infty = L_{\max} / 0,95$. O valor estimado da taxa de crescimento (k) foi obtido utilizando-se o método ELEFAN I (Eletronic Lengths-Frequency Analysis) (Pauly & David, 1981), inserido no programa FISAT.

O índice de performance de crescimento (φ) foi obtido para a espécie através da equação proposta por Pauly & Munro (1984): $\varphi = \log k + 2 \log L\infty$ enquanto a longevidade foi estimada segundo a equação proposta por Taylor (1958): $t\max = to + 2,996 / k$.

A mortalidade total (Z) aqui definida como igual à mortalidade natural (M), foi obtida segundo a fórmula empírica de Pauly (1980) que utiliza a informação dos parâmetros de crescimento (L∞ e k) e a temperatura média (°C) do ambiente em que a espécie foi coletada

$$\ln M = -0{,}0152 - 0{,}279 \ln L\infty + 0{,}6543 \ln k + 0{,}463 \ln T°C.$$

Com o objetivo de analisar a influência da variação temporal sobre o peso dos indivíduos, foi realizada uma análise de variância do fator de condição (variável resposta) em função do mês da amostragem (variável explanatória). O fator de condição foi obtido através da equação FC=Peso total/Comprimento padrão^b.

O padrão de recrutamento foi obtido através da distribuição de freqüência bimestral de comprimento padrão e dos parâmetros de crescimento (L∞ e k) estimados para a espécie, e para tal utilizou-se a rotina incluída no FISAT (Gayanilo & Pauly, 1997).

Tanto os dados de fator de condição ao longo do ano quanto o padrão de recrutamento foram contrastados graficamente com os dados de pluviosidade acumulada mensal, temperatura média do ar e comprimento do dia (horas com sol), com dados fornecidos pela EMBRAPA/CPAO.

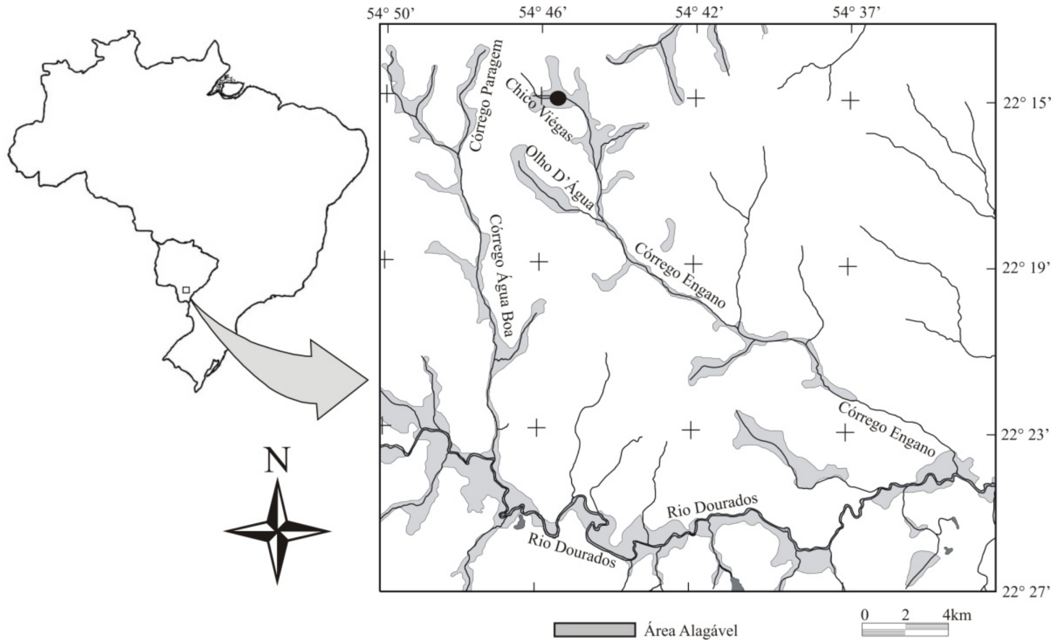

Figura 1. Mapa com a localização da área de estudo no córrego Chico Viégas, Bacia do rio Dourados, Alto rio Paraná, MS

Resultados

Foram obtidos dados de peso e comprimento de 464 indivíduos de *Serrapinnus notomelas*. O número de indivíduos coletados variou ao longo do ano, com menor número de indivíduos coletados no período seco (Média$_{(\text{outubro-março})}$=61,2±49,5; Média$_{(\text{abril-setembro})}$=16,2±8,1), apesar do aumento no esforço de captura. O comprimento padrão médio foi 26,2 mm (dp=4,31), variando entre 12 e 34 mm. O peso total médio foi 0,24 g (dp=0,14), variando entre 0,005 e 0,736g (Fig. 2).

Utilizando os dados de comprimento padrão, foi possível prever com precisão de 81,1% o peso dos indivíduos, sendo que o modelo gerado para *S. notomelas* foi Peso total=0,00000077*Comprimento padrão^{3,83}, como o intervalo de confiança estimado para o coeficiente angular da regressão variou entre 3,60 e 4,06 (α=0,05) constatou-se que a população estudada apresenta crescimento alométrico positivo (Fig. 3).

Estimou-se o comprimento assintótico para *S. notomelas* em 35,8 mm, enquanto a mortalidade natural (Z) foi estimada em 1,61 ano^{-1} e taxa de crescimento (k) em 1,05 ano^{-1} com longevidade estimada em 2,85 anos. O Índice de performance de crescimento (φ) calculado para *S. notomelas* foi de 3,129.

Constatou-se, através da análise de variância, que existe influência significativa da variação sazonal, sobre o fator de condição de *S. notomelas* (r^2=0,438; $F_{11,452}$=32,01; P<0,001), sendo que o fator de condição apresenta os maiores valores no início do período de seca (Abril a Junho). O pico de recrutamento para *S. notomelas* também ocorreu no mesmo período (Fig. 4), sugerindo maior intensidade na reprodução e, sendo assim, o aumento de peso indica o maior desenvolvimento gonadal, acompanhado da entrada de juvenis na população.

Através da analise gráfica da variação no fator de condição e do padrão de recrutamento constatamos que ambos os parâmetros populacionais apresentaram correlação com a pluviosidade, sendo que ambos aumentaram no final do período chuvoso e com redução de temperatura e comprimento do dia.

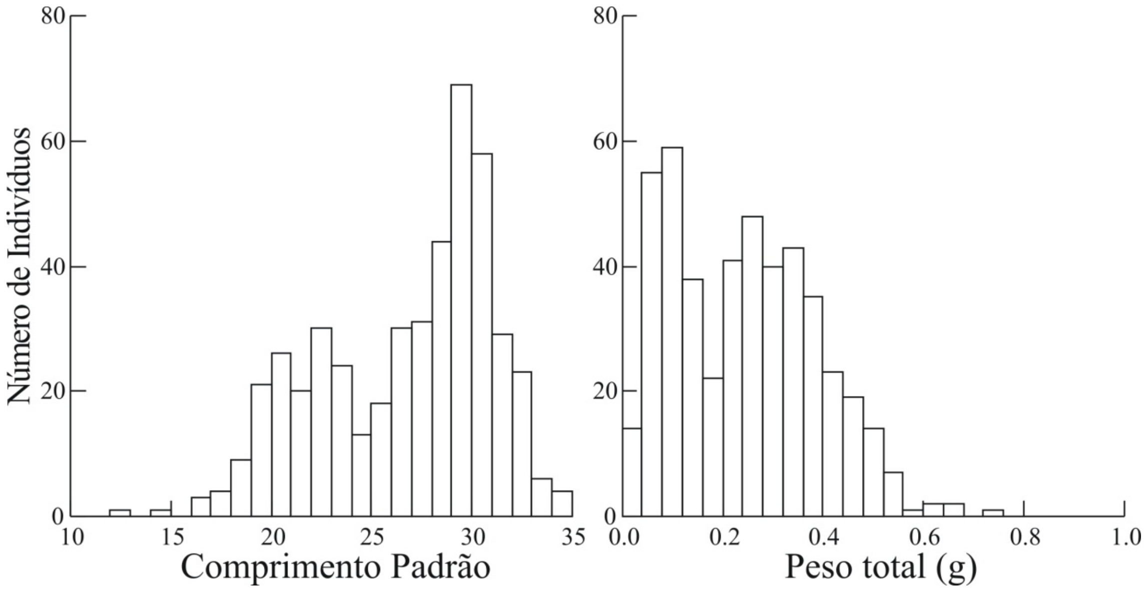

Figura 2. Histograma de freqüência para comprimento padrão (mm) e peso total (g) para *S. notomelas* no córrego Chico Viégas no período de outubro/2006 a setembro/2007.

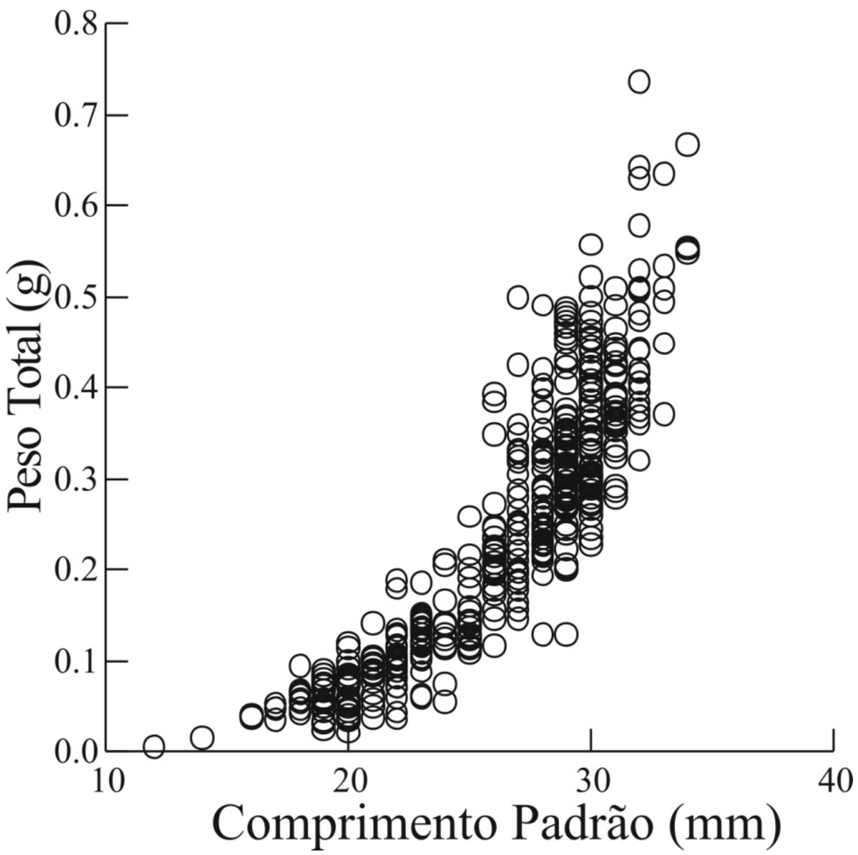

Figura 3. Relação Peso total/Comprimento padrão para *S. notomelas* no córrego Chico Viégas no período de outubro/2006 a setembro/2007.

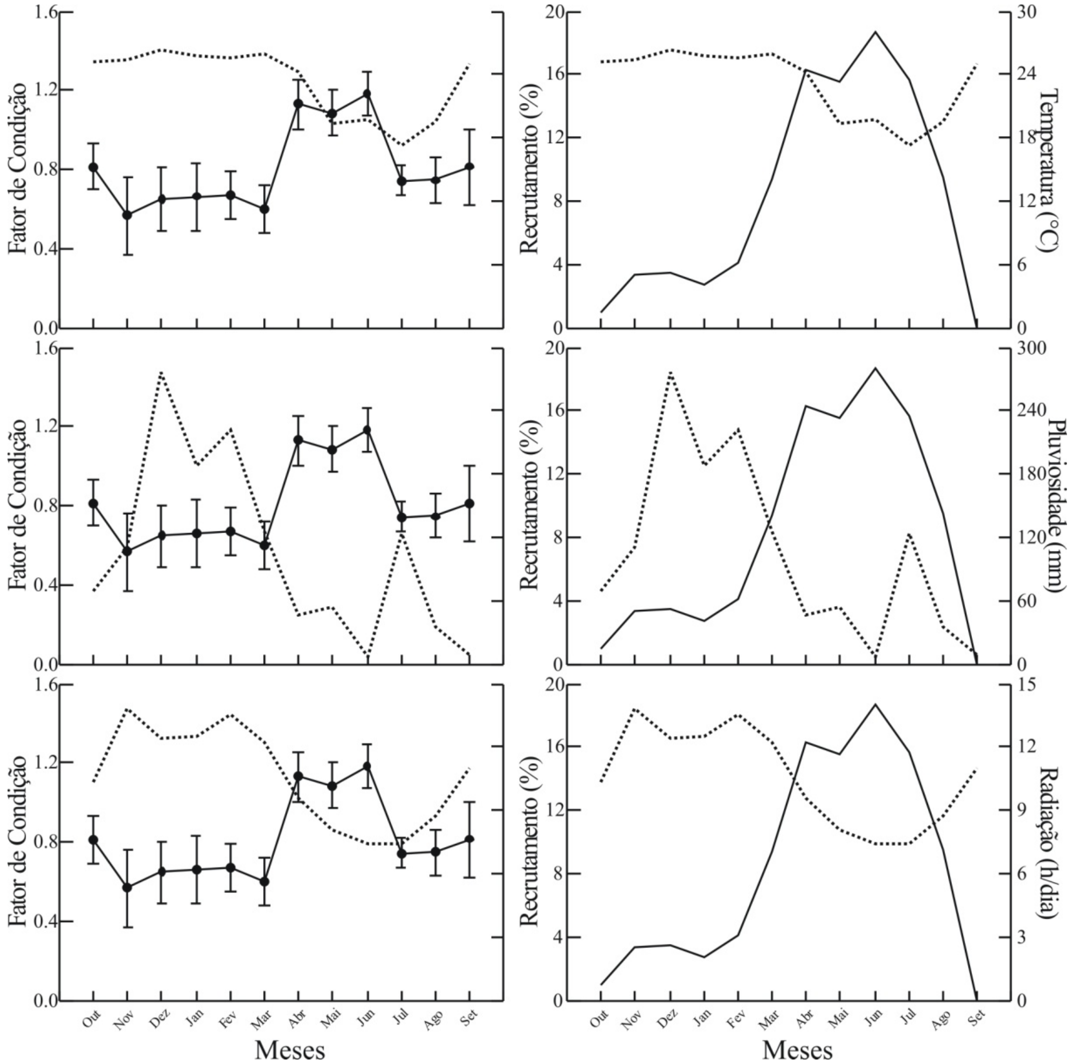

Figura 4. Relação entre o fator de condição (*1.000.000) e o recrutamento de *S. notomelas* com a temperatura média do ar (°C), pluviosidade acumulada mensal (mm) e tempo médio diário de radiação entre outubro/2006 e setembro/2007 no córrego Chico Viégas, Alto rio Paraná, MS.

Discussão

A estrutura em comprimento de uma população varia devido ao regime de recrutamento e mortalidade dos indivíduos. As alterações na estrutura em comprimento podem resultar do efeito das variáveis abióticas e bióticas na taxa de natalidade e sobrevivência de cada população (Gurgel 2004), da variação dos atributos ambientais, que determina o estado nutricional da população (Bagarinão & Thayaparam 1986).

Lizama & Ambrósio (1999) estimaram, na planície de inundação da bacia do rio Paraná, que *S. notomelas* apresentava o coeficiente angular da regressão “b” igual a 3,09, menor do que encontrado no presente estudo. Resultado similar foi encontrado por, Lourenço *et al.* (2008), em riachos da porção inferior da bacia do rio Ivinhema, onde o valor estimado foi de 3,08.

Assim, ambos os trabalhos, e nossos dados, mostram que esta espécie apresenta crescimento alométrico positivo, o que é relativamente esperado dado o fato desta ser uma espécie forrageira, que deve alcançar o comprimento máximo o mais rápido possível visando minimizar a chance de serem predados (Reznick *et al.* 1996). Contudo, no presente estudo constatamos que a população analisada apresenta maior taxa de mortalidade e taxa de crescimento, bem como uma menor longevidade. Strauss (1990) analisando a influência das características ambientais e da intensidade da predação sobre os parâmetros de história de vida de *Poecilia reticulata* constatou que a elevada predação influenciou significativamente as características das populações analisadas, bem como a variabilidade ambiental. Neste sentido é plausível supor que diferenças hidrológicas entre as porções média e inferior da bacia do rio Ivinhema, como temperatura, variabilidade na vazão, características físicas e químicas da água, possam interferir nas características populacionais avaliadas, diminuindo a longevidade e conduzindo a uma maior taxa de crescimento e mortalidade para a população analisada. Assim, considerando a ampla distribuição desta espécie na bacia do Alto Rio Paraná, é esperado que esta apresente uma razoável plasticidade fenotípica, o que permite que diferentes sub-populações expressem diferenças nos estimadores dos parâmetros populacionais, como resultado de diferenças nas características hidrológicas entre as regiões estudadas.

Durante as amostragens, duas espécies predadoras foram coletadas, sendo *Hoplias malabaricus* e *Crenicichla britskii*, o que, considerando o baixo volume do riacho amostrado permite sugerir que a taxa de predação sobre a população estudada deva ser elevada, corroborando a hipótese de rápido crescimento como estratégia de maximização do sucesso reprodutivo. De forma complementar, outra explicação para a elevada taxa de crescimento e mortalidade para a população estudada é a imprevisibilidade ambiental (estocasticidade) do riacho amostrado, uma vez que normalmente riachos de cabeceira são sujeitos a variações abruptas nas suas características hidrológicas, o que influencia inúmeras características evolutivas das comunidades de peixes (Castro, 1999) e poderia influenciar a dinâmica populacional das espécies aquáticas residentes e principalmente *S. notomelas*, dada a sua predileção por ambientes mais calmos, ou seja, menor velocidade da correnteza e menor profundidade (Súarez *et al.* 2007).

O claro padrão sazonal no fator de condição para a população estudada de *S. notomelas*, pode ser resultado da sua predileção por menores valores de velocidade da correnteza (Súarez *et al.* 2007), que atuaria com maior intensidade sobre os juvenis, assim a concentração da reprodução neste período poderia maximizar o sucesso reprodutivo, por minimizar a mortalidade nos primeiros estágios de desenvolvimento dos juvenis.

Como o pico de recrutamento também ocorre neste período, é provável que, apesar da redução do número de indivíduos, ocorra a interação entre a reprodução e a colonização do trecho amostrado por indivíduos juvenis provenientes de ambientes mais favoráveis à jusante, em pequenas área de planície alagável, muito comuns nos riachos da região.

Lizama & Ambrósio (2003) evidenciaram que o recrutamento de *Moenkhausia intermedia* é continuo e presente durante todo o ano, na planície de inundação do rio Paraná, embora ocorram períodos de maiores intensidades. Este padrão de recrutamento observado é característico de espécies de pequeno porte que habitam ambientes de água doce em regiões tropicais. Além disso, os picos de recrutamento na sua grande maioria coincidem com o período de mudança no nível da água, o que é condizente com nossos resultados.

Na porção inferior do rio Ivinhema, Lourenço *et al.* (2008) também constataram maior recrutamento de *S. notomelas* no período com menor pluviosidade, porém com dois picos no ano, uma vez que o mês de abril apresentou um pico de pluviosidade que diminuiu o recrutamento. Desta forma, a hipótese de correlação negativa entre a pluviosidade e recrutamento é corroborada mais uma vez.

Desta forma, o presente trabalho sugere que no Córrego Chico Viégas, Alto Rio Paraná, *S. notomelas* apresenta crescimento alométrico positivo, maior taxa de crescimento e de mortalidade, quando comparado às porções inferiores da bacia, e clara variação sazonal no fator de condição e no padrão de recrutamento. Estes resultados parecem refletir alguns aspectos básicos da biologia da espécie: 1) Alta taxa de crescimento como estratégia de compensação da elevada taxa de mortalidade e baixa longevidade, possivelmente como decorrência da predação ou de eventos estocásticos sobre a população e 2) A variação no fator de condição e no padrão de recrutamento pode ser uma resposta à maior fragilidade dos juvenis à elevada velocidade da correnteza e a entrada de indivíduos juvenis na população, indicando ou a atividade reprodutiva neste período ou a colonização por juvenis provenientes de trechos a jusante.

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Referências Bibliográficas

Bagarinão, T. & Thayaparan, K. 1986. The length-weight relationship, food habitats and condition factor of wild juvenile milkfish in Sri Lanka. **Aquaculture**, 55: 241-246.

Benedito-Cecilio, E., Agostinho, A. A. & Carnelos-Machado Velho, R. C. 1997. Length/weight relationship of fishes caught in the Itaipu reservoir Paraná, Brasil. **Naga**, 20(3-4): 57-61.

Braga, F. M. S. & Gennari-Filho, O. 1990. Contribuição para o conhecimento da reprodução de *Moenkhausia intermedia* (Characidae, Tetragonopterinae) na represa de Barra Bonita, rio Piracicaba, SP. **Naturalia**, 15: 171-188.

Bührnheim, C. M., Carvalho, T. P., Malabarba, L. R. & Weitzman, S. W. 2008. A new genus and species of characid fish from the Amazon basin - the recognition of a relictual lineage of characid fishes. **Neotropical Ichthyology**, 6: 663-678.

Castro, R. M. C. 1999. Evolução da ictiofauna de riachos sul-americanos: padrões gerais e possíveis processos causais. Pp.139-155. In: Caramaschi, E. P., Mazzoni, R. & Peres-Neto, P. R. (Eds) **Ecologia de peixes de riachos**. Serie Oecologia Brasiliensis, v. 6, PPGR-UFRJ. Rio de Janeiro, 1999.

Garutti, V. & Figueiredo-Garutti, M. L. 1992. Caracterização de populações do lambari *Astyanax bimaculatus* (Pisces, Characidae) procedentes do campus de Jaboticabal, UNESP, SP. **Naturalia**, 17: 17-29.

Gayanilo, F.C. Jr & Pauly, D. 1997. The FAO-ICLARM Stock Assessment Tools (FISAT) Reference manual. **FAO Computerized Information Series (Fisheries)**, 8: 1-196.

Gelain, D., Fialho, C. B. & Malabarba, L. R. 1999. Biologia reprodutiva de *Serrapinnus calliurus* (Caracidae, Cheirodontinae) do arroio Ribeiro, Barra do Ribeiro, Rio Grande do Sul, Brasil. **Comunicações do Museu de Ciências e Tecnologia PUCRS**, **Série Zoologia**, 12: 71-82.

Giamas, M. T. D., Santos, R. A., Vermulm Junior, H., Campos, E. C. & Camara, J. J. C. 1992. Determinação da curva de crescimento através da lepidologia em diferentes áreas do corpo de *Astyanax bimaculatus* (Linnaeus, 1758) (Pisces, characidae), na Represa de Ibitinga, SP. **Brazilian Journal of Veterinary Research and Animal Science**, 29(2): 185-192.

Gurgel, H. C. B. 2004. Estrutura populacional e época de reprodução de *Astyanax fasciatus* (Curvier) (Characidae, Tetragonopterinae) do Rio Ceara Mirim, Poço Branco, Rio Grande do Norte, Brasil. **Revista Brasileira de Zoologia**, 21(1): 131-135.

Hirano, R. F. & Azevedo, M. A. 2007. Hábito alimentar de *Heterocheirodon yatai* (Teleostei, Characidae, Cheirodontinae) de dois tributários do rio Ibicuí, Rio Grande do Sul, Brasil. **Biociências**, 15(2): 207-220.

Lévêque, C., Oberdorff, T., Paugy, D., Stiassny, M. L. J., & Tedesco, P. A. 2008. Global diversity of fish (Pisces) in freshwater. **Hydrobiologia**, 595**:** 545-567.

Lizama, M. A. P. & Ambrosio, A. M. 1999. Relação peso-comprimento e estrutura da população de nove espécies da família Characidae na planície de inundação do alto rio Paraná, Brasil. **Revista Brasileira de Zoologia,** 16(3): 779-788.

Lizama, M. A. P. & Ambrosio, A. M. 2002. Condition factor in nine species of fish of the Characidae family in the upper Parana River floodplain. **Brazilian Journal of Biology**, 62(1): 113-124.

Lizama, M. A. P. & Ambrosio, A. M. 2003. Crescimento, recrutamento e mortalidade do pequi *Moenkhausia intermedia* (Osteichthyes, Characidae) na planície de inundação do alto rio Paraná, Brasil. **Acta Scientiarum, Biological Sciences**, 25 (2): 328-333.

Lourenço, L. S., Súarez, Y. R., Florentino, A. C. 2008. Aspectos populacionais de *Serrapinnus notomelas* (Eigenmann, 1915) e *Bryconamericus stramineus* Eigenmann, 1908 (Characiformes: Characidae) em riachos da bacia do rio Ivinhema, Alto Rio Paraná. **Biota Neotropica**, 8(4): 1-7.

Lundberg, J. G., Kottelat, M., Smith, G. R., Stiassny M., Gill, A. C. 2000. So many fishes, so little time: An overview of recent ichthyological discovery in continental waters. **Annals of the Missouri Botanical Garden**, 87: 26-62.

Malabarba, L. R. 2003. Subfamily Cheirodontinae. Pp. 215-221. In: Reis, R. E., Kullander, S. O. & Ferraris Jr., C. J. (Eds). **Check list of the freshwater fishes of South and Central America**. Edipucrs, Porto Alegre, 742 p.

Oliveira, C. L. C., Fialho, C. B. & Malabarba, L. R. 2002. Período reprodutivo, desova e fecundidade de *Cheirodon ibicuhiensis* Eignmann, 1915 (Ostariophhysi: Characidae) do arroio Ribeiro, Rio Grande do Sul, Brasil. **Comunicações do Museu de Ciências e Tecnologia da PUCRS, Série Zoologia**, 15: 3-14.

Pauly, D. & David, N. 1981. ELEFAN I, a BASIC programme for the objective extraction of growth parameters from length frequencies data. **Meeresforschung**, 28(4): 205-211.

Pauly, D. & Munro, J. L. 1984. Once more on the comparison of growth in fish and invertebrates**. ICLARM Fishbyte,** 2(1):1- 21.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stock. **Internacional Council Exploration of**

the Sea, 39: 175-192.

Pauly, D. 1983. Some simples methods for the assessment of tropical fish stocks. **FAO Fisheries Technical Paper**, 234: 1-52.

Piana, P. A., Gomes, L. C., & Cortez, E. M. 2006. Factors influencing *Serrapinnus notomelas* (Characiformes: Characidae) populations in upper Parana river floodplain lagoons. **Neotropical Ichthyology**, 4(1): 81-86.

Reznick, D. N., Butler, M. J., Rodd, F. H. & Ross, P. 1996. Life-History evolution in guppies (*Poecilia reticulate*) 6. Differential Mortality as a mechanism for natural Selection. **Evolution**, 50(4): 1651-1660.

Silvano, J., Oliveira, C. L. C., Fialho, C. B. & Gurgel, H. C. B. 2003. Reproductive period and fecundity of *Serrapinnus piaba* (Characiade: Ceirodontinae) from the rio Ceará Mirim, Rio Grande do Norte, Brasil. **Neotropical Ichthyology**, 1(1): 61-66.

Strauss, R. E. 1990. Predation and life-history variation of *Poecilia reticulata* (Cyprinodontiformes: Poeciliidae). **Environmental Biology of Fishes**, 27: 121-130.

Súarez, Y. R., Valério, S. B., Tondato, K. K., Ximenes, L. Q. L. & Felipe, T. R. A. 2007. Determinantes ambientais da ocorrência de espécies de peixes em riachos de cabeceira da bacia do rio Ivinhema, Alto Rio Paraná. **Acta Scientiarum, Biological Sciences**, 19(2): 145-150.

Taylor, C. C. 1958. Cod growth and temperature. **Journal du Conseil International pour L'Ex-ploration de la Mer**, 23: 366 370.

Vari, R. P. & Malabarba, L. R. 1998. Neotropical Ichthyology: An Overview. Pp. 1-12. In: Malabarba, L. R., Reis, R. E., Vari, R., Lucena, Z. M. S. & Lucena, C. A. S. (Eds.). **Phylogeny and Classification of Neotropical Fishes**. 1 ed. Porto Alegre, Brasil: EDIPUCRS, 603 p.

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Scientific Note

New records of the brachyuran crabs *Hepatus pudibundus* (Aethridae) and *Persephona mediterranea* (Leucosiidae) in their southernmost Western Atlantic distribution

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Abstract. New findings as well as biological data on the presence of the brachyurans *Hepatus pudibundus* and *Persephona mediterranea* in the Uruguayan shelf are recorded and discussed. Both species have their southernmost limits there, where their occurrences have increased in the last 10 years.

Keywords: Uruguayan shelf, subtropical species, Decapoda, Brachyura.

Resumen. **Nuevos registros de los cangrejos braquiuros *Hepatus pudibundus* (Aethridae) y *Persephona mediterranea* (Leucosiidae) en el extremo sur de su distribución en el Atlántico Occidental**. Se registran y discuten nuevos hallazgos así como información biológica sobre la presencia de los cangrejos braquiuros *Hepatus pudibundus* y *Persephona mediterranea* en la plataforma uruguaya. Ambas especies tienen su límite sur de distribución aquí, donde su ocurrencia ha aumentado en los últimos 10 años.

Palabras clave: Plataforma uruguaya, especies subtropicales, Decapoda, Brachyura.

Living mostly in tropical waters, the brachyuran crabs of the families Aethridae and Leucosiidae are very scarcely represented south of Santa Catarina State, Brazil (28ºS) (Zolessi & Philippi 1995, Melo 1996, Spivak 1997, Boschi 2000).

Hepatus pudibundus (Dana, 1851) (Brachyura, Aethridae) (see Ng *et al*. 2008) is found from Guinea to southern Africa in the East Atlantic Ocean; and from Georgia (USA) to Rio Grande do Sul (Brazil) in the West Atlantic Ocean (Melo 1996). Juanicó (1978) registered the first and yet only detailed record for Uruguayan waters. The geographic distribution range for *Persephona mediterranea* (Herbst, 1794) (Brachyura, Leucosiidae) is from New Jersey (USA) to Uruguay (Coelho & Torres 1980, Bordin 1987, Melo 1996). However, these reports did not provide detailed data about the material collected in Uruguayan waters.

For both species there is no other available information on their southernmost Western Atlantic distribution. Here we report and discuss new findings of these species in Uruguayan waters based on several sources, including benthic surveys and occasionally collected material washed ashore. The first source includes a) fishing trip (June 2003) using a clam dredge, b) scientific survey using a beam trawl (November 2006) and a Spatangue dredge (April 2007) and c) fishing (October 2006) and scientific survey (January 2007) using a shrimp trawl. Incidentally captured specimens during the fisheries monitoring program of DINARA (Dirección Nacional de Recursos Acuáticos) (December 2002 and April 2007) using an Engel trawl were also considered (Table I). Bathymetric and sediment information was taken from scientific surveys.

Table I. Number of crabs analyzed (collected) for *H. pudibundus* and *P. mediterranea,* washed ashore (dead) and by each sampling procedure.

	H. pudibundus	***P. mediterranea***
Washed ashore	8	3
Beam Trawl	9	13
Shrimp trawl	6	2
Engel Trawl	12	25
Clam Trawl	27	22
Total	62	65

Individual morphometric data (0.01 mm) and wet weight (0.001 g) were registered. Measures of carapace width (CW: greatest width), abdomen width (AW: width of fifth abdominal somite), and chela length (CHL: propodus length) were taken. All captured crabs in the fishing trip (June 2003) of *H. pudibundus* were dissected in order to assess their gonad development stage according to Reigada & Negreiros-Fransozo (2000). For *H. pudibundus*, juveniles were considered after Mantelatto & Fransozo (1994) who established the morphologic sexual maturity at 32 - 34 mm of CW.

Total samples or voucher specimens were deposited in the Museo Nacional de Historia Natural y Antropología (MNHNM, Montevideo, Uruguay).

Hepatus pudibundus, including adults and juveniles (Table II), was found washed ashore (8 dead specimens) and between 5 and 31 m depth (Fig. 1), and mainly occurring in fine sands. From 12 females dissected, one was immature, two has rudimentary gonads, three were in intermediary stage and six presented developed gonads; one ovigerous female was found (September). From 12 males dissected, one resulted immature, five presented rudimentary gonads, two had developing gonads and two presented already developed gonads. Two specimens (a male and a female) were found immature despite being larger than 34 mm. Morphometric and weight data registered here were in accordance with Mantelatto & Fransozo (1992, 1994) for Brazilian specimens.

Table II. Ranges of individual morphometric data (mm) (CW: carapace width, AW: abdomen width and CWL: chela length) and wet weight (g) (WW), discriminated by sex for *H. pudibundus* and *P. mediterranea* and by state of maturity for *H. pudibundus*. The number of specimens is between parentheses. NA means not available.

	Hepatus pudibundus				***Persephona mediterranea***	
	Females (22)		**Males (35)**		**Females (26)**	**Males (38)**
	Juveniles (2)	**Adults (20)**	**Juveniles (12)**	**Adults (23)**		
CW	29.68 – 34.21	40.35 – 60.72	6.08 – 33.98	47.50 – 73.68	27.59 – 38.76	4.30 – 42.83
AW	5.68 – 9.36	11.27 – 18.51	0.50 – 4.30	6.41 – 11.13	17.81 – 28.84	0.80 – 8.87
CWL	11.84 – 13.74	17.30 – 26.15	2.60 – 14.42	21.53 – 39.13	20.87 – 30.02	1.10 – 38.72
WW	7.24 – 9.27	17.05 – 44.16	NA – 7.65	25.03 – 68.23	9.38 – 26.39	< 1.00 – 30.01

Persephona mediterranea was found washed ashore (3 dead specimens) and between 5 and 28 m depth (Fig. 1), including a wide range of sizes (Table II) and occurred in fine sands. Two ovigerous females were found (January). The morphology of this species makes difficult the macroscopic assessment of the gonad development stage of the individuals, which should be carried out based on histological studies.

The bathymetric range and sediment preferences of *H. pudibundus* and *P. mediterranea* registered in the Uruguayan waters fits within the already known for these species (see Mantelatto *et al*. 1995, Melo 1996, Bertini *et al*. 2001).

Hepatus pudibundus and *P. mediterranea* are very distinctive species, having singular morphological and chromatic features among the Uruguayan carcinofauna that diminishes the possibilities of being overlooked and enhances interest of occasional collections. In this sense, although being aware of the different effort of sampling, we detected a progressive colonization of both species into the Uruguayan coast. In fact, these were not cited by Barattini & Ureta (1961), which includes all distinctive brachyurans known to be washed ashore there, as are present cases. Furthermore, none were recorded by Itusarry (1984), who considered the decapod fauna of the zone inhabited by these species. Finally, no specimen was brought to the collections and/or researchers along the 80´ and 90’. Since a few years (2000-2001) *H. pudibundus* and *P. mediterranea* started to be usually collected in the Uruguayan coast, and even known by local fishermen whom already refer to these crabs using common names. In this sense, *H. pudibundus* and *P. mediterranea* are called “cofresito” (litlle coffer) and “San Antonio” (leaf beatle – Coleoptera-Chyrsomellidae) respectively, given the most remarkable morphological and chromatic features of each one. Furthermore, both species (especially *H. pudibundus*) has been brought to our attention in recent years during stomach content analysis of the Patagonian smoothhound (*Mustelus schmitti*) and loggerhead turtles (*Caretta caretta*) from the Uruguayan inner shelf (Karumbé and Gatuzo Projects, pers. comm.).

Mañé-Garzón (1968) and Milstein *et al*. (1976) reported *Persephona punctata* (Linnaeus, 1758) for the Uruguayan coast based on two specimens collected in the inner shelf. This species was otherwise cited as having the coast of Rio Grande do Sul (Brazil) as it southern limit of distribution (Bordin 1987, Melo 1996). We examined those two specimens (MNHNM 409 and 1222, respectivelly), which are juveniles (CL: 11.63 and 11.83 mm) without traces of chromatic design of *P. mediterranea*. The distinguishing characters between *P. punctata* and *P. mediterranea* (see Melo 1996) are difficult to assess in juvenile fixed specimens. In fact, some of the juveniles we collected and positively identified alive as *P. mediterranea*, had their marmorations vanished only few weeks after being fixed in formaline and preserved in alcohol. However, Mañé-Garzón (1968) mentioned orange symetrical spots for his specimen, which must therefore be referred to *P. mediterranea*. The identity of the specimen listed by Milstein *et al*. (1976) remains uncertain, as the presence of *P. punctata* in Uruguayan coast.

The reidentification of Mañé-Garzón´s specimen as *Persephona mediterranea* indicates the finding of this species in Uruguayan coast in 1963. The previous record of *H. pudibundus* is based on one specimen (MNHNM 1530) collected in 1976 (Juanicó 1978) and an additional specimen (MNHNM 1627) was found as being collected in the same opportunity; both are adult specimens. These findings indicate the presence, at least intermittently, of both species since that time. However, the material here reported confirms these species as established in the Uruguayan coast. Although we found ovigerous females, it is unknown if these finally implies successful recruitment for the local population. Given the ingression of subtropical water mixtured with coastal waters it is not unlikely that a larvae supply of slightly northern locations in southern Brazil coast may account for at least part of the Uruguayan populations, which in turns is responsible for the colonization of these warm water species.

Further research need to be done concerning abundance, life history and reproductive biology of these crabs at the edge of their southern distribution. Our findings further highlight the importance of monitoring the Uruguayan coast, which is the southernmost limit for many warm water species in accordance to the influence of Subtropical Waters (see e.g. Ortega & Martínez 2007). This is of particular interest here in a Global Warming scenario, where extreme oceanographic events (see e.g. Demicheli *et al*. 2006) may contribute not only to eventual colonization but to definitive establishment of a given species.

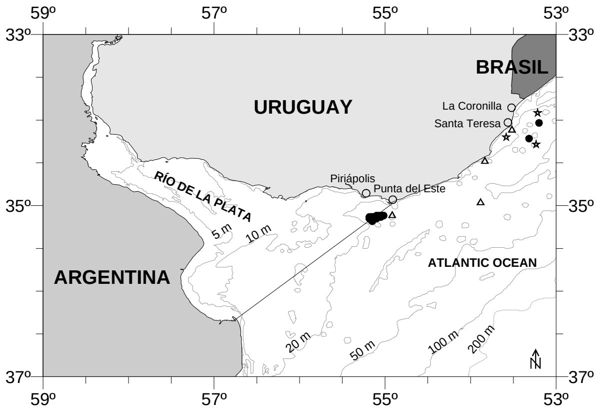

Figure 1. Sampling areas: (△) for *P. mediterranea*, (★) for *H. pudibundus,* (●) for both species and (○) localities where carapaces and dead crabs were found washed ashore.

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References

Barattini, L. P. & Ureta, E. H. 1961. La fauna de las costas del este (invertebrados). **Publicaciones de Divulgación Científica**. Museo “Damaso Antonio Larrañaga”, Montevideo. 195 p.

Bertini, G., Fransozo, A. & Costa, R. C. 2001. Ecological distribution of three species of *Persephona* (Brachyura: Leucosiidae) in the Ubatuba region, São Paulo, Brazil. **Nauplius**, 9(1): 31-42.

Bordin, G. 1987. Brachyura da plataforma continental do estado do Rio Grande do Sul, Brasil e áreas adjacentes (Crustacea, Decapada). **Iheringia**, **Serie Zoologia**, 66: 3-32.

Boschi, E. E. 2000. Species of decapods crustaceans and their distribution in the American marine zoogeographic provinces. **Revista de Investigación y Desarrollo Pesquero**, 13: 7-136.

Coelho, P. A. & Torres, M. F. A. 1980. Zoogeografía marinha do Brasil. II – Considerações ecológicas e biogeográficas sobre a família Leucosiidae (Decapoda, Brachyura). **Revista Nordestina de Biologia**, 3(especial): 67-77.

Demicheli, M., Martínez, A., Ortega, L., Scarabino, F., Maytía, S. & Demicheli, A. 2006. Mass stranding of *Argonauta nodosa* Lightfoot, 1786 (Cephalopoda, Argonautidae) along the Uruguayan coast (southwestern Atlantic). **Revista de Biología Marina y Oceanografía** 41(2): 147-153.

Itusarry, E. 1984. Taxonomía y distribución de los crustáceos (Decápodos) en el Frente Marítimo Uruguayo para los meses de febrero y marzo de 1982 (Cruceros 8201-8205) del B/P Lerez. Tesis de Licenciatura en Oceanografía Biológica, Facultad de Humanidades y Ciencias (Universidad de la República) Montevideo (unpublished).

Juanicó, M. 1978. Ampliación de la distribución geográfica de tres especies de Brachyura (Crustacea Decapoda) para aguas uruguayas. **Iheringia**, **Série Zoologia**, 51: 45-46.

Mantelatto, F. L. M. & Fransozo, A. 1992. Relação peso/largura da carapaça no caranguejo *Hepatus pudibundus* (Herbst 1785) (Crustacea, Decapoda, Calappidae) na região de Ubatuba, SP, Brasil. **Arquivos de Biologia e Tecnologia**, 35(4): 719-724.

Mantelatto, F. L. M. & Fransozo, A. 1994. Crescimento relativo e dimorfismo sexual em *Hepatus pudibundus* (Herbst, 1785) (Decapoda, Brachyura) no litoral norte paulista. **Papéis Avulsos de Zoologia**, 39(4): 33-48.

Mantelatto, F. L. M., Fransozo, A. & Negreiros Fransozo, M. L. 1995. Distribuição do caranguejo *Hepatus pudibundus* (Herbst, 1785) (Crustacea, Decapoda, Brachyura) na Enseada da Fortaleza, Ubatuba (SP), Brasil. **Boletim do Instituto Oceanográfico**, 43(1): 51-61.

Mañé-Garzón, F. 1968. *Persephona punctata punctata* (L) (Decapoda, Brachyura), de la costa oceánica uruguaya. **Revista de la Sociedad Uruguaya de Entomología**, 7: 62-65.

Melo, G. A. S. 1996. **Manual de identificação dos Brachyura (Caranguejos e Siris) do litoral Brasileiro**. Plêiade/FAPESP Ed., São Paulo, 604 p.

Milstein, A., Juanicó, M & Olazarri, J. 1976. Algunas asociaciones bentónicas frente a las costas de Rocha, Uruguay. Resultados de la campaña del R/V Hero, viaje 72-3ª. **Comunicaciones de la Sociedad Malacológica del Uruguay**, 4(30): 143-164.

Ng, P.K.L., Guinot, D. & Davie, P.J.F. 2008. Systema Brachyurorum: Part 1. An Annotated checklist of extant Brachyuran crabs of the world, **Raffles Bulletin of Zoology**, Supplement Series (17), 286 p.

Ortega, L. & Martínez, A. 2007. Multiannual and seasonal variability of water masses and fronts over the Uruguayan shelf. **Journal of Coastal Research**, 23(3): 618-629.

Reigada, A. L. D. & Negreiros-Fransozo, M. L. 2000. Reproductive cycle of *Hepatus pudibundus* (Herbst, 1785) (Crustacea, Decapoda, Calappidae) in Ubatuba, SP, Brazil. **Revista Brasileira de Biologia**, 60(3): 483-491.

Spivak E. D. 1997. Los crustáceos decápodos del Atlántico sudoccidental (25º - 55º S): distribución y ciclos de vida. **Investigaciones Marinas**, 25: 69-91.

Zolessi, L. C. & Philippi, M. E. 1995. Lista sistemática de Decapoda del Uruguay (Arthropoda: Crustacea). **Comunicaciones Zoológicas del Museo de Historia Natural de Montevideo**, 12(183): 1-24.

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Ballast water and sustainability: identification of areas for unballasting by geoprocessing — case study in Todos os Santos Bay, Brazil

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Abstract. This study focuses on the GIS identification of areas recommended for unballasting in exceptional circumstances, within the 200 nautical miles of the coast, when vessels and/or travelers are exposed to high-risk situations, as a preliminary attempt to implement in advance some guidelines of the International Convention for the Control and Management of Ships' Ballast Water and Sediments – 2004 (BWM). The Todos os Santos bay, located in the state of Bahia, Brazil, was chosen as a case study. The work starts with the definition of areas of exclusion, based on the identification of potential risk to urban areas, mangroves swamps, and nature conservation units, using as a parameter the speed of the water movement inside the bay. Overlaying the maps of areas susceptible to contamination by ballast water with thematic maps of water velocity and bathymetry, it was created a final map containing the areas recommended for unballasting of ships in exceptional circumstances. There, it was identified two contiguous regions (Area 1 with 16.19 km^2 and Area 2 with 15.20 km^2), being Area 2 more recommended for unballasting than Area 1.

Keywords: Geoprocessing, Ballast Water, Environmental Management, unballasting.

Resumo. **Águas de lastro e sustentabilidade: identificação de áreas para deslastre por geoprocessamento – estudo de caso na Baía de Todos os Santos-BA, Brasil.** O estudo trata da identificação, por geoprocessamento, de áreas com potencial de risco de contaminação ambiental por águas de lastro e áreas recomendadas para desastre em situações excepcionais, dentro das 200 milhas náuticas da costa, numa tentativa de avançar na operacionalização das diretrizes gerais da Convenção Internacional sobre controle e gestão de Água de Lastro e Sedimentos (BWM 2004). A Baía de Todos os Santos, Bahia – Brasil foi escolhida como estudo de caso. Inicialmente, procedeu-se à definição de áreas de exclusão baseadas na identificação de potencial de risco a áreas urbanas, áreas de manguezais e Unidades de Conservação, tomando-se como parâmetro a velocidade de deslocamento das águas no interior da baía. Cruzando-se o mapa de potencial de risco à contaminação por água de lastro, com os mapas de velocidade das águas e a batimetria, chegou-se ao mapa final de áreas recomendadas para deslastre de navios, em situações excepcionais. Foram identificadas duas áreas contíguas (Area 1 com 16.19 km^2 e Area 2 com 15.20 km^2), sendo a Area 2 mais recomendada para realização de deslastre que a Area 1.

Palavras-Chave: Geoprocessamento, Água de Lastro, Gestão Ambiental, deslastre

Introduction

The issue of sea pollution caused by maritime traffic has been debated more intensely since the intensification of commercial exchange by the end of the last century (Goldberg 1995, Elliot 2003). Among the many types of sea pollution, the one that has been drawing most attention is pollution resulting from the ballast water of ships. During the procedures of ballasting and unballasting, there is a transfer from one locality to another of contaminants and species of living beings, which include everything from viruses and bacteria to invertebrates, at a rate of between three to five billion tons of ballast water every year (Pollard & Hutchings 1990, Thresher 1999, Hayes & Sliwa 2003). This lead to the fear of the spread of epidemic diseases — such as cholera — and the outbreak of new epidemic diseases associated with the transport of microorganisms in ballast water. The epidemiological and environmental risk associated with the uncontrolled discharge of ballast water has become a source of growing concern among the governments of many countries. Just like the chemical pollutants, exotic invasive species are considered biological pollutants by Elliot (2003), which makes government of many countries to be increasingly geared to a measurable and anticipated form of detection of the risks involved. Thus, in this paper, the term "contaminants" in general also includes exotic invasive species and other harmful aquatic organisms and pathogens.

In this context, the International Convention for the Control and Management of Ships' Ballast Water and Sediments – 2004 (BWM) adopted in a Diplomatic Conference in February of 2004, is a very significant fact in environmental management in recent history. The BWM Convention objectives are "prevent, minimize and ultimately eliminate the risks to the environment, human health, property and resources arising from the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships' Ballast Water and Sediments, as well as to avoid unwanted side-effects from that control and to encourage developments in related knowledge and technology". About the control and management of ships' ballast water and sediments in maritime transport, the BWM Convention requires that the change of the content of ballast water tanks should be carried out in oceanic waters. In other special cases, when the vessel is caught up in an emergency situation and the navigability of the ship or safety of the crew is at stake, a competent authority should indicate an appropriate place for unballasting without any impact or risk to either human health or the ecosystem. (Regulation B-4, paragraph 4: "A ship conducting Ballast Water exchange shall not be required to comply with paragraphs 1 or 2, as appropriate, if the master reasonably decides that such exchange would threaten the safety or stability of the ship, its crew, or its passengers because of adverse weather, ship design or stress, equipment failure, or any other extraordinary condition").

Once Brazil has a coastline extension of nearly 8,500 km and an economic partner to countries all over the world with intense and constant maritime port movement, it is a country highly exposed to the possible environmental dangers resulting from the unballasting of commercial ships, with emphasis in the marine concern.

In this context, the purpose of the present work is a preliminary attempt to use a methodology based on geoprocessing to identify areas for the unballasting of ships under special circumstances and for their own safety, as were previewed in Regulation B-4, paragraph 4 of BWM Convention, taking the Todos os Santos bay, in the state of Bahia, Brazil, as case study. Thus, this study can be seen as an effort to prepare Brazilian government staff to handle GIS perspective in the control and management of ships' ballast water and sediments, considering the future entry into force of BWM Convention.

Study Area. The Todos os Santos bay (TSB) occupies an area of approximately 1,000 km^2 and has 184 km of continental coastal extension. The bay appears as a recess in the coastline by which the sea penetrates the continent, in the form of a channel between the city of Salvador and the island of Itaparica, in the state of Bahia. It has a width of nearly 9 km and a maximum depth of approximately 50 m, free of silting (CRA, 2001).

Characterized by a variety of estuary plains, small inland bays, flooded estuaries and mangrove swamps surrounding it, the bay has a complex tributary drainage network, with a total area of approximately 60,500 km^2. In spite of the fact that it faces a number of serious environmental challenges at specific points, the TSB has 54 islands and countless beaches around it, including 320 km of rocky sandy beaches that offer an indisputable tourist potential, all in an area that is well-served by a mesh of paved roads and easy access to the surrounding cities (CRA, 2001).

Material and Methods

Geoprocessing is a set of processes designed to support decision-making, logically and physically based on a technology known as Geographic

Information Systems (GIS), a computational structure that allows for the storing, retrieving, handling, and outputting of georeferenced data (Tomlinson & Boyle 1971, Aronoff 1991), supporting both quantitative and qualitative analysis (Pavlovskaya, 2006).

In order to identify areas recommended for unballasting, a general criteria structure is presented in Figure 1, similar to presented in Wood & Dragicevic (2007), based on Malczewski (1999). As a multicriteria evaluation (MCE), it was assumed there is no weight differences among the criterion layers and they were just normalized by defining the same amplitude of ordering theoretical axis (Malczewski, 1999).

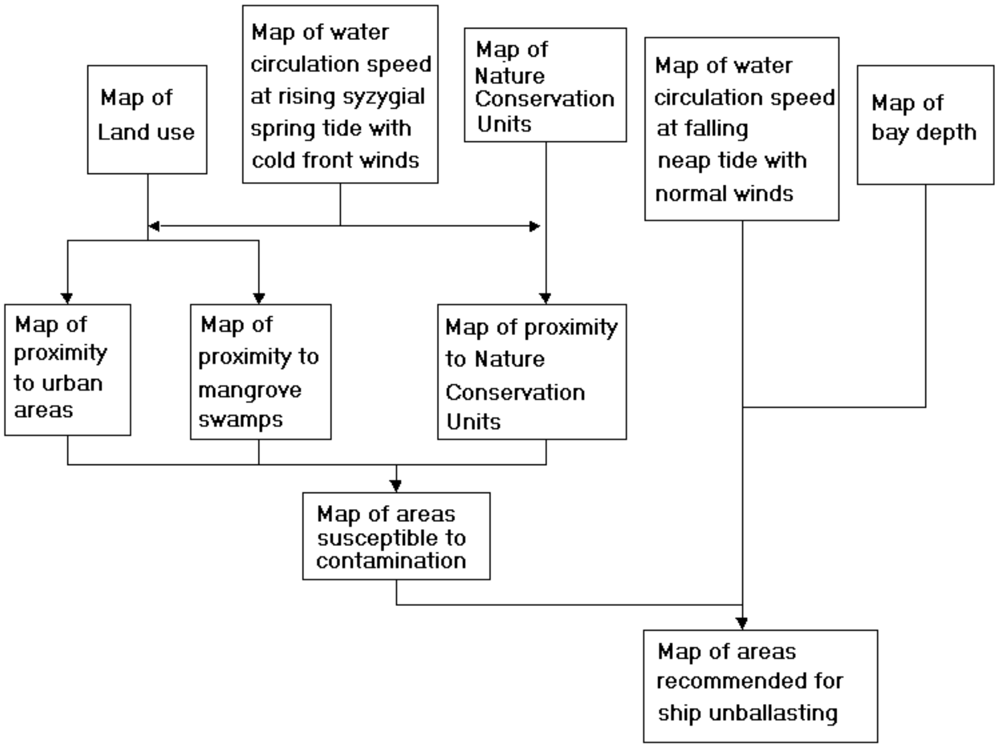

Figure 1. Flow chart of the procedures for identification of areas recommended for unballasting of ships inside the TSB.

The map of areas susceptible to contamination was get by overlapping three maps: proximity to urban areas, proximity to mangrove swamps, and proximity to nature conservation units (NCU). In every these three maps it was established a risk zone, corresponding to the capacity of a contaminant to reach a sensitive target land use. Each risk evaluation was done separately before being assessed in a integrated analysis procedure to produce a Map of areas susceptible to contamination.

The risk zone was determined based on physical data (water circulation speed), devised to express the spreading capacity of the contaminating load coming from the discharge of ballast water by a ship. The map of water circulation speed at rising spring tide with cold front winds, produced by the CRA, was chosen as the basis for this study, due to the fact that under such conditions the water circulation speed is maximized, sustaining a conservative analysis. The velocity of water circulation at the entrance to the bay at flood tide, multiplied by the time it takes for the tide waters to alternate between rising tide and ebb tide makes it possible to calculate the maximum reach of a contaminant during a complete period of spring tide with cold front winds, considering the fact that the tides alternate between their rising tide flux and ebb tide flux every 06:21h (six hours and twenty-one minutes). The width of the proximity buffer to urban areas, mangrove swamps, and NCU corresponds to this maximum reach of a contaminant during a complete period of spring tide with cold front winds.

Because of the generic character of this modelling process, it was not considered the possible influence of self movement of certain species or their larvae forms. In the same way, once it was proposed to locate the risk zone by the reach of water circulation speed, it was assumed that the contaminants body form or weight is negligible and every contaminant can be carried out at the same speed of the water in which it is immersed. The robustness of this modelling procedure is based on a heuristic evaluation of the risk, based on the uncertainty of the effective contamination, which is incorporated by mapping the buffering zones of the grades of probable risk.

The urban areas were selected in view of the possible impact on public health as the result of the presence of contaminants such as pathogenic microorganisms contained in the ballast water, which could lead to the outbreak of diseases transmitted in water, such as cholera, typhoid fever, and hepatitis A. In TBS, the urban areas area characterized as the projection of this area to TBS coastline, where it is situated all the beaches where people use for swimming, and it was done no distinction among these projections, considering that all of them had direct or indirect human contact. The mangrove swamps were chosen due to the fragility of these ecosystems and to the fact that they often are the reproduction sites for several marine organisms. Chemical contaminants present in ballast water could cause a serious damage to this very fragile ecosystem, besides the fact that the exotic invasive species contained in ballast water could upset the balance of the intricate web of ecological relationship among the species therein. Furthermore, the mangrove swamps, in contrast to the urban areas or the on-land NCU, suffer the direct impact of the contaminants found in ballast water because mangroves exist in an environment where water is a component, not only a contact medium. This was one more reason for choosing protection areas in the form of nature conservation units, to be mapped and evaluated in terms of areas of their proximity to ship unballasting.

By realizing the need to harmonize environmental interests with socioeconomic ones, studies must be conducted to identify areas recommended for unballasting within the range of the 200 nautical miles of the coast, under exceptional circumstances, excluding the areas which have been mapped for potential risk of contamination, to avoid arbitrary unballasting in any area near the coast. This anticipatory attitude meets the demands of planning based on a diagnostic approach to the real situation, according to a sustainable development point of view. Moreover, this proposition also meets the Regulation B-4, paragraph 2, of the International Convention for the Control and Management of ships' ballast water and sediment – 2004, which states that "In sea areas where the distance from the nearest land or the depth does not meet the parameters described in paragraph 1.1 or 1.2, the port State may designate areas, in consultation with adjacent or other States, as appropriate, where a ship may conduct Ballast Water exchange, taking into account the Guidelines described in paragraph 1.1".

To this end, the target of these areas should consider the greatest water circulation speed at ebb tide on the way out of the TSB, allowing for the greatest dilution of the contaminants present in the discharged ballast water and its quickest carrying away to open sea, far away from the coastline.

On the map showing the depth of the bay (bathymetric map), the deepest areas were positively selected, because they provide the maximum height of water columns and thus the greatest potential for dilution of the contaminants. The definitive criteria adopted are described in Table I.

Table I. Criteria used for classification on the map of areas recommended for ship unballasting.

Variables represented on the maps	**Criteria for classification**
Depth	Above 30 meters
Speed	Above 0.5 m/s
Potential risk	Medium, Low-Medium, and Low

Based on the map of water circulation speed, some areas were positively selected, those where the water velocity corresponded to the highest speed within the amplitude range of the locality. This circumstance favors the dilution of the contaminants present in the discharged ballast water and a quicker carrying away of these contaminants to the open sea, far from the coast. On the map showing the depth of the sea at the bay (bathymetric data), the deepest areas were positively identified.

The selection of areas with the greatest depth allows for the contaminants present in unballasted water to be diluted more easily, due to the greater height of the water column, thus minimizing the contamination risk potential. The overlaying of these two maps, cross-checked against the former map showing the areas susceptible to contamination, once again using Boolean analysis, led to the final map which shows the areas recommended for ship unballasting.

Results

The velocity of water circulation at the entrance to the bay at flood tide was determined as

0.5 m/s and the maximum spread of a contaminant during a complete cycle of spring tide with cold front winds was defined as 11,430 meters. This value was divided into three equal parts of 3,810 meters, to establish the areas of high, medium, and low risk potential in each proximity map: proximity to urban areas, to mangrove swamps, and to NCU. Farther than 11,430 meters, the potential risk would be null.

The quantitative results — in terms of territorial extension of each proximity zone on each map — are consolidated on Table II. So, after having started based on secondary governmental data, it was possible to proceed with the manipulation of the database in order to generate intermediary maps in the analysis structure presented in Figure 1. Those three maps overlaid, each given equal importance and analyzed according to the Boolean method, yielded a map of areas susceptible to contamination (Fig. 2).

Table II. Territorial extension of each proximity zone on the resulting maps of proximity (to urban areas, mangrove swamps, and nature conservation units) in the interior of Todos os Santos bay (Bahia state, Brazil).

Maps of proximity	**Area from 0 km to 3.81 km (km^2)**	**Area between 3.81 km and 7.61 km (km^2)**	**Area between 7.61 km and 11.43 km (km^2)**
To urban areas	761.2	714.2	419.8
To mangrove swamps	457.5	364.4	143.1
To nature conservation units	891.1	486.6	406.2

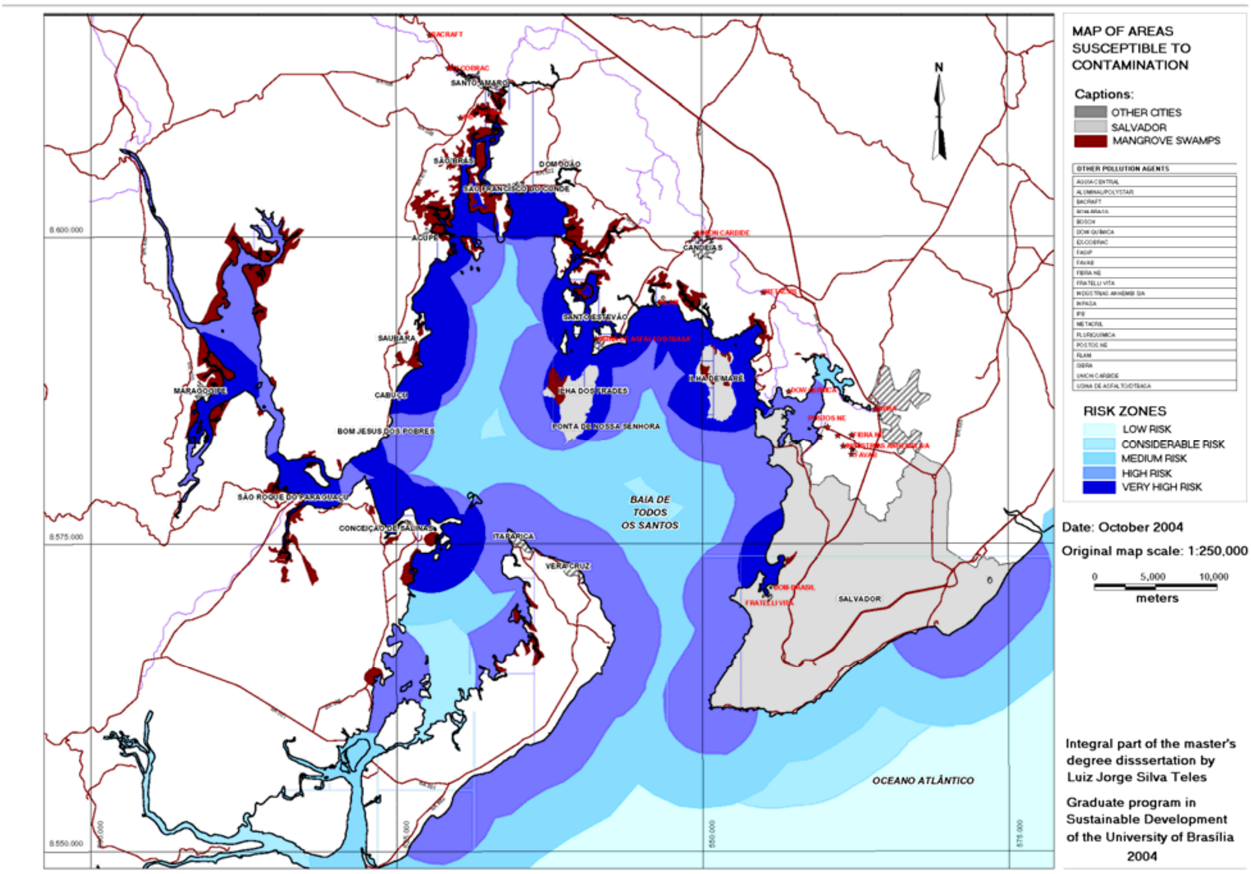

Figure 2. Map of areas susceptible to contamination (potential risk of contamination).

That is, at each point on the map five categories of potential risk were determined: very high, high, medium, low-medium, and low susceptibility to contamination. The most susceptible areas to contamination (very high risk) would be those which simultaneously ranked in the high risk categories on all three maps of proximity to urban areas, mangrove swamps, and nature conservation units. Accordingly, those areas that ranked in the low risk category on the three proximity maps would be classified as the areas as the lowest susceptible areas to contamination (low risk). These are the extremes of an orderly classificatory vector, where the intermediary classes are found. The complete criteria can be found on Table III and the width of the potential risk zones can be seen in Table IV.

To identify the areas recommended for ship unballasting, the greatest water circulation speed at ebb tide on the way out of the TSB should be found. The velocity range chosen was the one higher than 0.5 m/s, on the map of water circulation speed at neap tide with normal winds (when circulation velocity is minimized). Also, the deepest areas were searched to provide the maximum height of water columns and thus the greatest potential for dilution of the contaminants: the regions chosen were those with a depth greater than 30 meters, which represents the greatest depth within the amplitude range of that locality. The final map of the areas recommended for ship unballasting was shown in Figure 3.

Table III. Criteria adopted for the map of areas susceptible to contamination.

Potential risk	**Criteria for classification**
Very high	When the zones of greatest potential risk according to proximity (from 0 km to 3.81 km) overlaid each other on all three maps.
High	When two of the greatest potential risk zones according to proximity overlaid one another (from 0 km to 3.81 km).
Medium	Overlaying indicated one component in the range of 0 km to 3.81 km and two components in the range of 3.81 km to 7.61 km, or overlay showing the three components in the range of 3.81 km to 7.61 km.
Low-Medium	Overlay showing at least one component in the range of 3.81 km to 7.61 km.
Low	Overlay showing all components to be in the categories above 7.61 km.

Table IV. The territorial extension of the susceptible areas to contamination in the study area.

Classes of potential risk	**Within TSB (km^2)**	**Outside TSB (km^2)**
Very high potential risk	295.80	0.00
High potential risk	418.60	162.40
Medium potential risk	268.50	362.10
Low-Medium potential risk	42.48	145.20
Low potential risk	0.00	954.90
Totals:	1,025.38	1,624.60

In reality, the selected area is composed of two contiguous regions (1 and 2), which were chosen individually, then ranked between them according to the risk they presented due to their proximity to the interior of the TSB. Area 1 totals 16.19 km^2 and Area 2 totals 15.20 km^2. The two areas together total 31.39 km^2. Area 2 is more recommended for unballasting than Area 1. The precise geographical localization is presented in Table V.

Discussion

The map of proximity to urban areas locates the cities surrounding the TSB, including Salvador and the other cities in the metropolitan region under its direct influence. The map of proximity to mangrove swamps points out the sensitive areas of what still remains under the protection of the Área de Proteção Ambiental da Baía de Todos os Santos (Environmental Protection Area of Todos os Santos bay). These preliminary pieces of information make it possible to identify potential risk areas, and in the case of the bay of Iguapé, these data could serve as the primary risk assessment tool for the Marine Extractivist Reserve of the Iguapé Bay (ExRes), in the districts of Maragojipe and Cachoeira. The map of proximity to nature conservation units was made based on the location of the state NCU (environmental protection areas of Abaeté, TSB, Joanes/Ipitanga, and Bacia do Cobre) — under the management of the CRA — and on the location of the ExRes, a federal NCU for sustainable use.

The delimitation of the proximity zones surrounding the NCU, identifying those which represent potential risk of contamination to the coastal areas by ballast water, could provide valuable information for the preparation of the respective NCU management plan. This plan, despite being land-related, could help define "buffer zones," including the contiguous marine portions therein, as areas regulated from the point of view of anthropic activities in order to minimize the impact on biodiversity within the NCU.

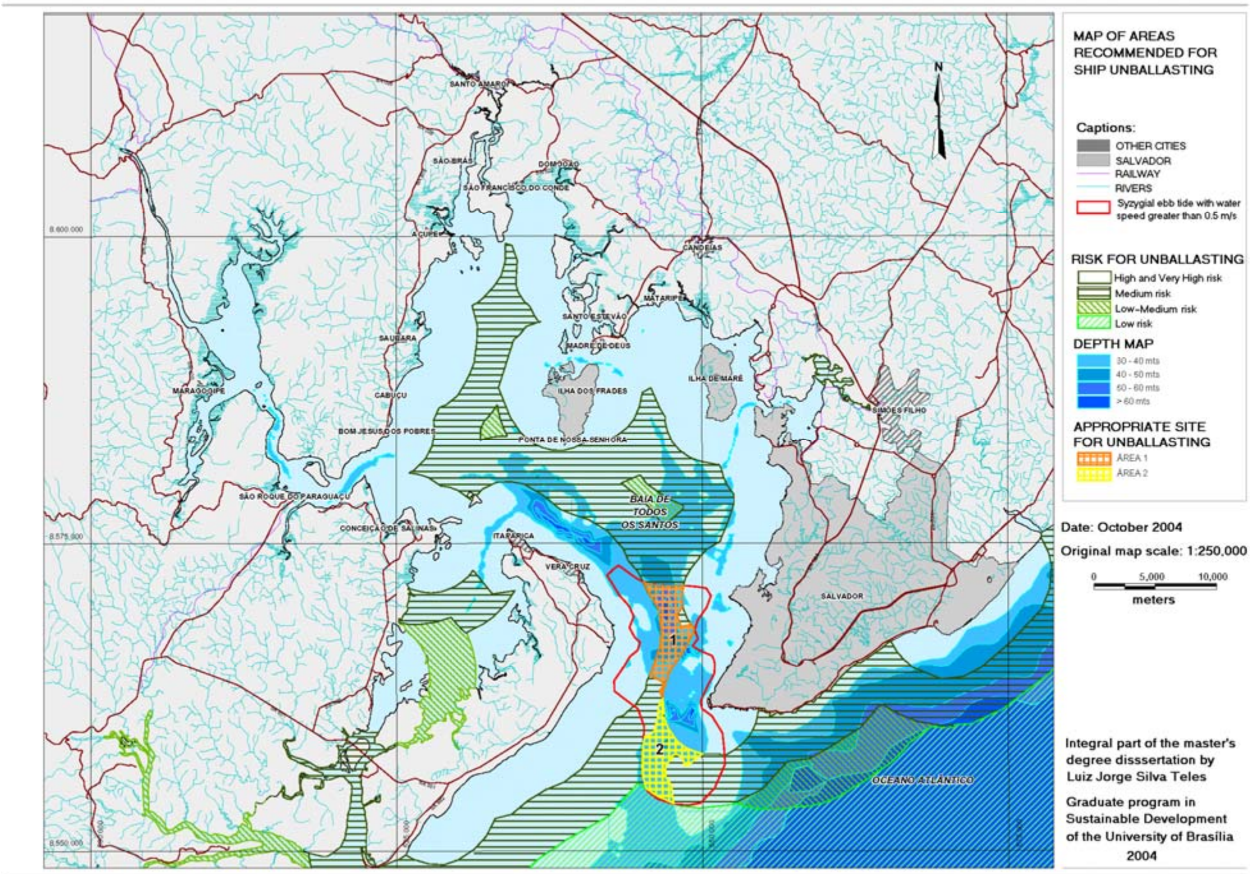

Figure 3. Map showing the areas recommended for ship unballasting.

Table V. The geographical localization of areas recommended for ship unballasting (UTM, SAD-69, zone 24).

Geographical localization of Area 1 (UTM)			Geographical localization of Area 2 (UTM)		
N	X	Y	N	X	Y
1	546.765	8.562.945	1	545.416	8.555.092
2	547.255	8.564.481	2	546.094	8.554.606
3	548.679	8.566.627	3	547.661	8.553.866
4	549.253	8.567.763	4	547.598	8.554.288
5	549.318	8.568.121	5	547.492	8.554.688
6	549.017	8.568.590	6	547.515	8.555.256
7	548.966	8.568.398	7	547.282	8.555.615
8	548.408	8.568.313	8	546.965	8.556.100
9	548.253	8.568.217	9	546.945	8.556.605
10	548.157	8.568.582	10	547.009	8.556.921
11	547.926	8.569.215	11	547.243	8.557.300
12	548.381	8.569.905	12	547.519	8.557.510
13	548.326	8.570.671	13	547.561	8.557.826
14	548.476	8.571.640	14	547.985	8.557.846
15	546.765	8.562.945	15	548.303	8.557.614
			16	545.416	8.555.092

Specifically in the case of the ExRes of Iguapé, the NCU management plan and the kinds of use of marine resources by the communities there settled depend on an evaluation of the potential risks to which they are susceptible. The vigilance exercised and even the social negotiation concerning the location of ship unballasting areas depend on the mapping of the zones of potential risks to which the marine resources of the ExRes and in particular the mangrove swamps therein are exposed.

The map of areas susceptible to contamination (Fig. 2) clearly shows the fragility of the TSB in regard to contamination by ballast water. Inside it, there is no area free from the risk of contamination in limit-situations — that is to say, in the extreme case of quickest contaminant spread, as would occur at spring tide with cold front winds.

The most critical areas, which are shown on this resultant map, are the ones which require the highest level of vigilance by competent authorities, in order to restrain the practice of ship unballasting.

It must be emphasized that the study area comprises a large region outside the TSB, including the coastal portions to the south — close to the island of Itaparica — and to the north of the bay. According to these data, the greatest part of the interior of TSB is categorized as high or very high risk, whereas no region inside it could be classified as low risk, thus revealing the fragility of the bay in regard to the discharge of ballast water by ships. The large low risk areas in the region of the study are located outside of the TSB.

The information generated by the study also provides valuable data for a coastal and marine ecological zoning; the areas in dark blue on the map of areas susceptible to contamination (Fig. 2) — a 3.81 km extension starting from the coastline — serve to outline the forbidden area, within which under no circumstances should the vessel perform unballasting. The areas in light blue constitute a moderate risk zone for unballasting.

After having chosen the appropriate site for the unballasting procedure based on Figure 3, and following the parameters decided upon for this purpose, it is believed that the process should cause the minimum possible risk of environmental contamination to the interior waters of the TSB. In the recommended area, the vessels will only be able to carry out the unballasting at ebb tide, so that the possible contaminants are taken away by the sea currents towards the deeper waters away from the coastline, where there is a higher degree of resilience and no risk of contamination to inland TSB. Moreover, since the chosen water circulation speed is moderate, the vessels can function normally at the moment of unballasting, without fearing the sea currents that circulate with a greater force of the tide which might jeopardize the safety of the ship.

The location of these areas should be previously communicated to the ships by the competent authorities, so that the ships that still have not followed the correct procedure — performing the unballasting process gradually during the journey — do so in the area specifically designated for unballasting with the minimum environmental impact possible. In fact, at the moment that the ships communicate the coordinates of their trajectory and/or of the scheduled unballasting, it is possible to compare those coordinates with the ones on the final map showing the areas recommended for ship unballasting. Then to judge, *ad hoc*, whether or not the ships have been operating according to the proper norms. Finally, the necessary adjustments regarding the location of the ship, by the retransmission of the correct coordinates with the location of the recommended areas for ship unballasting.

It is hoped that there can be a conciliation of environmental concerns with prevention procedures at the time of unballasting in locations considered safe outside the TSB. In this way, the vessels which have not carried out the procedure during the journey can continue their trip performing their duty of transporting goods. Also, they can go on integrating national and international economies, within the perspective of sustainable development, independently of the application of the adequate punishments to those who have violated the IMO norms.

Although this study was concluded in 2005, it seems still valid nowadays, even after the Resolution MEPC.151(55) – Guidelines on designation of areas for ballast water exchange (G14), adopted on 13 October 2006, which are created to support the already identified necessity for additional guidance on the designation of areas for ballast exchange, as stated by the Regulation B-4, paragraph 2, of the International Convention for the Control and Management of ships' ballast water and sediment – 2004.

According to this complementary guidelines, the identification of potential sea areas for ballast water exchange by a Port State requires consideration of legal aspects, important resources and protected areas, and navigational constraints. The G-14 is very clear in saying that "the location and size that provide the last risk to the aquatic environment, human health, property or resources should be selected for designation" (9.1). The identified ballast water exchange area(s) should be assessed in order to ensure that the designation will minimize any threat of harm to the environment, human health, property or resources taking into account but not limited to the following criteria: oceanographic (currents, depths), physico-chemical (salinity, nutrients, dissolved oxygen, chlorophyll 'a'), biological (presence of Harmful Aquatic Organisms and Pathogens, including cysts; organisms density), environmental (pollution from human activities), important resources (fisheries areas, aquaculture farms), ballast water operations (quantities, source, frequency). This assessment step follows the preliminary indication of area(s) promoted by this study and should be done by Port State to confirm the adoption of identified area(s) as official ballast water exchange area(s). Also, after the conclusion of the present manuscript, the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) just recently adopted in its 56th session (9-13 July 2007) guidelines for additional measures regarding ballast waters management, including emergency situations (G13). In this guidelines, it is required the precise co-ordinates where and applicable date when additional measures are applicable by a Party to prevent, reduce, or eliminate the identified potential harm from the introduction of harmful aquatic organisms and pathogens in the area to be covered by the additional measures. This study in a certain way fits this guidelines, as gives the motivations to improve environmental protection, the conditions (emergency situations, at ebb tide, and inside the recommended areas 1 and 2) and the precise localization where the orientation should be performed.

Conclusions and Recommendations

In an attempt to locate geographically the susceptible areas to contamination from ballast water in the Todos os Santos bay, a wide range of data that were dispersed have been collected, organized, and presented, regarding urban areas and mangrove swamps, the location of federal and state nature conservation units, water circulation conditions, and bathymetry in the TSB.

Geoprocessing has made it possible, through the cross-checking of several spatialized variables, to delimit an area of minimum environmental impact to be recommended to the competent authorities as the most suitable for ship unballasting, within the range of 200 nautical miles from the Brazilian coastline, in exceptional risk situations when the international norm of ship unballasting outside of the 200 nautical miles range cannot be followed.

This work has also demonstrated that an integrated management of both the coastal and marine zones, with regard to the challenge of ship unballasting, requires a coordinated, interdisciplinary effort, with the participation of sanitation, maritime, port, and environmental authorities, including environmentalists and NCU managers. Such a joint effort should result in a great accomplishment for the protection of the environment, while taking into account the operational expenses of the vessels, in order to avoid a negative economic impact on loading and unloading operations.

Since the focus of this study has been on the Todos os Santos bay, the results apply locally and constitute the main source of data for both Agência Nacional de Vigilância Sanitária (Anvisa — National Sanitary Vigilance Agency) and the local port authority. Nevertheless, since the methodology can be extended to other port regions, it is hoped that it will serve as a starting point for a qualified and effective dialogue with Anvisa in order to prove that, besides the procedures adopted by the countries which have progressed in this area of environmental awareness, new contributions arising from the fundamentals of geoprocessing can be applied not only in the state of Bahia, but in other Brazilian ports as well. Further, the modelling procedure based on GIS, described in this study, can be continuously refined by the addition of new map layers or parameters, giving more accurate locations, reinforcing the directions described in the Guidelines on designation of areas for ballast water exchange (G14), adopted by IMO on 13 October 2006.

It is now recommended that experimental field studies be conducted, in order to confirm the velocity of tide movements and the consequent transport of contaminants, as well as dispersion and dilution effects. These studies can contribute to the refining of the adopted model, to more accurately delineate the classification of the areas recommended in this study for ship unballasting. In addition, it is recommended to promote strategies for informing the social actors involved, so that the data about the location of the areas recommended for ship unballasting can be fully understood and assimilated. A wide but specific environmental education program shall be developed for all the social actors involved, complementary to the adoption of this kind of recommendation. This environmental education program can include themes about sustainability, individual and collective responsibility an ethics, besides the technical aspects of the ship unballasting and the prevention and minimization of the risks to the environment, human health, property and resources arising from the transfer of Harmful Aquatic Organisms and Pathogens. It can also be recommended a special emphasis onto the vessels commanders, because of the Brazilian experience with informations received about the ballast water exchange performed by vessels. This information is based on an exploratory study intended to identify pathogenic agents in ballast water (General Management of Ports, Airports and Borders Project – GGPAF 2002, Brazil) carried out by the Agência Nacional de Vigilância Sanitária (Anvisa — National Sanitary Vigilance Agency) in 2002, involving nine Brazilian ports and a sample of 99 vessels of several nationalities with maritime transit in national and international ports. This study found that 62% of the vessels whose commanders declared to have performed ballast water exchange in oceanic waters probably did not actually do so, or did it only partially, which means an environmental risk (Anvisa 2003). This conclusion was reached based on the adoption of salinity measurements, which indicated that the salinity found in the ballast water of those ships did not correspond to the levels which were to be expected in oceanic waters. According to Anvisa, the salinity levels, which were less than 35%, pointed to the probability that there was a substitution of the ballast water near the coast, or near river estuaries, which results in a reduction of salinity because of the addition of fresh water. This means they can be aware of the recommendations to perform the replacement of ballast water in oceanic waters or even to perform the ballast water exchange in areas recommended for ship unballasting in emergency situations.

Finally, the identification of possible unballasting areas near the coastline does not preclude the recommendation that, ideally, this procedure should be performed more than 200 nautical miles away from the coast, following the international guideline; nor should it hinder the search for alternative procedures, such as the installation of receptors of residuals like oil, ballast water, and other contaminants at the terminals, or the development of technologies for the decontamination of ballast tanks, ensuring both efficiency and safety, especially for the environment.

Cautionary Notes. It is important to say that the present Brazilian governmental management capability is limited by the lack of disposal data and communication due to the state organization based on federalism and the divisions on civil and military (in this case, navy force) data access, and this had reflections on the profoundity of this study: there were several difficulties to get hands on data, specially maps of water circulation and ships's movement routes. The land use map and the nature conservation unit map (both scaled at 1:250,000) were provided by the Center for Environmental Resources of the State of Bahia (Centro de Recursos Ambientais — CRA).

According to this structure, it was determined the areas of exclusion, that is, those considered to be risk areas, where ship unballasting would be neither recommended nor permitted. The criteria used to define the areas of exclusion were based on the potential risks to the environment or to public health resulting from the unballasting. It also could be previously cut out those area where ships cannot circulate by shallow waters where the navigation did not occur. In the present case study, because of the bay format, this previous exclusion was not done and this would not affect the final result, which is to match areas with minimum risks where ballast water exchange could be occur, differently of those area where ships presently discharges ballast water under normal conditions without any environmental concern. Any way, reviewing the methodological procedure, it can be said that in theory, this previous exclusion should be done at first.

Finally, a fuzzy logic approach could be applied as an improved assessment to this study and can be a strong suggest for further studies with this same goal, as can be seen in Peche and Rodríguez (2009).

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We are grateful to Agência Nacional de Vigilância Sanitária (Anvisa — National Sanitary Vigilance Agency), specially the section responsible for the Salvador port vigilance, for their logistical support to this study. We also wish to thank Ana Lúcia Aragão for her help in creating the maps.

References

Anvisa. 2003. Projetos GGPAF-2002 (ANVISA. Projects – GGPAF 2002). Brasília, Anvisa, 10 p. (also available at <http://www.anvisa.gov.br/divulga/public/index.htm>).

Aronoff, S. 1991. Geographic Information System: A Management Perspective. Otawa, WDL Publ.

CRA. Modelamento e Avaliação Ambiental. **Relatório de estudos básicos**. Salvador, BA. março/2001. 263 p.

Elliot, M. 2003. Biological Pollutants and Biological Pollution – An Increasing Cause for Concern. *Marine Pollution Bulletin,* Hull, UK. vol. 46,

p. 275-280.

Goldberg, E. D. 1995. Emerging Problems in the Coastal Zone for the Twenty-first Century. *Marine Pollution Bulletin*. California, USA, v. 31, n. 4-12, p. 152-158.

Hayes, K. R. & Sliwa, C. 2003. Identifying Potential Marine Pests – A Deductive Approach Applied to Australia. *Marine Pollution Bulletin*, Australia, v. 46, p. 91-98.

Malczewski, J. 1999. GIS and Multicriteria Decision Analysis. John Wiley & Sons, Inc. pp392.

Pavlovskaya, M. 2006. Theorizing with GIS: a tool for critical geographies? Environment and Planning A, 38:2003-2020.

Peche, R.; Rodríguez, E. 2009. Environmental impact assessment procedure: a new approach based on fuzzy logic. Environmental Impact Assessment Review, 29: 275-283.

Pollard, D. A. & Hutchings, P. A. 1990. A Review of Exotic Marine Organisms Introduced to the Australian Region. II Invertebrates and Algae. *Asian Fisheries Science*, Australia, vol. 3, p. 223-250.

Thresher, R. E. 1999. Diversity, Impact and Option for Managing Introduced Marine Species in Australian Water. *Australia's Journal of Environmental Management*, Australia, v. 6, p. 137-148.

Tomlison, R. & Boyle, R. 1971. The State of Development of Systems of Handling Natural Resources Inventory Data. Reprinted from *Cartographica*, v. 18, n. 4, p. 65-95.

Wood, L. J. & Dragicevic, S. 2007. GIS-based multicriteria evaluation and fuzzy sets to priority sites for marine protection. Biodiv. Conserv. 16:2539-2558.

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Distribution of planktonic cladocerans (Crustacea: Branchiopoda) of a shallow eutrophic reservoir (Paraná State, Brazil)

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Abstract. This study focused the spatial and temporal distribution of the composition, abundance, and diversity of planktonic cladocerans from eutrophic, Iraí Reservoir, as well as their relationships with some biotic and abiotic variables. The tested hypothesis was that cladocerans present higher variation in a temporal than in a spatial scale. The samples were taken monthly in 6 stations, from March/02 to July/03. Twenty-four taxa were identified, distributed in 7 families, the richest families being Daphniidae (6 spp.), Chydoridae (6 spp.), and Bosminidae (5 spp.). The most frequent and abundant species were *Bosmina hagmanni*, *Moina minuta,* and *Ceriodaphnia cornuta*. The highest abundances were found in September/2002. Temporally, rainfall influenced organism's distribution, while spatially cladocerans were more affected by reservoir hydrodynamics and wind action. The low species richness could be a reflection of the trophic state of the reservoir, in which a dominance of Cyanobacteria was observed during that study period. Both scales showed high variation, but only the temporal scale showed significant difference to richness and abundance. Nearby the end of this study, higher stable values of species richness were recorded, which could suggest an increase in the water quality due to des-pollutions actions.

Keywords: Cladocera, Iguaçu River basin, Iraí Reservoir, eutrophication, Cyanobacteria.

Resumo. Distribuição de cladóceros planctônicos (Crustacea: Branchiopoda) em um reservatório eutrófico raso (Paraná, Brasil). Esse estudo enfocou a distribuição espacial e temporal da composição, abundância e diversidade de cladóceros planctônicos em um reservatório eutrófico, reservatório do Iraí, bem como suas relações com variáveis bióticas e abióticas. A hipótese testada foi que os cladóceros apresentam maior variação em escala temporal do que espacial. As amostragens foram realizadas mensalmente em seis estações, entre março/02 e julho/03. Vinte e quatro táxons foram identificados, distribuídos em sete famílias, sendo Daphniidae (6 spp.), Chydoridae (6 spp.) e Bosminidae (5 spp.) as que ativeram maior número de espécies registradas. As espécies mais freqüentes e abundantes foram *Bosmina hagmanni*, *Moina minuta* e *Ceriodaphnia cornuta*. A maior abundância foi registrada em setembro/02. Temporalmente a pluviosidade influenciou a distribuição dos organismos, enquanto espacialmente os cladóceros foram mais afetados pela hidrodinâmica do reservatório e pela ação do vento. A baixa riqueza de espécies pode ser um reflexo do estado trófico do reservatório, no qual a dominância de Cyanobacteria foi observada quase que constantemente. Ambas as escalas apresentaram elevadas variações, porém somente a temporal apresentou diferença significativa para a riqueza e abundância. Próximo do final deste estudo, maiores valores estáveis de riqueza de espécies foram verificados, a qual pode sugerir uma melhoria na qualidade de água devido a ações de despoluição.

Palavras-chave: Cladocera, rio Iguaçu, reservatório do Irai, eutrofização, Cyanobacteria.

Introduction

The importance of continental aquatic ecosystems as a source of freshwater to human populations is unquestionable. However, anthropogenic activities have been degrading these environments and the water quality, altering its physical, chemical, and biological properties, a phenomenon called eutrophication (Bollmann & Andreoli 2005).

Changes in the nutrients dynamics of a water body alter the decomposition and production processes that directly affect the consumption. This fact can be evidenced studying planktonic microcrustaceans since its life cycle, development, and reproduction are influenced by biotic and abiotic factors of the environment (Branco & Cavalcanti 1999, Bini *et al*. 2008).

In tropical environments, rain and wind action are the major forces influencing cladocerans population structure, promoting the water column mixing, and stimulating nutrient cycling (Lopes *et al.* 1997, Sampaio *et al*. 2002). Factors as pH, dissolved oxygen, and nutrients (especially P and N) directly affect these organisms, because they strongly influence phytoplankton development (Bonecker *et al*. 2001, Matsumura-Tundisi & Tundisi 2003, 2005). Furthermore, cladocerans populations can oscillate in response to predation by other groups, like insect's larvae and small fishes (Meschiatti & Arcifa 2002).

Most cladocerans are herbivorous and phytoplankton feeders, transferring energy to higher trophic levels (Melão 1999). This is the reason why generalist's cladocerans species are able to develop in a high number of environments, like species of the Bosminidae family. Some large cladocerans (Sididae and Daphniidae families) have preference on the food item ingested, and they became more selective when there is food limitation (DeMott & Kerfoot 1982, Ferrão-Filho *et al*. 2003). Filamentous algae and presence of toxins affect cladocerans growth and filtering rates, besides to increase mortality and polymorphism, which in a spatial-temporal scale influences the composition, distribution and species succession (Ferrão-Filho & Azevedo 2003). This is particularly important in eutrophic reservoirs where food availability from cladocerans changes with time since cyanobacteria blooms, which occur during almost the whole annual cycle, can develop toxicity (Ferrão-Filho *et al.* 2003).

Temporal-spatial variations of microcrustaceans in Brazilian reservoirs have been extensively studied (Bonecker *et al*. 2001, Sampaio *et al.* 2002, Matsumura-Tundisi & Tundisi 2003, 2005, Corgosinho & Pinto-Coelho 2006). However, in small and eutrophic reservoirs, as the case of Iraí Reservoir and which is the aim of this study, the relationships between cladocerans assemblages and limnological factors (biotic and abiotic) are poorly known besides they can affect population structure. Lansac-Tôha *et al*. (2005), Velho *et al.* (2005), Serafim-Júnior *et al*. (2005) and Perbiche-Neves *et al*. (2007) studied this reservoir and attributed the homogeneity of zooplanktonic assemblages to the low depth, long residence time and elevated production, with the dominance of cyanobacteria. Pinto-Coelho *et al*. (1999) made similar observations to Pampulha Reservoir (MG), which is small, eutrophic and located in a region of strong urbanization. In small, shallow and polymictic reservoirs, Henry (1999) highlighted the wind action effects on the water column, where daily or temporary stratifications can occur, but they are subjected to the vertical homogenization in most part of the year.

The comprehension of the relationship between cladocerans assemblages and environmental conditions are important to the development of ecological tools used in management techniques and environmental restoration of eutrophic reservoirs. Also, the knowledge of those relations could be useful to understand Cladocera ecology in sub-tropical reservoirs, nevertheless used to water supply to the city of Curitiba and metropolitan region, composed of *ca*. 3.5 million habitants. The hypothesis tested in this study was that cladocerans variation occurs mainly in a temporal than in a spatial scale, associated to the small size of the reservoir, being a homogeneous assemblage, due the its relation to some limnological variables and specially to phytoplankton community, because their food item selectivity. The aim of this work was to describe: (i) the temporal-spatial distribution of some ecological attributes of cladocerans populations and the major limnological variables influencing them; (ii) the intensity of eutrophication that affect these organisms, and (iii) the relation between cladocerans and the phytoplankton community.

Material and Methods

Study area. The Iraí Reservoir (25º 25'49''S and 49º 06'40''W) is located in the basin of higher Iguaçu River among the cities of Pinhais, Piraquara, and Quatro Barras. It occupies an area of 14 km^2 in the alluvial plain of Iraí River. The mean water volume is $58x10^6$ m^{-3}, the theoretical residence time is 300 to 450 days, and the mean depth is 4 m. (Z_{max}=10 m). The margins are not vegetated, being composed mainly by pastureland (Andreoli & Carneiro 2005).

Iraí Reservoir was built in 2001 and its morphometrical and hydrological features have been causing Cyanobacteria proliferation since its filling, complicating water treatment and reducing water quality (Andreoli & Carneiro 2005).

One of the four main tributaries (Timbú River) is characterized by an elevated nutrient load, especially of phosphorus and nitrogen, due to the disordered urban occupation of the drainage basin. This fact, associated to the high residence time and low dept of the reservoir favored the development of blooms of Cyanobacteria, as *Anabaena* sp., *Cylindrospermopsis* sp., and *Microcystis* sp., promoting significantly changes in the water quality of the reservoir (Bollmann & Andreoli 2005).

Field work, samples and data analyses. The samples were obtained monthly from March/2002 to July/2003 in six stations in the reservoir, totalizing 102 samples. Stations 1, 2 and 3 were located in the dam axis (stations 1 and 3, Z_{max}= 4 m; station 2, Z_{max}= 8 m), and the others were in the main body the reservoir (stations 4, 5, and 6, Z_{max}= 3 m) (Fig. 1).

Two-hundred liters of sub surface water (due to low depth) were filtered in a conical plankton net (55 µm mesh size), using a motorized pump. The samples were narcotized with 4 % buffered formalin. Countings were made through subsamples of 1 mL using Stempel pipette, and a minimum of 200 individuals were counted per sample in a Sedgewick-Rafter chamber under optical microscope. Cladocerans are usually quantified in acrylic gridded Petri dishes using stereomicroscope. However, in this study, countings in Sedgewick-Rafter were possible due to the elevate number of small organisms. Identification of species was based in specialized literature, as Matsumura-Tundisi (1984), Elmoor-Loureiro (1998; 2007), Hollwedel *et al.* (2003) and Elmoor-Loureiro *et al.* (2004). Abundance data were expressed as individuals.m^{-3}.

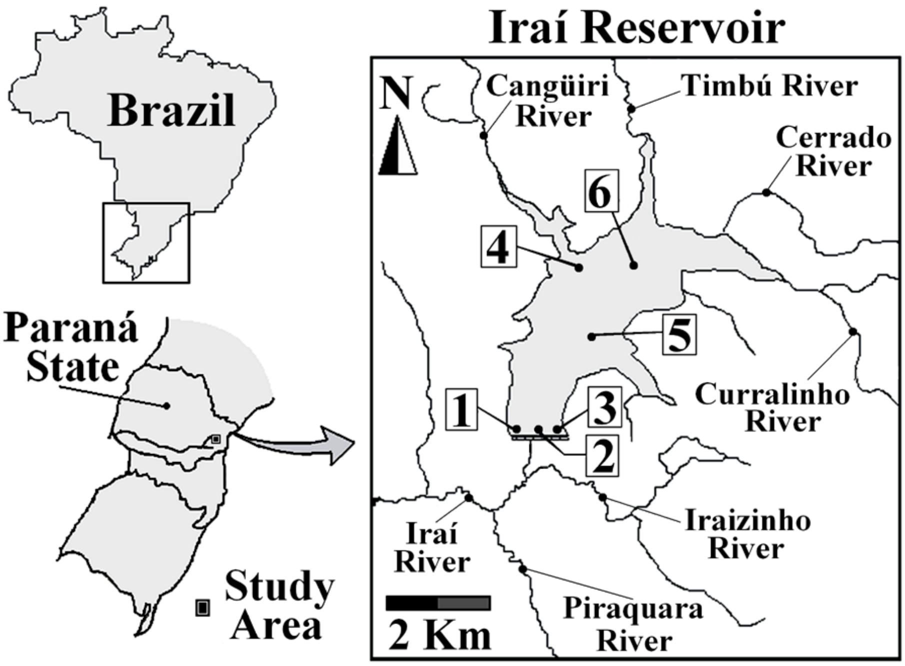

Figure 1. Localization of Iraí Reservoir (Paraná State) and of sampling stations

Non-parametric tests were used after Shapiro-Wilk normality test have indicated a not normal distribution. Organism's richness and abundance were analyzed using H Kruskal-Wallis ANOVA test ($p < 0.05$) to detect significant variations between sampling stations and months. Biotic and abiotic variables for limnological characterization were not different among the stations ($p > 0.05$). It was used data of station 2, in middle dam zone. Biotic and abiotic variables were related to the cladocerans abundance. Phytoplankton species abundance and cladocerans abundance interactions were analyzed using the Spearman correlation ($p < 0.05$). Due to the elevate number of statistical analyses applied, multiple comparisons tests between the means of analyzed categories were used to avoid error type I on null hypothesis. Multiple comparisons analyses of "p" values (Z, $p > 0.05$) were performed on the significance tests of H Kruskal-Wallis ANOVA and Bonferroni correction (β, $p > 0.05$) on Spearman correlations. Despite the corrections, infringements about null hypothesis were not significant. Biotic and abiotic variables were correlated with Cladocera using Factorial Analysis ($p < 0.05$) with extraction by Principal Component Analysis. Mantel test with 1000 permutations for dissimilarity matrices between cladocerans data versus phytoplankton data (also with Bray Curtis distances) versus abiotic data (with Euclidian distances) was performed, but a significant correlation was not obtained. Factorial Analysis was performed using Statistic 6.0 software (Statsoft 2002), and the other analyses were carried out using “R Development Core Team” (2009).

Data of abundance, composition and phytoplankton biomass, and water physical-chemical parameters (chlorophyll-a, pH, temperature, dissolved oxygen, electric conductivity, turbidity, organic nitrogen and total phosphorus) were obtained in same stations and months through the data base of "Projeto multidisciplinar de pesquisa em eutrofização de águas de abastecimento público”. For further details of sampling methodologies and analyses, as well as the responsible authors, see Andreoli & Carneiro (2005). Monthly mean pluviosity was obtained from data base of Technological Institute SIMEPAR.

Results

Species richness (S) values varied significantly during the studied months (H=71.23, $p < 0.00$), with lower mean value in March/2002 (S = 4.2), and higher mean value in December/2002 (S = 12) and November/2002 (S = 11.5). From November/2002 to February/2003 (rainy season), the highest means, maximum values and variation (standard deviation and min/max) in species richness were observed among the stations (Table I). After this, richness tended to stability from July (S: 7.5-10; mean: 8.7). Significant spatial variation of richness was not observed (H = 1.59, p = 0.97, Z = p > 0.05).

Table I. Cladocerans richness species (Mean, Standard deviation - SD and Minimum/Maximum - Min/Max) at Iraí Reservoir from March/2002 and July/2003 (N = 102).

2002	Mean	SD	Min/Max	2003	Mean	SD	Min/Max
Mar	4.2	±1.17	3-6	Jan	10.8	±2.64	8-15
Apr	6.0	±1.26	4-8	Feb	9.5	±1.64	7-12
May	5.5	±1.52	4-8	Mar	7.5	±1.05	6-9
Jun	6.7	±0.82	6-8	Apr	8.3	±2.16	5-11
Jul	6.5	±1.38	6-8	May	9.3	±1.63	9-12
Aug	6.3	±1.63	4-9	Jun	10.0	±0.63	9-11
Sep	7.7	±1.51	6-10	Jul	7.7	±2.07	8-11
Oct	8.8	±1.47	7-11				
Nov	11.5	±1.87	9-14				
Dec	12.0	±1.79	9-13				

A total of 24 species was identified (Table II). The most frequent cladocerans species in the samples were *Bosmina hagmanni* (94%), followed by *Moina minuta* (84%), *Ceriodaphnia cornuta* (70%), *Bosmina longirostris* (67%), and *Ceriodaphnia silvestrii* (64%). *Bosmina hagmanni* was also the most abundant species during the whole study period (relative abundance = 65 %). Chydoridae and Daphniidae families presented higher richness (six species), and the last family was the most abundant. Five Bosminidae species were recorded (Table II).

In a temporal scale, a significant difference in cladoceran abundance was observed along the studied months ($p < 0.00$, H = 70.68), but with no distinguished pattern of variation. Lower abundances were found in March/2002 and 2003, and in June and July/2003. A peak of abundance was observed in September/2002, and to the following months, elevated densities were observed until January/2003. In May/2003 values also increased (Fig. 2).

Most cladocerans species, mainly the more abundant, followed the variation showed in Figure 2. The variation was especially evident to smaller cladocerans, as *B. hagmanni* responsible for the density peak during September/2002, when densities were more than 12 fold higher compared to previous months (≈ 600,000 org.m^{-3}). In October/2002, abundance of that species decreased progressively until its absence in March and April/2003. *Moina minuta* higher densities were found in May/2002 (≈ 55,000 org.m^{-3}), and population declined in August and September/2002. A peak of *Ceriodaphnia cornuta* was observed in October/2002 (≈ 60,000 org.m^{-3}).

Table II. Recorded species at Iraí Reservoir, relative abundances (Ab %), and frequency of occurrence (Fr %) in the samples, from March/2002 to July/2004.

Taxa	Ab%	Fr%	Taxa	Ab%	Fr%
Bosminidae			**Ilyocryptidae**		
Bosmina hagmanni Stingelin, 1904	65.4	94.1	*Ilyocryptus spinifer* Herrick, 1882	<0.1	3.3
Bosmina huaronensis Delachaux, 1918	2.3	40.3	**Macrothricidae**		
Bosmina longirostris Müller, 1785	4.8	58.8	*Macrothrix squamosa* Sars, 1901	<0.1	0.8
Bosmina tubicen Brehm, 1953	<0.1	2.5	**Moinidae**		
Bosminopsis deitersi Richard, 1895	1.5	40.3	*Moina micrura* Kurz, 1874	<0.1	3.3
Chydoridae			*Moina minuta* Hansen, 1899	6.6	84.0
Alona guttata Sars, 1862	<0.1	10.0	*Moinodaphnia macleayi* King, 1853	<0.1	0.8
Alona intermedia Sars, 1862	<0.1	2.5	**Sididae**		
Alona monocantha Sars, 1901	0.1	15.1	*Diaphanossoma birgei* Korineck 1981	0.4	35.2
Alonella dadayi Birge, 1910	<0.1	3.4	*Diaphanossoma brevireme* Sars 1901	0.1	11.7
Chydorus eurynotus Sars, 1901	1.3	37.8	*Diaphanossoma spinulosum* Herbst, 1967	0.1	11.7
Chydorus nitidulus Sars, 1901	0.2	11.7			
Daphniidae					
Ceriodaphnia cornuta Sars, 1886	5.0	73.1			
Ceriodaphnia cf. *laticaudata* Müller, 1867	0.6	24.3			
Ceriodaphnia reticulata Jurine, 1820	2.7	43.7			
Ceriodaphnia silvestrii Daday, 1902	3.7	72.2			
Daphnia gessneri Herbst, 1967	<0.1	8.4			

Considering larger cladocerans (> 1.00 mm), their densities were less representative compared to smaller species. *Diaphanosoma birgei* reached a peak in November/2002 (≈ 2,000 org.m^{-3}) and was always recorded since then. This species was absent in the previous samples (June, August, and September/2002). *Daphnia gessneri* was not found in the first months, appearing in the samples in October/2002, with increasing populations densities in the following months.

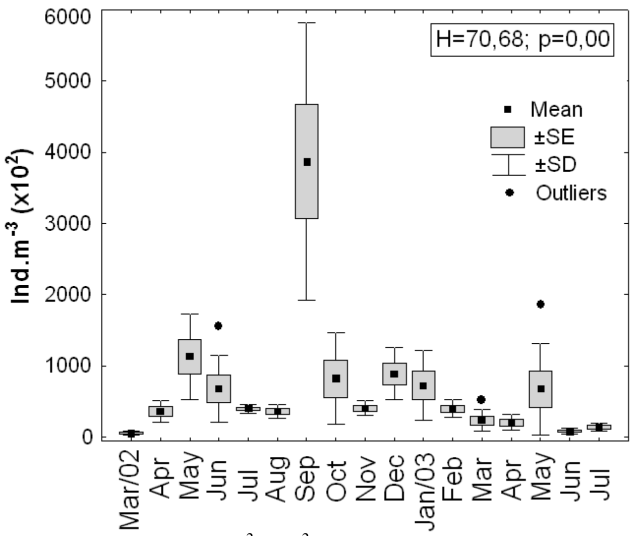

Figure 2. Cladocerans mean densities (individuals.m^{-3} x10^{3}) from March/2002 to July/2003, at Iraí Reservoir (N=102).

Inside Iraí Reservoir, *B. hagmanni* population densities were, generally, slightly higher in stations 1 and 3, located in the left and right margins of the dam, while *C. cornuta* was more abundant at station 5, followed by stations 1 and 3. Some larger species, like *D. birgei,* presented elevated maximum abundances in stations 4 and 5, and *D. gessneri* in station 6 (Fig. 3). It was not detected any significant difference between total and species abundance among sampling stations (H = 4.54, p = 0.60, Z = p > 0.05).

Significative Spearman correlation (R) between dominant cladocerans abundance and phytoplankton densities showed positive correlation with two *Ceriodaphnia* and two Chydoridae species with densities of *Microcystis aeruginosa*, one of the most abundant Cyanobacteria present in the reservoir in this study. There were no positive correlations between cladocerans and the other algae genera (β = p > 0.05) (Table III).

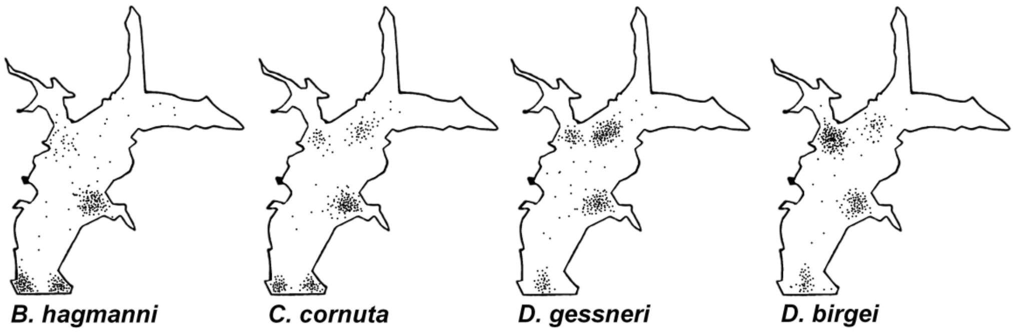

Figure 3. Spatial distribution of some cladocerans species inside Iraí Reservoir. Dark paths represent higher mean abundances from March/2002 to July/2003. For localization of stations sampling, see Figure 1.

Table III. Significative Spearman correlations between cladocerans and phytoplankton considering the mean population density during the studied period (p<0.05). Aual- *Aulacoseira alpigena,* Miae- *Microcystis aeruginosa,* Momi- *Monoraphidium minutum*, Peum- *Peridinium umbonatum*, Scen- *Scenedesmus sp.*, Tetr- *Tetraedon sp*, Uros- *Urosolenia sp*.

	Aual	Miae	Momi	Peum	Scen	Tetr	Uros
C. cornuta		0.72		-0.63	-0.72		
C. reticulata	-0.63				-0.69		
C. silvestrii		0.73			-0.76	-0.64	
C. eurynotus		0.73			-0.79	-0.67	
C. nitidilus		0.79		-0.69	-0.71	-0.72	
D. gessneri	-0.79		-0.77			-0.66	
D. birgei							-0.79
D. brevireme							-0.75

Spearman correlations were not significant (p < 0.05) among environmental variables (dissolved oxygen, pH, electric conductivity, total phosphorus, organic nitrogen, water transparency, and chlorophyll-a) and cladocerans population densities (β = p > 0.05). Results from Factor Analysis (Factor 1: 31.59%, Factor 2: 22.10%) indicated a close relation between cladoceran abundance and mean pluviosity (Fig. 4). Slightly correlation among Cladocera with phytoplankton and turbidity in the second factor were observed.

The pluviometric means at Iraí Reservoir region showed an increase in rainfall episodes in September/2002, indicating the beginning of rainy period (Fig. 5). In the same month, the peak of *B. hagmanni* density was observed in station 2, calling attention a peak in phytoplankton abundance one month before (August/2002). In dry period of 2002 (May from August) were recorded a decrease in the pluviometric indexes, as to April to June of 2003, when cladocerans abundances were also low, except in May/2003.

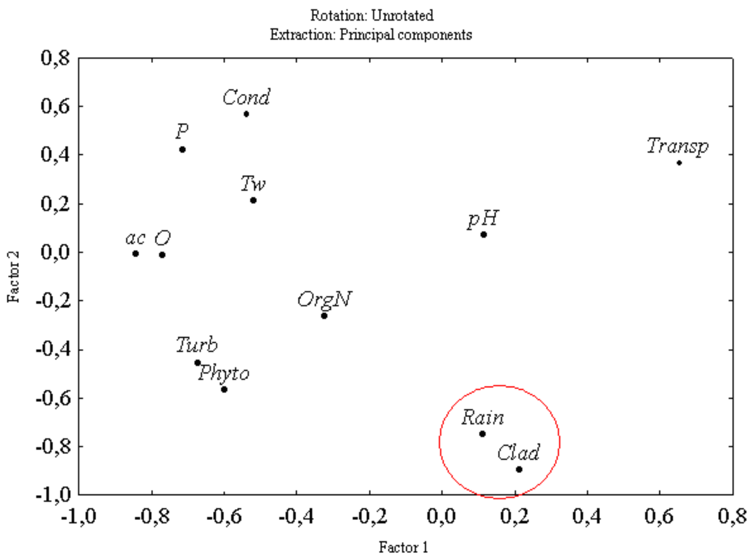

Figure 4. 2D loadings for factors 1 and 2 of the Factor Analysis of station 2. ac: a-chlorophyll; Clad: cladocerans total density; Cond: electrical conductivity; O: dissolved oxygen; OrgN: organic nitrogen; Phyto: phytoplankton's species richness; TotP: total phosphorus; Rain: mean rainfall for each month; Transp: Secchi's transparency; Turb: turbidity; Tw: water temperature.

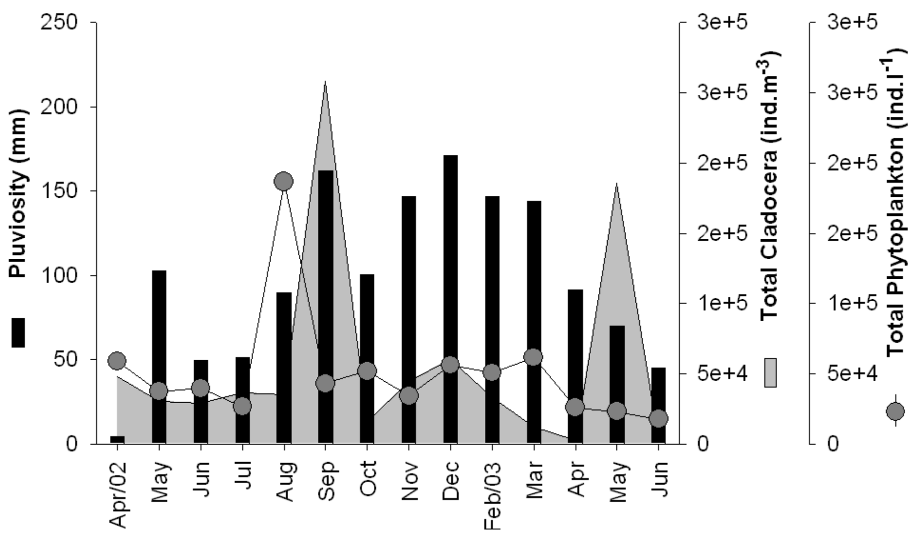

Figure 5. Mean pluviosity, total Cladocera and phytoplankton abundance in station 2 between April/2002 and June/2003.

Discussion

Most species recorded in this study are commonly found in the basin of Paraná River, especially the dominant planktonic, as *B. hagmanni*, *M. minuta,* and *C. cornuta* (Nogueira *et al.*, 2008). These species were also found in other aquatic Brazilian environments (Robertson & Hardy 1984, Santos-Wisniewski *et al.* 2000). In general, Bosminidae, Moinidae, and Daphniidae families are dominant in lenthic aquatic ecosystems like reservoirs as verified by Sampaio *et al*. (2002). Lansac-Tôha *et al*. (2005) also found the dominance of these families at Iraí Reservoir.

Representants of Macrothricidae and Ilyocryptidae families were less common in this study. They living in the littoral zone or nearby (Serafim-Júnior *et al.* 2003), and their presence in limnetic zone is accidental. The same consideration can be done to the Chydoridae family, but *C. eurynotus* and *C. nitidilus* were found in relatively high abundances compared to the other species of this family. Records of Chydoridae in the limnetic zone were found by Paggi & José de Paggi (1990) that considered some *Alona* species as pseudoplanktonic since its abundance was higher in the limnetic zone compared to the littoral zone of river channel and floodplain lakes.

Cladocerans are affected by several factors at Iraí Reservoir, mainly due to its shallowness, presenting a large superficial area as shown in Figure 1. In the beginning of the rainy season, increased nutrients availability to the water column allowed their incorporation by the aquatic communities (Nogueira *et al.* 2008, Serafim-Júnior *et al*. 2005). The low depth and the geomorphology of the reservoir induce organic matter and nutrients accumulation, and consequently, phytoplankton presence in areas next to the margins, favoring the development of small cladocerans. Larger species, however, are distributed in areas far from the dam.

The great amplitude variation of species richness in the rainy season can be related to two factors. First, the spatial heterogeneity of cladocerans, which explore the environment in different ways (Pinel-Alloul 1995), searching for adequate conditions for their development, for example, when an increase in altimetric quote and volume of the reservoir raises food availability and alter the phytoplankton community. Second, rain effect is noticeable because it causes the transport of autochthonous (from littoral zone) and allochtonous materials (from tributaries and other smaller lakes in the same basins). Lansac-Tôha *et al*. (2005) found slightly higher cladocerans richness at Iraí Reservoir during the rainy period.

Generally, there was an increase in cladocerans species richness during this study, possibly reflecting the processes of colonization and stabilization of the water column, a fact also observed in other reservoirs (Esteves & Camargo 1983). A trend of cladoceran temporal variation was observed after November/2002, when a richness peak was observed, followed by stable values, with a mean of 8.7 species. In contrast, in the same period, considering other plankton communities, Fernandes *et al*. (2005) did not find a pattern of species richness variation and abundance of the phytoplankton in Iraí Reservoir, as well as Perbiche-Neves *et al*. (2007) studying copepods. Also despollution actions were made in Iraí drainage basin and it can reflect in better quality water conditions. Elmoor-Loureiro *et al.* (2004) verified similar conditions in Paranoá Reservoir (Brazil), with new cladoceran records after a long period of water quality treatment of this reservoir.

Spatial variation of the most limnological features of the reservoir was very similar and homogeneous (Andreoli & Carneiro 2005), except by the concentration of nitrogenates and phosphates forms due to the tributaries rivers. Except the nutrients, homogeneous conditions can be associated to the constant cladocerans species numbers among sampling stations, probably related to the carrying capacity of the reservoir. Begon (2007) comments about this for ecological communities in general. Generally, in small and shallow reservoirs, two important parameters that promote water column mixing in reservoirs are the tributaries water velocity and wind dynamics. At Iraí Reservoir, wind effect is very important because its action on water surface causes accumulation of nutrients and algae in areas next to the dam (Gobbi *et al.* 2005), also influencing, as an example, the phytoplankton community (Fernandes *et al*. 2005) and the spatial distribution of copepods (Perbiche-Neves *et al*. 2007). Wind can also affect cladocerans spatial distribution, but a significant difference was not detected in the total abundance of cladocerans assemblages, as well as of species richness in this study.

Considering cladoceran temporal abundance peaks, was noticed the dominance of small organisms, especially *B. hagmanni*. In contrast, Elmoor-Loureiro (1988) states that to *B. longirostris*, *B. hagmanni* have never been associated to eutrophic environments and that elevated densities of these species were found in lakes with low nutrients. Thus, *B. hagmanni* dominance can be related with other variables not favorable to the dominance of *B. longirostris*, but detailed studies, as laboratory bioassays must be carried out to evaluate this relations. Dominance of small cladocerans like bosminids in eutrophic reservoirs was also found in other Brazilian studies (Branco & Cavalcanti 1999, Pinto-Coelho *et al.,* 1999, Sendacz *et al.,* 2006). It can be suggested that the dominance of *B. hagmanni* was favored by the eutrophication of Irai Reservoir, because this species corresponded to more than half of the total relative abundance. On the other hand, other species of the Daphniidae, Sididae, and Moinidae families were dominant in oligo/mesotrophic environments like some reservoirs of high Paranapanema River (Nogueira *et al.,* 2008).

Although not so abundant as *B. hagmanni*, *M. minuta* and *C. cornuta* elevated abundances can be explained by the adaptation of these species to food resources. They fed not only on phytoplankton, but also on detritus and bacteria (DeMott & Kerfoot 1982, Dole-Olivier *et al.* 2000). Furthermore, they have a fast development, associated to the high water temperature in the rainy season and to the great offer of food during the whole year at Iraí Reservoir, represented by Cyanobacteria. According to Monakov (2003), predation of cladocerans on bacterioplankton is one of the reasons of the development success of these organisms in adverse conditions. Success of this species was verified in many reservoirs in Paranapanema River (Brazil) (Nogueira *et al*., 2008).

Generally, large cladocerans abundance is low when compared to small cladocerans, however, their biomass is high, balancing the contribution of these organisms to the community (Sendacz *et al*., 2006; Corgosinho & Pinto-Coelho, 2006). Studies indicate that large cladocerans fed on algae, few species are detritivorous, and most species are selective to food quality (DeMott & Kerfoot 1982, de Bernardi *et al.* 1987). Other studies show that herbivory on large phytoplankton, as large colonies of Cyanobacteria by zooplanktonic filter feeders is difficult and energetically poor, especially if it involves algae toxicity (Ferrão-Filho & Azevedo 2003). Considering *Ceriodaphnia cornuta*, a dominant cladoceran in this study, the explanation of the high correlation with *M. aeruginosa* could be the great niche variety that this species could occupy, feeding, in this case, on Cyanobacteria early associated with cyanotoxins in Iraí Reservoir (Fernandes *et al.* 2005).

Ferrão-Filho & Azevedo (2003) found that feeding on colonial (*Microcystis*) and filamentous algae is difficult to small cladocerans and that they feed mainly on individual or in decomposition cells. Apparently, only large cladocerans, as *Daphnia*, are able to feed on individual cells or colonies of *Microcystis* (Rohrlack *et al.* 1999, Nandini 2000). Kobayashi *et al.* (1998) also state that large cladocerans are able to feed efficiently on large *Microcystis* colonies and that this can be influenced not only by alga toxicity, but also by colony disaggregation. The same was observed in Trabeau *et al.* (2004) experiments, that rising alga biovolume and microcystin production observed a decline of *Daphnia* populations, associated to an increase in energetic costs of feeding. Conversely, Alva-Martinez *et al.* (2001) detected an increase of population growth of one species of *Daphnia* and one of *Ceriodaphnia* when fed with increasing concentrations of *Microcystis aeruginosa*. Similar results could be expected in Iraí Reservoir, but laboratory bioassays are needed to test the influence of food on cladocerans populations.

Other phytoplankton species demonstrated negative correlation with cladocerans, as *D. gessneri*, that showed a negative correlation with *A. alpigena*, *M. minutum,* and *Tetraedon* sp. Lampert (1987) states that *Daphnia* feeding apparatus is specialized to feed on nanoplankton (5-60µm, according to Hutchinson 1967), and that ingested algae species can vary with the animal body size. Considering the three cited algae species, they are too large to be consumed by *D. gessneri*, explaining the negative correlation found in this study.

Diaphanosoma birgei and *D. brevireme* showed a negative correlation with the diatomacean *Urosolenia* sp. Despite baccilariophyceans are considered an indispensable food item to cladocerans that feed on periphyton, they are not commonly ingested by planktonic cladocerans (Nogueira *et al.* 2003). In the other hand, for copepods, Perbiche-Neves *et al.* (2007) found a high positive correlation with the diatomaceans during the same period of the present study at Iraí Reservoir.

After *B. hagmanni* peak in September/2002 there was a subsequent decline of *Bosmina* population's densities, when *Microcystis aeruginosa* cells densities was higher within chlorophyll-levels until January/2003. This decline could be related to the difficult of cladocerans in feeding on Cyanobacteria colonies, or due to the toxicity of the alga. The fact that *M. aeruginosa* and cladocerans densities decreased in October/2002 and that cladoceran species richness raised after October can indicate an increase in the food offered to cladocerans. *M. aeruginosa* blooms can also be associated with the population increase or appearance of the larger cladocerans *Daphnia* and *Diaphanosoma* in the lake that could be favored by the development of this alga.

Pinel-Alloul *et al.* (1988), studying the spatial distribution of zooplankton suggests that developmental stage, body size, and periodicity are factors that can influence data obtainment of population density horizontal variation and zooplankton species richness. However, tropical lakes are generally small, shallow, and it is difficult to establish a large scale of spatial heterogeneity (Rocha *et al.* 1995, Sarma *et al.* 2005). In these cases, density and species richness spatial variation can only be determined when adjacent regions of lenthic zones are included in the sampling program. Areas next to the margins, where detritus and cyanobacterians accumulate due the low water flux and wind direction, favor the development of small cladocerans, while larger species find better habitat conditions and greater food diversity in areas far from the dam.

Through the studied months, elevated rain episodes promoted water column mixing, occasioning slightly relation with turbidity in factor analysis, returning nutrients and organic matter to the water column, causing the abundance peak of *B. hagmanni* in September/2002. The water column mixing increased the nutrients availability to the primary producers, and, in this case, high abundance of cyanobacterians favored the appearance and development of larger cladocerans. This can also be associated to an increase of the food quantity and quality available, promoting the development of more species, explaining the elevated cladoceran species richness during the summer of 2002 and 2003 years. But in the absence of higher pluviosity, it was also verified a peak of phytoplankton abundance, like in August/02, represented by strategic cyanobacterians that can development in such conditions.

Both spatial and temporal variations were relevant but the first was not significant, rejecting in part the hypothesis that the temporal variation was more probable. Spatial variation was influenced mainly by morphometrical characteristics of the reservoir, and temporal variation by climatic changes in the sampling period, especially pluviosity and water temperature, very contrasting events in sub-tropical regions. Seasonal and temporal variation of species richness and population densities described in this study probably is due to alterations in the hydrological and biological characteristics of the reservoir. The modifications can be considered responses to natural processes of colonization and to environmental natural changes, or also a result of the management performed by the responsible sanitation company in the reservoir, in consequence of the degradation of water quality.

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References

Alva-Martínez, A. F., Sarma, S. S. S. & Nandini, S. 2001. Comparative population dynamics of three species of Cladocera in relation to different levels of *Chlorella vulgaris* and *Microcystis aeruginosa*. **Crustaceana,** 74(8): 749-764.

Andreoli, C. V. & Carneiro, C. 2005. **Gestão Integrada de Mananciais de Abastecimento Eutrofizados.** Capital, Curitiba, 500p.

Begon, M., Townsend, C. R. & Harper, J. L. 2006. **Ecology: from individuals to ecosystems**. 4[a] Ed. Blackwell publishing, Malden, 738p.

Blettler, M. C. M. & Bonecker, C. C. 2006. Avaliação da biomassa de microcrustáceos em ambientes aquáticos continentais. **Interciência**, 31(8): 591-597.

Bini, L. M., Silva, L. C. F. da, Velho, L. F. M., Bonecker, C. C. & Lansac-Tôha, F. A. 2008. Zooplankton assemblages concordance patterns in Brazilian Reservoirs. **Hydrobiologia**, 598: 247 – 255.

Bollmann, H. A. & Andreoli, O. R. 2005. Água no sistema urbana. Pp.83-119. *In:* Andreoli, C. V. & Carneiro, C. (Eds.). **Gestão Integrada de Manaciais de Abastecimento Eutrofizados.** Capital, Curitiba, 500 p.

Bonecker, C. C., Lansac-Tôha, F. A., Velho, L. F. M. & Rossa, D. C. 2001. The temporal distribution patterns of copepods in Corumbá Reservoir, State of Goiás, Brazil. **Hydrobiologia,** 453/454: 375-384.

Branco, C. W. & Cavalcanti, C. G. B. 1999. A ecologia das comunidades planctônicas no lago Paranoá. Pp. 575-595. *In:* Henry, R. (Ed.). **Ecologia de reservatórios: Estrutura, função e aspectos sociais.** FAPESP/FUNBIO, Botucatu, 794p.

Casanova, S. M. C. & Henry, R. 2004 Longitudinal distribution of copepods in the transition zone Paranapanema River-Jurumirim Reservoir (SP, Brazil) and interchanges with two lateral lakes. **Brazilian Journal Biology,** 64(1): 11-26.

Corgosinho, P. H. C. & Pinto-Coelho, R.M. 2006. Zooplankton biomass, abundance and alometric patterns along an eutrophic gradient at Furnas Reservoir (Minas Gerais- Brazil). **Acta Limnologica Brasiliensa,** 18(2): 213-224

DeBernardi, R.; Guissani, G. & Manca, M. 1987. Cladocera: predators and prey. **Hydrobiologia,** 145: 225-243.

DeMott, W. R. & Kerfoot, W. C. 1982. Competition among cladocerans: Nature of the interactions between *Bosmina* and *Daphnia*. **Ecology,** 6(63): 1949-1966.

Dole-Oliver, M. J., Galassi, D. M. P., Marmonier, P. & Creuzé Des Châtelliers, M. 2000. The biology and ecology of lotic microcrustaceans. **Freshwater Biology,** 44: 63-91.

Elmoor-Loureiro, L. M. A.. 1998. **Manual de Identificação de Cladóceros Límnicos do Brasil**. Universa, Brasília, 155p.

Elmoor-Loureiro, L. M. A., Mendonça-Galvão, L. & Padovesi-Fonseca, C. 2004. New cladoceran records from Lake Paranoá, Central Brazil. **Brazilian Journal of Biology,** 64(3A): 415-422.

Elmoor-Loureiro, L. M A. 2007. Phytophilous cladocerans (Crustacea, Anomopoda and Ctenopoda) from Paranã River Valley, Goiás, Brazil. **Revista Brasileira. de Zoolologia**, 24(2): 344-352.

Elser, J. J., Elser, M. M. & Carpenter, S. R. 1988. Zooplankton- mediated transitions between N- and P-limited algal growth. **Limnology and Oceanography,** 33: 1-14.

Esteves, F. A. & Camargo, A. F. 1986. Sobre o papel de macrófitas aquáticas na estocagem e ciclagem de nutrientes. **Acta Limnologica Brasiliensa,** 1: 273-298.

Fernandes, L. F., Wosiack, A. C & Pacheco, C. V., Domingues, L. & Lagos, P. D. 2005. Cianobactérias e Cianotoxinas. Pp. 367-388. *In:* Andreoli, C. V. & Carneiro, C. (Eds.). **Gestão Integrada de Mananciais de Abastecimento Eutrofizados**. Capital, Curitiba 500p.

Ferrão-Filho, A. S. & Azevedo, S. M. F. O. 2003. Effects of unicellular and colonial forms of toxic *Microcystis aeruginosa* from laboratory cultures and natural populations on tropical cladocerans. **Aquatic Ecology,** 37: 23–35.

Ferrão-Filho, A. S., Arcifa, M. S. & Fileto, C. 2003. Resource limitation and food quality for cladocerans in a tropical Brazilian lake. **Hydrobiologia,** 491:201-210.

Gobbi, M. F., Gobbi, E. F. & Reksidler, R. 2005. Modelagem Matemática. Pp. 189-212. *In:* Andreoli, C. V. & Carneiro, C. (Eds.). **Gestão Integrada de Mananciais de Abastecimento Eutrofizados.** Capital, Curitiba, 500p.

Hollwedel, W., Kotov, A. A. & Brandorff, G. O. 2003. Cladocera (Crustacea: Branchiopoda) from the Pantanal, Brazil. **Arthropoda Selecta**, 12(2): 67-93.

Kobayashi, T. A., Hardiman, C. S. & Gallagher, L. 1998. Grazing by a resident macrozooplankton community and non-resident *Daphnia carinata* King: a preliminary incubation study. **Lakes and** *Reservoir Management***,** 3: 193-203.

Lampert, W. 1987. Feeding and nutrition in *Daphnia*. Mem. Ist. Ital. Idrobiol. 45: 143-192.

Lansac-Tôha, F. A., Bonecker, C. C. & Velho, L. F. M. 2005. Estrutura da comunidade zooplanctônica em reservatórios. Pp. 115-127. *In:* Rodrigues, L.; Thomaz, S. M.; Agostinho, A. A.; Gomes, L. C. (Eds.). **Biocenoses no reservatório: padrões espaciais e temporais**. RIMA, São Carlos, p.115-127.

Lopes, R. M., Lansac-Tôha, F. A. & Serafim-Júnior, M. 1997. Comunidade zooplanctônica do reservatório de Segredo. Pp. 39-60. ***In:*** Agostinho, A. A. & Gomes, L. C. **(Eds.).** Reservatório de Segredo: base para o manejo**. Eduem,** Maringá, p.39-60.

Lurling, M. & Vandonk, E. 1997. Life history consequences for *Daphnia pulex* feeding on nutrient-limited phytoplankton. **Freshwater Biology,** 38: 693–709.

Matsumura-Tundisi, T. 1984. Occurrence of species of the genus *Daphnia* in Brazil. **Hydrobiologia,** 112: 161-165.

Matsumura-Tundisi, T. & Tundisi, J. G. 2003. Calanoida (Copepoda) species composition changes in the reservoirs of São Paulo state (Brazil) in the last twenty years. **Hydrobiologia,** 504: 215-222.

Matsumura-Tundisi, T. & Tundisi, J. G. 2005. Plankton richness in a eutrophic reservoir (Barra Bonita Reservoir, SP, Brazil). **Hydrobiologia,** 542(1): 367-378.

Melão, M. G. G. 1999. A produtividade secundária do zooplâncton: métodos, implicações e um estudo na Lagoa Dourada. Pp. 151-183. *In:* Henry, R. (Ed.). **Ecologia de reservatórios: estrutura, função e aspectos sociais.** Fapesp/Fundibio, Botucatu, 794p.

Meschiatti, A. J. & Arcifa, M. S. 2002. Early life stages of fish and the relationships with zooplankton in a tropical Brazilian Reservoir: Lake Monte Alegre. **Brazilian Journal Biology,** 62(1): 41-50.

Monakov, A. V. 2003. **Feeding of Freshwater Invertebrates**. Kenobi Productions, Ghent, 321p.

Nandini, S. 2000. Responses of rotifers and cladocerans to *Microcystis aeruginosa* (Cyanophyceae): a demographic study. *Aquatic Ecology*, 34: 227–242.

Nogueira, M. G., George, D. G. & Jorcin, A. 2003. Estudo do zooplâncton em zonas litorâneas lacustres: um enfoque metodológico. Pp. 83-128. *In:* Henry, R. (Ed.). **Ecótonos nas interfaces dos ecossistemas aquáticos.** RIMA, São Carlos, 360p.

Nogueira, M. G., Reis Oliveira, P. C. & Britto, Y. T. 2008. Zooplankton assemblages (Copepoda and Cladocera) in a cascade of reservoirs of a large tropical river (SE Brazil). **Limnetica,** 27(1): 151-170.

Paggi, J. C. & José de Paggi, S. 1990. Zooplâncton de ambientes lóticos e lênticos do Rio Paraná médio**. Acta Limnologica Brasiliensa,** 3: 685-719.

Perbiche-Neves, G., Serafim-Júnior, M., Ghidini, A. R. & Brito, L. 2007. Spatial and temporal distribution of Copepoda (Cyclopoida and Calanoida) of an eutrophic reservoir in the basin of upper Iguaçu River, Paraná, Brazil. Acta **Limnologica Brasiliensa,** 19(4): 393-406.

Pinel-Alloul, B., Downing, J. A., Pérusse, M. & Codin-Blumer, G. 1988. Spatial heterogeneity in freshwater zooplankton: variation with body size, depth, and scale. **Ecology**, 69(5): 1393-1400.

Pinel-Alloul, B. 1995. Spatial heterogeneity as a multiscale characteristic of zooplankton community. **Hydrobiologia**, 300/301: 17-42.

Pinto-Coelho, R. M., Coelho, M. M, Espírito-Santo, M. M. & Cornelissen, T. G. 1999. Efeitos da eutrofização na estrutura da comunidade planctônica no lago da Pampulha, Belo Horizonte – MG. Pp. 553-572. *In:* Henry, R. (Ed.). **Ecologia de reservatórios: estrutura, função e aspectos sociais.** FAPESP/FUNBIO, Botucatu, 794p.

Robertson, B. A. & Hardy, E. R. 1984. Zooplankton of Amazonia lakes and rivers. Pp. 337-352. *In:* Sioli, H. (Ed.), **The Amazon.** Springer-Verlag, Dodrecht, 761p.

Rocha, O., Sendacz, S. & Matsumura-Tundisi, T. 1995. Composition, Biomass and Productivity of Zooplankton in Natural Lakes and Reservoirs in Brazil. Pp. 151-166. *In:* Tundisi, J. G.; Bicudo, C. E. M. & Matsumura-Tundisi, T. (Eds.). **Limnology in Brazil**. Academia Brasileira de Ciências, Rio de Janeiro, 376p.

Rohrlack, T., Henning, M. & Johl, J. 1999. Mechanisms of the inhibitory effect of the cyanobacterium *Microcystis aeruginosa* on *Daphnia galeata*'s ingestion rate. **Journal Plankton Research,** 21(8): 1489-1500.

Sampaio, E. V., Rocha, O., Matsumura-Tundisi, T. & Tundisi, J. G. 2002. Composition and abundance of zooplankton in the limnetic zone of seven reservoir of Paranapanema River, Brazil. **Brazilian Journal Biology,** 62(3): 525:545.

Santos-Wisniewski, M. J., Rocha, O., Rietzler, A. C. & Espíndola, E. L. G. 2000. Diversidade do zooplâncton nas lagoas marginais do rio Mogi-Guaçu: 2 Cladocera (Crustácea: Branchipoda). Pp. 559-586. *In:* Santos, J. G. & Pires, J. S. R. (Eds.). **Estação ecológica do Itajaí – Vol 2.** RIMA, São Carlos, 2867p.

Sarma, S. S. S., Nandini, S. & Gulati, R. D. 2005. Life history strategies of cladocerans: comparisons of tropical and temperate taxa. **Hydrobiologia,** 542: 315-333.

Sendacz, S., Caleffi, S. & Soares J. S. 2006. Zooplankton biomass of reservoirs in different trophic conditions in the State of São Paulo, Brazil. **Brazilian Journal Biology,** 66: 337-350.

Serafim-Júnior, M., Lansac-Tôha, F.A., Paggi, J.C., Velho, L.F.M. & Robertson, B. 2003. Cladocera fauna composition in a river-lagoon system of the upper Paraná River floodplain, with a new record for Brazil. **Brazilian Journal Biology**, 63: 349-356.

Serafim-Júnior, M., Ghidini, A. R., Perbiche-Neves, G. & Brito, L. 2005. Comunidade Zooplanctônica. Pp. 409-434. *In:* Andreoli, C. V. & Carneiro, C. (Eds.). **Gestão integrada de mananciais de abastecimento eutrofizados**. Capital, Curitiba, p. 500.

StatSoft, Inc. 2002. **STATISTICA** (data analysis software system), version 6.0 www.statsoft.com.

Trabeau, M., Bruhn-Keup, R., Mcdermott, C., Keomany, M., Millsaps, A., Emery, A. & Stasio-Junior, B. 2004. Midsummer decline of a *Daphnia* population atttibuted in part to cyanobaterial capsule production. **Journal Plankton Research,** 26(8): 949-961.

Velho, L.F.M.; Lansac-Tôha, F.A. & Bonecker, C.C. 2005. Distribuição Longitudinal da Comunidade Zooplanctônica em Reservatórios. Pp. 129-136. In: Rodrigues, L.; Thomaz, S.M.; Agostinho, A.A. & Gomes, L.C. (eds.). **Biocenoses em Reservatórios: Padrões Espaciais e Temporais.** RIMA, São Carlos, 321p.

Whiteside, M. C., Willians, J. B. & White, C. P. 1978. Seasonal abundance and pattern of Chydorid Cladocera in mud and vegetative habitats. **Ecology,** 59(6): 1177-1188.

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First report of larval *Spiroxys* sp. (Nematoda, Gnathostomatidae) in three species of carnivorous fish from Três Marias Reservoir, São Francisco River, Brazil

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Abstract. The objective of this paper was to evaluate the parasitism by nematode larvae at three species of carnivorous fish in the Três Marias Reservoir, Brazil. It was verified 108 individuals of *Pygocentrus piraya* (Cuvier, 1819), 168 *Serrasalmus brandtii* Lütken, 1875, and 112 *Cichla kelberi* Kullander & Ferreira, 2006. A total of 59 individuals of nematode larvae were found in the three hosts and identified as third stage (L_3 or infective larvae of definitive host) *Spiroxys* sp.. The parasitic indexes were more elevated in the *P. piraya* and *S. brandtii*, although the prevalence and abundance of *Spiroxys* sp. were higher in smaller specimens of *S. brandtii*. This may be explained since these juveniles feed some arthropods, that serve as intermediate hosts and fish parasitized by larvae of *Spiroxys* sp. while foraging. Just two individuals of *C. kelberi* were parasitized by *Spiroxys* sp. and this rare occurrence was shown to be accidental. This record adds to the current knowledge of this nematode's life cycle and provides evidence that these carnivorous fish serve as paratenic hosts of *Spiroxys* sp. larvae in that Reservoir.

Key words: *Pygocentrus piraya*, *Serrasalmus brandtii*, *Cichla kelberi*, paratenic host fish.

Resumo: **Primeiro registro de larvas de S*piroxys* sp. (Nematoda, Gnathostomatidae) em três espécies de peixes carnívoros do Reservatório de Três Marias, Rio São Francisco, Brasil.** O objetivo deste trabalho foi avaliar o parasitismo de larvas de nematóides em três espécies de peixes carnívoros no Reservatório de Três Marias, Minas Gerais. Foram examinados 108 indivíduos de *Pygocentrus piraya* (Cuvier, 1819), 168 de *Serrasalmus brandtii* Lütken, 1875 e 112 de *Cichla kelberi* Kullander & Ferreira, 2006. Um total de 59 indivíduos de nematóides larvais encontrados nas três espécies de hospedeiros foram identificadas como *Spiroxys* sp., no terceiro estágio (L_3 – larva infectante ao hospedeiro definitivo), cujos índices parasitários foram mais elevados em *P. piraya* e *S. brandtii*. Contudo, a prevalência e a abundância de *Spiroxys* sp. foram mais elevadas em espécimes menores de *S. brandtii*, pois os juvenis desta espécie se alimentam de artrópodes (com hospedeiros intermediários) e peixes parasitados pelas larvas de *Spiroxys* sp.. Apenas dois indivíduos de *C. kelberi* hospedaram larvas de *Spiroxys* sp. o que pode ter sido acidental. Os resultados encontrados neste trabalho associados ao conhecimento do ciclo de vida dos nematóides evidenciam que estes peixes carnívoros atuam como hospedeiros paratênicos das larvas de *Spiroxys* sp. no Reservatório de Três Marias.

Palavras-chave: *Pygocentrus piraya*, *Serrasalmus brandtii*, *Cichla kelberi*, hospedeiros paratênicos

Introduction

Três Marias Reservoir is located on the Upper São Francisco River, São Francisco River Basin, in the central region of the State of Minas

Gerais, Brazil. It was inundated in 1961 and at its maximum level has a surface area of roughly 100 thousand hectares and volume of 21 billion cubic meters (Britski *et al*. 1988). It is important to regulate the level of water in the River San Francisco for navigation, control of floods, irrigation and electric power production (Sampaio & López, 2003).

The endemic serrasalmines *Pygocentrus piraya* (Cuvier, 1819) and *Serrasalmus brandtii* Lütken, 1875 and the allochtonous cichlid *Cichla kelberi* Kullander & Ferreira, 2006, are important fishes in fisheries along the São Francisco River. *Pygocentrus piraya* is commonly known as "piranha". It can reach a total length of 51 cm (Pinkguni 1997) and weigh over 6 kg (Ferreira *et al*. 1996). It is carnivorous, preferentially feeding on other fish (Britski *et al*. 1988, Alvim 1999), behaves opportunistically (Gomes 2002) and gregariously and generally inhabits lentic environments (Braga 1975). It is abundant in the Três Marias Reservoir (Britski *et al*. 1988). *Serrasalmus brandtii* is commonly known as "pirambeba" or "white piranha" (Jegú 2003), and can reach a total length of 31 cm and weight of 700 g (Braga 1975). According to Gomes & Verani (2003), *S. brandtii* is generally smaller than *P. piraya*. It is also carnivorous, preferentially feeding on other fish (Alvim 1999, Gomes 2002) and can tear pieces from its prey with its sharp cutting teeth (Britski *et al.* 1988). Alvim (1999) concluded that *S. brandtii* is a piscivore that feeds mainly on the fins of smaller fish. Pompeu & Godinho (2003) classify *S. brandtii* as a piscivore-insectivore species. *Cichla kelberi*, known commonly as "tucunaré" is a species originally from the Tocantins River Basin (Kullander & Ferreira 2006) that lives in lentic environments where it reproduces mainly during the rainy season (Zaret 1980). Tucunarés have been caught by professional fishermen in Três Marias Reservoir since 1982, but it is not known how the species was introduced (Magalhães *et al.* 1996).

Moreira (1994) reported *Procamallanus (Spirocamallanus) inopinatus* Travassos, Artigas & Pereira, 1928 in *P. piraya* from the Três Marias Reservoir. Moravec *et al.* (2008) redescribed and reported *Cystidicoloides fischeri* (Travassos, Artigas & Pereira, 1928) in *P. piraya* and *S. brandtii* from the same locality. Santos (2008) found *Spinitectus rodolphiheringi* Vaz & Pereira, 1934 in *P. piraya*., *Philometra* sp. in *S. brandtii*., *Rhabdochona* sp. in *C. kelberi*, as well as *Hysterothylacium* sp., *Goezia*. sp. and *Capillostrongyloides* sp. from these carnivorous hosts.

This work constitutes the first about the various parasitological studies of the carnivorous fish from the Três Marias Reservoir. The aim of this study was to evaluate the ecological-parasite descriptors of the nematode larvae (prevalence, intensity and mean abundance) with the biotic aspects of the hosts (sex and total length), feeding behavior and collection period (dry and wet period) of these important carnivorous fish from the Três Marias Reservoir.

Materials and Methods

The collection of hosts was as follows: 108 specimens of *P. piraya* were caught between July and August, 2004 (dry season) and December, 2004 and January, 2005 (wet season); 168 specimens of *S. brandtii* were caught between July to August, 2004 and July, 2005 (dry season) and January, 2004 and January, 2005 (wet season); and 112 specimens of *C. kelberi* were collected between August, 2004 and July to August, 2005 (dry season) and between December to January, 2004 and January, 2005 (wet season). The fishes were collected in the Três Marias Reservoir, in the area of influence of the Borrachudo River (18º12'59"S, 45º17'34"W), Upper São Francisco River, in the municipality of Três Marias, State of Minas Gerais, Brazil by fishermen from the Estação de Hidrobiologia e Piscicultura of the Companhia de Desenvolvimento dos Vales do São Francisco e do Parnaíba (EPT/CODEVASF).

The specimens of *P. piraya* and *S. brandtii* were identified and classified according to Britski *et al*. (1988) and Jegú (2003), while the specimens of *C. kelberi* according to Kullander & Ferreira (2006). The nominal taxa of fish followed FishBase (Froese & Pauly 2007). The larval specimens of Nematoda were collected, fixed and processed according to Amato *et al*. (1991) and identified and classified according to Moravec (1998).

The ecological descriptors utilized in the parasitological results followed Bush *et al*. (1997). The statistical tests were only applied for the larval nematodes of fish species with prevalence of 10% or higher, following the recommendation of Bush *et al.* (1990). All the statistical analyses applied to the infrapopulations followed Zar (1996), at a significance level of $p<0.05$.

Voucher specimens of *P. piraya, S. brandtii* and *C. kelberi,* were deposited in the Museu de Zoologia of the Universidade de São Paulo, São Paulo, Brazil (MZUSP: 95150, 95148 and 95149). Voucher specimens of nematode larvae from the three hosts were deposited in the Coleção Helmintológica do Instituto Oswaldo Cruz (CHIOC: 36959, 35557, 36953, respectively), Rio de Janeiro, Brazil.

Results and Discussion

Of the 108 specimens of *P. piraya* collected, 56 were males with average total length of 18.1 ± 4.4 cm (11.1 to 30.5 cm) and average weight of 169.8 ± 180.1 g (21.0 to 835.0 g), and 52 were females with average total length of 21.4 ± 6.0 cm (13.0 to 34.0 cm) and average weight of 323.4 ± 308.4 g (40.0 to 1225.0 g). Of the 168 specimens of *S. brandtii* collected, 55 were males with average total length of 16.2 ± 3.5 cm (9.5 to 27.0 cm) and average weight of 96.9 ± 96.4 g (11.0 to 500.0 g), and 113 were females with average total length of 16.9 ± 4.6 cm (8.5 to 29.5 cm) and average weight of 125.5 ± 142.9 g (7.0 to 657.0 g). Of the 112 specimens of *C. kelberi* collected, 59 were males with average total length of 29.6 ± 6.2 cm (18.0 to 48.0 cm) and average weight of 419.2 ± 285.3 g (85.0 to 1540.0 g), and 53 were females with average total length of 28.4 ± 4.4 cm (20.0 to 35.5 cm) and average weight of 366.9 ± 179.7 g (85.0 to 684.0 g).

A total of 59 specimens (27 in *P. piraya*, 30 in *S. brandtii* and two in *C. kelberi*) of nematode larvae found in the three hosts were identified as third stage (L_3) *Spiroxys* sp.; prevalence was higher in *S. brandtii* and the mean intensity and mean abundance were higher in *P. piraya* (Table I).

Table I. Prevalence (P), intensity range (IR), mean intensity (MI) and mean abundance (MA), with the respective standard deviation (SD), and site of infection (C = coelome, IC = intestinal cecum, E = stomach, AG = anterior gut, MG = middle gut, GB = gall bladder) of *Spiroxys* sp. from three hosts, piscivorous fish from Três Marias Reservoir, Upper São Francisco River, Brazil.

	Parasitic indexes of *Spiroxys* sp.				
Hosts	**P (%)**	**IR**	**MI±SD**	**MA±SD**	**Site of infection**
Pygocentrus piraya	12.9	1-6	1.93±1.49	0.25±0.83	C, IC, AG, GB
Serrasalmus brandtii	13.1	1-4	1.36±0.85	0.18±0.55	C, E, AG, MG
Cichla kelberi	1.8	1	1.0	0.018±0.13	C, MG

The prevalence and mean abundance of *Spiroxys* sp. were not influenced by sex, total length and collection period of *P. piraya*. The prevalence and mean abundance of these larvae were also not influenced by either sex or collection period of *S. brandtii*. On the other hand, the prevalence and mean abundance of *Spiroxys* sp. were higher in smaller fish (Table II). As only two specimens of *C. kelberi* were parasitized by *Spiroxys* sp., it was not possible to conduct the statistical analyses for these specimens.

Table II. Analysis of the parasitic indexes (P= prevalence, A= abundance) of *Spiroxys* sp. under the possible influence of sex, total length and collection period of two serrasalmine fish from Três Marias Reservoir, Upper São Francisco River, Minas Gerais, Brazil.

	Pygocentrus piraya		***Serrasalmus brandtii***	
	P	**A**	**P**	**A**
Sex	X^2= 0.02 p= 0.89	U= 1425.00 p= 0.84	X^2= 0.68 p= 0.40	U= 2922.00 p= 0.52
Total length	r= -0.14 p= 0.74	r_s= 0.001 p= 0.99	r= -0.94 p= 0.0003*	r_s= -0.25 p= 0.001*
Collect period	X^2= 0.62 p= 0.43	U= 1318.00 p= 0.37	X^2= 0.75 p= 0.38	U= 3304.50 p= 0.47

*Significant values: p<0.05; X^2: Chi-square with Yates correction; U: Mann Whitney test; r: Pearson's correlation; r_s: Spearmann's correlation rank.

According to Moravec (1998), *Spiroxys* Schneider, 1866 is represented by seven species that infect freshwater chelid turtles of Central and North America. Of these, four have been reported in Mexico: *Spiroxys contortus* (Rudolphi, 1819), *S. corti* Caballero, 1935, *S. susanae* Caballero, 1941 and *S. triretrodens* Caballero & Zerecero, 1943. Because the morphological characteristics at the species level only become evident in adult specimens, it was only possible to identify the larvae to the genus level. Freshwater fishes are paratenic hosts of these larvae. Moravec (1998) suggested the possibility that the larvae of *Spiroxys* found in fish are *S. contortus*, a well-distributed and common species.

Moravec *et al*. (1995) inventoried the

Spiroxys present in the coelomic cavity, mesentery and intestines of *Cichlasoma meeki* (Brind, 1918), *C. urophtalmus* (Günther, 1862), *Poecilia velifera* (Regan, 1914), *Poecilia* sp. and *Astyanax fasciatus* (Cuvier, 1819) in the state of Yucatan, Mexico. Mendoza *et al*. (2004) reported these species in *Dormitator maculatus* (Bloch, 1792) (paratenic host) from Alvarado Lake, Mexico. In Brazil, Isaac *et al*. (2004) found larvae of *Spiroxys* in *Gymnotus* spp. caught in the Baía River in the State of Mato Grosso do Sul. In the present work, these larvae were found in the stomach, intestinal cecum, anterior and middle gut and gall bladder of the three host carnivores examined, two of them endemic serrasalmines of the São Francisco River Basin and one an *allochtonous* cichlid native to the Tocantins River Basin. Therefore, besides the possibility that smaller "piranha" ingest greater quantities of arthropods, our findings suggest that carnivorous fish also prey on foraging fish parasitized by larvae of *Spiroxys* sp. (one of the authors of this study previously found *Spiroxys* larvae in foraging fish in the Três Marias Reservoir) and are thus acting as paratenic hosts of these nematodes in Três Marias Reservoir.

Despite the possibility of behavioral differences between male and female fish, mainly during the spawning season when females generally become stressed and vulnerable to infections, there was no difference in the parasitic indexes of the larvae of *Spiroxys* sp. between the male and female carnivorous fishes studied here.

Spiroxys sp. was significantly more prevalent and abundant in smaller specimens of *S. brandtii*. This can be explained by the piscivorous-insectivorous feeding habit of juvenile "pirambebas", as reported by Pompeu & Godinho (2003), including the intermediate host species of this nematode among the various arthropods eaten. According to Moravec (1998), fish act as paratenic hosts of these larvae (L_3 or infective larvae of the definitive host), when feeding on infected aquatic insects (intermediate hosts), and the definitive hosts are freshwater chelid turtles. This study, besides the finding that smaller "pirambebas" can ingest greater quantities of arthropods, suggests that they also feed on foraging fish parasitized by larvae of *Spiroxys* sp., meaning these fish act as paratenic hosts of these nematodes in Três Marias Reservoir.

According to Paperna (1996), if nematode larvae are not eliminated by the host's immune system or by some regulatory system of the parasite intensity, they can remain viable for a long time until reaching their definitive hosts. The low intensity of *Spiroxys* sp. found in the three hosts analyzed, particularly in *C. kelberi* (where only two specimens were parasitized), can be explained by the elimination of these larvae by the immune system of these hosts, or also by the sporadic feeding on these larvae by the fish species studied.

The three carnivorous species were all infected by *Spiroxys* sp. larvae, but the parasitism pattern between the two serrasalmines endemic to the São Francisco River Basin was similar, that is, there was no quantitative difference between them. However, in *C. kelberi* these larvae were rare and the parasitism was probably accidental in this cichlid.

Despite the results found in this study, it is probable that the diets of the serrasalmine fish (based on arthropods infected with *Spiroxys* larvae) were similar throughout the year in the Três Marias Reservoir since the prevalence and abundance of these larvae were not influenced by the fish collection period.

Besides being considered definitive hosts of some parasite species, these findings indicate that the carnivorous fish from the Três Marias Reservoir analyzed in this study can be classified as paratenic hosts of *Spiroxys* larvae, indicating the complexity of the host-parasite relationship in the aquatic system in question.

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References

Alvim, M. C. C. 1999. Caracterização alimentar da ictiofauna em um trecho do Alto rio São Francisco, município de Três Marias – MG. **Master Thesis.** Universidade Federal de São Carlos, São Carlos, Brazil, 83 p.

Amato, J. F. R., Boeger, W.A. & Amato, S.B. 1991. **Protocolos para laboratório – coleta e processamento de parasitos de pescado.**

Imprensa Universitária, Seropédica, 81 p.

Braga, R. A. 1975. **Ecologia e etologia das piranhas do nordeste do Brasil (Pisces – Serrasalmus Lacépède, 1803).** DNOCS, Fortaleza, 268 p.

Britski, H. A., Sato, Y. & Rosa, A. B. S. 1988. **Manual de identificação de peixes da região de Três Marias (com chaves de identificação para os peixes da Bacia do São Francisco).** 3[a] ed., CODEVASF, Brasília, 115 p.

Bush, A. O., Aho, J. M. & Kennedy, C. R. 1990. Ecological versus phylogenetic determinants of helminth parasite community richness. **Evolutionary Ecology**, 4: 1-20.

Bush, A. O., Lafferty, J. M. & Shostak, A. W. 1997. Parasitology meets ecology on its own terms: Margolis *et al*. revisited. **Journal of Parasitology,** 83: 575-583.

Ferreira, R. M. A., Bazzoli, N., Rizzo, E. & Sato, Y. 1996. Aspectos reprodutivos da piranha *Pygocentrus piraya* (Teleostei, Characiformes), espécie nativa da bacia do rio São Francisco. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, 48: 71-76.

Froese, R. & Pauly, D. 2007 (Eds.). **FishBase** – World Wide Web electronic publication, accessible at http://www.fishbase.org. (Accessed 01/18/2007).

Gomes, J. H. C. 2002. Ecologia trófica de espécies de peixes do reservatório de Três Marias (MG). **PhD. Thesis.** Universidade Federal de São Carlos, São Carlos, Brazil, 142 p.

Gomes, J. H. C. & Verani, J. R. 2003. Alimentação de espécies de peixes do reservatório de Três Marias. Pp. 195-227. In: Godinho, H. P. & Godinho, A. L. (Eds.). **Águas, peixes e pescadores do São Francisco das Minas Gerais.** Puc Minas, Belo Horizonte, 458 p.

Isaac, A., Guidelli, G. M., França, J. G. & Pavanelli, G. C. 2004. Composição e estrututa das infracomunidades endoparasitárias de *Gymnotus* spp. (Pisces: Gymnotidae) do rio Baía, Mato Grosso do Sul, Brasil. **Acta Scientiarum. Biological Sciences**, 26: 453-462.

Jegú, M. 2003. Subfamily Serrasalminae. Pp. 182-196. In: Reis, R. E., Kullander, S. O. & Ferraris, C. J. (Eds.). **Checklist of the freshwater fishes of South and Central America.** EDIPUCRS, Porto Alegre, 729 p.

Kullander, S. O. & Ferreira, E. J. G. 2006. A review of the South American cichlid genus *Cichla*, with descriptions of nine species of Teleostei: Cichlidae. **Ichthyological Exploration of Freshwaters**, 17: 289-398.

Magalhães, A. L. B., Sato, Y., Rizzo, E., Ferreira, R. M. A. & Bazzolli, N. 1996. Ciclo reprodutivo do tucunaré *Cichla ocellaris* (Schneider, 1801) na represa de Três Marias, MG. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia,** 48: 85-92.

Mendoza, J. M., Sarabia, D. O., López, R. C. & López, J. F. 2004. Helmintos del pez *Dormitator maculatus* (Osteichthyes: Eleotridae) de Alvarado, Veracruz, México. **Revista de Biologia Tropical**, 52: 393-396.

Moravec, F. 1998. **Nematodes of freshwater fishes of the Neotropical Region.** Academy of Sciences of the Czech Republic, Praha, 464 p.

Moravec, F., Vivas-Rodríguez, C., Scholz, T., Vargas-Vásquez, J., Mendoza-Franco, E., Schmitter-Soto, J. J. & Gonzáles-Solís, D. 1995. Nematodes parasitic in fishes of cenotes (= sinkholes) of the Peninsula of Yucatán, Mexico. Part 2. Larvae. **Folia Parasitologica**, 42: 199-210.

Moravec, F., Santos, M. C. & Brasil-Sato, M. C. 2008. Redescription of *Cystidicoloides fischeri* based on specimens from piranhas in Brazil, and erection of a new genus (Nematoda: Cystidicolidae). **Journal of Parasitology**, 94: 889-897.

Moreira, N. I. M. 1994. Alguns nematódeos parasitos de peixes na represa de Três Marias, Bacia do Rio São Francisco, Minas Gerais. **Master Thesis.** Universidade Federal de Minas Gerais, Minas Gerais, Brazil. 102 p.

Paperna, I. 1996. **Parasites, infections and diseases of fishes in África – An update.** CIFA Technical Paper, 211 p.

Pinkguni, M. 1997. **Pirañas: cuidados – crianza – especies.** Editorial Hispano Europea, Barcelona, 64 p.

Pompeu, P. S., Godinho, H. P. 2003. Ictiofauna de três lagoas marginais do médio São Francisco. Pp. 167-181. In: Godinho, H. P. & Godinho, A. L. (Eds.). **Águas, peixes e pescadores do São Francisco das Minas Gerais.** PUC Minas, Belo Horizonte, 458 p.

Sampaio, E. V., López, C. M. 2003. Limnologia física, química e biológica da represa de Três Marias e do São Francisco. Pp. 71-92. In: Godinho, H. P. & Godinho, A. L. (Eds.). **Águas, peixes e pescadores do São Francisco das Minas Gerais.** PUC Minas, Belo Horizonte, 458 p.

Santos, M. D. 2008. Comunidades parasitárias de três espécies de peixes carnívoros do Reservatório de Três Marias, Alto Rio São Francisco, Minas Gerais, Brasil. **PhD. Thesis.** Universidade Federal Rural do Rio de Janeiro, 243 p.

Zar, J. H. 1996. **Biostatistical Analysis.** Prentice Hall, New Jersey. 662 p.

Zaret, T. M. Life history and growth relationships of *Cichla ocellaris*, a predator South American Cichlid. **Biotropica**, 12: 144-157, 1980.

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The nuisance of medusae (Cnidaria, Medusozoa) to shrimp trawls in central part of southern Brazilian Bight, from the perspective of artisanal fishermen

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Abstract. Large aggregations of medusae hinder trawl fishing in coastal waters of several locations worldwide by clogging nets. In Paraná, scyphozoan medusae reach biomass peaks during springtime, when they saturate shrimp trawl nets. In order to assess possible disturbances to trawling caused by species of medusa, 48 fishermen who regularly use fishing trawls from 10 communities in the states of Paraná and Santa Catarina, southern Brazil, were interviewed. The general attitude of the respondents toward jellyfishes was found to be negative. Fishermen associated medusae, particularly the scyphomedusa *Lychnorhiza lucerna*, with net clogging. Two cubomedusa species, *Chiropsalmus quadrumamus* and *Tamoya haplonema*, and the hydromedusa *Olindias sambaquiensis* were singled out for the painful stings they cause. Large aggregations of medusae in fisheries shorten the duration of trawl hauls, displace hauls to areas further away from the landing ports and prompt fishermen to shift to other fishing gears such as anchored gillnet and drift net, amongst others. The fishermen hold a body of ethnobiological knowledge about jellyfish, such as the identification of toxic species and their seasonal occurrence, and have designed gimmicks to prevent medusae from entering the nets.

Key words: Bloom, shrimp, *Lychnorhiza lucerna; Olindias sambaquiensis;* jellyfish

Resumo. O entrave de medusas (Cnidaria, Medusozoa) aos arrastos de camarões na parte central do embaiamento sul do Brasil, pela perspectiva de pescadores artesanais. Ao entupirem redes de arrasto, grandes populações de macromedusas atrapalham a pesca de arrasto em águas costeiras de vários locais do mundo. No Paraná, as macromedusas Scyphozoa, quando atingem os picos de tamanho e biomassa durante a primavera, podem encher completamente redes de arrastos camaroeiros. Para verificar possíveis distúrbios gerados pelas espécies de medusas locais aos arrastos, 48 pescadores atuantes nessa arte de pesca foram entrevistados em 10 comunidades do litoral do Paraná e Santa Catarina. A visão geral dos entrevistados em relação às medusas é negativa. Os pescadores associaram principalmente a cifomedusa *Lychnorhiza lucerna* ao entupimento de redes. Duas espécies de cubomedusas (*Chiropsalmus quadrumamus* e *Tamoya haplonema*) e a hidromedusa *Olindias sambaquiensis* foram responsabilizadas por dolorosas queimaduras. Grandes agregações de medusas nos locais de pesca diminuem o tempo dos lances de arrastos, deslocam essas operações e causam a evasão para outras artes de pesca como o fundeio e o caceio. Os pescadores detêm um vasto conhecimento etnobiológico sobre as medusas, como o reconhecimento de espécies tóxicas, conhecimento sobre a sazonalidade das ocorrências e artifícios para evitar a entrada de medusas nas redes.

Palavras-chave: Floração, camarão sete-barbas, *Lychnorhiza lucerna; Olindias sambaquiensis;* zooplâncton gelatinoso

Introduction

The occurrence of medusa or jellyfish (Cnidaria, Medusozoa) in high densities is a common phenomenon in coastal waters around the world and, occasionally, these animals completely dominate the planktonic biomass (e.g. Pagès *et al.* 1996, Benovic & Lucic 2001, Mills 2001). Due to their large size and the accidents with toxic species, the presence of jellyfish on beaches and shallow coastal waters is readily noticed by the public perception (review in Purcell *et al.* 2001, Haddad Jr. 2002, Purcell *et al.* 2007, Neves *et al.* 2007).

Large medusa aggregations can interfere with fishing activities in two ways: 1) via food chain, either competing for food with commercial species (Ishi & Tanaka 2001, Purcell & Sturdvant 2001, Uye & Ueta 2004; Barz & Hirche 2005) or directly preying upon eggs and larvae of commercial fishing resources (review in Purcell & Arai 2001); 2) via clogging of nets, when large numbers of medusae are caught in a short period, causing stinging accidents (Guest 1959), damaging fishing gear (Brierley *et al.* 2001) and obstructing or displacing local fishing activities (Russell 1970, Brodeur *et al.* 2002, Uye & Ueta 2004; Kawahara *et al.* 2006a).

Over the last decades, disturbances of fishing operations caused by large medusae appear to be correlated with recent population increases (Brierley *et al.* 2001, Brodeur *et al.* 2002, Uye & Ueta 2004; Kawahara *et al.* 2006a) and/or with the introduction of exotic species (Mills, 2001; Galil and Zenetus 2002; Graham *et al.* 2003). Such disturbances may be much more frequent than reported in the literature, as remarked by Purcell *et al.* (2007).

In Brazil, Mianzan and Guerrero (2000) reported high biomass of the large hidrozoans *Olindias sambaquiensis* F. Müller, 1861 and *Rhacostoma atlantica* L. Agassiz, 1850, in Cabo de Santa Marta upwelling (28ºS), but quantitative data on scyphomedusae is yet to be published. It is known, however, that macromedusae such the Hydrozoa *O. sambaquiensis*, the Cubozoa *Chiropsalmus quadrumamus* (F. Müller, 1859) and the three Scyphozoa *Lychnorhiza lucerna* Haeckel, 1880, *Phyllorhiza punctata* von Lendenfeld, 1884 and *Chrysaora lactea* Eschscholtz, 1829 occur in large numbers in trawl nets, stranded on the beach or floating on the water surface (Vannucci, 1951; Silveira and Cornelius 2000, Morandini *et al.* 2005; Haddad and Nogueira, 2006; Nogueira and Haddad 2006).

On shallow waters (<20 m) of the South Brazilian Bight (SBB), small-scale shrimp trawls can be filled up with medusae and their biomass exceed that of all other animal groups (Graça-Lopes *et al.* 2002, Branco and Verani 2006). Recent investigations on the biology of medusae on the coast of Paraná, comprising more than eight years of monthly sampling, revealed that short ten-minute trawls could catch dozens of kilograms (Fig.1) of the scyphomedusa *L. lucerna*, mainly in springtime (Nogueira, Haddad and Nagata unpublished data). In the present study, face-to-face interviews with artisanal fishermen from 10 communities of Paraná and north of Santa Catarina were conducted in order to ascertain whether such high scyphomedusae biomass represents a nuisance to shrimp trawls. Only Uye & Ueta (2004) used the same method to report fishery losses caused by gelatinous plankton. Based on a fishermen poll, these authors analyzed the increase of *Aurelia aurita* populations in the Island Sea of Japan during the last 20 years.

Figure 1. Catch of a small-scale shrimp trawl haul of 15 minutes, with abundance of *Lychnorhiza lucerna* in Paraná coast, Brazil. Courtesy of Cláudio D. Natividade.

Despite increased attention given to medusa disturbances to fishing worldwide (e.g. Mills 2001, Kawahara *et al.* 2006a, Purcell *et al.* 2007) and the great abundance of jellyfish on the Brazilian coast, which can potentially interfere with fishing operations, no study has investigated the social and commercial impacts in Brazil. This paper also documents, for the first time, information on fishermen's ethnobiological knowledge concerning these gelatinous animals.

Material and Methods

Study Site. The continental shelf is well developed along the Southern Brazilian Bight (SBB), reaching 175 to 190 km width. Along the coastline of the States of Paraná and Santa Catarina, between the beaches of Pontal do Sul and Itapema do Norte – SC (Fig. 2), local fishermen target more than 70 species of fish and shellfish. The main fishing resource in the area, however, is the sea-bob shrimp *Xiphopenaeus kroyeri* Heller, 1862, caught primarily by bottom trawling carried out by small trawling vessels (Natividade *et al.* 2004). This practice is limited to ca. 20 km off shore, where depths are 6 meters in average. (Andriguetto-Filho *et al.* 2006).

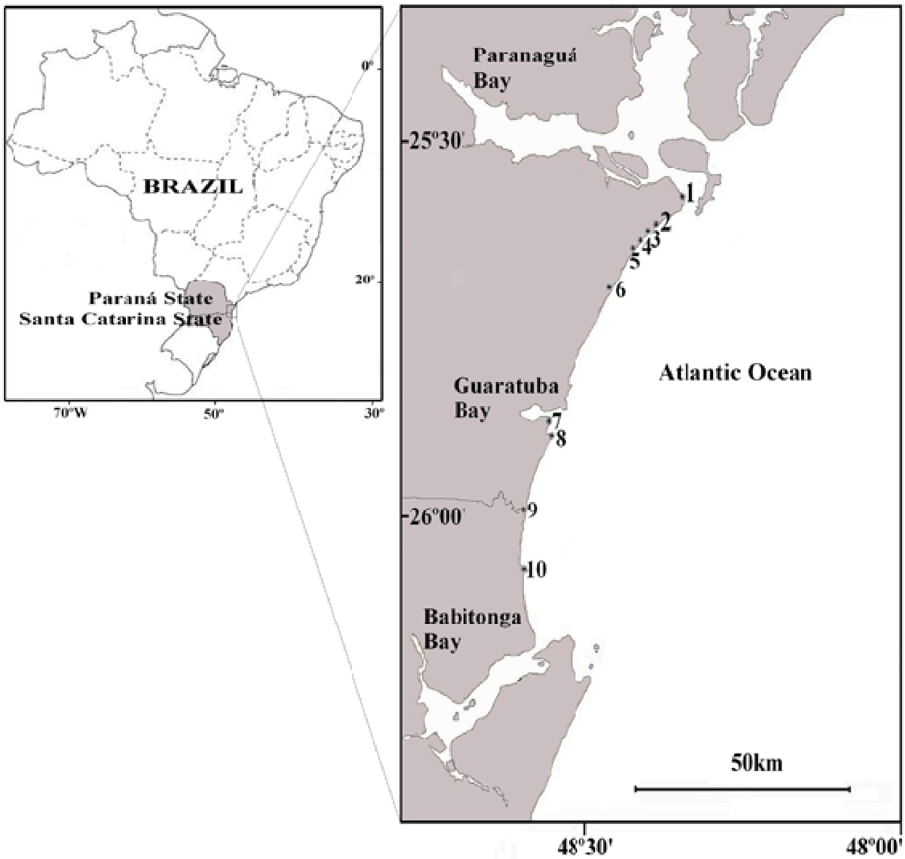

Figure 2. Site of interviewed fishing communities on Paraná and Santa Catarina states. 1- Pontal do Sul; 2 – Atami; 3– Barranco;4- Shangrilá; 5– Ipanema; 6– Praia de Leste; 7- Caieiras; 8- Brejatuba; 9- Barra do Saí; 10- Itapema do Norte.

Data Collection. Standardized questionnaires and open interviews (Table I) were given to 48 trawl fishermen active in 10 communities of Paraná and northern Santa Catarina (Fig. 2), over given periods from 2003 to 2004 and from 2006 to 2007. The following information was asked in the questionnaire: I) age of the fisherman; II) time of experience on fishing activities; III) whether trawling gear is used exclusively or not; IV) whether they report economic losses caused by jellyfish; V) whether large numbers of jellyfish cause an impediment to trawling; and VI) amount of time wasted when trawling results in massive jellyfish captures. When answers to the questionnaire suggested the presence of large medusae concentrations in the trawls, the following information was also gathered: A) references to jellyfish as a nuisance to trawls; B) reports of accidents caused by toxic species; and C) whether time of hauls was shortened in periods of large jellyfish abundance.

For the category of open interviews, 20 local expert fishermen, very experienced in the practice of trawl fishing, were recommended by researchers and members of the communities (Table I).

Formalin-fixed individuals of seven species of medusa frequently caught in trawl nets in the area (*Lychnorhiza lucerna, Phyllorhiza punctata, Chrysaora lactea, Chiropsalmus quadrumamus, Tamoya haplonema* F. Muller, 1859, *Olindias sambaquiensis* and *Rhacostoma atlantica*,) were displayed to the fishermen. After observing the material, the fishermen were asked the following questions about the various species: I) popular names and diagnostic characteristics; II) toxicity and treatments; III) seasonality, occurrence patterns and atypical occurrences; IV) biological aspects of medusae; and V) methods employed to prevent nuisance to trawl caused by large populations of medusae.

The data was analyzed according to the model of union of all individual competences. Every piece of information concerning the subject was taken into account, and a quali-quantitative treatment of the data was conducted (Marques 1991).

Table I. Number of fishermen interviewed on each fishing community from Paraná (PR) and north Santa Catarina (SC) coast.

Community sampled	***Standardized interviews***	***Opened interviews***
Pontal do Sul (PR)	8	4
Atami (PR)	2	1
Barranco (PR)	1	-
Shangrilá (PR)	7	6
Ipanema (PR)	1	-
Praia de Leste (PR)	7	1
Caieiras (PR)	5	2
Brejatuba (PR)	9	3
Barra do Saí (SC)	7	2
Itapema do Norte (SC)	1	1
Total	**48**	**20**

Results

Standardized interviews with trawl fishermen. Among the 48 interviewed fishermen, ages varied from 26 to 70 years (mean of 44, standard deviation of ± 12.98). Half of them had been in the fishing trade for more than 30 years and 22.9% made exclusive use of trawling gear.

Most fishermen (70.8%) claimed financial losses caused by high densities of medusae. A smaller percentage (29.17%) failed to correlate medusae with economic loss, but acknowledged time wasted and regarded the medusae as natural nuisances to the fishing activity (Table II).

Table II. Answers about the jellyfish effect on fishing, following interviews (n = 48) to fishermen.

Questions	**Yes**	**No**
Do jellyfish cause economic losses to trawlers?	70,83%	29,17%
Have you ever avoided fishing because of the large amount of jellyfish?	58,33%	41,67%
Have you ever hurried your return from a fishery because of the large number of jellyfish?	68,75%	31,25%

Among 34 respondents who claimed some economic loss, 73.5% reported a concomitant scarcity of shrimp in the same period (n=25) and 58.8% referred to extra fuel expenses to avoid medusae aggregations (n=20). Whenever a dramatic amount of large medusae was caught, 29.4% of the respondents (n=10) conveyed that they opened the cod-end, releasing all catches, including the shrimps. When the same 34 respondents were asked about what measures they took to mitigate the losses, 25% (n=8) answered none. Those who replied affirmatively (75%, n=26) said that they had changed their regular trawl activities to: I - fishing with gill nets (n=17); II - fishing at night, when the jellyfish move up to the surface (n=10); III - make use of gimmicks to reduce the amount of jellyfish during shrimp trawls (n=9); IV - explore other, more distant places such as Superagüi Island (n= 2).

There was marked similarity in the following reports from the respondents (n=48):

<u>I – Influence on trawling</u> – A view of medusae as pests, a cause of clogging of trawl nets, reduction in trawling time and time wasted.

<u>II - Accidents with toxic species</u> – All

fishermen reported frequent accidents that cause pain in the arms and trunk, making work extremely arduous.

III - By-catch – Medusae are more abundant in trawl nets than in other gears and can take up almost all the net space.

IV – Seasonal Occurrence – All respondents observed the seasonality of medusae and reported inter-annual fluctuations. They did not report any recent frequency increase in massive occurrences of medusae.

V – The duration of hauls - was significantly affected in periods of large amounts of medusae (Mann-Whitney, Z corrected = -8.47; $p < 0.001$; n=48), when shorter hauls were performed (Fig. 3).

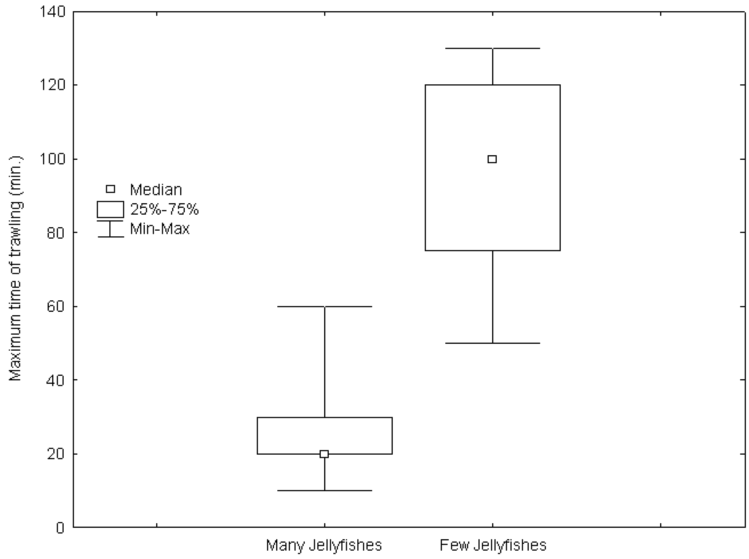

Figure 3. Maximum time of hauls performed by fishermen in periods of few medusae and in periods of many medusae (n=48).

Open interviews with local experts. Even though distinct names were not assigned to all species displayed, the fishermen showed familiarity with the jellyfish. The characteristics used to define the species and their respective popular names are summarized in Table III.

Table III. Popular names assigned by fishermen to the local large medusae and characteristics used for identification.

Species	*Common name*	*Characteristic according to interviews and frequency allocation of this feature. (n =20)*
Olindias sambaquiensis	água-viva relojinho	Yellow radial canals (20)
Chrysaora lactea	água-viva	-
Chiropsalmus quadrumanus	água-viva copo	Cuboid bell, palmate pedalium very toxic (5)
Lychnorhiza lucerna	água-viva, bolota, cabeça d'água	Hemispherical bell and cross-shaped stomach (11)
Tamoya haplonema	água-viva	Pedalium with a single long tentacle very toxic, called cords (11)
Rhacostoma atlantica	água-viva	Flat bell and consistent mesoglea (1)
Phyllorhiza punctata	água-viva	Brown hemispherical bell with white spots (8)

All species were referred to as "água-viva" (jellyfish). Other popular names such as medusa or "mãe d`água" were not mentioned. Only *O. sambaquiensis* was recognized by all respondents as "água-viva relojinho" (little watch jellyfish) or "relojinho"; however, five respondents also gave these same popular names to another species, *R. atlantica.* Some less careful fishermen confused Scyphozoa and Cubozoa species, simply assigning the name "água-viva" to them all, but such generalization was quite infrequent. *Phyllorhiza punctata* was pointed out as an unknown jellyfish until the years 2000-2001 by fishermen of Pontal do Sul, Caieiras and Brejatuba (n=11; 55%). The pedalia and tentacles of *C. quadrumanus* and *T. haplonema*, known as strings, were singled out as structures that cause painful stings by 5 and 11 respondents, respectively.

Knowledge concerning the toxicity of medusae to human skin was consistent with literature. Only three out of 20 respondents stated that all species cause stings, while the remaining associated toxicity with selected species only (Table IV).

Table IV. Trawl fishermen's knowledge on the toxicity of the species occurring in local trawls and a comparison with records in the literature (Haddad Jr. *et al*., 2002; Morandini *et al.* 2005).* Accidents according to the literature.

Species	*Number of fishermen who attributed stings to the species (N=20)*	*Toxicity for humans following literature*
*Olindias sambaquiensis**	20	High
Chrysaora lactea	3	Moderate
*Chiropsalmus quadrumanus**	9	High
Lychnorhiza lucerna	3	Low (only at oral arms filaments)
*Tamoya haplonema**	16	High
Rhacostoma atlantica	4	Low
Phyllorhiza punctata	3	Low

According to 90% of the respondents (n=18), the peak of large jellyfish abundance occurs in late winter to early summer (September to January). Due to the open character of the interviews, some informants reported four months of abundance, while others reported only one. In order to equalize the weight of the answers in the analysis, to each answers was attributed a weight of 1 (one), and this value was then divided by the total number of months mentioned in each interview. Thus, when only one month of high jellyfish concentrations was reported, a weight of 1 was attributed to this month; when two months were reported, the weight was 0.5; three months, mentioned, each one received 0.33; and four months, 0.25. Figure 4 shows the frequency of reports for each month of large abundance of medusae, as informed by the interviewers.

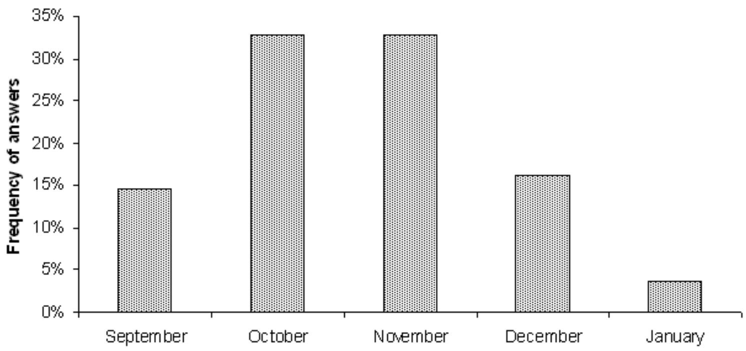

Figure 4. Periods of greater abundance of jellyfish, as the open interviews (N=18).

Throughout the open interviews, consensual biological knowledge emerged spontaneously from the accounts of various informants, highlighting their knowledge about interactions between medusae and fishing:

(1) Medusae concentrate on the surface during the night and in the bottom during the day (N=14; 70%). According to the respondents, even though large numbers of medusae can be seen on the water surface at night, they are either rare or absent in night trawls.

(2) Use of the crab *Ocypode quadrata* Fabricius 1787 (the Atlantic ghost crab, popularly known as "guaruçá" or "maria farinha", flour mary) in the treatment of stings (N=14; 70%). The respondents reported the application of a macerate of this crab over the sting to relieve pain, especially in accidents involving children and sea bathers. Some of them stated that it is an effective medicine and they have made use of it in many occasions. This information was given by fishermen of all communities and also by local residents not involved in fishing activities.

(3) Use of gimmicks in the trawl nets to reduce the catch of medusae was reported by 55% of the respondents (N=11). In order to avoid hauling

medusae, three types of modifications in the trawl nets were suggested, all of them reducing the vertical opening of the trawl to force the catch to concentrate in the bottom. They are: I – remove floats from the upper panel of the trawl (reported in Atami and Shangrilá); II - remove floats from the upper panel and set weights (reported in Pontal do Sul and Itapema do Norte); III – tie a rope between the upper and lower panels, restricting the opening of the mouth (reported in Shangrilá, Brejatuba and Barra do Saí).

Discussion

Standardized interviews with trawl fishermen. Some authors have briefly documented the presence of high concentrations of medusa in trawl catches in Brazil (Vannucci, 1954; Graça-Lopes *et al.* 2002), but knowledge about the dynamics of small-vessel trawls is still more restricted in the area studied. Consequently, several aspects addressed in this paper had not been mentioned in previous contributions (Andriguetto-Filho 2003; Chaves *et al.*, 2002; Chaves and Robert 2003; Robert and Chaves, 2006; Andriguetto-Filho *et al.* 2006).

Few respondents use trawling exclusively. Alternative fishing gear can be important in periods of large jellyfish aggregations, as for example set-nets, which are not compromised by asggregarions. However, in the Sea of Japan, set-nets failed to avoid medusa nuisance (Kawahara *et al.* 2006a). Medusae reduce the amount of time spent on trawl fishing, as they either make fishermen return sooner (68.75%), or discourage their activity (58.3%) altogether. A behavioral model for the fishing daily routine of factory trawlers in the west coast of North America was described by Dorn (2001), who pointed out some hierarchical levels of decisions-making such as: 1) go out fishing or not; 2) select a patch or fishing ground on which to operate. As detected during the interviews, these decisions are also relevant to the fishing dynamics of the communities studied in this research. When jellyfish are in high concentrations, trawlers either avoid fishing altogether (58.3%) or target other fishing resources by using gillnets (35.4%).

Scyphomedusa blooms also disrupt fisheries, such as those of *Nemopilonema nomurai* (Kishinouye 1922) in the Sea of Japan (Kawahara *et al.* 2006a) and *Rhopilema nomadica* Galil, Spanier, and Ferguson, 1990, in the Mediterranean Sea (Galil and Zenetus 2002). Some examples of the direct impact of medusae on trawling fisheries worldwide are summarized in Table V. Colonies of the bryozoan *Membraniporopsis tubigera* (Osburn, 1940) have been clogging trawl nets in southern Brazil (Gordon *et al.* 2006), apparently, in a similar manner to medusae.

Dorn (2001) remarks that a trawl fisherman controls fuel expenditure by minimizing his transits between fishing locations. This behavior is equivalent to that of a predator foraging in his territory. During the interviews, fishermen reported that they can avoid hauling over medusa aggregations by communicating with each other by radio or visually, tracing the outline of a medusa umbrella with hand gestures. In addition, they tend to trawl at different depths to escape the aggregations. This locomotion between fishing grounds may result in waste of time and fuel.

In the opinion of the respondents, the obliteration of trawl nets by medusae is noticeable in the power boost needed for pull of the boat. Also the net tends to float, failing to catch the shrimp as a demersal species, and the clogging causes a layer of water in the front of the mouth, which precludes the catching of other organisms. Consequently, hauls are compromised by the reduction in trawling time, similarly to what was observed by Kraeuter and Setzler (1975) in the estuaries of Georgia. Along the coast of Paraná, large catches of *L. lucerna* (>100kg) during 10 to 20 minute trawls either result in a major waste of time sorting out the catch, or end up with the entire volume of the trawl being discharged. *L. lucerna* causes fishing troubles also in the northern coast of Argentina, in summertime (Schiariti *et al.* 2008).

Open interviews with local experts. Fishermen's knowledge about the toxicity of different species of medusa was consistent with scientific literature. In the Brazilian coast, the medusae responsible for the most painful envenomations, two cubozoan and the hydrozoan *O. sambaquiensis*, are the only species recorded in accidents with bathers by Haddad Jr. *et al.* (2002). Guest (1959), for instance, mentions that *C. quadrumanus* was a painful obstacle to fishermen of Matagorda Bay in Texas in some years where blooms occur. *O. sambaquiensis* is regarded as a nuisance to tourism in some regions of Argentina (Mianzan and Zamponi, 1988).

Table V. Published reports of cnidarian jellyfish interfering with trawling operations around the world.

Species/Class	Local	Year (months)	Nuisance to trawling	Source
	North America			
Chrysaora melanaster (Brandt, 1835) **Scyphozoa**	Bering Sea	1990-1999 (Jun-Sep)	- Clog fishing nets. - Fishing vessels shunned areas with high jellyfish biomass	Brodeur *et al.* (2002)
Chiropsalmus quadrumanus **Cubozoa**	Matagorda Bay (Texas, USA)	1955 and 1956 (Aug - Sep)	- Stings to fishermen.	Guest (1959)
Stomolophus meleagris (L. Agassiz 1862) **Scyphozoa**	Estuaries of Georgia - USA	1972 (Abr-May)	- Clog fishing nets. - Reduction of trawling time.	Kraueter & Setzler (1975)
Phyllorhiza punctata **Scyphozoa**	Gulf of México	2000 (May – Sep)	- Clog fishing nets. - Losses to comercial shrimp as high as US$ 10 million in 2000.	Graham *et al.*(2003)
	South America			
Lychnorhiza lucerna **Scyphozoa**	Southern Brazil coast	Sep-Nov	- Clog fishing nets. - Shorten the duration of trawl hauls. - Displacing these hauls to areas further away from the landing ports. - Fishermen temporarily shift the fishing gears to anchored gillnet and drift net.	Present work
L. lucerna	Northern Argentina coast	Dec-May	- Clog/Damage fishing nets. - Reduce total fishing captures and catch quality. - Prevent fishermen to operate.	Schiariti *et al.* (2008)
Olindias sambaquiensis **Hydrozoa**	Southern Brazil – Northern Argentina coast	Jul-Oct	- Clog fishing nets. - The author cite that shrimp move off shore from the aggregation of jellies. - Stings to fishermen.	Vannucci (1951) Present work
	Africa			
Chrysaora hysoscella Linne, 1766 **Scyphozoa**	Namibian Benguela	Aug.-Sep.	- Clog/Burst fishing nets. - Collapse of pilchard fishery.	Brierley *et al.* (2001)

Table V. Published reports of cnidarian jellyfish interfering with trawling operations around the world (continued).

Species⁄Class	Local	Year (months)	Nuisiance to trawling	Source
	Europe			
Periphylla periphylla (Perón & Lesueur, 1810) **Scyphozoa**	Lurefjorden Fjord , Norway	Late 1940´s , since 1973 (Oct-Nov and Apr-May)	- Clog fishing nets. - Impeding trawl operations in the period of high biomass.	Fossa (1992)
Aurelia sp. **Scyphozoa**	North Atlantic of U.K.	Abr-Aug	- Clog⁄Burst fishing nets. - Displace hals to other areas. - Cod-end is open due to the weight. - Fishermen think that fish move away from the aggregation	Russell (1970)
Rhizostoma octopus Vanhöffen 1906 **Scyphozoa**	Black Sea	No available date	- Clog fishing nets.	Netchaerff & Neu 1940 *apud* Russel (1970)
Rhopilema nomadica autor? **Scyphozoa**	Mediterranean coast of Israel	Since mid 1980´s (Jun-Sep)	- Clog fishing nets. - Impeding trawl operations in periods of high biomass.	Lotan *et al*. (1992) Galil & Zenetos (2002)
	Asia			
Crambionella orsini (Vanhöffen 1888) **Scyphozoa**	Gulf of Oman and Persian Gulf		- Decreased catches in artisanal and industrial fisheries. - Damage to fishing gear.	Daryanabard & Dawson (2008)
Cyanea capillata (Linnaeus, 1758) **Scyphozoa**	Yangtze Estuary, China	Since 2004 (May)	- Clog fishing nets.	Xian *et al.* (2005)
Aurelia sp. **Scyphozoa**	Seto inland Sea, Japan	Summer	- Clog⁄Burst fishing nets. - Declining catches of zooplanctivorous fishes. - Reducing catches quality. - Stings to fishermen. - Increased labor to remove medusae from the nets.	Uye & Ueta (2004) Uye & Shimauchi (2005)
Nemopilonema nomurai **Scyphozoa**	Along coast of Japan	2002 – 2006 (Aug-Dec)	- Clog⁄Burst fishing nets. - Lower catches of finfish. - High mortality of finfish by nematocyst venom, and lower commercial value. - Increased labor to remove medusae from the nets. - Higher risk of capsizing trawl boats - Stings to fishermen.	Kawahara *et al.* (2006)

Accidents with fishermen happen during sorting of the catch, when urticating substances are released from the nematocysts or when they inadvertently touch certain parts of the animal's body, especially the tentacles. Structures such as tentacles and pedalia of cubomedusae, especially of *T. haplonema*, called "strings", are avoided for their high toxicity, which is justifiable by the greater concentration of nematocysts on those structures (Arai, 1997). Fishermen interviewed in this study did not associate the abundant *L. lucerna* with stings, eruptions or pain symptoms, although its oral arms filaments, when healthy, can cause little pain to hand human skin (Haddad personal observation). The absence of tentacles in Rhizostomeae scyphozoan medusae, like *L. lucerna*, generally results in reduced stings. However, three species of this same group, *Rhopilema hispidum*, *R. esculentum* and *Nemopilema nomurai*, highly exploited for human consumption as a delicacy in China, Japan and other Asian countries, have been attributed to accidents by fishermen in Japan (Kawahara *et al.* 2006b). Nematocyst toxins may diminish the market value or even preclude the commerce of exploitable species (Kawahara *et al.* 2006a; Purcell *et al.* 2007).

The seasonality in the life cycle of large medusae is a widely known phenomenon (Russell 1970; Arai 1997) and empiric observations along decades of trawl fishing provided the respondents with knowledge about the temporal fluctuation in medusa biomass. The months of large medusa biomass peaks indicated by the fishermen (Fig. 4) are the same cited in the literature of great abundance of the scyphomedusa *L. lucerna* (Silveira and Cornelius 2000; Morandini 2003; Nogueira and Haddad, unpublished data). This observation suggests that trawlers are aware not only of the periodicity of their target resources, but also of the other conspicuous elements of fishery. Although the bathymetric distribution of *L. lucerna* is not known, aggregations of this species possibly overlap with the occurrence zone of the shrimp *X. kroyeri*, which is limited to a maximum depth of 20 m (Andriguetto Filho *et al.* 2006).

As revealed by the fishery experts, the use of a macerate made with the crab *Ocypode quadrata* is a form of treatment against stings commonly practiced by the communities in the coast of Paraná. Fishermen from Cananéia and Guarujá, southern coast of São Paulo, make a similar use of it (Sérgio Stampar, personal communication). There is no mention of such treatment for cnidarian's stings in the literature. However, an adequate treatment can be conducted with a cold compress of saltwater or cold packs, and intramuscularly dipirona for pain control (Haddad Jr. *et al.* 2002).

Diel vertical migration (DVM) is documented for the great majority of zooplankton taxa, including medusae (Youngblouth and Blanstedt, 2001; Hays 2003; Sparks *et al.*, 2005). Common migration patterns usually involve individuals staying in deeper regions of the water column during the day and moving closer to the water surface at night. This behavior was reported for the medusae by 70% of the respondents and 30% of them pointed out that the ascent to the surface would be favorable for trawling during the night. The species that display such behavior were not distinguished in the interviews. In the area studied, large medusae aggregations have not been recorded on the water surface, at least during the day, with the exception of the zooxanthellate *P. punctata* (Haddad and Nogueira, 2006).

All modifications in the trawl nets, believed to reduce the intake of jellyfish, are based on the fishermen's perspective about the position of the animals in the water column. According to them, the shrimp *X. kroyeri* is a demersal species, while medusae would be found in mid-water. Thus, upon restricting the vertical opening of the trawl net – by removing the floats, placing weights or bringing the upper and lower panels close together with ropes – fewer medusas would be caught and the shrimp catch would not be affected. Contrary to the respondents' perception of medusae occurring in the mid-water position, acoustic surveys in Rio de la Plata estuary demonstrated aggregates of *L. lucerna* close to the bottom (Alvarez-Colombo *et al.* 2003). Along the coasts of Paraná and north of Santa Catarina, several trawl nets operating without floats have been observed, but other modifications have not. Jellyfish-exclusion devices of the "blubber-chute" type (Broadhurst and Kennelly 1996) or Jellyfish Excluder for Towed Fishing Gear "JET" (Matsushita and Honda 2006) have been developed in Australia and Japan. Such devices, set inside the trawl net, filter away larger organisms, excluding them through an exit window in the back of the net.

Many reports on trawl net clogging concern introduced medusae (Galil *et al.* 1990; Graham *et al.* 2003), a fact not observed in this study. The scyphomedusa *P. punctata* reappeared in the coast of Paraná in 2001, occurring in great abundance during summer and early autumn (Haddad and Nogueira 2006). The respondents noticed the appearance of this species, previously unknown to them (55%), but stated that it does not interfere with local trawls, because this scyphomedusa is more often encountered on the superficial layer of water (Haddad and Nogueira 2006).

Large Scyphozoa medusae (around 18 species, mainly in the Order Rhizostomeae) are a culinary delicacy in Southeast Asia, and over a thousand of years they have been locally exploited (Omori & Nakano, 2001, Schiariti 2008). The jellyfish market is steadily increased, particularly in Japan, Taiwan, South Korea, Indonesia, Malaysia and China. Commercial catches have increased since the 1970´s and regularly exceed 300 000 tons⁄year in wet weight (Omori and Nakano 2001). Medusae are fished in many places and countries of Southeast Asia, like Philippines, Vietnam, Malaysia, Thailand, Indonesia, Singapore and Myanmar and, more recently, small-scale exploitation has begun in Australia, India, Mexico, Turkey and the United States (Hsieh *et al.* 2001). By adding value to jelly discards, important benefits to fisheries and environment may be created. A trawl-clogger, *Stomolophus meleagris* (L. Agassiz 1862) in the coastal waters of U. S. A. is a successful commercial example (Kraueter and Setzler, 1975, Hsieh, 2001). Recent investigations on the development of jellyfish fisheries in the north of Argentina revealed that the costs involved in harvesting and processing *L. lucerna* are relatively low (Schiariti, 2008). The seasonal high biomass of this medusa in the south of Brazil and north of Argentina, the world requirements to attenuate pressure on individual fishing stocks and the increasing demand for this kind of food products points *L. lucerna* as a potential new resource to future sustainable exploration.

According to the results obtained by this study, the scyphomedusa *L. lucerna* is responsible for clogging trawl nets in the coast of Paraná due to its large spring biomass, causing a variety of disturbances to the routine of that fishing gear. The hydromedusa *O. sambaquiensis* and the cubomedusae *T. haplonema* and *C. quadrumamus* are the main species responsible for accidents with fishermen. The records of local knowledge on large medusae prompt other studies to evaluate the effectiveness of modifications in trawl nets suggested by fishermen to exclude medusae. One of the most valorous conclusions of this research, however, is that fishermen seem to possess ethnobiological knowledge that highlights the importance of welcoming their participation in integrated coastal management plans.

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References

Alvarez-Colombo, G., Mianzan, H. & Madirolas, A. 2003. Acoustic characterization of gelatinous-plankton aggregations: four case studies from the Argentine continental shelf. **ICES Journal of Marine Science**, 60: 650–657.

Andriguetto-Filho, J. M. 2003. Mudança técnica e o processo de diferenciação dos sistemas de produção pesqueira do Litoral do Paraná, Brasil. **Desenvolvimento e Meio Ambiente** 8, 43-58.

Andriguetto-Filho, J. M., Chaves, P. T.C., Santos, C. & Liberati, S. A. 2006. Diagnóstico da pesca no litoral do estado do Paraná. Pp. 117-140. *In*: Isaac, V., Martins, A.S., Haimovici, M., Andriguetto-Filho, J.M. (Eds.). **A pesca marinha e estuarina do Brasil no início do século XXI: Recursos, tecnologias, aspectos socioeconômicos e institucionais**. Editora Universitária - Universidade Federal do Pará, Belém, 188 p.

Arai, M. N. 1997. **A functional biology of Scyphozoa**, Chapmam and Hall, London.

Barz, K. & Hirche, J.-H., 2005. Seasonal development of scyphozoan medusae and the predatory impact of *Aurelia aurita* on the zooplankton community in the Bornholm Basin (central Baltic Sea). **Marine Biology**, 147: 465–476.

Benovic, A. & Lucic, B. 2001. Jellyfish outbreaks: natural cycle or stress response effect? **CIESM (Commission Internationale pour l'Exploration Scientifique de la mer Méditerranée) Workshop Series**, Naples, Italy, 14 : 59–62.

Branco, J. O. & Verani, J. R. 2006. Pesca do camarão sete-barbas e sua fauna acompanhante, na Armação do Itapocoroy, Penha, SC. Pp. 153-170. *In*: Branco, J.O., Marenzi, A.W.C., (Eds.). **Bases ecológicas para um desenvolvimento sustentável: estudos de caso em Penha, SC**. Editora da Univalli, Itajaí, 291 p.

Brierley, A. S., Axelsen, B.E., Buecher, E., Sparks, A.J., Boyer, H. & Gibbons, M.J. 2001. Accoustic observation of jellyfish in Namibian Benguela. **Marine Ecology Progress Series**, 210: 55-66.

Broadhurst, M. K. & Kennelly, S.J. 1996. Rigid and flexible separator panels in trawls that reduce the by-catch of small fish in the Clarence

River prawn-trawl fishery, Australia**. Marine Freshwater Research,** 47(8): 991– 998.

Brodeur, R. D., Sugisaki H. & Hunt Jr., G.L. 2002. Increases in jellyfish biomass in the Bering Sea: implications for the ecosystem. **Marine Ecology Progress Series,** 233: 89–103.

Chaves, P., Pichler, H. & Robert, M. 2002. Biological, technical and socioeconomic aspects of the fishing activity in a Brazilian estuary. **Journal of Fish Biology**, 61(Suppl. A): 52- 59.

Chaves, P.T.C. & Robert, M.C. 2003. Embarcações, artes e procedimentos da pesca artesanal no litoral sul do Estado do Paraná, Brasil. **Atlântica**, 25(1): 53-59.

Daryanabard, R. & Dawson, M. N. 2008. Jellyfish Blooms: *Crambionella Orsini* (Scyphozoa: Rhizostomeae) in the Gulf of Oman, Iran, 2002-2003. **Journal of Marine Biology Association of the United Kingdom**, 88, 477-483.

Dorn, M. W. 2001. Fishing behavior of factory trawlers: a hierarchical model of information processing and decision-making. **ICES Journal of Marine Science**, 58: 238–252.

Fossa, J. H. 1992. Mass occurrence of *Periphylla periphylla* (Scyphozoa, Coronatae) in a Norwegian fjord. **Sarsia**, 77: 237– 251.

Galil, B. S., Spanier, E. & Ferguson, W.W. 1990. The scyphomedusae of the Mediterranean coast of Israel, including two Lessepsian migrants new to the Mediterranean. **Zoologische mededelingen**, 64: 95–105.

Galil B, & Zenetos A. 2002 A sea change— exotics in the eastern Mediterranean Sea. Pp. 1-19. *In*: Leppakoski E, Gollasch S & Olenin S (Eds.), **Invasive aquatic species of Europe: distribution, impacts and management**. Kluwer Academic Publishers, Dordrecht, 548p.

Gordon P. D., Ramalho V. L. & Taylor, P. D. 2006. An unreported invasive briozoan that can affect livelyhoods – *Membraniporopsis tubigera* in New Zealand and Brazil. **Bulletin of Marine Science**, 78(2): 331-342.

Graça-lopes R., Puzzi, A., Severino-Rodrigues E., Bartolotto A. S., Guerra D. S. F. & Figueiredo K. L. B. 2002. Comparação entre a produção de camarão-sete-barbas e de fauna acompanhante pela frota de pequeno porte sediada na praia de Perequê, estado de São Paulo, Brasil**. Boletim do Instituto de Pesca**, 28(2), 189-194.

Graham, W. M., Martin, D. L., Felder D. L., Asper, V. L. & Perry, H. M. 2003. Ecological and economic implications of a tropical jellyfish invader in the Gulf of Mexico. **Biological Invasions,** 5: 53–69.

Guest, W. C. 1959. The occurrence of the jellyfish *Chiropsalmus quadrumanus* in Matagorda Bay, Texas. **Bulletin Marine Science of the Gulf and Caribbean,** 9(1): 79-83.

Haddad, M. A. & Nogueira Jr., M. 2006. Reappearance and seasonality of *Phyllorhiza punctata* von Lendenfeld (Cnidaria, Scyphozoa, Rhizostomeae) medusae in southern Brazil. **Revista Brasileira de Zoologia**, 23(3): 824-831.

Haddad Jr., V.; Silveira, F. L.; Cardoso, J. L. C. & Morandini, A.C. 2002. A reporto f 49 cases of cnidarian envenoming from southeastern Brazilian coastal waters. **Toxicon,** 40: 1445-1450.

Hays, G.C. 2003. A review of the adaptative significance and ecosystem consequence of zooplankton diel vertical migrations. **Hydrobiologia**, 503: 163-170.

Hsieh, Y-H.P., Leong, F.-M.& Rudloe, J. 2001. Jellyfish as food. **Hydrobiologia** 451, 11–17.

Ishii, H. & Tanaka, F. 2001. Food and feeding of *Aurelia aurita* in Tokyo Bay with an analysis of stomach contents and a measurement of digestion times. **Hydrobiologia,** 451: 311–320.

Kraueter, J.N. & Setzler, E.N. 1975. The seasonal cycle of Scyphozoa and Cubozoa in Georgia estuaries. **Bulletin of Marine Science,** 25(1): 66–74.

Kawahara, M., Uye, S-i., Ohtsu, K. & Iizumi, H. 2006a. Unusual population explosion of the giant jellyfish Nemopilema nomurai (Scyphozoa: Rhizostomeae) in East Asian waters. **Marine Ecology Progress Series**, 307: 161–173.

Kawahara, M., Uye, S-i, J. Burnettb & Mianzan H. 2006b. Stings of edible jellyfish (*Rhopilema hispidum, Rhopilema esculentum* and *Nemopilema nomurai*) in Japanese waters. **Toxicon,** 48: 713–716.

Lotan, A., Ben-Hillel R. & Loya Y. 1992. Life cycle of *Rhopilema nomadica*: a new immigrant scyphomedusan in the Mediterranean. **Marine Biology**, 112: 237–242.

Marques, J.G.W. 1991. Aspectos ecológicos na etnoictiologia dos pescadores do Complexo Estuarino-Lagunar Mundaú-Manguaba. **PhD. Thesis**. Universidade Estadual de Campinas, Campinas, Brasil, 292 p.

Matsushita Y. & Honda, N., 2006. Method of designing and manufacturing JET (Jellyfish

Excluder for Towed fishing gear) for various towed fishing gears. **Bulletin of Fisheries Research Agency**, 16: 19–27.

Mianzan, H.W. & Zamponi, M.O. 1988. Estudio bioecologico de *Olindias sambaquiensis* Müller, 1861 (Limnomedusae; Olindiidae), en el area de Monte Hermoso. II. Factores metereológicos que influyen en su aparicion. **Iheringia, Serie Zoologia**, 2: 63-68.

Mianzan, H. W. & Guerrero, R. A. 2000. Envirommental patters and biomas distribution of gelatinous macrozooplânkton. Three study cases in the South-western Atlantic Ocean. **Scientia Marina,** 64(1), 215-224.

Mills, C.E. 2001. Jellyfish blooms: are populations increasing globally in response to changing ocean conditions? **Hydrobiologia,** 451: 55-65.

Morandini, A.C. 2003. Estrutura Populacional de *Chrysaora lactea* e *Lychnorhiza lucerna* (Cnidaria; Scyphozoa) em amostras de plâncton, com a redescrição das espécies. **PhD. Thesis**. Universidade de São Paulo, São Paulo, 115p.

Morandini, A. C., Ascher, D., Stampar, S. N. & Ferreira, J. F. V. 2005. Cubozoa e Scyphozoa (Cnidaria: Medusozoa) de águas costeiras do Brasil. **Ilheringia, Serie Zoologia**, 95(3): 281-294.

Natividade, C. D.; Pereira, M. J. C. & Andriguetto, J. M. 2006. Small-scale fishing landings on the coast of the State of Parana, Brazil, from 1977 to 2000, with emphasis on shrimp data. (Proceedings of the International Coastal Symposium 8), **Journal of Coastal Research**, SI 39: 35-39.

Neves, F. R., Amaral, F. D. & Steiner, A. Q. 2007. Levantamento de registros dos acidentes com cnidários em algumas praias do litoral de Pernambuco (Brasil). **Ciência e Saúde Coletiva,** 12(1): 231-237.

Nogueira Jr, M. & Haddad, M. A. 2006. Macromedusae (Cnidaria) from the Paraná Coast, Southern Brazil. (Proceedings of the International Coastal Symposium 8), **Journal of Coastal Research**, SI 39: 1161-1164.

Omori, M. & Nakano, E. 2001. Jellyfish fisheries in southeast Asia. **Hydrobiologia,** 451: 19-26.

Pagès, F., White, M.G. & Roadhouse, P.G. 1996. Abundance of gelatinous carnivores in the nekton community of the Antarctic Polar Frontal Zone. **Marine Ecology Progress Series**, 141: 139–147.

Purcell, J. E., Graham, W. M. & Dumont, H. J. (Eds.). 2001. Jellyfish blooms: ecological and societal importance. **Hydrobiologia,** 451: 1-333.

Purcell, J.E. & Sturdevant, M.V. 2001. Prey selection and dietary overlap among zooplanktivorous jellyfish and juvenile fishes in Prince William Sound, Alaska. **Marine Ecology Progress Series**, 210: 67–83.

Purcell, J. E. & Arai, M. N. 2001. Interactions of pelagic cnidarians and ctenophores with fish: a review. **Hydrobiologia**, 451: 27-44.

Purcell, J. E., Uye, S.-i. & Lo, W-T. 2007. Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review. **Marine Ecology Progress Series**, 350: 153–174.

Robert, M. C. & Chaves, P. T. C. 2006. Dinâmica da atividade pesqueira artesanal em duas comunidades da região litorânea limítrofe Santa Catarina - Paraná, Brasil. **Boletim do Instituto de Pesca,** 32(1): 15–23.

Russell, F. S. 1970. **The Medusae of British Isles, volume II: Pelagic Scyphozoa**. Cambridge University Press, 283p.

Schiariti, A., Kawahara, M., Uye, S-i. & Mianzan H. W. 2008. Life cycle of the jellyfish *Lychnorhiza lucerna,* (Scyphozoa: Rhizostomeae). **Marine Biology**, 156: 1-12.

Schiariti, A. 2009. Historia de vida y dinámica de poblaciones de *Lychnorhiza lucerna* (Scyphozoa) ¿Un recurso pesquero alternativo? **PhD. Thesis.** Universidad de Buenos Aires, Buenos Aires, 223 p.

Silveira, F. L. & Cornelius, P.F.S. 2000. Novas Observações Sobre Medusas (Cnidaria, Scyphozoa, Rhizostomeae) no nordeste e no sul do Brasil. **Acta Biologica Leopoldensia**, 22 (1), 9–18.

Sparks, C., E. Buecher, A. S., Brierley, B.E., Axelsen, A.J., Boyer, H. & Gibbons, M.J. 2001. Observations on the distribution and relative abundance of the scyphomedusa *Chrysaora hysoscella* (Linné, 1766) and the hydrozoan *Aequorea aequorea* (Forskal, 1775) in the northern Benguela ecosystem. **Hydrobiologia,** 451: 275-286.

Uye, S-i. & Shimaush H. 2005. Population biomass, feeding, respiration and growth rates, and carbon budget of scyphomedusa *Aurelia aurita* in the inland Sea of Japan. **Journal of Plankton Research** 27(3): 237-248.

Uye, S-i & Ueta, U. 2004. Recent increase of jellyfish population and their nuisance to fisheries in the Inland Sea of Japan. **Bulletin of the Japanease Society of Fisheries and**

Oceanography, 68(1): 9-19.

Vannucci, M. 1951. Hydrozoa e Scyphozoa existentes no Instituto Paulista de Oceanografia. I. **Boleim do Instituto Oceanográfico da Universidade de São Paulo**. 2(1), 69-149.

Vannucci, M. 1954. Hydrozoa e Scyphozoa existentes no instituto oceanográfico II. **Boletim do Instituto Oceanográfico da Universidade de São Paulo**, 5: 95-148.

Xian, W., Kang, B. & Liu, R. 2005. Jellyfish blooms in the Yangtze Estuary. **Science,** 307: 41.

Youngbluth, M. J. & Båmstedt, U., 2001. Distribution, abundance, behavior and metabolism of *Periphylla periphylla*, a mesopelagic coronate medusa in a Norwegian fjord. **Hydrobiologia** 451, 321–333.

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Comportamento Predatório *Ex situ* do Caranguejo *Menippe nodifrons* Stimpson, 1859 (Decapoda, Brachyura) sobre Moluscos Gastrópodes

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Abstract. Predatory Behaviour *Ex situ* of the Stone Crab *Menippe nodifrons* Stimpson, 1859 (Decapoda, Brachyura) on Gastropods in Laboratory. Laboratory experiments were used to study the effect predation of the crab *Menippe nodifrons* Stimpson, 1859 on gastropods *Stramonita haemastoma* Linnaeus, 1758 *Tegula viridula* Gmelin, 1791 and *Neritina virginea* Linnaeus, 1758. The observed aspects had been of prey preference, handling time, predation techniques, prey critical size and chelal biomechanic analysis of the crabs. The crabs and the clams had been collected in the beach of the Pacheco, located in the city of Caucaia-Ce. *Menippe nodifrons* preferred *Neritina virginea* over both *S. haemastoma* and *Tegula viridula*, and *S. haemastoma* was strongly preferred over *T. viridula*. The males crabs preyed more heavily upon *Neritina virginea* than on both gastropods *Stramonita haemastoma* and *Tegula viridula*, while the females had eaten indistinctly the three gastropods. There were differences in hadling times between *Neritina virginea*, *Stramonita haemastoma* and *Tegula viridula*. The mean critical size for *Neritina virginea* was significantly smaller than for *Stramonita haemastoma*, which in turn was smaller than for *Tegula viridula*. The claws of the crab *Menippe nodifrons* are well designed for breaking shells. Differences in the morphological and mechanical features of crab claws reflect their function and account for many of the observed differences in prey handling techniques and foraging behaviour.

Key words: Prey preference, Predation, Molluscs

Resumo. Foi realizado experimento em laboratório para observar a predação do caranguejo *Menippe nodifrons* sobre três espécies de moluscos gastrópodes: *Stramonita haemastoma*, *Tegula viridula* e *Neritina virginea*. Foram obervados a preferência pela presa, tempo de predação e manipulação da presa, tamanho crítico da presa, e análise biomecânica das quelas. Os caranguejos e os moluscos foram coletados na praia do Pacheco, localizada no município de Caucaia-Ce. *Menippe nodifrons* alimentou-se das três espécies de gastrópodes, com uma maior preferência alimentar por *N. virginea* em relação aos outros moluscos oferecidos *S. haemastoma e T. viridula*. A predação pelos caranguejos foi maior sobre *S. haemastoma*, do que em *T. viridula*. Os machos predaram mais ativamente *Neritina virginea*, enquanto as fêmeas não tiveram preferência por nenhuma das presas oferecidas, predando-as indistintamente. O tempo de manipulação foi menor para *N. virginea* do que para *S. haemastoma* e *T. viridula*. O tamanho crítico da presa foi menor para *N. virginea*, seguida por *S. haemastoma* e *T. viridula* respectivamente. As quelas são desenhadas para quebrar conchas dos moluscos. O comportamento predatório do caranguejo *Menippe nodifrons* está diretamente relacionado ao nível de especialização de suas quelas, das características morfológicas e vulnerabilidade de suas presas.

Palavras-Chave: Preferência pela presa, Predação, Moluscos

Introdução

Entre as espécies de caranguejos observadas por Vermeij (1977) como importantes predadores de moluscos gastrópodes, destacam-se as pertencentes às famílias Xanthidae, Menippidae e Carpilidae, em especial os dos gêneros *Carpilius* Leach, 1823; *Eriphia* Latreille, 1817; *Ozius* H. Milne Edwards, 1834; *Lydia* Gistel, 1848; *Galene* de Haan, 1833 e *Menippe* de Haan, 1833.

Caranguejos do gênero *Menippe* são considerados excelentes predadores por serem animais de médio a grande porte (Bert 1992) e, principalmente, por possuírem quelas especializadas em quebrar e abrir conchas de muitos moluscos (Lindberg & Marshall 1984).

Os caranguejos quebram as conchas de suas presas de duas maneiras, por tritura/esmagamento ("crushing"), e por descascamento ("peeling"). A primeira consiste em comprimir a concha entre duas superfícies duras, como por exemplo, entre os dedos fixo e móvel das quelas. O segundo tipo de quebra consiste no descascamento, no qual a borda de crescimento da concha (o lábio externo nas conchas de gastrópodes e a superfície livre das valvas de bivalves) é atacada pelo caranguejo. Começando pelo lábio, o caranguejo quebra a concha pedaço por pedaço em direção ao ápice, até os tecidos serem expostos para o consumo (Palmer 1979, 1999). Crustáceos decápodos moluscívoros têm mostrado possuir um importante papel no processo de evolução das conchas através da predação utilizando a técnica de esmagamento (Berteness & Cunningham 1981).

O caranguejo *Menippe nodifrons* Stimpson, 1859 é uma espécie encontrada no litoral brasileiro, ocorrendo em quase toda a sua extensão, desde o Maranhão até a costa de Santa Catarina, podendo ser encontrado ainda na Florida, Antilhas, Norte da América do Sul, Guianas, Atlântico Oriental e África Tropical (Coelho 1967, 1972; Melo 1996). Esse caranguejo, característico de costões rochosos, recifes de arenito e estuários, pode ser encontrado no médio-litoral em praias de águas rasas e nas poças de marés; sob as rochas, entre fendas e pilares de atracadouros ou, ainda, na base de plantas de mangue, madeira podre no solo e bancos de ostras (Coelho 1967; Furtado-Ogawa 1972; Fausto-Filho 1976; Melo 1996).

Apesar da abundância e relativa facilidade de coleta, trabalhos realizados com a espécie *M. nodifrons* no Brasil são escassos (Castro & Araújo 1978; Oshiro 1999, Fransozo *et al.* 1999), e os aspectos de sua biologia e ecologia são pouco conhecidos, particularmente aqueles relativos à sua dieta e ao seu comportamento predatório (Turra *et al.* 2005; Madambashi *et al.* 2005). Com isso, esse trabalho teve como objetivo estudar o comportamento predatório do caranguejo *M. nodifrons* em condições de laboratório, sobre três espécies de moluscos gastrópodes: *Stramonita haemastoma* (Linnaeus, 1758), *Tegula viridula* (Gmelin, 1791) e *Neritina virginea* (Linnaeus, 1758), observando sua preferência alimentar, tempo de predação que o caranguejo investe em cada espécie de presa, análise biomecânica das quelas e do tamanho crítico das presas e técnicas de manipulação empregadas.

Materiais e Métodos

Coleta dos caranguejos e moluscos. Os caranguejos e moluscos foram coletados manualmente nos meses de março e julho de 2004, na zona entre-marés da Praia do Pacheco, Município de Caucaia, Ceará (3°44'S, 38°39'W). Caranguejos machos e fêmeas foram capturados aleatoriamente, enquanto no caso dos moluscos, apenas espécimes que não possuíam conchas danificadas foram coletados. Os animais foram acondicionados em recipientes contendo água marinha e levados ao Laboratório de Invertebrados Marinhos do Departamento de Biologia, da Universidade Federal do Ceará. Os caranguejos foram aclimatizados em aquários individuais de 5 litros e os moluscos em aquários de 20 litros, ambos com aeração artificial, contendo água do mar, em temperatura ambiente (37°C) e salinidade de 35.

Todos os animais coletados foram medidos com o auxílio de um paquímetro (± 0,01mm de acurácia). No caso dos caranguejos, foram medidos comprimento (do sulco entre os pedúnculos oculares na margem anterior até o final da margem posterior) e largura do cefalotórax (entre as margens ântero-laterais na altura do 3º espinho); além do comprimento (da ponta do própodo ou dedo fixo até a linha de junção entre o carpo) e largura das quelas (porção mais alargada da palma). Já as presas foram mensuradas da seguinte forma: *Stramonita haemastoma* da espira ao canal sifonal anterior; *Tegula viridula* e *Neritina virginea* da espira até o lábio externo.

Experimento de preferência alimentar. Um total de 23 caranguejos, sendo 9 machos e 14 fêmeas, com comprimento do cefalotórax variando de 20-40mm, foram colocados individualmente em um aquário de 5L e deixados por 48h sem alimento. Após esse período foram acrescentadas em cada aquário, as três espécies de presas. Para cada molusco retirado após a predação, era verificado se a concha fora danificada ou se apresentava cicatrizes. Esse experimento teve duração de um mês. As presas tinham os seguintes intervalos de classes de tamanho: *S. haemastoma* (10-25 mm); *T. viridula* (10-20 mm) e *N. virginea* (10-15 mm).

Para as análises de preferência alimentar por *M. nodifrons,* foi utilizado o pacote estatístico Bioestat 2.0 (Ayres *et al*. 2000), sendo aplicado nesse tratamento o teste χ^2 (qui-quadrado) não-paramétrico para cálculo de proporções. Foram consideradas as seguintes hipóteses para o experimento de preferência alimentar:

H_o: Não existe preferência alimentar da espécie *M. nodifrons* por uma das presas *S. haemastoma*, *T. viridula* ou *N. virginea*.

H_a: Existe preferência alimentar da espécie *M. nodifrons* por uma das presas *S. haemastoma*, *T. viridula* ou *N. virginea*.

Entre os sexos as hipóteses testadas para a preferência alimentar foram:

H_o: Não existe preferência alimentar em machos de *M. nodifrons* por *S. haemastoma*, *T. viridula* ou *N. virginea.*

H_a: Existe preferência alimentar em machos de *M. nodifrons* por *S. haemastoma*, *T. viridula* e *N. virginea*.

H_o: Não existe preferência alimentar em fêmeas de *M. nodifrons* por *S. haemastoma*, *T. viridula* ou *N. virginea*.

H_a: Existe preferência alimentar em fêmeas de *M. nodifrons* por *S. haemastoma*, *T. viridula* ou *N. virginea*.

Experimento de tempo de predação e Manipulação das presas. O experimento foi realizado com 16 espécimes de *M. nodifrons*, (10 fêmeas e 6 machos). Assim como no experimento de preferência, os caranguejos foram acondicionados em aquários individuais, nas mesmas condições descritas anteriormente. A duração do experimento foi de um mês e as observações realizadas a cada duas horas. Cada uma das espécies de molusco foi oferecida por 10 dias aos caranguejos até o final do experimento.

Para a determinação do tempo de predação das presas por parte do caranguejo, foi observado o tempo de inicio da captura até a dispensa da concha. Em seguida, as conchas eram examinadas para se observar a efetividade da predação pelos caranguejos, ou seja, o consumo das partes viscerais dos moluscos. Somente foram analisadas as conchas vazias ou parcialmente consumidas. O tempo foi marcado com o uso de cronômetro e calculado através da diferença entre os intervalos inicial e final da predação. Todos os tempos foram transformados de horas para minutos.

Para avaliar se houve diferença entre os sexos de *Menippe nodifrons* em relação ao tempo de predação sobre os três tipos de presas oferecidas, foi realizado o teste *t* de Student (Zar 1999). A variável sob teste é o tempo de predação, em minutos, medido separadamente entre machos e fêmeas de *M. nodifrons* sobre as três espécies de presa.

Para o experimento de tempo de predação foram testadas as seguintes hipóteses:

H_o = machos e fêmeas utilizam o mesmo tempo de predação sobre *S. haemastoma*

H_a = machos e fêmeas utilizam tempos de predação diferentes sobre *S. haemastoma*

H_o = machos e fêmeas utilizam o mesmo tempo de predação sobre *T. viridula*

H_a = machos e fêmeas utilizam tempos de predação diferentes sobre *T. viridula*

H_o = machos e fêmeas utilizam o mesmo tempo de predação sobre *N. virginea*

H_a = machos e fêmeas utilizam tempos de predação diferentes sobre *N. virginea*

Também foi realizado o teste de Kruskall-Wallis (Zar 1999) para avaliar se o tipo de presa interfere no tempo de predação pelo caranguejo *Menippe nodifrons*. A variável sob teste é o tempo de predação, medido em minutos, da espécie *M. nodifrons* sobre as três espécies de presa. As seguintes hipóteses foram testadas:

H_o = o tempo de predação é igual sobre *S. haemastoma*, *T. viridula* e *N. virginea*

H_a = o tempo de predação é diferente sobre *S. haemastoma*, *T. viridula* e *N. virginea*

Tamanho crítico da presa e Espessura das conchas

O tamanho crítico foi calculado através de uma razão simples entre a média dos tamanhos da largura (tamanho da volta corporal) das presas (LP) e dos comprimentos da quelas maiores (QM) dos caranguejos (Vermeij 1976; Berteness & Cunningham 1981; Boulding 1984; Smallegange & Van Der Merr 2003). Segundo Smallegange & Van Der Merr (2003), esse valor indica quantas vezes a largura da presa é maior que o comprimento da quela e o quanto esse parâmetro é importante na escolha das presas e na manipulação das mesmas. O tamanho crítico será usado para auxiliar na caracterização das técnicas aplicadas pelos caranguejos diante da forma da concha das três presas oferecidas.

As espessuras das conchas foram verificadas através da mensuração das espessuras dos lábios interno (medida do lábio adjacente a columela) e externo (medida do lábio oposto a columela) das conchas em cada espécie de gastrópodo. Foi utilizado um paquímetro de ± 0,01mm de acurácia para anotação das medidas. No total foram amostradas 20 conchas de cada presa e calculada as médias das medidas dos lábios interno e externo para cada espécie conforme Trussell (1996). As médias das medidas do lábio externo foram analisadas estatísticamente usando ANOVA: 1 critério, seguido do teste de Tukey HSD para comparações múltiplas (Zaar, 1999), para testar a hipótese nula (H_0), de que as médias das espessuras das conchas das presas são similares ($\mu_1 = \mu_2 = \mu_3$), ou a alternativa (H_a), no qual as médias são diferentes ($\mu_1 \neq \mu_2 \neq \mu_3$).

Análise biomecânica das quelas. Foram observadas as características morfológicas e biomecânicas das quelas de *M. nodifrons.* As análises consistiram em descrever a forma da dentição localizada na superfície dos dedos fixo e do dátilo (móvel). Também foi realizado cálculo da vantagem mecânica das quelas. A vantagem mecânica (VM) é um valor adimensional calculado através de uma razão simples L1/L2, onde L1 é a distância entre o ponto de rotação do dátilo (no eixo fixo) até o ponto de inserção do apodema (tendão dos grandes músculos das quelas) e L2 a distância do ponto de rotação até a ponta do dátilo.

Esse parâmetro está associado com o nível de especialização das quelas em quebrar conchas resistentes à predação por caranguejos moluscívoros (Seed & Hughes, 1995, 1997; Yamanda & Boulding, 1998). Considera-se um valor de VM > 0,3 para espécies de caranguejos com quelas especializadas em quebrar conchas duras e resistentes. Quando a VM é menor que 0,3 os caranguejos são considerados pouco especialistas na quebra de conchas mais duras (Warner & Jones, 1976; Bronw *et al.*, 1979; Elner & Campbell, 1981). Foi calculado o valor da vantagem mecânica nas quelas de 18 caranguejos, entre machos (n = 09) e fêmeas (n = 09), em seguida calcularam-se as médias dos valores obtidos.

Resultados

Preferência alimentar. A espécie *Menippe nodifrons* consumiu as três espécies de presas oferecidas (Fig. 1) por ordem de preferência: *Neritina virginea* (44,9%); *Stramonita haemastoma* (29,7%) e *Tegula viridula* (25,4%), o teste χ^2 mostrou significância com valor igual a 8,73 (g.l. = 2) para $\alpha = 0,05$ e $p = 0,0127$. Dessa forma, aceita-se a hipótese alternativa (H_a), de que existe preferência alimentar do caranguejo *M. nodifrons* por uma das presas.

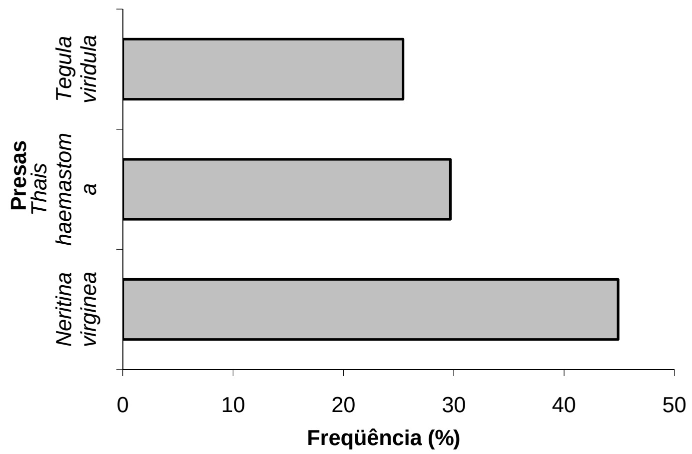

Figura 1. Frequência de consumo das presas *Stramonita haemastoma*, *Tegula viridula* e *Neritina virginea* pelo caranguejo *Menippe nodirons*.

Entre os sexos a preferência alimentar (Fig. 2) observada em machos de *M. nodifrons* mostrou alta significância estatística com o teste χ^2, para o valor calculado igual a 16,28 (g.l. = 2); $p < 0,01$. Dessa forma, aceita-se a hipótese alternativa (H_a) de que machos de *M. nodifrons* preferem uma das três presas oferecidas. A ordem de preferência alimentar entre machos de *M. nodifrons* por uma das presas foi: *N. virginea* (n = 34), *S. haemastoma* (n = 15) e *T. viridula* (n = 10). Para as fêmeas de *M. nodifrons,* não houve significância para o teste χ^2, sendo o valor calculado ($\chi^2 = 0,17$, g.l = 2, $\alpha = 0,05$) menor que o valor esperado. Sendo assim, aceita-se a hipótese nula (H_o), onde fêmeas do caranguejo *M. nodifrons* não tiveram preferência alimentar por nenhuma das três presas oferecidas, selecionando-as igualmente durante a predação, *S. haemastoma* (n = 26), *T. viridula* (n = 25) e *N. virginea* (n = 28).

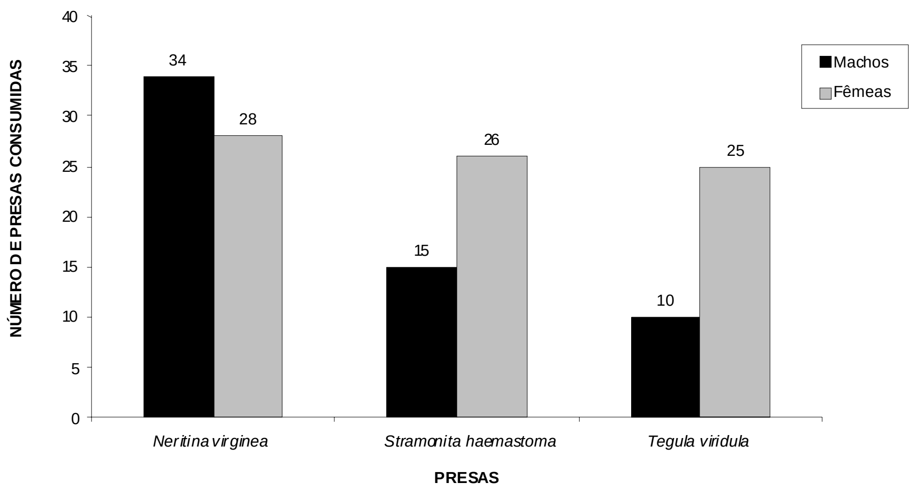

Figura 2. Preferência alimentar do caranguejo *Menippe nodifrons* pelas presas oferecidas em relação ao sexo.

Tempo de Predação. Os resultados do teste *t* mostraram que entre machos e fêmeas de *M. nodifrons* não houve diferença significativa em relação ao tempo de predação sobre *S. haemastoma* (t = 0,505; *p* = 0,620), *T. viridula* (t = - 0,088; *p* = 0,932) e *N. virginea* (t = 0,056; *p* = 0,956). Dessa forma, aceita-se a hipótese nula (H_o), onde machos e fêmeas de *M. nodifrons* utilizam o mesmo tempo de predação para capturar e consumir *S. haemastoma*, *T. viridula* e *N. virginea*.

Considerando-se o teste de Kruskall-Wallis para avaliar se o tipo de presa interfere no tempo de predação do caranguejo *M. nodifrons,* os resultados expressos na Figura 3 mostram que a espécie utiliza tempos de predação diferentes (hipótese alternativa) sobre *S. haemastoma*, (106,1 min), *T. viridula* (120,7 min) e *N. virginea* (44,2 min), com base no valor de H = 39,85 com elevada significância estatística, ao nível de 1% (p< 0,01); g.l. = 2.

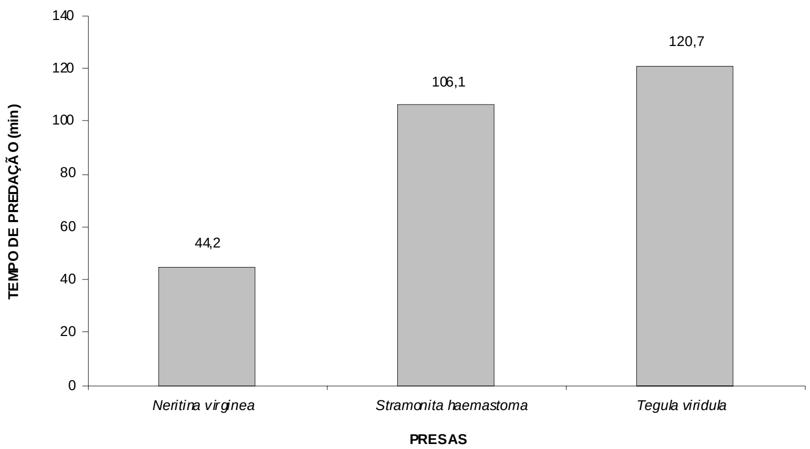

Figura 3. Tempo de manipulação requerido pelo caranguejo *Menippe nodifrons* sobre as três presas oferecidas.

A Figura 4 mostra a relação entre a preferência alimentar e o tempo de manipulação das presas conforme os resultados obtidos para o caranguejo *M. nodifrons*. O tempo de manipulação aumenta enquanto a preferência alimentar diminui para as diferentes presas oferecidas.

Manipulação das presas. Menippe nodifrons manipulou as três espécies de presas usando técnicas de esmagamento e também de descascamento (Fig. 5). A técnica de esmagamento consistiu em capturar a presa pela sua volta corporal (Fig. 5c, 5d) e abraçá-la, empurrando-a contra seu corpo. Enquanto isso, os primeiros e segundos pares de pereiópodos (patas locomotoras) auxiliavam na manipulação da presa e levavam os moluscos até os apêndices bucais (maxilípedes). A quela maior quebrava a concha dos gastrópodes entre o dedo fixo e o dátilo no meio da volta corporal, ou então, como ocorreu algumas vezes em *S. haemastoma* (Fig. 5a, 5b), a concha dos moluscos era quebrada com essa quela através do ápice. Quando a presa era capturada, a quela menor era inserida na abertura labial da concha, enquanto o caranguejo tentava quebrá-la com a maior quela através da técnica de esmagamento. O esmagamento ocorreu em todas as presas, porém em *Neritina virginea* essa técnica foi predominante, não ocorrendo descascamento.

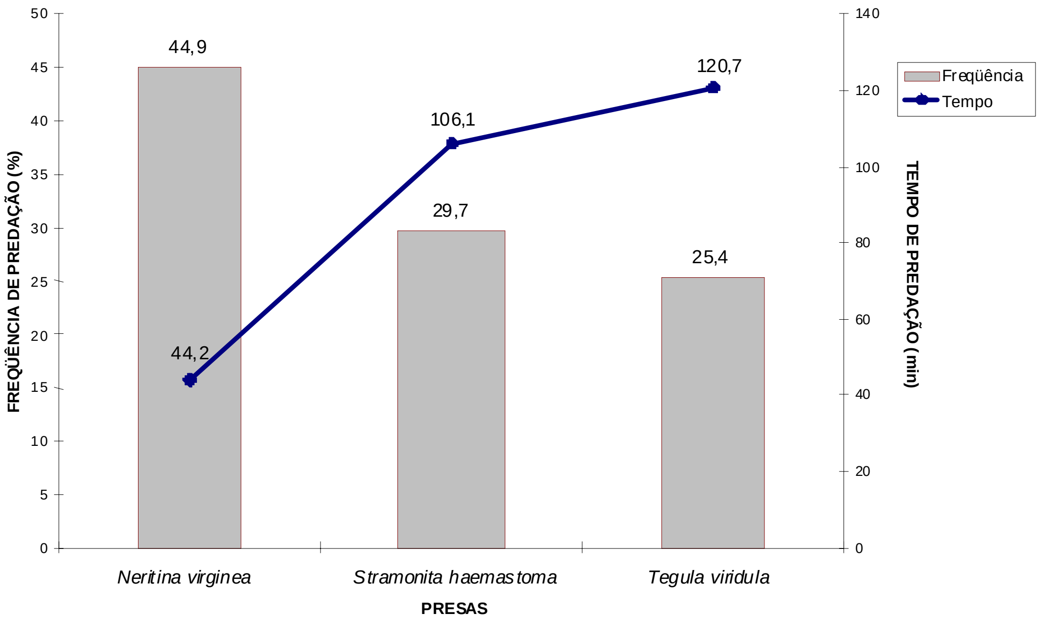

Figura 4. Relação entre tempo de manipulação e preferência alimentar do caranguejo *Menippe nodifrons* sobre as três espécies de presas oferecidas.

Por outro lado, em *S. haemastoma* e *T. viridula* a técnica predominante foi o descascamento, ocorrendo o esmagamento poucas vezes (Fig. 5c, 5d, 5e, 5f). Ao fazerem uso da técnica de descascamento, os caranguejos reposicionavam a concha, inseriam o dedo fixo e o dátilo da quela maior entre a abertura do lábio externo da concha, apoiando a concha com a quela menor e os primeiros pares de pereiópodos. Algumas vezes, os caranguejos faziam uso da quela menor para aplicar o descascamento. Em seguida, eles raspavam e cortavam essa região do lábio externo da concha para facilitar a exposição do conteúdo visceral do gastrópode, que podia ser consumido total ou parcialmente pelos apêndices bucais. Quando as presas eram *S. haemastoma* e *T. viridula*, caranguejos menores sempre realizavam a técnica de descascamento, já os caranguejos maiores fizeram uso, algumas vezes, do esmagamento. Tanto os caranguejos grandes, como os pequenos utilizaram a técnica de esmagamento para predar *N. virginea* (Fig. 5g, 5h).

Tamanho crítico da presa e Espessura das conchas. Os valores abaixo mostram as médias para largura das presas *Stramonita haemastoma*, *Tegula viridula* e *Neritina virginea* e comprimento da quela maior do caranguejo *Menippe nodifrons*. O gastrópode *Neritina virginea* foi a espécie que apresentou o menor tamanho crítico (TCP = 0,34), em seguida obteve-se os respectivos valores para *S. haemastoma* (TCP = 0,38) e *T. viridula* (TCP = 0,50).

No quadro I observa-se os resultados para os valores das médias calculadas para as espessuras do lábio interno e para o lábio externo. A espessura da concha para o lábio externo (região onde ocorre a manipulação por *peeling* e mais susceptível ao ataque pelo caranguejo) foi menor em *Neritina virginea* (μ_1 = 0,22), seguida pelas médias de *Tegula viridula* (μ_2 = 0,95) e *Stramonita haemastoma* (μ_3 = 1,15), bem como as médias para o lábio interno também foram respectivamente menores em *N. virginea* (μ_1 = 0.66), seguida de *T. viridula* (μ_2 = 1.97) e *S. haemastoma* (μ_3 = 4.40).

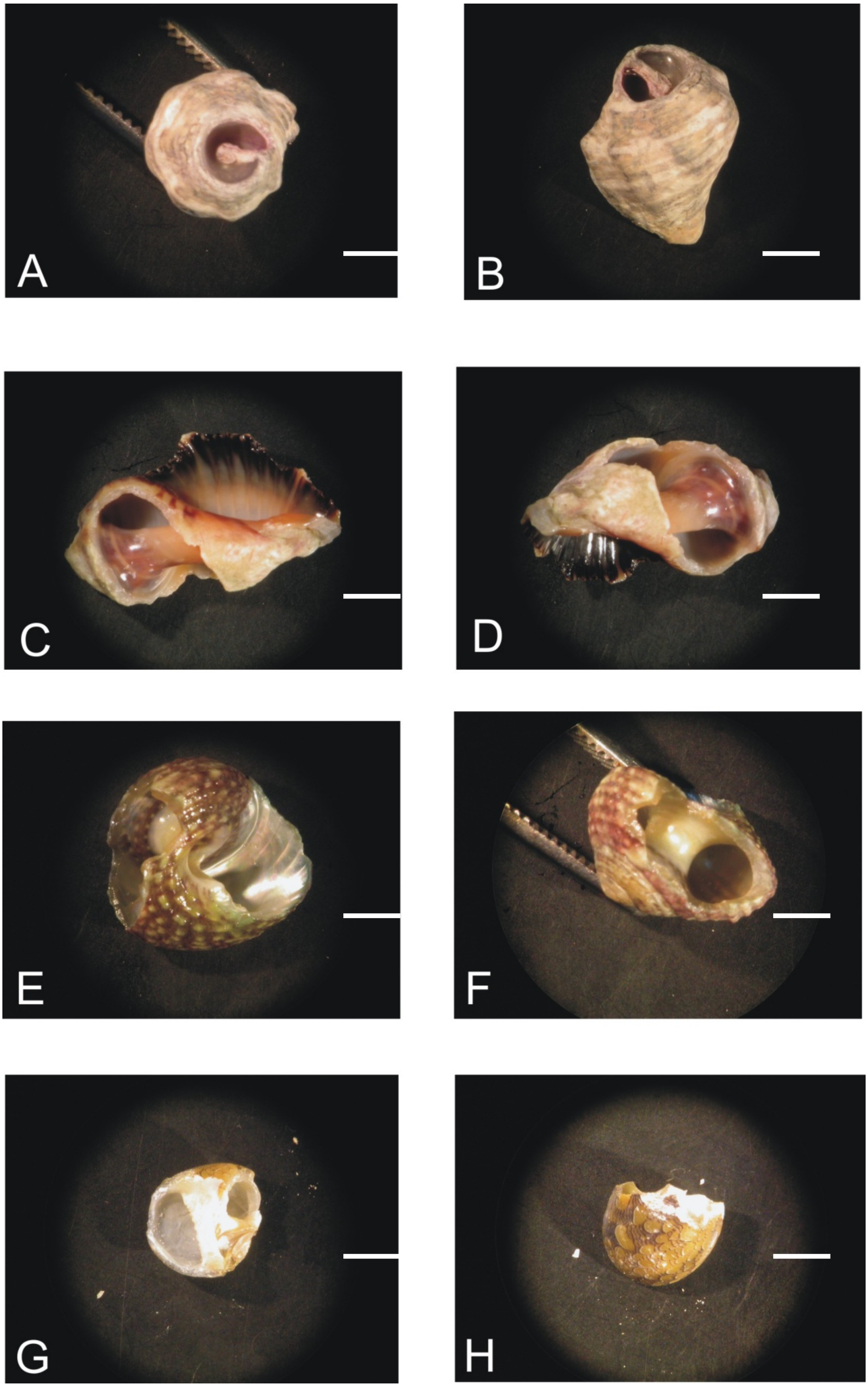

Figura 5. Cicatrizes nas conchas predadas por *Menippe nodifrons* através das técnicas de esmagamento (*crushing*) e descascamento (*peeling*): (A, B, C, D) *Stramonita haemastoma*; (E, F) *Tegula viridula*; (G, H) *Neritina virginea*.

Quadro I. Espessuras do lábio interno e externo em conchas de *Neritina virginea*, *Tegula viridula* e *Stramonita haemastoma*.

Presas	Lábio interno			Lábio externo		
	Média	**Erro Padrão**	**N**	**Média**	**Erro Padrão**	**N**
Neritina virginea	0,66	0,02	20	0,22	0,02	20
Tegula viridula	1,97	0,07	20	0,95	0,04	20
Stramonita haemastoma	4,40	0,18	20	1,15	0,08	20

As médias da espessura do lábio externo diferiu estatisticamente entre as três espécies de presas (ANOVA, $F = 79.90$, $gl = 2$, $p = 0.000$) rejeitando-se a hipótese nula (H_0). O teste de Tukey mostrou as médias significativamente diferentes ($HSD_{0.05} = 0.19$ e $HSD_{0.01} = 0.24$) conforme a Tabela I.

Tabela I. Teste de Tukey HSD para comparação múltipla entre as médias do lábio externo das presas: *Neritina virginea*, *Tegula viridula* e *Stramonita haemastoma*.

Médias	μ_2	μ_3
μ_1	$p < 0.01$	$p < 0.01$
μ_2		$p < 0.05$

Análise biomecânica das quelas. As quelas de *Menippe nodifrons* são dimórficas e apresentam dentições distintas em suas superfícies internas dos dedos fixos (própodo) e dos dátilos (dedo móvel). Na base do dedo fixo da quela maior é observado um tubérculo bastante proeminente em forma de molar, o qual é chamado de dente molariforme, seguido de outros tubérculos menores não pontiagudos. A superfície interna do dátilo (dedo móvel) também apresenta tubérculos menores e menos proeminentes do que aqueles encontrados no dedo fixo da quela maior (própodo). A quela menor apresenta dentições em forma de serra, tanto na parte interna do dátilo, como na superfície basal do dedo fixo. Os dentes são pequenos e pontiagudos. Nas quelas menores não se formam tubérculos em forma de molar como nas quelas maiores.

M. nodifrons também apresentou diferenças no valor da vantagem mecânica (VM) calculado para as duas quelas (Tabela II). Os resultados, considerando-se o total entre machos e fêmeas da espécie, foi de VM = 0,38 para a quela maior (QM) e VM = 0,32 para a quela menor (Qm). Dessa forma, o valor numérico da vantagem mecânica das quelas de *M. nodifrons* são maiores que 0,3 caracterizando-os como especialistas em quebra de conchas duras e resistentes.

Tabela II. Valores mínimos da vantagem mecânica (L1/L2; onde L1 = segmento do eixo fixo ao ponto de inserção no tendão do músculo maior; L2 = segmento do eixo fixo a ponta do dátilo) das duas quelas do caranguejo *Menippe nodifrons*. QM = quela maior; Qm = quela menor

	Vantagem mecânica	
	QM	**Qm**
Machos	0,41	0,33
Fêmeas	0,36	0,31
Média VM	**0,38**	**0,32**

A Tabela III mostra a relação das características morfológicas das quelas de *M. nodifrons* e suas respectivas vantagens mecânicas. As técnicas de manipulação descritas anteriormente caracterizam a ação das quelas sobre as conchas dos moluscos predados.

Tabela III. Características morfológicas e biomecânicas das quelas do caranguejo *Menippe nodifrons*.

	Morfologia dos dentes	Tipo de quela	Vantagem mecânica	Ação sobre conchas de moluscos
Quela maior (QM)	Molariformes	Esmagadora	0,38	Esmagamento *"crushing"*
Quela menor (Qm)	Pontiagudos	Cortadora	0,32	Corte *"peeling"*

Discussão

Preferência alimentar. No presente estudo o caranguejo *M. nodifrons* mostrou ter uma preferência maior por *Neritina virginea* nos experimentos realizados, em relação às outras duas presas oferecidas *Stramonita haemastoma* e *Tegula* *viridula*. A ocorrência desse comportamento, provavelmente, está relacionada ao fato de *N. virginea* possuir características morfológicas, como espessura da concha mais fina (ver Tabela 2) e lisa (sem ornamentações espinhosas), que a tornam mais susceptível e vulnerável ao caranguejo quando comparada a *S. haemastoma* e *T. viridula*. Estes dois gastrópodes possuem um lábio externo mais espesso, concha mais dura e ornamentada com pequenos espinhos. A concha de *S. haemastoma* possui uma espira mais alta do que a concha de *Tegula viridula*, essa característica pode aumentar a vulnerabilidade do molusco ao ataque pelo caranguejo, conforme foi observado na preferência maior de *M. nodifrons* por *S. haemastoma* em relação a *T. viridula*. Outra característica favorável ao menor ataque do caranguejo sobre *T. viridula* em relação a *S. haemastoma*, se dá pela presença de uma abertura menor da concha naquela, dificultando a manipulação das partes viscerais do molusco pelo predador.

Turra *et al.* (2005) estudaram o comportamento predatório do caranguejo *Menippe nodifrons* sobre os gastrópodes *S. haemastoma* e *Tegula viridula*, e verificaram que esse caranguejo predava mais ativamente sobre *S. haemastoma* do que em *T. viridula*, essas observações estão de acordo com os resultados observados no presente estudo.

A seleção do tamanho da presa é um importante componente no processo pelo qual as comunidades são estruturadas através da predação (Sammerson & Perteson 1984; Hines *et al*. 1990). Alguns estudos sobre predação de moluscos por caranguejos têm mostrado que existe uma preferência, destes últimos, por presas de tamanhos menores ou intermediários, em relação às presas de tamanhos maiores (Sanches-Salazar *et al*. 1987; Coombes & Seed 1992; Juanes & Hartwick 1990; Juanes 1992; Brown & Haihgt 1992). Existem fatores que possuem importante papel na seleção da presa por caranguejos entre os quais, pode-se citar a relação entre tamanho do caranguejo e da presa, nível de saciedade, dentição, abertura e força da quela e tempo de manipulação da presa (Yamada & Boulding 1998).

Sih (1987) reporta que muitos predadores evitam atacar presas que dificultam claramente a captura, manipulação ou ingestão através dos mais variados mecanismos de defesas. Diversas características da morfologia, como espessura, ornamentação e diminuição da abertura das conchas de gastrópodes têm sido relatadas como responsáveis por reduzir diretamente a vulnerabilidade dos moluscos ao ataque de seus predadores, como, por exemplo, caranguejos moluscívoros.

Entre os machos de *M. nodifrons* houve uma preferência maior por *N. virginea* em relação às espécies *S. haemastoma* e *T. viridula*. Em contraposição, as observações realizadas com fêmeas não foram estatisticamente significantes o suficiente para apontar alguma preferência por uma das presas. Esse comportamento entre machos pode ter como possível causa, o fato deles evitarem danificar suas quelas atacando uma presa mais fácil de ter a concha quebrada, pois, caso contrário, as quelas poderiam perder sua funcionalidade em outras atividades importantes na vida desses animais como, por exemplo, a reprodução (Juanes & Hartwick 1990; Juanes 1992).

Muitos crustáceos decápodos evitam o risco de danificarem suas quelas durante a predação de moluscos de conchas mais resistentes escolhendo presas de tamanhos menores (Juanes 1992). Para Lee (1995), do ponto de vista evolutivo, a importância funcional das quelas nos decápodos (principalmente os braquiúros), é regida por três grandes forças seletivas: comportamento alimentar, interações competitivas e hábitos reprodutivos. Juanes (1992) observa que para a maioria dos crustáceos decápodos, principalmente entre os braquiúros, a danificação parcial ou total das quelas pode vir a ter um efeito ecológico de alta importância ao longo da vida desses animais. Esses efeitos implicam em mudanças nos hábitos alimentares, no comportamento predatório, no crescimento, nas trocas do exoesqueleto (ecdises), na regeneração de partes perdidas, nas taxas de mortalidade e no sucesso reprodutivo (Davis *et al*. 1978; Savage & Sullivan 1978; Sekkelsten 1988; Juanes & Hartwick 1990).

Estudos prévios corroboram o fato de que caranguejos moluscívoros preferem se alimentar de presas menores e que ofereçam menos riscos de danos às quelas, principalmente no caso dos machos, onde a mesma é usada no processo copulatório (Davidson 1986; Juanes & Hartwick 1990; Juanes 1992; Brown & Haight 1992; Richardson & Brown 1992; Vermeij 1995; Brousseau *et al*. 2001; Smallegange & Van Der Meer 2003).

O tempo de manipulação foi menor na espécie *N. virginea* quando comparado às duas outras espécies de moluscos, sendo essa, aliado ao tamanho e morfologia da concha, uma das prováveis razões da preferência de *M. nodifrons* por *N. virginea*. A frágil concha de *N. virginea* permitiu que o caranguejo fizesse uso do "crushing" para expor seus tecidos, o qual é uma técnica mais rápida do que o descascamento, usado para predar conchas mais resistentes como as de *S. haemastoma* e *T. viridula*.

De acordo com Davidson (1986) em seus estudos sobre o comportamento predatório do caranguejo *Ovalipes catharus* sobre moluscos, a variação no tempo de predação ocorreu quando os caranguejos empregaram, para abrir as conchas, técnicas diferentes que dependiam, sobretudo, do tamanho da presa, da resistência da concha e provavelmente da vulnerabilidade da presa.

De acordo com os estudos realizados por Brown & Haight (1992) sobre aspectos predatórios do caranguejo *Menippe adina* o handling time dos caranguejos sobre *S. haemastoma* e *Crassostrea virginica* aumentou com o tamanho da presa. Esse aumento no tempo de predação, provavelmente, ocorreu devido às técnicas de "crushing" e "peeling" utilizadas nos diferentes tamanhos de presas oferecidas; os caranguejos levam mais tempo para manipular as presas quando o "peeling" é utilizado no lugar do "crushing".

Lawton & Hughes (1985) reportam que o método de descascamento para quebrar conchas de paredes espessas em gastrópodes aumenta substancialmente com o tamanho da concha. Para *M. nodifrons* as observações encontradas estão de acordo com os estudos citados acima e também conforme os relatados para o caranguejo *Ovalipes catharus* (Davidson 1986) e para a espécie de siri azul *Callinectes sapidus* (Seed & Hughes 1997).

Manipulação das presas e Análise Biomecânica das quelas. O caranguejo *Menippe nodifrons* manipulou as presas usando principalmente as técnicas de esmagamento e descascamento. O "*crushing*" (Zisper & Vermeij 1978; Palmer 1979) ou esmagamento foi uma técnica de ataque mais eficiente e mais rápida para quebrar as conchas. Enquanto que o "*peeling*" (Palmer 1979) técnica que consistia em raspar e cortar foi utilizada quando os caranguejos tinham dificuldades maiores em quebrar as conchas. Esta última técnica foi predominante em conchas de *Stramonita haemastoma* e *Tegula viridula*. O uso desta técnica pelos caranguejos pode ter uma relação direta com as características morfológicas das conchas desses gastrópodes, pois quando os caranguejos utilizaram esse método o tempo de manipulação aumentou e as dificuldades de manipulação eram maiores. A técnica de esmagamento ou "*crushing*" foi predominante em *Neritina virginea*. Esse fato por ter implicação na maior vulnerabilidade desse gastrópode diante da eficiência de *M. nodifrons* em capturá-la e consumí-la.

Bertness & Cunnigham (1981) estudando os métodos de predação dos caranguejos moluscívoros *Eriphia squamata* e *Ozius verreauxii* mostraram que entre as duas espécies de caranguejos os métodos de predação foram similares, com o "*crushing*" sendo usado pelos caranguejos de forma bem sucedida sobre conchas de tamanhos relativamente menores, e o "*peeling*" em conchas de tamanhos maiores ou valores próximos ao tamanho crítico da presa.

O descascamento é uma tática de predação usualmente mais comum quando as presas são mais resistentes ao esmagamento (Du Preez 1984; Seed & Hunghes 1995). Para *Menippe nodifrons* as técnicas e métodos empregados sobre as três espécies de presas são similares aos encontrados para outras espécies de braquiúros (Berteness & Cunningham 1981; Boulding 1984; Davidson 1986).

As características morfológicas das quelas do caranguejo *Menippe nodifrons* são muito similares às observações realizadas para as quelas dos caranguejos da família Xanthidae (Vermeij, 1995) e dos gêneros *Eriphia* e *Ozius* (Bertness e Cunningham 1981; Seed e Hughes 1995) e principalmente com as quelas de *Menippe mercenaria* e *Menippe adina* (Lindberg & Marshall 1984; Brown & Haight 1992).

As quelas de *M. nodifrons* são biomecanicamente especializadas para quebrar moluscos de conchas duras e resistentes, essas características estão conforme estudos realizados para a morfologia das quelas de decápodos (Yamada & Boulding 1998). Nesse estudo, o caranguejo *Menippe nodifrons* apresentou vantagem mecânica das duas quelas acima de 0,3 (V.A. = 0,38 para quela maior e V.A. = 0,32 para a quela menor). Além disso, *M. nodifrons* possui duas quelas dimórficas que apresentam características distintas quanto a função em quebrar as conchas de moluscos. A quela maior possui características de estruturas fortes e dentições molariformes usadas para esmagar as conchas, já as quelas menores são estruturas mais delicadas, com dentes em forma de serra especializadas em raspagem, corte e captura da presa. Essas características estão de acordo com observações realizadas por Seed & Hughes (1995, 1997), para estudos descritos sobre a morfologia das quelas em algumas famílias de caranguejos moluscívoros (Parthenopidae, Xanthidae, Grapsidae, Calappidae, Cancridae e Portunidae).

Tamanho Crítico das presas e Espessuras das conchas. O tamanho crítico das presas *Neritina virginea*, *Stramonita haemastoma* e *Tegula viridula* pode ter influenciado na escolha da presa preferida e na técnica de manipulação observada para cada uma delas. *Neritina virginea* foi a presa com menor tamanho crítico e também a única a ter a concha quebrada por "*crushing*". Para as outras duas espécies de presas, em *S. haemastoma* o tamanho crítico foi menor do que em *Tegula viridula*. Nessas duas presas os caranguejos manipularam muito mais vezes através de "*peeling*" do que por "*crushing*". Esse fato pode ter relação com as características das conchas desses gastrópodes e também pode ser efeito da limitação mecânica das quelas imposta pelo tamanho crítico das presas.

Smallegange & Van Der Meer (2003) reportaram que o tamanho crítico em caranguejos da espécie *Carcinus maenas* tem influência não só na escolha do tamanho de suas presas, como também nas técnicas utilizadas. Ou seja, eles observaram que os caranguejos mudavam de técnica quando o tamanho da presa apresentava um valor (tamanho crítico da presa), no qual a largura dos moluscos forçou os caranguejos a trocarem o método de "*crushing*" pelo de "*peeling*". Estudos anteriores têm reportado que a largura dos moluscos é, sem dúvida, uma importante característica determinante na escolha da presa em outras espécies de caranguejos (Boulding 1984) e nos decápodes (Griffiths & Seiderer 1980).

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Referências Bibliográficas

Ayres, M., Ayres, M., Ayres, D. L, Santos, A. S., 2000. **BioEstat 2.0: Aplicações estatísticas nas áreas das ciências biológicas e médicas.** Sociedade Civil Mamirauá/CNPQ, Belém/Brasília.

Bert, T.M., 1992. Proceedings of a Symposium on Stone Crab (Genus *Menippe*) Biology and Fisheries. **Florida Marine Research Publications.** 50: 01-118.

Bertness, M.D., Cunningham, C., 1981. Crab Shell-crushing predation and gastropods architectural defense. **J. Exp. Mar. Biol. Ecol.** 50: 213-230.

Boulding, E.G., 1984., Crab-Resistant features of shells of burrowing bivalves: Decreasing vulnerability by increasing handling time. **Journal of Experimental Marine Biology and Ecology.** 76: 201-223,

Brousseau, D. J., Filipowicz, A., Baglivo, J. A., 2001.Laboratory Investigations of effects of predator sex and size on prey selection by the Asian crab *Hemigrapsus sanguineus*. **Journal of Experimental Marine Biology and Ecology.** 262: 199-210.

Brown, K.M., Haight, E., 1992. The foraging ecology of the gulf of Mexico stone crab *Menippe adina* (Williams et Felder). Journal of Experimental Marine Biology and Ecology. 160, 67-80.

Brown, S.C., Cassuto, S.R., Loos, R.W. 1979. Biomechanics of chelipeds in some decapod crustaceans. **J. Zool., Lond.** 188: 143-159.

Castro, A. C. L., Araújo, I. A. E., 1978. Aspectos biológicos do siri-guajá *Menippe nodifrons* Stimpson, 1859, na Ilha de São Luís, Estado do Maranhão, Brasil. **Boletim do Laboratório de Hidrobiologia.** 9: 7-26.

Coelho,P.A., 1967.Os crustáceos decápodos de alguns manguezais penambucanos. **Trab. Inst. Oceanogr.** Univ. Fed. Pe. – Recife. 7/8: 71-90.

Coelho, P.A., Ramos, M.A., 1972. A contribuição e a distribuição da fauna de decápodos do Litoral Leste da América do Sul entre as Latitudes de 5° N e 35° S. **Trab. Oceanogr. Lab. Ciênc. Mar.** 13: 55-76.

Coombes, M. R. A., Seed, R. , 1992. Predation of the black mussel *Septifer virgalus* by the red-eyed crab *Eriphia laevimana smithii* (Xanthidae). **Asian Marine Biology.** 9: 245-258

Davidson, R. J., 1986. Mussel selection by the paddle crab *Ovalipes catharus* (White): evidence of flexible foraging behaviour. **Journal of Experimental Marine Biology and Ecology.** 102: 281-299.

Davis, G. E.; Baughman, D. S.; Chapman, J. D.; Macarthur, D.; Pierce, A. C, 1978. Mortality associated with declawing stone crabs, *Menippe mercenaria*. Rep. T-522, South Florida Res. Ctr., Homestead.

Du Preez, H.H., 1984. Molluscan predation by *Ovalipes functatus* (De Haan) (CRUSTACEA: BRACHYURA: PORTUNIDAE). **Journal of Experimental Marine Biology and Ecology.** 84: 55-71.

Elner, R. W., Campbell, A., 1981. Force, function, and mechanical advantage in the claw of the American lobster *Homarus americanus* (Decapoda: Crustacea). **J. Zool. London.** 173: 395-406.

Fausto-Filho, J., 1976. Primeira Contribuição ao Inventário dos crustáceos decápodos marinhos do nordeste brasileiro. **Arq. Est. Biol. Mar. univ. Fed.** Ce. 6 (1): 31-37.

Fransozo, A., G., Bertini, M.O.D. Côrrea., 1999. **Population biology and habitat utilization of the stone crab *Menippe nodifrons* Stimpson,1859 (Decapoda, Xanthidae) in Ubatuba region, Brazil.** p.275-281. *In:* J.C. Vaupel Klein & F.R. Schram (Eds). *The Biodiversity Crisis and Crustacea. 12, Crustacean Issues.* A.A. Balkema/Rotterdam.

Furtado-Ogawa, E. , 1972. Notas bioecológicas sobre a família Xanthidae no Estado do Ceará (Crustacea:Brachyura). **Arqui. Ciênc. do Mar.** 12 (2): 99-104

Griffiths, C. L., Seiderer, J. L., 1980. Rock lobsters and mussels – limitations and preferences in a predator-prey interaction. **Journal of Experimental Marine Biology and Ecology.** 44: 95-109.

Hines, A. H., Haddon, A. M., Wiechert, L. A., 1990. Guild structure and foraging impact of blue crabs epibenthic fish in a subestuary of Chesapeake Bay. **Marine Ecology Progress Series**. 67: 105-126.

Juanes, F., 1992. Why do Decapod crustaceans prefer small-sized molluscan prey? **Marine Ecology Progress Series.** 87: 239-249.

Juanes, F., Hartwick, E. B., 1990. Prey Size Selection in Dungeness Crabs: The effect of claw damage. **Ecology.** 71 (2): 744-758.

Lawton, P., Hughes, R. N., 1985. Foraging behaviour of the crab *Cancer pagurus* feeding on the gastropods *Nucella lapillus* and *Littorina littorea*: comparisons with optimal foraging theory. **Mar. Ecol. Prog. Ser.** 27: 143-154.

Lee, S. Y., 1995. Cheliped size and structure: the evolution of a multifunctional decapod organ. **Journal of Experimental Marine Biology and Ecology.** 193: 161-176.

Lindberg, W., Marshall, M. J., 1984 Species Profiles: **Lifes Hitories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida).** U. S. Fish and Wildlife Service, U. S. Corps of Engineers, 17, Florida.

Mandambashi, A. M., Christofoletti, R. A., Pinheiro, M. A. A. (2005) Natural Diet of the crab *Menippe nodifrons* Stimpson, 1859 (Brachyura, Menippidae) in Paranapuã Beach, São Vicente (SP), Brasil. **Nauplius** 13 (1): 77-82.

Melo, G. A. S. , 1996. **Manual de Identificação dos Brachyura (caranguejos e Siris) do Litoral Brasileiro.** Plêiade/FAPESP. 603, São Paulo.

Oshiro, L. M. Y. , 1999. Aspectos reprodutivos do caranguejo guaiá *Menippe nodifrons* Stimpson, 1859 (Crustácea, Decapoda, Xanthidae) da Baía de Sepetiba (RJ). **Revista Brasileira de Zoologia.** 16 (3): 827-834.

Palmer, A. R., 1979. Fish predation and evolution of gastropod shell sculpture, experimental and geographical evidence. **Evolution**. 33: 697-713.

Palmer, A. R., Taylor, G. M., Barton, E., 1999. Cuticle strenght and size-dependence of safety factors in Cancer crab claws. **Biol. Bull.** 196: 281-294

Richardson, T. D., Brown, K. M., 1992. Predation risk and feeding in an intertidal predatory snail. **Journal of Experimental Marine Biology and Ecology.** 163: 169-182.

Sanchez-Salazar, M. E., Griffiths, C. L., 1987. The effect of size and temperature on the predation of coockies *Cerastoderma edule* (L.) by the shore crab *Carcinus maenas* (L.). **Journal of Experimental Marine Biology and Ecology.** 111: 181-193.

Savage, T., Sullivan, J. R., 1978. **Growth and claw regeneration on the stone crab, Menippe mercenaria. Florida Mar. Res. Plub. 32**, Florida Dept. Nat. Res., St. Petersburg.

Seed, R., Hughes, R. N., 1995. Criteria for prey size-selection in mollucisvorous crabs with contrasting claw morphologies. **Journal of Experimental Marine Biology and Ecology.** 193: 177-195.

Seed, R., Hughes, R. N., 1997.Chelal Characteristics and Foraging Behaviour of the crab *Callinectes sapidus* Rathbun. **Estuarine, Coastal and Shelf Science.** 44: 221-229.

Sih, A., 1987. **Predators and Prey Lifestyles: An Evolutionary and Ecological Overview**, 203-224, in Kerfoot, W. C. & Sih, A. (eds.), Predation: Direct and Indirect Impacts on Aquatic Communities. Trustees of Dartmouth College, 383, New Englnd.

Smallegange, I. M., Van Der Meer, J., 2003. Why do shore crabs not prefer the most profitlable mussels? **Journal of Animal Ecology.** 72: 599-607.

Sekkelsten, G. I., 1988. Effect of handicap on mating success in male shore crabs *Carcinus maenas*. **Oikosv.** 51: 131-134.

Summerson, H. C., Peterson, C. H., 1984. Role of predation in organizing benthic communities of a temperate zone seagrass bed. **Mar. Ecol. Prog. Ser.** 15: 63-77.

Turra, A., Denadai, M. R., Leite, F. P. P., 2005. Predation on gastropods by shell-breaking crabs: effects on shell availability to hermit crabs. **Mar. Ecol. Prog. Ser.** 286: 279-291.

Trussel, G. C. (1996) Phenotypic Plasticity in na intertidal snail: The role of a common crab predator. **Evolution.** 50 (1): 448-454.

Vermeij, G. J., 1976. Interoceanic differences in vulnerability of shelled prey to crab predation. **Nature**. 260: 135-136.

Vermeij, G. J., 1977 Patterns in crab claw size: The geography of crushing. **Syst. Zool.** 26: 138-151.

Vermeij, G. J., 1995. A natural History of Shells. Princeton Science Library, 293, Princeton.

Warner, G. F., Jones, A. R., 1976. Leverage and muscle type in crab chelae (Crustacea: Brachyura). **J. Zool., Lond.** 180: 57-68.

Yamada, S. B., Boulding, E. G., 1998. Claw morphology, prey size selection and foraging efficiency in generalist and specialist shell-breaking crabs. **Journal of Experimental Marine Biology and Ecology**. 220: 191-211.

Zar, J. H., 1999. **Biostatistical analysis**. Prentice Hall, Englewood Cliffs, NJ.

Zisper, E.; Vermeij, G. J. , 1978. Crushing Behaviour of tropical and temperate crabs. **Journal of Experimental Marine Biology and Ecology**. 31: 155-172.

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Aspectos fitosanitarios de los manglares del Urabá Antioqueño, Caribe colombiano

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Resumen. Se presenta una síntesis del estado del conocimiento de la presencia de *Agrobacterium* sp. y *Neoteredo reynei* asociados a diferentes estructuras de los manglares del Urabá antioqueño en la costa Caribe de Colombia.

Palabras clave: manglares, moluscos teredos, bacterias, impactos, Caribe, Colombia

Abstract. Phytosanitary aspects of the mangroves the Urabá Antioqueño, Colombian Caribbean. A synthesis of the state of the knowledge of the presence of *Agrobacterium* sp. is presented. and *Neoteredo reynei* associated to different structures of the mangroves of the Uraba antioqueño in the coast Caribbean of Colombia.

Key words: mangroves, shipworms molluscs, bacterias, impacts, Caribbean, Colombia

Introducción

En el desarrollo de las actividades realizadas para la elaboración del Diagnóstico de los Manglares del Caribe Colombiano, objetivo de la primera fase del Proyecto PD 171/91 Rev 2 Fase I, se logró el reconocimiento de los manglares desde Cabo Tiburón en el Urabá chocoano hasta Castilletes en el Departamento de la Guajira, identificando tanto los aspectos técnicos generales de éste ecosistema, como las entidades y comunidades relacionadas.

Los manglares del Golfo de Urabá están siendo afectados por diversos problemas fitosanitarios, causando el deterioro del bosque y en consecuencia afectando a las comunidades que hacen uso de sus productos. El reconocimiento indicó que dentro de los problemas encontrados el de mayor incidencia es la presencia de un barrenador de raíces y tronco, que afecta el mangle rojo o canillón (*Rhizophora mangle*), no obstante, adicionales reconocimientos comprobaron el ataque en árboles del mangle blanco o bobo (*Laguncularia racemosa*).

Mediante las observaciones preliminares y la consulta de información sobre el tema, se logró determinar que el agente causante es un molusco teredínido *Neoteredo reynei* (Sánchez-Alférez & Álvarez-León, 2000), que afecta, en especial, a *R. mangle*, y en menor proporción a *L. racemosa*, ascendiendo por las raíces, hasta perforar el fuste logrando en algunos casos debilitar la estructura provocando el volcamiento.

La mayoría de investigaciones en el país, se centran en los daños que se presentan por ataque de moluscos, entre ellos el teredo, en árboles, muertos o apeados, del Pacífico y en menor porcentaje en el Caribe. La revisión se amplió al campo internacional, encontrándose registros de ataque de teredo en árboles vivos en los manglares de Brasil, la Florida y en la costa de Kerala (Arabia), información que sirvió de base para proponer el estudio realizado por el Proyecto Manglares de Colombia y la Corporación para el Desarrollo Sostenible de Urabá (CORPOURABA), con el objeto de conocer mas de cerca la problemática fitosanitaria de los manglares del Golfo y plantear alternativas para nuevas investigaciones.

Antecedentes. La presencia del barrenador fue detectada por el Proyecto Manglares de Colombia, en sus diferentes recorridos, en las bocas del río Atrato en el Urabá antioqueño, mas exactamente en las Bahías de El Roto, Tarena, Hierbazal, y Marirrio, al igual que en la Ensenada de Rionegro. Adicionalmente en otros Departamentos como en Sucre: Ciénaga de la Caimanera, Guacamayas y Bahía de Barbacoas, en Bolívar: Bahía de Cartagena. Finalmente y de acuerdo con los campesinos de la zona, se puede también encontrar en los manglares de la Bahía de Cispatá (Córdoba).

De acuerdo con Turner (1966), algunos organismos marinos pueden causar, al menos en una de las etapas de su ciclo de vida, deterioro (erosión, descomposición, transformación) de los sustratos donde habitan. Se conocen como biodeterioradores y pueden colonizar sustratos orgánicos o inorgánicos. Sandoval *et al.* (1995) indican que los principales sustratos orgánicos donde habitan los biodeterioradores son las maderas, principalmente troncos y raíces muertas de mangle u otras especies vegetales. Los moluscos bivalvos que actúan como biodeterioradores de madera son ampliamente conocidos como plagas de muelles, pilotes y otras estructuras civiles construidas en madera (Turner, 1984). Los primeros registros sobre teredos en Colombia datan de agosto de 1499, en los relatos que Américo Vespucio realizó sobre algunos sitios de la Guajira, "vale la pena recordar esos nombres que dicho navegante dio a los accidentes geográficos que encontró durante el recorrido por la costa, a saber: Cabo de la Esperanza (tal vez Punta Espada en la Guajira); almadraba, que es un lugar para la pesca de atunes; lago, lugar de aguas tranquilas que bien puede ser la Bahía de Portete o Bahía Honda; aguada, donde por causa de la broma o teredo, el terrible gusano destructor de la madera de las embarcaciones, las carabelas hicieron agua..." (Anónimo, 1996).

En general en Colombia, la mayoría de registros de teredos como biodeterioradores de madera han sido realizados en el Pacífico, teniendo en cuenta el daño económico que ha representado al sector maderero de la zona. Jaime R. Cantera, Biólogo docente de la Universidad del Valle ha sido uno de los pocos estudiosos de éstos bivalvos a nivel nacional, sin haber llegado a mencionar en sus publicaciones el ataque de teredo en las raíces superiores o fustes de árboles de mangle en pie, aspecto que ha llamado la atención de los conocedores del manglar y que ha sido la principal razón por la cual, la Corporación Autónoma Regional de Urabá CORPOURABA y el Proyecto Manglares de Colombia (MMA / OIMT), decidieran realizar el primer acercamiento al conocimiento sobre la incidencia del teredo como hospedero en raíces y troncos de los manglares en pie en el Urabá antioqueño.

El objetivo general del trabajo se centro en la realización de un muestreo en los manglares de Urabá, para obtener información sobre la incidencia del ataque del teredo y proponer con mayor conocimiento trabajos puntuales que aseguren el manejo fitosanitario de los manglares a nivel nacional. Para el cumplimiento de dicho objetivo, se plantearon los siguientes objetivos específicos: (1) Realizar una adecuada identificación del teredo que ataca individuos vivos de mangle en Urabá. (2) Determinar si las agallas observadas en los manglares de Urabá, están relacionadas con el ataque del teredo. (3) Determinar las zonas con mayor presencia de teredo en las bocas del río Atrato, plantear hipótesis sobre los posibles factores que inciden o favorecen su presencia. (4) Determinar la incidencia y severidad del ataque de teredo en las zonas muestreadas. (5) Recomendar acciones para el mayor conocimiento de los problemas fitosanitarios detectados y su posible control. (6) Dar las pautas generales para la continuidad de los estudios e investigaciones en favor de mejorar las condiciones sanitarias de los manglares, como contribución a las Corporaciones Autónomas Regionales (CAR's) para iniciar sus programas de manejo.

Materiales y Metodos

Se planteó la aplicación de una estrategia de intervención ágil que asegurara la optimización de los recursos tiempo y presupuesto, procurando obtener información mediante la cual se lograran los objetivos planteados.

Inicialmente se pretendió la adecuación de metodologías de muestreo diseñadas para estudios fitosanitarios en plantación, pero se descartaron, teniendo en cuenta que la toma de datos por observación y medición de parámetros estructurales no eran suficientes para lograr la información requerida, por lo tanto se planteó una metodología, que además de incluir la toma de información de estructura para el conocimiento del bosque, mediante el apeo de árboles precisara las variables severidad e intensidad del ataque.

La metodología planteada se aplicó en los manglares de las bocas del río Atrato y en la Ensenada de Rionegro. Inicialmente sobre cartografía reciente se definieron unas zonas preliminares de trabajo, las cuales se replantearon con la revisión física en campo, de acuerdo con la incidencia observable del ataque.

Diseño del muestreo. Con base en los trabajos realizados para manglares, incluyendo el diagnóstico efectuado por el Proyecto Manglares de Colombia, el muestreo se realizó mediante el levantamiento de líneas base, perpendiculares a la línea de costa en las cuales se ubicaron dos parcelas para toma de información con un área individual aproximada de 25 m^2 cada una y distanciadas entre si aproximadamente 80 m. La parcela número 1 se ubicó lo más cerca posible de la línea de costa.

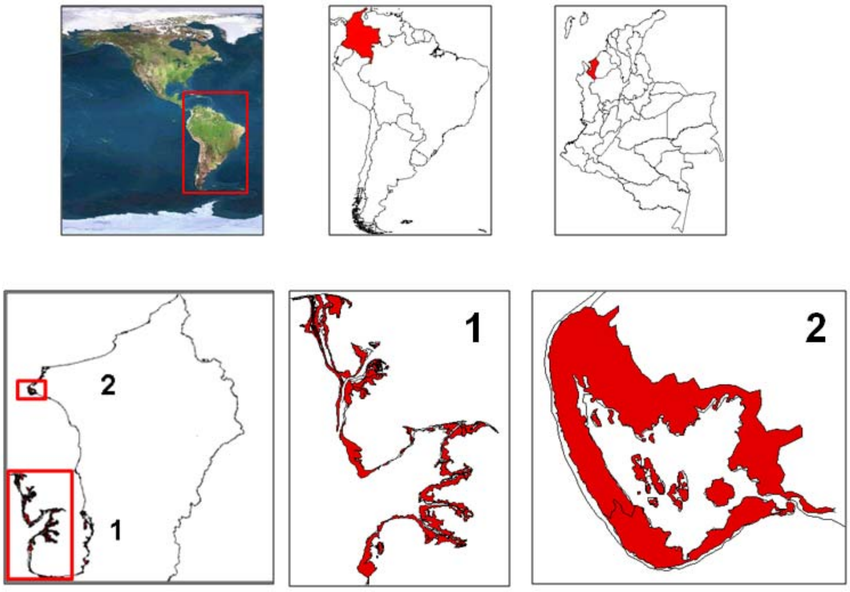

Figura 1. Ubicación de la zona de muestreo en el Golfo de Urabá (Colombia). (1) Bocas del Atrato, (2) Ensenada de Rionegro; con la localización de las parcelas establecidas.

En la línea base se levantó un perfil de vegetación, en cada parcela de muestreo se realizaron las correspondientes mediciones para evaluar los parámetros estructurales, en especial para el estado de latizal y fustal y se incluyó el muestreo de la regeneración natural, adaptando los conceptos de Falla (1970) en: fustales (diámetro superior a 15 cm), latizales (diámetro entre 5 y 15 cm) y brinzales establecidos (diámetro entre 2,5 y 5 cm). Para la regeneración natural se realizó el muestreo dentro de la misma parcela de 25 m^2 un área de 1m^2, seleccionada al azar.

En la parcela de 25 m^2, se midieron el total de fustales, latizales y brinzales establecidos. Además de los parámetros estructurales se realizaron las mediciones sobre el ataque del teredo.

Daño causado por *Neoteredo reynei*. Para el análisis de ésta información, se realizó el apeo de tres árboles, tomados al azar dentro de la parcela. En cada árbol, se contabilizó el número total de raíces incluyendo la base del tronco o raíz principal. El fuste del árbol apeado y con el ataque visible del barrenador, se cortó en secciones de un metro y en cada una de ellas se cuantificó el área afectada, mediante el conteo de galerías, así como el porcentaje del área afectada con base en el total del corte, de igual forma se evaluó el daño en las raíces.

En cada estructura (raíz o fuste) cortada se realizó la observación sobre la presencia o no del teredo, con base en la obtención de éste, ya fuera completo o por partes, esto teniendo en cuenta que los cortes fueron realizados con motosierra, la cual seccionaba el animal de encontrarse en la galería cortada.

Variables analizadas. (1) Número de árboles afectados en cualquiera de sus estructuras (raíces o fuste) con relación al cien por ciento de los individuos de la parcela. (2) Número de raíces atacadas por árbol y promedios por parcela y por línea, esto con base en el porcentaje del área afectada y en el número de galerías, con la misma salvedad en el caso de galerías múltiples. (3) Número de fustes atacados y altura de presencia de galerías, tomada a partir de la altura de la última raíz. (4) Área del daño, se evaluó con relación al cien por ciento del área total de la sección cortada, diferenciando entre raíces y fuste y se domina en los resultados como grado de afectación. (5) Número de galerías, en cada una de las estructuras cortadas, raíces y fuste, se contabilizó el número de galerías presentes. En algunos casos, el conteo no fue posible, debido al alto grado de deterioro a causa del ataque, para éste caso se incluyó en el cuadro de toma de información el resultado de número de galerías con la letra "M" de múltiples, para efecto del análisis, no se tuvo en cuenta la letra M realizando la correspondiente aclaración. (6) Presencia o no del teredo, ésta variable se consideró si se observaba el animal ya fuera entero o cortado.

Metodologia para analizar las agallas. En el campo dentro de un bosque localizado en Apartado (Ant.) se tomaron muestras de agallas de varios tamaños tratando de incluir lesiones jóvenes y adultas, las cuales fueron analizadas en el laboratorio de Sanidad Forestal de la Universidad Distrital "Francisco José de Caldas". En el laboratorio se hicieron observaciones macro y micrsocópicas buscando la presencia de signos del posible agente causal. Así mismo de hicieron siembras en medios semisólidos específicos para *Agrobacterium*.

Metodología para analizar el molusco. Se tomaron muestras de *N. reynei* y se enviaron a la Universidad de Sao Pablo en Brasil, en donde se realizó la correspondiente identificación además de algunos análisis adicionales sobre la estructura interna del molusco. Se tomaron seis *N. reynei* de diferentes tamaños, obtenidos con extrema dificultad, teniendo en cuenta que el molusco expande su cuerpo ocupando la galería y al menor corte o pinchazo vacía los líquidos contenidos en su estructura y por lo tanto reduciendo el diámetro con el inminente peligro de cortarlo al mínimo tirón, igualmente no fue posible obtener un animal halando alguno de sus extremos ya que presenta resistencia y a la menor presión se rompe.

Metodología para determinar la salinidad y la temperatura. Para determinar los niveles de salinidad y de temperatura del agua dentro y fuera de las parcelas, se utilizo un refractómetro de campo y un termómetro de cubeta, los cuales permitieron conocer las variaciones de estos parámetros durante el periodo de observación.

Resultados

Generales. Se logró la aplicación de la metodología en ocho líneas de muestreo completas incluyendo el levantamiento de información en las respectivas 16 parcelas. Adicionalmente se realizaron observaciones en algunos sitios de los cuales se obtuvo información sin aplicar la metodología, debido a las condiciones externas de sanidad de los árboles.

El cubrimiento del trabajo se extendió en las bocas del río Atrato, desde la Bahía de Marirrio al sur de las mismas bocas, hasta Boca Tarena, pasando por las Bahías de la Paila, la Burrera y Matuntugo, al igual que en la Ensenada de Rionegro. Las observaciones sin aplicación de la metodología se realizaron al sur de Turbo en los bosques de manglar de la boca del río Currulao, preservados por la influencia de grupos al margen de la ley.

De las ocho líneas establecidas, seis se ubicaron en las bocas del Río Atrato y dos en la Ensenada de Rionegro. En el Atrato se procuró una distribución uniforme hacia el norte y sur cubriendo una extensa zona distribuida en cuatro (4) líneas hacia el sur de Bocas del Atrato o Turbito así: la línea número 1 en el Brazo La Burrera, las líneas 2 y 3 en la Bahía de Marirrio y la línea 4 en la Bahía la Paila. Hacia el norte se establecieron la línea 7 en el Caño Matuntugo y la línea 8 en Boca Tarena. (Figura 2)

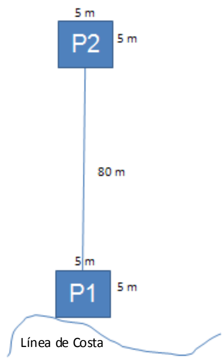

Figura 2. Diagrama de las parcelas establecidas y monitoreadas, en el bajo río Atrato (Caribe colombiano).

Las 16 parcelas cubrieron un área total de 400 m^2, distribuida uniformemente tanto a la orilla de manglar, sobre el cuerpo de agua, como a 80 metros hacia el interior del mismo. En total en el área de parcela se inventariaron 57 árboles en los tres estados de crecimiento dados: fustal, latizal y brinzal establecido. La altura promedio en las parcelas vario entre 6.1 m en la parcela 2 de la línea La Burrera y 20 m en las parcelas 2 de las líneas La Paila, Matuntugo y Rionegro II. Dichos promedios se ven disminuidos en las parcelas 2 debido a la mayor presencia de las categorías latizo y brinzal establecido.

De los 57 árboles totales el 96 % correspondió a *R. mangle* y 4% a *L. racemosa*. De estos 57 árboles se evaluaron mediante la aplicación de la metodología de apeo y corte de raíces un total de 37 árboles, correspondiendo al 65 % del total de la población encontrada en el área muestreo.

De los 37 árboles evaluados, 11 (29.7%) se encontraron afectados a nivel de los fustes, con un grado de afectación o daño en promedio del 18.2%, lo que correspondió a un promedio de 3.5 galerías por árbol. Se detecto un caso de galería múltiple en la parcela 1 de la línea 3 Marirrio (árbol 2).

El 54% (20 árboles) de los árboles evaluados, se encontraron afectados a nivel de raíz. De las 349 raíces cortadas, estaban infectadas 39 (11%). El grado de afectación en promedio es del 20%, en las raíces infectadas con un promedio de 2.7 galerías. Cabe destacar que en dos raíces se encontraron galerías múltiples (Marrirrio I y II parcela 1 árboles 3 y 2 respectivamente).<

Se detectó la presencia de siete *N. reynei* en seis árboles, lo cual equivale al 16,2 % del total de árboles evaluados (37), encontrando un teredo en las raíces y seis a nivel de fuste.

Resultados a nivel de líneas de muestreo. Comparando los resultados entre las ocho líneas de muestreo se encontró que las líneas que presentaron mayor cantidad de árboles afectados a nivel de raíces fueron: Marirrío 1 con seis y Marirrío 2 con cinco, lo que corresponde respectivamente al 30 y 25 % del total de los árboles afectados a nivel de raíces; el menor resultado se encontró en La Paila con cero árboles afectados.

Con relación al daño a nivel de raíces se encontró que las líneas con mayor cantidad de raíces afectadas fueron Marirrio II, con 15 y Marirrio I con 14 y la de menor fue la Paila con cero raíces afectadas, correspondiendo respectivamente al 38,5, al 35,9 y al 0 % del total de las raíces afectadas. El mayor grado promedio de afectación correspondiente al porcentaje de área afectada en la sección del corte, se presentó en las líneas Rionegro I y II con el 50% de afectación para cada una y el menor se obtuvo en la Línea 4 La Paila, con 0%. La línea con mayor promedio de galerías encontradas fue Marirrio 2 con 6,2 galerías, y la de menor promedio fue La Paila con cero galerías; cabe destacar que en las líneas Marirrio 1 y 2, se encontró una raíz en cada línea con galería múltiple.

La evaluación de daño a nivel de fuste, indicó que la mayor cantidad de fustes afectados se encontraron en las líneas Marirrio 1 y 2 con 4 fustes cada una, correspondiendo al 72,8 % del total y las menores fueron Rionegro I y II, y Boca Tarena con cero. La línea la Burrera presento el mayor grado promedio de afectación con un 30%. La mayor cantidad de galerías promedio se encontró en la línea Marirrio II con 5 galerías, destacando que un fuste de la línea Marirrio II presento galerías múltiples.

La mayor presencia de *N. reynei* ocurrió en la línea Marirrio 2 con cuatro ejemplares, lo cual equivale al 57% del total; seguida por la línea Marirrio 1 con dos ejemplares, lo que equivale al 28,6% del total y por último la línea la Burrera con un ejemplar, lo cual corresponde al 14,4 % de la presencia total de teredos.

Relación entre las parcelas y la distancia de la costa. La mayor cantidad de árboles se evaluaron en la Parcela 1, con un total de 22 árboles o 59,4%, el restante 46 % (15 árboles) se ubicó en la Parcela 2.

La mayor cantidad de raíces afectadas se encontró en las parcelas ubicadas a 80 m de la costa, con un porcentaje del 51.3 % en relación con el total de raíces afectadas. El mayor grado promedio de afectación, ocurrió en las Parcelas 1, al igual que el mayor número promedio de galerías con un 41,1% y 3 galerías respectivamente; cabe anotar que dos raíces presentaron galerías múltiples.

El análisis de los fustes indicó que las parcelas ubicadas a cero metros de la costa presentaron la mayor número promedio de fustes afectados, con un total de 7 o 63,7% del total. El mayor grado de afectación promedio se encontró en las parcelas ubicadas a cero metros de la costa con 24,6%, al igual que el mayor promedio de galerías con 4,8; destacándose que un fuste presento galería múltiple.

Se encontraron cuatro *N. reynei* en las parcelas ubicadas a 0 m y 3 ejemplares en las parcelas ubicadas a 80 m de la costa.

Los análisis micro y macroscópico de las agallas no mostraron signos de hongos, bacterias o nemátodos. En los cultivos en medios semisólidos no se pudo aislar *Agrobacterium* sp.

Salinidad y temperatura. En la Tabla I, se relacionan los parámetros obtenidos dentro del área de la parcela de muestreo.

Discusión

De acuerdo con los objetivos planteados se resalta el hecho de haber logrado la primera clasificación del agente causal de los daños a los manglares del Urabá Antioqueño, reportes que hasta la fecha no había sido realizado y el cual nos acerca al conocimiento del comportamiento anormal del molusco ascendiendo en los árboles a niveles poco comunes para su especie. Aspecto interesante y el cual es objeto de mayores estudios que analicen los diversos factores que han propiciado el actual comportamiento.

El resultado de los análisis numéricos ha indicado que la zona más afectada es la Bahía de Marirrio y en especial los árboles que se localizan sobre la línea de costa o playa. Así mismo las zonas de menor observación y presencia del *N. reynei* se localizan al extremo norte o Boca Tarena. Un aspecto que llamó la atención fue no haber detectado en el estudio la presencia del ataque en la ensenada de Rionegro, sitio en el cual las observaciones preliminares indicaron un alto índice de ataque, corroboradas por los pescadores, moradores permanentes del sector. Este resultado se atribuye tanto a la aleatoriedad del muestreo como a la premura del tiempo que impidió localizar con mayor exactitud todas las áreas afectadas.

Tabla I. Salinidad y temperatura en las aguas adyacentes a las parcelas. P = Parcelas 1 y 2

Línea No.	**Zona**	**Salinidad (ups)**		**Temperatura (°C)**		**Hora (H-M)**	
		P1	**P2**	**P1**	**P2**	**P1**	**P2**
T1	La Burrera	5	3	28	23	10:10	11:45
T2	Marirrio I	14	5	24	23	12:18	13:35
T3	Marirrio II	5	5	25	23	12:15	14:00
T4	Bahía Paila	5	0	26	26	13:40	14:00
T5	Rionegro I	15	15	28	20	11:30	12:25
T6	Rionegro II	14	12	26	26	13:45	14:35
T7	Matuntugo	3	2	27	27	13:40	14:10
T8	Boca Tarena	3	3	27	27	10:50	11:30

De acuerdo con información adicional compilada en el desarrollo del trabajo, las variables salinidad y temperatura, al parecer tienen poca incidencia con la presencia del ataque de teredo y menos con el hecho de que el animal logre ascender en los fustes llegando a alturas poco comunes en la especie. Las variables que al parecer tiene algún grado de incidencia podrían estar relacionadas con la descarga sedimentaria que se vierte al Golfo, al igual que los factores que inciden en la adhesión y cantidad de larvas del molusco. Además, *N. reynei* se adapta muy bien a vivir en las áreas de manglar poco influenciadas por las aguas marinas. La ocurrencia de *N. reynei* principalmente en las áreas internas de bosque del mangle y viviendo incluso en áreas degradadas de manglar han sido registrado por Lopes & Narchi (1993, 1997) en el mangle de Praia Dura (São Paulo) Brasil y por Rancurel (1971) en los mangles del río de Bandama (África). Los caracteres anatómicos de *N. reynei* descritos por Turner (1966), Rancurel (1971) y Lopes *et al.* (2000) sugieren que esta especie usa la madera como fuente principal de su alimentación, mientras sólo depende del plancton disponible, durante las pleamares.

En líneas generales la incidencia del ataque a nivel de raíz es alta en relación al total de la muestra, teniendo en cuenta que de 37 árboles evaluados el 57 % se encontró afectado y en especial llama la atención que los cortes fueron en su totalidad aéreos, arriba de 30 cm sobre el nivel medio del suelo, indicando que el molusco, aunque normal su presencia en las raíces de *R. mangle*, si asciende anormalmente en la zona objeto de la evaluación.

La incidencia a nivel de fuste se considera numéricamente baja, con un promedio de 29.7% con relación al total de fustes evaluados, aunque este porcentaje ecológica y económicamente puede considerarse alto, si se tiene en cuenta adicionalmente la calidad de los árboles afectados y los costos económicos de presentarse este ataque en bosques objeto de aprovechamiento.

En cuanto a la severidad al nivel de raíces, el análisis numérico indica que de un total promedio de 9.5 raíces por árbol, 1,95 fueron atacadas, este resultado es bajo teniendo en cuenta que en cada una de éstas raíces el área promedio afectada fue del 20 %, lo que puede indicar un bajo porcentaje de inestabilidad del árbol si se consideran las fuerzas físicas que lo mantienen en pie. Aspecto por analizar mas detenidamente ya que estos resultados son generales, al particularizar se podría observar que el porcentaje de raíces afectadas se dio con mayor incidencia en los árboles ubicados en las parcelas número 1 o sea, a cero metros de la costa, sitios en los cuales se presenta por observación el mayor porcentaje de árboles caídos por efecto de la pérdida de estabilidad.

La severidad de ataque al nivel de árbol es de 55% si se tiene en cuenta que de los 20 árboles afectados en las raíces en 11 ascendió el ataque al fuste. Lo que indica un alto grado de daño por árbol. Esto quiere decir que el árbol que logra ser objeto de ataque por teredo tiene una alta probabilidad de sufrir daños en sus estructuras.

Un análisis detallado de otros parámetros tales como la salinidad y temperatura de los sitios de muestreo, indica una leve variación, poco representativa para el análisis en cuestión, aspecto que debe analizarse con mayor profundidad con base en los resultados hasta ahora obtenidos y con muestreos secuenciales en el tiempo para lograr determinar variación, ya que se considera que un dato puntual no es representativo.

Estudio sobre agallas. En la realización del diagnóstico de los manglares en las bocas del Atrato, las observaciones generales indicaron inicialmente la presencia en los árboles de unas formaciones a modo de agallas en todas sus estructuras (fuste, ramas, raíces). Dichas formaciones se presentan como un afloramiento de la madera como si explotara y quisiera salir de la corteza, su consistencia es fuerte y no presenta ningún tipo de secreción. Desde el golfo las formaciones de mayor tamaño se asemejan a los nidos del comején y por tal razón se ha dicho que los manglares de Urabá, están siendo afectados por éstos insectos. Al detectar la presencia y ataque de los teredos, se consideró que dichas estructuras o afloramientos de la madera pueden ser también una respuesta visible a la presencia de teredo en las raíces del árbol, hipótesis que se pretendió comprobar con la realización de un muestreo paralelo al trabajo del teredo.

Las observaciones macroscópicas en campo y laboratorio confirman la ocurrencia de agallas o tumores de los cuales no fue posible evidenciar estructuras de organismos patógenos. La sintomatología observada y la ausencia de signos de bacterias, hongos o nemátodos, indica que se trata de lesionas ocasionadas por *Agrobacterium tumefasciens*, patógeno comúnmente registrado en especies forestales y que causa esta sintomatología. La biología de este patógeno hace difícil su aislamiento a partir de lesiones desarrolladas, ya que se conoce que penetra principalmente por heridas e induce la formación del tumor alterando la información genética a nivel del núcleo de la célula sin que se requiera su presencia para la posterior proliferación del tejido. Otra forma de tratar de aislar *Agrobacterium* seria a partir de muestras de suelo circundante a los árboles afectados; en este caso sería a partir de muestras de suelo o acumulaciones superficiales de materia orgánica pero estos análisis no se realizaron.

La bacteria penetra por heridas, principalmente, aunque algunas pueden hacerlo por aberturas naturales. *Agrobacterium* sp. es muy específico de heridas, así mismo es una bacteria aerobia, por lo que se presume que el sitio de entrada debe corresponder inicialmente a zonas expuestas al aire, descartando el hecho de que el daño por teredos incida en favorecer la entrada de la bacteria, considerando que la larva del molusco normalmente penetra por la base de la raíz. La bacteria es aerobia, pero existe la inquietud de si el ataque ha podido iniciarse por las raíces cuando estas están expuestas debido a cambios en la altura de la marea Una vez éste es inducido, la bacteria no necesita estar allí para que siga produciendo el sobre-crecimiento. Esta es la razón por la cual solamente es posible aislarla de lesiones muy jóvenes.

Viendo las agallas desde éste punto de vista, se puede concluir que no necesariamente existe relación entre el ataque del *N. reynei* y el *Agrobacterium* sp.

Conclusiones

En líneas generales se recomienda que los próximos estudios sobre el tema, se relacionen con la profundización del conocimiento sobre el *N. reynei*, y en especial con lo relacionado con el tipo de larva, los factores que inciden en su arraigo y las cantidades de las mismas en las aguas del Golfo, al igual que los predadores y condiciones que han generado cambios en su comportamiento.

Así los resultados del presente estudio indiquen la sectorización del ataque en zonas con mayor vulnerabilidad, se recomienda profundizar el conocimiento del ataque con el animo de garantizar que el *N. reynei* no se especialice colonizando mayor cantidad de hospederos y por ende amplíe su radio de acción.

El posible control del ataque debe estar relacionado con los resultados obtenidos sobre el conocimiento de la larva y su comportamiento.

Es importante aclarar que adicionalmente a cualquier resultado de manejo y control de agentes destructores como el molusco bivalvo en cuestión, debe proyectarse el área del conocimiento de manglares hacia el ordenamiento y manejo silvicultural de los mismos garantizando de éste modo bosques de calidad genética, sanidad fitosanitaria y económicamente rentables.

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Referencias

Anónimo. 1996. **Revista Credencial Historia**. Edic. 82: 3-5.

Falla-Ramírez, A. 1970. Definición de términos silviculturales. Proy. INDERENA / PNUD-FE / FAO / COL 14. **Boletim Técnico**, 3 (1): 1-20.

Lopes, S. G. B. C. & Narchi, W. 1993. Levantamento e distribuição das espécies de Teredinidae (Mollusca, Bivalvia) no manguezal da Praia Dura, Ubatuba, São Paulo, Brasil. **Boletim do Instituto Oceanográfico**, 41: 29-38.

Lopes, S. G. B. C. & Narchi, W. 1997. Recrutamento larval e crescimento de Teredinidae (Mollusca - Bivalvia) em região entremarés de manguezais. **Revista Brasileira de Oceanografia**, 45: 77-88.

Lopes, S. G. B. C., Domaneschi, O., de Moraes, D. T., Morita, M. & Meserani, G. L. C. 2000. Functional anatomy of the digestive system of *Neoteredo reynei* (Bartsch, 1920) and *Psiloteredo healdi* (Bartsch, 1931) (Bivalvia: Teredinidae), pp. 257-271 In: Harper, E. M., J. D. Taylor & J. A. Crame (eds.) **The Evolutionary Biology of the Bivalvia.** The Geological Society of London. London (U. K.).

Rancurel, P. 1971. Les Teredinidae (Mollusques Lamellibranches) dans les lagunes de Côte d' Ivoire. **Memóries of Recherche Science Techenologie Outre-Mer**, 47: 1-235.

Sánchez-Alférez, A. S. & Alvarez-León, R. 2000. First report of *Neoteredo reynei* (Bivalvia: Teredinidae) in the mangrove swamps of the Colombian Caribbean. **UCR-Revista de Biologia Tropical**, 48 (2/3): 720.

Sandoval, F., Cantera-Kintz, J. R. & Bolívar, G. A. 1995. Bivalvos biodeterioradores de la madera en la Bahía de Buenaventura, Pacífico Colombiano. Tomo I pp. 214-244 In: Cantera-Kintz, J. R. & J. D. Restrepo-Angel (eds.) **Delta Río San Juan, Bahías de Málaga y Buenaventura, Pacífico colombiano**. Univ. EAFIT / Univ. del Valle / COLCIENCIAS. Medellín (Ant.) Colombia, 337 p.

Turner, R. D. 1966. **A survey and illustrated catalogue of the Teredinidae (Mollusca, Bivalvia)**. The Museum of Comparative Zoology, Harvard University. Cambridge (Mas.) USA, 262 p.

Turner, R. D. 1984. An overview of research on marine borers: past progress and future direction, pp. 1-16 In: **Marine biodeterioration, an interdisciplinary study**. Annapolis (Maryland) USA.

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Variação sazonal e mudanças ontogênicas na dieta de *Menticirrhus americanus* (Linnaeus, 1758) (Teleostei, Sciaenidae) na baía de Ubatuba-Enseada, Santa Catarina, Brasil

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Abstract. Seasonal variation and ontogenetic shifts in the diet of Menticirrhus americanus (Linnaeus, 1758) (Teleostei, Sciaenidae) in Ubatuba-Enseada Bay, Santa Catarina, Brazil. Ontogenetic and seasonal changes in the diet of the southern kingfish Menticirrhus americanus sampled at Ubatuba-Enseada, Santa Catarina northern coast, were investigated. Trawl nets were used for the monthly surveys during October (2003) and September (2004). Stomachs of 137 individuals between 4.2 and 31.8 cm were analyzed. The species showed a carnivorous and benthic food habit, composed mainly by crustaceans, fishes and polychaetes. According to the similarity analyses, the use of food resources was influenced by seasonal and ontogenetic variations. Juveniles and adults share the same resources, but in different ways. Crustaceans showed higher representativeness in all the size-classes. Polychaetes were the most important items ingested by small individuals (up to 12.1 cm), decreasing this importance with *M. americanus* sexual maturity, when fishes were more important in the diet. Crustaceans were the most important items in spring and winter, substituted by fishes in summer. Hypothesis concerning diet shift and prey availability were discussed.

Key words: coastal region, feeding, food habits, food items

Resumo. Foram investigadas as variações ontogênica e sazonal na dieta da betara *Menticirrhus americanus* coletadas na baía de Ubatuba-Enseada, no litoral norte de Santa Catarina. Redes de arrasto com porta foram utilizadas para as coletas mensais, entre outubro de 2003 e setembro de 2004. Foram analisados 137 estômagos provenientes de indivíduos entre 4,2 e 31,8cm. O hábito alimentar da espécie é carnívoro e bentófago, composto principalmente por crustáceos, peixes e poliquetas. As análises de similaridade revelaram que o uso de recursos foi influenciado pelas variações sazonais e ontogênicas. Juvenis e adultos compartilharam os mesmos recursos, porém de formas diferentes. Em todas as classes de tamanho os crustáceos apresentaram alta representatividade. Poliquetas foram os itens mais importantes para os indivíduos pequenos (até 12,1cm), diminuindo sua importância com a chegada da maturidade sexual da betara, quando os peixes passam a adquirir elevada importância na dieta. Entre as estações do ano, os crustáceos foram importantes como itens alimentares na primavera e inverno, substituídos por peixes no verão. Hipóteses relativas a mudanças na dieta e a disponibilidade de presas são discutidas.

Palavras chaves: alimentação, hábitos alimentares, região costeira, itens alimentares

Introdução

Menticirrhus americanus (Linnaeus, 1758) distribui-se desde Cape Cod (Estados Unidos) até Buenos Aires (Argentina) (Menezes & Figueiredo

1980), e é conhecida popularmente como betara ou papa-terra, sendo encontrada sobre fundos arenosos e areno-lodosos em águas costeiras de pouca profundidade e em regiões estuarinas (Rondineli et al. 2007). Na ictiofauna registrada na baía de Ubatuba-Enseada em Santa Catarina, esta espécie apresenta grande freqüência nos arrastos de fundo, ocorrendo de forma abundante com outros representantes das famílias Sciaenidae, Paralichthyidae e Tetraodontidae (Freitas et al. 2005, Freitas et al. 2007).

Os sciaenídeos são comumente citados como os principais componentes do *bay-catch* nas pescarias de arrasto direcionadas para o camarão sete-barbas, sendo que a abundância de *M. americanus* sugere que a mesma desempenha papel importante na dinâmica deste sistema (Coelho et al. 1986, Andrigueto-Filho 2002, Chaves et al. 2003). Apesar disto, e do fato que a partir dos estudos sobre a alimentação podem ser obtidas importantes informações para a administração dos recursos pesqueiros (Zavala-Camin 1996, Hahn et al. 1997), poucos estudos que abordam diretamente a dieta da espécie foram realizados. Os principais trabalhos se restringem ao sudeste e sul do Brasil (Lunardon-Branco et al. 1991, Rodrigues 2003, Rondineli et al. 2007).

A ausência de estudos que abordem a composição detalhada e utilização dos recursos alimentares por *M. americanus* no litoral de Santa Catarina vem de encontro à necessidade de se obter informações biológicas básicas que subsidiem propostas de manejo mais abrangentes para a espécie, tendo em vista seu valor comercial para a pesca artesanal. Em função disso, este trabalho foi realizado com o objetivo de fornecer informações sobre a variação ontogênica e sazonal na alimentação da espécie, contribuindo assim para um melhor entendimento sobre a interação da fauna de peixes com o ambiente costeiro.

Material e Métodos

Foram realizadas amostragens mensais entre outubro de 2003 e setembro de 2004 na baía de Ubatuba-Enseada (26º11' S e 48º29'O), litoral norte do estado de Santa Catarina, Brasil (Figura 1). Os exemplares foram coletados mensalmente por meio de nove arrastos consecutivos, com duração de cinco minutos cada, realizados por embarcação artesanal denominada de "arrasteiro". A embarcação possui oito metros de comprimento, e é equipada com redes de arrasto com portas, contendo sete metros de comprimento, três metros de altura e com malha de três centímetros entre nós consecutivos na região do ensacador.

Após a coleta, os indivíduos foram fixados em formol 10% e, posteriormente, conservados em álcool 70%. Em laboratório, os mesmos foram medidos (comprimento padrão), pesados e dissecados para a retirada do estômago. No laboratório de Ictiologia do Museu de História Natural Capão da Imbuia, os conteúdos estomacais foram analisados sob microscópio estereoscópico e realizada a identificação dos itens alimentares com auxílio de bibliografia específica e consulta a especialistas (Melo 1996, Amaral et al. 2005). Para auxiliar nas análises e discussões, os itens macroscópicos identificados na dieta natural da espécie foram posteriormente agrupados em categorias taxonômicas mais amplas (Decapoda, Dendrobranchiata, Caridea, Anomura, Brachyura, Stomatopoda, Amphipoda, Isopoda, Polychaeta, Sipuncula, Osteichthyes e restos de Crustacea).

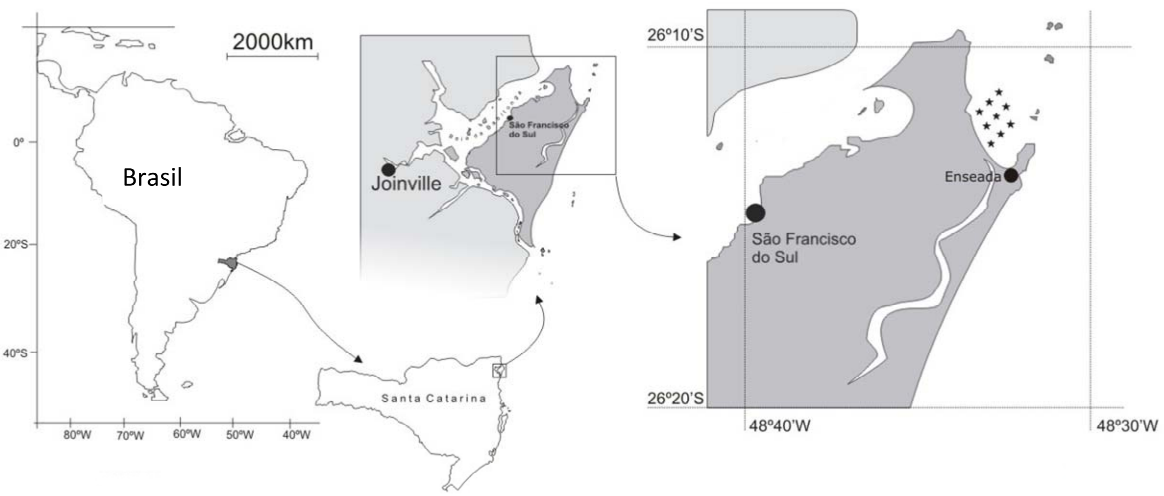

Figura 1. Localização da área de estudo na baía de Ubatuba-Enseada, São Francisco do Sul, SC, Brasil. Os asteriscos representam os locais dos arrastos.

Para as análises da dieta foram utilizados dois métodos: o método da Freqüência de Ocorrência (FO), que corresponde à freqüência percentual do número de estômagos em que ocorre determinado item alimentar em relação ao número de estômagos com alimento (Zavala-Camin 1996) e o método Volumétrico, pelo qual o volume é expresso em forma percentual, considerando o volume de dado item alimentar em relação ao volume de todos os itens alimentares presentes nos estômagos, permitindo informações sobre a participação de cada item na alimentação (Hyslop 1980, Zavala-Camin 1996). A integração dos dois métodos escolhidos para a análise da alimentação foi realizada através do Índice Alimentar (IAi) de Kawakami & Vazzoler (1980). Neste estudo, assumiu-se que não ocorrem diferenças significativas entre a alimentação de machos e fêmeas, fato esse já verificado para a espécie (Castillo 1986).

Para a análise das variações ontogênicas foram determinadas classes de comprimento pelas diretrizes de *Sturges* (Vieira 1980), a partir da qual foram estabelecidas sete classes de comprimento com intervalos de 3,9 cm, sendo eles 4,2─8,1(classe 1), 8,2─12,1(classe 2), 12,2─16,1(classe 3), 16,2─20,1(classe 4), 20,2─24,1(classe 5), 24,2─28,1(classe 6), 28,2─32,1(classe 7).

Para o estudo das variações sazonais e ontogênicas da dieta da espécie foram efetuadas análises de escalonamento multidimensional não métrico (MDS) com sobreposição de cluster de ligação completa. Para estas análises foram utilizados os Índices Alimentares dos itens registrados, sem qualquer transformação dos dados de freqüência. As estações do ano foram definidas da seguinte forma: primavera, de setembro a novembro; verão, de dezembro a fevereiro; outono, de março a maio e inverno, de junho a agosto. As matrizes de similaridade entre as amostras (sazonais e ontogênicas) foram geradas por meio do coeficiente de *Bray-Curtis*. As análises foram realizadas através do pacote Primer-E Ltd (Clarke & Warnick 2001).

Resultados

Dentre os 137 tratos digestórios analisados foram identificados 35 itens na dieta da espécie, os quais foram agrupados em 13 categorias taxonômicas, listadas na Tabela I.

Os itens alimentares com maior freqüência de ocorrência nos estômagos foram os restos de Crustacea (48,9%), Polychaeta (46%) e Osteichthyes (29,9%) e os menos freqüentes foram Isopoda (2,9%), Anomura (2,2%) e Sipuncula (0,7%), este último ocorrendo em apenas um estômago. As categorias mais representativas na dieta, por ordem de importância alimentar, foram: Crustacea (que incluiu Decapoda não identificados, Dendrobranchiata, Caridea, Anomura, Brachyura, Stomatopoda, Amphipoda, Isopoda e restos de Crustacea) com 51,8%, Osteichthyes com 27,8% e Polychaeta com 14,1%. Este mesmo índice mostrou a pouca importância dos Isopoda (0,01%) e Sipuncula (0,05%) (Tabela II).

Os poliquetas constituíram a categoria alimentar mais importante para indivíduos entre 4,2 e 8,1 cm (41,6%) e entre 8,2 e 12,1 cm (36,7%). Entre 12,2 e 16,1 cm, Dendrobranchiata foi a categoria com maior representatividade nos estômagos (28,7%), seguido por Polychaeta (22,8%) que também ocorreu em alta freqüência nos estômagos (57,1%). Entre 16,2 e 20,1 cm, os restos de Crustacea representaram a categoria mais importante (28,2%) e freqüente (64,7%). Também teve alta freqüência de ocorrência Polychaeta (47,1%) e os peixes (35,3%), porém com menores IAi, 25,5% e 25,3% respectivamente. Na classe 20,2 e 24,1 cm, a importância dos crustáceos na dieta foi dada principalmente por Dendrobranchiata (32,7%), muito embora Polychaeta e Osteichthyes tenham sido categorias freqüentes (52% e 40%, respectivamente). Na classe 28,2 e 32,1 cm, as categorias mais freqüentes foram os restos de Crustacea (75%), Decapoda e peixes (50%), este último com a maior representatividade (62,6%) entre as categorias alimentares analisadas (Tabela III).

Nas análises de agrupamento, as maiores similaridades foram encontradas entre as classes de comprimento 1-2, 3-4 e 5-6 em função dos valores dos Índices Alimentares (IAi) observados. A similaridade entre as classes 1, 2, 3 e 4 ocorreu em função da representatividade de restos de Crustacea (com maior representatividade nas classes 3-4) e Polychaeta (com maior importância nas classes 1-2). Nas classes 5 e 6, a similaridade verificada ocorreu principalmente em função dos itens Decapoda e Dendrobranchiata. Entre as classes de tamanho consideradas, a menor similaridade foi observada para a classe 7, o que ocorreu em função da representatividade de Osteichthyes na dieta (Figura 2).

O agrupamento das classes 1-2 com 3-4 se deve à participação dos poliquetas (com maior importância nas classes 1-2 e com certa representatividade nas classes 3-4) e crustáceos (com maior representatividade nas classes 3-4 e importantes também nas classes 1-2).

Tabela I. Lista dos itens alimentares identificados e agrupamentos taxonômicos (em negrito), obtidos a partir dos conteúdos estomacais de *M. americanus* analisados.

Filo Arthropoda
Subfilo Crustacea
Ordem Decapoda (Dec)
Subordem Dendrobranchiata (Den)
Superfamília Penaeoidea
Família Penaeidae - *Xiphopenaeus kroyeri*
Família Ogyrididae - *Ogyrides alphaerostris*
Subordem Pleocyemata
Infraordem Caridea (Car)
Infraordem Anomura (Ano)
Superfamília Talassinoidea
Superfamília Hippoidea
Família Albuneidae - *Albunea* sp.
Lepidopa sp.
Infraordem Brachyura (Bra)
Família Xanthidae - *Pimlumnus* sp.
Família Portunidae - *Callinectes* sp.
Ordem Stomatopoda (Sto)
Família Squillidae - *Squilla neglecta*
Ordem Amphipoda (Amp)
Família Gammaridae
Família Caprellidae
Restos Amphipoda
Ordem Isopoda (Iso)
Restos Crustacea (RCr)
Filo Annelida – Polychaeta (Pol)
Família Eunicidae
Família Lumbrimeridae
Família Sigalionidae
Família Glyceridae
Restos Polychaeta
Filo Sipuncula (Sip)
Filo Chordata – **Osteichthyes (Ost)**
Família Engraulidae
Ordem Pleuronectiformes
Família Paralichthydae
Ordem Anguiliformes
Família Ophictidae - *Ophichthus gomesii*
Restos Osteichthyes
Material não identificado (NI)

Tabela II. Freqüência de Ocorrência (%FO), Percentagem Volumétrica (%V) e Índice Alimentar (IAi) das categorias alimentares presentes na dieta de *M. americanus*.

Categorias	%FO	%V	IAi
Restos Crustacea	48,9	8,6	15,6
Decapoda não identificados	23,4	14,1	12,2
Dendrobranchiata	21,2	22,8	17,8
Caridea	8,8	1,5	0,5
Anomura	2,2	3,8	0,3
Brachyura	21,2	5,6	4,4
Stomatopoda	7,3	1,6	0,4
Amphipoda	19,0	0,8	0,6
Isopoda	2,9	0,1	0,01
Polychaeta	46,0	8,3	14,1
Sipuncula	0,7	2,0	0,05
Osteichthyes	29,9	25,1	27,8
NI	29,2	5,7	6,2

Tabela III. Freqüência de ocorrência (%FO) e Índices Alimentares (IAi) das categorias alimentares identificadas entre as classes de comprimento padrão (cm) de *M. americanus*. Em negrito estão destacadas as categorias com maior Freqüência de Ocorrência e sublinhadas aquelas de maior importância alimentar. n = número de indivíduos.

	Classes de comprimento padrão (cm)													
	1 n=24		**2** n=32		**3** n=28		**4** n=17		**5** n=25		**6** n=7		**7** n=4	
	FO	**IAi**	**FO**	**IAi**	**FO**	**IAi**	**FO**	**IAi**	**FO**	**IAi**	**FO**	**IAi**	**FO**	**IAi**
RCr	**50**	<u>25</u>	**31,3**	<u>14,8</u>	**53,6**	<u>20,5</u>	**64,7**	<u>28,2</u>	**48**	6,9	**57,1**	11,9	**75**	4,3
Dec	8,3	0,8	12,5	1,4	**25**	6,2	23,5	10,1	**40**	<u>15,5</u>	**42,9**	<u>21,8</u>	**50**	<u>22</u>
Den	0	0	9,4	6,9	**35,7**	<u>28,7</u>	11,8	5	**36**	<u>32,7</u>	**42,9**	<u>40,4</u>	0	0
Car	4,2	0,4	9,4	1,5	14,3	0,8	5,9	0,3	4	0,03	**28,6**	3,2	0	0
Ano	0	0	0	0	0	0	0	0	12	3,9	0	0	0	0
Bra	16,7	3,8	15,6	1,4	14,3	1,0	**23,5**	1,6	**36**	9,0	**28,6**	10,1	**25**	0,5
Sto	0	0	15,6	1,7	3,6	0,01	5,9	0,4	8	0,7	0	0	**25**	0,3
Amp	**25**	7,9	**28,1**	3,9	17,9	0,6	11,8	0,2	20	0,2	0	0	0	0
Isso	0	0	9,4	0,3	3,6	0,01	5,9	0,07	0	0	0	0	0	0
Pol	**41,7**	<u>41,6</u>	**50,0**	<u>36,7</u>	**57,1**	<u>22,8</u>	**47,1**	<u>25,5</u>	**52**	8,9	14,3	0,08	0	0
Sip	0	0	0	0	0	0	0	0	0	0	14,3	6,4	0	0
Ost	16,7	15,9	**28,1**	<u>18,5</u>	**28,6**	17,5	**35,3**	<u>25,3</u>	**40**	<u>18,0</u>	**28,6**	2,1	**50**	<u>62,6</u>
NI	20,8	4,7	34,4	13	25,0	1,9	23,5	3,4	36	4,0	28,6	4	50	10,4

Classe 1 (de 4,2–8,1 cm); Classe 2 (8,2 – 12,1 cm); Classe 3 (12,2 -16,1 cm); Classe 4 (16,2 – 20,1 cm); Classe 5 (20,2- 24,1 cm); Classe 6 (24,2 – 28,1 cm) e Classe 7 (28,2 - 32,1 cm).

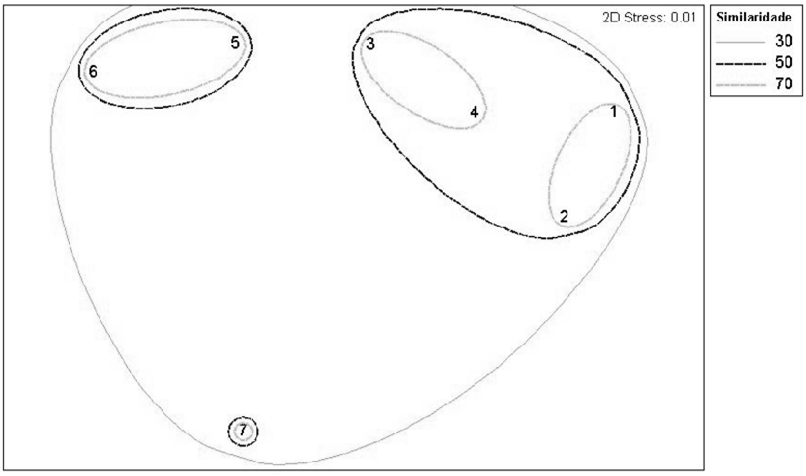

Figura 2. Representação gráfica bidimensional das classes de tamanho, com base no Índice Alimentar (IAi) de *M. americanus,* obtida por meio da análise de escalonamento multidimensional não-métrico (MDS) com sobreposição de cluster de ligação completa. Os traços representam os diferentes graus de similaridade obtidos através da análise de cluster. Classes de tamanho: 1 (de 4,2–8,1 cm); Classe 2 (8,2 – 12,1 cm); Classe 3 (12,2 -16,1 cm); Classe 4 (16,2 – 20,1 cm); Classe 5 (20,2- 24,1 cm); Classe 6 (24,2 – 28,1 cm) e Classe 7 (28,2 - 32,1 cm).

Variações sazonais entre as importâncias dos itens alimentares foram observadas. O item Crustacea Decapoda representou 32% da alimentação na primavera, seguido pelo item Dendrobranquiata (22,7%). No verão o item mais representativo foi Osteichthyes (peixes), seguido do item Restos de Crustacea. No outono foi verificada uma lata predominância de Polychaeta (48%) e Restos de Crustácea (27%), enquanto que no inverno Dendrobranquiata (31,6%) foi o item mais representativo, seguido por Polychaeta (19,2%) (Tabela IV). Na análise de agrupamento sazonal, uma maior similaridade entre os Índices Alimentares (IAi) foi observada entre a primavera e o inverno, em função do item Dendrobranquiata (22,7% e 31,6%, respectivamente) (Fig. 3).

Tabela IV. Índice Alimentar (IAi) sazonal das categorias alimentares de *M. americanus*. PRI=primavera, VER=verão, OUT=outono, INV=inverno. (n=número de indivíduos).

Categorias Alimentares	**PRI**	**VER**	**OUT**	**INV**
	n=30	n=36	n=30	n=41
Restos Crustacea	10,2	16,3	27,0	10,8
Decapoda não identificados	31,7	4,7	0,6	11,8
Dendrobranchiata	22,7	4,6	1,8	31,6
Caridea	1,7	<0,1	-	0,8
Anomura	-	-	-	3,3
Brachyura	7,7	6,5	1,1	1,1
Stomatopoda	-	0,5	0,2	1,3
Amphipoda	1,0	0,2	0,1	0,8
Isopoda	<0,1	-	-	<0,1
Polychaeta	5,4	4,5	48,0	19,2
Sipuncula	0,6	-	-	-
Osteichthyes (peixes)	8,4	54,7	16,1	18,6
NI	10,5	8,1	5,2	0,5

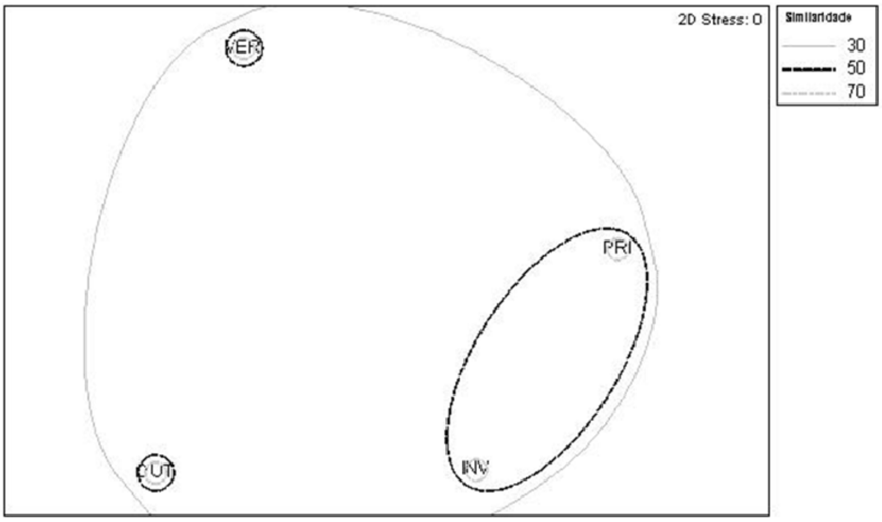

Figura 3. Representação gráfica bidimensional de distribuição das amostras sazonais dos Índices Alimentares (IAi) de *M. americanus*, obtidas por meio da análise de escalonamento multidimensional não-métrico (MDS) com sobreposição de cluster de ligação completa. Os traços representam os diferentes graus de similaridade obtidos através da análise de cluster. PRI=primavera, VER=verão, OUT=outono e INV=inverno.

Discussão

Menticirrhus americanus apresentou hábito alimentar predominantemente carnívoro e bentófago, apesar da presença de organismos bentopelágicos (Dendrobranchiata) e pelágicos (Engraulidae). A dieta foi representada principalmente por crustáceos, peixes e poliquetas, organismos pertencentes tanto à epifauna como à infauna. A preferência pelos itens registrados já foi constatada por muitos autores para diversos representantes da família Sciaenidae (Amaral & Migotto 1980, Haimovici et al. 1989, Chaves & Vendel 1998, Vendel & Chaves 1998, Camargo & Isaac 2004), sendo que a espécie *M. americanus* é conhecida por ter hábitos demersais (Smith & Wenner 1985, Rondineli et al. 2007). A boca inferior, típica para a ingestão de organismos que vivem junto ao substrato (Chao & Musick 1977), e o barbilhão utilizado para detecção química e tátil das presas (Vazzoler 1975, Castillo et al. 2000), são estruturas que facilitam a atividades de forrageamento, quando a espécie pode localizar e predar organismos que costumam permanecer enterrados ou semi-enterrados no substrato (Almeida et al. 1997, Zahorcsak et al. 2000).

A importância de Crustacea na alimentação da betara foi registrada em diversas localidades ao longo da costa Sudeste/Sul do Brasil (Franco 1959, Castillo 1986, Lunardon-Branco 1990, Lunardon-Branco et al. 1991, Chaves & Umbria 2003, Rondineli et al. 2007). De fato a importância de crustáceos na alimentação de peixes bentófagos da costa sul do Brasil já foi reportada por Haimovici et al. (1989) e, segundo Edgar & Shaw (1995), a disponibilidade desses organismos é responsável por regular a produção de peixes no Oeste da Austrália. Além dos crustáceos, peixes e poliquetas também apresentam relativa importância na alimentação da espécie (Castillo 1986, Lunardon-Branco et al. 1991, Chaves & Umbria 2003, Rondineli et al. 2007), assim como de outras congêneres (Bearden 1963, Castillo et al. 2000). Com relação aos poliquetas, muito embora este item já tenha sido considerado como preferencial na dieta de espécimes estudados por Amaral & Migotto (1980) no litoral de Ubatuba (SP), eles apresentaram maior importância apenas para indivíduos de menor porte (<12,1 cm) (quando comparados com os itens crustáceos e peixes). Isto pode ter ocorrido em função da facilidade de digestão destes animais (Bregnballe 1961 apud Almeida et al. 1997). Além disso, deve-se também considerar que as carapaças e pereiópodes dos crustáceos podem permanecer por mais tempo no estômago que outros itens, tendendo assim a uma superestimativa da sua real ingestão (Chaves & Vendel 1996).

No presente estudo foi observada uma mudança nas presas preferenciais entre as classes de tamanho menores (4,2 a 8,1 cm) e maiores (28,2 a 32,1 cm). Nas demais classes, notou-se a variação na importância de itens secundários, demonstrando que a espécie é capaz de responder a mudanças na utilização ou disponibilidade das potenciais presas. A mudança na dieta das espécies de peixes carnívoros está de fato relacionada com mudanças ontogênicas (Wootton 1990, Zavala-Camin 1996), as quais estariam relacionadas com a ocupação de diferentes ambientes (ou estratos) de acordo com seu desenvolvimento (Nikolski 1963), ou com a dificuldade de captura de algumas presas em função de sua grande mobilidade e de flutuações verticais na massa d'água (Carqueija et al. 1995). Os resultados aqui encontrados corroboram os obtidos por Bearden (1963), que constatou uma maior freqüência de poliquetas e anfípodas em indivíduos menores de 13,4 cm. Os poliquetas ocorreram em altas freqüências no presente estudo em exemplares menores (entre 4,2 e 12,1 cm), constituindo a categoria de maior importância, e de importância secundária até 20,1 cm. A preferência por esses organismos em exemplares menores já havia sido constatada por outros autores (Chaves & Umbria 2003, Almeida et al. 1997, Vendel & Chaves 1998). Tal diferenciação no hábito alimentar de uma espécie durante o desenvolvimento é uma adaptação para melhor aproveitamento do alimento disponível, que visa diminuir a competição intraespecífica por alimento ou suprir necessidades fisiológicas que o peixe possa ter em função de migração, maturação sexual e reprodução (Braga & Braga 1987).

Muito embora o ambiente pareça não apresentar variações acentuadas no padrão de ocorrência para a maioria dos itens alimentares, alterações sazonais entre os itens principalmente no que diz respeito à importância alimentar foram observadas. A preferência de peixes, principalmente em indivíduos adultos, pode estar associada ao aumento da atividade alimentar dos adultos nos meses do verão. Este aumento na preferência pelo hábito alimentar ictiófago no verão também foi constatado por Vendel & Chaves (1998) na dieta de *Bairdiella ronchus* no litoral do Paraná. Já a importância dos poliquetas constatada no outono pode estar relacionada principalmente ao fato de que 90% dos exemplares analisados estão contidos nas quatro primeiras classes (entre 4,2 e 20,1 cm) nas quais os poliquetas apresentaram elevada importância na alimentação. Tal plasticidade na dieta das espécies de acordo com a estação pode estar associada à disponibilidade de alimento e aos movimentos migratórios da fauna (Zavala-Camin 1996). Associações entre as mudanças nos itens da dieta e a disponibilidade de invertebrados foram encontradas por Wakabara et al. (1993) e Chaves & Umbria (2003).

A partir dos resultados obtidos verificou-se que a espécie possui hábito alimentar bastante diversificado, com a dieta baseada essencialmente em crustáceos, peixes e poliquetas. Juvenis e adultos (machos > 15 cm e fêmeas > 18 cm de comprimento total, sensu Muniz & Chaves 2008) compartilharam os mesmos recursos, porém, de formas diferentes. Esse fato pode estar relacionado tanto à redução da competição intra-específica como a diferentes necessidades energéticas, além da acessibilidade do predador à presa. Variações sazonais estiveram relacionadas à importância dos itens na dieta, o que pode estar associado a um possível aumento da disponibilidade dos itens em determinadas estações.

Referências Bibliográficas

Almeida, Z. S., Fonsêca-Genevois, V. & Vasconselos-Filho, A. L. 1997. Alimentação de *Achirus lineatus* (Teleostei, Pleuronectiforme: Achiridae) em Itapissuma – PE. **Boletim do Laboratório de Hidrobiologia**, 10: 79-95.

Amaral, A. C. Z. & Migotto, A. E. 1980. Importância dos anelídeos poliquetas na alimentação da macrofauna demersal e epibentônica da região de Ubatuba. **Boletim do Instituto Oceanográfico**. 29 (2): 31-35.

Amaral, A. C. Z., Rizzo, A. E. & Arruda, E. P. 2005. **Manual de identificação dos invertebrados marinhos da região Sudeste-Sul do Brasil**. São Paulo: EDUSP. 288p.

Andriguetto-Filho, J.M. 2002 Sistemas técnicos de pesca no litoral do Paraná: caracterização e tipificação. Pp. 213-233. In: Raynaut, C., Zanoni, M., Lana, P.C., Floriani, D., Ferreira, A.D.D., Andriguetto-Filho, J.M. (Ed.). **Desenvolvimento e meio ambiente: em busca da interdisciplinaridade**. Pesquisa urbanas e rurais. Editora UFPR, Curitiba.

Bearden, C. M. 1963. A contribution to the biology of theking whitings, genus *Menticirrhus*, of South Carolina. **Bears Bluff Laboratories**, 38: 3-27.

Braga, F. M. S. & Braga, M. A. A. S. 1987. Estudo do hábito alimentar de *Prionotus punctatus* (Bloch, 1797) (Teleostei, Triglidae), na região da Ilha Anchieta, estado de São Paulo, Brasil. **Revista Brasileira de Biologia**, 47 (1/2): 31-36.

Camargo, M. & Isaac, V. 2004. Food categories reconstruction and feeding consumption estimates for the Sciaenid *Macrodon ancylodon* (Bloch & Schneider), and the congenerics fishes *Stellifer rastrifer* (Jordan) and *Stellifer naso* (Jordan) (Pisces, Perciformes) in the Caeté Estuary, Northern Coast of Brazil. **Revista Brasileira de Zoologia**, 21 (1): 85-69.

Carqueija, C. R. G., Souza-Filho, J. J., Gouvêa, E. P. & Queiroz, E. L. 1995. Decápodos

(Crustacea) utilizados na alimentação de *Dasyatis guttata* (Bloch & Schneider) (Elasmobranchii, Dasyatididae) na área de influência da Estação Ecológica Ilha do Medo, Baía de Todos os Santos, Bahia, Brasil. **Revista Brasileira de Zoologia**, 12 (4): 833-838.

Castillo, V. R. A. 1986. Estudo sobre a biologia e o ciclo de vida de *Menticirrhus americanus* (Linnaeus,1758) (Ubatuba 25º 30' – Cananéia 25º 05'S São Paulo). **Dissertação de Mestrado**. Universidade de São Paulo, Instituto Oceanográfico, São Paulo, 150 p.

Castillo, N. B., Cárdenas, L. A. A. & Magaña, F. G. 2000. Espectro alimentario de la berrugata californiana *Menticirrhus undulatus* de Laguna Ojo de Liebre, Baja California Sur, México. **Ciencias Marina**, 26 (4): 659-675.

Chao, L. N. & Musick, J. A. 1977. Life history, feeding habits, and functional morphology of juvenile sciaenid fishes in the York River estuary, Virginia. **Fisheries Bulletin**, 75: 657-702.

Chaves, P. T. C., Cova-Grando, G. & Calluf, C. C. H. 2003. Demersal ichthyofauna in a continental shelf region on the south coast of brazil exposed to shrimp trawl fisheries. **Acta Biológica Paranaense**, 32(1, 2, 3, 4): 69-82.

Chaves, P. T. C. & Umbria, S. C. 2003. Changes in diet composition of transitory fishes in coastal systems, estuary and continental shelf. **Brazilian Archives of Biology and Tecnology**, 46 (1): 41-46.

Chaves, P. T. C. & Vendel, A. L. 1996. Aspectos da alimentação de *Genidens genides* (Valenciennes) (Siluriformes, Ariidae) na baía de Guaratuba, Paraná. **Brazilian Archives of Biology and Tecnology**, 41 (4): 423-428.

Chaves, P. T. C. & Vendel, A. L. 1998. Feeding habits of *Stellifer rastrifer* (Perciformes, Sciaenidae) at Guaratuba mangroove, Paraná. Brasil. **Revista Brasileira de Zoologia,** 13 (3): 669-675.

Clarke, K.R., Warnick, R.W. 2001. **Change in marine communities: an aproach to statistical analysis and interpretation**. Plymouth Marine Laboratory, Plymouth, UK.

Coelho, J. A. P., Puzzi, A., Graça-Lopes, R., Rodrigues, E. S. & Preto-Jr, O. 1986. Análise da rejeição de peixes na pesca artesanal dirigida ao camarão sete-barbas (*Xiphopenaeus kroyeri*) no litoral do estado de São Paulo. **Boletim do Instituto de Pesca São Paulo**. 13 (2): 51-61.

Costello, M. J. 1990. Predator feeding strategy and prey importance: a new graphical analysis. **Journal of Fish Biology**, 48: 607-614.

Edgar, G. J. & Shaw, C. 1995. The production and trophic ecology of shallow-water fish assemblage in southern Australia. II. Diets of fishes and trophic relationships between fishes and benthos at Western Port, Victoria. **Journal of Experimental Marine Biology**, 194: 83-106.

Franco, G. T. 1959. Nota preliminar sobre a alimentação de alguns peixes comercias brasileiros. **Anais da Academia Brasileira de Ciências**, 31 (4): 589-593.

Freitas, M. O., Hostim-Silva, H., Corbetta, R., Daros, F. 2005. Dados preliminares da ictiofauna demersal da Praia de Enseada, São Francisco do Sul - SC. **XVI Encontro Brasileiro de Ictiologia**, João Pessoa.

Freitas, M. O., Silva, M. H., Schwarz, R., Spach, H. L. 2007. A variabilidade temporal da comunidade de peixes em uma área de pesca do camarão sete-barbas no sul do Brasil. **XVII Encontro Brasileiro de Ictiologia**, Itajaí.

Hahn, N. S., Fugi, R., Almeida, V. L. L., Russo, M. R. & Lourero, V. E. 1997. Dieta e atividade alimentar de peixes do reservatório de Segredo. Pp. 141-162. In: Agostinho, A. A. & Gomes, L. C. (Eds). **Reservatório de Segredo: bases ecológicas para o manejo.** EDUEM, Maringá, 387p.

Haimovici, M., Teixeira, R. L. & Arruda, M. C. 1989. Alimentação da castanha *Umbrina canosai* (Pisces:Sciaenidae) no sul do Brasil. **Revista Brasileira de Biologia**, 49 (2): 511-522.

Hyslop, E. J. 1980. Stomach contents analysis – a review of methods and their application. **Journal of Fish Biology**, 17: 411-429.

Kawakami, E. & Vazzoler, G. 1980. Método gráfico e estimativa de índice alimentar aplicado no estudo de alimentação de peixes. **Boletim do Instituto Oceanográfico**, 29 (2): 205-207.

Lunardon-Branco, M. J. 1990. Hábitos alimentares de *Menticirrhus littoralis* (Holbrook, 1860) (Perciformes: Sciaenidae) na Baía de Paranaguá e adjacências – Paraná - Brasil. **Arquivos de Biologia e Tecnologia**, 33 (3): 717-725.

Lunardon-Branco, M. J., Silva, J. L., Verani, J. R. & Branco, J. O. 1991. Comportamento alimentar de *Menticirrhus americanus* (Linnaeus, 1758) (Perciformes: Sciaenidae) no litoral do Paraná, Brasil. **Arquivos de Biologia e Tecnologia**, 34 (3/4): 487-502.

Melo, G.A.S. 1996. **Manual de identificação dos**

Brachyura (Caranguejos e Siris) do litoral brasileiro. Plêiade/FAPESP, São Paulo, 603p.

Menezes, N. A. & Figueiredo, J. L. 1980. **Manual de peixes marinhos do sudeste do Brasil. IV. Teleostei (3)**. Museu de Zoologia da Universidade de São Paulo, São Paulo, 96p.

Muniz, E. R. & Chaves, P. T. C. 2008. Condição reprodutiva da betara preta, *Menticirrhus americanus* (Teleostei, Sciaenidae), na pesca realizada no litoral norte de Santa Catarina, Brasil. **Acta Scientiarum** 30(4): 339-344.

Nikolski, G. V. 1963. **The ecology of fishes**. Academic Press, London, 352p.

Rodrigues, F. L. 2003. Relações tróficas de *Menticirrhus americanus* e *Menticirrhus littoralis* na zona de arrebentação das praias arenosas adjacentes a barra do Rio Grande, RS, Brasil. **Dissertação de Mestrado**, Fundação Universidade Federal do Rio Grande, 104 p.

Rondineli, G. R., Braga, F. M. S., Tutui, S. L. S., Bastos, G. C. C. 2007. Dieta de *Menticirrhus americanus* (Linnaeus, 1758) e *Cynoscion jamaicensis* (Vaillant & Bocourt, 1883) (Pisces, Sciaenidae) no sudeste do Brasil, Estado de São Paulo. **Boletim do Instituto de Pesca**, 33(2): 221 – 228.

Smith, J. W. & Wenner, C. A. 1985. Biology of the southern kingfish in the south Atlantic bight. **Transactions American Fishery Society**, 114 (3): 356-366.

Vazzoler, G. 1975. Distribuição da fauna de peixes demersais e ecologia dos Sciaenidae da Plataforma Continental brasileira, entre as latitudes 29º21’S (Torres) e 33º41’S (Chuí). **Boletim do Instituto Oceanográfico**, 24: 85-169.

Vendel, A. L. & Chaves, P. T. C. 1998. Alimentação de *Bairdiella ronchus* (Perciformes, Sciaenidae) na Baía de Guaratuba, Paraná, Brasil. **Revista Brasileira de Zoologia**, 15 (2): 297-305.

Vieira, S. 1980. **Introdução à Bioestatística**. Campus, Rio de Janeiro, 196p.

Wakabara, Y., Tararam, A. S. & Flynn, M. N. 1993. Importance of the macrofauna for the feeding of young fish species from infralittoral of Arrozal-Cananeia lagoon estuarine region (25º02’S – 47º56’W) – Brazil. **Boletim do Instituto Oceanográfico**, 41 (1/2): 39 – 52.

Wootton, R. J. 1990. **Ecology of teleost fishes**. Chapman & Hall, London, 404p.

Zahorcsak, P., Silvano, R. A. M. & Sazima, I. 2000. Feeding biology of a guild of benthivorous fishes in a sandy shore on south-eastern Brazilian coast. **Revista Brasileira de Biologia**, 60 (3): 511-518.

Zavala-Camim, L. A. 1996. **Introdução aos estudos sobre alimentação natural em peixes**. EDUEM, Maringá, 129p.

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Do fallen fruit-dwelling chironomids in streams respond to riparian degradation?

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Abstract. There is little information on the impacts of deforestation on the aquatic insects associated with fallen-fruits in Neotropical streams. Given the argumentation that fallen-fruit dwelling insects may depend on the availability of fruits in streams and consequently on the riparian forest condition, we hypothesized that fallen-fruit dwelling chironomid Endotribelos would differ in streams whose catchments differed in land use, particularly riparian forest conditions. To test this hypothesis we experimentally placed fruits in streams characterized by a gradient of riparian forest degradation We applied correlation analysis between Endotribelos mean density by fruit, number of colonized fruits, and environmental variables. All results evidenced that fallen-fruit chironomid Endotribelos were affected by riparian degradation.

Key words: Chironomidae, Endotribelos, lotic systems, anthropogenic impacts, deforestation

Resumo. Chironomidae em frutos caídos em córregos respondem à degradação da mata ripícola? Existem poucas informações sobre repostas de insetos que vivem em frutos caídos em córregos frente ao desmatamento e à degradação da mata ripícola na região Neotropical. Considerando a argumentação que insetos vivendo em frutos caídos podem depender da disponibilidade de frutos em córregos e, consequentemente, da condição da floresta ripícola, nós hipotetizamos que Chironomideos Endotribelos seriam diferentes em córregos em diferentes usos do solo, particularmente na condição de mata ripícola. Para testar essa hipótese, experimentalmente colocamos frutos em córregos caracterizados por gradiente de degradação de mata ripícola. Nós avaliamos relações entre a densidade média de Endotribelos por frutos, número de frutos colonizados e variáveis ambientais. Todos os resultados evidenciaram que Chironomidae, particularmente Endotribelos, em frutos respondem previsivelmente à condição da mata ripícola.

Palavras-chave: Chironomidae, Entotribelos, sistema lótico, impacto antropico, desmatamento

Introduction

The effects of land use on aquatic insects have been documented in different parts of the world, but there is still much debate regarding the predictability of the responses of different taxa under different terrestrial disturbances (Bonada *et al*. 2006). In general, it has been suggested that aquatic insects respond to point source pollution in a very predictable way, but respond to diffuse pollution in a more complex and variable manner (e.g. Allan 2004, Downes *et al*. 2005).

Tropical forests host intriguing interactions between fruits and fruit-eating animals in both terrestrial and aquatic habitats (Janzen 1974, Araujo-Lima & Goulding 1997, Wantzen & Junk 2006). In these areas, there is a great amount of fruits falling into streams. This fruit input may occur continuously over the year, and consists mostly of large, fleshy fruits that are of high nutritional value. Therefore, fallen fruits potentially represent an important resource for stream macroinvertebrates (Larned *et al.* 2001, Roque *et al.* 2005). Among aquatic insects inhabiting fallen fruits**,** the larvae of the chironomid *Endotribelos* Grodhaus, 1987, are the most common insects inside fallen-fruits in Neotropical streams (Roque *et al.* 2005, Roque & Trivinho-Strixino 2008). *Endotribelos* larvae have also been reported living in macrophytes, detritus, wood, leaves, and freshwater sponges (Grodhaus 1987; Roque et al. 2005).

Endotribelos larvae are a potentially useful group for assessing diffuse anthropogenic impacts on streams, because of their dependence on resources from the riparian forests. Furthermore, there are advantages in using fallen fruits as a natural ecological unit in sampling designs due to their ephemeral, patchy distribution and discrete character that allow testing hypotheses that explicitly address influence of landscape use, habitat, and resources on distribution of aquatic insects. This is particularly worthwhile because in most studies on aquatic systems, the delineation of sampling units is arbitrary, which result, in many cases, in problems with statistical assumptions and biological meanings.

There are several mechanisms through which riparian degradation may affect insects inhabiting fallen fruits in aquatic systems. These include a reduction in the number of fallen fruits in the stream, an increase in sediments, and an increase in primary productivity. In this study we hypothesized that riparian degradation may lower the availability of primary resources for chironomids, either directly (i.e. reduce the number of fallen fruits) or indirectly (i.e. reduce the accessibility of fruits by insects, through sedimentation). To test the stated hypothesis, we experimentally placed fruits in streams and evaluated whether abundance and frequency of *Endotribelos* is related to riparian forest degradation. Considering that (i) resource may be defined as an organism requirement for its survival, growth and reproduction; (ii) the availability of resources can influences the structure and dynamics of ecological systems; (iii) in general the primary resources limit the community productivity (Nowlin *et al.* 2008), we expect that fallen fruit-dwelling chironomids would differ in streams whose catchments differed in land use, particularly riparian forest conditions.

Material and Methods

Study area. We conducted the experiment in six streams in São Carlos city, southeastern Brazil (22°01’S, 47°53’W). The region was characterized in the past by extensive areas of Cerrado (savanna) and Atlantic semi-deciduous forest (Soares *et al.* 2003), both considered hot spots of biodiversity (Myers *et al.* 2000). Currently, the area is dominated by sugar cane plantations, pastures, small forest fragments, and riparian buffer strips along the streams with different levels of connectivity, size and preservation. Regional climate is Cwa (Köppen classification), with wet summer and dry winter. All study sites were first and second order streams with similar topographic gradients ($<5^o$), but located in pasture areas with varied condition of riparian forest.

Stream and riparian forest variables. We measured environmental variables at each site to characterize habitat conditions and degree of human disturbance. Conductivity and pH were measured in 3 different sections of each site using a Horiba U-10 or a Yellow Springs-556 water checker equipped with multiple probes. We used the mean of these measures in the statistical analyses. Predominant substrates were estimated visually as the proportion of the stream bottom covered by boulder and cobble (>256 mm), gravel (2-255 mm), sand (0.125-2 mm), and mud (<0.125 mm). To assess physical and biological conditions of the riparian zone and stream channel morphology at the local scale, we applied 7 metrics and their respective scores from the “Riparian Channel and Environmental Inventory” (RCE) for small streams (Petersen Jr. 1992). The RCE scores were applied to each sampling site, which consisted of 100m of stream. These metrics were: 1) land-use pattern beyond the immediate riparian zone, 2) width of riparian zone from stream edge to field, 3) completeness of riparian zone, 4) vegetation of riparian zone within 10m of channel, 5) retention devices, 6) channel sediments, and 7) stream-bank structure. Thus, our RCE final score for each stream refers to the sum of scores of these 7 metrics and higher RCE scores are associated with more intact riparian areas.

Selected fruits. *Syagrus romanzoffiana* (Chamisso) Glassman, popularly called Jerivá, is a common palm in semi-deciduous forest and riparian forests in South-eastern Brazil and their fruits are considered important resources to terrestrial fruit-eating animals. The fruit is an ovoid drupe 15cm in diameter with a soft endocarp and woody endocarp. Individuals of these plants produce fruit all the year round. We collected fruits of *S. romanzoffiana* from tree individuals in the campus of the Universidade Federal de São Carlos, São Carlos, following three criteria: similar size, ripeness and level of herbivory.

Sampling design. We threaded a nylon line through 21 fruits from which we made three "necklaces" with 7 fruits each. These were randomly placed in pool areas of each stream. The insertion of the nylon line in the fruits likely did not influence the larval colonization process, because decomposition starts from the top of the fruit and most of the larvae occupy these areas (personal observation).

The fruits were placed in the streams on 10-11 August 2006 and removed after seven days. Each fruit was isolated and transported to the laboratory. This period of exposure (seven days) was defined after a preliminary experiment conducted by the authors (unpublished data). No large rainfall event occurred in our study area during this period.

Data analysis. We sorted and identified all insects of each fruit. Some fruits were lost during the experiment, so we standardized the number of fruits used in the analyses by those found not completely embedded by sediments.

We did not analyze the number of lost fruits and fruit embeddedness as a surrogate measure of anthropogenic impacts, because in two low impacted streams (Canchim and Aeroporto stream), despite having a wide forest buffer, the stream-banks had been disturbed by foraging pigs which covered many fruits by sediments and some fruits were eaten by terrestrial frugivores.

Larval densities were expressed as the mean number of larvae per fruit and the proportion frequency of colonized fruits (number of fruit with larvae/total of number). To choose meaningful non-correlated environmental predictors we carried out a Principal Component Analysis on all measured stream and riparian forest variables. The Broken-Stick method (Jackson 1993) was used as a stopping-rule in the PCA.

After that we performed correlation analysis for the (*Endotribelos*) chironomid mean density (log x+1) and frequency of colonized fruits (response variables) against the selected axes of PCA (predictor variables). We report R^2 for each correlation. Because geographical data such as these are generally spatially autocorrelated (Legendre 1993), so that degrees of freedom are inflated and P-values for R are underestimated. To correct for spatial autocorrelation, we calculated for each correlation the effective number of degrees of freedom according to Dutilleul's method (Dutilleul 1993). We report adjusted P-values based on the effective degrees of freedom. The analyses were performed using the package Spatial Analysis Macroecology v. 3.0, SAM (Rangel *et al.* 2006).

Results

Endotribelos mean density and frequency of colonized fruits varied considerably among streams and the values were highest at conserved areas (Table I).

The first principal component axis accounted for 63% of the variability in stream environmental variables and it was the only one selected by Broken stick model. PC1 evidenced a gradient of riparian degradation. Sites with lower PC1 scores were degraded areas (most correlated with high values of conductivity and smaller values of RCE scores) while those with higher PC1 scores were located in conserved areas (correlated with high values of RCE and DO scores) (Tables I and II).

Endotribelos mean density and frequency of colonized fruits seem to increase with increasing PCA scores (good condition of riparian forest), as evidenced by positive values of correlations (r^2 = 0.77; P_{adj} = 0.06 and r^2 = 0.79; P_{adj} = 0.05, respectively).

Table I. *Endotribelos* mean density, frequency of colonized fruits, and environmental variables across different streams in the State of São Paulo, Brazil.

Streams	Mean density	Frequency	RCE	pH	Conductivity	DO	Canopy	Lat (Y)	Long (X)
1	0.00	0.00	28	6.60	94	2.50	1	-22.039	-47.829
2	1.80	0.80	135	6.70	13	5.70	3	-21.882	-47.906
3	0.18	0.18	65	6.00	12	6.00	2	-21.019	-47.836
4	0.61	0.38	115	7.20	12	7.20	2	-21.954	-47.837
5	0.50	0.40	175	7.00	16	7.30	3	-21.926	-47.911
6	0.07	0.07	24	6.80	16	6.40	1	-22.038	-47.780
7	21.80	1.00	160	6.60	14	5.20	3	-22.044	-47.824
8	2.90	1.00	185	5.40	10	7.90	3	-21.951	-47.838

Table II. Summary of the environmental variables and of the results of Principal Component Analysis across different streams in the State of São Paulo, Brazil, and correlation coefficients between principal component scores and the environmental variables.

	Streams		Principal Components
Variables	Mean	SD	PC-1
RCE	92	63.99	0.825
pH	6.45	0.64	-0.473
Conductivity (µS cm^{-1})	26.16	33.28	-0.879
DO (Mgl^{-1})	5.95	1.87	0.938
Variance explained %			63% (Broken stick 52%)

Discussion

The negative effects of degradation of riparian cover caused by deforestation, overgrazing and other land use practices on macroinvertebrate communities have been reported worldwide (e.g. Iwata *et al.* 2003, Allan 2004, Sweeney *et al.* 2004, Couceiro *et al.* 2007). Although researchers report that row crop and other forms of intensive cultivation strongly affect stream condition, the influence of pasture agriculture (Strayer *et al.* 2003) and forest fragmentation (Nessimian *et al.* 2008) may be less pronounced.

Fallen-fruit dwelling insects may depend on the availability of fruits in streams and consequently on the riparian forest condition, and regarding the advantages in using them as indicators of less pronounced and diffuse impacts, it would be expected that the distribution of these animals could be predict based on environmental variables related to anthropogenic impacts. Our results support this expectation. The negative effects of the riparian degradation on frequency of colonized fruits and on *Endotribelos* mean density by fruit may be attributable to a number of interacting reasons. The principal reasons, by which forest degradation influences stream macroinvertebrate densities, are sedimentation, hydraulic alteration, and loss of large organic matter inputs (Allan 2004). Environmental disturbances in degraded streams, such as sedimentation, have long been suggested to be one of the most important causes for loss of species and reduction in density of some macroinvertebrate groups. The principal mechanisms behind are: (i) increasing turbidity, scouring and abrasion, (ii) impairing substrate suitability for biofilm production, (iii) decreasing food quality causing bottom-up effects through food webs, (iv) in-filling of interstitial habitat that harms crevice-occupying invertebrates (v) coating of gills and respiratory surfaces and (vi) reducing stream habitat heterogeneity (Cordone & Kelly 1961, Quinn *et al.* 1992, Wood & Armitage 1997, Wantzen 1998, Allan 2004).

An increase in primary productivity is also expected to occur in some deforested small streams, with consequences in macroinvertebrate communities. The most common effect is a positive and food related association between macroinvertebrate abundance and periphyton biomass, and also functional changes characterized by higher dominance of collectors and grazers (Vannote *et al.* 1980, Bojsen & Jacobsen 2003). In our study, we could observe high amounts of periphyton on the surface of the fruits in the most degraded streams and occurrence of non-specialists fruit dwelling chironomids (e.g. *Chironomus*) living around the fruits. This observation, associated with the smaller frequency of colonized fruits by *Endotribelos*, indicates a replacement of "typical dwelling fruit chironomids" by more tolerant taxa. Moreover, animals influenced by or depend on basal food resources from riparian vegetation can suffer additional negative effects on its occurrences and densities due to direct losses, changes and decreases of the basal resources (Benstead & Pringle 2004).

From a bioassessment perspective, despite the potential application of fallen-fruit dwelling insect information, we consider that before using *Endotribelos* as an indicator group of forest degradation, at least for non extreme situations that are more difficult to assess, we need to know threshold levels of disruption involving linkages between terrestrial and stream habitats and resources that affect fallen-fruit dwelling insect abundances.

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References

Allan, JD 2004. Landscape and riverscapes: the influence of land use on stream ecosystems. **Annual Review of Ecology, Evolution, and Systematics,** 35: 257-284.

Araujo-Lima, C. & Goulding M. 1997. **So fruitful a fish: ecology, conservation, and aquaculture of the Amazon's tambaqui.** Columbia University Press, New York, 157 p.

Benstead, JP & Pringle, CM 2004. Deforestation alters the resource base and biomass of endemic stream insects in eastern Madagascar. **Freshwater Biology,** 49: 490-501.

Bojsen, BH & Jacobsen, D. 2003. Effects of deforestation on macroinvertebrate diversity and assemblage structure in Ecuadorian Amazon streams. **Archiv fur Hydrobiologie**, 158: 317-342.

Bonada, N., Prat, N., Resh, VH & Statzner, B. 2006. Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. **Annual Review of Entomology**, 51: 495-523.

Couceiro, SRM, Hamada, N., Luz, SLB, Forsberg, BR & Pimentel, TP 2007. Deforestation and sewage effects on aquatic macroinvertebrates in urban streams in Manaus, Amazonas, Brazil. **Hydrobiologia,** 575: 271-284

Cordone, AJ & Kelley, DW 1961. The influences of inorganic sediment on the aquatic life of streams. **California Fish and Game**, 47: 189-228.

Downes, BJ, Lake, PS, Glaister, A. & Bond, NR 2005. Effects of sand sedimentation on the macroinvertebrate fauna of lowland streams: are the effects consistent? **Freshwater Biology**, 51: 144-160.

Dutilleul, P. 1993. Modifying the t test for assessing the correlation between two spatial processes. **Biometrics**, 49: 305-314.

Grodhaus G. 1987. Endochironomus Kieffer, Tribelos Townes, Synendotendipes, n. gen., and Endotribelos, n. gen. (Diptera: Chironomidae) of the Nearctic region. **J Kansas Entomol Soc**. 60:167–247.

Iwata, T., Nakano, S. & Inoue, M. 2003. Impacts of past riparian deforestation on stream communities in a tropical rain forest in Borneo. **Ecological Applications**, 13: 461-473.

Jackson, DA. 1993. Stopping rules in principal components analysis: a comparison of heuristical and statistical approaches. **Ecology**, 74: 2204-2214.

Janzen, DH 1974. Tropical blackwater rivers, animals, and mast fruiting by the Dipterocarpaceaea. **Biotropica**, 6: 69-103.

Larned, ST, Chong, CT & Punewal, N. 2001. Detrital fruit processing in a Hawaiian stream ecosystem. **Biotropica**, 33: 241-248.

Legendre, P. 1993. Spatial autocorrelation: trouble or new paradigm? **Ecology**, 74: 1659-1673.

Myers, N., Mittermeier, RA, Mittermeier, CG., Fonseca GAB & Kent, J. 2000. Biodiversity hotspots for conservation priorities. **Nature**, 403: 853-858.

Nessimian, JL, Venticinque, EM, Zuanon, J., De Marco Jr., P., Gordo, M., Fidelis, L., Batista, JD, Juen, L. 2008. Land use, habitat integrity and aquatic insect ssemblages in Central Aamazonian streams. **Hydrobiologia**, 614: 117-131.

Petersen Jr, RC 1992. The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. **Freshwater Biology**, 27: 295-306.

Quinn, JM, Davies-Colley, RJ, Christopher, WH, Vickers, ML & Ryan, PA 1992. Effects of clay discharges on streams. 2. Benthic invertebrates. **Hydrobiologia**, 248: 235-247.

Rangel, TFLVB, Diniz-Filho. JAF & Bini, LM 2006. Towards an integrated computational tool for spatial analysis in macroecology. **Global Ecology and Biogeography**, 15: 321-327.

Roque, FO, Siqueira, T. & Trivinho-Strixino, S. 2005. Occurrence of chironomid larvae living inside fallen-fruits in Atlantic Forest streams, Brazil. **Entomologia y Vectores**, 12: 275-282.

Roque, FO & Trivinho-Strixino, S., 2008. Four new species of Endotribelos Grodhaus, a common fallen fruit-dwelling chironomid genus in Brazilian streams (Diptera: Chironomidae: Chironominae). **Studies on Neotropical Fauna and Environment**, 3: 191–207.

Soares, JJ, Silva, DW & Lima, MIS 2003. Current state and projection of the probable original vegetation of the São Carlos region of São Paulo State, Brazil. **Brazilian Journal of Biology**, 63: 527-536.

Strayer, DL, Beighley, RE, Thompson, LC, Brooks, S. & Nilsson, C. 2003. Effects of land cover on stream ecosystems: roles of empirical models and scaling issues. **Ecosystems**, 6: 407-23.

Sweeney, BW, Bott, TL, Jackson, JK, Kaplan, LA, Newbold, JD, Standley, LJ, Hession, WC & Horwitz, RJ 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. **Proceedings of the National Academy of Sciences**, 28: 14132-14137.

Vannote, RL, Minshall, GW, Cummins, KW, Sedell, KW & Cushing, CE 1980. The river continuum concept. **Canadian Journal of Fisheries and Aquatic Sciences**, 37: 130-137.

Wantzen, KM, 1998. Effects of siltation on benthic communities in clear water stream in Mato Grosso, Brazil Verh. **Int. Verein. Limnol**, 26: 1155-1159.

Wantzen, KM & Junk, WJ 2006. Aquatic-terrestrial linkages from streams to rivers: biotic hot spots and hot moments. **Archives fur Hydrobiolie,** 158: 595-611.

Wood PJ & Armitage, PD 1997. Biological effects of fine sediment in the lotic environment. **Environmental Management**, 21: 203-217.

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Ecotoxicological analysis of cashew nut industry effluents, specifically two of its major phenolic components, cardol and cardanol

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Abstract. Cashew nut processing plant is a major industry in almost all northeastern States of Brazil. The technical cashew nut shell liquid (CNSL), which contains mainly cardanol, cardol, polymeric material, and traces of methyl-cardol, is the most abundant by-product of this process. The high level of CNSL in the effluent generated during production is a potential environmental toxin. This is the first study that has assessed the toxicity of this industrial effluent, specifically two of its major components, cardol and cardanol, using the brine shrimp (*Artemia* sp.) lethality assay. Effluents were collected at a cashew nut processing plant located in Fortaleza, Ceará, Brazil. Cardol and cardanol were isolated from the technical CNSL. The LC_{50} of cardol was 0.56 and 0.41 mg/L after 24 and 48 hr exposures, respectively, and of cardanol was 1.59 and 0.42 mg/L. The LC_{50} values for crude effluent were 1.38 and 0.60 % after 24 and 48 hr exposures, respectively, and were 2.16 and 0.88 % for treated effluent. Data from this study suggested that the cashew nut industry effluents are highly toxic to the environment. The current treatment strategy to minimize the toxicity of this industry's effluent is insufficient and must be improved.

Keywords: acute toxicity test, *Artemia* sp., phenols, CNSL, effluent treatment

Resumo. Caracterização ecotoxicológica dos efluentes da indústria de beneficiamento da castanha de caju, especificamente de dois dos seus componentes fenólicos: cardol e cardanol. O beneficiamento da castanha de caju é uma das mais desenvolvidas atividades em quase todos os estados do Nordeste brasileiro, em especial no Ceará. O líquido da casca da castanha (LCC), no qual estão presentes cardóis, cardanóis, material polimérico e traços de metil-cardol, é o mais abundante sub-produto e o alto teor de LCC torna potencialmente tóxico o efluente gerado durante o processo. Este é o primeiro estudo em que a toxicidade deste efluente é avaliada, assim como de dois dos seus componentes (cardol e cardanol), utilizando o teste de toxicidade aguda com *Artemia* sp. Os efluentes foram coletados em uma indústria localizada em Fortaleza, Ceará, Brasil. O cardol e o cardanol foram isolados do LCC técnico. A CL_{50} média do cardol foi 0,56 e 0,41 mg/L após 24 e 48 h de exposição, respectivamente, e a do cardanol foi 1,59 e 0,42 mg/L. Os valores de CL_{50} obtidos dos experimentos com o efluente bruto foram 1,38 e 0,60% após 24 e 48 h, respectivamente, e 2,16 e 0,88% para o efluente tratado. Os resultados do estudo sugerem que os efluentes desta indústria são altamente tóxicos. A estratégia de tratamento atualmente empregada para minimizar a sua toxicidade é insuficiente e deve ser revista.

Palavras-Chave: teste de toxicidade aguda, *Artemia* sp., fenóis, LCC, tratamento de efluentes

Introduction

The cashew (*Anacardium occidentale* L.) is a well-known member of the ANACARDIACEA family and is commonly found in northeast Brazil. The cashew nut has been commercially exploited since colonization. Brazil, India and Mozambique, are the leading cashew nut producers in the world (Paramashivappa *et al.* 2001, Kumar *et al.* 2002).

The process of the improvement of the cashew involves four basic stages: stockpiling, structuring of the chestnut for use, extraction of the almond, and refinement (Moura *et al.* 2005). The technical cashew nut shell liquid (CNSL), containing the phenolic compounds, cardanol (60-65%), cardol (15-20%), polymeric material (10%), and traces of methyl-cardol, is the most abundant by-product of cashew improvement (Paramashivappa *et al.* 2001, Kumar *et al.* 2002, Trevisan *et al.* 2006). CNSL is used for industrial technological applications, biological/pharmaceutical applications, friction dust production by the automobile industry, and in certain polymeric/surface coating applications (Stasiuk *et al.* 2008).

Analysis of potential mutagenic, carcinogenic and cocarcinogenic activities of CNLS demonstrated that it may be a weak promoter of carcinogenesis but presented no mutagenic or cocarcinogenic activity (George & Kuttan 1997). Epidemiological studies suggested that CNSL may contribute to oral submucous fibrosis (Varghese *et al.* 1986). In addition, its phenolic components exerted several biological activities, including antioxidant (Trevisan *et al.* 2006, Façanha *et al.* 2007), inhibition of acetylcholinesterase (Stasiuk *et al.* 2008) and membrane perturbation (Stasiuk & Kozubek 2008).

There is no direct evidence regarding the toxicity of CNSL or its major phenolic components. However, the effluent generated during the improvement of the cashew nut could be considered potentially harmful to the environment due to the high CNSL content. Previous studies have not fully characterized these effluents. Moura *et al.* (2005) described the physical-chemical properties of the effluents obtained at different stages of the process, and concluded that among the analyzed parameters, the tenor of oil and greases is about two times the value allowed by environmental legislation standards (CONAMA 2005). The pH, alkalinity, turbidity, and the COD/BOD ratio were considered acceptable according to environmental legislation. There are no data available regarding the toxicity of this effluent using an ecotoxicological approach.

The analysis of the hazards of effluents should include ecotoxicological bioassays (Environmental Canada 1999, U.S. EPA 2002, CONAMA 2005), so that the potential toxicity to the environment can be assessed. This study is the first to assess the toxicity of the cashew nut improvement industry effluent and two of its major components, cardol and cardanol.

To assess the toxicity of these components, a brine shrimp (*Artemia* sp.) lethality assay was employed. The intrinsic features of the *Artemia* genus make it a suitable organism for ecotoxicological assays, as it is a robust and cost-effective model system (Nunes *et al.* 2006). Therefore, it is an effective model system for large scale analysis of industrial effluents (Guerra 2001).

Material and Methods

Effluent collection

The effluents were collected at a cashew nut improvement industry located in Fortaleza, Ceará, Brazil. The factory has a small sewage treatment plant, which filters, minimally treats and decants the effluent before releasing it into the environment. The samples were collected every week from April through June of 2006 before (crude effluent) and after treatment (treated effluent). A total of 40 samples were collected, which included 20 crude and 20 treated effluents, and they were placed in 100 mL amber glass flasks. The samples where stored at 4°C until analysis.

Cardol and cardanol isolation

Cardol and cardanol were isolated from the technical cashew nut shell liquid according to the procedures described by Paramashivappa *et al.* (2001) and Kumar *et al.* (2002). Technical CNSL was dissolved in methanol, ammonium hydroxide (25%) was added, and the solution was stirred for 15 min. The cardanol was extracted by adding hexane (4 times), followed by a 5% HCl wash of the organic layer. The hexane fraction was then dried over anhydrous sodium sulfate and the solvent was evaporated under reduced pressure to obtain pure cardanol. The methanolic ammonia solution was extracted with ethyl acetate/hexane (4:1), followed by a 5% HCl wash of the resulting organic layer, and a distilled water wash. The remaining fraction was dried over anhydrous sodium sulfate and the solvent was evaporated under reduced pressure to obtain pure cardol.

Brine shrimp lethality assay

Brine shrimp (*Artemia* sp. Leach) eggs were hatched in a beaker filled with seawater under constant aeration. After 48 hr, the nauplii were collected by pipetting and were counted macroscopically in the stem of the pipette using a lighted background. Ten nauplii were transferred to each well of a 24-multi-well plate containing the samples. The crude and treated effluent concentrations ranged from 0.06 to 32 %, from 0.01 to 30 mg/L for cardanol, and from 0.001 to 3 mg/L for cardol. The plates were incubated under illumination. Survivors were counted after 24 and 48 hr of incubation, and the percentage of deaths at each dose and control (seawater plus vehicle) was determined (Veiga & Vital 2002).

Sodium dodecyl sulfate (SDS, BIORAD) was used as reference toxicant as suggested by Veiga & Vital (2002). A stock solution of 1000 mg/L was prepared, and concentrations of 15, 21, 27, 34, 42, 51 and 61 mg/L were used in the assay.

Statistical analysis

In accordance with U.S. E.P.A. standards (U.S. EPA 2002), three experimental replicates were used for each dilution and for control tests. Data were analyzed as means ± standard deviation (SD). The LC_{50} (median lethal concentration) values and their 95% confidence intervals (CI 95%) were obtained using the Trimmed Spearman-Karber test (Hamilton *et al.* 1977). LC_{50} values were compared using paired (same sample with different exposure time of 24 or 48 hours) or unpaired (different) samples, with the Student's t-test with a 5% significance level.

Results and discussion

Negative controls showed nauplii survival greater than 90% in all assays. SDS was used as a positive control, and its effects were highly reproducible across experiments (Figure 1). The mean LC_{50} ± SD was 24.8 ± 2.2 mg/L (n = 6, coefficient of variation of 9.0%) and the data were within the acceptable LC_{50} range (Veiga & Vital 2002). Physical-chemical analysis of the control water and test samples demonstrated that DO, pH and salinity were within the desirable range for use in toxicity testing (data not shown).

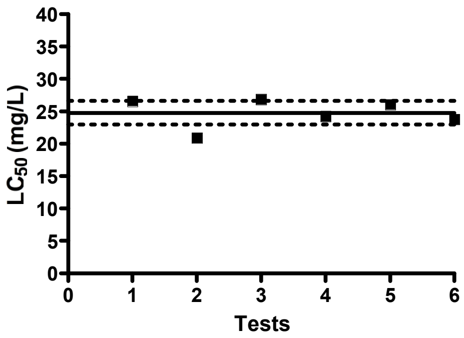

Figure 1. Mean LC_{50} values and the upper and lower intervals (mean ± 2SD) obtained from the acute toxicity test with *Artemia* sp. with sodium dodecyl sulfate after 24 hours.

The acute toxicity test using *Artemia* sp. nauplii is a major worldwide assay for measuring the toxicity of chemical substances (Barahona & Sánchez-Fortún 1996, Guerra 2001, Svensson *et al.* 2005, Nunes *et al.* 2006). Previous studies indicate that *Artemia* nauplii are highly sensitive to phenolic compounds, which are the major constituents of cashew nut industry effluents. In 1996, Barahona and Sánchez-Fortún (1996) assessed the sensitivity of three age classes of *Artemia salina* nauplii to eight phenolic compounds: pentachlorophenol (PCP), 2,6-dichloroindophenol (2,6-DCIP), 2,4-dinitrophenol (2,4-DNP), o-nitrophenol (o-NP), p-nitrophenol (p-NP), diamidophenol, diaminophenol and 2,6-dimethylphenol (2,6-DMP). The most sensitive to these phenolic compounds was the 48 hr age class, which had an LC_{50}s that ranged from 0.3 mg/L for PCP to 2.4 mg/L for p-NP.

Due to their increased sensitivity, 48 hr old *Artemia* sp. nauplii were used in this study to evaluate the toxicity of cardol and cardanol, which are two of the major components of cashew nut industry effluents. It should be noted that there are no studies assessing the toxicity of these compounds in the *Artemia* sp. model. Figure 2 shows the variation of LC_{50} values obtained from the acute toxicity test with cardanol and cardol in *Artemia* sp. in different experiments.

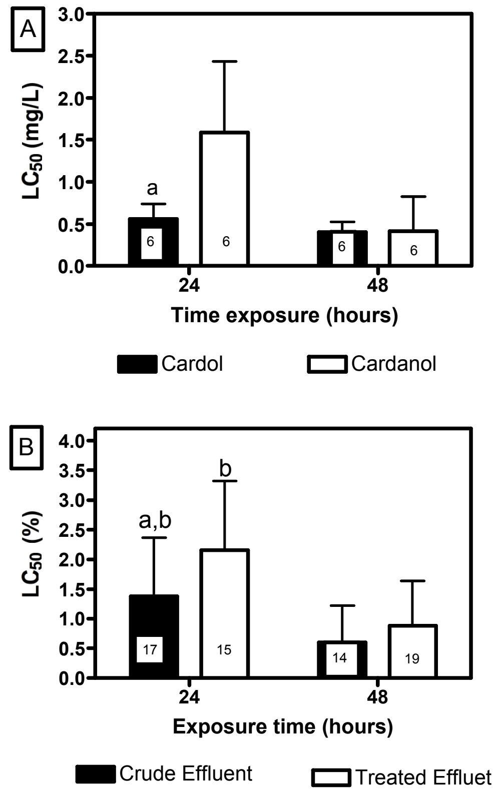

Figure 2. Effect of cardanol and cardol (A) or the cashew nut industry effluents (B) in the acute toxicity test with *Artemia* sp. after 24 and 48 hours incubation. Data are presented as mean ± SD from n experiments (n showed inside the bars). a, $p < 0.05$, t-test comparing cardol and cardanol or crude and treated effluents at the same exposure time. b, $p < 0.05$, paired t-test comparing different exposure time for the same compound or effluent.

These data indicated that these phenolic compounds were highly toxic under these assay conditions. Cardol had an LC_{50} of 0.56 mg/L and 0.41 mg/L after 24 and 48 hr exposures, respectively. Cardanol had an LC_{50} of 1.59 mg/L and 0.42 mg/L after 24 and 48 hr exposures, respectively. At 24 hr of exposure, cardol was significantly more toxic than cardanol ($p < 0.05$), but after 48 hr of exposure, there was no difference in toxicity ($p > 0.05$).

The hazardous effects of phenolic compounds have been extensively studied. According to Veeresh *et al.* (2005), a concentration above 1 mg/L can affect aquatic life, while Newman and Unger (2003) recognize deleterious effects at concentrations as low as 1 µg/mL. Au *et al.* (2003) demonstrated that phenolic concentration of 0.1 mg/L affect the spermatogenesis of the sea urchin *Anthocidaris crassispina* impairing the reproduction. According to them, phenolic compound disrupted the spermatozoid membrane structure. The acute toxicity of phenol was also demonstrated using *Baetis rhodani* larvae with a LC_{50} around 2.1mg/L after 11 days of incubation (Khatami *et al.* 1998). As noticed in the present work, the lethal effects in *Artemia* nauplii occurred in the same concentration range, reinforcing the high sensitivity and robustness of this *Artemia* nauplii assay in measuring the toxicity of phenolic compounds, and support the idea of using this assay to assess and monitor the toxicity of the cashew nut industry effluent.

Both crude and treated cashew nut industry effluent was toxic to *Artemia* nauplii (Figure 2). The LC_{50} values for the crude effluent were 1.38 ± 0.99 % and 0.60 ± 0.62% after 24 and 48-hr exposures, respectively, and were 2.16 ± 1.16 % and 0.88 ±0.76 %, respectively, for treated effluent. These LC_{50} values indicated there is a statistically significant ($p < 0.05$) difference between the toxicity of crude and treated effluent after 24 hr of exposure, with the treated effluent exhibiting a slightly lower toxicity (Figure 2).

However, there was no significant difference after 48 hr ($p > 0.05$). These data indicate that the industrial treatment of the effluent is not efficient in removing the toxicity. As mentioned previously, this treatment includes a filtration, a small primary treatment and a decantation step. Table I summarizes the toxicities of several other effluents obtained with the *Artemia* nauplii model.

Table I. *Artemia's* sensitivity to several types of raw effluents in the literature.

Test Species	Exposure period and endpoint	Effluent	Toxicity value (LC_{50})	Reference
Artemia salina	24 hr	Chemical plant.	2.73 – 35.5%	Guerra (2001)
Artemia sp.	24 hr	Olive oil mill	4.5 %	Aggelis et al. (2003)
Artemia salina	24 hr	Oilfield	1.2 %	Campos et al.(2002)
Artemia salina	24 hr	Landfill leachate	70 – 80%	Svensson et al. (2005)
Artemia salina	24 hr	Alcohol distillery	1.5%	Santana and Machado (2008)
Artemia salina	24 hr	Textile	55%	Souza et al. (2007)
Artemia sp.	24 hr	Cashew nut industry	1.38 - 2.16 %	Present work

These data indicate that *Artemia*'s sensitivity is rather variable, with LC_{50} values ranging from 1.2% for waste water from an oilfield to almost 80% for a landfill leachate. In fact, the toxicity is intimately associated with the chemical composition of the tested effluent. Studies with leachate water from landfills suggested that ammonium and ammonia are responsible for the acute toxicity observed in *Artemia salina* (Aggelis *et al.* 2003, Svensson *et al.* 2005). In comparison, according to Guerra (2001) and Aggelis *et al.* (2003), the toxicity of chemical plant and olive mill effluents, respectively, is due to the presence of phenolic compounds. The use of a bioreactor, inoculated with the fungi, *Pleurotus ostreatus,* for the treatment of olive mill wastewaster was efficient in removing phenolic compounds and toxicity, suggesting that a correlation exists between these two parameters (Aggelis *et al.* 2003). As previously mentioned, data on the chemical composition of the cashew nut industry effluent are scarce, but preliminary analysis showed high phenol content due to the CNLS contents of cardol, cardanol and anacardic acid. The high toxicity observed for the isolated phenols, cardol and cardanol, potentially contributed to the toxicity of the cashew nut industry effluent.

Conclusion

Overall, these data demonstrate that cashew nut industry effluents are highly toxic in the *Artemia* sp. model and are potentially harmful to the environment. Thus, the acute toxicity test using *Artemia* nauplii could be considered a sensitive, practical and feasible method to monitor the toxicity of effluent generated by the cashew nut improvement industry. Since the crude and treated toxicities exhibited similar toxicities after 48 hr, it can be concluded that the current industrial treatment is inefficient in removing toxic components. An efficient treatment strategy must be adopted by the industry to reduce the environmental impact that results from the production process.

References

Aggelis, G., Iconomou D., Christou M., Bokas D., Kotzailias S., Christou Z., Tsagou V., Papanikolaou S. 2003. Phenolic removal in a model olive oil mill wastewater using *Pleurotus ostreatus* in a bioreactor cultures and biological evaluation of the process. **Water Research**, 37: 3897-3904.

Au, D. W. T., Yurchenko, O. V., Reunov, A. A. 2003. Sublethal effects of phenol on spermatogenesis in sea urchins (*Anthocidaris crassipina*). **Enviromental Research,** 93:92-98.

Barahona, M. V. & Sánchez-Fortún, S. 1996. Comparative sensitivity of three age classes of *Artemia salina* larvae to several phenolic compounds. **Bulletin of Environmental Contamination and Toxicology**, 56: 271-278.

Campos, J. C., Borges, R. M. H., Oliveira Filho, A. M., Nóbrega, R., Sant'anna Jr. G. L. 2002. Oilfield wastewater treatment by combined microfiltration and biological processes. **Water Research**, 36: 95-104.

CONAMA – Conselho Nacional do Meio Ambiente. 2005. Resolução No. 357 de 17 de março de 2005.

Environmental Canada - Guidance document an application and interpretation of single-species test in environmental toxicology. 1999. EPS 1/RM/34. 203pp.

Façanha, M. A., Mazzetto, S. A., Carioca, J. O., Barros, G. G. 2007. Evaluation of antioxidant properties of a phosphorated cardanol compound on mineral oils (NH10 and NH20). **Fuel**, 86: 2416-2421.

George, J. & Kuttan, R. 1997. Mutagenic, carcinogenic and cocarcinogenic activity of cashewnut shell liquid. **Cancer Letters**, 112: 1-16.

Guerra, R. 2001. Ecotoxicological and chemical evaluation of phenolic compounds in industrial effluents. **Chemosphere**, 44: 1737-1747.

Hamilton, M. A., Russo, R. C., Thurston, R. V. 1977. Trimmed Spearman-Karber method for estimating median lethal concentrations in toxicity bioassays. **Environment Science Technology**, 11: 714-719.

Khatami, S. H., Pascoe, D., Learner, M. A. 1998. The acute toxicity of phenol and unionized ammonia, separately and together, to the ephemeropteran *Baetis rhodani* (Pictet). **Environmental Pollution**, 99: 379-387.

Kumar, P. P., Paramashivappa, R., Vithayathil, P. J., Rao, A. S. 2002. Process for Isolation of Cardanol from Technical Cashew (*Anacardium occidentale* L.) Nut Shell Liquid. **Journal of Agriculture and Food Chemistry**, 50: 4705-4708.

Moura, T. N., Jerônimo, C. E. M., Sousa, J. F., Melo, H. N. S. 2005. Profile of the characterization of effluents of the industry of improvement of cashew nuts. 2th Mercosur Congress on Chemical Engineering. Cod 902.

Newman, M. C. & Unger, M. A. 2003. **Fundamentals of Ecotoxicology.** 2^a Edition. Lewis Publishers, New York, 433 p.

Nunes, B. S., Carvalho, F. D., Guilhermino, L. M., Stappen, G. V. 2006. Use of the genus Artemia in ecotoxicity testing. **Environmental Pollution**, 144: 453-462.

Paramashivappa, R., Kumar, P. P., Vithayathil, P. J., Rao, A. S. 2001. Novel Method for Isolation of Major Phenolic Constituents from Cashew (*Anacardium occidentale* L.) Nut Shell Liquid. **Journal of Agriculture and Food Chemistry**, 49: 2548-2551.

Satana, V. S. & Machado, N. R. C. F. 2008. Photocatalytic degradation of the vinasse under solar radiation. **Catalysis Today**, 133: 606-610.

Souza, S. M. A. G. U., Forgiarini, E., Souza, A. A. U. 2007. Toxicity of textile dyes and their degradation by the enzyme horseradish peroxidase (HRP). **Journal of Hazardous Materials**, 147: 1073-1078.

Stasiuk, M. & Kozubek, A. 2008. Membrane perturbing properties of natural phenolic and resorcinolic lipids. **FEBS Letters**, 582: 3607-3613.

Stasiuk, M., Bartosiewicz, D., Kozubek, A. 2008. Inhibitory effect of some natural and semisynthetic phenolic lipids upon acetylcholinesterase activity. **Food Chemistry**, 108: 996-1001.

Svensson, B. M., Mathiasson, L., Martensson, L., Bergstrom, S. 2005. *Artemia salina* as test organism for assessment of acute toxicity of leachatewater from landfills. **Environmental Monitoring and Assessment**, 102: 309-321.

Trevisan, M. T. S., Pfundstein, B., Haubner, R., Wurtele, G., Spiegedhalder, B., Bartsch, H., Owen, R. W. 2006. Characterization of alkyl phenols in cashew (*Anacardium occidentale*) products and assay of their antioxidant capacity. **Food and Chemical Toxicology**, 44: 188-197.

US-EPA - Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. 2002. Environmental Protection Agency. Report EPA-821-R-02-012. Washington, Fifth Edition.

Varghese, I., Rajendran, R., Sugathan, C. K., Vijayakumar, T. 1986. Prevalence of oral submucous fibrosis among the cashew workers of Kerala-South India. **Indian Journal of Câncer**, 23: 101-104.

Veeresh, G. S., Kumar, P., Mehrota, I. 2005. Treatment of phenol and cresols in upflowanaerobic sludge blanket (UASB) process: a review. **Water Research**, 39: 154-170.

Veiga, L. F. & Vital, N. 2002. Teste de toxicidade aguda com o microcrustáceo *Artemia* sp. Pp 111-122. *In*: Nascimento, I. A., Sousa, E. C. P. M., Nipper, M. (Ed.). **Métodos em Ecotoxicologia Marinha: Aplicações no Brasil**. vol 1. Editora Artes Gráficas e Indústria Ltda, São Paulo, 262 p.

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Primeiro registro de nidificação de tartarugas marinhas das espécies *Eretmochelys imbricata* (Linnaeus, 1766) e *Lepidochelys olivacea* (Eschscholtz, 1829), na região da Área de Proteção Ambiental Delta do Parnaíba, Piauí, Brasil

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Resumo. Ninhos de tartarugas marinhas encontrados na praia do Arrombado, no Estado do Piauí, contribuem com dados qualitativos sobre o comportamento reprodutivo das espécies de *Eretmochelys imbricata* e *Lepidochelys olivacea* no Litoral Norte do Brasil.

Palavras-Chave: comportamento reprodutivo, distribuição geográfica, biodiversidade.

Abstract. First record of nesting of the species *Eretmochelys imbricata* (LINNAEUS, 1766) and *Lepidochelys olivacea* (ESCHSCHOLTZ, 1829) at the Área de Proteção Ambiental Delta do Parnaíba, Piauí, Brazil. Nests of sea turtles found in the Arrombado's beach, in the Piauí State, contribute to qualitative data on the reproductive behavior of the species of *Eretmochelys imbricata* e *Lepidochelys olivacea* on the Northern coast of Brazil.

Keywords: reproductive behavior, geographic distribution, biodiversity.

Introduction

As tartarugas marinhas são répteis que existem há mais de 150 milhões de anos. Atualmente, são reconhecidas sete espécies no mundo, das quais cinco frequentam a costa brasileira, a saber: tartaruga cabeçuda, *Caretta caretta* (Linnaeus 1758); tartaruga verde, *Chelonia mydas* (Linnaeus 1758); tartaruga de couro, *Dermochelys coriacea* (Linnaeus 1766); tartaruga de pente, *Eretmochelys imbricata* (Linnaeus 1766) e tartaruga de oliva, *Lepidochelys olivacea* (Eschscholtz 1829) (Marcovaldi & Marcovaldi 1999). Esta nota apresenta informações sobre a ocorrência de desova das espécies *E. imbricata* e *L. olivacea* no Litoral Norte do Brasil, ambas classificadas em estado "crítico" e "vulnerável" de extinção, respectivamente (IUCN 2008).

Esses animais migram por longas distâncias para atender às suas necessidades alimentícias e reprodutivas. Em todas as espécies, as fêmeas realizam mais de uma postura por temporada, porém, não se reproduzem em anos consecutivos (Rossi 2007). O intervalo entre eventos reprodutivos pode variar entre 1 a 9 anos, dependendo da espécie (Miller 1997). No caso da *E. imbricata* e *L. olivacea*, as posturas podem ser realizadas -aproximadamente- a cada 3 e 2 anos, respectivamente (Gomes *et al.* 2006). Durante uma postura, a espécie *E. imbricata* pode colocar de 110 a 180 ovos e a *L. olivacea* de 105 a 120 ovos por desova (Eckert 2000) .

Os ninhos foram encontrados na Região da Área de Proteção Ambiental (APA) do Delta do Parnaíba, no trecho de 2,5 km da praia do

Arrombado, município de Luis Correia, no Estado do Piauí, Brasil (UTM 2906967, 41540717; 24M zone) (Figura 1). O primeiro registro foi de um ninho da espécie *L. olivacea*, aberto (naturalmente) no dia 24 de abril de 2009, às 10:00h. O ninho possuía 0,47 m de profundidade, com um número total de 128 ovos, classificados em: (02) natimortos, (06) não eclodidos e (120) eclodidos. O segundo caso foi uma eclosão ocorrida às 21:40h do dia 28 de junho de 2009 da espécie *E. imbricata*. O ninho possuía 0,52 m de profundidade, com um número total de 123 ovos, classificados em: (10) natimortos, (07) não eclodidos e (106) eclodidos. Os materiais biológicos coletados estão disponíveis no Laboratório de Zoologia da Universidade Federal do Piauí/ UFPI – CMRV, de acordo com a licença do IBAMA-SISBIO, protocolada sob N° 14052-1.

A área de estudo (Figura 1) inserida nesse contexto geográfico abrange o litoral piauiense, que possui 66 km de extensão, caracterizado por erosão marinha e formação de enseadas. No trecho das ocorrências, a areia possui granulometria grossa com declividade de praia moderada e sem presença de berma.

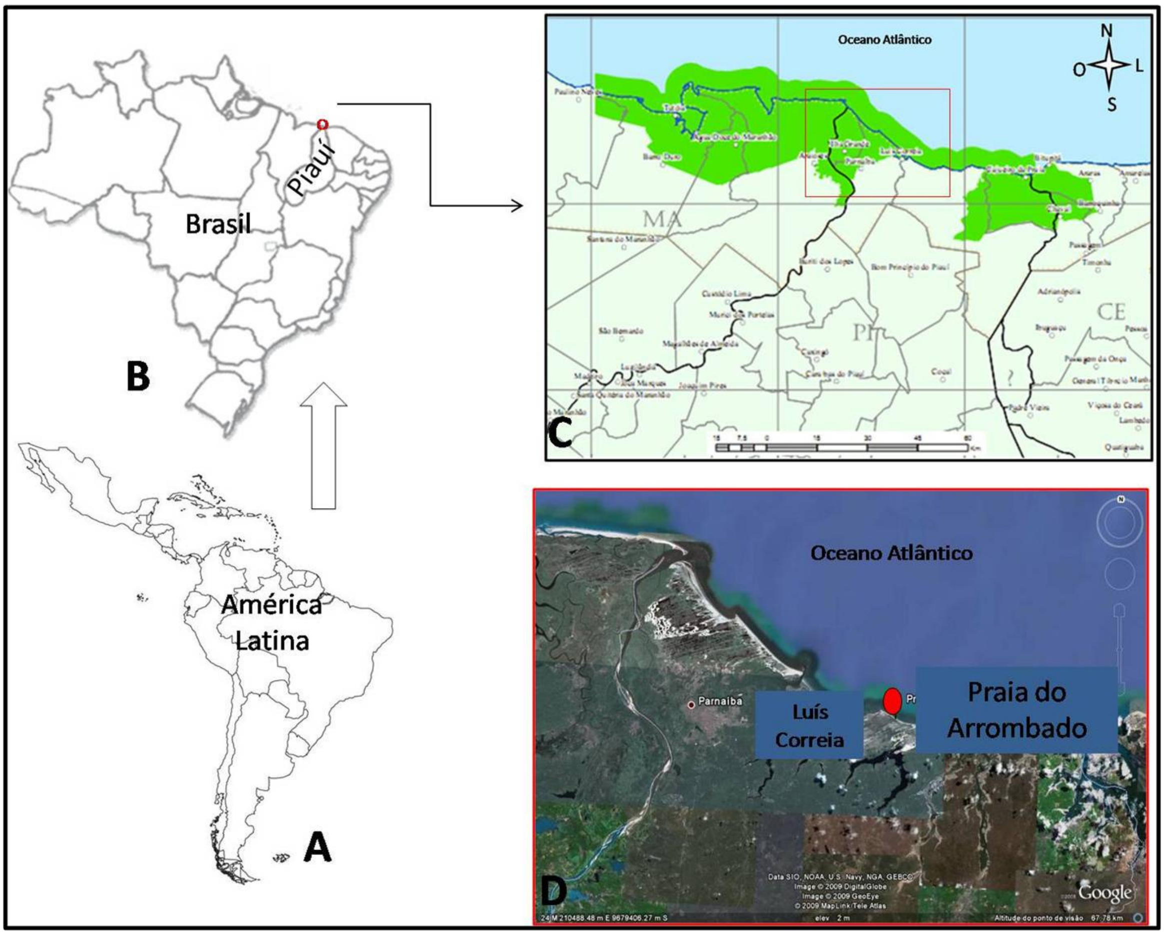

Figura 1. A – Mapa da América Latina; B – Mapa do Brasil com destaque em vermelho para a localidade de ocorrência das desovas; C – Mapa da área de Proteção Ambiental do Delta do Parnaíba (em verde), com destaque em vermelho para a área destaca abaixo (adaptado de MMA, IBAMA, Diretoria de Ecossistemas (2004)); D – Mapa com destaque para o município de Luís Correia, em vermelho a área das desovas na Praia do Arrombado, Piauí, Brasil (adaptado de Google Earh, Data SIO, NOAA, US, Navy, NGA, GEBCO (2009)).

Lima (2002) registra a presença de ninhos da espécie *E. imbricata*, na praia do Futuro e na praia da Prainha, ambas localizadas no litoral leste do Estado do Ceará, e ninho de *L. olivacea* na praia de Patos, também situada no litoral cearense (Lima *et al*. 2003). Entretanto, o presente trabalho contribui com outro registro de ocorrência de desova das espécies *E. imbricata* e *L. olivacea* para praia do Arrombado, no Estado do Piauí, a aproximadamente 370 km da praia do Futuro e 220 km da praia de Patos, as duas áreas de ocorrências mais próximas para as espécies em estudo. Essas distâncias foram mensuradas com o auxílio do programa Google Earth (2009), seguindo a zona costeira litorânea.

Vale ressaltar que as áreas de maior ocorrência de nidificação (quantitativamente) são a praia de Pipa e praia do Forte (*E. imbricata*), nos Estados do Rio Grande do Norte e Bahia respectivamente (Santos 2008) e a praia de Pirambu (*L. olivacea*), no Estado de Sergipe (Silva 2007).

São escassos os dados de comportamento reprodutivo e não reprodutivo das populações de tartarugas marinhas do Litoral Norte do Brasil. Assim, o único registro de comportamento reprodutivo para o litoral do Piauí, trata-se da desova de um exemplar da espécie *Dermochelys coriacea* em 2004, na mesma área geográfica desta ocorrência (Loebmann *et al*. 2008).

Dessa forma, os resultados deste trabalho confirmam a necessidade de monitoramento e pesquisa na referida região, bem como no entorno da APA do Delta do Parnaíba.

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Referências

Eckert, K. L.; Bjorndal, K. A.; Abreu-Grobois, F. A. & Donnelly, M. (Editores). 2000 (Traducción al español). **Técnicas de Investigación y Manejo para la Conservación de las Tortugas Marinas**. Grupo Especialista en Tortugas Marinas UICN/CSE. Publicación 4, 270 p.

Google; Maplink/ Tele Atlas; Europa Technologies. 2009. **Google Earth**. Download disponível em http://earth.google.com.br (Acessado 27/07/2009).

Gomes, M. G. T.; Santos, M. R. de D. & Henry, M. 2006. Tartarugas marinhas de ocorrência no Brasil: hábitos e aspectos da biologia da reprodução. **Rev. Bras Reprod Anim.** 30: 19-27.

IUCN, 2008. **IUCN Red List of Threatened Species -** World Wide Web electronic publication, accessible at www.iucnredlist.org. (Acessado 26/07/2009).

Lima, E. H. S. M. 2002. Alguns dados sobre desova de tartaruga de pente (*Eretmochelys imbricata*) no litoral leste do Ceará. **Congresso Brasileiro de Zoologia.** UNIVALI, Itajaí, 24:426.

Lima, E. H. S. M.; Melo, M. T. D. & Barata, P. C. R. 2003. First record of olive ridley sea turtle (*Lepidochelys olivacea*) nesting in the State of Ceará, Brazil. **Marine Turtle Newsletter**, Wales, 99, p. 20.

Loebmann, D.; Legat, J. F. A.; Puchnick-Legat, A; Camargo, R. C. R. de; Erthal, S.; Severo, M. & Góes, J. M. de. 2008. *Dermochelys coriacea* (Leatherback Sea Turtle) Nesting. **Herpetological Review** 39 (1) p. 81.

Marcovaldi, M. A. & Marcovaldi, G. G. 1999. Marine Turtles of Brazil: the history and strutucture of Projeto TAMAR IBAMA. **Biological Conservation** 91: 35-41.

Miller, J. D. 1997. Reproduction in sea turtles. Pp.: 51-81. *In:* Lutz P. L & Musick J. A. (Eds.).**The Biology of Sea Turtles.** CRC Press, Boca Raton, Boston, London, New York, Washington, D. C.

Rossi, S. 2007. Estudos do impacto da fibropapilomatose em Chelonia mydas (LINNAEUS, 1758) (Testudines, Cheloniidae). **Dissertação de mestrado**. Universidade de São Paulo, São Paulo, Brasil, 104 p.

Santos, A. J. B. 2008. Aspectos da biologia reprodutiva de *Eretmochelys imbricata* (Testudines, Cheloniidae) no litoral sul do Rio Grande do Norte, Brasil. **Dissertação de Mestrado**. Universidade Federal do Rio Grande do Norte, Natal, Brasil. 45 p.

Silva, A. C. C. D da.; Castilhos, J. C. de.; Lopez, G. G. & Barata, P. C. R. 2007. Nesting biology and conservation of the olive ridley sea turtle (*Lepidochelys olivacea*) in Brazil, 1991/1992 to 2002/2003. **Journal of the Marine Biological Association of the United Kingdom**. 87: 1047–1056.

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Composição e abundância de ovos e larvas de peixes na baía da Babitonga, Santa Catarina, Brasil

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Abstract. Composition and abundance of fish eggs and larvae in the Babitonga Bay, Santa Catarina, Brazil. Estuaries are high biological productivity areas and play an important role as nursery grounds for early life stages of fishes. The aim of this work was to describe the spatial and temporal distribution of ichthyoplankton composition and abundance in the main channel of the Babitonga bay. The mean surface temperature and salinity were 24.3°C and 28.2, respectively. Throughout the study period 4079 fish eggs and 1779 larvae were collected. Higher egg and larval densities were observed in spring, summer, and in the innermost channel area where salinity was lowest. Eighty-one percent of the eggs were Engraulidae. Twenty-five *taxa* of fish larvae were represented, 7 of which were identified to species. Most abundant families were Sciaenidae, Engraulidae, Gobiidae, Haemulidae, Mugilidae, Sparidae, Blenniidae and Carangidae. Sciaenidae larvae from *taxa* with economic importance were represented by *Bairdiella ronchus*, *Cynoscion* sp., *Umbrina* sp., *Stellifer* sp., *Menticirrhus* sp., *Pogonias cromis and Micropogonias furnieri*. Spatial and temporal distribution of *Lycengraulis grossidens* larvae were wide, and it was registered in all sampling sites and seasons, except winter. This study shows the role of Babitonga Bay as a nursery for species of estuarine and coastal fish assemblage. In that area the knowledge on ichthyoplankton is sparse and further studies are recommended.

Key words: plankton, ichthyoplankton, subtropical bay, coastal environment, South Atlantic

Resumo. Os estuários são áreas altamente produtivas e exercem papel fundamental como berçário para os estágios iniciais de peixes. O objetivo desse trabalho foi descrever a distribuição espacial e temporal da composição e abundância do ictioplâncton no canal principal da baía da Babitonga. A média de temperatura foi 24,3ºC e de salinidade foi 28,2. Durante o período de estudo foram coletados 4079 ovos e 1779 larvas. Na primavera, no verão e na área mais interna onde a salinidade foi menor ocorreram as maiores densidades tanto de ovos quanto de larvas. 81% dos ovos eram de Engraulidae. As larvas foram identificadas como 25 *taxa*, dos quais 7 até espécie. As famílias mais abundantes foram Sciaenidae, Engraulidae, Gobiidae, Haemulidae, Mugilidae, Sparidae, Blenniidae e Carangidae. Larvas de Sciaenidae de *taxa* com importância econômica foram representadas por *Bairdiella ronchus*, *Cynoscion* sp., *Umbrina* sp., *Stellifer* sp., *Menticirrhus* sp., P*ogonias cromis* e *Micropogonias furnieri*. Espacialmente e temporalmente larvas de *Lycengraulis grossidens* ocorreram amplamente, foram encontradas em todos os pontos amostrais durante o estudo e ausentes apenas no inverno. Este estudo demonstrou o papel da baía da Babitonga como criadouro para espécies da assembléia de peixes estuarina e costeira. O conhecimento sobre o ictioplâncton na área de estudo é escasso e mais estudos são recomendados.

Palavras-chave: plâncton, ictioplâncton, baía subtropical, ambiente costeiro, Atlântico Sul

Introdução

Os estuários são economicamente importantes devido a sua alta produtividade biológica ser associada à ocorrência de estágios iniciais de muitos organismos, ou seja, apresentarem importância como áreas de desova e berçário para muitas espécies (Able 1978, Muelbert & Weiss 1991, Mann & Lazier 1996, Keller *et al.* 1999, Thayer *et al.* 1999, Fujita *et al.* 2002, Pérez-Ruzafa *et al.* 2004). Os estuários da costa do Atlântico Sul são áreas importantes para desova e desenvolvimento de muitos peixes, e essa função merece especial atenção dos cientistas (Sinque & Yamanaka 1982).

A dinâmica ictioplanctônica em estuários brasileiros ainda encontra-se sob a ameaça da carência de informações. Embora já existam resultados de trabalhos realizados nas regiões norte e nordeste (Castro & Bonecker 1996, Mafalda Jr. & Silva 1996, Barletta-Bergan *et al*. 2002, Mafalda Jr. *et al*. 2004, Bonecker *et al*. 2007, Bonecker *et al*. 2009), na região sudeste (Soares *et al*. 1991, Andreata *et al*. 1998, Joyeux *et al*. 2004, Castro *et al*. 2005, Coser *et al*. 2007) e na região sul (Muelbert & Weiss 1991, Souza-Conceição *et al*. 2005, Souza-Conceição 2008, Macedo-Soares *et al*. 2009), ainda é possível verificar ecossistemas com informações escassas a este respeito.

Neste contexto, sem ter sido devidamente estudada em relação ao ictioplâncton e sob a ameaça de alterações pela pressão antrópica de entorno, destaca-se a baía da Babitonga, um dos principais complexos estuarinos do Sul do Brasil. Localizada no litoral Norte de Santa Catarina, possui volume aproximado de 7,8 x 10^8 m^3 de água, amplitude de maré de 1,30 m com duração aproximada de seis horas (IBAMA 1998, Knie 2002). A oeste, a baía limita-se na porção setentrional com a Serra do Mar e a leste com a ilha de São Francisco do Sul (IBAMA 1998, Knie 2002, Cremer 2006). Assim a baía pode ser dividida em três grandes segmentos: a região do Canal do Linguado, que contorna a ilha na sua porção sul; a região do Rio Palmital, ao norte e com características estuarinas em boa parte de sua extensão; e o corpo central da baía propriamente dito (Cremer 2006).

Um aspecto importante a ser destacado é o grande número de comunidades pesqueiras presentes na baía da Babitonga, as quais conforme dados do Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renováveis (IBAMA 1998) compreendem mais de mil pescadores e respectivas famílias. Esta área estuarina está ligada a base da renovação do sustento destes pescadores, no papel de criadouro de muitas espécies de peixes exploradas na área. Entretanto, este papel ou função da área em questão ainda precisa de informações de base como a distribuição espaço-temporal do ictioplâncton. A informação sobre a composição de espécies e a abundância do ictioplâncton auxilia na localização e descrição de áreas e padrões de distribuição de desovas para espécies não-residentes e locais, servindo também para determinar áreas importantes com a função de berçários (Chute & Turner 2001).

Do ponto de vista econômico, o ictioplâncton é o componente mais importante da comunidade zooplanctônica pela relevância na renovação de estoques pesqueiros. Seu estudo é importante para avaliar o potencial comercial de recursos pesqueiros existentes em áreas pouco conhecidas, determinar a susceptibilidade dos mesmos e estabelecer medidas para o aproveitamento sustentável (Navarro-Rodríguez *et al*. 2006). A baía da Babitonga possui elevado potencial de renovação das populações de peixes para sua área interna e plataforma adjacente. Esta área estuarina possui três quartos de todo o ecossistema manguezal presente em Santa Catarina (Cunha *et al*. 1999), o que potencializa a função de criadouro de peixes. Desta maneira, o principal objetivo do presente trabalho foi estudar a distribuição espacial e temporal da composição e abundância do ictioplâncton ao longo do canal principal do complexo estuarino da baía da Babitonga durante o transcorrer de um ciclo anual.

Material e Métodos

A baía da Babitonga está situada no norte do litoral catarinense entre as coordenadas geográficas de 26º02’ - 26º28’S e 48º28’ - 48º50’W, a qual apresenta uma superfície de 130 km² e profundidade média de 6 metros (IBAMA 1998). Neste importante ambiente estuarino foi realizada a aquisição dos dados biológicos e ambientais em quatro pontos amostrais (Fig. 1), sendo um ponto próximo à barra, um na área adjacente ao porto do município de São Francisco do Sul, um intermediário (Ilha do Araújo) e um ponto mais interno (Ilha da Rita). Foram realizadas coletas nos meses de abril, julho, setembro e novembro de 2004, e janeiro e abril de 2005.

As amostras foram obtidas com uma rede de plâncton cônica de 40 cm de diâmetro, 200 µm de abertura de malha e equipada com fluxômetro para medir o volume de água filtrado. A rede utilizada no trabalho foi escolhida para abranger os estágios de desenvolvimento de menores classes de tamanho dentro do ictioplâncton conforme Matsuura & Nakatani (1980), Johnson & Morse (1994) e Chute & Turner (2001), reduzindo assim o escape e a extrusão. As coletas ocorreram durante o dia e para reduzir problemas de evasão foi utilizada cor de malha clara. Os arrastos foram oblíquos, integrando toda a coluna d’água e duraram 2 minutos devido à colmatação da rede, sendo repetidos caso isto ocorresse. Foram registradas, por ponto amostral em superfície, a temperatura (°C) através de termômetro de mercúrio (precisão de 0,1°C) e a salinidade através de refratômetro de campo (precisão de 1,0). As amostras foram fixadas em solução formalina a 4%.

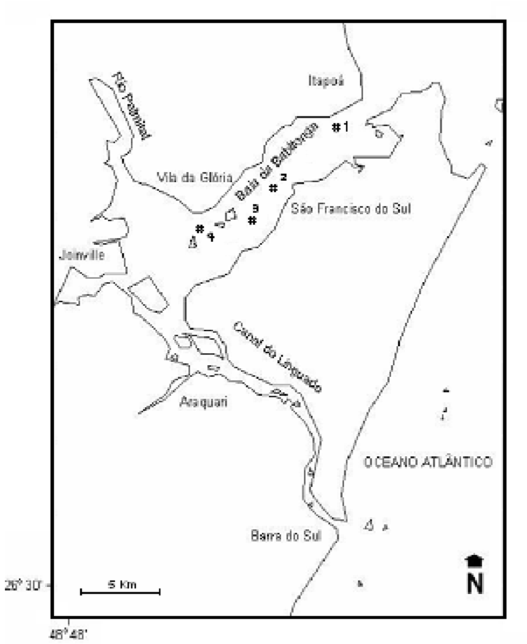

Figura 1. Área de estudo e localização dos pontos amostrais (1: barra; 2: porto; 3: ilha do Araújo; e 4: ilha da Rita) no canal principal da baía da Babitonga.

No laboratório foi determinado o biovolume zooplanctônico através do método volumétrico, em mililitros, e posteriormente calculado por cem metros cúbicos (mL.100m^{-3}). Em seguida, o ictioplâncton foi triado sob microscópio estereoscópico binocular, sendo posteriormente calculadas as densidades de ovos e larvas de peixe por cem metros cúbicos (n°.100 m^{-3}). Para a análise qualitativa, os ovos foram identificados em dois grupos, os pertencentes à Engraulidae e outros, e as larvas de peixes foram identificadas ao menor táxon possível de acordo com referências bibliográficas especializadas (Colton & Marak 1969, Russel 1976, Johnson 1978, Matsuura & Nakatami 1979, Fahay 1983, Leis & Rennis 1983, Leis & Trnski 1989, Órtiz-Galindo *et al*., 1990, Moser 1996, Matsuura & Suzuki 1997, Ré 1999, López *et al*. 2002, Cuartas *et al*. 2003, Mata *et al*. 2004, Richards 2006).

A variação dos parâmetros de temperatura e salinidade entre coletas e pontos amostrais foi testada pelo teste não-paramétrico de Kruskall-Wallis (p<0,05). Em caso de significância foi aplicado teste de Dunn (p<0,05). Os testes citados foram realizados através do programa Statistica 6.0. Para o estudo de padrões de distribuição do ictioplâncton uma análise de agrupamento foi realizada através do programa PRIMER 6.1.7 (Plymouth Marine Laboratory, Inglaterra). Para separar os agrupamentos significativamente diferentes (p<0,05) foi utilizado o teste SIMPROF. Os dados de densidade foram transformados através da função Log (x+1), utilizado como coeficiente de distância a similaridade de Bray-Curtis e método de agrupamento pela média de seus valores de similaridade (UPGMA) (Clark & Warwick 1994).

Resultados

No transcorrer do estudo a temperatura da água variou de 18 a 28°C, com média de 24,3ºC (Fig. 2) e não apresentou variação significativa (p<0,05) entre os pontos amostrais, porém houve variação significativa (p<0,05) entre as coletas (Tabela I). A salinidade variou de 23 a 36, com média de 28,2 (Fig. 2) e não apresentou variação significativa tanto entre as coletas quanto entre os pontos amostrais.

Para a densidade do biovolume zooplanctônico, obteve-se os maiores valores no mês de julho, nos pontos do porto e da barra, quando foi observada grande quantidade de gelatinosos nas amostras. Menores valores ocorreram nas coletas de abril de 2004 e abril de 2005 (Fig. 3), quando foram registrados valores para as características físicas e químicas correspondentes ao fim do verão na área de estudo.

No total foram coletados 4079 ovos e 1779 larvas ao longo do período de estudo. Os ovos foram identificados como 3319 de Engraulidae e 760 de outras famílias. Entre as larvas foram identificados 25 *taxa* ao todo, 8 ao nível de família, 10 de gênero e 7 de espécie (Tabela II). O pico da abundância de ovos ocorreu para todos os pontos amostrais no mês de novembro, sendo que a maior densidade registrada ocorreu na Ilha da Rita. Em relação às larvas, a abundância também foi maior no mês de novembro em todos os pontos amostrais, porém o maior valor de densidade de larvas foi encontrado na Ilha do Araújo (Fig. 3).

Ao longo do período de estudo a maior densidade de ovos registrada refere-se a Engraulidae, porém com ocorrência concentrada em setembro, novembro e janeiro. Em novembro foi registrada sua maior abundância para todos os pontos amostrais. Os ovos de outras famílias ocorreram durante todo o estudo, com as maiores densidades em setembro e novembro na Ilha da Rita e em janeiro na Ilha do Araújo (Fig. 3).

As famílias Engraulidae, Sciaenidae, Gobiidae, Haemulidae, Mugilidae, Sparidae, Blenniidae e Carangidae foram as mais abundantes (Tabela II). Nos meses de setembro e novembro de 2004 e janeiro de 2005 foi encontrado o maior número de *taxa*, enquanto que em julho de 2004 foram identificadas somente larvas de Sciaenidae e

Blenniidae. Nas identificações, embora não quantificada, foi observada a presença de grande variedade de sub-estágios de desenvolvimento entre os ovos e as larvas.

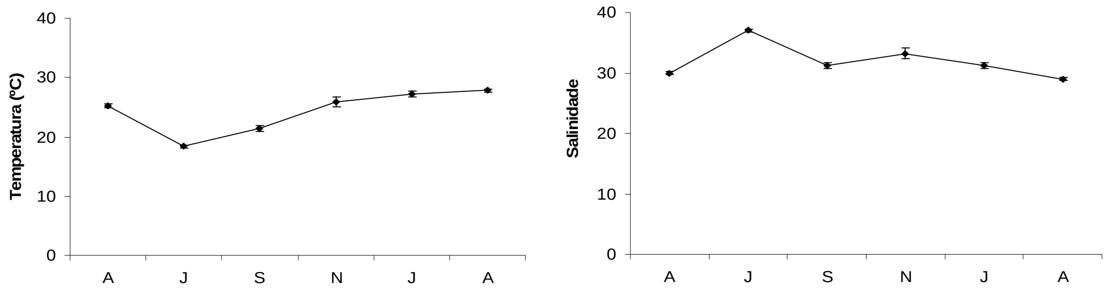

Figura 2. Variação média e desvio padrão da temperatura (ºC) e da salinidade nos meses de coleta na baía da Babitonga, Santa Catarina (A: abril, J: julho, S: setembro, N: novembro e J: janeiro).

Tabela I. Resultado dos testes não-paramétricos de Kruskall-Wallis (p<0,05) e de Dunn (p<0,05) para as variáveis de salinidade e temperatura (°C) entre os pontos amostrais e entre as coletas (n.s.: não significativo; Ab: abril; Jul: julho; Set: setembro; Nov: novembro; Jan: janeiro).

	Comparações	
Parâmetros	**Pontos Amostrais**	**Coletas**
Salinidade	n.s.	n.s.
Temperatura (°C)	n.s.	Ab/04 x Jul/04; Ab/04 x Set/04; Ab/04 x Jan/05; Ab/04 x Ab/05; Jul/04 x Set/04; Jul/04 x Nov/04; Jul/04 x Jan/05; Jul/04 x Ab/05; Set/04 x Nov/04; Set/04 x Jan/05; Set/04 x Ab/05; Nov/04 x Jan/05; Nov/04 x Ab/05

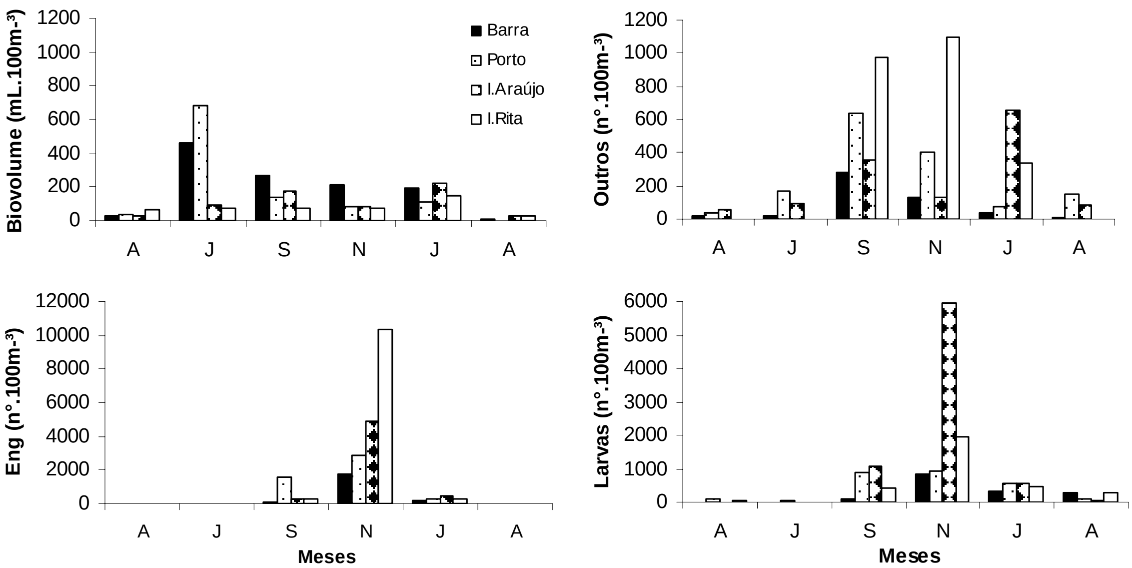

Figura 3. Variação da densidade do biovolume zooplanctônico (mL.100m^{-3}), ovos de Engraulidae (n°.100m^{-3}), ovos de outras famílias (n°.100m^{-3}) e larvas de peixes (n°.100m^{-3}) para os pontos amostrais no período entre abril de 2004 e abril de 2005 (A: abril, J: julho, S: setembro, N: novembro, J: janeiro).

Na análise de agrupamento dois pontos amostrais do mês de julho não foram agrupados aos demais devido a não captura de larvas. Os demais pontos levaram a formação de três grupos (Fig. 4), distinguidos pela sazonalidade da abundância das larvas de peixes. O resultado evidenciou entre pontos amostrais e meses um gradiente de época mais fria e seca (com baixa abundância de larvas) para época caracterizada por meses mais quentes e úmidos, nos quais foram obtidas as maiores abundâncias de larvas e também o maior número de *taxa* (Fig. 4).

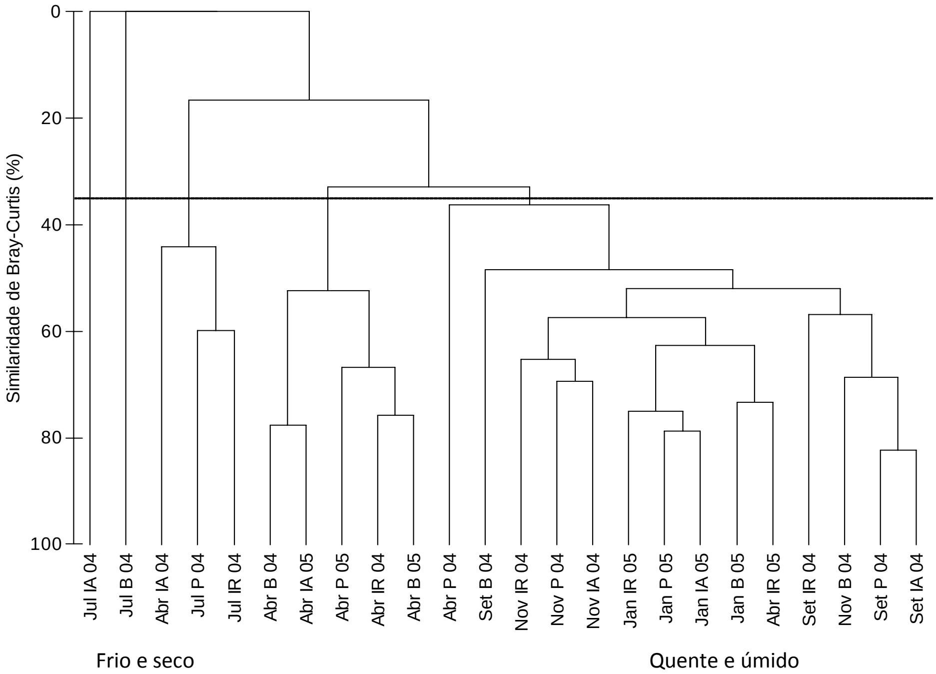

Figura 4. Dendograma de similaridades entre as amostras coletadas na baía da Babitonga nos meses de Abril (Abr), Julho (Jul), Setembro (Set) e Novembro (Nov) de 2004 e Janeiro (Jan) e Abril (Abr) de 2005. As amostras foram agrupadas pela similaridade de Bray-Curtis e método de agrupamento UPGMA sobre a matriz de densidades de larvas transformadas em Log (x+1).

Discussão

O registro de temperatura exibiu homogeneidade entre os pontos, sem diferenças significativas ($p<0,05$), porém entre os meses observou-se variação significativa ($p<0,05$). Os resultados indicaram a importância da variação temporal da temperatura na área de estudo e a ocorrência de dois períodos distintos ao longo do ano. Em estudo pretérito os resultados para estas variáveis físicas e químicas foram semelhantes e o estuário classificado como homogêneo, ou seja, sem a ocorrência de gradientes verticais físico-químicos significativos (IBAMA 1998). A variação com tendência inversa da temperatura com a salinidade está relacionada ao balanço hídrico anual na área da baía da Babitonga, ou seja, principalmente pela sazonalidade das chuvas.

A distribuição espaço-temporal do zooplâncton tem forte relação com muitas das propriedades físicas e químicas de um estuário (Lopes 1996, Zucon & Loyola-e-Silva 1993). O biovolume de zooplâncton ocorreu em densidades mais elevadas de julho a janeiro, em paralelo ao aumento observado das densidades de ovos e larvas de peixe. No entanto a maior elevação do biovolume ocorreu em julho, principalmente em decorrência da grande quantidade de gelatinosos observada nas amostras do presente estudo. Segundo Freitas & Muelbert (2004) esta elevação do biovolume em paralelo a do ictioplâncton estaria estrategicamente ligada a maior disponibilidade de alimento para as larvas de peixe geradas. Fatores ambientais como luz, temperatura, salinidade e pressão, e fatores biológicos como concentração de alimento, apresentam importantes gradientes espaço-temporais. Estes gradientes justificam o comportamento de organismos planctônicos que realizam migrações diárias, proporcionando desta forma importantes variações no volume do plâncton no decorrer do tempo (Lopes 2006).

A baía da Babitonga está inserida em uma região com evidente sazonalidade, o que proporciona grande variação nas densidades do ictioplâncton ao longo do tempo. Este fato fica evidente ao observar coletas com maiores densidades nos meses de primavera e de início do verão em comparação com as demais estações. Macedo-Soares *et al*. (2009) registraram padrão semelhante na laguna de Ibiraquera e Muelbert & Weiss (1991) para o estuário da Laguna dos Patos, sendo que os autores associaram à variação sazonal da temperatura. A temperatura é uma importante variável ambiental que além de influenciar a distribuição sazonal do ictioplâncton, pode controlar a taxa de crescimento larval (Hakala *et al*. 2003).

A composição de assembléias larvais em águas costeiras pode ser relacionada com o regime das correntes locais, os tipos de habitats e as massas d'água que ocorrem em uma região (Vélez *et al*. 2005). Os mesmos autores, Weiss & Krug (1977) e Castello & Krug (1978), sugerem para baías estuarinas que as larvas em pré-flexão refletem os padrões espaciais, temporais e as localidades de desova dos adultos, sendo que nas áreas onde as larvas de peixes eram predominantemente espécies residentes, teriam sido retidas pelo padrão de circulação interno destas baías e pelo comportamento larval. O mesmo padrão foi encontrado na baía da Babitonga para espécies residentes como *L. grossidens*, uma vez que houve maior abundância destas larvas nos dois pontos mais internos (predominantemente em pré-flexão), indicando que são retidas neste ambiente devido à dinâmica do sistema e por sua própria ecologia, além destas áreas serem propícias ao desenvolvimento. Esta constatação permite sugerir em estudos futuros, envolvendo diferentes amostradores, a análise espaço-temporal detalhada de classes de tamanhos e sub-estágios do ictioplâncton na baía da Babitonga.

A estrutura da assembléia ictioplanctônica indica resultar da combinação da seleção do local de desova pelos adultos, processos físicos e adaptações biológicas das larvas em relação a estes processos (Powles *et al*. 1984). Quando se compara as assembléias de larvas de peixes em regiões estuarinas deve ser levada em conta a metodologia empregada, esforço amostral, a extensão dos corpos de água e as condições ambientais (Barletta-Bergan *et al*. 2002). O método empregado no presente estudo, conforme esperado de acordo com outros autores (Johnson & Morse 1994, Chute & Turner 2001), proporcionou a captura proporcionalmente maior de menores larvas (estágios mais iniciais) e permitiu a análise comparativa de sua distribuição em relação às prováveis áreas de desovas dos adultos conforme Vélez *et al*. (2005), Weiss & Krug (1977) e Castello & Krug (1978). Este fato, associado a elevadas densidades de ovos nas ilhas do Araújo e da Rita, evidenciou a importância da área mais interna da baía da Babitonga como sítio de desovas de componentes da assembléia de peixes, especialmente daqueles registrados no presente estudo (Tabela II, Fig. 3).

Vásquez-Yeomans & Richards (1999) encontraram Engraulidae, Gobiidae e Carangidae entre as dez famílias dominantes para a baía de Ascensión. Castro *et al*. (2005) registraram em grande abundância Engraulidae, Clupeidae, Sciaenidae, Blenniidae e Gobiidae na baía de Guanabara. Em comparação, excluindo-se Clupeidae que deve ser resultado de uma maior proximidade com o mar no referido estudo, as demais famílias estiveram também entre as mais abundantes na baía da Babitonga (Tabela I). Na baía da Guanabara, as famílias de larvas de peixes pelágicos foram as mais abundantes, com dominância de Engraulidae (Castro *et al*. 2005). No presente estudo a mais abundante foi Engraulidae, representada por *L. grossidens*, o qual foi o principal representante pelágico encontrado e o único componente registrado desta família. Os engraulídeos são pequenos, primariamente peixes planctófagos, recrutam em águas costeiras e produzem ovos planctônicos (Moser 1996), sendo que a maioria das espécies possui larvas pelágicas (Richards 2006). As larvas de *L. grossidens* preferem águas rasas e de menor salinidade, condição encontrada em estuários. Na laguna dos Patos os ovos ocorrem durante todo o ano, principalmente na primavera e verão, desovados em águas costeiras e transportados para a laguna (Weiss & Krug 1977). Esta espécie se desenvolve e cresce neste estuário até a fase de juvenil, quando as larvas se encontram em áreas mais internas da laguna devido a características favoráveis ao término da metamorfose (Weiss & Krug 1977). As larvas desta espécie são mais abundantes em águas de menor salinidade e altas temperaturas, os autores complementam ainda que no caso de larvas com tamanho inferior a vinte milímetros a abundância decresce em direção a altas salinidades e baixas temperaturas (Castello & Krug 1978).

A abundância e ampla distribuição espaço-temporal de estágios iniciais de sciaenídeos registrada no presente estudo ressaltam a importância da baía da Babitonga como criadouro de peixes importantes para a pesca. Sciaenidae compreende espécies que habitam ambientes tropicais-temperados marinhos, salobros e de água doce, com integrantes de grande importância comercial (Moser 1996). Muitas espécies desta família usam os estuários como berçários, que devido às suas características aumentam as taxas de sobrevivência, de alimentação e de crescimento, onde sazonalmente dominam o nécton (Sardiña & Carzola 2005).

Tabela II. Lista taxonômica e densidade em 100m³ dos *taxa* obtidos para as larvas no canal principal da baía da Babitonga (SC) por mês de coleta em cada ponto amostral (B: barra, P: porto, IA: ilha do Araújo e IR: ilha da Rita).

Taxa	Abril 2004				Julho 2004				Setembro 2004				Novembro 2004				Janeiro 2005				Abril 2005			
	B	P	IA	IR	B	P	IA	IR	B	P	IA	IR	B	P	IA	IR	B	P	IA	IR	B	P	IA	IR
Lycengraulis grossidens	-	113,0	-	76,2	-	-	-	-	5,5	185,6	194,6	8,8	400,1	514,4	3635,3	144,8	-	82,1	47,0	69,8	-	-	-	6,5
Gobiesocidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,3	-	-	-	-	-	-	-	-
Carangidae	-	508,7	-	-	-	-	-	-	5,5	-	-	8,8	-	8,1	-	26,8	-	-	18,8	13,9	-	-	-	-
Trachurus lathami	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43,6	-	-	-	-	-	-	-	-	-
Haemulidae	71,2	-	-	76,2	-	-	-	-	27,8	25,3	7,7	70,8	85,7	16,3	21,8	59,0	115,5	45,6	56,4	27,9	186,6	72,9	54,1	45,8
Orthopristis ruber	-	-	-	-	-	-	-	-	-	-	-	-	9,5	-	-	5,3	-	-	-	-	-	-	-	-
Sparidae	-	-	-	-	-	-	-	-	-	67,4	93,4	70,8	38,1	16,3	32,7	-	-	-	-	-	-	-	-	-
Sciaenidae	-	-	-	-	-	9,2	-	-	33,3	194,0	381,5	168,1	209,5	179,6	1441,0	880,0	22,0	82,1	28,2	13,9	-	-	6,7	19,6
Bairdiella ronchus	-	-	-	-	-	-	-	-	-	-	-	-	-	73,4	534,9	305,8	22,0	27,3	75,4	125,7	-	-	-	13,1
Cynoscion sp.	-	56,5	-	-	-	-	-	-	-	101,2	171,3	-	57,1	-	54,5	-	-	27,3	-	69,8	-	6,6	-	-
Umbrina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	8,1	54,5	-	-	27,3	9,4	-	-	-	-	19,6
Stellifer sp.	-	56,5	-	-	-	-	-	-	-	-	15,5	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10,7	-	-	-	-	-	-	-	-
Pogonias cromis	-	-	-	-	-	-	-	-	-	-	7,7	-	-	-	-	-	-	-	-	-	-	-	-	-
Micropogonias furnieri	-	-	-	-	-	-	-	-	-	-	-	-	-	8,1	-	-	-	-	-	-	-	-	-	-
Kyphosus sp.	-	-	-	-	-	-	-	-	-	16,8	15,5	-	-	-	-	-	-	-	-	-	-	-	-	-
Mugilidae	-	-	-	-	-	-	-	-	-	-	7,7	8,8	9,5	-	109,1	375,6	-	-	-	-	-	-	-	6,5
Mugil curema (gaimardianus)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,5	-	-	-	-	-	-	-
Blenniidae	-	-	54,9	-	-	18,4	-	8,5	11,1	-	7,7	-	9,5	32,6	10,9	32,1	27,5	18,2	-	-	-	-	-	45,8
Gobiidae	-	56,5	54,9	228,6	-	-	-	-	5,5	278,4	155,7	44,2	19,0	16,3	32,7	37,5	121,0	255,5	310,2	111,8	120,7	13,2	-	124,5
Sphyraena sp.	-	-	-	-	-	-	-	-	-	-	-	17,7	-	-	-	32,1	-	-	-	-	-	-	-	-
Citharichthys sp.	-	-	-	-	-	-	-	-	22,2	-	-	-	9,5	-	-	-	-	-	-	-	-	-	-	-
Etropus sp.	-	-	-	-	-	-	-	-	-	-	-	-	9,5	-	-	-	-	-	-	-	-	-	-	-
Achirus sp.	-	-	-	-	-	-	-	-	-	-	-	-	9,5	16,3	10,9	16,0	5,5	-	-	27,9	-	-	-	-
Sphoeroides sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,1	9,4	13,9	-	-	-	-

Foram registradas larvas de *Cynoscion* sp., *Menticirrhus* sp., *Stellifer* sp., *M. furnieri*, , *B. ronchus*, *Umbrina* sp., e *P. cromis*. Sinque (1980) em seu trabalho com larvas de Sciaenidae na região estuarino-lagunar de Cananéia registrou a presença em menores densidades dos 3 primeiros citados acima e maior para *M. furnieri*, entretanto para todos os quatro a ocorrência ao longo do ano foi correlata para épocas mais quentes. Gêneros como *Cynoscion*, *Pogonias*, *Micropogonias* e *Menticirrhus* possuem importância comercial e recreacional (Ditty 1989, Ibama 1998). Na pesca artesanal realizada na área e adjacências da baía da Babitonga um item muito capturado é *B. ronchus*, a qual foi a mais representativa dentre as larvas registradas. Neste gênero os adultos e juvenis são usualmente encontrados em baías, nos fundos lodosos e arenosos, e a desova ocorre preferencialmente em estuários (Johnson 1978). Além de Sciaenidae, muitos dos organismos identificados são descritos como freqüentes nas capturas da pesca na área de estudo (IBAMA 1998), principalmente os vários exemplos de importância para a categoria artesanal (*e.g.*: *Mugil curema*, *Citharichthys* sp., *Sphoeroides* sp. e outros)

O número de *taxa* identificados para a baía da Babitonga evidencia sua importância como criadouro de muitos componentes da assembléia de peixes, fato também registrado por vários outros autores em diversos sistemas estuarinos brasileiros (Muelbert & Weiss 1991, Barletta-Bergan *et al*. 2002, Joyeux *et al*. 2004, Castro *et al*. 2005, Bonecker *et al*. 2007, Coser 2007, Bonecker *et al*. 2009, Macedo-Soares *et al*. 2009).

No presente estudo foi registrada a ocorrência de ovos e larvas de peixes em todo o canal e em todos os meses amostrados, principalmente na primavera e verão, o que indica que este ambiente estuarino representa uma área de desova e crescimento larval para estes organismos. A alta abundância, variedade e diferentes estágios de peixes observados no ictioplâncton reforçam o importante papel de criadouro da baía da Babitonga, a necessidade de propostas para sua conservação e a sugestão de mais estudos.

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Referências Bibliográficas

Able, K. W. 1978. Ichthyoplankton of the St. Lawrence Estuary: Composition, Distribution and Abundance. **Journal of the Fisheries Research Board of Canada**, 35: 1518-1531.

Andreata, J. V., Pinet, J. A. X. & Soares, C. L. 1998. Composição e distribuição espacial do ictioplâncton da laguna de Jacarepaguá, Rio de Janeiro, Brasil. **Boletim do Laboratório de Hidrobiologia**, 11: 42-52.

Barletta-Bergan, A., Barletta, M. & Saint-Paul, U. 2002. Structure and Seasonal of larval fish in the Caeté river estuary in North Brazil. **Estuaries, Coastal and Shelf**, 54: 193-206.

Bonecker, A. C. T., Castro, M. S., Namiki, C. A. P., Bonecker, F. T. & Barros, F. B. A G. 2007. Larval fish composition of a tropical estuary in northern Brazil (2º18’-2º47’S/044º20’-044º25’W) during the dry season. **Pan-American Journal of Aquatic Sciences**, 2(3): 235-241. Disponível em: http://www.panamjas.org/pdf_artigos/PANAMJAS_2(3)_235-241.pdf.

Bonecker, F. T., Castro, M. S. & Bonecker, A. C. T. 2009. Larval fish assemblage in a tropical estuary in relation to tidal cycles, day/night and seasonal variations. **Pan-American Journal of Aquatic Sciences**, 4(2): 238-245. Disponível em: http://www.panamjas.org/pdf_artigos/PANAMJAS_4(2)_239-246.pdf.

Castello, J. P. & Krug, L. C. 1978. Distribution, growth and spawning groups of the manjuba (*Lycengraulis grossidens*) in the estuary of the lagoa dos Patos – Rio Grande do Sul – Brazil. **Atlântica**, 3: 33-46.

Castro, M. S. & Bonecker, A. C. T. 1996. Ocorrência de larvas de peixe no sistema estuarino do rio Mucuri. **Arquivos de Biologia e Tecnologia**, 39(1): 171-185.

Castro, M. S., Bonecker, A. C. T. & Valentin, J. L. 2005. Seasonal variation in fish larvae at the entrance of Guanabara Bay, Brazil. **Brazilian Archives of Biology and Technology**, 48(1): 121-128.

Chute, A. S. & Turner, J. T. 2001. Plankton studies in Buzzards Bay, Massachusetts, USA. V. Ichthyoplankton, 1987 to 1993. **Marine Ecology Progress Series,** 224: 45-54.

Clark, K. R. & Warwick, R. M. 1994. **Change in marine communities: An approach to statistical analysis and interpretation**. [S.I.]:

Plymouth Marine Laboratory, Plymouth, England. 147p.

Colton, J. B. & Marak, R. R. 1969. **Guide for Identifying the Common Planktonic Fish Eggs and Larvae of Continental Shelf Waters, Cape Sable to Block Island**. Bureau of Comercial Fisheries. Woods Hole Oceanographic Institution, Woods Hole. 43 p.

Coser, L. M., Pereira, B. B. & Joyeux, J. C. 2007. Descrição da comunidade ictioplanctônica e sua distribuição no estuário dos rios Piraquê-Açu e Piraquê-Mirim, ES, Brasil. **Interciencia**, 32(4): 233-241.

Cremer, M. J., Morales, P. R. D. & Oliveira, T. M. N. 2006. **Diagnóstico ambiental da baía da Babitonga**. UNIVILLE/Joinville. 256 p.

Cuartas, A., Rosas, J., Velásquez, A. & Cabrera, T. 2003. Inducción al desove, desarrollo embrionário y larval del corocoro rayao *Haemulon bonariense* Cuvier, 1830 (Pisces: Haemulidae). **Revista de Biologia Marina y Oceanografía**, 38(1): 27-37.

Cunha, S. R., Nascimento, J., Lima, G. B., Zacharjasiewick, G., Crestani, D. E. V., Mafra Jr., L. L., Pazeto, F. D., Sant'Ana, F. & Costa, C. F. B. 1999. Distribuição e biomassa de macroalgas em um manguezal da baía da Babitonga, SC: Resultados preliminares. **Notas técnicas da FACIMAR**, 3: 1-15.

Ditty, J. G. 1989. Separating early larvae of Sciaenids from the western North Atlantic: a review and comparison of larvae off Louisiana and Atlantic coast of the U.S. **Bulletin of Marine Science**, 44(3): 1083-1105.

Fahay, M. P. 1983. **Guide to the early stages of marine fishes occuring in the western north atlantic ocean, Cape Hatteras to the Southern Scotian Shelf**. Journal Northwest Atlantic Fisheries Science, (4). 423 p.

Freitas, D. M. & Muelbert, J. H. 2004. Ichthyoplankton distribution and abundance off Southeastern and Southern Brazil. **Brazilian Archives of Biology and Technology**, 47(4): 601-612.

Fujita, S., Kinoshita, I., Takahashi. I. & Azuma, K. 2002. Species composition and seasonal occurrence of fish larvae and juveniles in Shimanto Estuary, Japan. **Fisheries Science**, 68: 364-370.

Hakala, T., Viitasalo, M., Rita, H., Aro, E., Flinkman, J. & Vuorinen, I. 2003. Temporal and spatial variation in the growth rates of baltic herring (*Clupea harengus membras* L.) larvae during summer. **Marine Biology**, 142: 25-33.

Ibama. 1998. **Proteção e controle de ecossistemas costeiros manguezal da baía da Babitonga**. Instituto Brasileiro do Meio Ambiente. Coleção Meio Ambiente. Série Estudo Pesca, n°25. Brasília. 145 p.

Johnson, G. D. 1978. **Development of fishes of the Atlantic Bight. An atlas of egg, larval, and juvenile stages. IV. Carangidae trought Ephipiidae**. U.S. Department of the Interior, Fish and Wildlife Service, Biological Services Program. FWS/OBS-78/12 314 p.

Johnson, D. L. & Morse, W. W. 1994. Net extrusion of larval fish: correction factors for 0.333 mm *versus* 0.555mm mesh bongo nets. **NAFO Sci. Coun. Studies**, 20: 85-92.

Joyeux, J. C., Pereira, B. B. & Almeida, H. G. 2004. The flood-tide ichthyoplanktonic community at the entrance into a brazilian tropical estuary. **Journal of Plankton Research**, 26(11): 1277-1287.

Keller, A. A., Klein-MacPhee, G. & Burns, J. 1999. Abundance and distribution of ichthyoplankton in Narragansett Bay, Rhode Island, 1989-1990. **Estuaries**, 22(1): 149-163.

Knie J. L. W. 2002. **Atlas Ambiental da Região de Joinville: complexo hídrico da baía da Babitonga**. Fundação do Meio Ambiente de Santa Catarina. Joinville, Santa Catarina. 144p.

Leis, J. M. & Rennis, D. S. 1983. **The larvae of Indo-Pacific coral reef fishes. University of Hawai Press**. Hawai . 269 p.

Leis, J. M. & Trnski, T. 1989. **The larvae of Indo-Pacific Shorefishes. University of Hawai Press**. Hawai. 1º ed. 371 p.

Lopes, C. L. 2006. Variação espaço-temporal do ictioplâncton e condições oceanográficas na região de cabo Frio. **Tese de Doutorado**, Instituto Oceanográfico da Universidade de São Paulo, São Paulo, 226p.

Lopes, R. M. 1996. Hydrography and zooplankton community structure: a comparative study among estuaries of the Juréia-Itatins ecological station (Southeastern Brazil). **Nerítica**, 10: 27-40.

López, P., Rosas, J., Velásquez, A., Cabrera, T. & Manera, C. 2002. Desarrollo embrionario y larvae del bobo *Diplectrum radiale* Quoy y Gaimard, 1824 (Pises: Serranidae). **Revista de Biología Marina y Oceanografia**, 37(2): 127-137.

Macedo-Soares, L. C. P., Birolo, A. B. & Freire, A. S. 2009. Spatial and temporal distribution of fish eggs and larvae in a subtropical coastal lagoon, Santa Catarina State, Brazil. **Neotropical Ichthyology**, 7(2): 231-240.

Mafalda Jr., P. O. & Silva, V. R. F. 1996. Caracterização do ictioplâncton do sistema estuarino-lagunar de Jequiá, Alagoas. **Boletim de Estudos em Ciências do Mar,** 9: 89-104.

Mafalda Jr., P. O., Sinque, C., Muelbert, J. H. & Souza, C. S. 2004. Distribuição e abundância do ictioplâncton na costa norte da Bahia, Brasil. **Tropical Oceanography**, 32(1): 68-88.

Mann, K. H. & Lazier, J. R. N. 1996. **Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans**. Blackwell Science. Massachusetts. 394 p.

Mata, E., Rosas, J., Velásquez, A. & Cabrera, T. 2004. Inducción hormonal al desove y descripción larval del corocoro *Orthopristis ruber* Cuvier (Pisces: Haemulidae). **Revista de Biologia Marina y Oceanografia**, 39(1): 21-29.

Matsuura, Y. & Nakatani, K. 1979. Ocorrências de larvas e jovens de peixes na ilha de Anchieta (SP), com algumas anotações sobre a morfologia da castanha, *Umbrina coroides* CUVIER, 1830. **Boletim do Instituto Oceanográfico**, 28(1): 165-183.

Matsuura, Y. & Nakatani, K. 1980. Variability in quantity of zooplankton, fish eggs and larvae associated with two different mesh size in bongo nets. **Atlântica**, 4:43-52.

Matsuura, Y. & Suzuki, K. 1997. Larval development of two species of barracuda, *Sphyraena guachancho* and *S. tome* (TELEOSTEI: Sphyraenidae), from southeastern Brazil. **Ichthyological Research**, 369-378.

Moser, H. G. 1996. **The early stages of fishes in the California Current Region. California Cooperative Ocean Fisheries Investigations (CALCOFI)**. ATLAS N° 33. Allen Press, Inc., Lawrence, Kansas, USA. XII + 1505 p.

Muelbert, J. H. & Weiss, G. 1991. Abundance and distribution of fish larvae in the channel area of the Patos Lagoon Estuary, Brazil. **In: Larval fish recruitment and research in the Americas: proceedings of the 13° annual fish conference**. México. 43-54.

Navarro-Rodriguez, M. C., Guevara, L. F. G., Flores-Vargas, R., Ruelas, M. E. G. & González, F. M. C. 2006. Composición y variabilidad del ictioplancton de la laguna El Quelele, Nayarit, México. **Revista de Biología Marina y Oceanografia**, 41(1): 35-43.

Ortíz-Galindo, J. L., Matus-Nivón, E., Ramírez-Sevilla, R. & González-Acosta, B. 1990. Embrión, larva y prejuvenil del sol mexicano *Achirus mazatlanus* (Pisces: Soleidae). **Revista de Biologia Tropical**, 38(2A): 195-204.

Pérez-Ruzafa, A., Quispe-Becerra, J. I., García-Charton, J. A. & Marcos, C. 2004. Composition, structure and distribution of the ichthyoplankton in a Mediterranean coastal lagoon. **Journal of Fish Biology**, 64: 202-218.

Powles, H., Auger, F. & Fitzgerald, G. J. 1984. Nearshore ichthyoplankton of a north temperate estuary. **Canadian Journal of Fisheries and Aquatic Sciences**, 41: 1653-1662.

Ré, P. M. A. B. 1999. **Ictioplâncton estuarino da península Ibérica (Guia de Identificação dos ovos e estados larvares planctônicos)**. Lisboa. 141 p.

Richards, W. J. 2006. **Early Stages of Atlantic Fishes. An Identification Guide for the Western Central North Atlantic**. CRC / Taylor & Francis. 2v. 2640p.

Russell, F. S. 1976. **The Eggs and Planktonic Stages of British Marine Fishes**. Academic Press. London. 524 p.

Sardiña, P. & Carzola, A. C. L. 2005. Feeding habits of the juvenile striped weakfish, *Cynoscion guatucupa* Cuvier 1830, in Bahía Blanca estuary (Argentina): seasonal and ontogenetic changes. **Hydrobiologia**, 532: 23-38.

Sinque, C. 1980. Larvas de Sciaenidae (Teleostei) identificadas na região estuarino-lagunar de Cananéia. **Boletim de Zoologia**, 5: 39-77.

Sinque, C. & Yamanaka, N. 1982. Fish eggs and larvae survey of Cananéia estuary, São Paulo-Brazil. **Brazilian Arquives of Biology and Technology**, 25(3/4):301-311.

Soares, C. L., Andreata, J. V. & Marca, A. G. 1991. Composição e sazonalidade do ictioplâncton da laguna de Marapendi, Rio de Janeiro, Brasil. **Biotemas**, 4(2): 35-49.

Souza-Conceição, J. M., Rodrigues-Ribeiro, M. & Castro-Silva, M. 2005. Dinâmica populacional, biologia reprodutiva e o ictioplâncton de *Cetengraulis edentulus* Cuvier (Pisces, Clupeiformes, Engraulidae) na enseada do Saco dos Limões, Florianópolis, Santa Catarina, Brasil. **Revista Brasileira de Zoologia**, 22(4): 953-961.

Souza-Conceição, J. M. 2008. Praias estuarinas como habitat de criação para estágios iniciais de peixes na ilha de São Francisco do Sul (baía da Babitonga, Santa Catarina). **Tese de Doutorado**, Universidade Federal do Paraná, Curitiba, 198p.

Thayer, G. W., Powell, A. B. & Hoss, D. E. 1999. Composition of larval, juvenile, and small adult fishes relative to changes in environmental conditions in Florida Bay. **Estuaries**, 22(2B): 518-533.

Vásquez-Yeomans, L. & Richards, W. L. 1999. Variación estacional del ictioplancton de la Bahía de la Ascensión, Reserva de la Biosfera de Sian Ka'an (1990-1994). **Revista de Biologia Tropical**, 47(Supl.1): 197-207.

Vélez, J. A., Watson, W., Arntz, W., Wolff, M. & Schnack-Schiel, S. B. 2005. Larval fish assemblages in Independencia Bay, Pisco, Peru: temporal and spatial relationships. **Marine Biology**, 147: 77–91.

Weiss, G. & Krug. L. C. 1977. Características do desenvolvimento e metamorfose de *Lycengraulis olidus* (Engraulidae) e *Brevoortia pectinata* (Clupeidae) no estuário da lagoa dos Patos, Brasil. **Atlântica**, 2(1): 83-117.

Zucon, M. H. & Loyola-e-Silva, J. 1993. Distribuição espacial de foraminíferos e tecamebas do estuário do rio Piauí, Sergipe. **Nerítica**, 7(1-2): 57-69.

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Software & Book Review Section

Poseidon Linux 3.x - The Scientific GNU/Linux option

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Abstract. This software review is about the newest version of Poseidon Linux (3.x). The current Poseidon Linux is a remastering from Ubuntu LTS family (Long Term Support), with extra specific software applicable to many areas of scientific research and education. It contains specialist software for GIS/Mapping, bathymetry, numerical modeling, 2D/3D/4D visualization, bioinformatics, chemistry, statistics, as well as tools for creating simple and complex graphics and programming languages. It also includes basic packages as would be expected on a normal desktop, such as a complete office suite, internet browser, e-mail client, instant messaging, chat, multimedia and many other tools. Poseidon Linux can run in two modes, as a live-DVD or installed on the hard disk. There are versions for 32 and 64 bit computers, and support for Brazilian Portuguese, English, Spanish, French, Greek, Italian and German languages.

Resumo. Poseidon Linux 3.x – A opção científica GNU/Linux. Esta resenha trata da nova versão do software Poseidon Linux (3.x). A versão atual é uma remasterização a partir do sistema operacional Ubuntu, família LTS (Suporte de Longo Prazo), com pacotes extras para várias áreas da ciência e educação. Contém programas específicos para SIG/mapeamento, batimetria, modelagem numérica, visualização 2D/3D/4D, bioinformática, química, estatística, bem como ferramentas para elaboração de gráficos simples e complexos e linguagem de programação. Inclui também os programas necessários encontrados num sistema operacional desktop, tais como suporte completo para escritório, navegador de internet, programas para envio e recebimento de mensagens instantâneas, multimídia e várias outras ferramentas. O Poseidon Linux pode ser utilizado de duas formas: diretamente do DVD, sem instalá-lo, ou instalando-o no disco rígido do computador. É apresentado nas versões 32 e 64 bits e pode ser totalmente configurado em Português do Brasil, Inglês, Espanhol, Francês, Grego, Italiano e Alemão.

History

The Poseidon Linux project started in Brazil, in September 2004 with the goal of building a GNU / Linux distribution for academic and scientific use. It was originally based on Knoppix/Kurumin until 2006, because of the live-CD and Portuguese language support (Ferreira et al. 2006). Three versions were publicly released then (1.2, 1.3 and 2.0). Version 2.0 (from late 2005) was extremely popular within Brazil, receiving excellent reviews from Brazilian press and it was recognized and supported by people like John "Maddog" Hall (Linux International), government institutions like the Brazilian National Spatial Research Institute (INPE – http://www.inpe.br/), among others. However, requests from scientists and students outside of Brazil pointed out the need for a version with greater language support.

By early 2008, a new version was ready. This version (3.0) was a complete redesign, based on Ubuntu 8.04 with Long Term Support – LTS (Canonical Ltd., 2008), which represents a mature Linux distribution, for the first time supporting multiple languages. This helped Poseidon Linux (3.0) to achieve a wider distribution being used in many universities and research institutes around the world. Along with the release of Poseidon Linux 3.1, a 64 bit version had also debuted, altogether with the "standard" 32 bit version.

Advantages of this GNU/Linux distribution

As it was created by young scientists for scientific use, this ensures that Poseidon Linux reflects, in most cases, the needs and wishes of this community. It contains several must-have programs for daily use at any college, school or within the laboratory (see Table I). Scientists are able to make suggestions and requests for additional bundled software or additional features by contacting the team at http://www.poseidonlinux.org. This encourages users to take an active interest in their software and should ensure that Poseidon Linux continues to improve and provide for the needs of this community.

Poseidon Linux is composed of free, and open source software (with some rare exceptions), that mean that the users are assured of the four principles of GNU General Public License or just GNU-GPL (GNU Project, 2007): freedom to run the program, for whatever purpose; freedom to study how the program works, and adapt it to their needs; freedom to redistribute copies; freedom to improve the program, and release their improvements to the public. This assures the right to employ Poseidon Linux for any kind of use: academic, professional, and of course, personal home use.

Following the trend started by Knoppix (Knopper, 2003), Poseidon Linux comes as a Live-DVD that allows the potential user to evaluate the software by running it directly from the optical drive, without installing it on to the hard-drive of his/her computer. Most of the software included runs well from the DVD, but slower than when installed on a hard-drive. If the user likes Poseidon Linux then it is highly recommended to install it on the hard-drive for maximum performance. One possibility is to install Poseidon Linux in parallel with another operating system, such as Windows or Mac OS X, and choosing which system to use from a boot-manager (included).

Being open source software, Poseidon Linux has zero cost. Within the current financial global situation, governments and academic institutions have a higher need to reduce expenditure. One option, then, is the use of open source - free software. The saving to a department in software costs becomes particularly apparent when we analysis the costs of common scientific software needed today in academic work. By using such a system as Poseidon Linux, an institution may save several thousand Euros in software costs and/or licenses. The following table (Table I) shows partially the current software included, and is also used to illustrate an estimated saving by using Poseidon Linux compared to "proprietary" software (prices may vary, but the idea is still valid).

Some real cases of Use, to exemplify the usability

GIS example. Seabed relief maps in three dimensions from off the Brazilian coast (and some oceanic islands) were produced by Ferreira et al. (2005) and Madureira and Ferreira (2007), using open source software included in Poseidon Linux (Fig. 1). The analysis and visualization was carried out using bathymetric data collected along several scientific acoustic fisheries surveys conducted between 11° and 34°S in the South Western Atlantic. Additional data was obtained from data sets made available on the Internet and used to increase the resolution showing in greater detail many undersea features. These structures were named following the guidelines of GEBCO’s Sub-Committee on Undersea Feature Names (SCUFN).

These 3D maps show a real application of open source software in Oceanography/Bathymetry. The main software used was: GMT (for filtering and grid interpolation) and GRASS (for grid manipulation and visualization in 3D). This was proven to be a robust, fast and stable combination, allowing analysis and visualization of really large data-sets.

Bioinformatic example. Poseidon Linux and its included software were used extensively by Vaz et al. (2008). Part of the work involved sequencing a specific gene from the catfish *Rhamdia quelen* (GH - growth hormone) and development of 3D models of the tertiary structure from the resulting protein (Fig. 2).

Specific software used: ClustalX: was used to align sequences of Growth Hormone (GH) gene querying obtained from Genbank; PerlPrimer: was used to design degenerated primers; Sequin: DNA Sequence Submission Tool was used for submission of the gene sequence to Genbank; PyMol Molecular Graphics System: was used to analysis 3D molecular models of proteins.

Table I. Estimated costs of proprietary software compared to some software included in Poseidon Linux.

Free Software	Proprietary Software	Estimated Price (US$)	Area
GRASS	ArcInfo + modules 3D and Spatial + ENVI + Fledermaus	30,000	GIS
SPRING	ArcEditor	10,000	GIS
QGIS / Terraview	Arcview	1,500	GIS
GMT	Surfer	600	GIS
PROJ + GDAL + OGR	ArcToolbox (in ArcGIS)		GIS
MB System	Caraibes	25,000	Bathymetry and Multibeam processing
OpenDX	BYVision	3,500	Visualization in 2D/3D/4D
Octave	Matlab + modules for finance, signal analysis and statistics	4,400	Numerical Modeling
Maxima	Mathematica	2,495	Math
R + Rcmdr + RKward	STATISTICA ADVANCED	12,120	Statistics/Math
Gperiodic	The Elements and Isotopes	300	Chemistry
GPSDrive and GPSMan	Microsoft MAPPOINT GPS 2009	343.19	GPS maping
Dia	MS Visio Professional 7	559.95	Diagram
QTIPlot	OriginPro 8	1,875	Graphics
Lyx or Kile	Scientific Word	875	Professional Typesetting
GChemPaint	Symyx Draw	777	Draw Chemical Molecules
Fityk	PeakFit	575	Curve Fitting
QCAD or SAGCAD	AutoCAD LT	900	CAD/Engineering

Table I. Estimated costs of proprietary software compared to some software included in Poseidon Linux (continued).

Free Software	Proprietary Software	Estimated Price (US$)	Area
Virtualbox	Vmware	189	Desktop Virtualization
Blender	Maya or 3D Studio	3,500	Computer Graphics and Animation
Audacity	Sound Forge	300	Multimedia
PostegreSQL or MySQL	Oracle 10g (Enterprise)	40,000	Database
PostGIS	ArcSDE	1,800	Database for GIS
GCC	Intel C Compiler	400	Programing
G77	Intel FORTRAN Compiler	700	Programing
ClustalX, NCBI Tools, TreePuzzle, TreeView, and others	Vector NTI Advance + Sequence Analysis Software Ruo	4,800 + 10,000	Bioinformatic
Cn3D	Hyperchem	1,494	Bioinformatic
Softwares for a normal desktop (internet, mail,office, etc)	Windows, Antivirus, Office, Corel Draw, Photoshop, DVD, CD Burner, Firewall, PDF, HTML, Publishing, etc...	15,000	Softwares for Workstation
MapServer	ArcIMS	10,000	Webmapping
	TOTAL (in US$)	**168,859.95**	**For 1 license of each proprietary software**

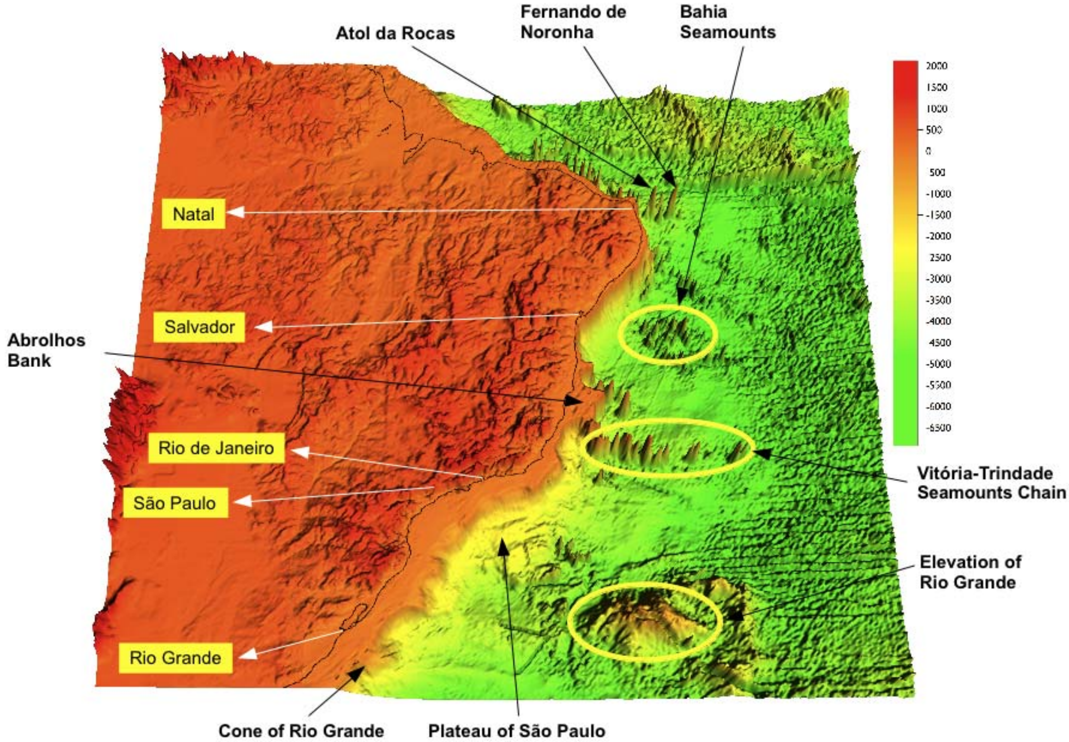

Figure 1. Map from the South Brazilian coast (Ferreira *et al.* 2005).

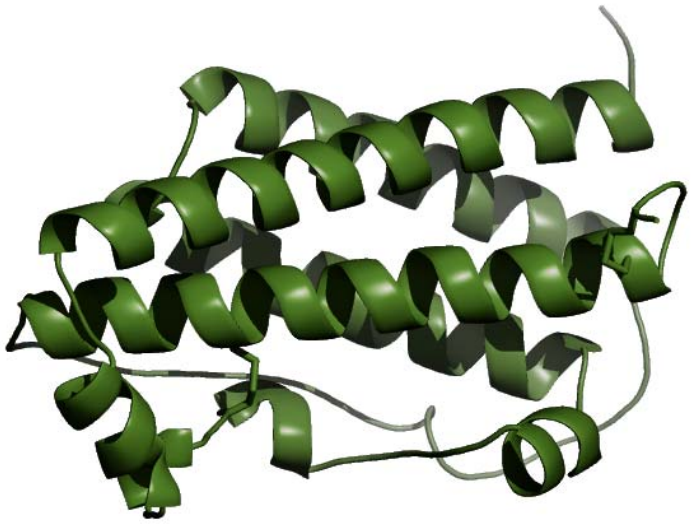

Figure 2. 3D model from *Rhamdia quelen* Growth Hormone (two disulfide bonds in detail) performed - from modeling to drawing - under Poseidon Linux.

Conclusions and Remarks

The philosophy behind Poseidon Linux is the same as mainstream science: free access to new technologies and the freedom to exchange knowledge between scientists and the general public. This allows people from developed to developing countries to have the same access to high quality scientific software.

Born out of a local effort (in Brazil), to initiate and encourage the use of high quality free software for academic and scientific purposes, Poseidon Linux has evolved and gone far beyond the original aims of the project. Even when there was only a single Portuguese language website, it scored the millionth access hit in 2006 (after only two years of existence), with hits recorded from all over the world. Today's version 3.1 has support for 7 languages and websites in three languages (check http://www.poseidonlinux.org/). Poseidon Linux has confirmed users in North and South America, several countries in Europe, and Asia. Many of these users are using Poseidon Linux as their main tools and operating system for scientific computing.

With these facts in hand, we can conclude that Poseidon Linux has filled an existing gap to provide scientists an alternative to proprietary software and proprietary operating systems (like MS Windows, Mac OS X and UNIX). But Poseidon Linux is not just for scientists; it offers a stable, mature and secure platform for everyday computing. Being Open Source software it offers the student high quality software of the same standard as the academic department they are studying without undue financial burden. Also, for the home user, it offers all the ordinary software for communication, internet, multimedia experience, production packages, and even some games. For more advanced users, it may be a chance to study and improve the tools, since the source code is readily available, and a chance to take open source tools to new and unexplored areas of science and knowledge. Finally the Poseidon Linux team sees it as a solution to avoid the use of pirate software, and all the potential problems that this causes to the academic world.

Poseidon Linux can be downloaded from: http://g3pd.ufpel.edu.br/mirrors/poseidon/

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References

Canonical Ltd. 2008. **Ubuntu Home Page**. World Wide Web eletronic publication, accessible at http://www.ubuntu.com. Accessed 18/08/2009.

Ferreira, C. S., Madureira, L. S., Klippel, S., Weigert, S., Habiaga, R. G. P. & Duvoisin, A. C. 2005. **Mapas do Relevo marinho das regiões sudeste, sul e central do Brasil: acústica e altimetria. Série documentos REVIZEE: Score Sul. São Paulo**. 40p. ISBN 85-98729-10-8. Also accessible at: http://www.mma.gov.br/estruturas/revizee/_arquivos/revizee_relevo.pdf

Ferreira, C. dos S., Velasco, G., Vaz, B. dos S., Albergone, E. H. & Hellebrandt, D. 2006. Poseidon Linux – uma distribuição Linux voltada para público acadêmico e científico. **PanamJAS**, 1(2): III-VI. ISSN 1809-9009. Available at http://www.panamjas.org/published.php

GNU Project. 2007. **GNU General Public License**. World Wide Web eletronic publication, accessible at http://www.gnu.org/copyleft/gpl.html. (Acessed 18/08/2009).

Knopper, K. 2003. **Knoppix Linux Live CD**. World Wide Web eletronic publication, accessible at http://www.knoppix.org. (Accessed 18/08/2009).

Madureira, L. S. & Ferreira, C. S. 2008. **Mapa 3D da costa brasileira e ilhas oceânicas**. Atlas National Geografic, v.2: 91-92, São Paulo, ISBN 978-85-364-0391-5.

Vaz, B. S., Cerqueira, G.M., Moreira, C.G.A., Manzke, V.H.B., Andre, J.S. & Moreira, H.L.M. 2006. *Rhamdia quelen* growth hormone precursor (gh) gene, complete cds. **GenBank®: NIH genetic sequence database.** Wide Web eletronic publication, accessible at http://www.ncbi.nlm.nih.gov/entrez/viewer.fcgi?db=nuccore&id=118498502. (Accessed 18/08/2009).


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