PANAMJAS
Pan-American Journal of Aquatic Sciences

# A new hypothesis on the influence of the El Niño/La Niña upon the biological productivity, ecology and fisheries of the Southern Brazilian Bight

EDUARDO TAVARES PAES [1] & LUIZ EDUARDO DE SOUZA MORAES [2]

[1, 2] *Biological Oceanography and Fishery Ecology Group, Remote Sensing Division, Instituto Nacional de Pesquisas Espaciais (INPE), Avenida dos Astronautas 1758,12227-010, São José dos Campos, Brazil*
[1] *etpaes@dsr.inpe.br,* [2] *lemoraes@dsr.inpe.br.*

**Abstract.** The Southern Brazilian Bight (SBB) is a large semi-enclosed marine ecosystem which stands as one of the most productive coastal regions of Brazil, supporting more than 20% of Brazilian industrial fisheries. Primary production is sustained by the upwelling of the cold and nutrient rich South Atlantic Central Water during the austral summer, provided by a seasonal meteorologically controlled upwelling system, coupled with the frequent development of eddies from Brazil's Current. Many of the exploited fish species spend their planktonic stages confined within the SBB dependencies. The paper brings out some evidences about possible El Niño/La Ninã teleconnections and their possible effects over the oceanographic regime and biological productivity; and therefore, over the living resource dynamics of the studied area. Among these evidences are the modifications detected in the community structure of benthic fishes at an upwelling "hot-spot" (Arraial do Cabo), as well as the fluctuations of the Brazilian sardine catches, which seem to be in phase with intense El Niño events. New evidences are presented through a Hovmoller temperature diagram which shows the presence of cold waters over the SBB's shelf during the 1982/83 El Ninõ/La Niña, contrasting with the less intense 1986/87 phenomenon.

**Key words:** ENSO, El Niño/LaNiña, Brazilian sardine, Coastal upwelling, Teleconnections.

**Resumo. Uma nova hipótese sobre a influência do El Niño/La Niña na produtividade biológica, ecológica e pesqueira da Plataforma Continental Sudeste Brasileira.** A Plataforma Continental Sudeste Brasileira (PCSB) é uma unidade ecossistêmica marinha semi-fechada, constituindo uma das regiões costeiras mais produtivas do Brasil, sendo responsável por mais de 20% do total das capturas da pesca industrial brasileira. A produção primária é sustentada pelo mecanismo de ressurgência costeira controlado por parâmetros meteorológicos, acoplado a ocorrência freqüente de meandramentos ciclônicos da Corrente do Brasil. Várias espécies, incluindo as espécies de peixes exploradas comercialmente, provavelmente passam a maior parte de suas fases planctônicas confinadas nas dependências da PCSB. Este artigo traz algumas evidencias sobre possíveis teleconexões entre os fenômenos El Nino e La Nina, e seus efeitos sobre as condições oceanográficas e, conseqüentemente, sobre os padrões de produtividade da área estudada. As evidencias apresentadas incluem modificações na estrutura da comunidade de peixes demersais em uma área de manifestação mais intensa da ressurgência costeira (Arraial do Cabo - RJ), bem como as flutuações observadas nas capturas da Sardinha brasileira. Evidências adicionais são apresentadas através de um diagrama de Hovmoller da temperatura sub-superficial, mostrando a presença de águas frias e mais produtivas sobre a PCSB durante o El Niño intenso de 1982/83, em contraste com a ocorrências de águas mais quentes e menos produtivas no El Nino menos intenso de 1986/87.

**Palavras-chave:** ENSO, El Niño/LaNiña Sardinha brasileira, Ressurgência, Teleconexões.

## Introduction

The Southern Brazilian Bight (SBB) comprehends a 150.000 km² semi elliptic portion of Brazil's coast, located between 23°S and 29°S. The coast line orientation stands from NE to SW, except at the northern limits (South of Arraial do Cabo) where it presents a remarkable E-W deflection, and at the southern limits (Cabo de Santa Marta), where

it deflects South. At both latitudinal extremes, the shelf width is severely shortened (50 km and 70 km, respectively), contrasting with the broader intermediate section at 25°-27°S, reaching a maximum extension of 230 km offshore (Castro *et al.* 2006) (Figure 1). The sediment is composed, mainly, by thick layers of sand, silt and clay (Mahiques *et al.* 1999).

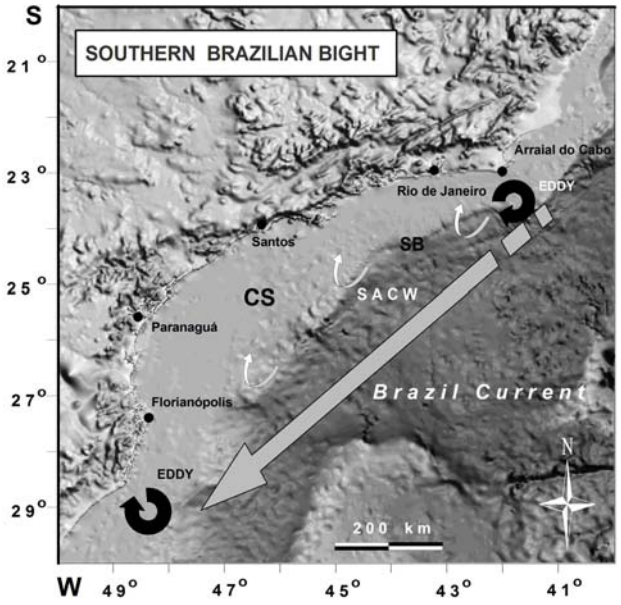


**Figure 1**. Map of the Southern Brazilian Bight, showing the limits and main oceanographic features. CS: Coastal Shelf. SB: Shelf Break. SACW: South Atlantic Central Water.

The region comprises some of the most productive coastal fishing grounds of Brazil, accounting for more than 20% of the total national marine harvest between 1977 and 1995 (FAO 2000, Vasconcellos & Gasalla 2001). Nevertheless, the SBB productivity cannot be regarded as strong in the context of eastern boundary systems such as the Benguela and Peru currents (Valentin & Coutinho 1990). Apart from localized estuarine inputs, two upwelling mechanisms are responsible for providing nutrients to the marine environment: the Coastal Upwelling and the Shelf Break Upwelling.

The coastal upwelling is a seasonal phenomenon, mostly tied to meteorological factors in a synoptic scale. During summer, when the prevailing winds blow from the First Quadrant (N–E), the wind components result in a NE direction (Wainer & Tachetto, 2006) inducing the offshore transport of the Coastal Water (CW) through Ekmann dynamics. Consequently, the cold and nutrient rich South Atlantic Central Water (SACW) moves from offshore depths of 300m to shallower portions of the shelf, often reaching the photic zone, and establishing a stable termocline at depths of 10 to 15m (Castro-Filho et al. 1987, Fonzar 1994). During winter the incidence of Third Quadrant (S – W) winds is enhanced - due to a higher frequency in the generation and displacement of frontal systems along the southern coast - and the wind components assume an inverse direction (SW-NE). The transportation of the surface water, is thus reversed, causing the subsidence of the water layers below the picnocline, rising the average sea level near the coast. The persistence of these conditions is usually followed by the subsidence of coastal waters and termocline disruption up to the 50m isobath, due to the intrusion of offshore waters, represented mainly by the southern branch of the warm and nutrient-poor Brazil Current (BC).

The Coastal upwelling accounts for most of the oceanographic-environmental variability at the SBB. Primary production is higher during summer, as an obvious consequence of the nutrient inputs from the SACW intrusions. Conversely, oligotrophic conditions prevail during winter months (Aidar et al. 1993), when the termocline is disrupted, and the warm Tropical Water (TW) from the BC occupies the shelf. In this way, most of the fish species and benthic fauna concentrate their spawning seasons during summer (Pires-Vanin & Matsuura 1993, Matsuura 1995). Furthermore, the trawl fisheries at the SBB also presents a seasonal pattern, which is consistent with the above described oceanographic dynamics (Borzone et al.1999).

Another phenomenon that may account for Primary production rises in the SBB is the Shelf Break Upwelling, which is caused by cyclonic meanderings (eddies) of the Brazil Current, between the 70 – 100m isobaths. These cyclonic vortices can also bring SACW to surface layers, providing nutrient inputs to the photic zone. The mechanisms underlying their genesis are still unknown, but Castro-Filho et al. (1987), and Campos et al. (1995, 2000), suggested that these features could result from baroclinic instabilities, in association with topographic discontinuities at the sea bottom, as well as drastic deflections of the coast line, which might amplify small disturbances on the course of the Brazil Current. Drastic shifts on the coast line orientation and bottom topography are found on the northern and southern limits of the SBB, where cyclonic eddies are more frequently detected. Three or four eddies can be easily found each year along the SBB domain, usually semi-stationary traveling slowly southwards (Castro et al. 2006).

Paes (1996) and Paes & Rossi-Wongtschowski (1997) proposed that the SBB should be considered as a Mesoscale Semi-Enclosed Ecosystem, limited to the North and South by the

persistent cyclonic meanderings of the BC and, to the West by the Brazil Current. They also suggested that some of the pelagic and benthic populations should spend part of their life cycles confined within the SBB, under the influence of regional oceanographic processes. Therefore, any long term or wider scale phenomena which might cause any degree of disruption of these processes may exert influence on these living resources.

### *ENSO Effects in Brazil*

El Niño Phenomenon is a recurrent, quasi-periodic appearance of warm sea surface water in the central equatorial Pacific Ocean generated by ocean-atmosphere interactions internal to the tropical Pacific and overlying atmosphere, this anomaly can sometimes reverse and lead to the presence of cold waters in the aforementioned region (La Niña), thus the term El Niño – Southern Oscillation (ENSO) is widely used to refer to this oceanic-atmospheric seesaw. ENSO is recognized as the largest mode of interannual variability of the global climate system, with a recurrence period around the 2–8 year band (Santos, 2006). Dijkstra (2006), and references their in, provide detailed descriptions of its development, teleconnections, indexes and diverse related effects.

ENSO events are generally associated to well known meteorological anomalies in Brazil, such as severe droughts on the northeastern States and floods at the South (Grimm *et al.* 1998, Pezzi & Cavalcanti 2001, Cardoso & Silva Dias 2006). The first evidences of oceanographic anomalies at the SBB were described by Martin *et al.* (1988), who detected an increase in the frequency of cold water upwelling at Arraial do Cabo, during the warm 1982 ENSO. Lentini *et al.* (2001) also found that negative SST anomalies at the Western Atlantic (22° to 42°S) generally occurred on warm ENSO events, and speculated about a connection between both phenomena.

Similarly, anomalous oceanographic patterns were also detected in areas outside the SBB during ENSO dominated years. Depetris *et al.* (1996) observed higher freshwater inputs from La Plata River during the 1982/1983 ENSO, leading to altered patterns of water mass distribution on Uruguay's continental shelf (Piola *et al.* 1998). These anomalies were related to the positive SST anomalies in the Pacific, during a warm ENSO event. The increase of the Patos Lagoon discharge during the 1987 ENSO also had similar effects, altering salinity patterns on the coast of Rio Grande do Sul (Ciotti *et al.*1995, Lima *et al.* 1996).

ENSO effects over Brazilian fish faunas are also registered in the literature. Garcia *et al.* (2001, 2003, and 2004) analyzed the fish communities from Patos Lagoon estuary during the 1983/1983 and 1997/98 ENSO episodes and found significant changes in species composition and diversity patterns. Also, estuarine-resident, estuarine-dependent and marine-visitor species groups were replaced by freshwater species. These changes were related to a remarkable increase in the freshwater discharge into the estuary, caused by the abnormal rainfall registered for the study period. As highlighted before, the anomalous rainfall patterns over Southern Brazil are one of the well known meteorological discontinuities observed during ENSO events (Ropelewski & Halpert 1987, Aceituno 1988, Grimm *et al.* 1998). On the other end of the spectra, Benthic fish communities from Negro River (Amazon Basin) also suffered with the abnormal rain patterns during the same ENSO event (Chao *et al*. 2004). Community composition, abundance, biomass and diversity changed drastically due to the reduction in the river flood plain area, caused by an extended dry season in Northern Brazil during 1997 and 1998.

Paes *et al.* (1999) and Moraes (2000) suggested that the oceanographic changes predicted for intense ENSO events might be followed by changes in the community structure of benthic-demersal fishes of the SBB, with diverse consequences for the local multi specific fisheries. In Arraial do Cabo, during the 1997/1998 ENSO, species usually found at deeper regions and lower temperatures, as well as species that followed the displacement of the oceanic front (Paes, 1996, Rossi-Wongtschowski & Paes, 1993), presented higher relative abundances, when compared to non-ENSO years (Moraes 2000). Some icthtyophagous species such as the hake (*Merluccius hubsii*), the flatfish *Paralichthys patagonicus*, and the Brazilian flathead *Percophis brasiliensis* were also more abundant during this period. Some of these species feed mainly on small pelagic juveniles, which are usually associated with high production areas, or high productivity peaks.

### *Baselines and new evidences of the ENSO influence over the SBB*

As stated before, the changes in oceanographic conditions and coastal circulation observed in the SBB may be related to strong warm ENSO episodes, through atmospheric teleconnections.

According to Kousky *et al.* (1984) and Kousky & Cavalcanti (1984), the heavy rainfall over South and Southeastern Brazil during the autumn and winter of 1983 was caused by an intensification of the Subtropical Jet Stream (SJS), followed by a persistent Higher Atmospheric Blockage over Southern South America. Frontal systems generated at higher latitudes usually travel north or eastwards at a faster pace during the Austral winter. In the autumn and winter of 1983, this tendency changed and the systems were blocked south of the SJS. The systems kept a stationary position North of the blockage zone. A strong convection, a common feature of SJSs (Whitney 1977), was observed south of these systems, causing excessive precipitation at the 29º S latitude. As suggested by Bjerknes (1969), and demonstrated by Arkin (1982); this high level (10 to 15 km) air stream becomes more intense at the Eastern Pacific during warm ENSO events. The SJS not only blocked the northward displacement of frontal systems, but also stopped the eastward movement of tropospheric waves at middle latitudes (Figure 2). As a consequence, the frequency of blockage zones increased over the Eastern Pacific and South America during the 1983 ENSO.

During intense warm ENSOs (*sensu* Trenberth 1997) such as in 1982-83 and 1997-98 (Figure 3); the northern portion of the blockage zone should be persistently submitted to summer weather conditions, with the prevalence of First Quadrant Winds, even during winter months. These conditions would allow the upwelling process to persist, without the usual disruption caused by the winter subsidence, thus keeping the oceanic front at shallower depths for extended periods (Martin et al. 1988, 1993, Paes *et al.* 1999). At "weaker", or less intense events (*sensu* Trenberth 1997) as in 1976-77 and 1986-87, the blockage zone shifts northwards, allowing the frontal systems to travel over the southern coast, further contributing for the SACW subsidence. Martin *et al.* (1988) suggested that the position of the SJS over the continent is consistent with the intensification and disappearance of the surface upwelling of the SACW at Cabo Frio.

Concerning the ENSO counterpart, known as "La Niña", scarce information is available about its effects over the Brazilian meteorological conditions. According to the CPTEC/INPE report (1998), the best known effects over Brazil's climate are: (i) the increase in Frontal Systems displacement velocity over Southern Brazil between September and February, causing rainfall reduction; (ii) a slight reduction in winter temperatures at the Southeastern States; (iii) Heavy rainfall over Northern and Eastern Amazon and (iv) Eventual rainfall increase over the Northeastern semi-arid regions.

Due to the irregular frequency of "La Niña", or cold ENSO events, little is known about the possible teleconnections and effects over the coastal circulation and oceanographic conditions of the studied area. It is believed that the strong negative SST anomalies observed in the Equatorial Pacific could, somehow, inhibit the coastal upwelling in the SBB, probably due to the quasi-absence of the Jet Stream over South America (Arkin 1982). On the other hand, Lentini *et al.* (2001) detected both cold southward and warm northward advected SST anomalies in the SBB during the 1988-1989 event.

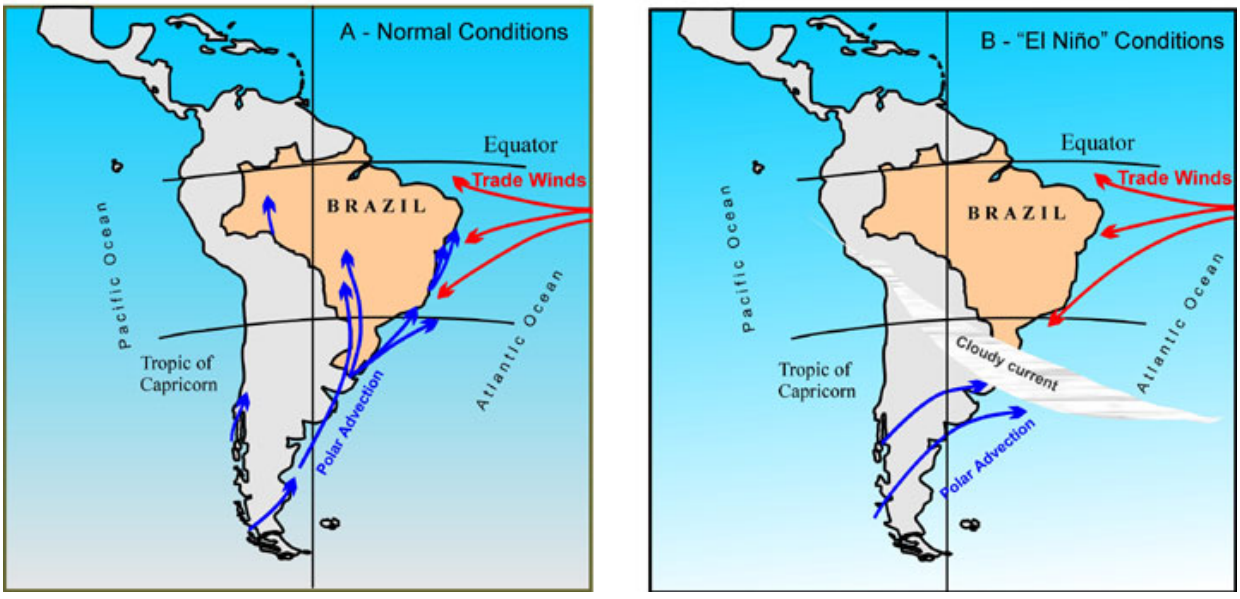


**Figure 2**. Schematic representation of the Subtropical Jet Stream (Represented by Cloudy current) during "Normal" and "El Niño" situations. Modified from Martin et al. 1988.

Another evidence of the interaction between ENSO events and the oceanographic conditions of the SBB lies within the primary productivity patterns and the Brazilian sardine fisheries. The Brazilian sardine (*Sardinella brasiliensis*) is endemic at the SBB, and from an ecological point of view, it is also the most important small pelagic stock inhabiting the region. During the 80's, the sardine accounted for 32% of the total catch in the SBB, and about 25% of the gross Brazilian marine fish production (IBAMA 1995).

In a pioneering work, Matsuura (1996) suggested that the major breaks in the Brazilian sardine catches during 1976 and 1988 were related to cyclic deficiencies in the SBB upwelling mechanism. The highest annual catch occurred in 1973, reaching the historical mark of 228 thousand tons. In 1976, this value dropped to 100 thousand tons. A similar behavior was observed during the 80's: 1984 yields reached 140 thousand tons, dropping to 75 thousand tons in 1988. In the 90's, the catches increased from 1992 to 1997, reaching 118 thousand tons, and then decreased again to less than 30 thousand tons in 2000 (Cergole 2000) (Figure 3). These production breaks occurred one or two years after "weaker" warm ENSO events (Paes *et al.* 2007), whereas higher yields were recorded approximately one or two years after intense warm events.

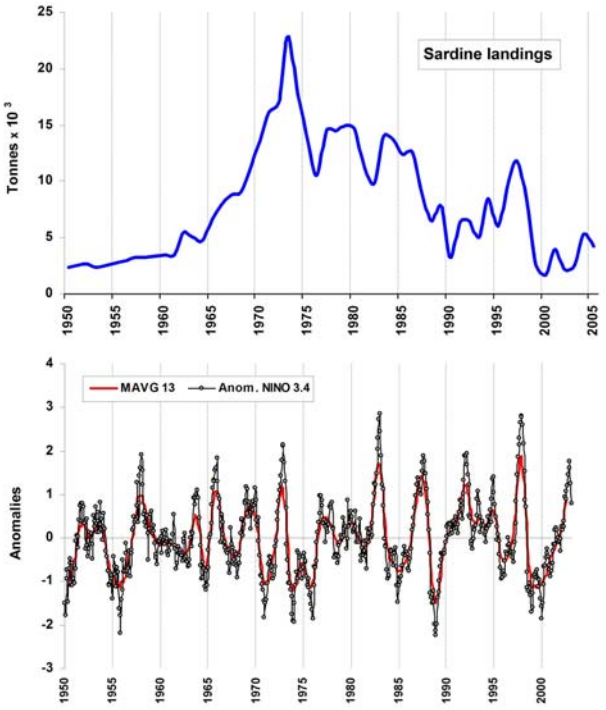


**Figure 3**. Sardine landings in the Southern Brazilian bight (SBB), from 1950 to 2005 (source: FAO, 2000) and monthly SST Anomalies for the Region Niño 3.4 ( data from www.cpc.ncep.noaa.gov). MAVG13, moving average 13.

It must be highlighted that about 84% of the commercial catches of the Brazilian sardine are composed by one year old individuals (Cergole 1993, Matsuura 1996). As the primary productivity in the shallow portions of the SBB is enhanced during the austral summer, phytoplankton patches are formed above the thermocline, providing a food source for the survival of the fish larvae (Matsuura 1990). Bakun & Parrish (1990) suggested that the reproductive stock of the Brazilian sardine takes great advantage from these periodic enrichments.

Besides these evidences from the literature, another result which can strengthen the main hypothesis is presented on Figure 4. We used the data provided by several oceanographic cruises, and compiled by the National Oceanographic Data Bank (BNDO), from Brazil's Navy. Water temperature measured in a depth of 10 to 45m between the 30 and 65m isobaths was analyzed with a time x latitude Hovmoller diagram, covering a period from 1980 to 1987. From February 1982 to December 1983, temperatures lower than 19°C were found along the southern part of SBB. This period coincides with the 1982-83 historically intense warm ENSO. Between 1986 and 1987, during a "weaker" El Niño, an inverse situation was observed at the same area, with typical winter temperatures, higher than 22°C.

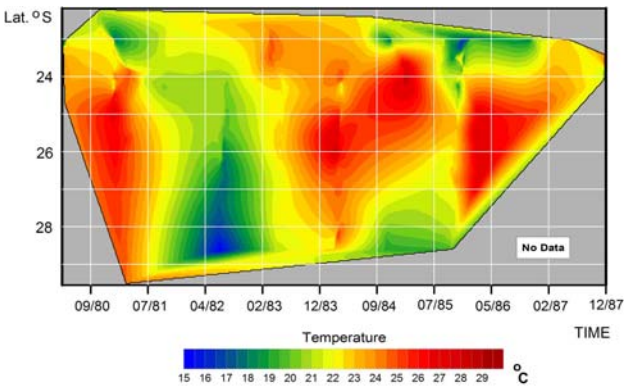


**Figure 4**. Hovmoller Diagram (Latitude x Time) of sub-superficial Temperature of SBB.

## Discussion

The occurrence of intense and warm "El Niños" tends to intensify the Subtropical Jet Streams, creating a blockage zone which shall hamper the northeastward advance of the frontal systems over the SBB. Meteorological conditions North of these blockages should be characterized by N-NE winds, favoring the offshore transport of water and the upwelling of the SACW. The region located South of the SJS, should be submitted to S-SW winds, favoring the inshore transport of water and the subsidence of the termocline. The

displacement of these blockage zones could define potentially higher and lower productivity periods as well as the amount of the SBB area which shall be submitted to favorable/unfavorable conditions for primary production.

According to Matsuura (1988), the Brazilian sardine spawning is favored by termocline stability and high primary productivity. Spawning occurs during the late spring and austral summer, mainly between Paranaguá and Florianópolis (Figure 1). The position of the SJS, in relation to the above cited area could, then, define the stock recruitment for the subsequent years, according to the prevailing oceanographic conditions. We suggest that, one or two years before the higher catches, during intense ENSOs, the SJS may be situated further South from the area delimited above. Lower catches, on the other hand, would suggest that the blockage zone shifted northward, as a result of a weak warm ENSO. The occurrence of La Niña events, on the other hand, could generate similar conditions due to a transitory weakness in the SJS, as observed by Atkins (1982), during such phenomena.

In the fishery context, the idea of a probable mechanism linking the oceanographic conditions of the SBB and the occurrence intense ENSO events could be further detailed in two non-exclusive sub hypotheses:

1 – After an intense warm ENSO, the primary productivity and the pelagic fishery production should expect an increase, in relation to non ENSO periods.

2 – After a “moderate” or “weak” warm ENSO, or an intense La Niña, the pelagic production would be lower. Nevertheless, some cathadromic species of commercial interest such as mullets, croaker and shrimps may benefit from the prevailing conditions, since a fair amount of moderately pristine estuaries are still available at the southern Brazilian coast.

Regarding the second sub hypothesis, it must be emphasized that most of the cathadromic species (mullets particularly) are winter spawners, producing neustonic eggs and larvae (Vieira & Scalabrini 1991). These strategies should be favored during the establishment of blockages over lower latitudes, due to the prevalence of inshore transport. Therefore, during La Niña and weak El Niños, the main sources of nutrients at shallow depths are represented by coastal ecosystems such as estuarine and mangrove complexes, along with rainforests. This idea shall raise discussions about preservation issues regarding these notoriously threatened ecosystems.

On the other hand, the eventual increase in predators abundance during intense ENSOs pointed by Moraes (2000) at Arraial do Cabo could locally limit the recruitment of some pelagic species. Nevertheless, little is known about the dynamics of the local food webs, the real values of the biomass consumed by predators. Furthermore, many mid and top predators are also targeted by the multispecific fishery carried at the SBB.

In order to definitely test the main hypothesis, several data sets (climatologic, oceanographic, ecological and fisheries) from many different sources should be analyzed in a multidisciplinary approach. Models for prevision and a management strategy for the main fisheries of the SBB should be pursued as a main goal for the future.

## Acknowledgements

We would like to thank the Researchers from Instituto de Estudos do Mar Almirante Paulo Moreira (IEAPM) E. B. Fagundes Netto, L. R. Gaelzer and F. C. Fernandes for the fish data and support during the Project MOMAM (Monitoramento do Meio Ambiente Marinho). Raissa O. T. Paes for help in revising English text version. E.T. Paes financial support was provided by CNPq and FAPERJ pos-doc fellowships. L. E. S. Moraes MSc. Fellowship was supported by CAPES.

## References

Aceituno, P. 1988. On the Functioning of the Southern oscillation in the South America Sector. Part I: Surface Climate. **Monthly Weather Review**, 116: 505-524.

Aidar, E., Gaeta, S. A., Gianesella-Galvão, S. M. F., Kutner, M. B. B. & Teixeira, C. 1993. Ecossistema costeiro subtropical: nutrientes dissolvidos, fitoplâncton e clorofila –a e suas relações com as condições oceanográficas na região de Ubatuba, SP. **Publicações Especiais do Instituto Oceanográfico São Paulo**, 10: 9-43.

Arkin, P. A. 1982. The relationship between interannual variability in the 200 mb tropical wind field and the Southern Oscilation. **Monthly Weather Review**, 110: 1393-1404.

Bakun, A. & Parrish, R. H. 1990. Comparative studies of coastal pelagic fish reproductive habitats: the Brazilian sardine (*Sardinella aurita*). **Journal Du Conseil Conseil International Pour L'Exploration De La Mer,** 46: 269-283.

Bjerknes, J. 1969. Atmospheric teleconnections from the equatorial Pacific. **Monthly Weather Review**, 97: 163-172.

Borzone, C. A., Pezzuto, P. R. & Marone, E. 1999. Oceanographic characteristics of a multispecific fishing ground of Southern Brazil. **Marine Ecology, Edinburgo,** 20(2): 31-146.

Campos, E. J. D., Gonçalves, J. E. & Ikeda, Y. 1995. Water mass characteristics and geostrophic circulation in the South Brazil Bight: Summer of 1991. **Journal of Geophysical Research**, 100(9): 18537-18550.

Campos, E. J. D., Velhote, D. & Silveira, I. C., 2000. Shelf Break Upwelling Driven by Brazil Current Cyclonic Meanders. **Geophysics Research Letters**, 27(6): 751-754.

Castro-Filho, B. M., Miranda, L. B. & MIYAO, S. Y. 1987. Condições hidrográficas na plataforma continental ao largo de Ubatuba: variações sazonais e em média escala. **Boletim Instituto Oceanográfico São Paulo**, 35(2): 135-151.

Castro, B. M., Lorenzzetti, J. A., Silveira, I. C. A. & Miranda, L. B. 2006. Estrutura Termohalina e Circulação na Região entre Cabo de São Thomé (RS) e o Chuí (RS). Pp 11-120. *In*: Rossi-Wongttschowski, C.L.B & Madureira, L.S. (Eds.). **O Ambiente Oceanográfico da Plataforma Continental e do Talude na Região Sudeste do Brasil**. Editora da Universidade de São Paulo (EDUSP), São Paulo, 466 p.

Cergole, M. C. 1995. Stock assessment of Brazilian sardine, *Sardinela brasiliensis*, of the south-eastern Coast of Brazil. **Scientia Marina**, 59(3-4): 597-610.

Chao, N. L., Chao, L. N. & Souza, M. J. F. T. 2004. Spatial and temporal variation of benthic fish assemblages during the extreme drought of 1997-98 (El Niño) in the middle rio Negro, Amazonia, Brazil**. Neotropical Ichthyology**, 2:(3): 127-136.

Ciotti, A. M., Odebrecht, C., Fillmann, G. & Moller, O. O. 1995. Freshwater Outflow And Subtropical Convergence Influence On Phytoplankton Biomass On The Southern Brazilian Continental Shelf. **Continental Shelf Research**, 15(14): 1737-1756.

CPTEC/INPE. 1998. La Nina. **Relatório Técnico.** Accessible at www.cptec.inpe.br/products /laninha/laninha3p.html. (Accessed in 22/05/2007).

Depetris, P. J., Kempe, S., Latif, M. & Mook, W. G. 1996. ENSO controlled flooding on the Paraná river (1904 – 1991). **Naturwisssen-chaften**, 83: 127–129.

Dijkistra, H. A. 2006. The ENSO phenomenon: Theory and mechanisms. **Advances in Geosciences**, 6:3-15.

FAO, 2000. FAO Fisheries Department, Fishery Information, Data and Statistics Unit. FISHSTAT PLUS: Universal software for fishery statistical time series. Version 2.3.

Fonzar, B. C. 1994. A circulação atmosférica na América do Sul: os grandes sistemas planetários e subsistemas regionais que atingem o continente: localização e trajetória. **Cadernos de Geociências IBGE**, 11: 11-33.

Garcia, A. M., Vieira, J.P. & Winemiller, K. O. 2001. Dynamics of the shallow-water fish assemblage of the Patos Lagoon estuary (Brazil) during cold and warm ENSO episodes. **Journal of Fish Biology.** 59: 1218 - 1238

Garcia, A. M., Vieira, J. P. & Winemiller, K. O. 2003. Effects of 1997-1998 El Niño on the dynamics of shallow-water fish assemblage of Patos Lagoon Estuary (Brazil). **Estuarine, Coastal and Shelf Science**, 57(3): 489-500.

Garcia, A. M., Vieira, J. P., Winemiller, K. O. & Grimm, A. M. 2004. Comparison of the 1982-1983 and 1997-1998 *El Niño* effects on the shallow-water fish assemblage of the Patos Lagoon estuary (Brazil). **Estuaries**. 27(6): 905-914

Grimm, A. M., Ferraz, S. E. T. & Gomes, J. 1998. Precipitation anomalies in Southern Brasil associated with El Niño and La Niña Events. **Journal of Climate**, 11: 2863–2880.

IBAMA. 1994. Sardinha, atuns e afins. Relatório das Reuniões dos grupos Permanentes de Estudos - GPE's. Estudos de pesca 11, IBAMA, Brasília, Brazil. 201 p.

Kousky, V. E., Kagano, M. T. & Cavalcanti, I. F. A. 1984. A review of southem Oscilation oceanic-atmosphere-circulation changes and related rainfall anomalies. **Tellus,** 36(A): 490-504.

Lentini, C. A. D., Podestá, G. G., Campos, E. J. D. & Olson, B. D. 2001. Sea surface temperature anomalies on the Western South Atlantic from 1982 to 1994. **Continental Shelf Research**, 21: 89-112.

Lima, I. D., Garcia, C. A. E. & Moller Jr. O. O. 1996. Ocean surface processes in the Southern Brazilian shelf: Caracterization and seasonal variability. **Continental Shelf Research**, 16(10): 1307–1317.

Mahiques, M. M., Mishima, Y. & Rodrigues, M. 1999. Characteristics of the sedimentary organic matter on the inner and middle continental shelf between Guanabara Bay and São Francisco do Sul, Southeastern Brazilian Margin. **Continental Shelf Research**, 19: 775-798.

Martin, L., Flexor, J. M. & Valentin, J. L. 1988. Influence du phénomène océanique pacifique "El Niño", sur l'"upwelling" et le climat de la région du Cabo Frio, sur la côte brésilienne de l'État de Rio de Janeiro. **Comptes rendus de l'Académie des sciences**, 307(11): 1101-1105.

Matsuura, Y. 1988. Synopsis on the reprodutive and early life history of Brazilian sardine. *Sardinella brasiliensis*, and related environmental conditions. **Annex VIII. IOC Workshop Report**, 65:1-8.

Matsuura, Y. 1995. Os Ecossistemas Brasileiros e os Principais Macrovetores de Desenvolvimento. **Subsidios ao Planejamento da Gestão Ambiental**.- 4. Nº6 - Exploração Pesqueira. MEEC-PNMA, 158 p.

Matsuura, Y. 1996. A probable cause of recruitment failure of the Brazilian sardine *Sardinella aurita* population during the 1974/75 spawning season. **South African Journal of Marine Science**, 17: 29-35.

Moraes, L. E. S. 2000. Correlações entre fenômenos de larga escala "El Niño/La Niña e a estrutura da comunidade de peixes demersais da região de Ressurgência de Cabo Frio. Rio de Janeiro Brasil. **MSc. Thesis**, Instituto de Biologia Marinha, Universidade Federal Fluminense, Rio de Janeiro, Brazil, 246 p.

Paes, E. T. 1996. As Associações de peixes demersais da plataforma de Ubatuba (SP), e seus principais agentes estruturadores locais, regionais e históricos. **PhD. Thesis**, Instituto Oceanográfico, Universidade de São Paulo, Brazil, 228p.

Paes, E. T. & Rossi-Wongtschowski, C. L. B. 1997. A plataforma continental sudeste brasileira como um ecossistema semi-fechado: um estudo baseado nos efeitos locais, regionais e históricos sobre a estrutura das comunidades de peixes demersais. **VII Colacmar. Congresso Latino-americano sobre Ciências do Mar**, Santos-SP, 2: 254-255.

Paes, E. T., Moraes, L. E., Fernandes, F. C., Fagundes Netto, E. B. & Gaelzer, L. R. 1999. Influência do fenômeno "El Niño" sobre as comunidades de peixes demersais da região de ressurgência de Arraial do Cabo Rio de Janeiro Brasil. **VIII Colacmar. Congresso Latino-americano sobre Ciências do Mar** , Trujillo-Peru, 36-39.

Paes, E. T., Soppa, M. A. & Souza, R. B. 2007. Covariações entre os desembarques da sardinha-verdadeira - Sardinella janeiro (Eigenmann, 1894), em seus extremos de ocorrência na Plataforma Sudeste Brasileira, e as anomalias de temperatura superficial do mar medidas por satélite. **Anais do XIII Simpósio Brasileiro de Sensoriamento Remoto.** Florianópolis. 4651-4658.

Pezzi, L. P. & Cavalcanti, I. F. A. 2001. The Relative Importance of ENSO and Topical Atlantic Sea Surface Temperature Anomalies for Seasonal Precipitation over South America: A Numerical Study. **Climate Dyn.**, 17: 205-212.

Piola, A. R., Möller Jr., O. O., Charo, M. & Martinez, C. 1998. Continental shelf water off eastern South America - 20° to 40°. **An. 10th Symposium on Global Change Studies - American Meteorological Society**, 9–12.

Pires-Vanin, A. M. S. & Matsuura, Y. 1993. Estrutura e função do ecossistema de plataforma continental da região de Ubatuba. Estado de São Paulo: uma introdução. **Publicações Especiais do Instituto Oceanográfico São Paulo**, 10: 1-8.

Ropelewski, C. F. & M. S. Halpert. 1987. Global and regional scale precipitation patterns associated with the El Niño / Southren Oscillation. **Monthly Weather Review**, 115: 1606-1626.

Rossi-Wongtschowski, C. & Paes, E. T. 1993. Padrões espaciais e temporais da comunidade de peixes demersais do litoral norte do Estado de São Paulo - Ubatuba, Brasil. **Publicações Especiais do Instituto Oceanográfico São Paulo**, 10: 169-183.

Santos, J. L. 2006. The Impact of El Niño - Southern Oscillations Events on South America. **Advances in Geosciences**, 6: 221-225.

Trenberth, K. E. 1997. The definition of El Niño. **Bulletin of the American Meteorological Society**, 78(12): 2771–2777.

Valentin, J. & Coutinho, R. 1990. Modelling maximum chlorophyll in the Cabo Frio (Brazil) upwelling: a preliminary approach. **Ecological Modelling,** 52: 103-113.

Vasconcellos, M. & Gasalla, M. A. 2001. Fisheries catches and carryng capacity of marine ecosystem in southern Brazil. **Fisheries Research**, 50: 279-295.

Vieira, J. P. & Scalabrini, C. 1991. Migração reprodutiva da "tainha" (*Mugil platanus* Gunther, 1980) no sul do Brasil. **Atlântica**, 13(1): 131-141.

Wainer, I. & Taschetto, A. S. 2006. Climatologia na região entre Cabo de São Tomé (RJ) e o Chuí (RS). Diagnóstico para os períodos relativos aos levantamentos pesqueiros do Programa REVIZEE. Pp 121-160. *In*: Rossi-Wongttschowski, C. L. B & Madureira, L. S. (Eds.). **O Ambiente Oceanográfico da Plataforma Continental e do Talude na Região Sudeste do Brasil**. Editora da Universidade de São Paulo (EDUSP), São Paulo, 466 p.

Whitney, L. F. Jr. 1977. Relationship of the subtropical jet stream to severe local storms. **Monthly Weather Review**, 105: 398-412.

Received April 2007
Accepted May 2007
Published online June 2007