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Fisheries of *Anomalocardia brasiliana* in Tropical Estuaries

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Abstract. Tropical estuaries support a large number of people through the exploitation of natural living resources based on traditional knowledge. This has been the only responsible for resource conservation. Molluscs were the first marine living resource to be used worldwide due to its easy collection, and are still heavily exploited. *Anomalocardia brasiliana* occurs along a wide latitudinal range of the Western Atlantic Ocean and Caribbean (16ºN-33ºS), and is the basis of traditional economies, supporting hundreds of thousands of families. Ecological and socioeconomic changes result in resource exploitation patterns of different sustainability levels. Average shell length at exploited sites is reducing with time, and falling below the ideal harvesting size (20 mm). However, population densities are increasing, giving the erroneous notion of increase in biomass. In Brazil there are marine protected areas focused on the conservation of traditional livelihoods based on the exploitation of *A. brasiliana*. But this socioeconomic and ecological resource remains poorly managed and its ecology is not considered in action plans aiming at preserving estuaries, the species and helping those who depend on it. Actions aiming at finding better uses of estuarine habitats and living resources will, ultimately benefiting other resources, estuarine diversity, productivity, integrity and life quality.

Keywords: Northeast Brazil, RESEX, traditional fisheries, natural living resources, coastal management

Resumo. Pesca da *Anomalocardia brasiliana* em estuários tropicais. Os estuários tropicais suportam um grande número de pessoas através da exploração dos recursos vivos baseado no conhecimento tradicional. Até então, este tem sido o único mecanismo responsável pela conservação dos recursos. Por sua fácil coleta, os moluscos foram os primeiros recursos marinhos vivos extraídos em todo mundo, e ainda são pesadamente explorados. *Anomalocardia brasiliana* ocorre no Oceano Atlântico Ocidental e Caribe (16ºN-33ºS), e é a base da economia tradicional, suportando centenas de milhares de famílias. Mudanças socioeconômicas e ecológicas resultam no padrão de exploração em diferentes níveis de sustentabilidade. O comprimento médio das conchas nos locais explorados tem reduzido com o tempo, e encontra-se abaixo do tamanho ideal de coleta (20 mm). No entanto, as densidades populacionais aumentam dando a errônea noção de aumento de biomassa. No Brasil, existem áreas protegidas focadas na conservação do modo de vida tradicional baseado na exploração de *A. brasiliana*. Mas este recurso permanece com poucas ações de manejo e sua ecologia não é considerada em planos de ação para preservação dos estuários, nem a espécie e nem aqueles que dependem dela. Ações encontradas apontam os melhores usos dos habitas estuarinos e recursos vivos, garantindo outros recursos, diversidade estuarina, produtividade, integridade e qualidade de vida.

Palavras chave: Nordeste do Brasil, RESEX, pesca tradicional, recurso natural vivo, gerenciamento costeiro

Introduction

Traditional and commercial exploitation of some coastal natural living resources around the world is resulting in a new tragedy of the commons (Hardin 1968). The inexistence of conservation measures, based on traditional and scientific knowledge, may accelerate the depletion and exhaustion of intertidal mollusc species. In Spain, a decade of overexploitation of *Venerupis decussate* and *Cardium edule* was responsible for the decrease of stocks of these two species (Frangoudes *et al.* 2008). In Chile and Peru stocks of commercially important species (*Argopecten purpuratus*, *Thais chocolata* and *Aulacomya ater*), were affected by fisheries, in addition to El Niño events (Urban 1994, Thatje *et al*. 2008).

Brazil and Guadeloupe present a wide and intense fisheries activity of the venerid clam *Anomalocardia brasiliana* (Mollusca; Bivalvia; Veneridae) with social and economic importance for large groups of less favoured families at tropical coastal communities of the Western Atlantic (Barletta & Costa 2009, Silva-Cavalcanti & Costa 2009, 2010a). The meat is sold, and represents the main (often the *only* and *irreplaceable*) source of monetary income for entire families, especially female centered groups (Silva-Cavalcanti & Costa 2009, 2010a). Due to its nourishing composition, *Anomalocardia brasiliana* is an important source of protein and lipids and a cultural element of Brazilian and Caribbean cuisines.

Common uses of the shell include raw material for hand crafts, building material, source of calcium carbonate for chicken feed and other industrial processes (Bispo *et al.* 2004), road pavement and house decoration (Alves *et al*. 2006). Some traditional communities still use this mollusc species for medicinal purposes. Scientifically, the animal is a potential source of heparin and histamine (Dietrich *et al*. 1985), bioindicator of water quality and pollution (Wallner-Kersanach *et al*. 1994, Kehrig *et al*. 2006, Silva *et al*. 2008) and paleo-oceanographic bioindicator for sea level and climatic changes (Angulo 1993).

This work aims at, through a literature review, to describe the state of the art of the *Anomalocardia brasiliana* fishery and identify ways of strengthening traditional livelihoods that depend on this resource. Compilation, systematization, analysis and critics of the existing information are made here as the first steps to support the planning of its use; encourage scientific research and improve decision making; guarantee the continuation of ecological services and life quality for traditional coastal populations.

Biology and Ecology of the Species – An Overview

Anomalocardia brasiliana has a smooth, shiny and thick trigonal valves. It occurs at estuaries mouths from the Caribbean to sub-tropical Brazil (Rios 1985, Monti *et al*. 1991), and was also found fossilized in Pleistocene deposits from Uruguay, where the influence of the Brazil Current on nearshore ecosystems weakens (Martínez *et al*. 2001) (Fig.1).

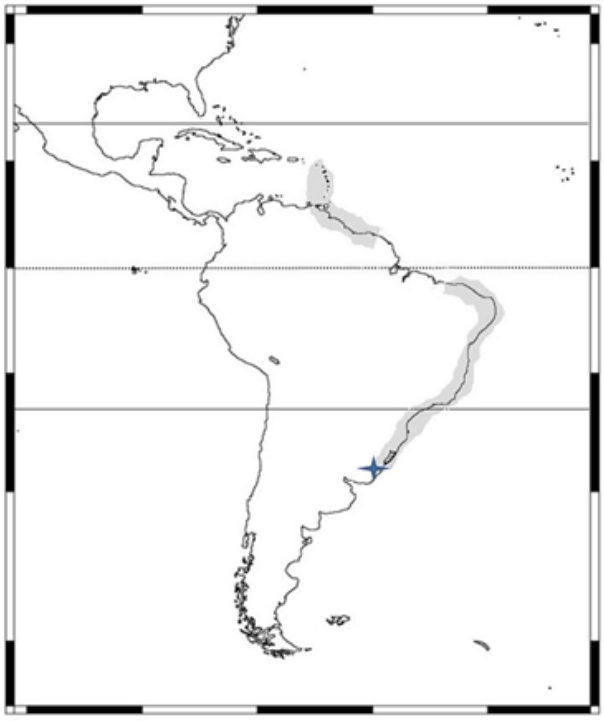

Figure 1. Present ocurrence of *Anomalocardia brasiliana*, from the Caribbean (~16^{o}N) to Sub-Tropical South America (~33^{o}S).

Length is used as the reference metrics in growth studies and for fisheries regulation purposes (Arruda-Soares *et al.* 1982, Araújo, 2001). Sexes are separate and fertilization is external. Spawning and fertilization occur along the whole year (iteroparous) (Mouëza *et al*. 1988, Barreira & Araújo 2005), with some peaks during more favourable conditions. Gonadal development can be partitioned in five stages: undifferentiated, ripening, ripe, spawning and spawned (Narchi 1976, Barreira & Araújo 2005). The first sexual maturation and formation of gametes was observed in individuals with a total length (T_L) 7-18mm at sub-tropical latitudes (Boehs 2000, Araújo 2001) and 13-18mm at tropical areas (Barreira & Araújo 2005). Periods of cold water temperature induce more frequent and/or prolonged sexual rest (Araújo 2001) **(**Table I). Larvae are

pelagic which explains high geographical genic diversity (Arruda *et al*. 2009). The larval stage is two weeks long (Mouëza *et al.* 1999). Longevity is around two to three years (Monti *et al*. 1991).

Table I. Patterns of the reproductive cycle of *Anomalocardia brasiliana* along the species latitudinal range.

	Spawning Peak	**Sexual Rest**	**Water Temperature (˚C)**	**Salinity**	**Examples**	**Source**
Equatorial	July to October and February to April	No rest	25-36	10-35	Brazilian Northeast (3-7 ˚ S)	Barreira & Araújo (2005) Araújo & Rocha-Barreira (2004); Grota & Lunetta, 1980, 1982.
Tropical	Continuous	Short	25-30	17-38	Guadeloupe (~16 ˚ N)	Monti *et al*. (1991)
Sub-Tropical	August to November and December to April	Long	15-32	25-35	Brazilian South and Southeast (23- 27 ˚ S)	Araújo (2001) Barletta & Costa (2009)

Anomalocardia brasiliana are sensitive to salinity variations and may experience high mortalities due to heavy rains (Monti *et al*. 1991, Mouëza *et al*. 1999, Estrada 2004). Populations increase during dryer periods, when juveniles settle, especially at the infra-littoral (Arruda-Soares *et al*. 1982). When salinity is lower than 22 or higher than 40, the shells remain closed for long periods. This mechanism allows, temporally, the maintenance of affordable osmotic conditions inside the locked shell when individuals are exposed to either diluted or hyper-saline environments (Leonel *et al*. 1983). Density of *A. brasiliana* populations is affected by variations of salinity. High population densities (*e.g*. 700 ind.m^{-2}) for salinity 38 are registered at Guadeloupe (Monti *et al*. 1991); 12700 ind.m^{-2} at Rio Grande do Norte under salinity 49 (Rodrigues *et al*. 2008); 2118 ind.m^{-2} (salinity 41) and 28.8 ind.m^{-2} at salinity 35 in Ceará (Araújo & Rocha-Barreira 2004) (Fig. 2a).

The species is resistant to hypoxic conditions (Arruda-Soares *et al*. 1982, Boehs *et al* 2000), being able to withstand events of acute eutrophication and recolonizing anoxic intertidal sediments as soon as they are re-exposed to oxygenated waters.

Anomalocardia brasiliana lives from the intertidal zone to a depth of 1.5 m, especially along mangrove borders. Usually it is buried in the sediment at less than 20cm deep (Mouëza *et al*. 1999). Sediment's grain size also affects its distribution (Araújo & Rocha-Barreira 2004). Areas with smaller grain sizes favour the persistence of juvenile individuals (Araújo & Rocha-Barreira 2004). Fine sands are preferred for settlement (Rodrigues *et al*. 2008) and areas with coarse sand, where the environment is harsher during low tides, are habitable only by adult individuals.

Other factor which influences the distribution of this species is the accumulation of vegetation and vegetal debris, which makes a thick decaying bed from where *A. brasiliana* is absent (Monti *et al*. 1991). The proportion of juveniles is higher in non-vegetated areas (Guiss 1995).

Spatial distribution may also be affected by spatial variability in the intensity of larval settlement and post-settlement processes, mostly predation on new settlers. Recruits and juveniles can be found in larger numbers on the upper fringes of the intertidal flats, which suggests areas of preferential settling for the larvae and eventual horizontal migration across the intertidal area with age (Boehs & Magalhães 2004). The horizontal distribution across the intertidal zone shows that all sizes, but preferably juveniles, live at the higher strata. At the lower intertidal strata mostly adults survive (Monti *et al*. 1991). Settlement on intertidal flats is probably a strategy to avoid predators and contributes to successful settling (Boehs & Magalhães 2004). Predation pressure is higher down the shore (Boehs & Magalhães 2004). At the ecosystem level, this species main functions are nutrient and trace elements cycling, calcium carbonate source, and biomass production. Natural predators of *A. brasiliana* are rays, puff-fish, herons and starfish.

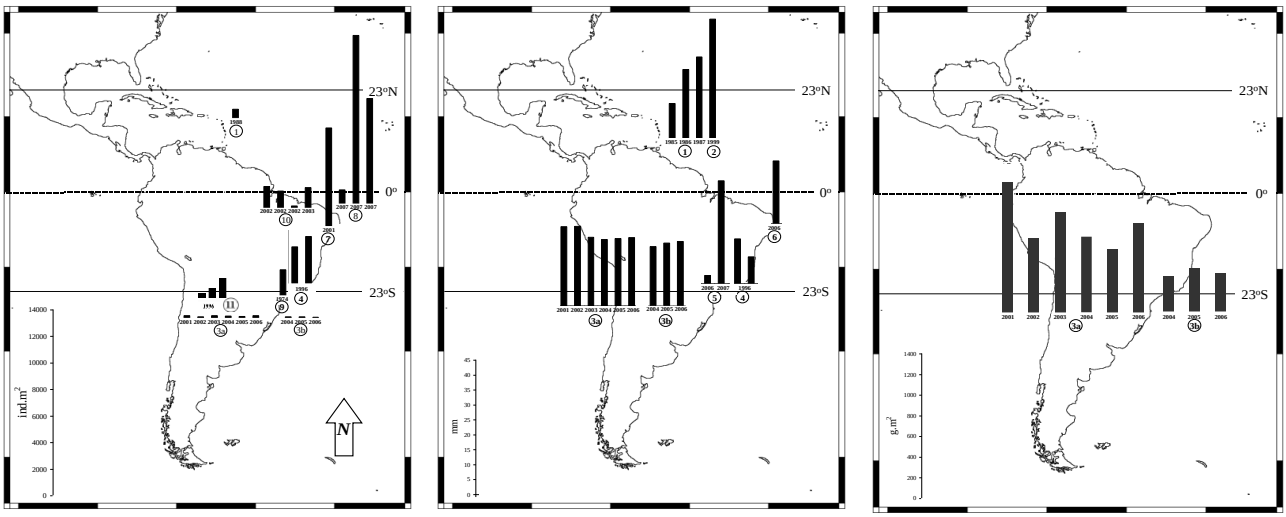

Figure 2. Distribution of *Anomalocardia brasiliana* and information on fisheries stocks available in the literature. (a) Density; (b) Shell length and (c) Biomass.Sources: 1. Monti *et al*. 1991, 2. Mouëza *et al*. 1999, 3a. Schio *et al*. 2007(Base beach), 3b. Schio *et al*. 2007 (Baixio beach), 4. Figueredo & Lavrado 2007, 5. Mattos *et al*. 2008, 6. Lima *et al*. 2007, 7. Paiva 2002, 8. Rodrigues *et al*. 2008, 9. Schaeffer-Novelli 1976, 10. Araújo & Rocha-Barreira 2004, 11. Boehs *et al*. 2008.

Traditional Explotaition of the Resource

Along the South American Atlantic coast the presence of shell middens (in Portuguese *sambaquis*) document the exploitation of estuarine bivalves (*Crassostrea rhizophorae*, *Anomalocardia brasiliana, Tagelus plebeius, Mytella falcata, M. guyanensis*, *Iphigenia brasiliana*) since thousands of years ago (Scheel-Ybert *et al*. 2003). However, the ecological and economic significance of *A. brasiliana* remains poorly understood, even where this species is an important ecological functional element in estuarine ecosystems.

The filter feeding habit of *A. brasiliana* increases the possibility of microbiological contamination (*Escherichia coli*, *Streptococcus faecalis* and *Clostridium perfrigens*). With the increase of contamination of coastal waters by sewage, there have been cases of food intoxication, which may be considered a serious problem of public health. Also, sewage might be responsible for parasitism in *A. brasiliana* (Nishida *et al*. 2006a) and in this way compromises meat quality.

Discarded shells piled up around fishers' houses, creating solid wastes, public health issues and blocking small tidal creeks, impeding tidal flow. In the past they have contributed to the formation of *sambaquis*. Some communities have arranged for wasted shells to be used in situ and/or collected by foreign traders for other uses which include raw material for hand crafts, building material, calcium carbonate for chicken feed and other industries, road pavement and house decoration.

Anomalocardia brasiliana fisheries are developed at small villages, from where the production is exported to larger urban areas. The meat, although pre-cooked, is a highly perishable product. Refrigeration is increasingly accessible in small communities, but this is still not the general case in Brazil. For the commercialization of the resource usually there is the participation of a middle-man, who exports the production from the community. The middle-man comes periodically and buys the production of a whole community (Silva-Cavalcanti & Costa 2009, 2010a). It is also possible that a local buyer centralizes the production and, a second buyer takes it to the consumers centers (Alves *et al*. 2005, Ocampo-Thomason 2006). Different levels of dependence exist in respect to these middle-people at each community, also varying along the year. Otherwise, the meat is directed to subsistence of the families.

Intense fisheries tends to increase density (ind.m^2) (Arruda-Soares *et al*. 1982, Netto & Lana 1994), but not necessarily the biomass available. Density is high due to increased recruitment, probably facilitated by excessive harvesting. In extreme cases, individuals may not reach first maturation size, then population average sizes tend to decrease with time. The quality of the meat can be compromised (unpleasant taste), since the average size is too small to be harvested and consumed (Fig. 2b).

Species of the same ecological guild have also been reported to suffer the same problem. *Venerupis decussate* in Galicia (Frangoudes *et al* 2008); *Aulacomya ater* in Chile and Peru (Urban 1994, Thatje *et al*. 2008) and; *Anadara tuberculosa, A. similis* and *A. grandi* at Ecuador (Ocampo-Thomason 2006), all present the same ecological function and socio-economic importance and have shown decrease in population average size along the years. Excessive harvesting, catch of individuals bellow maturation size, tools to increase fisheries yields used by unskilled people are sometimes pointed as a cause of changes in these molluscs populations. Several environmental factors may be responsible for the decrease and depletion of shellfish stocks (Urban 1994). However, some short term detectable changes can be attributed to human interferences. The magnitude of anthropogenic stresses leading to environmental changes can be responsible even for population extinction, due to overexploitation and habitat modification. Sewage, solid wastes (*e.g.* dredged spoils), deforestation, loss of water quality and increased sedimentation are direct and indirect threats to resource sustainability and exploitation.

Many coastal populations survive almost solely from molluscs fisheries. The activity involves the whole community, inclusive women, who are often accompanied by their children (Silva-Cavalcanti & Costa 2009, 2010a). Often they go fishing from the shore, but those who use small boats have a larger yield per tidal cycle, since they can carry larger quantities back home. These fisheries, as all estuarine uses, are strongly influenced by the tidal cycles (Alves *et al*. 2005, Nishida *et al*. 2006a, b, c). Spring tides are reported as being the most profitable time to fish *A. brasiliana* (Arruda-Soares *et al*. 1982). Tide is an increasingly important factor as one travels north along the Brazilian coast. In the South of Brazil, tidal ranges are in the order of a few centimeters, while in the north of the country it ranges around 7-8m. Knowledge of tidal rhythms is essential to guarantee the yields of the fishing effort (Alves *et al*. 2005, Nishida *et al*. 2006a, b, c). Quality and quantity of the product vary with time in short (lunar cycles) and large (seasons) time scales (Nishida *et al*. 2006b).
2004, Schio *et al*. 2007, Silva-Cavalcanti & Costa 2009, 2010a). The smallest shell length reported in the literature about *A. brasiliana* fisheries in Brazil is 10 mm (Lima *et al*. 2007) (Fig.2b).

A pilot survey at Pernambuco State showed that the majority of harvested individuals were near

Only basic equipment and some abilities, that in many cases they have learned from their parents, are needed (Ocampo-Thomason 2006, Frangoudes *et al*. 2008, Silva-Cavalcanti & Costa 2009, 2010a). There is a social hierarchy among fishers (lobster > fish > crabs > mussels), and social segregation based on the resource exploited may occur even within the community. For fisheries of other species of molluscs the predominance of women or men will depend on the target species. Traditional populations exploiting coastal resources are capable of tracing mental calendars and maps to locate more efficiently their resources (Begossi 2001, 2006, Nishida 2006a), and identify in detail each of the species they exploit.

Another important feature related to the fisheries of *A. brasiliana* and other species of molluscs is the lack of territorialism, also observed for crab gatherers. For these groups, the whole space is common. Fishermen, on the contrary, are extremely territorialists (Begossi 2001), but among these bottom strata of the traditional communities this is not observed.

This activity generates an income of U$ 0.6 to 3 per kg of clean meat, which corresponds to 8kg of total harvest. Values per kg of clean meat vary according to season, quality of product and buyer (Silva-Cavalcanti & Costa 2009, Silva-Cavalcanti & Costa 2010a). Family income is almost invariably below U$100, the Brazilian minimum wage. Women have a slightly lower income than men (Silva-Cavalcanti & Costa 2009, 2010a) and when compared with crab gatherers in the same area (Alves *et al*. 2005). Estuaries of the Brazilian Northeast have an economically important mollusc fauna; economic/social value/catch of this animal group decreases roughly in the following sequence: *Crassostrea rhizophorae* > *Lucina pectinata* > *Tagelus plebeius* > *Mytella falcata* or *M. guyanensis* > *Iphigenia brasiliana* > *Anomalocardia brasiliana*.

Over the last decade or so, traditional coastal populations in Brazil have perceived the depletion of *Anomalocardia brasiliana* through the decline in shell length (Fig. 2b). The perception that size of clams in the catch is declining is constructed along the history of the relation between the fisher and the environment. Shell length was also reported to be decreasing in the scientific literature (Nishida *et al*. the shell length of sexual differentiation. The higher frequencies of extraction are of individuals between 16 to 22mm (Fig. 3). There is no information about the sizes included in the catch in the past for this region.

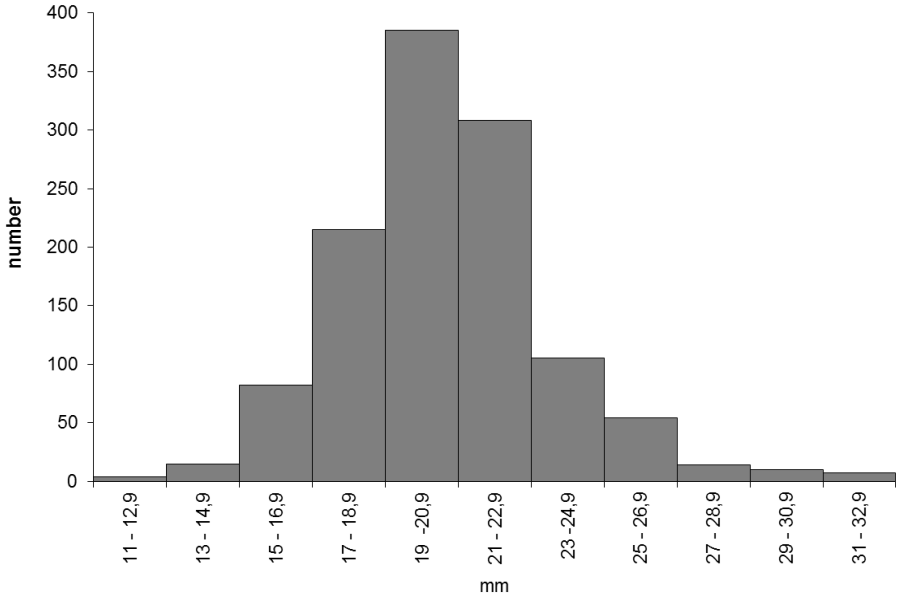

Figure 3. Shell length (mm) of *Anomalocardia brasiliana* measured at two traditional coastal communities at Pernambuco State (Northeast Brazil) (n = 1199).

In Guadeloupe, *A. brasiliana* has disappeared from most areas where it used to be fished (Mouëza *et al*. 1999). Some authors have recommended 20 mm as the minimum harvest able size for commercial purposes (Arruda-Soares *et al*. 1982, Araújo 2001). Selective gear may help improving size-selectivity. Nishida and collaborators (2006c) have described some tools used to improve the yields of benthic mollusks that include a size selection mechanism. For instance the trolley has an average selection size of 22mm ± 0.26 and 25 mm ± 0.18 with the rake. These devices do not differ greatly from handmade catches reported by the same authors (24 mm ± 0.19). Works conduced in South Brazil have shown that a mesh size of 11mm does not capture individuals with less than 21mm (Schio & Pezutto 2008).

An ideal minimum size cannot be recommended unless it is experimentally determined for each site (or at least for wide latitudinal bands) (Silva-Cavalcanti & Costa 2011). A possible conservation measure would be the use of standard equipment to easily measure shell length on site. The Brazilian Environmental Agency (IBAMA) has established minimum capture length for crustaceans (lobster, crab and prawns) and fishes based on standards (e.g. mesh size). However, no regulatory standard size is established for *A. brasiliana*, nor other mollusc species. Some fishers try to "sieve-out" the small individuals, but the process is rough and kills a large number. Besides, the "mesh" they use is not uniform, and not so frequently used to possibly contribute in species/resource conservation. But selectivity of catches is possible only where large individuals are still available (Alves *et al*. 2005).

Several measures are cited in the international literature as conservation measures of natural resources: rotation, reproductive reserves, closed season, license systems, determination of carrying capacity of the fisheries resource, daily quotas, access restrictions and size limits (Shepherd 1993, Castilla & Defeo 2001, Morsan 2007, Frangoudes *et al*. 2008). Some of these measures are exemplifyed and briefly discussed on Table II and III. A state- and research-supported co-governing system is the basis of a successful sustainable fisheries strategy (Allison & Ellis 2001, Saint-Paul 2006, Ocampo-Thomason 2006, Frangoudes *et al*. 2008).

To protect the traditional livelihood and their natural resources, Brazilian authorities created Extractive Reserves (RESEX – in Portuguese *Reserva Extrativista*) (SNUC 2000). RESEXs are considered territorial spaces destined to the exploration and renewal of natural resources by traditional populations in a sustainable way, guaranteeing the preservation of the resources for future generations (SNUC 2000). Brazil has seven Marine RESEX (www.cnpt.ibama.gov.br) and twenty other areas under consideration for new ones. The RESEX is indicated as a type of control of over-exploitation of natural marine resources. Pirajubaé (27°S; 1,444 ha; 600 families in 1992) and Acaú-Goiana (07°S; 6,680 ha; 420 families in 2007) were created as a result of a long tradition in the

exploitation of *A. brasiliana*.

At Pirajubaé RESEX the exploitation plan is based on a rotation system between two areas. Along the years the spatial distribution of *A. brasiliana* has been monitored and individual size declined (26.5 mm in 2001 to 22.9 mm in 2006), as also did biomass (Fig. 2c) (Schio *et al*. 2007). Probably overexploitation is responsible for the decrease in size of individuals, but no corrective measures were implemented (Pezzuto & Echternacht 1999; Schio *et al*. 2007). For Acaú-Goiana, no management plan has yet been decided, therefore no concrete conservation action has been taken (Silva-Cavalcanti & Costa 2010b).

An important issue about the conservation of this species is that studies about growth have not been conducted within *completely* protected areas, neither including subtidal areas which are seldom exploited. These areas may function as reproductive reserves, guaranteeing a significant part of the larvae to colonize the exploited banks when sites are under conditions of intense fisheries. These areas would serve as sowing areas, increasing the chances of fertilization and supplying larvae to other regions. However, the preservation of the species and of this sort of fisheries might depend on the creation of no-take zones that encompass the whole depth gradient (meso- and infra-littoral), even within RESEXs. In neither of the existing RESEX for *A. brasiliana* fisheries this measure has been previewed.

In Galicia some measures of conservation were responsible for decreasing the impact over *Venerupis decussate* and *Cardium edule*. Over fifty years a series of measures were established to control their exploitation. Control of exploitation was directly proportional to the rigour of the conservation measures and self-vigilance within the community. The main conservation measure was co-governance, in order to prevent internal poaching, minimum size and maximum quantity per day (Frangoudes *et al*. 2008). This allowed production control and regulation of the activity, taking into account market demands, which increased financial income (Frangoudes *et al*. 2008).

Recovery and Conservation of Anomalocardia brasiliana Stocks

Anomalocardia brasiliana exploitation in Brazil needs to be managed within and outside extractive reserves. Poor knowledge about its biology and ecology, and their seasonal and latitudinal variations, is presently a possible hindrance which can only be overcome with qualification of communities, the incorporation of traditional knowledge to formal management practices and improvement of conditions even within traditional livelihoods (Allison & Ellis 2001). Also, when other marine species are exploited and protected, the whole ecosystem diversity and productivity will also benefits from the measures taken.

One factor that may have led to the decline of *Anomalocardia brasiliana* populations to levels at which harvesting is no longer economically viable (*e.g.* Guadeloupe) was the lack of conservation measures, including the continuous exploitation of small individuals. The same may happen at sites along the Brazilian coast if, coupled to the loss of estuarine environmental quality, over exploitation is continued (*e.g.* Saubara – Bahia State and Mangue Seco – Pernambuco State). In order to promote recovery and conservation of *A. brasiliana* populations as the basis of a sustainable exploitation, there are some aspects to be considered in the management of the resource (Table III).

The coupling of traditional and formal knowledge is a promising start (Allison & Ellis 2001, Nishida *et al*. 2006a, b, c, Saint-Paul 2006, Ocampo-Thomason 2006). However, traditional knowledge must be recovered and recorded before it disappears under the social pressure of newcomers (rural workers displaced from sugar-cane plantations and the urban unemployed) and extreme poverty of the traditional families (Silva-Cavalcanti & Costa 2009, 2010a). Studies that transcend standard academic barriers and look at environmental problems from an integrative and interdisciplinary point of view will generate new insights in resource management and appreciation of the human dimension of many environmental problems faced today by these communities.

The biology and ecology of *A. brasiliana* is not fully understood by members of traditional communities. Biological monitoring and science translation to communication to communities will be necessary at sites under managerial intervention to assess the efficiency of conservation actions (Garcia *et al.* 2008). Long-term monitoring programs are important to check on improvements and stabilization of population parameters which can support corrective/conservation measures for each ecosystem, even outside reserves.

Co-management and self-governance may help in resource conservation and contribute to support traditional livelihoods. Both require organization and the provision of training (Castilla & Defeo 2001, Ocampo-Thomason 2006, Saint-Paul 2006), which are uncommon in the case of Brazil. There are some fishers and/or women associations, but most individual fishers can not afford paying to participate and remain marginalized from group

decisions and benefits. Real ethno-management can only be achieved with inclusion of all social strata. The idea of territory is still allien to most *A. brasiliana* traditional fishers. However, it is present when a RESEX is solicited by a traditional community, who recognizes the conservation unit territory as "their own" to exploit. When this idea is externally proposed as a tool to control harvesting and management of the resource it is not possible to guarantee the success of resource conservation (Raemaekers & Britz 2009, San Martín *et al*. 2009).

Brazilian RESEXs and non-protected areas (the large majority of the exploitation sites) should be treated differently (Table II). A large number of communities, involving numerous families and covering extensive areas of the Brazilian littoral are at sites of difficult access and are presently abandoned by the state. These communities live from the extraction of coastal living and non-living resources, including *A. brasiliana*. So, managerial actions aimed at RESEX may not be the best practicable options in their case. RESEX remain restricted to special cases along the Brazilian coast in terms of resource conservation and support for livelihoods; they should be regarded as pilot experiments.

Conservation measures should always consider three aspects: size, time of the year and quotas. The establishment of quotas can be successfully achieved as far as some studies are made to determine how much capture is necessary to support a family with dignity. The establishment of quotas must also take into consideration how much, and for how long a stock supports harvesting. It might be necessary to establish a quota per family or person or day. There is a risk that not all the families will be able to harvest freely everyday in order to recover and/or maintain stocks. The establishment of quotas of exploitation can be a corrective measure for some sites/times provided effective law enforcement and ecological knowledge are present.

Size (T_L mm) is an important variable for assessing sexual maturation of the population. Implementation of size as a control requires size-selective harvest gear, *e.g*. a mesh size that retains only individuals >20 mm. Examples exist along the coast of sieving and washing the catch through plastic and metallic grids, but not necessarily for size control (Nishida *et al*. 2006c). Gear choice, in this case, aims at harvesting larger quantities in less time, increasing capture. In Brazil there is very little or no control of size class fished, or a definition of time of the year when fishing should be avoided. Normative regulation must, however, take into consideration traditional knowledge and social needs (Nishida *et al*. 2006c). Women and children may prefer to use their hands, while men prefer to use tools to increase yields and reduce effective fishing time (Silva-Cavalcanti & Costa 2009, 2010a).

Temporal limits to *A. brasiliana* harvesting is probably the most controversial of all possible measures. The resource yield and availability vary at different time scales (lunar cycle, seasonal cycle etc). Also, latitudinal differences in the clam's life cycle exists that prevent choosing a single closed season for the whole territory. Closed season may work well only under certain circumstances (Arendse *et al.* 2007). For the traditional populations concerned, it would be probably difficult to give-up fishing at any time of the year. No rule applies for the Brazilian coast, as the different populations and cultures need particular calendars.

In general the meat yields are higher in summer, probably due to the maturation of the gonads, which increases the conditioning index of the animals (Arruda-Soares *et al*. 1982). It will also happen according to the moon phase (Nishida *et al*. 2006a, b). At this time of the year harvest is at its peak, since the meat can be directly sold to restaurants and tourists at a higher price and profit. To suspend or control harvest during the summer season would call for some sort of social rescue for the traditional populations living from *A. brasiliana*. This sort of practice already exists for lobsters in Brazil. During the time when fishing is suspended, registered fishermen receive a pension from the federal government to support their families. In the case of prawns and crabs there are also closed seasons, but no government pension is dispensed for fishermen. However, such measures may be controversial, and require social organization and direct state action.

Traditional coastal populations fight against social marginalization and exclusion as best as they can, but both human and mollusc populations are fragile. *Anomalocardia brasiliana* is "the last choice" to be accessed when no other resources (lobster, fish, prawns, wood, crabs, in this order) are available. Traditional communities become increasingly less selective with economic pressure, especially men. There is nowhere else to turn to since this is the lowest they can go in the social scale. Even healthy coastal environments can not be responsible for supporting large crawds of unemployed people from other groups and cultures (Ocampo-Thomason 2006, Saint-Paul 2006). Poorly managed resources will lead to low resilience (Adger *et al*. 2005, Kesavan & Swaminathan 2006).

Table II. Management alternatives for traditional fisheries of benthic molluscs deployed by different governments and communities.

	Definition	Created by	Positive points	Negative points
Extractive Reserves - RESEX (Brazil) [1]	Territorial spaces designated to the exploration of natural resources by traditional populations in a sustainable way, ultimately aiming at environmental conservation.	Traditional fishers and Government established conservation unit; Co-managed by locals and federal gov.	-delimitation of fisheries areas; -Access exclusive to traditional fishers.	- Mal-function of co-management due to uneven participation of the stakeholders; -Absence of fishers from legal decisions; -poor environmental laws enforcement.
Cofradías (Spanish) [2]	Fishers self- organizations, institutions that hold the role of fisheries organization in their designated areas.	Local fishers	-Co-management; -Social organization; - Rules legitimized by the group; - Increased cooperation with research.	- Conflicts inside the groups required negotiations, consensus and exercise of leadership; - Deeply modified existing social structures (reduce the number of traditional fishers).
Territorial Use Rights (TURF) or *Áreas de Manejo y Explotación de Recursos Bentónicos* (AMERBS) (Chile) [3, 4]	Legal and managerial instrument for the management of benthic fisheries. Not established by tradition.	Local fishers	-CPUE increased were introduced; -Co-management among *caletas*; -Self-regulation;	-Conflicts from existence of dual management system; -Little flexibility and no local control over management actions; -Little effective participation of fishers in monitoring and management; -No clear rules on harvest in response to monitoring results; - Overlap of fishing areas.
Mangrove Reserve *Cayapas-Mataje* REMACAM (Ecuador) [5]	Management strategy of allocating areas for each community traditional use and management. *Custodía*	Local people and Government	- Economic practices as charcoal production and logging forbidden; - Gathering practices permitted to local people only; - Community presents management plan and geo-referenced map of the *custodía*: -Decreased mangrove clearing; - Social organization among fishers.	- Not cited.

1. Silva-Cavalcanti & Costa (2009); 2. Frangoudes *et al*. (2008); 3. González *et al*. (2006); 4. Raemaekers & Britz (2009) and 5. Ocampo-Thomason (2006).

Other bivalve species which are normally left behind will go from by-catch to target species. Normally *A. brasiliana* gatherers are species-selective. However, occasionally they include other species (*Tagelus plebeius*, *Iphigenia brasiliana*, *Pugilina morio*) in the catch. These other species have normally a lower density where *A. brasiliana* occurs at high densities. If the meat yield of the target species is noticed to decrease, they may become less selective and start to exploit the other species to increase the meat weight in each trip. Resilience of traditional communities is still significant (Ocampo-Thomason 2006, Allison & Ellis 2001), but may drop drastically in the foreseeable future. Global and local changes as El Niño and deforestation can alter environmental conditions and consequently resource availability. Increasing capability of detecting early warning and timely reactions environmental changes may help improving resource exploitation. This may only be achieved through research at different time and geographical scales, including regional and local.

Table III. Aspects in *Anomalocardia brasiliana* fisheries management aiming at the conservation of ecological and social functions.

Aspect	Issue	Suggestion
Coupling of traditional and formal knowledge	Traditional knowledge is threatened by external social pressures as non-traditional workers and extreme poverty of traditional families.	Capacity building at local schools for teachers in ecological issues; Adult education; Recording and discussion of traditional knowledge from the community; Skills to deal with middle-men and in the natural products market; Incentive to research in protected areas.
Co-management	Uncontrolled fisheries and other activities within the conservation unity or ecological territory.	Social organization around participative and deliberative councils; Recognition under "fair trade" labels; Idea of territories and differentiated space utilization within each one of them.
Establishment of quotas	Lack of monitoring of the fisheries yields for detection of changes in the stock.	Determination of the total abundance, number of fishers and average effort to base the quota per family.
Size control	Decreasing average sizes within the population.	*In situ* tool to gauge size and guarantee capture of >20mm individuals.
Tools	Low selectivity and high mortality of captured individuals.	Limit use of tools in order to adequate capture among family groups.
Environmental restoration	Habitat loss and resource depletion.	Preserved no-take zones as seeding areas.

Another aspect to be considered in order to recover and maintain resource availability is environment restoration, which would benefit all resources and traditional groups involved, and ultimately the society at large. Recovery implies that a system in poor ecological health will return to a previous condition after being degraded or disrupted. The return to the original state may happen with (active recovery) or without (passive recovery) human intervention (Hamilton & Snedaker 1984, Rönnbäck *et al*. 2007). Recovery will happen once the stressor is removed; and can be facilitated by management action, or be a response to management action. Recovery of depleted stocks of *A. brasiliana* may be helped by the establishment of no take zones, to be used as seeding areas (Ocampo-Thomason 2006, Morsan 2007). Delimitation of these areas should take into account the diversity of habitats in the ecosystem, difficulty of access by the traditional and non-traditional communities, oceanographic conditions, food availability for the animal, and ethno-ecological factors. Conservation measures taken during years at Galicia and Chile can serve as base for implementation of conservation measures in Brazil and other parts (Urban 1994, Frangoudes *et al.* 2008). Management measures such as rotation and reproductive reserves can be implemented with some compatible level of change in capture and livelihoods.

The use of technologies to improve product value is also important in the process of resource conservation, since monetary financial yields can improve with the same amount of catch. Most important in the case of *A. brasiliana* would be

quality control during pre-cooking; handling, packaging, storage, and distribution.

The use of the shell, also part of the resource, should be encouraged. New uses might be sought aiming at income generation for the families and communities involved. Formal education also helps recovering and preserving coastal living resources though conventional social skills (basic management, financial literacy and logistics) that can be related to the natural and food products market. Communities need to be able to deal with the middle-man and market values. Ecological sustainable development requires an implementation of long-term strategy and a change in behaviour in the exploitation of natural resources.

Anomalocardia brasiliana is a predominantly Brazilian species, therefore is fisheries is not well known outside the national context. Studies concerning this species and its capture by traditional and non-traditional populations have started only in the 1970s. Management practices came into play only recently, during the 1990s with the establishment of RESEXs. This living resource is now only starting to bring its contributions to other traditional and non-traditional communities around the world dealing with the exploitation of molluscs or other living coastal resources. Due to the large area of occurrence of the species, number of communities exploiting the resource and the significance of the income generated within these communities, *A. brasiliana* may still offer a number of opportunities to study and experiment with resourced exploitation.

References

Adger, W.N., Hughes, T.P., Folke, C., Carpenter, S.R. & Rockström, J. 2005. Social-Ecological Resilience to Coastal Disasters. **Science,** 309: 1036-1039.

Allison, E.H. & Ellis, F. 2001. The livelihoods approach and management of small-scale fisheries. **Marine Policy**, 25: 377–388.

Alves, M. S., Silva, M. A., Melo Júnior, M., Paranaguá, M.N. & Pinto, S. L. P. 2006. Zooartesanato comercializado em Recife, Pernambuco, Brasil. **Revista Brasileira de Zoologia,** 8: 99-109.

Alves, R.R.N., Nishida, A.K. & Hernandez, M.I. 2005. Environmental perception of gatherers of the crab "caranguejo-uçá" (*Ucides cordatus*, Decapoda, Brachyura) affecting their collection attitudes. **Journal Ethnobiology and Ethnomedicine,** 1: 10.

Angulo, R. J. 1993. Indicadores biológicos de paleoníveis marinhos na costa paranaense. **Boletim Paranaense de Geologia,** 41: 1-34.

Araújo, C. M. M. 2001. Biologia reprodutiva do berbigão *Anomalocardia brasiliana* (Gmelin, 1791) (Mollusca, Bivalvia, Veneridae) na Reserva Extrativista Marinha de Pirajubaé **Doctorate Thesis** . Universidade de São Paulo - Ciências Biológicas (Biologia Genética), 204p.

Araújo, M.L.R & Rocha-Barreira, C. A. 2004. Distribuição espacial de *Anomalocardia brasiliana* (Gmelin 1791) (Mollusca, Bivalvia, Veneridae) na praia do Canto da Barra, Fortim, Ceará, Brasil. **Boletim Técnico do CEPENE**, 12: 11-21.

Arendse, C.J., Govender, A. & Branch, G.M. 2007. Are closed fishing seasons an effective means of increasing reproductive output? A per-recruit simulation using the limpet Cymbula granatina as a case history. **Fisheries Research**, 85: 93–100.

Arruda, C. C. B., Beasley, C. R., Vallinoto, M., Marques-Silva, N. S & Tagliaro, C. H. 2009. Significant genetic differentiation among populations of *Anomalocardia brasiliana* (Gmelin, 1791): A bivalve with planktonic larval dispersion. **Genetic and Molecular Biology,** 32: 423-430.

Arruda-Soares, H., Schaeffer-Novelli, Y. & Mandelli, J. 1982. *Anomalocardia brasiliana* (Gmelin, 1791) bivalve comestível da região do Cardoso, Estado de São Paulo: aspectos biológicos de interesse para a pesca comercial. **Boletim do Instituto de Pesca,** 9: 21-38.

Barletta, M. & Costa, M. 2009. Living and non-living resources exploitation in tropical semi-arid estuaries. **Journal of Coastal Research,** IS 56: 371-375.

Barreira, C. A. & Araújo, M.L.R. 2005. Ciclo reprodutivo de *Anomalocardia brasiliana* (Gmelin 1791) (Mollusca, Bivalvia, Veneridae) na praia do canto da Barra, Fortim, Ceará, Brasil. **Boletim do Instituto de Pesca**, 31: 9-20.

Begossi, A. 2001. Mapping spots: fishing areas or territories among islanders of the Atlantic Forest (Brazil). **Regional Environmental Change,** 2: 1-12.

Begossi, A. 2006. Temporal stability in fishing spots: conservation and co-management in Brazilian artisanal coastal fisheries. **Ecology and Society,** 11: 5.

Boehs, G. 2000. Ecologia Populacional, Reprodução e Contribuição em Biomassa de *Anomalocardia brasiliana* (Gmelin, 1791)

(Bivalvia: Veneridae) na Baía de Paranaguá, Paraná, Brasil. **Doctorate Thesis**. Universidade Federal do Paraná – Zoologia. 201p.

Boehs, G., Absher, T. M. & Cruz-Kaled, A. 2000. Composition and distribution of benthic mollusc on intertidal flats of Paranaguá Bay (Paraná, Brazil). **Sciencia Marina,** 64: 537-543.

Boehs, G; Absher, T. M. & Cruz-Kaled, A. C. 2008. Ecologia populacional de ***Anomalocardia brasiliana*** (Gmelin, 1791) (Bivalvia, Veneridae) na baia de Paranaguá, Paraná, Brasil **Boletim do Instituto de Pesca,** São Paulo 34: 259-270.

Boehs, G. & Magalhães, A. R. M. 2004. Simbiontes associados com *Anomalocardia brasiliana* (Gmelin, 1791) (Mollusca, Bivalvia, Veneridae) na ilha de Santa Catarina e região continental adjacente, Santa Catarina, Brasil. **Revista Brasileira de Zoologia,** 21(4): 865-869.

Castilla, J. C. & Defeo, O. 2001. Latin American benthic shellfisheries: emphasis on co-management and experimental practices. **Reviews in Biology and Fisheries**, 11: 1-30.

Dietrich, C.P., Paiva, J.F., Moraes, C. T., Takahashi, H. K., Porcianatto, M. A., Santos, E.A. & Nader, H. B. 1985. Isolation and characterization of a heparin with high anticoagulant activity from *Anomalocardia brasiliana*. **Biochemical and Biophysics Acta**, 843: 1-7.

Estrada, T.E.M.D. 2004. Aspectos morfométricos de conchas de *Anomalocardia brasiliana* (Gmelin 1791) da região Sudeste do Brasil. **Masters Thesis**. Universidade Estadual de Campinas (Ecologia). 72p.

Figueredo, M.I.S & Lavrado, H.P. 2007. Estrutura populacional de *Anomalocardia brasiliana* (Gmelin, 1791) (Mollusca Bivalvia) em uma lagoa hipersalina (Lagoa de Araruama, RJ). **XII Congresso Latino-Americano de Ciências do Mar. XII COLACMAR**, Florianópolis, 15 a 19 de abril de 2007. CD-ROM.

Frangoudes, K., Marugán-Pintos, B. & Pascual-Fernández, J.J. 2008. The case of women access to co-governance and conservation: The case of women shellfish collectors in Galicia (Spain). **Marine Policy,** 32: 223-232.

Garcia, S.M., Allison, E.H, Andrew, N.J.; Béné, C.; Bianchi, G; de Graaf, G.J.; Kalikoski, D.; Mahon. R. & Orensanz, J.M. 2008 *In:* **Towards Integrated Assessment and Advice in Small-Scale Fisheries- Principles and Processes.** FAO Fisheries Technical Papers 515, 104 pages.

González, J., Stotz, W., Garrido, J., Orensanz, L., Parma, A., Tapia, C. & Zuleta, A. 2006. The Chilean TURF system- How is it performing in the case of the loco fishery? **Bulletin of Marine Science,** 78: 499-527.

Grotta, M & Lunetta, JE 1980. Ciclo sexual de *Anomalocardia brasiliana* (Gmelin, 1791) do litoral de Estado de Paraiba. **Revista Nordestina de Biologia** (Paraíba) 3: 5-55.

Grotta, M & Lunetta, JE 1982. Reproductive physiological variation of ***Anomalocardia brasiliana*** (Gmelin, 1791) (Mollusca, Bivalvia), in different latitudes. **Revista Nordestina de Biologia** (Paraíba) 5: 21-28.

Guiss, C. 1995. Influência da Gramínea *Spartina alterniflora* (Loiseleur, 1807) sobre a distribuição e densidade do bivalve *Anomalocardia brasiliana* (Gmelin, 1791). **Master Thesis**. Universidade Federal do Paraná - Zoologia. 73p.

Hamilton, L.S. & Snedaker, S.C. (Eds.), 1984. **Handbook for mangrove area management**. East-West Environmental and Policy Institute, IUCN, UNESCO, UNEP. 123p.

Hardin, G. 1968. The tragedy of the commons. **Science**, 162: 1243-1248.

Kehrig, H.A., Costa, M. F., Moreira, I. & Malm, O. 2006. Total and methyl Mercury in different species of mollusc from two estuaries in Rio de Janeiro state. **Journal of Brazilian Chemical Society**, 17: 1409-1418.

Kesavan, P. C. & Swaminathan, M. S. 2006. Managing extreme natural disasters in coastal areas. **Royal Society of London Transactions Series,** 364(1845): 2191-2216.

Leonel, R.M.V., Magalhães, A.R.M. & Lunneta, J.E., 1983. Sobrevivência de *Anomalocardia brasiliana* (Gmelin, 1791) (Mollusca: Bivalvia), em diferentes salinidades. **Boletim de Fisiologia da Universidade de São Paulo,** 7: 63-72.

Lima, H.C., Barbosa, J.M. & Correia, D.S. 2007. Extração de marisco por moradores da comunidade de Baira-Mar 2, Igarassu-PE. **VII Jornada de Ensino, Pesquisa e Extensão**. Recife: JEPEX, SP, Adaltech.

Martínez, S., Ubilla, M., Verde, M., Perea, D., Rojas, A., Guérèquiz, R. & Piñeiro, G. 2001. Paleoecology and geocronology of Uruguayan Coastal Marine Pleistocene Deposits. **Quaternary Research,** 55: 246-254.

Mattos, G., Cardoso, R.S. & Caetano, C.H.S. 2008. Dinâmica populacional de *Anomalocardia brasiliana* (Gmelin, 1791) (Bivalvia:Veneridae) na praia das Fleixeiras, Ilha de Itacuruça, Rio de Janeiro- Resultados preliminares. **III Congresso Brasileiro de Oceanografia-CBO 2008, I Congresso Ibéro-Americano de Oceanografia**, Fortaleza (CE), 20 a 24 de maio de 2008.

Monti, D., Frenkiel, L. & Möueza, M. 1991. Demography and growth of *Anomalocardia brasiliana* (Gmelin) Bivalvia: Veneridae) in a mangrove in Guadalupe (French West Indies). **Journal of Molluscan Studies,** 57: 249-257.

Morsan, E. 2007. Spatial pattern, harvesting and management of artisanal fishery for purple clam (*Amiantis purpurata*) in Patagonia (Argentina). **Ocean and Coastal Management,** 50: 481-497.

Mouëza, M., Frenkiel, L. & Monti, D., 1988. Reproduction et Dynamique des population des mollusques bivalves d'interet commercial en Guadalupe: *Anomalocardia brasiana* Gmelin et *Lucina pectinata* Gmelin. **Rapport Action Concertée Oceanologie Commision CODERT; MRT**; 66p.

Mouëza, M., Gros, O. & Frenkiel,L. 1999. Embryonic, larval and postlarval development of the tropical clam, *Anomalocardia brasiliana* (Bivalvia, Veneridae). **Journal of Molluscan Studies**, 65: 73-88.

Narchi, W. 1976. Ciclo anual da gametogênese de *Anomalocardia brasiliana* (Gmelin, 1791) (Mollusca: Bivalvia). **Boletim de Zoologia da Universidade de São Paulo,** 1: 331-350.

Netto, S. A. & Lana, P.C. 1994.Effects of sediment disturbance on the structure of benthic fauna in a subtropical tidal creek of southeastern Brazil. **Marine Ecology Progress Series**, 106: 239-247.

Nishida, A. K. Nordi, N. & Alves, R.N. 2004. Abordagem etnoecologica da coleta de moluscos no litoral paraibano. **Tropical Oceanography,** 32: 53-68.

Nishida, A. K., Nordi, N. & Alves, R.R.N. 2006a. Molluscs production associated to lunar-tide cycle; A case study in Paraíba State under ethnoecology viewpoint. **Journal of Ethnobiology and Ethnomedicine,** 2: 28.

Nishida, A.K., Nordi, N. & Alves, R.R.N. 2006b. The lunar-tide cycle viewed by crustacean and mollusc gatherers in the State of Paraíba, Northeast Brazil and their influence in collection attitudes. **Journal of Ethnobiology and Ethnomedicine,** 2:1.

Nishida, A.K., Nordi, N. & Nobrega Alves, R.R. 2006c. Mollusc gathering in Northeast Brazil; An ethnoecological approach. **Human Ecology,** 34: 133-145.

Ocampo-Thomason, P. 2006. Mangroves, people and cockles: impacts of the shrimp-farming industry on mangrove communities in Esmeraldas Province, Ecuador. 140-153, In: CAB International, 2006. **Environment and Livelihoods in Tropical Coastal Zones: Managing agriculture-fishery-aquaculture conflicts** (eds. C.T. Hoanh, T.P. Tuong, J.W. Gowing and B. Hardy). 323p.

Paiva, A. C. G. 2002. Macrofauna de substratos inconsolidados da zona entre - marés em duas localidades do Canal de Santa Cruz (Forte Orange e Itapissuma) Pernambuco, Brasil. **Masters Thesis**. Universidade Federal de Pernambuco – Departamento de Oceanografia. 92p

Pezzuto, P. R. & Echternacht, A. M. 1999. Avaliação de impactos da construção da via expressa SC-Sul sobre o berbigão *Anomalocardia brasiliana* (Gmelin, 1791)(Mollusca: Pelecypoda) na reserva extrativista marinha do Pirajubaé (Florianópolis, Santa Catarina, Brasil). **Atlântica** 21: 105-119.

Raemaekers, S. J.-P.N. & Britz, P. J. 2009. Profile of the illegal abalone fishery (*Haliotis midae*) in the Eastern Cape Province,South Africa: Organised pillage and management failure. **Fisheries Research**, 97: 183–195.

Rios, E.C. 1985. **Seashells of Brasil**. Rio Grande. RS XII.

Rodrigues, A.M., Marques, A.O., Fernandes, R.T.V. & Henry-Silva, G.H. 2008. Distribuição e abundancia do molusco bivalve *Anomalocardia brasiliana* (Gmelin, 1791) nas praias da região estuarina do rio Apodi/Mossoró/RN. **III Congresso Brasileiro de Oceanografia-CBO 2008, I Congresso Ibéro-Americano de Oceanografia**, Fortaleza, 20 a 24 de maio de 2008.

Rönnbäck, P., Crona, B. & Ingwall, L. 2007. The return of ecosystem goods and services in replanted mangrove forests: perspectives from local communities in Kenya. **Environmental Conservation,** 34: 313–324.

San Martín, G., Parma, A.M. & Orensanz, J.M. 2009. The Chilean experience with territorial use rights in fisheries. *In*: **Handbook of Marine Fisheries Conservation and Management**, pp. 324-337. Eds. R. Q.

Grafton , R. Hilborn, D. Squires, M. Tait and M. Williams. Oxford University Press.

Saint-Paul, U. 2006. Interrelations among mangroves, the local economy and social sustainability: a review from a case study in north Brazil. 154-162, In: CAB International, 2006. **Environment and Livelihoods in Tropical Coastal Zones: Managing agriculture-fishery-aquaculture conflicts** (eds. C.T. Hoanh, T.P. Tuong, J.W. Gowing and B. Hardy). 323p.

Schaeffer-Novelli, Y. 1976. Alguns aspectos ecológicos e análise da população de *Anomalocardia brasiliana* (Gmelin, 1791) Molusca-Bivalvia na praia do Saco da Ribeira, Ubatuba, Estado de São Paulo. **Doctorate Thesis**. Instituto de Biociências, Universidade de São Paulo, 119p.

Scheel-Ybert, R., Eggers, S., Wesolowski , V., Petronilho, C.C., Boyadjian, C.H., De Blasis, P.A.D., Barbosa-Guimarães M. & Gaspar, M.D. 2003. Novas perspectivas na reconstituição do modo de vida dos sambaquieiros: uma abordagem multidisciplinar. **Revista de Arqueologia**, 16: 109-137.

Schio, C., Souza, D.S. & Pezzuto, P.R., 2007. Dinâmica populacional do berbigão *Anomalocardia brasiliana* (Gmelin, 1791) (Mollusca: Pelecypoda) na Reserva Extrativista Marinha de Pirajubaé-SC, Brasil. **XII Congresso Latino Americano de Ciências do Mar (COLACMAR),** 15 a 19 de abril de 2007. CD-ROM.

Schio, C. & Pezzuto, P.R. 2008. Seletividade da draga de mão (gancho) empregada na pescaria do berbigão *Anomalocardia brasiliana* na Reserva Extrativista Marinha de Pirajubaé-SC. **IV Congresso Brasileiro de Oceanografia-CBO 2010**. Rio Grande (RS), 17 a 21 de maio de 2010. CD-ROM.

Shepherd, J.G. 1993. Closure of fisheries during the spawning season are not necessarily a very effective conservation measure. *In:* **Key issues in the Conservation of Fisheries.** Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research, Laboratory Leaflet ,72 (Lowestoft, UK): 13-14.

Silva, G.P.E, Hatje, V., Santos, W. N.L., Costa, L.M., Nogueira, A.R.A. & Ferreira, S.L.C. 2008. Fast method for the determination of copper, manganese and iron in seafood samples. **Journal of Food Composition and Analysis,** 21, 259-263.

Silva-Cavalcanti, J. S. & Costa, M. 2009. Fisheries in Protected and Non-Protected areas: What is the difference? The case of *Anomalocardia brasiliana* (Gmelin, 1971) (Mollusca: Bivalvia) at tropical estuaries of Northeast Brazil. **Jounal of Coastal Research,** IS 56: 1454-1458.

Silva-Cavalcanti, J. S. & Costa, M. 2010a. Percepção ambiental de marisqueiros em áreas sob diferentes níveis de proteção formal. **IV Congresso Brasileiro de Oceanografia-CBO 2010**. Rio Grande (RS), 17 a 21 de maio de 2010. CD-ROM.

Silva-Cavalcanti, J. S. & Costa, M. 2010b. Avaliação de recursos em reservas extrativistas: viabilidade e ações de manejo da *Anomalocardia brasiliana.* **IV Congresso Brasileiro de Oceanografia-CBO 2010.** Rio Grande (RS), 17 a 21 de maio de 2010. CD-ROM.

Silva-Cavalcanti, J. S. & Costa, M. 2011. Density and biomass of *Anomalocardia brasiliana* within a coastal conservation unit at the Brazilian Northeast. Aquatic Biology (in prep).

SNUC – **Sistema Nacional de Unidades de Conservação**, 2000. Law 9985 (18th July 2000). Establishes the Brazilian National System of Conservation Areas. (available at www.mma.gov.br).

Thatje, S., Heilmeyer, O. & Laudien, J. 2008. Climate variability and El Niño Southern Oscillation: implications for natural coastal resources and management. **Marine Research,** 62: S5-S14.

Urban, H.-J. 1994. Upper temperature tolerance of ten bivalve species off Peru and Chile related to El Niño. **Marine Ecology Progress Series,** 107: 139-145.

Wallner-Kersanach, M; Lobo, SE & Da Silva, EM 1994. Depuration effects on trace metals in *Anomalocardia brasiliana* (Gmelin, 1791). **Bulletin of Environmental Contamination and Toxicology**, 52: 840-847.

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